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(eds.)

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Preface

This e-book contains selected presentations from the "20th European Roundtable on Sustainable Consumption and Production" which was held in September 2021 in Graz, Austria.

The Roundtable was first held in Graz in 1994 under the title "European Roundtable on Cleaner Production Programs“ and returned this year with its 20th edition. In its almost 30 years, the Roundtable has taken place in many European countries and has contributed significantly to the development of research on sustainability.

In the first years, the focus was on clean technologies (cleaner production, pollution prevention, etc.) and their development and dissemination, but over time the focus has shifted to systemic issues. Currently, the Roundtable no longer focuses on technologies but instead on systems. Contributions to the Roundtable program range from design to production to consumption, with a strong emphasis on sustainability and resource efficiency throughout the whole cycle.

We now know that consumer behavior – individual and public - is a key issue in a new, more sustainable economic system. The Roundtable responded to this change by updating its name to "European Roundtable on Sustainable Consumption and Production". And of course, with the political pressure to restructure the global economic system toward a "CIRCULAR ECONOMY" and the propagated "Green Deal", the systemic aspect has gained even further importance.

With its 20th edition, a special focus was set on the role of cities in economic change. We considered both the citizens' perspective and engagement, as well as the role of administrations and politics.

The Roundtable also hosted the “Biannual Workshop on Advanced Energy Systems / BIWAES”, which had previously been a separate series of workshops. This event highlighted the importance of new, more sustainable energy systems for the future of a livable planet; again, with a focus on the role of cities.

There was also a change in the way the event was presented. It is no longer a series of lectures, but instead an event with many workshops and interactive sessions. Nevertheless, the Roundtable continues to offer the opportunity to present, discuss and publish research results to young researchers. Several international research programs see erscp21 as an effective dissemination event and hold their consortium meetings in its environment.

The organizers - StadtLABOR Innovations for Urban Quality of Life ltd. in cooperation with the Institute for Process and Particle Technology of the Graz University of Technology - have decided not to print the conference proceedings, but to make them widely available as an e-book with the publishing house at TU Graz. This is done in an effort to conserve resources.

The organization was actively supported by the erscp-society and the PREPARE group. Special thanks also go to the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology for supporting the event.

We hope this publication is interesting to its readers and inspires innovative work in the future

Graz, September 2021

Hans Schnitzer for the whole organization team

Scientific Committee

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251 Supporting Sustainable Behaviour by Citizen's Participation in Group Activities

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Abstract

For at least 50 years, citizens have been promised measures aimed at curbing climate change, introducing a circular economy, and promoting sustainable consumption and production. However, there is lack of concrete political actions of governments and parliaments to stop the real threats of climate change. Appeals to governments to finally deliver on the promises of top-down measures have been noted but, despite the official announcements of governments worldwide no real effect is in sight. On the other hand, newer technological developments (digitization, networking, communication software) in the sense of bottom-up make it possible to rethink and reshape citizens' participation in ways that would have been considered impossible not long ago. They are already being used in a participatory way and could in the future be a useful complement to so-called 'representative democracy' and help to influence the reflections and actions of all stakeholders, including the citizens themselves, in the direction of sustainability and the circular economy. Of course, the *effective* use of these social and technical possibilities requires the fundamental willingness of stakeholders and potential addressees to allow participation to go beyond the current extent. Of the methods and procedures currently in use, (a) one participation method is currently favoured in Europe (Germany, Ireland, UK, etc.) and will be considered in more detail: Randomly and representatively composed small groups develop topic- and problem-centred proposals for activities and actions to be implemented by citizens, authorities, or other stakeholders. We will discuss ways of optimizing this participation process. Especially, as an alternative and complement, (b) the output-, action-, and impact-oriented participation of citizens in digital councils for solving problems will be considered. We recommend, to combine both the methods (a) and (b) for reaching

sustainable actions which are acceptable for citizens. However, for optimizing the citizen driven problem-solving process further research is necessary. Thus, we define appropriate research questions. Furthermore, it will be discussed how an important overarching goal of citizens' participation can be achieved, namely, to involve 'the citizens' in the development and design of future participation projects, technology and communication structure in a transparent, effective, and environmentally friendly way.

Keywords: Participation, Group Activities, Digitalization, Behaviour Change, Sustainable Actions

Introduction

For at least 50 years, citizens have been promised measures aimed at curbing climate change, introducing a circular economy, and promoting sustainable consumption and production. However, there is lack of concrete political actions of governments and parliaments to stop the real threats of climate change: The rainforest is being cut down, gas, oil and coal are being extracted and burned, the industrialization of agriculture is being promoted with tax money despite devastating consequences (pesticides, mass animal husbandry), air traffic and kerosene consumption increased worldwide, exports and global trade destroy local productions and markets, and so on.

There is a lack of concrete political actions of governments and parliaments to stop the real threats of e.g., climate change. Appeals to governments (as for example by the Fridays for Future movement or Greta Thunberg) to finally deliver on the promises of top-down measures have been noted but, despite the official announcements of governments worldwide no real effect is in sight.

With the new president of the European Commission (flanked by the new US president, and the president of China), serious top-down measures seem to be planned, which are hopeful and have already been reflected (albeit repeatedly) in the EU research and innovation programme (e.g. European Commission, 2020). However, the planning of a late change in the agricultural economy, the non-transparent Brussels lobbying, the lack of centralization, the low influence and the national composition of the EU Parliament, the short election periods, which make it difficult to pursue long-term goals, the technology-centricity etc. – and not least previous experiences – give rise to scepticism.

In view of e.g. the current climate crisis, however, quick, urgent and effective measures are needed to ensure that countermeasures are still possible at all. There is no doubt that a large part of the necessary measures must be decided and implemented by politics. In addition, it is the financially strong institutions and individuals who can develop and implement measures due to their material power. However, precisely from these two groups of addressees little can be expected due to systemic problems.

In this respect, complementary bottom-up approaches (Bergman et al., 2010) are needed to get masses of people to change their lifestyles. The goal is not only to change individual consumer behaviour, but also a change in attitude towards life. Individuals should learn together, work on problems and courageously commit to solving them – also in companies (Hammerl et al., 2009) and organizations (Banerjee, 2016).

More recent technological developments and innovations (digitization, networking, communication software) in the sense of bottom-up make it possible to rethink and reshape citizens' participation in ways that would have been considered impossible not long ago. They are already being used in a participatory way and could in the future be a useful complement to so-called 'representative democracy' and help to influence the reflections and actions of all stakeholders, including the citizens themselves, in the direction of sustainability and the circular economy. Of course, the effective use of these social and technical possibilities requires the fundamental willingness of stakeholders and potential addressees to allow participation to go beyond the current extent.

Phenomena such as declining voter turnout, hate postings, the need for campaign goodies, etc. seem to increase the willingness of political, administrative and economic stakeholders not only to allow participation, but even to encourage it in a moderate way. An example is from the city of Graz, which is hosting this conference. Graz calls itself a Smart City, and even has a department for citizen participation. However, the extent of citizen participation is limited - for example, Graz citizens were recently asked to submit innovative proposals to the city, and 300k Euros were allocated for their realisation (Graz.at, 2021). On the other hand, for reports, a feasibility study, evaluation, advertising, and marketing for a potential mini-subway in Graz, which have been initiated by the mayor of Graz without the involvement of regular citizens the costs were more than 700 k in total.

At least, the Stadlabor Graz, under the management of Barbara Hammerl and Hans Schnitzer, were able to closely cooperate with the city in the context of city-district initiatives and to involve engaged local communities and citizens.

However, some basic questions remain: Do citizens actually want to participate and what should such a participation look like? To quote a book-title from Mausfeld (2015): ‘Why are the lambs silent?’ In any case, without the active involvement of citizens as well as their sustainable consumption and actions, the global climate crisis won`t be solved. For instance, in the EU individual households account for nearly 20% of total carbon dioxide emissions (Gwozdz et al., 2020).

Methods

It seems obvious that behavioural change towards sustainable consumption and production should not rely on purely top-down approaches but requires bottom-up initiatives by the engagement and involvement of citizens. The prerequisites for such a (sustainable) behavioural change of citizens are the perceived *self-efficacy* (Bandura, 1977), the avoidance of *learned helplessness* (Seligman et al., 1979), *fear mongering* and *mind manipulation* (Mausfeld, 2019) or *corporate power* (Eckert, 2019).

Thus, it is necessary to ask which methods and procedures of citizen participation currently exist to bring about changes at different levels through direct or indirect influence or through stimulating self-reflection? The different levels can be ordered from global (e.g. UN), continental (e.g. EU), national (e.g. Austria), regional (e.g. Styria), local (e.g. Graz) down to specific households and individuals. It could be argued that behavioural changes even at the highest levels should be possible with effect and without problems: e.g. if all smokers, drug consumers, all beef consumers worldwide would agree to stop their consumption simultaneously and permanently, the consequences for the environment, health etc. would be enormous. The individual who agrees will argue that it is easy to change one's own behaviour, but that the more people who need to be convinced, the less influence they will have on the behaviour of others.

Changing one's own behaviour usually requires acquiring knowledge, insight, attitudes, etc. These are necessary but not sufficient prerequisites - individual behavioural changes are also based on highly complex processes of a cognitive, emotional and motivational nature.

It is a well investigated fact that even motivated persons with appropriate knowledge often do not decide and behave according to his/her attitudes, values, emotions and cognitive insights (Courtenay-Hall and Rogers, 2002). This is called ‘knowledge-behaviour gap’, ‘value-action gap’, or ‘attitude-behaviour gap’ - and may or may not cause ‘cognitive dissonance’ (Festinger, 1957). A wide range of established and empirically-validated cognitive models on behavioural change have been developed, aiming to explain and predict this gap, for example (see also Albert et al., 2021; Bedek and Albert, 2019; Hagger et al., 2020).

- Social Cognitive Theory (Bandura, 1977, 2001),
- Health-Belief Model (Becker, 1974; Janz and Becker, 1984),
- Theory of Reasoned Action (Fishbein and Ajzen, 1975),
- Theory of Planned Behaviour (Ajzen, 1985, 1991),
- Protection Motivation Theory (Rogers 1975, 1983),
- Health Action Process Approach (Schwarzer 1992, 2008),
- Transtheoretical model (Prochaska and DiClemente, 1983; Prochaska and

Velicer, 1997), or the
- Precaution Adoption Process Model (Weinstein et al., 1998).

Because of the attitude behaviour gap it is difficult to change her/his *own* behaviour even if a person is motivated to do so. Nevertheless, many individuals and groups are convinced that they can legally influence and change the behaviour of *others* in various ways, directly and indirectly.

Legal aspects of citizen participation

Legal civic participation is not self-evident even in democratic states; e.g. in one of the oldest democracies, Switzerland, women's suffrage (voting and electoral rights) was introduced only 50 years ago in 1971. Even today, many citizens living in Europe are denied democratic forms of participation: e.g., around 70k asylants (in the minimum income scheme) are living in Austria for an indefinite period and do not have the right to vote (Statistik Austria, 2019); also, e.g. in Hungary, the right to demonstrate was recently restricted (Euronews, 2018), and in Poland the rights to freedom of expression and association have been reduced in 2020 (Amnesty International, 2021).

The legal framework for citizen participation obviously has to be permanently defended and protected - although the legal framework is internationally and nationally defined and guaranteed by a multitude of legal provisions. As an example, we will briefly mention and comment on the current legal framework in Germany. We would expect that the current legal regulations are a ‘holy grail' and ‘living rights'.

First, let us look at the laws for participation in a parliamentary democracy - regulations for adult citizens in Germany:

In principle, Art 21 GG stipulates: The parties shall participate in the formation of the political will of the people. This principle is further extended in the Political Parties Act.

§1 PartG para. 2 states: The parties shall participate in the formation of the political will of the people in all areas of public life, in particular by influencing the shaping of public opinion, stimulating and deepening political education, promoting the active participation of citizens in political life.

However, reality is different. The interests and needs of the people are less and less represented by the parties. The decline in voter turnout clearly shows that this representation of the will of the people no longer works. Political decisions are significantly influenced by certain groups who see themselves as experts for selected legislative projects. This kind of participation goes by the name of lobbying. The problems of this practice have been the subject of public debate for some time. In general, these are representatives of financially strong institutions that exert more or less direct influence on political decisions and legislative projects, primarily pursuing particular interests rather than the common welfare.

According to Art. 17 GG, the submission of petitions and complaints is permitted as a further participation option, a very vague principle that primarily concerns the rule of law aspect.

Petitions, referenda, and plebiscites are possible in principle, but only in special cases and to a limited extent. The procedures are regulated by a Bundestag resolution and regulations of Federal States. Compared to the effect of the afore mentioned lobbyists, these forms of participation are relatively ineffective. Petitions are statements without binding character, referenda are limited to a few legally possible decisions and thus exposed to great hurdles, citizens' petitions at regional level are laid down in municipal ordinances.

Second, notice that also children and adolescents have rights for participation and should exercise them with respect to becoming full citizens in the future. Thus let us have a look at the laws for participation of children and adolescents - taking international and German regulations into account (Turek, 2012).

For instance, the 'Deutschlandfunk' (2021) stated recently, that children's participation in Germany is not yet a matter of course: According to the representative study by World Vision (2018), there are major deficits in schools of all places. This is a fact, even though participation is enshrined in law in Germany, both in the school laws of the federal states (Kulturministerkonferenz, 2020) and via the UN Convention on the Rights of the Child and the UN Convention on the Rights of Persons with Disabilities, which have the status of federal law in Germany. Even the Standing Conference of the Ministers of Education and Cultural Affairs of the Federal States and the Federal Ministry for Families make recommendations on 'human rights education in schools' (Kulturministerkonferenz, 2018) and on quality standards for children's participation. However, the practice of participation by children and young people often looks different. Also, for vocational schools, there is the fact that even though the state ministries of education and cultural affairs consult the student councils, central areas lie with the chambers, says the state student representative for vocational schools in Bavaria.

Without going into details, we suppose that the situation in other European countries are more or less the same: Legal regulations exist, however their usage is far behind possibilities, that means, real participation of individuals or groups does not or only partly exist - whatever the reasons might have been. Looking forward, already existing digitalisation and communication technology seems to be the basis as a 'game changer' regarding citizens' participation. However available technology is only one aspect, citizens also have to be aware of real problems they are willing and able to solve in groups.

Process-oriented group activities for participatory problem-solving

For supporting sustainable consumption and production by citizen's participation in group activities, from a psychological point of view, the citizens are performing group problem solving and decision making. As a consequence, involving citizens in group activities for solving problems and elaborating ideas and suggestions for policy makers, may stimulate and support behavioural change, for example, with regards to sustainable consumption and production. The underlying rationale for this claim is as follows: as it will be outlined in the section 'Procedures for 'representative' participation of citizens in councils for problem-solving', the perceived justice of a decision or problem solution – and in consequence, its' justification – is considered as higher, if the individuals were involved in the decision making and/or problem solving process; even if the final decision and/or solution is not in line with their own, initially preferred decision and/or solution (Brockner and Wiesenfeld, 1996). If such participatory group activities lead to a higher justification, it is reasonable to assume that the individuals' commitment towards the final decision and/or solution is increased. Such an increased commitment may reduce the above mentioned 'attitude-behaviour gap' - even if such a reduction may be reached by overcoming cognitive dissonance (Festinger, 1957), i.e. changing and adapting attitudes due to the change of the behaviour. In addition to that, being confronted with ideas from others with different backgrounds, and in particular in the context of diverse groups, may lead to more acceptance towards attitudes, solutions and decisions that are not perfectly in line with one's own (Brandstätter and Schuler, 1976).

Different models exist on describing stages, phases, or steps of a collaborative problem solving process (e.g. Bell, 1982) or by suggesting facilitating conditions (e.g. McFadzean and Nelson, 1998); among them, is a generic one by University of Minnesota Libraries Publishing (2013):

- *Problem definition*: Define the problem by creating a problem statement that summarizes it.
- *Problem analysis*: Analyse the problem and create a problem question that can guide solution generation.
- *Solution generation*: Possible solutions should be offered and listed without stopping to evaluate each one.
- *Solution evaluation*: Evaluate the solutions based on their credibility, completeness, and worth.
- *Solution implementation and assessment*: Aside from enacting the solution, groups should determine how they will know the solution is working or not.

Of course, each of these five steps of collaborative problem solving can be divided into smaller sub steps, e.g. *Problem definition* includes detecting the problem, *Problem* *analysis* includes goal setting, *Solution generation* includes brainstorming, *Solution evaluation* includes decision making, and *Solution implementation and assessment* includes concrete actions and later assessments in order to determine the sustainability of the implementation.

The question remains, if face-to-face group activities are as efficient, effective and successful as virtual or digital group activities (e.g. Purvanova, 2014). On the one hand, it is reasonable to assume that technological solutions to facilitate virtual meetings and group activities are getting more and more advanced in the near future. On the other hand, such virtual or digital group activities have several advantages: they can be more spontaneous, and more people may be able to participate due to their (comparatively) independence of a certain location and the lack of time constraints.

Thus, the questions arise, which methods and procedures of citizens' digital participation in groups are currently available, common, and ready for digitalization and which of the more ‘traditional’ approaches of citizens’ participation can be digitized, for example citizens’ assemblies, opinion polls, petitions, demonstrations, participation in political parties or citizens' initiatives (see also Kubicek et al., 2009). A few examples are online platforms such as U_CODE (2020), an ‘Urban Collective Design Environment’, Change.org (2007) for initiating online petitions, or aula (2014), that aims to enable students to participate in decisions in school-related topics.

Procedures for ‘representative’ participation of citizens in councils for problem-solving

Of the methods and procedures currently in use, however, another participation method is currently favoured in Europe (Germany, Ireland, UK, etc.), a modified form of agile hackathons, and will be considered in more detail here: Randomly and representatively composed small groups develop topic- and problem-centred proposals for activities and actions to be implemented by citizens, authorities, or other stakeholders. The overall objective is to involve a representative set of people composed of small teams with the task to work out proposals and solutions for a given challenge.

The new feature of current citizens’ councils is ‘random selection / sampling’ or ‘drawing of lots’ (Franke, 2017). Thus, currently, citizens' councils are randomly selected people who, with the support of moderators and experts, work in small teams on a joint position on a given issue and discuss the result with politicians. Examples are ‘Citizens' Council on Germany's Role in the World’ (Germany’s Role, 2021) and ‘Citizens' Council on Climate Protection’ (Deutsche Welle, 2021). The random principle is intended to ensure that the selection represents the population to be considered.

The main advantage of such a random selection is that one of Leventhal`s rules to ensure procedural justice (Leventhal, 1980) is fulfilled – at least from a statistical point of view: representativeness. A sufficiently large set of smaller teams that constitute the citizens' council, each team consisting of up to ten individuals which were randomly selected from the population, should represent the population. In addition to that, every citizen has the same chance to be chosen for a citizens' council. On the downside, minorities could be even more underrepresented (compared to their already smaller group-size in the population) in the outcome of the decision: If majorities dominate nearly all single smaller teams constituting the citizens' council, and the 'winner-takes-all principle' is applied to come up with suggestions and recommendations from the single teams, minorities may not have the chance that their suggestions are reflected in the decision of the council. The winner-takes-all principle is for example applied in case of the US majority vote system.

However, also other selection processes and rules on how to select members for the smaller teams are feasible (for a schematic overview see Figure 1; inspired by Allianz Vielfältige Demokratie, 2017).

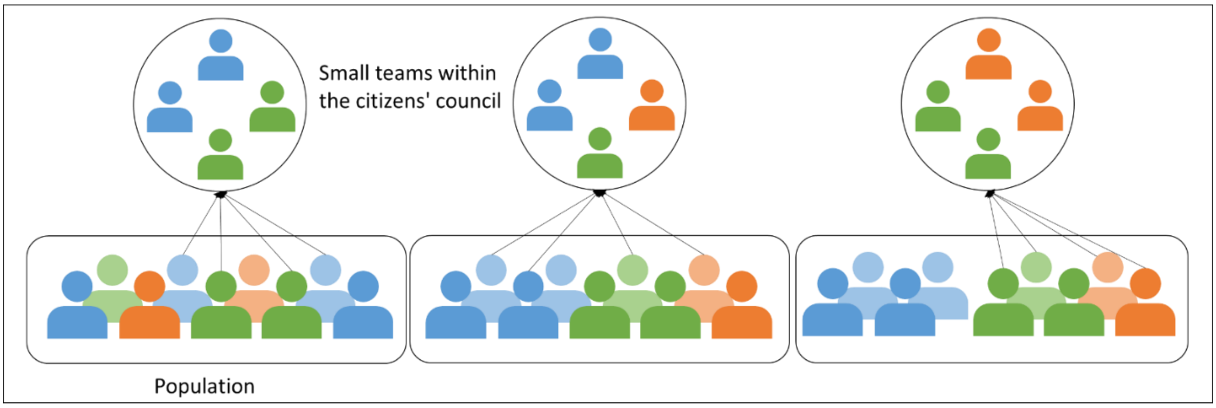

Figure 1. Schematic overview on prototypic selection rules for members of the smaller citizens' council teams: random selection from the population (left), quota selection process (middle), and quota selection process from pre-defined subgroups (right).

A quota selection process would ensure that at least a single member from each subgroup is represented in the smaller teams. This would have the advantage that the voices of minorities (or coalitions of minority groups) are more likely to be reflected in the final outcomes, i.e. suggestions and recommendations of the citizens' council, to be implemented by the policy makers. However, to ensure high quality some disadvantages have to be solved: First, the question is what variables (e.g. gender, age, socio-economic background, etc.) to include in defining the quotes / subgroups. Second, who is authorized to decide upon the selection of these variables – policy makers? For example, right-wing policy makers may not want to include people with migratory backgrounds. Third, it is questionable if individual members of a certain subgroup (defined by others) actually consider themselves as belonging to this subgroup. And finally, even if a certain individual identifies herself/himself as a member of a particular subgroup, the basic question is if individuals can actually represent a larger collective. A basic premise of identity politics is the assumption, that members of social groups (e.g. based on race, gender, sexual orientation, etc.) share the same (or at least similar) experiences and that these experiences shape common belief systems and political attitudes (e.g. Crenshaw, 1991).

A more restrictive quota selection process (see Figure 1, right) would include only subgroups who would be actually affected by the decision. As an example, it could be argued that for the decision on where to build a new kindergarten within a city-district, only parents of younger kids should be included in the citizens' council. Here, the same open questions and potential disadvantages from a democratic and social justice perspective as for the quota selection process described above, remain. In addition to that, who has the authority to decide upon the inclusion / exclusion of certain sub groups? As for the previous example, nearby residents of the potential locations of the 'new kindergarten' may also want to participate in the decision process.

Results and Discussion

Surprisingly, the topic of citizen participation has only recently 'boiled up' again, although, for instance, (a) citizen participation existed in Europe more than two thousand years ago (Athenian Democracy, 2021), (b) Hannah Arendt already proposed citizen councils more than 50 years ago (Ledermann, 2019), (c) electronic technology and computer conferencing for citizen participation were used as early as 1975 (Sheridan, 1975) and 1979 (Crickman and Kochen, 1979), respectively, and (d) in Germany, an Internet-based citizen participation platform was developed and tested as early as 2001 (Märker, Hagedorn, Trénel, Gordon, 2001).

Experience so far has shown that citizens' interest in such a form of participation is very high. However, difficulties have also become apparent that suggest further development of participation instruments.

The problems can be outlined with the following points:

- *Selection principle*: The random selection chosen is very understandable in order to achieve representativeness. However, one problem associated with this is of a demographic nature. Our population is ageing and thus the proportion of old people is increasing disproportionately. On the other hand, major political decisions are about long-term effects that affect the old much less than the young. Random selection, however, would inevitably lead to an overrepresentation of the old. The selection would therefore have to be linked to the impact on different stakeholder groups in a form yet to be found.
- *Group size*: Another aspect is the group size. Currently, groups most often consist of far more than 10 people, which is suboptimal from the point of group *problem solving research.*

- *Moderation*: The next problem is the selection of moderators and experts. It has been shown that with the selection of moderation and expert input chosen so far, the results were and are "polished by consensus". In this respect, the question arises as to how the various interests can be supplemented/supported by appropriate expert input.
- *Topic setting*: Topic setting is another aspect that should not be left to chance or to a small interest group. A rather problematic example was the Citizens' Council "Germany's Position in the World". The topic was deliberately predetermined by the Bundestag because too many conflicts were feared with the topic of "climate protection".
- *Adoption of results*: And finally, there is always the question of whether the results will be adopted. In this respect, too, there are initial experiences that make it clear that the motivation of the people involved suffers when they experience that the hard-won results disappear in a drawer.

Nevertheless, in summary, compared to the forms of participation offered so far, digital citizens' councils are a new instrument of participation that can potentially have an impact on political decision-making. One of the most important features is that in principle every citizen has randomly the chance to contribute. Insofar the method can (directly or indirectly) contribute to representative democracy using modern technology, and thus, modernizing and improving citizen participation.

Output-, action-, and impact-oriented participation of citizens in councils for problem-solving

Above, the question was addressed how citizens can and should be adequately statistically represented in differently composed groups in order to ‘give them a voice’ and to influence political decisions and actions. Until now, it has been proposed that the interests of the majority of the citizens should be represented in those councils, and also the interests of the minorities have to be taken into account.

In the following, however, the participation of citizens in differently composed groups will be mentioned from a different perspective. Specifically, we address the question how digitized group-work can be used to ensure that (a) as many possible relevant points of view and potential solutions are not only discussed by many different councils when trying to solve a complex problem, but also (b) lead to concrete problem solutions and sustainable actions. In this context, each alternative for a potential solution is of equal importance, regardless of how many people or groups prefer a particular alternative. Thus, even a potential solution proposed by only one individual may be realized – rather than a solution originally contributed by a majority of people or groups.

Of course, in the problem-solving process, a decision-making and implementation phase must be also provided, and the sustainability of the implementation should be evaluated in a follow-up phase. Sustainable and transparent impact is important not only for solving a detected problem. The method of citizens' participation will not be used any more in the future without tangible impacts, rewarding participants' efforts and contributions. The method needs to have long lasting success.

With these aims in mind, the general question arises, how to design the participation and problem solving process with respect to its' final sustainable impact. How to create collective sustainable problem solving processes based on distributed intelligence of humans, machines, and digital connectivity?

Rather than presenting solutions, we will identify questions for future research, creating potentially new methods, and enabling measures to establish a basis for bottom-up approaches.

In particular, several specific aspects need to be specified for optimizing the method and foster positive aspects and avoiding negative ones; some of them are:

- What about taking each of the five problem solving steps as a separate problem solving step with input from former steps and as output for the next one?
- Each group of citizens can be assigned to the whole process or to a single step; either for problem solving and/or evaluating the work of other groups.
- Digitization allows to increase the number of participating citizens and groups without increasing the optimal group size and to use any digital means for supporting the groups and improving effective work. What critical mass of people must be reached in order to create new sustainable solutions and to correct existing insufficient decisions, made by politicians and policy makers?
- How to support the application of methods and models of computational and mathematical psychology in each of the steps and sub steps for problem solving in a transparent way?
- What about applying the power of artificial intelligent algorithms and to realize transparency of these methods?
- How to assess, predict and measure 'sustainability' of solutions by applying digital methods?
- Another important aspect of sustainability is the intended knowledge transfer, competence development and behavioural change of individuals and groups. How to assess these effects and how to use these effects for refining the involved feedback-loops?
- How to handle the amount of data, foster transparency, and automatically analyse, compare, summarize digitized results of participatory group activities.
- Finally, how to achieve an overarching goal of citizens' participation, namely, to involve 'the citizens' in the development and design of future participation projects, technologies and structures in a transparent, effective, and

environmentally friendly way, i.e. creating the future of digitalized citizens' participation. Of course, experts should contribute methodological approaches which are appropriate to move forward towards future digital participation.

There exists already a large body of experiences regarding impact-oriented group working, as well from the analogue and the digital world. Thus, for constructing and establishing citizen councils some of these methodological approaches and recommendations will be briefly mentioned:

There is the need to identify specific problems in given settings that might be local, regional, or national. The corresponding required skills encompass analytical thinking, knowledge, communication skills and awareness about the *Sustainable Development Goals* (SDGs) of the *United Nations*, the *Main Objectives of the European Union*, and the above mentioned Legal Aspects of Citizen Participation.

- One instrument that supports action learning is *Design Thinking* (Siang et al., 2021). The instruments ensure in-depth analysis of problems, taking into account stakeholder interests.
- Other important elements are inspiring examples and inputs from existing solutions.
- Furthermore, the process of design thinking requires the development of prototypes that need to be evaluated by stakeholders or experts to get feedback.
- Team and group organization should follow SCRUM principles (Latre, 2019) with sprint, daily meetings, reviews and retrospectives. Short sprints lead to quick results, feedback and success experiences, short daily meetings are the basis for coordination and improvements. Reviews with e.g. experts ensure critical view on proposals and retrospectives improves the team work of the group.

These aspects allow to improve at least some of the relevant analogue and digital components: moderation, team organization, expert input, and impact.

Combining representative and impact-oriented approaches, and overcoming the gap between knowledge/motivation and action

The two described approaches are not mutually exclusive – on the contrary, they complement each other. The result of an impact-oriented process cannot be realized without sufficient acceptance of citizens. The representative approach is a prerequisite in terms of a bottom-up process.

However, there are two obstacles of a similar character: (a) the gap between knowledge and motivation at one hand and action at the other, (b) between the results of citizen councils and actions of stakeholders or policy makers.

Often, the results of citizens' councils affect the citizens themselves, i.e., results are addressed by and to themselves. The required knowledge may have been shared with others, and the motivation to change behaviour may have been stimulated and aroused. However, this does not necessarily trigger actual behavioural change and corresponding actions, even not in the absence of *learned helplessness* or other barriers. Bridging the gap between knowledge and motivation on the one hand, and transforming motivation into actual behavioural change on the other, is extremely difficult to achieve, as already indicated by the different theoretical and empirical approaches mentioned above (see also Albert et al., 2021; Bedek and Albert, 2019; Hagger et al., 2020).

It seems reasonable to assume that motivation increases due to the participation in councils. As a consequence, the compliance to actually implement the councils` outcomes by concrete actions increases if previous councils have shown tangible impact. Besides the influence of the group situation, anticipated *expectation of success* and rewards play a role in changing behaviour. The extent to which people are affected and involved also has an impact. Local and regional behavioural goals are implemented more successfully.

Independent of the rules on how to select the individual members of the citizens' councils, how to compose the groups etc., it is essential for both the general approaches' sustainability and success on the long term, that the actual policy makers (legislative branch at the city district, city, federal or national level) actually implement the suggestions and recommendations of the citizens' councils. Consider that policy makers do not implement unpleasant suggestions and recommendations – this would have devastating effects on the citizens' motivation to engage in such councils and to invest time and creativity to come up with suggestions in the future. Most theories on (perceived) social justice / fairness, developed and empirically validated in the field of Social Psychology, distinguish between at least two forms of justice / fairness: distributive and procedural fairness (e.g. Cropanzano and Folger, 1996). Others also include a third form, called interactional justice (e.g. Skralicki and Folger, 1997). Distributive justice is the perceived fairness about the outcomes of a decision, procedural justice is the perceived fairness about the process to come up with the decision, and interactional justice, which is informed by the perception of the quality of the interpersonal treatment received during the decision making process. Even if people are not satisfied with the outcome of a decision for themselves, the overall perceived fairness remains high if the procedural justice is considered as high (Brockner and Wiesenfeld, 1996). Thus, procedural justice is considered as essential element for subjectively perceived fairness and justice. Leventhal (1980) suggested six rules on how to ensure procedural justice (called consistency, bias suppression, accuracy, correctability, representativeness, and ethicality), whereas these rules may be – depending on the concrete situation – some rules are considered as more or less important (VanYperen et al., 1999).

Conclusions

For solving the problems at hand and shaping a sustainable future, the engagement and participation of citizens is absolutely necessary to achieve the required behavioural changes, either by the stimulation of new behaviours and/or the suppression/inhibition of old behaviours. The current ‘silver bullet’, that randomly selected people work out solutions in statistically representative groups is certainly an important step in the right direction, but it is too one-sided. Rather, many groups should be formed (a) in order to realize the different aspects and methods of group composition and (b) to fulfil the need for small working groups. The digitized results of the different groups can be combined in a bias-neutral way and subsequently evaluated. Evaluation and cross-validation can be done either by the existing groups or by systematically newly composed groups. Groups can also be formed in this evaluation phase in which control- and communication-expertise might be more represented. Semantic technologies can be used to make the flood of digital information manageable and communicable in a transparent way. Follow-up feedback procedures guarantee that the impact of participation is recorded and communicated. In this way, the motivation of the participating citizens can be maintained. It is possible that, in the sense of *observational learning*, even those citizens who have withdrawn from participation due to *learned helplessness* may become active and involved again.

Finally, it should be pointed out that from a psychological point of view there are problems of behavioural change that are difficult to solve and resistant to change (addiction, hatred, habitually behaviour). In such cases, for example, the question arises whether ‘unethical’, non-participatory methods of behavioural change seem appropriate, i.e. through regulations and coercion. For example, the wearing of seat belts was introduced against the majority of car drivers. The current switch to smart meters is in many cases against the declared will of consumers.

The authors take the view that in all these cases, too, the participation of individuals and groups concerned is necessary in order to achieve sustainable behavioural changes.

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155 Repair in the Circular Economy: Towards a National Swedish Strategy

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Abstract

Extending the lifetime of products is seen as a key objective for realising the vision of a Circular Economy. One way to increase the lifespan of products is to enable more repair activities. However, consumers encounter a variety of barriers for repairs, prompting public authorities in Europe and the US to adopt or propose policies in support of consumer repairs. Sweden has recently adopted a circular economy action plan, where increasing the number of consumer repairs is a stated objective. However, Sweden has so far only adopted a few repair policies, most notably through the tax reliefs for the repair sector that were implemented in 2017. The aim of this contribution is to research how Sweden could develop a more comprehensive policy mix for promoting consumer repairs, also by taking into consideration initiatives from other countries and regions. The research is based on a literature review and semi-structured interviews with policymakers and other relevant actors in Sweden, Europe and the US. The study shows that a lot of interesting initiatives aiming at increasing repairs are currently being proposed. The new requirements related to repairs, developed within the European Union's (EU) Ecodesign Directive, have been positively received but the process is cumbersome and it will take time before their full effect becomes evident. Initiatives, such as the French repairability index and the French repair fund will create incentives for the producers to design more repairable products and make it easier for consumers to repair. On the same track, the Repair Network of Vienna with its repair vouchers makes repairs cheaper and more trustworthy. Also, the US policy proposals on right-to-repair laws would help to create an open market for repairs for a lot of products. Sweden has the possibility to gain knowledge through the implementation of similar policies, and by considering new policies suggested in literature and by the interviewees. Thus there is potential for Sweden to be a front-runner in creating a more resource efficient society through increased repair activity. Concluding, some preliminary proposals for a future policy mix are presented.

Keywords: Repair, Repair policy, Right-to-Repair, Circular Economy, Ecodesign.

Introduction

Product repairs can support the slowing and closing of material loops, and increase product lifetimes, thereby contributing to the transition to a circular economy (Svensson-Hoglund et al., 2021). Yet, there are indications that the number of product repairs has decreased in recent years, and that throwing away a broken product instead of repairing it is becoming “normalized” (Bakker et al., 2014; McCollough, 2009). The approach towards repair in the European Union (EU) and the United States (US) has different framings: in the US repair is seen primarily as a consumer issue, whereas in the EU repair is more closely connected to environmental issues and the circular economy (Svensson-Hoglund et al. 2021). In the US, several states have proposed right-to-repair (R2R) laws that aim to strengthen consumers’ rights and opportunities in relation to repair, and open up the market for repairs for more commercial actors (Svensson-Hoglund et al. 2021). In the EU, certain R2R obligations have been adopted through the Ecodesign Directive (2009/125/EC). For instance, for some product categories producers are obliged to provide professional repairers with spare parts for up to ten years (European Commission, 2019). However, in order to reach more substantial levels of consumer repairs, a more comprehensive package of policies is needed, where EU member states also adopt national policies (European Commission, 2015; Milios, 2018; 2021a). Through national initiatives that complement EU policies, there is a chance to gain momentum towards a situation where repair is ”normalized” (Dalhammar et al., 2021a).

Some EU member states have already adopted progressive circular economy policies, cf. Table 1, and this development is expected to continue (Dalhammar et al., 2021b).

Table 1. Examples of adopted and proposed policies to increase product lifetimes

Practice	Definition	Examples of laws & policies promoting the practice
Longer product lifetimes through design	Extending the technical lifetime through product design, e.g. using more durable materials or adopting design changes to make the product easier to repair	Ecodesign regulations have regulated minimum lifetimes for some products/components (EU level) Changes in mandatory consumer warranties (several EU countries) Modulated fees in producer responsibility schemes (France) Eco-labels with criteria that aims to prolong product lifetimes (e.g. TCO certified)

		Proposals to provide durability information on products at point of sale
Repair	Extending the life of a product during its first use by retaining or restoring its functionalities with minor repairs that can be done by manufacturers or professional service providers	Right-to-repair obligations in Ecodesign Directive (e.g. provision of spare parts, ease of disassembly) (EU level) Repairability index (France) Repair fund linked to producer responsibility schemes (France) Lower taxes for the repair sector (several countries) Local and regional initiatives, such as Repair Network Vienna (includes repair vouchers)
Reuse	Extending the life of a product or part by having a second hand user utilize it for the same original purpose with no or only minor enhancements and changes; can be combined with refurbishing	Re-use parks and re-use malls (several cities and regions in Europe) Quality labels for re-used products (several regions and cities) Support re-use in waste laws
Remanufacture	Enabling a full new service life of a product via a standardized industrial process that takes place within industrial or factory settings, in which cores are restored to original as-new condition and performance, or better. The remanufacturing process is in line with specific technical specifications, including engineering, quality, and testing standards, and typically yields fully warranted products (and per agreement of global industry members).	Support to Remanufacturing networks (EU has provided such support) Public procurement of remanufactured products such as laptops and furniture (several countries) Changing trade agreements to support trade in remanufactured products (discussed at global level)

Clearly, the current policy situation in the EU is quite dynamic, and it is important that front-runner countries (e.g. France) adopt progressive policies, as this can lead to a situation where other countries can follow. Further, national initiatives will be important stimulus for further EU policy developments (Dalhammar, 2007)

The aim of this research is to investigate how Sweden could develop a comprehensive policy mix for promoting consumer repairs, and what we can learn from other countries and regions. The research included an analysis of: i) how Sweden, the EU, progressive EU member states and the US supports repairs; ii) what Sweden can learn from other countries and regions; and iii) an analysis of what policies should be adopted at the EU level vs. the national level.

Methods

The methods included a literature review and an interview study. The literature review was performed in order to provide information on the role of repair in the circular economy, and to obtain an overview of existing and proposed policies. The literature review was conducted using relevant search words (i.e. repair, circular economy, policy, strategy, USA, Sweden, EU) in Web of Science, Scopus and Google Scholar. The search for keywords was performed both in English and Swedish. Additional literature was found through the search of the relevant themes in public documents, and through recommendations by the interviewees.

The interview study contained 15 semi-structured interviews with experts in the field; see Table 2. A number of experts were contacted, and more names were provided through the "snowballing" method (i.e. experts proposing other experts). 15 people agreed to be interviewed during the available time period for this research.

Table 2. List of interviewed actors.

Respondent	Date	Organisation
European actors		
1	12 Mar. 2021	Repair network
2	16 Mar. 2021	NGO
3	17 Mar. 2021	NGO
4	17 Mar. 2021	Repair and re-use company
5	25 Mar. 2021	NGO
6	1 Apr. 2021	Repair company
7	9 Apr. 2021	NGO
Actor in the US		
8	30 Mar. 2021	NGO

Swedish actors		
9	23 Mar. 2021	National authority
10	26 Mar. 2021	Repair section of large OEM
11	29 Mar. 2021	Researcher
12	29 Mar. 2021	National delegation for circular economy
13	30 Mar. 2021	National authority
14	14 Apr. 2021	Politician
15	12 Apr. 2021	NGO

Semi-structured interviews were considered the most appropriate way to conduct this research, as it provides the possibility for interviewees to share insights and allows for exploring new issues brought up during the interviews. The interview guide had 17 questions, related to inter alia: how the interviewees work with repairs, their ideas and expectations related to existing and adopted EU and national policies for repairs, and their views on what kinds of policies the EU and European countries should develop.

Due to the ongoing pandemic, all interviews were conducted online through video communication software. The interviews lasted between 30 and 60 minutes and were conducted in English or Swedish.

The policy analysis methodology presented by Walker (2000) was used as guidance when discussing the appropriate policy mix. This was further informed by proposals in relevant literature, and by the opinions of the interviewees.

Results

The results section is divided in two parts: the literature review and the interviews. In the discussion section that follows, the results and the implications for Swedish and European policies are analysed.

Literature review

Barriers for consumer repairs

Whether a consumer chooses to repair a broken product or not depends on a number of factors, including the price of the repair, the price of a new product, and the cost – in time and money required to get a good repair service (Ackermann et al., 2018; Maitre-Ekern & Dalhammar, 2019). If the price of a new product is not much higher than the costs of repair, a consumer is likely to buy a new product instead of proceeding to repairs (Cerulli-Harms et al., 2018 Jaeger-Erben et al., 2021; Laitala et al., 2021). Apart from the price issue, other barriers for repairs include lack of knowledge (Woidasky & Cetinkaya, 2021), product design (Cooper & Salvia, 2018) and existing laws (Svensson-Hoglund et al., 2021). Consumers are also likely to be influenced by various cultural and social factors that affect the choice to repair or not (Ackermann et al., 2018; Jaeger-Erben et al., 2021).

Technical barriers may be due to design, poor quality materials, or lack of spare parts or proper repair information (Maitre-Ekern & Dalhammar, 2019; Hernandez et al., 2020). Design that does not support disassembly – e.g. by gluing components – or requires specific tools for repairs, constitutes a barrier for repairs (Cooper & Salvia, 2018; Maitre-Ekern & Dalhammar, 2019). Moreover, rapid technological development can also lead to problems for repairers, who need to keep updated in order to perform repairs (Hernandez et al., 2020).

Functional obsolescence can, for instance, happen in the case that an important component in a product breaks down, even if the other parts of the product function properly (Cordella et al., 2021; Jaeger-Erben et al., 2021). Furthermore, software updates can often lead to a situation where older models of a product do not function as intended (Maitre-Ekern & Dalhammar, 2016).

The economic case for repairs is undermined by structural factors. Quite often, considering the price of repairs and warranties provided when buying a new product, it is not beneficial for consumers to undertake repairs. This situation is significantly affected by the fact that products are typically produced in countries where the price of labour is low, whereas the price of labour needed for repairs is high in most OECD countries (Bocken, 2020; Cerulli-Harms et al., 2018; Maitre-Ekern & Dalhammar, 2019). If spare parts are expensive or hard to get, this can also affect the price of repairs negatively (Svensson-Hoglund et al. 2021).

Regarding administrative barriers, laws related to chemicals and intellectual property rights (such as patents and copyrights) are often barriers for repairs (Svensson-Hoglund et al. 2021), as they can hinder the use/re-use of spare parts, and be used by Original Equipment Manufacturers (OEMs) to restrict access to spare parts or raise the price of spare parts. They can also hinder independent repairers form repairing a product.

Social and cultural barriers may be due to consumer actions and habits. A desire for novelty can lead to discarding of functioning products (Jaeger-Erben et al., 2021; Laitala et al., 2021). This is especially relevant for products with short innovation cycles like computers and cell phones, as consumers tend to a have high expectations related to performance and aesthetics (Jaeger-Erben et al, 2021; Maitre-Ekern & Dalhammar, 2016). Low prices for many products lead to less ”economic and emotional” investment in products, which inhibits the incentives for repairs (Ackermann et al., 2018; Cooper & Salvia, 2018; Hernandez et al., 2020). Further, the cost in terms of money, time and energy for performing repairs is often considered to be high, whereas the repair service is not always of high quality (Jaeger-Erben et al., 2021). An overview of consumer repair barriers is presented in Figure 1.

Technical barriers

- Lack of supply of necessities that make the repair possible (spare parts, tools, etc.)
- Lack of information on how the product can be repaired
- Products are not designed to be repaired
- Safety issues when repairs are carried out by people with lack of knowledge or without supervision
- Repair allows for continued use of low-efficiency goods, which is not environmentally beneficial
- Low-skilled repairers have difficulty accessing the information made available through manuals
- Limited accessibility to spare parts and repair information
- Planned and functional obsolescence

Administrative barriers

- Lack of appropriate legislation regarding design for repairability and access to repair necessities (spare parts, tools etc.)
- Repair is hampered by legislation on intellectual property rights that instead favours innovation
- Warranty in accordance with the Consumer Law does not apply
- Contract law includes repair-limited clauses
- Chemical tax is applied to spare parts that can be reused, which affects the price of repair
- Chemicals legislation makes it illegal to use certain spare parts (that do not comply with revised chemical requirements)

Economic barriers

- Cheap and low-quality new goods are increasing in the market
- Cost in time and inconvenience when choosing repair
- Lack of quality repair services
- The possibility of repair is hampered by the fact that the manufacturer can control the supply (of parts)
- Repair is perceived as risky
- Repair is seen as a loss for the manufacturer, offering a new product instead

Social and cultural barriers

- Lack of confidence in repairs
- The repair profession is classified as a "low-status" job, which leads many people to abandon this profession
- Lack of emotional and financial attachment to the product, which affects the willingness to maintain and repair
- Lack of knowledge, time and awareness to maintain and handle properly a product
- Desire to replace an old product instead of repair (psychological obsolescence)

Figure 1. Overview of consumer repair barriers
(own illustration based on Svensson-Hoglund et al., 2021 and Hernandez et al., 2020).

Policies at the EU level

The most important policy development at the EU level concerns new requirements under the Ecodesign Directive, with some new product regulations adopted in October 2019. Manufacturers and importers of some product groups must now supply professional repairers with spare parts for at least 7 years (and at most 10 years), and deliver them within 15 workdays (European Commission, 2019). It is also stated that repair should be possible with commonly available tools, and that repair information shall be accessible (European Commission, 2019). These requirements entered into force in 1 March 2021 for four product categories.

These new requirements have been criticized for mainly being aimed at professional repairers, and it is unclear what categories of actors can be considered professionals (HOP, 2020; Mikolajczak, 2021). The regulations state that the repairers should have the necessary technical expertise and be present in a register set up by the respective EU member states. Few member states have such registers yet, and therefore it is the manufacturers that decide which repairers are to be considered professional ones (Mikolajczak, 2021). HOP (2020) argues for further developments, to ensure that independent repairers and consumers can access spare parts and repair manuals. It has also been argued that requirements related to repairs must be adopted for many more product categories (Keirsblick et al., 2020). Additionally, the delivery time must be shorter than 15 working days, as long waiting times reduce the attractiveness of repairs (HOP, 2020; Mikolajczak, 2021). Another issue to consider is software-hardware interactions, to be better regulated under the Ecodesign Directive (HOP, 2020; Zuloaga et al., 2021).

Mandated by the European Commission, the European standardization organisations have developed a number of standards that can support future regulations under the Ecodesign Directive, as well as other policies like labelling (Dalhammar et al., 2021c; Tecchio et al., 2017). One of the standards related to repairs, among other things it includes a basis for a scoring system to rate products' 'repairability'; cf. Table 3 (see also Cordella et al., 2019).

Table 3. Examples of criteria in repairability scorecard (based on EN 45554:2020).

Aspect	**Examples**
Design for disassembly	Fastener types
Tools and interface	Necessary tools required for repairs Diagnostic support and interfaces
Repair environment required	Workshop environment required for conducting repairs
Skill level	Skill level needed for conducting repairs
Software and data management influencing repair opportunities	Password and factory reset Data management
Return options for products	Available return options for repair, re-use or upgrade processes
Repair information	Availability for different actors (e.g. authorized and independent repairers, consumers) Comprehensiveness of information

Access to spare parts	Duration (time) that spare parts will be available Spare parts interfaces Spare parts availability for different actors (e.g. authorized and independent repairers, consumers)

In the area of consumer law, the EU has adopted a new Directive on sale of goods (Directive (EU) 2019/771). Among other things, the Directive includes certain changes regarding consumer guarantees, and the right for consumers to ask for repairs as redress options when a product is faulty. The Directive is however not expected to have large implications for repairs.

The latest EU Circular Economy Action Plan (European Commission, 2020a) and the New Consumer Agenda (European Commission, 2020b) include a number of initiatives to strengthen consumer repairs, but it remains to be seen what the legislative proposals regarding these will be.

There is a growing number of proposals for future circular economy policies at the EU level. The European Parliament has recommended that the European Commission should ”develop and introduce mandatory labelling, to provide clear, immediately visible and easy-to-understand information to consumers on the estimated lifetime and reparability of a product at the time of purchase” (Article 6(b) in European Parliament resolution 2020/2021(INI)). Proposals for such a labelling system do exist in literature, but there is certain uncertainty on how to apply it in practice (Cordella et al., 2019).

In a white paper, HOP (2020) presents 20 measures to combat planned obsolescence. These include measures aimed at advertising, and also: a durability/repair index for products (harmonised in the EU); proposal for the implementation of an EU repair fund (similar to the planned French one; see below); requirements that producers account for how long they will provide spare parts; and suggestions for EU member states to have more flexibility regarding changing Value Added Tax (VAT) for the repair sector and for green products (through changes of the VAT Directive 2006/112/CE).

National policies

France seems to be a leader when it comes to repair related policies. The country has criminalized planned obsolescence (Maitre-Ekern and Dalhammar, 2016) and through the recently adopted “anti-waste law” (Law 2020-105) France is the first country to introduce a mandatory repairability index (Law 2020-105 Article 16 L 541-9-2) (Ministry of Ecological Transition, 2020a). The aim of the index is both to provide relevant information on repairability to consumers, and to provide incentives for producers to design more repairable products.

The law also introduces so-called repair funds (Law 2020-105 Article 62 L 541-10-4&5) (Ministry of Ecological Transition, 2020a). Depending on whether the product complies with certain criteria or not, the producer pays money into a fund, arranged through the producer responsibility schemes. That money can be used to reduce the costs for consumer repairs when undertaken at professional repairers. The criteria will be designed for relevant product groups/sectors. Producers of household appliances, including electric and electronic equipment (mobile phones, computer equipment, large and small household appliances, TV sets, hi-fi stereo systems etc.) and furniture need to provide spare parts from the date that the last product of a certain model was put on the market (Law 2020-105 Article 19 L 111-4) (Ministry of Ecological Transition, 2020b). The use of re-used/harvested spare parts is encouraged. From January 2022 it is also lawful to use 3D printing to print spare parts that are no longer available on the market (Law 2020-105 Article 19 L 111-4).

France has also made use of modulated fees in producer responsibility schemes to support product longevity and repairs. A bonus-malus system is applied, where the producer fee is based on various criteria (Micheaux & Aggeri, 2021), e.g.:

- Dishwashers and washing machines: if a producer supplies spare parts for 11 years there is 20% reduction of the fee;
- Vacuum cleaners: if a producer fails to provide certain technical information to authorized repairers, it leads to 20% increase of the fee;
- Computers: 20% reduction of the fee is granted if product updates can be performed by commonly available tools.

So far, the application of modulated fees and the bonus-malus system has not affected product design but it may happen over a longer term (Micheaux & Aggeri, 2021). Further, implementing such a scheme at the EU level would provide stronger incentives (Micheaux & Aggeri, 2021).

In Austria a number of local repair networks have been created, to make it easier for consumers to identify professional repairers (Lechner et al., 2021; Piringer & Schada, 2020). The cities of Graz and Vienna both have such networks, receiving funding form the respective municipal authorities. Repairers who want to join the networks must comply with certain criteria, e.g. that repair activities represent a large portion of their turnover, that there is price transparency towards consumers, and that the repairers do not solely serve one brand of products (Lechner et al., 2021; Piringer & Schada, 2020). The networks also offer a platform for various activities, including information sharing and swapping of spare parts (Lechner et al., 2021; Whalen et al., 2018).

The two networks subsidise consumer repairs, but use different systems. In Graz, the consumer can get a subsidy for half the repair cost, max. 100 EUR per year and household (Lechner et al., 2021). The consumer is entitled to the subsidy after the repair has taken place. In Vienna, consumers can download repair checks, which they hand in to repairers (thus, they get the subsidy at the time of purchasing the repair service), and it covers 50% of the cost of repairs up to maximum of 100 EUR (Piringer

& Schada, 2020). Subsidies can only be used at repairers that are part of the network. This is a way to increase quality control and to ensure that money is mainly used at independent repairers (mainly engaged with repairs and serving several brands).

In the US, several states have proposed laws of fair repairs (fair repair bills), with the purpose to make it legal for consumers and independent repairers to repair electrical and electronic products. This includes proposals on making spare parts and repair manuals available. While the proposed bills have different content, most of them aim to provide consumers and independent repairers with the same repair information and spare parts that are provided to authorized repairers (Svensson-Hoglund et al., 2021). Only three of the bills require producers to develop more sustainable and repairable products. The aim of the bills is rather to strengthen consumer rights, whereas environmental benefits are seen as a side effect (Svensson-Hoglund et al., 2021).

In Sweden, some tax measures to promote repairs were implemented in 2017 (Dalhammar, 2020; Milios, 2021b). One measure was to reduce the VAT for repair services of bikes, footwear and textiles from 25% to 12%. A second measure was to allow a tax deduction for repair services conducted in homes, allowing 50% of the labour cost to be deducted. An interview study with repair shops indicated that the measures had little effect on consumer demand for repairs (Almén et al., 2020). Potential explanations include low awareness among consumers; repair services are still quite expensive; and that consumers often buy cheaper products of low quality which undermines the case for making repairs (Almén et al., 2020). In April 2021 a government proposal was launched, proposing that the tax deductions (see above) would also be available for repair services outside the home, and include new product categories like furniture, prams and certain tools (Ministry of Finance, 2021). The proposed measures are currently being debated.

Interviews

The results from the interviews are presented under the following headings: product design; increased awareness about repair; access to and price for repair services; alternative business models; the need for progressive countries; and Swedish actors.

Product design

All interviewees agreed that product design is a key issue for consumer repairs, and that ecodesign measures should be regulated at the EU level. Only EU rules can make a difference at global level, not national ones.

While all respondents consider the new rules under the Ecodesign Directive related to repairs to be a step in the right direction there was disagreement on how important they will be. Some respondents thought they can be very influential, while other interviewees expressed more caution, and stressed that the devil is in the detail; the wording of future regulations and other EU laws and policies will be decisive.

Among current problems identified by the interviews were: the rules mainly aim to support professional repairers; few product groups are regulated yet; and the regulated product groups are not those with the greatest environmental potential. Two of the respondents also believed that large producers will be good at identifying and making use of existing loopholes in ecodesign regulations, and also stressed that sanctions need to be deterrent enough to matter to large producers.

Another problem identified concerned the slow process of implementing ecodesign regulations. A product-specific approach is probably necessary in most cases, as product groups and sectors differ, but it also means that the process is slow; especially as the resources devoted to ecodesign are limited in the EU. Several interviewees also pointed out that this means that EU member states need to keep pushing in order to speed up developments.

The interviewees also stressed that spare parts are expensive to produce, and that a better product design could keep down the need for spare parts. Among proposals from interviews were: to include more product groups under ecodesign regulations; to regulate the price for spare parts in order to make them less expensive; to enact stricter regulations of software and its updates, as this often lead to premature obsolescence; to increase the transparency for consumers regarding spare parts and expected product lifetimes; to change intellectual property laws so as to enable 3D printing of spare parts; to ensure that most products can be repaired with commonly available tools; to set stricter requirements regarding the maximum time for producers to deliver spare parts; and to quote requirements for using recycled material in products.

Increased awareness about repair

Several respondents stated that they see an increasing willingness to repair among consumers. But generally, consumers' awareness about repair activities is considered to be low: it is important to inform consumers about their rights, and about the positive impacts of repairs.

A majority of interviewees were in favour of campaigns related to repair, and to include information about repair in school curricula. This could increase awareness about how to self-repair stuff, and what kind of faults that could be repaired at a professional repairer. It can also increase the general acceptance for future repair policies. Further, there was a need to attract more young people to become repairers, as recruitment to this profession is often difficult.

One interviewee stated the importance of persuading consumers to keep their products for a long time, which is hard when the advertising industry aims to make people switch products more often; this highlights the need to also regulate advertising per se. It was also stressed by one interviewee that we need to change consumer mentality: it should not be OK to own many products.

All interviewees thought that labelling of products – related to their durability/lifetime and repairability – would be a very important policy development. This could lead to better understanding among consumers, and ultimately affect purchasing decisions. It can also change design practices among manufacturers, who will use the label as a benchmarking system. The interviewees thought that the French repairability index was an important initiative, though the current design of the system has some flaws. A couple of respondents pointed out that under the scheme, products that were not very repairable (due to the design) could get a good score, if for example the producers have a good score for supplying spare parts. One interviewee pointed out that the index should also include go/no-go criteria to better address this problem. Several interviewees however still saw the index as a very positive development, and thought that problems would be addressed, stressing that all new policies have problems in the beginning. Some interviewees also stressed that France does the right thing by going ahead, as this puts pressure on the European Commission to propose EU policies. One interviewee also claimed that the French index has led to some positive developments, for instance Samsung has published more repair manuals.

The majority of respondents stressed that provision of information is not very effective as a standalone policy intervention, since the market is not "self-correcting" and many manufacturers will not change practices due to informative policies alone.

The access to and price for repair services

Several interviewees stressed that consumer law can be a key enabler of repair services, through strengthened guarantees. Also, several respondents stressed that repair services should be more visible in city centres, highlighting the need for some public support for facilities, tools and marketing.

In Sweden, the municipalities have far-reaching powers, enjoy a high degree of autonomy, and exercise strong control over waste management. This means that it makes sense that they also take some responsibility for repair infrastructure and support relevant actors. One respondent also thought that they could support schemes for offering repair in homes for some product categories, like furniture.

The majority of interviewees stressed the need for a coordinated national repair network, which can assist the identification of repairers, registered in a database. This could then constitute the repair register envisioned in Ecodesign regulations. The majority of respondents thought that 'Repair Network Vienna' could serve as an example for other cities and countries. Of course, this network only includes repairers that comply with strict criteria; having such exclusionary criteria would require a strong political commitment.

Regarding the price of repairs, several interviewees stressed the need for national initiatives that make repair more economically attractive. Two respondents stressed that VAT reduction for repairs should be considered for all types of repair activities;

four interviewees stressed the importance for the EU to change the VAT Directive in order to support repairs. One respondent advocated raising the VAT for new products at the same time, to increase the effect. Some interviewees thought that the Vienna repair vouchers should be adopted in more places, as they do not only increase the number of repairs but there is also some evidence that the quality of repairs (including quality of spare parts) is increased, since consumers are more willing to invest in quality when 50% of the price is subsidized. However, some interviewees thought the public sector should not subsidize this, but rather the producers. The planned French repair funds were seen as a step in the right direction in this regard. The benefit of such a system is that it provides direct incentives for design changes among producers.

One respondent brought up the issue of educating consumers about the ”total cost of ownership”: that a 300 EUR dishwasher that lasts 3 years is more expensive than a 1000 EUR dishwasher that lasts 20 years. Therefore, durability labelling should include measures that allows for consumers to better compare price and lifetime.

Alternative business models

Many corporations would need to change their business models (BMs) in order to really move towards a repair economy. Several interviewees view the current linear economy as a significant barrier for such developments. Too many BMs are based on selling low quality products, which may undermine consumer confidence also for higher quality products. Both regulations and “carrots” are required. Various taxes, or eco-modulation schemes could be applied to reward better products and ”punish” low quality ones. Other proposals include stimulus to product-service system solutions, or policies to make costs for repair during the product lifetime being part of the price of a product at the time of sale. ’Fixed price repair’ – when consumers pay the same price regardless of what the repair costs – seems to lead to more consumer repairs and should be encouraged.

The need for progressive countries

All respondents agreed that we need progressive countries, but had slightly different views on how countries should lead. Some respondents stressed the need to protect the integrity of the EU Internal Market, which is in jeopardy if EU member states have many diverse polices. Other interviewees thought it was important that EU member states learned from each and adopted similar polices, in order to strengthen the case for adopting EU-wide policies. EU member states sometimes can have more expertise than the Commission in some areas of regulation and can play an important role in pushing developments.

Swedish actors

The Swedish interviewees regarded the recently adopted Swedish national action plan for circular economy as a step in the right direction. The interviewees stated that more is needed and that – as usual – there is too much focus on recycling. The respondents want a more progressive ”push” to really change the rules of the game. It was also pointed out that many measures discussed in the action plan were already being implemented.

One question concerned how Swedish authorities should cooperate in order to best move forward in adopting a comprehensive policy mix for repairs. The interviewees had slightly different ideas on this, and it can depend on the product group and the context. But cooperation may be required between the Environmental Protection Agency, the Energy Agency and the Chemicals Agency, and possibly also involve cooperation with various governmental functions and committees.

Discussion

The results indicate the need to simultaneously address various issues – product design, consumer awareness, business models etc. – in order to increase the number of repairs. Policies at both the EU level and EU member state level are needed in order to move forward. EU-level policies constitute the most appropriate approach to regulate some issues concerning product repair, whereas policy making at member states can be important as ”first movers” or pioneers when it comes to certain policy approaches. Over time, it is likely that EU policies will be adopted, and then take priority over member state policies. At this point in time, there could be a reason for EU member states to coordinate their policies, at least to some extent; there is for example no reason for all member states to have their own repairability indexes, durability indexes, and product labelling schemes.

Sweden has the potential to learn, and be inspired by, from initiatives in other countries and regions. This includes the French national policies, and also regional and local actions, like Repair Network Vienna. It became evident trough the interviews in this research that the Swedish actors asked for a clearer and more comprehensive strategy to change the rules of the game on the market.

Based on the literature review and interview study, some important areas where the EU and Sweden should consider future policy developments are elaborated in Figure 2 below.

Proposals for future policy instruments

National level – Sweden

Administrative

- Set up a repair register for e.g. spare parts and information manuals, including also independent repairers.
- Increase the availability of spare parts, for example by allowing 3D printing and stricter regulation when implementing the Ecodesign Directive.
- Review the relevant legislation so as to prevent intellectual property rights from hindering repairs and the rejection of repairs by embedded software in products.
- Extend the product guarantee period and include an additional warranty period after the repair of a product.
- Design policy instruments that favour circular business models, for instance by setting a fixed price for repairs.

Economic

- Introduce customised fees and repair funds, similar to the case of France.
- Further reduce VAT rates on repair service, similar to the case of Malta.
- Introduce repair networks with repair checks, like in Vienna.

Informative

- Implement a repair index based on that of France.
- Set as a requirement that repairs are highlighted in products' marketing.
- Educate and train professionals in repairing, and introduce repair activities in the education system.

EU-level

Administrative

- Call on the European Commission to revise the Ecodesign Directive to include consumers and independent repairers.
- Include sustainability aspects in future policy instruments in order to incentivise products that are both durable and repairable.

Economic

- Take into consideration the price aspect of spare parts when designing future policy instruments.
- Reform the VAT Directive, so that all repair service can benefit from the tax reduction and so that VAT can be removed completely.

Informative

- Introduce a harmonized sustainability/repair index within the EU.

Figure 2. Proposals for future policy instruments for Sweden and the EU.

Conclusions

This contribution investigated how Sweden, the EU, and some progressive EU member states, along with the USA, strategically approach the issue of repairs at a policy level, by promoting repair opportunities. This investigation aimed at identifying a number of specific policy instruments that Sweden could adopt in a potential future Swedish repair strategy ,or lobby for vis-à-vis the EU.

The EU collectively, and its member stated individually, work in different ways to achieve a resource-efficient circular economy, where administrative, economic and informative instruments are used vis-à-vis producers, consumers and the market. The EU has implemented new repair criteria in the Ecodesign Directive, and has proposed policy repair initiatives – but the process is slow and not all member states are able to follow. France has adopted a number of forward-looking instruments, which in various ways enable consumers to repair and put pressure on producers to produce more sustainable products. Furthermore, Vienna has shown with its repair networks that it is possible to make repairs cheaper while increasing both consumer confidence and the quality of the repair service. In the USA the states act mainly via consumer law initiatives that can result in increased repair possibilities for a large number of product groups, if they are adopted. On the other hand, Sweden's action plan for CE contains only few new initiatives, and apart from tax reduction measures that promote repair, there is not much substance in the rest of the document concerning repairs.

In an effort to increase the proportion of repairs in Sweden – and potentially in the EU in the future – additional commitments are required. Based on the empirical evidence analysed (literature and interviews), this article resulted in a number of potential policy interventions that Sweden and the EU should focus on in the future (cf. Figure 2).

It is up to the member states and the EU to draw upon these policy approaches and adopt a balanced policy mix to address the issue of enabling repairs in a holistic manner and by taking into account the associated environmental, economic and social impacts. Ultimately, increasing repair opportunities in Sweden and the EU, and promoting the transition to a repair society, would also contribute to achieving both the Paris Agreement's target and the Swedish national climate target, while at the same time the consumption of resources has the potential to be significantly reduced.

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123 Designing an assessment methodology and tool for Circular Economy academic projects

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Abstract

This project responds to the research question of how to evaluate circular economy projects in the academic context. For this purpose, it takes two programs, Recircula Challenge and Circular Economic Awards, of the HUB Recircula of the Polytechnic University of Catalonia (UPC) as case studies. The development of the project follows the Action-Research methodology. For its process, the Recircula HUB organisation, the participants of the competition, and the jury of the Recircula Challenge program were involved. The project methodology is divided into three cycles; the first cycle defines the problem; for that end, it analyses different circular economy evaluation methodologies currently used in organisations and companies and defines the requirements to be met by the evaluation tool of the program. The second cycle co-designs the tools and develops the circular economy evaluation methodology using templates and rubrics created ad-hoc for each program. The third cycle evaluates and reflects on the tools and the implementation process by analysing consistency and validity. Finally, the project shows the two tools developed in this project consisted of templates for the participants and evaluation rubrics for the jury members. It concludes by pointing out the importance of learning and awareness-raising resources for university students and its potential to improve circular economy in higher education. Moreover, the results of the work show that environmental impacts are the most difficult to understand and the least adequate to evaluate. Therefore, it is necessary to deepen and reinforce this aspect among students and participants of the programs through workshops, working examples, and reviewing the criteria established for its evaluation. To this end, it is very important to achieve a common understanding of the designed tool and its concepts. To conclude, at present, Circular Economy projects are at the forefront of Sustainable Development; this work seeks to generate greater awareness and appreciation in academia by introducing the concepts and methods to measure such projects' results.

Keywords: Circular Economy, Sustainability education, indicators, rubric, impact

Introduction

The current linear (extract-use-throw) production model relies on the use of the environment and natural resources to continue to have destructive effects on the planet. However, the current climate, ecological and environmental crisis highlight the need to introduce changes to alleviate production and consumption model pressures on Earth. In this line, the circular economy emerges as a potential alternative to the conventional model. In the European context, it is strongly promoted through the new Circular Economy Action Plan mechanisms; in 2015, the ambitious "Closing the Loop" action plan was adopted (European Commission [EC], 2012). It has been followed by the recent "A new Circular Action Plan" in 2020, part of the European Green Deal (EC, n.d.). Furthermore, Sustainable Development Goal (SDG) 12 aims to ensure sustainable production and consumption patterns globally.

This new paradigm, born in the 1980s from the philosophy of industrial ecology (Andersen, 2007), proposes to rethink and redefine current needs and how to satisfy them following three basic principles; extending the useful life of products, maintaining their usefulness, optimizing the resources used throughout the life of the product by minimizing their negative impacts, and closing the cycle by retaining value of the materials used. Unfortunately, not all circular models are sustainable. Therefore, it is important to assess the model's sustainability by combining two key concepts: the need for transformation to a resource-efficient model and the need for a more sustainable society.

Context of the case study

The work frames in the HUB Recircula of the Universitat Politècnica de Catalunya (UPC). It aims to educate future experts in the Circular Economy and SDG 12, aiming to do more and better with less to decouple economic growth from environmental degradation, increase resource efficiency, and promote sustainable lifestyles. Furthermore, the HUB acts as a network between students and public and private entities; the relation is established through different programs, Recircula Challenge and Circular Economy Awards. The Recircula Challenge program spotlights the problems private and public organisations face and incentivises the participants to give potential solutions upon the circular model. The Circular Economy Awards program recognises the best circular economy final study project of UPC.

Considering that there are no tools to evaluate the results of circular economy projects at the academic level, this paper aims to answer the following research question: "How to evaluate circular economy projects in a systematic, objective, and efficient way in the academic context?".

In this line, the general objective of this work is to design a tool for the evaluation of projects that assesses the circularity of them for the two programs, Recircula Challenge and Circular Economy Awards. The tool has to be flexible, meaning that it has to apply to any project results evaluation regarding the circular economy. Furthermore, it will serve as a learning resource for authors of the projects and evaluate the programs mentioned above. This last application has two objectives: on the one hand, to guide the participants to carry out their self-assessment and measure their performance. On the other hand, systemise and standardise the jury's assessment and obtain a unique ranking that compares the different projects. For this, two specific goals have been defined:

- **Versatile Assessment:** The first goal considers versatility as a key characteristic to evaluate projects since students develop projects of diverse nature. The tool has to be valid in circular economy technical nature projects.
- **Holistic assessment:** The second goal is to obtain a holistic evaluation. The tool has to systematically evaluate the critical aspects that make the project sustainable and circular, thus assessing the potential for success of long or short term projects.

To that point, the work redefines the evaluation of both programs, including cross-cutting criteria (circular economy) to evaluate the proposals in their entirety. To that end, ad-hoc evaluation has been conducted by integrating the specific rules of each competition, defined by the HUB management, thus differentiating two tools, one for each program. Both tools are based on different rubrics at three-level that have made possible to establish the evaluation criteria. The evaluations of all members generate the final ranking list from which the award-winning projects are discussed.

In this work Recircula Challenge 2021 edition has been piloted; the jury members and the authors of the works who were subsequently evaluated participated actively. As a result of their continuous feedback during the tool development process, the proposed improvements have been established.

Finally, this work contributes to meeting different SDGs; the HUB Recircula aims to create knowledge to achieve SDG 12 for Sustainable Production and Consumption. On the other hand, the HUB also acts as a connector to create new alliances between public-private actors and students from different universities since it accepts the participation of contestants not linked to the UPC, favouring the achievement of SDG 17 (Alliances to achieve the Goals). Lastly, this work tries to develop a fair and equitable evaluation method for the named contests at the UPC responding to SDG 16 of Peace, Justice and Solid Institutions. However, it should be mentioned that these programs aim to visualise the good work of students, but mainly to raise awareness and sensitise future professionals on the need for action in changing the production and consumption model.

Method

The work has followed Action – Research (AR) methodology (Coughlan & Coghlan, 2002). It is a participatory process characterised by active and close contact between the researcher and the agents of the organisation - in the context of this work is the Recircula HUB - so that both form part of the research team and constantly interact in the process (Hussey Roger & HusseyJill, 1997). This method aims to analyse new facts and at the same time collaborate in the transformation of certain unsatisfactory conditions. Therefore, it is of the utmost importance that the researcher understands the reason for the work. Likewise, the concept of AR refers to a learning process, which involves understanding and managing the knowledge acquired from the existing theory and apply it in practice. The AR process has four basic phases: planning, action, development, and reflection (Mertler, 2008). The methodology consists of continuous cycles of reflection, whose strong point is to understand in-depth the phenomenon to be analysed and increase the level of knowledge of the problem (Alan & Emma, 2011). These phases can be broken down into nine specific measures that make up the complete cycle.

The planning phase is responsible for defining the plan before development (measures of planning phase: identification and definition of the scope of the content; a collection of information; literature review; development of the research plan). Next, the act phase implements the plan (measures of act phase: implementation of the plan and piloting; data analysis). Subsequently, the development phase is an action plan that includes the review and improvements of the phase before (measures of development phase: development of an action plan). Finally, the reflection phase reflects the entire process and shares the results obtained (measures of reflection phase: communication of results; the reflection of the process).

In this work, three research cycles have been designed. The first cycle, called the definition of the problem, aims to study current methods to evaluate the circular economy and identify the requirements of the tool. The second cycle, called the design of the tool, aims to develop an evaluation tool for academic projects. The last and final cycle called evaluation reflects on the tool development process (see Figure 1). The research methodology has a common base, the problem definition cycle, which derives into two parallel tool development cycles: the Recircula Challenge and the Circular Economic Awards. Finally, the process ends with the evaluation cycle applied in the first case (Recircula Challenge), since it is where the developed tool has been implemented and piloted. Therefore, in the evolution of this work, three different states are differentiated:

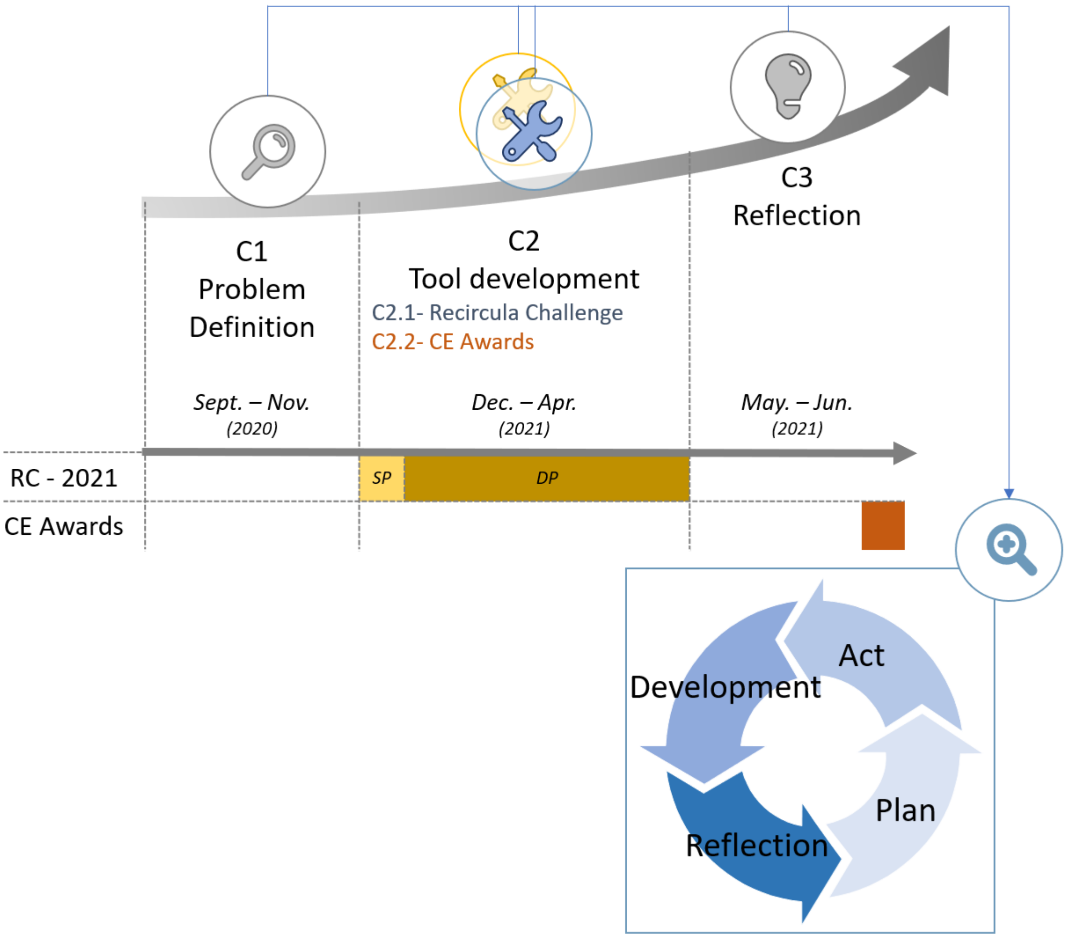

Figure 1. AR Cycles.

Note: RC: Recircular Challenge; CE Awards: Circular Economy Awards; SP: Selection Phase; DP: Development Phase.

Cycle one – Problem Definition

The problem definition cycle includes everything related to state of the art in circular economy assessment tools. Moreover, the co-definition done with the programs' organisers gathers the points to measure with the tool. Regarding the literature research, scientific and non-scientific articles dealing with indicators or circular economy assessment tools have been analysed; see Figure 2 for the applied process.

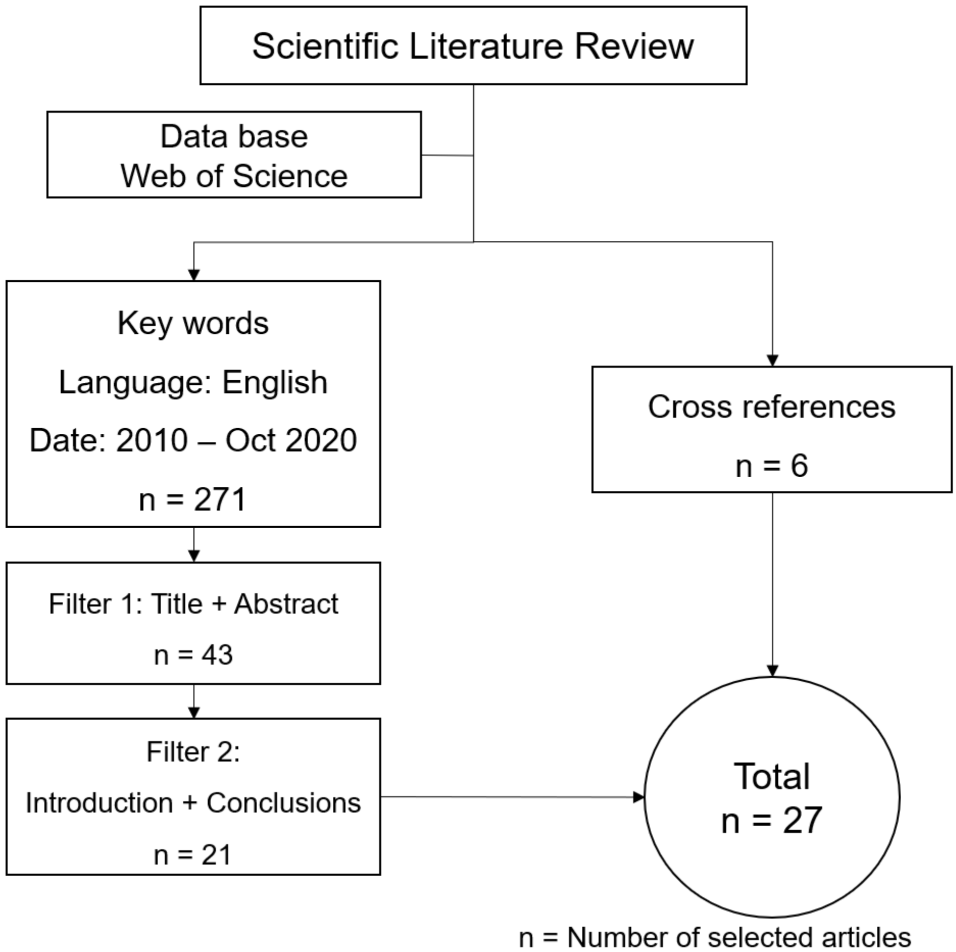

Figure 2. Process for literature review.

In addition, the programs' contents provide the established criteria and the aspects that the tool must include.

Cycle two – Tool development

The second cycle focuses on the design of the tool. This stage involves multiple actions to build the evaluation methodology. The tool has been developed starting from cycle one. Successive cycles of action and development have been necessary to validate the tool with the coordinators of the programs. The second cycle ends with a joint reflection between the participants and the members of the jury.

The first step is to design the evaluation method; to that end, rubrics and report templates have been used. The evaluation rubric is composed of levels, categories, categories definition, and criteria that define each level's requirements. The template for participants is compound by different categories and phases, explicitly describing each category's requirements. Then, the validation of rubrics criteria and templates has involved successive implementation and piloting of the tool. Finally, the utility and difficulty of the tool have been valorised by participants and members of the jury.

Cycle three - Evaluation

Finally, the final evaluation has been done in the third cycle from the observed results and the development process. For this, the repeatability of the evaluations and its limitations have been analysed.

The agreement of the evaluation is measured by Fleiss Kappa coefficient (Fleiss, 1981) that represents the level of association between the evaluations. In addition, the global score (final quantification of the project grade carried out by means of the weighted average of the dimension evaluations) of the kappa coefficient has been analysed. This coefficient measures the degree of concordance of nominal or ordinal evaluations carried out by multiple evaluators when evaluating the same samples. The statistic can vary between -1 and +1; being -1 no agreement in nothing observed, 0 the agreement not better than chance, and values greater than 0 increasing agreement; the maximum value is+1, which indicates a perfect agreement.

Results and Discussion

Recricular Challenge

This program has two phases, the selection phase, which aims to select those projects that fulfill the program requirements, and the development phase, in which participants expose the solutions and the best project is awarded.

Selection Phase

The categories of the evaluation rubric, the definition, and the weight for each category are described in Table 1. Next, the jury member has to identify the level of the evaluation scale for every project. The average of the evaluation is the final score; for the initial question, more than half of the jury has to give a positive response to the project for continuing in the program.

Table 1. Selection phase rubric.

Evaluation category	**Definition**	**Weight**	**%**
Circularity, systematic vision, and efficiency in the use of resources.	It is the essence of the program. The following question is answered: *" Is a technology-based solution proposed, and does it improve the life cycle of products or services following the principles of the circular economy sustainably?"*	Yes/No	-
Design and quality Technique.	The projects in this first installment are in the phase of ideation, so it requires: • Definition of the problem and objectives of the draft • Definition of the methodology to achieve the objectives	5/9	50
Social impact of the proposal.	It refers to which sector and segment of society target the proposal and which actors they want to involve in the project; it has been characterized as: • Potential market and socio-economic impact provided	2/9	22,5
Innovation and creativity.	The innovation and creativity potential of the proposal	2/9	22,5

After implementing the first evaluation rubric, an evaluation meeting was held from which the following comments about the tool were received:

- The rubric is too developed to assess a large number of projects; it requires a lot of time to assess the projects (average of 4.5 hours to evaluate 21 projects; 13 minutes / project);
- There is a necessity to simplify the categories of evaluation;
- Rubric levels and scores vary, complicating the assessment.

Five members carried out the evaluation using tool out of eleven who completed the jury. After these comments, the decision to modify and simplify the evaluation was taken. As a result, the following two categories were left:

- Circularity, systemic vision and efficient use of resources: adaptation to the challenge
- Design and technical quality

Development Phase

The development phase is structured in two sections, feasibility of the project and impacts, each of them contains three categories:

A. Project feasability - 50%

A.1 Project identification, obajectives and proposed solution - 20%

A.2 Network and key stakeholders – 15%

A.3 Design, quality and technical feasibility – 15%

B. Impacts - 50%

B.1 Social impacts – 20%

B.2 Environmental impacts – 20%

B.3 Economic impacts – 10%

Tool valorisation

The form for participants and jury members has six questions that briefly collect their perception of the usefulness of the tool, the difficulty of completing it, along their comments. A total of seventeen people responded; the results are described below.

The majority of the participants found the template useful; 58% answered that they found it useful or very useful, while 16% believed it was not useful. If we compare with the difficulty, 25 % believe that it is difficult, and 50 % think that it is easy or very easy to complete. Thus, in general, the template has been useful, while its difficulty has varied.

Regarding the template sections, the easiest ones to complete were; identifying the problem, objectives, and solution and calculating the economic impact, while calculating the environmental impact was the most difficult section. Furthermore, the difficulty of the different sections ranges from easy to complete to adequate difficulty; although the difficulty is intermediate, the sections "Design, quality and technical feasibility" and "Environmental impact" are the most difficult to complete for the participants.

On the other hand, the participants' comments highlight the issue with the template format; several participants are not satisfied with the design: font, colors, etc. On the other hand, other comments pointed to the way how the challenge organisers sent the template to the participants, the lack of different template languages diversity, and the lack of a model template that they could follow. Moreover, suggestions to define more than one template model were received.

Regarding the jury's assessment results, the answers suggest that the difficulty of completing the evaluation rubric is great although the tool was found useful. Two out of five felt that was difficult compared to one who felt it was easy, but all five felt it was a useful, quite useful, or very useful tool for evaluation. Regarding the categories, the survey asked about the adequacy of the criteria for evaluating the proposals. In general, the opinions are that the tool is adequate, except for environmental impact and economic impact. In general, positive comments were received, but suggestions for improvements aim to restructure the template and rubric.

Circular Economy Awards

Circular Economy Awards program has unified the template with the rubric, having a single product, see Table 2 for the program template and rubric scheme.

Table 2. Circular Economy Awards template and rubric scheme.

Project category	Weight (%)	Dimensions	Weight of the dimension (%)
Scope	15	Temporal scope	30
		Geographic and sectoral scope of the project	35
		Potential audience / Market	35
Circularity	25	Circularity	50
		Creativity and innovation for the EconomyCircular	50
Sustainability	10	Dimensions of Sustainable Development	60
		SDG-related indicators	40
Result	50	Project impact / Proposal effectiveness	30
		Efficiency in the use of resources	30
		Feasibility of the proposal	20
		Risks and opportunities	20

From the general comments, the main difficulty is the length of the template. Therefore, it was denied implementing the tool in the 2021 edition without prior training and dissemination. Finally, it has been decided to pilot its implementation in the Master projects of 2021 edition without being mandatory to complete all the sections. This is because the template should collect the information of the works and should not develop anything outside the scope of the already finished final work projects.

Evaluation Cycle

All the jury members agreed that all the requirements of the program phases were integrated into the evaluation as well as the project impact assessment. But, anyway, some difficulty has been observed when identifying impacts and subsequently measuring them. Due to this, the jury brainstormed to give ideas for improvements, being following three the most liked ideas:

- The necessity to train on how to measure impacts within the program's workshops
- The necessity to define a template example so that participants have a reference
- The necessity to integrate the rubric in the template

Therefore, the methodology to measure the impacts of the projects should be reviewed. The template defines a section for each impact category which can be too ambitious when no further help has been given to the participants. Modifying the template to a freer format (providing a clear definition of the objective) could facilitate the participant's task. Moreover, adding the evaluation rubric in the template would not only improve the transparency in the evaluation, but it could also improve job performance.

Finally, it should be noted that the impact of the program on participants has not been evaluated; the HUB provides a series of workshops where different useful tools are explained for the development of proposals. In addition, the problems that arise in the Recircula point out real cases of the private and public organisations that need innovative solutions. For future editions, the program impact assessment on the participants could be measured, considering the rise of environmental awareness and the acquired knowledge about tools and methodologies for evaluating circular projects.

Regarding the rubrics agreement study, which measures the concordance between the evaluators, between the different phases, the results evidence that it has been improved from a weak level (k=0.37) to a moderate level (k=0.47). It means that the rubrics have been adapted between the two phases. In the selection phase, the rubric was implemented for the first time, while the development phase rubric is the improved and adapted version of the rubric of the selective phase. On the other hand, credibility is provided by the continuous revisions and meetings held during rubrics development, which ensures that the criteria may be adjusted to the reality of the program.

However, the objective is not to have a *k* coefficient of one since it would mean that there is no variability between the evaluations of different people; therefore, a single evaluator would be sufficient to evaluate all the projects. Moreover, the program invites different profiles of experts precisely to diversity the perspectives, so the tool's objective is not to eliminate subjectivity in the evaluations.

On the other hand, from the selective phase, where the projects are not very mature and dispersed (in some cases), there is an improvement in the consistency of the evaluations to the development phase that could be due to the improvement of the rubric criteria definitions. Still, the main reason is the maturity of the projects, as they evolve from the first phase and, what is more, the template factor, as it defines the requirements of each section in detail.

Likewise, and intuiting that the template improves the reliability of the evaluations, consideration should be given to introducing the rubric in the participants' template for self-evaluation. In this way, the differences between the evaluations of the jury and the participants could be analysed.

Conclusions

This work answers the research question of how to evaluate circular economy projects in a systematic, objective and efficient way in the academic context. It does so by developing tools composed of templates and assessment rubrics that identify the characteristics to be assessed. Therefore, the objective of designing an evaluation tool for circular economy projects for the Recircula Challenge and Circular Economy Awards programs has been achieved. Furthermore, the result of the work is a new contribution for the UPC, since previously it has not worked in this type of tools oriented to the academic context.

The tools cover the most relevant categories to systematise the evaluation of the projects. Although ad-hoc tools have been developed each competition, the same development process has been followed. The following can be concluded:

A shared language and understanding by all users of the tools (participants and jury members, in addition to the whole organisation of the programs) about the concepts and factors included in the circular economy projects are necessary to achieve the objective of this work. Therefore, constant communication between program organisers has been a key aspect to agree on the tools.

On the other hand, measuring the results of the projects has been one of the difficulties identified by this project. The first limitation has been in the measurement methodology since the indicators are diverse, and their application depends on the type of action. For this reason, it was decided to develop a set of indicators adaptable to different types of proposals. Moreover, not having specified or limited the measurement of impact has made its subsequent evaluation difficult, and therefore its assessment criteria are generalised.

During the tool building, the characteristics of academic circular economy projects have been defined. Since these characteristics are subjective and ambiguous concepts, they have been discussed and reflected upon. Finally, the tool attempts to integrate the different approaches in the evaluation.

Recircula Challenge

In general, a high degree of usefulness of both the template and the rubric has been observed from the piloted tools; the surveys show that the "Environmental Impacts" section is the most difficult to understand and the least adequate to evaluate. Therefore, it is necessary to deepen and reinforce this aspect through workshops, other work examples, and reviewing the criteria established for its evaluation. To this end, it is very important to achieve the aforementioned understanding.

On the other hand, the consistency and validity of the rubrics analysis indicate a high variability among the qualifications of the jury members. However, this is not an aspect that should be evaluated negatively since each jury member responds to a different profile of expertise. Therefore the variability in the evaluations is accepted. Likewise, the tool has to be revised and adapted along the next editions since the diversity of evaluated projects gives versatility and flexibility.

Circular Economy Awards

The fact that it has not been possible to implement and pilot the tool in this program has not allowed obtaining user ratings. From the feedback of the members of the jury of the last edition and the organisers of the HUB, a need for gradual integration of the tool has been concluded. This tool is considered to support the development process as it integrates the structure of the works and the self-evaluation rubric.

In the evaluation, the results section dimensions and criteria have been the most difficult to establish. This section covers environmental, social, and economic impacts holistically. The key for its evaluation was to focus on assessing the efficiency and effectiveness of the project.

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164 Sustainable and circular battery management - Conceptualization of an information model

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Abstract

Circular value chains of electric vehicle traction batteries have the potential to offer benefits, such as securing the supply of raw materials, reducing environmental stresses, as well as enhancing social equity. For a linear value chain being able to transition towards a more circular one, value chain stakeholders are facing different decision-making situations for which they require high-quality data. Such data could be provided by digitalization and its respective information technologies, such as the digital twin, which could resume the function as driving technology for so-called digital battery passports. In this context digital twin-driven digital battery passports may serve as valuable data source for respective value chain stakeholders, who are facing different decision-making situations when pursuing sustainable and circular product management efforts. However, for a digital battery passport being a useful supporting tool, it needs to offer appropriate information to its users. This contribution provides a conceptual information model of a digital battery passport for an electric vehicle traction battery in the context of sustainable product management. The conceptual model was developed by conducting a stakeholder mapping according to SCOPIS, a systematic literature review, as well as three focus group workshops with industry experts. These steps allowed to pursue a conceptual battery passport due to firstly generating an understanding of potential passport users, respective use cases, as well as data needs and requirements. The concept presented in this work details information types and requirements for different use cases of sustainable and circular battery management. With respect to structure, the current concept iteration comprises four information categories: (1) battery, (2) sustainability and circularity, (3) diagnostics, maintenance, and performance, and (4) value chain actors. The concept further constitutes of seven underlying information levels to structure presented information in a more meaningful way. The conceptual battery passport contains next to sustainability and circularity performance-related information also in-depth information on product performance and electrical engineering-related properties, as well as battery health to provide potential

users with support in their sustainable battery management efforts in the context of a circular economy. With respect to future research steps, the presented concept will be further enhanced by results derived from on-going follow-up interviews. The validated concept will serve as foundation for a comprehensive information model for a digital battery passport for an electric vehicle traction battery.

Keywords: digitalization, data management, sustainability, circular economy, digital battery passport

Introduction

The push of powertrain electrification for road transport decarbonization purposes is projected to lead to an increase in the demand of corresponding electric vehicle traction batteries (EVB) in the upcoming years (Olivetti et al., 2017; Slater et al., 2019). EVBs contain in general critical raw materials, such as lithium, natural graphite, and cobalt. Such raw materials are sourced in countries, such as Chile, Bolivia, DR Congo, and China (Ballinger et al., 2019; Mayyas, et al., 2019). From an European perspective, supplies of such materials have to be secured (Mayyas et al., 2019), which could be achieved by pursuing the transition from traditional linear to more circular value chains (Buruzs and Torma, 2017). Next to securing raw material supplies, more circular value chains hold the potential to offer relief of environmental stresses, as well as enhanced social equity (Millar, et al., 2019). This has been also recognized by policymakers, such as the European Commission who is demanding in their proposal for a new regulation for batteries and waste batteries a transition towards more sustainable and circular battery value chains (European Commission, 2020). Such a transition requires the involvement of value chain stakeholders, who are facing decision-making situations when pursuing such a transition (Honic et al., 2019c). However, to support aforementioned decision-making situations, high-quality data is needed (Ellingsen et al.,2017; Saidani et al., 2019). In this context, digital battery passports (DBPs) have the potential to serve value chain stakeholders as valuable data source (Heinrich and Lang, 2019; Honic et al., 2019b). In general, DBPs are said to be unique for each battery, and contain respective value chain and life cycle data (Lemos, 2020). Such applications could be driven by information technologies, such as the digital twin, due to its ability to collect, store, analyze and monitor real-time data of its physical counterpart (Jones et al., 2020). Thus, DBPs could yield the potential to resume the function as enablers of sustainable and circular value chains (Circular Economy Initiative Deutschland, 2020; Honic et al., 2019b). The potential of such applications has also been recognized by the European Commission, who is demanding the implementation of DBPs for industry batteries, as well EVBs by January 2026 (European Commission, 2020). However, for a DBP to be able to resume such a supporting function, it has to fulfil value chain stakeholders' respective data needs and requirements, thus providing stakeholders with appropriate information (Honic et al., 2019a,b). Therefore, this work addresses the following question: *What kind of information does a digital twin-driven DBP for an EVB has to offer to respective value chain stakeholders to support their sustainable product management efforts?*

On the one hand, this work provides a conceptual DBP for an EVB in the context of sustainable product management (SPM). The presented conceptual DBP elaborates on an early version (Berger et al., 2021) by including the findings from empirical validation. On the other hand, the paper reports first theoretical and empirical insights into a DBP's data needs and requirements, potential data sources and implementation barriers. The empirical findings were derived in a set of focus group workshops with 22 stakeholders from the EVB value chain. The term SPM is defined as product management, which strives to minimize negative environmental and social impacts, whilst pursuing value chain-loop closing pathways.

Methods

The conceptual DBP presented in this work was developed in three research steps: (1) a stakeholder mapping according to the supply chain orientated process of identifying stakeholders (SCOPIS) (Fritz et al. , 2018), (2) a systematic literature review according to PRISMA (Moher et al., 2009), as well as (3) conducting three stakeholder focus group workshops (total n = 22). The stakeholder mapping served to identify potential users of a DBP. The consequently conducted systematic literature review built on the results derived from the SCOPIS and served to develop potential use cases for a DBP. This in turn allowed to derive potential information requirements a DBP has to fulfil in the context of sustainable product management. To identify suitable references for the SCOPIS and systematic literature review, the database Scopus, as well as search engines (Google Scholar, Ecosia) were used. With respect to selection criteria, publications in the English and German language were considered. A time horizon between 2010-2021 was chosen due to electric vehicles entering the mass market in 2009 (Tsakalidis and Thiel, 2018). Publications were not excluded based on their geographical context due to EVB value chain's being global ones (Mayyas et al., 2019; Rafele et al., 2020). With respect to publication types, both, peer-reviewed journal articles, as well as grey literature was considered. An exemplary list of employed keywords for the SCOPIS and PRISMA approach are provided in Table 1.

Table 1. Exemplary list of keywords for the SCOPIS and the literature review according to PRISMA

traction battery" AND "value chain"	"traction battery" AND "supply chain"	"lithium battery" AND "value chain"	"lithium battery" AND "supply chain"
"lithium battery" AND "second life"	"battery" AND "value chain"	"battery" AND "supply chain"	"digital battery passport"
"battery" AND "state of health assessment"	"battery" AND "stathe of health indicator"		

The literature review for research step one (SCOPIS) and two (stand-alone systematic literature review) was conducted between October 2020 and January 2021. The derived sample for both research steps led to an initial sample of 1140 peer-reviewed articles and 50 grey literature references. This sample was then subjected to several screening processes (i.e., title and abstract screening, full-text screening). References were excluded when they did not have any relations to the EVB value chain, EVB value chain actors, the EVB life cycle, EVBs in the context of circular economy, digital product passports, or potential use cases and respective data needs. Further references were identified during the full-text screening stage by applying a snowballing approach. The overall process resulted in 129 references that were used to develop the concept presented in this paper. A depiction of the sample development can be seen in Figure 1.

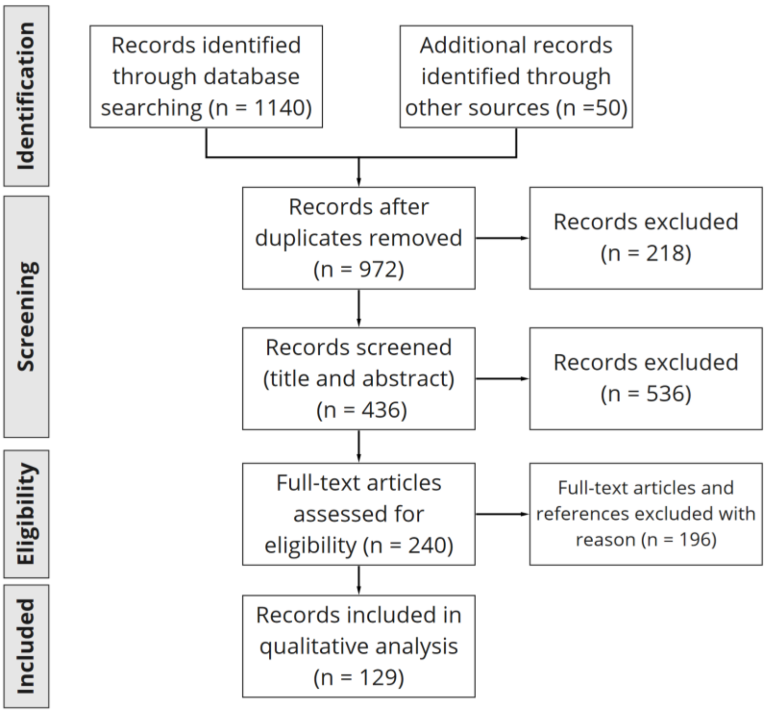

Figure 1. Literature sample development according to the PRISMA guidelines (Moher et al., 2009) in research step one and two.

After carrying out the stakeholder mapping and the systematic literature review, the respectively derived information served to develop a preliminary conceptual DBP. Therefore, identified data needs and requirements were compiled and grouped into information categories, which resulted in a preliminary conceptual DBP. This preliminary concept was subjected to a validation by conducting three online focus group workshops with industry experts. The focus group workshops served to generate deeper knowledge about the EVB value chain and its constitution, data needs and requirements a DBP should fulfil, as well as potential DBP implementation barriers. In total 20 EVB value chain representatives participated in the focus group series. With respect to participant selection criteria, as industry experts were considered who had affiliations to the EVB value chain, as well as minimum of five years of experience in the field. In addition, further participants were nominated by already recruited ones. Thus, the expert recruiting process was carried out in a systematic sampling approach.

Results and Discussion

This section contains the so far derived conceptual DBP, as well as its respective discussion. The proceeding content is structured as follows: Firstly, the conceptual DBP and its current structure is presented. Secondly, a discussion about data needs and requirements, thus what kind of information does a DBP of an EVB has to offer to its potential users, is provided. Subsequently, potential DBP data sources, as well as implementation barriers are discussed.

Results: Conceptual digital battery passport - overview

The conceptual DBP presented in this work consist currently of four main information categories, namely (1) battery, (2) sustainability and circularity, (3) diagnostics, maintenance, and performance, and (4) value chain actors. Those main categories further comprise respective sub-information categories. Therefore, the conceptual DBP was further structured by introducing underlying information levels, which contain respective sub-information categories. The pursuit of a “level” or “layer” logic was pursued to present a structured, and more meaningful conceptual DBP. However, the information levels do not indicate the degree of confidentiality. An overview of the developed concept and its first three information layers is provided in Figure 2. A more detailed description on the developed categories’ content and function, as well as discussions are provided in the proceeding sub-sections.

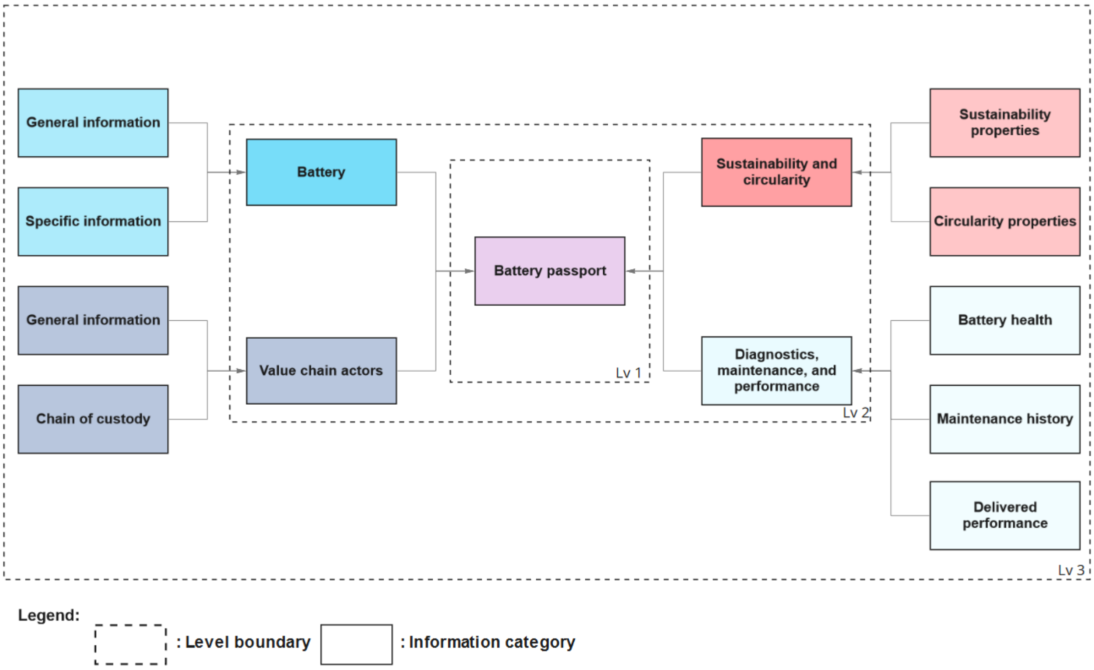

Figure 2. Concept of a Digital Battery Passport for an EVB (own depiction). Lv = level.

Results: Conceptual digital battery passport - battery

The main information category *battery* serves to provide value chain stakeholders with information that allows them to clearly identify the EVB at hand. Such information can be perceived as prerequisite when sustainable product management efforts are pursued (Honic et al., 2019b). Otherwise, value chain stakeholders might lack understanding of the product of interest, which in turn may complicate the pursuit of suitable actions to improve upon the sustainability and circularity performance of an EVB (Honicet al., 2019b).

Therefore, the main information category *battery* contains product-related information, which can be further divided into two sub-categories: *general product information*, and *specific product information* (see Figure 2). The sub-category *general product information* provides information on the battery type (e.g., a battery for an electric vehicle, a battery for energy storage purposes), battery chemistry, battery identifier (e.g., serial number, batch number), as well as battery manufacturer-related information (e.g., name of manufacturer, location of production site). The sub-category *specific product information* provides information on overall battery performance-related indicators (e.g., driving range, lifespan, charging times, energy consumption), as well as employed materials and substances (e.g., material/substance type, function). In addition, this sub-category contains information with respect to pack, module and cell level on electro and electrochemical engineering-related specifications (e.g., energy density, power density, energy content), as well as battery structure (e.g., number of modules, number of cells, employed assembly processes).

The preliminary category development was carried out by consulting peer-reviewed articles in the context of EVBs and EVB performances (e.g., Chen et al., 2019; Philippot et al., 2019; Stampatori et al., 2020), structure (Bai et al., 2020; Coffin and Horowitz, 2018; Jussani et al., 2017), as well as digitalization and circular economy (Wang & Wang, 2019). Furthermore, material passport-related research served for concept development purposes (Honic et al., 2019a,b,c). In addition, grey literature in the context of EVBs and circular economy (Brudermüller, 2020; Circular Economy Initiative Deutschland, 2020; Koller, 2020), as well as material passports provided inspiration for the concept development (Heinrich and Lang, 2019). In addition, publications provided by policymakers, such as the European Commission were consulted, due to them demanding the disclosure of certain product-related information on DBPs in the years to come (European Commission, 2020).

The preliminary information content of this category was further validated by industry experts in an online focus group workshop setting. The workshop participants came to the consensus that the information content of this category can be perceived as backbone of a DBP due to being needed to clearly identify the product at hand.

Results: Conceptual digital battery passport - sustainability and circularity

When facing decision-making situations related to sustainable product management, information about the product's sustainability and/or circularity performance (i.e., status quo, as well as life cycle performance) will be required. Such information serves to formulate and define targets for performance improvement purposes, as well as respective strategies and measures to reach said targets. In addition, such information may serve to identify potential life cycle hotspots, thus potential areas of improvement.

The main category *sustainability and circularity* provides information related to an EVB's sustainability and circularity performance. Category respective information can be further split into two sub-categories: *sustainability properties*, and *circularity properties* (see Figure 2). The sub-category *sustainability properties* provides information on an EVB's environmental and social impact. Hence, this sub-category contains information on respective indicators, corresponding impact categories, calculation methods, used inventory data for social and environmental assessment purposes, as well as applied standards and impact assessment methods. Furthermore, this sub-category provides information on employed material (e.g., hazardous, critical, primary/secondary). The sub-category *circularity properties* provides information on the EVB's circularity performance. In terms of structure and content, this sub-category follows the same logic as the preceding described sub-category. In addition, this sub-category provides information with respect to battery module and pack assembly processes, disassembly instructions, as well as pursued product design types (e.g., design for recycling, design for disassembly).

The preliminary category development was carried out by consulting peer-reviewed literature on material passports (Honic et al.,2019a,b,c), digitalization and sustainable supply chain management (Kouhizadeh et al., 2021; Nandi et al., 2021; Saberi et al., 2019; Wang and Wang, 2019), sustainability and circularity assessments (Ellingsen et al., 2014; Parchomenko et al., 2019; Saidani et al., 2019), as well as EVBs and EVB structure (Bai et al., 2020; Jussani et al., 2017). In addition, grey literature related to EVBs and the circular economy (Circular Economy Initiative Deutschland, 2020; Koller, 2020), product and material passports (Brudermüller, 2020; Heinrich and Lang, 2019), as well as regulatory papers (European Commission, 2020) were consulted.

The information content of this category was further subjected to expert validation in an online focus group workshop series. In general, focus group participants agreed upon the importance of environmental impact-related information on a DBP. With respect to information on an EVB's social, as well as circularity performance some experts approved of such information being available on a DBP, whilst others did not perceive them as critical, thus important compared to information on environmental performances. In addition, most experts did not perceive the other described information aspects (e.g., information on indicators used, respective impact categories, calculation methods) as must have information on a DBP.

Results: Conceptual digital battery passport - battery diagnostics, maintenance, and performance

When an EVB retires it may still qualify for entering a second battery life, thus allowing the potential pursuit of value chain loop-closing pathways other than recycling (Koller, 2020). To identify appropriate loop-closing pathways respective value chain stakeholders, such as waste battery collectors, require information on the EVB's health status (Bai et al., 2020; Circular Economy Initative Deutschland, 2020; Koller, 2020).

The main information category *diagnostics, maintenance, and performance* provides information related to an EVB's health status, carried out maintenance-related actions, and delivered performance. Category respective information can be further divided into three sub-categories: *battery health*, *maintenance history*, and *delivered performance* (see Figure 2). The sub-category *battery health* provides information on an EVB's health-related indicators, such as state of health, state of charge, and rest of useful life. The sub-category *maintenance history* provides information on carried out maintenance and repair work during the EVB's use phase, respective triggers of said work, as well as on the party who carried out respective work. The sub-category *delivered performance* provides information on an EVB's so far delivered performance in terms of, for example, charging/discharging cycles, covered mileages, provided operation time.

This main category was developed by consulting peer-reviewed articles with focus on battery diagnostics and battery second life (Canals Casals et al., 2019; Lipu et al., 2018; Richa et al. , 2017; Xiong et al., 2018). Furthermore, grey literature on EVBs and the circular economy (Circular Economy Initiative Deutschland, 2020; Koller, 2020), product and material passports (Brudermüller, 2020; Heinrich and Lang, 2019), as well as regulatory papers (European Commission, 2020) were used for concept development purposes.

The preliminary information content of this category was subjected to expert validation in an online workshop series. The majority of experts expressed the need of battery diagnostics-related information to ensure safe EVB handling, as well as to decide if an EVB may qualify for a second life. Some experts rejected the idea of providing operational EVB-related data (i.e. battery health-related data), thus any form of real-time dynamic data, on a DBP due to such data changing rather quickly, and given the lifespan of EVBs large data volumes would be the result. This in turn may lead to data collection, processing and storage issues.

Results: Conceptual digital battery passport - value chain actors

To ensure and enhance transparency along the entire EVB value chain, information on involved actors, as well as their respective roles and responsibility is required. Enhanced transparency, in turn, may further enhance and strengthen trust between value chain stakeholders, whilst supporting respective decision-making situations (Saberi et al., 2019).

The main information category *value chain actors* provides information, which allows to clearly identify actors with relations to the EVB of interest. Category respective information can be divided into two sub-categories: *general actor information* and *chain of custody* (see Figure 2). The sub-category *general actor information* provides information, which allows clear identification of actors related to the EVB during its entire life cycle, regardless to what extent (e.g., suppliers of active materials, manufacturers of cells, waste battery collectors). Therefore, information such as name of involved actors (e.g., company name), actor type and function (e.g., supplier of raw materials), location of value-adding activity (e.g., production site of cells), as well as actor identifiers (e.g., trade registration number) is affiliated to this sub-category. The sub-category *chain of custody* provides information that allows to clearly identify value chain actors' responsibilities related to the EVB of interest. This does not only include responsibilities of the physical product, respective components or related services, but also responsibilities with respect to sustainability and circularity-related performances.

This main category was developed by consulting peer-reviewed literature with focus on digitalization and manufacturing (Tao et al., 2018), as well as digitalization and sustainable supply and product management (Kouhizadeh et al., 2021; Nandi et al., 2021; Sarkis et al., 2020). Furthermore, regulatory papers (European Commission, 2020), and grey literature related to EVBs and circular economy were used for concept development purposes (Circular Economy Initiative Deutschland, 2020; Koller, 2020).

The preliminary information content of this category was subjected to expert validation in an online focus group workshop series. With respect to general information on value chain actors, workshop participants approved of such information being on a DBP. With respect to chain of custody-related information some participants did not see pressing need of such information being disclosed on a DBP (e.g., due to lack of regulatory pressure).

Discussion: Data needs and requirements

The proposed conceptual DBP provides in general information related to (1) the product itself, (2) the product's sustainability and circularity performance, (3) the product's health status, as well as (4) involved actors along the product's life cycle.

Product-related information has been identified as backbone of a DBP. This finding is based on literature (Bai et al., 2020; Chen et al., 2019; Circular Economy Initiative Deutschland, 2020; Coffin and Horowitz, 2018; Heinrich and Lang, 2019; Honic et al., 2019b,c; Philippot et al., 2019; Stampatori et al., 2020), which allowed to deduce the need of such information to enable DBP users to clearly identify the EVB at hand, thus providing contextualization. This has been further confirmed by industry experts who participated in the carried out online focus group workshop series.

The importance of sustainability and circularity-related information can be deduced through literature (Heinrich and Lang, 2019; Honic et al., 2019a,b,c), but has been also recognized by focus group participants. Participants have put emphasise on the importance on environmental impact-related information, such as information on an EVB's carbon footprint. This perception can be explained by provided incentives by policymakers (e.g., introduction of carbon footprint-related thresholds, which a product may not exceed when entering a certain market) (European Commission, 2020). However, sustainability encompasses not only an environmental perspective, but also a social one, which needs to be taken into consideration (Millar et al., 2019). This could be achieved if policymakers were to also emphasise the importance of the social dimension of sustainability, thus defining respective targets. Otherwise, value chain actors might focus on the environmental dimension of sustainability only, thus neglecting social sustainability-related issues. With respect to sustainability-related indicators, some participants focused on the importance of the carbon footprint. However, to manage the sustainability performance of an EVB, more than one indicator will be needed; be it to express environmental or social performances. Otherwise, at best one-sided sustainability-related improvements could be achieved, meaning that one indicator may indicate that the sustainability performance of the product of interest has improved. However, when considering other indicators, the performance may have remained the same, or even deteriorated. Concerning circularity performance-related information, literature (Parchomenko et al., 2019; Saidani et al., 2019) indicates its importance. However, focus group participants did not reach a consensus if such information is needed on a DBP. Some emphasised its importance, whilst others could not relate to this opinion due to them perceiving the concept of circular economy as being rather generic, thus leading to different possible scenarios (e.g., recycling of certain kinds of materials, repurpose activities). However, circularity performance-related information should be provided by a DBP to allow DBP users to get information of the status quo of said performance. Otherwise, respective decision-makers cannot tell if so far pursued circularity performance improvement efforts have been fruitful.

In general, knowledge about the performances mentioned above is needed when improvement is sought after. This, in turn, allows decision-makers to formulate and define respective targets and measures to achieve them. Workshop participants' reluctance could be explained by findings stemming from literature (Parchomenko et al., 2019; Saidani et al., 2019), which state that the assessment of circularity performances is rather new to practitioners compared to the assessment of environmental performances. As a result, practitioners are rather unfamiliar with tools and indicators that may assess circularity-related performances (Parchomenko et al., 2019; Saidani et al., 2019). In addition, compared to, for example, environmental impact assessment, there is a lack of standardization when it comes to circularity assessment. This could further explain why some workshop participants have not perceived circularity performance-related information as needed on a DBP. With respect to the information aspect related to used indicators, respective impact categories, used inventory data, applied assessment standards and calculation methods, most workshop participants did not perceive them as a pressing issue in the context of DBPs. However, it can be argued that such information is needed to ensure transparency of sustainability and circularity performance-related information provided by a DBP. In addition, such information may further enhance the meaning of provided performance results to DBP users (e.g., what does this result mean, how does it impact the environment).

To pursue appropriate EVB value chain loop-closing pathways (e.g., repair, repurpose, recycling) battery diagnostics-, performance-, maintenance-related information should be provided by a DBP. This information need can be deduced from literature (Circular Economy Initiative Deutschland, 2020; Koller, 2020). However, workshop participants provided mixed opinions on a DBP containing such information. While some participants opined that such information has to be on a DBP to enable the pursuit of appropriate value chain loop-closing pathways, some experts opposed this idea. The reasoning behind said opposition was the concern that adding dynamic data, in particular real-time data, (i.e. battery diagnostics and performance-related data) to a DBP, will enhance the complexity of DBP implementation. Real-time dynamic data, such as battery diagnostics-related data changes instantly during its use phase. Due to EVBs offering lifespans of at least eight years, it can be assumed that massive volumes of data would be generated during its use phase. Thus, experts raised the concern of data collection, processing and storage issues. In addition, some participants voiced the concern that battery health-related indicators are not straightforward to collect (e.g., due to the different calculation approaches) (Lipu et al., 2018). Keeping that concern in mind, when it comes to data types (e.g., static, dynamic, real-time), it needs to be taken into consideration when it makes sense to employ which kind of data type. In the case of battery diagnostic, maintenance and performance-related information, some workshop participants proposed that it could be sufficient to update respective data at specific points during the EVB's lifespan (e.g., during vehicle service, in case of changing ownerships).

To enhance the transparency along the EVB value chain, value chain actors-related information is required, which in turn may enhance trust amongst value chain stakeholders. This finding can be deduced by literature (Brudermüller, 2020; Heinrich and Lang, 2019; Nandi et al., 2021; Sarkis et al., 2020). Focus group participants, in general, approved of basic value chain actor-related information being disclosed on a DBP. However, the concern was raised that some value chain actors are most likely to be reluctant to disclose their involvement due to perceived competitive drawbacks (e.g., loss of business to competitors, damage of reputation).

Discussion: Data sources and providers for a DBP

The conducted stakeholder mapping, as well as stand-alone literature review allowed to further deduce that value chain stakeholder are prone to resume the role as data providers for DBPs (Circular Economy Initative Deutschland, 2020; Heinrich and Lang, 2019; Honic et al., 2019c). The same information was provided by workshop participants, who emphasised that all EVB value chain stakeholders have a hold over data needed on a DBP. Some participants further provided that there are current uncertainties with respect to data needs and requirements in the upcoming years. Thus, as much data as possible should be collected and stored on a DBP. This uncertainty poses, in general, a challenge when digital product passport development efforts are pursued. On the one hand, if all kinds of value chain-related data were to be collected and stored on a DBP, it cannot be ruled out that a DBP's sustainable product support function might suffer due to it containing redundant data. On the other hand, if only data were to be collected on a DBP that is perceived as important from today's perspective, data could be overlooked, which might be of interest in the future (e.g., due to regulatory mandates).

Discussion: Potential DBP implementation barriers

The conducted desk research and focus group workshop series, further provided insights of potential DBP implementation barriers. From literature, implementation barriers in the form of information losses along value chains, due to insufficient documentation efforts, as well as scepticism regarding data sharing can be deduced (Honic et al., 2019 c; Saidani et al., 2019; Wang and Wang, 2019). Those findings have been confirmed by focus group participants, who named implementation barriers with respect to violation of intellectual property rights. Thus, some participants voiced the concern of potential competitive drawbacks if, for example, competitors were able to access sensitive information via DBPs. In addition, some participants raised concerns, which are linked to one often quoted benefit DBPs might offer: enhanced transparency along the value chain (Circular Economy Initiative Deutschland, 2020; Heinrich and Lang, 2019). In this context, it was provided that some value chain actors could be reluctant to share certain kinds of data due to potential reputation damages, as well as perceived loss of business to fellow competitors. Thus, one of the major challenges when it comes to DBP implementation is most likely to be the incentivization of value chain actors to share their data.

Conclusions

This work provides a conceptual DBP of an EVB, which outlined data needs and requirements a DBP should fulfil to support EVB value chain stakeholders in their sustainable EVB management efforts. The current version of the conceptual DBP was developed by conducting desk research, as well as by seeking out validation provided by industry experts. This allowed to explore theoretical potentials of a DBP in the context of sustainable product management. To further push the development of a more practical concept, next research steps comprise further validation efforts (e.g., by conducting follow-up interviews), as well as further deepen the understanding of data availability of needed data, thus further investigating power dynamics along the EVB value chain. In addition, further research will focus on developing a preliminary information model for a digital twin-driven DBP based on the final version of the conceptual DBP. Thus, questions with respect to, *inter alia*, EVB specifications that have to be abstracted, data model structures, as well as data types have to be pursued.

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143 A conceptual framework for applying residential demand response strategies based on household characteristics: Results from a Swedish case study

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Abstract

Residential demand response (DR) has the potential to provide increased demand flexibility, realizing the benefits of smart grids for a more efficient and sustainable power supply system. The interest in DR strategies has increased over the last decade, along with the growing need to balance electricity supply and demand. DR helps account for variability of renewable energy production and new daily load profiles—with the incorporation of low carbon technologies such as electric vehicles—by dynamic pricing schemes.

The way in which people consume electricity (i.e. daily habits and routines) and the way that they respond to DR incentives (i.e. willingness to adjust their consumption patterns) greatly varies among demographics. Previous studies have found that the effectiveness of a residential DR program may be dependent on different socio-economic and dwelling characteristics. However, it is difficult for researchers and industry practitioners to identify where the challenges and opportunities of implementing specific DR strategies geographically lie, lacking the tools to quickly identify suitable areas to upscale successful DR programs.

This study presents a six-step conceptual framework that aims to address these challenges by proposing a systematic approach to visually identify the potential for applying DR strategies in different neighborhoods. The visualization tool will help implement more accurate DR strategies to curb electricity demand from appliances and devices, allowing for a more resilient smart grid. A case study in Stockholm was carried out to demonstrate the applicability and usefulness of the framework. The results analyzed and displayed neighborhoods that contained specific socio-economic compositions similar to the case study, enabling DR strategies to be upscaled.

This framework has the potential to support researchers, policy makers, and utilities and energy companies in finding suitable areas where DR programs can be customizable to residential needs and lifestyle patterns, thus saving significant time and resources.

Key words

Demand Response, Electricity Consumption, Data mapping, Grid Flexibility, Household

Introduction

New policy priorities and technological innovations have driven global, national, and local energy systems to change (UNIDO, 2018). From 2010 until 2017, there has been an average 8% increase per year in renewable energy capacity globally. In 2017, a new record was observed as renewable power generation accounted for almost a quarter of total global power generation in 2017 (IRENA, 2018). Nevertheless, the increase of variable renewable energy such as solar and wind power creates challenges for the current grid (IRENA, 2020). The increase in variable renewable energy is essential in achieving global climate goals, however as its supply is dependent on the uncontrollable resources such as solar and wind, it creates transmission congestion and introduces balancing challenges to the current grid (IPCC, 2007; IRENA, 2020). This has created a demand for flexible solutions where the consumption and production of electricity can be managed to the grid's requirements and energy balance. A key-solution to creating a more flexible and low-carbon grid is through demand response (IEA, 2017, 2018; IRENA, 2020).

Demand Response (DR) can be defined as the mechanism in which energy demand is temporarily changed in response to a price or another signal to provide a grid balancing service, while simultaneously creating the potential for consumers to save on electricity costs (Gellings, 2009; IEA, 2018; Palensky & Dietrich, 2011; Saini, 2007). It is estimated that in 2040, 20% of global electricity consumption will be available for DR (IEA, 2017). The realization of residential DR programs is affected by both the way in which people consume electricity (i.e. daily habits and routines) and the way they respond to DR incentives (i.e. willingness to adjust their consumption patterns) (IEA, 2018). A better understanding of these consumption patterns and interactions—visible in residents' daily load profiles, responses to residential DR programs, and use of appliances—will support advancements within DR strategies. This may lead to reductions in energy consumption and enable peak load shifting. In this paper, the term 'DR programs' will be used to describe specific hard- and software, as well as incentives that enable consumers to shift their load. 'DR strategies' will be defined as the umbrella-term that describes all potential approaches when managing DR. This study will focus on demand response within residential settings, therefore excluding any demand response in industrial settings.

The implementation of a DR program is non-trivial. Besides identifying new ways to save and manage energy consumption, knowing where to strategically deploy these programs geographically can be challenging as it is both time and resource consuming. Current studies focus on examining the impact of DR programs by studying household electricity usage and interaction with DR programs with respect to various characteristics such as age, income, and educational level (D'Oca et al., 2018). This provides insights on how, what, and when DR programs should be used to manage energy consumption. However, previous research has focused less on answering the question of *where* the challenges and opportunities of implementing specific DR strategies lie geographically.

The aim of this study is to provide increased understanding of the potential of demand response by developing a conceptual framework for identification, analysis, and visualization of household characteristics that affect the response to DR programs in specific geographical areas. The conceptual framework aims to support the development of residential DR strategies and help DR programs reach a greater potential by enabling more effective deployment. The conceptual framework can provide streamlined steps to strategically implement DR programs on a wider scale by matching different socio-economic households with recommended DR programs**.** Thus, the framework can assist researchers, policy-makers, and energy and utility companies to increase the effectiveness of flexible energy consumption and cost savings through DR programs, as well as provide insight into how future DR applications may vary and be optimized on a neighborhood scale.

This paper presents a conceptual framework for DR program designers (e.g. researchers, DSO's) and implementers (e.g. housing developers, governments) that shows where DR programs should be deployed to obtain the best results.

To demonstrate the framework's potential benefits, the six-step framework is applied to a case study in Stockholm, Sweden, which uses a DR program that includes home energy management systems (HEMS). The objective of the conceptual framework is to visualize the extent to which specific Stockholm neighborhoods show household characteristics that could be considered suitable for specific DR programs. The visualization can be represented in either *single* filter maps i.e. maps where one characteristic is visualized, or *multi* filter maps i.e. in which several characteristics are visualized. Moreover, applying multiple filters on maps, can help identify areas with a specific combination of household characteristics for upscaling and customizing future research.

This paper is divided into six main sections. The following section discusses related work and presents the most common and impactful household characteristics influencing energy consumption. Subsequently, Section 3 describes the proposed conceptual framework for demand response strategies in six steps. Section 4 applies this framework to a case study about Stockholm, with a special focus on the Stockholm Royal Seaport (SRS). Section 5 discusses the conceptual framework, its applications, limitations, and potential; moreover, it discusses the results of the Stockholm case study. Lastly, Section 6 provides conclusions to this paper.

Household characteristics influencing electricity consumption

A systematic literature review was conducted to understand and identify what household characteristics affect residential energy use and interactions with demand response programs. The keywords chosen for the literature review were “demand response”, “household” or” dwelling” or “residential” and “electricity” or “energy”, and “characteristic” or “behavior" or “factor” for example “household electricity behavior”.

The outcome of the literature review show that the majority of previous research mainly examined the household characteristics impact on electricity usage by considering appliance use and load profiles (Bedir & Kara, 2017; Hayn et al., 2014; Jones & Lomas, 2015; Kavousian et al., 2013; Matsumoto, 2016; Mcloughlin et al., 2012; Yohanis et al., 2008). Other studies focused more on how household characteristics impact the interaction of DR programs and the comparison of energy efficient appliances to DR strategies to reduce electricity use (Gram-hanssen, 2011; Podgornik et al., 2016; Vassileva et al., 2012a). However, the most influential factors vary in different studies. A review of a collective body of research was therefore conducted to identify the six most influential household characteristics related to behavior that could affect electricity use and energy feedback, as well as user interactions with DR programs.

Income

Income is one of the most studied household characteristics in regard to electricity use. Hayn et al. (2014), Matsumoto (2016) and Podgornik et al. (2016) all found that income was one of the most significant factors. Both Hayn et al. (2014) and Podgornik et al. (2016) found that increasing income leads to increasing electricity use. However, Hayn et al. (2014) explains that this could be because households with higher income tend to be of a bigger household and therefore use more electricity. Matsumoto (2016) on the other hand found that in fact not all cases show that high income households use more electricity as they tend to have newer and energy efficient appliances than low income households. High income households also spend more time outside of the house as they can afford to live more dynamic lifestyles leading to them using less electricity at home. Income also indicates the employment status of residents. Residents that work at an office will also lead to less time spent at home during the day (Matsumoto, 2016). This is also one of the reasons why high-income households have a different load profile from low-income households. Yohanis et al. (2008) found that residents in high-income households use 2.5 times more electricity during the evening and also consume significant electricity during the morning, whilst low-income households have a relatively constant consumption except for a peak around dinner time.

Age

Residents above the age of 60(±5) often use less electricity as they own fewer electricity-consuming gadgets like several TVs and PCs (Jones & Lomas, 2015) and are more resource-conscious (Kavousian et al., 2013). However, per capita, elderly people use most electricity (Matsumoto, 2016) as they often live in single households and spend more time at home (Hayn et al., 2014). In absolute numbers, middle-aged people, from 30+ to 60 (±5) years old, have the highest electricity consumption (Hayn et al., 2014; Matsumoto, 2016), primarily because middle-aged people often have children or teenagers living at home but less electricity per capita (Hayn et al., 2014). Concerning interactions with demand response programs, Vassileva et al. (2012a) found that 1) elderly people preferred to receive information via displays, 2) information via email was more suitable for middle-aged people working who already have to consult their email accounts, and 3) younger people preferred interaction through mobile applications with a more interactive and game-oriented approach.

Household composition

Households with more than three residents often indicates a family that most likely consists of either children, teenagers, or both. Previous research shows that large households have a greater electricity use of residents however that per-capita, they have the lowest electricity use (Gram-hanssen, 2011; Hayn et al., 2014). Families with children—which sometimes entail adults working part-time—also spend more time at home (Bedir & Kara, 2017). Families with teenagers and children also use energy-intensive appliances such as dishwashers, washing machines, television, and computers more frequently (Jones & Lomas, 2015). Teenagers and children are less conscious of consuming energy and less concerned with financial implications (Jones & Lomas, 2015), however they tend to be more concerned about the environmental impacts that high energy-consuming lifestyles have with age, and they may become increasingly capable of lowering their energy use over time (Gifford & Nilsson, 2014).

Educational level

Another socio-economic factor studied is the level of education, and most studies have seen a significant correlation between a household’s electricity consumption and the level of education (Gram-hanssen, 2011; Mcloughlin et al., 2012). Mcloughlin et al. (2012) found that education level was more related to social class and is perhaps more correlated to income, as previously mentioned (Hayn et al., 2014). Bedir & Kara (2017) showed that an observer group where the majority had a university education were more conscious about sustainable energy use and had more energy-saving lamps and solar panels. Another study by Bartiaux & Gram-Hanssen (2005) showed that their electricity consumption, in fact, did decrease with an increased level of education. Seemingly, as formal education increases, so does one's concern for the environment (Gifford & Nilsson, 2014).

Surface area

Several studies have shown that a household's surface area has a significant correlation with electricity consumption (Bedir & Kara, 2017; Hayn et al., 2014). As the surface area of a dwelling increases, so does the electricity consumption, because this often indicates more bedrooms (Hayn et al., 2014), thus more residents in the household.

Employment status

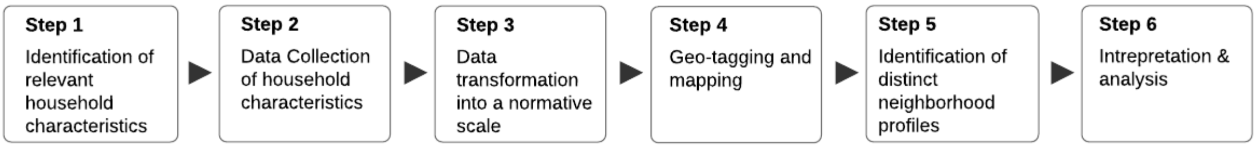
The employment status of residents can have a big influence on electricity use as it tends to impact time spent at home. Hayn et al. (2014) confirmed that unemployed residents had the highest electricity use, followed by self-employed residents as they tend to spend more time at home. Moreover, unemployed households were the largest share of single households making the electricity use per capita higher (Hayn et al., 2014). Self-employed also have more office equipment at home, which increases electricity use. Also, as mentioned previously in Section 2.1, households with all residents at work or school show clear peaks in the morning and evening, where high energy-consuming appliances like washing machines and dishwashers were used more frequently after work.

Based on the literature findings above, this study summarizes that it is difficult to predict user energy consumption patterns based on socio-economic and dwelling characteristics alone. It can be concluded that behavior is unique to each household and therefore different incentives and interactions are needed for an efficient use of DR programs. This paper allows these unique behavioral patterns to be visualized and mapped. By providing information on where specific household characteristics lie geographically, stakeholders can plan accordingly, resulting in more accurate DR program placement.

A conceptual framework for estimating the potential of DR

The six steps outlined in this section describe a structural method on how to create neighborhood profiles and analyze these with respect to any specific DR study or project. A flow chart summary of the steps is depicted in Figure 1.

Figure 1: The six-step conceptual framework to estimate the potential of DR in specific areas consisting of: 1) relevant household characteristic identification, 2) data collection, 3) data transformation, 4) geotagging and mapping, 5) distinct neighborhood profiles identification, and 6) interpretation and analysis.



Step 1: Identification of the relevant household characteristics

The initial step concerns the identification of the relevant household characteristics that influence consumption patterns and user interactions of DR programs. These vary greatly among different households as different households have different incentives to reduce electricity consumption. The literature review in Section 2 shows six paramount household characteristics that could affect electricity use and energy feedback. Note that these characteristics can differ slightly, depending on country, region, and neighborhood. Additionally, household characteristics can be weighed differently depending on the importance of specific characteristics.

Step 2: Data collection

This step concerns the collection of data related to the identified household characteristics of the previous step. Data can either be collected from previous studies or be recollected from various data sources. Data sources may include governmental databases, corporate databases, or other agencies that hold relevant and trustworthy data. Moreover, data about the number of people in a neighborhood should always be collected as reference data. Lastly, the collected data should contain a set of geotags representing different blocks or neighborhoods in the area.

Step 3: Data transformation into a normative scale

This step concerns the transformation of the provided data to a normative format. A normative format enables characteristics to be easily visualized on different maps (Wilke, 2019). The format(s) in which the data is obtained can differ and may contain missing values; this is why the data needs to be transformed to a normative scale. A dataset containing the total number of households in the neighborhood should be used as a reference for the size of the neighborhood. If the number of elements of an individual household characteristic in each neighborhood is not equal to the reference size, the share of each element should be extrapolated to match the reference size. The extrapolated data for the household, residents, and education type characteristics is normalized per neighborhood. The integer value of these characteristics is divided by the reference size of the neighborhood, resulting in the share of people having a certain characteristic. This is called the Normative Unit, as depicted in Table 1. Table 1 provides an overview of the possible obtained data format and the required format for characteristic mapping. If data is already provided in a normative format, no transformations are needed.

Table 1: Overview of data formats required for household characteristic mapping.

	Type household	**Type neighborhood**	**Type normative (required)**	**Normative unit**
Average salary [SEK/year]	Decimal number	Decimal number	Decimal number	**[SEK/year]**
Households, residents, and education type	Boolean	Integer	Percentage	[%]

Average surface area [m²]	Decimal number	Decimal number	Decimal number	[m²]

Step 4: Geo-tagging and mapping

This step concerns geotagging the data in the format suitable for the mapping software (e.g, Tableau, GIS, Google Maps). Matching neighborhoods with corresponding zip-codes is a commonly used way of geotagging. However, if the neighborhoods and zip codes differ significantly, alternative tools can be used e.g. longitude and latitude coordinates. Subsequently, the geotagged dataset can directly visualize the presence of different characteristics in a specific area. Neighborhoods can then be filtered by their normative units using a filtering system. This step can be disregarded if the provided data set already contains adequate geographical information.

Step 5: Identification of distinct neighborhood profiles

This step describes the creation of neighborhood profiles by combining the transformed data depicted on the maps and the literature. In total two types of neighborhood profiles should be created. Firstly, the list of neighborhood profiles as developed in Steps 2-4. Secondly, a reference neighborhood profile. This profile should represent an ideal or preferred neighborhood for a desired DR program or research projects. This preferred neighborhood profile can be created by setting boundary conditions for each household characteristic. The conditions can be created based on the average household characteristics of previous studies or projects. For example, to research the effectiveness of a DR strategy for people with different levels of education, it would be preferable to have two fairly similar neighborhoods, except for the level of education.

Step 6: Interpretation and analysis

The last step concerns the interpretation of the maps, multi-filter mapping, and linking the results back to recommendations from Section 2. The realization of DR programs in specific neighborhoods can now be assessed for optimization. The individual maps of the aforementioned characteristics open up the opportunity for governments, utilities, corporations, and researchers to improve decision making when rolling out DR programs in particular neighborhoods. Multiple layers can filter specific requirements for a potential program and thereby reduce the time needed to find suitable neighborhoods. Moreover, the conditions of the reference neighborhood as described in Step 5 can be used as filters to find similar/preferable neighborhoods in the area, directly visible on a map.

The framework in practice: Stockholm case study

To demonstrate the applicability and potential benefits of the framework, a case study was conducted choosing Stockholm as the demonstration area. Stockholm was chosen for three main reasons. First, the energy system in Sweden is progressive in adopting a low-carbon economy and therefore likely to be an early adopter of a variety of DR programs (IEA, 2019). Second, the ambition of Stockholm to be fossil free by 2040 requires action in terms of energy saving in the built environment (City Executive Office Stockholm, 2016). This incentive creates demand for future DR. Third, Sweden, and Stockholm in particular, has available data about various household characteristics creating a suitable testbed for such research.

A research study was then chosen to demonstrate how the conceptual framework can support the continuation and expansion of research, as it geographically identifies where other potential research areas of interest lie. The study from Nilsson et al. (2018) at the Stockholm Royal Seaport (SRS) was examined in this research for three main reasons. First, this study was carried out in Stockholm, matching the region of our other dataset. Second, this study focuses on DR programs which are highly affected by household characteristics. This aligns with what Nilsson et al. (2018) found: "The fact that our study shows that households tend to act on HEMS highly individually emphasizes that household energy consumption not necessarily is driven by economically rational decisions but rather influenced by a wide range of behavioral factors.” Third, this research also aims at increasing effectiveness and upscaling as described by Nilsson et al. (2018): “to provide a more comprehensive understanding of how HEMS are used and responded to among the average population requires studies of greater scale, including a larger sample of households of varying socio-economic characteristics.”

Stockholm case study: Data and methods

The first five steps of the conceptual framework were completed according to the process explained in Section 3 to comprehend the quantity and geography of household characteristics across Stockholm.

Step 1: Identification of the relevant household characteristics

The six characteristics identified for this case study are based on studies where both living conditions, weather, and climate are relatively similar to the Stockholm region as described in the literature review in Section 2. The six factors, as identified and elaborated upon in Section 2, are the following: Income, Household Composition, Education Level, Surface Area, Age, and Employment Status.

Step 2: Data collection

A dataset containing the relevant household characteristics was collected from a European engineering consultancy company active in the fields of construction, architecture, and environmental engineering located in Stockholm, Sweden. The dataset contained anonymized data of individual households of almost all neighborhoods in the Stockholm municipality. The characteristics discussed in Section 2 were presented in the dataset for each neighborhood.

Socio-economic and dwelling characteristics

- Number of residents
- Number of people in the age group 0-20, 20-64, 65+
- Average salary per person
- Amount of households with composition: single without children, single with children, couples without children, couples with children, household with children, household without children
- Amount of people who achieved a maximum educational level of elementary school, high school, and post-high school
- Amount of buildings from before 1930, 1931-1940, 1941-1950, 1951-1960, 1961-1970, 1971-1980, 1981-1990, 1991-2000, 2001-2010, and 2011-Present

Moreover, the collected data from the Nilsson et al. (2018) study was requested to create a profile for this specific neighborhood. The socio-economic and dwelling characteristics as described above were taken from this dataset.

Step 3: Data transformation into a normative scale

First, neighborhoods with missing data were removed from the datasheet. Missing fields accounted for less than 1% of the total dataset. Afterwards, all data was cross-checked for correctness, taking into account common demographic data. Secondly, all values were transformed from absolute values to relative values as described in Table

1. All absolute occurrences were divided by the size of the neighborhood. If the total sum did not add up to 100% due to missing data, the ratios were extrapolated to enable comparisons. Thirdly, the division of household type was changed from the original format to a more generally used format (single, couple, family), i.e. columns of ‘single with children,’ ‘household with children,’ and ‘couples with children’ were merged and labeled as *family*, the categories ‘household without children’ and ‘couples without children’ were merged and labeled as *couples*, and the category ‘single without children’ was relabeled as *single*. Data from the Nilsson et al. 2018 study was similarly transformed and normalized to the same format as de

Step 4: Geotagging and mapping

All zip codes covering the neighborhoods were identified and tagged to the name of neighborhoods using open source zip code data. The newly composed dataset was used as input for a visualization software. The geotag enabled the visualization software to map, using different colors, the intensity of different characteristics for specific neighborhoods.

Step 5: Identification of distinct neighborhood profiles

A list of neighborhoods profiles with their respective characteristics were composed from the main dataset, and the dataset from Nilsson et al. 2018.

To identify relevant neighborhoods the filters as depicted in Table 3 are applied. These filters were determined based upon the Parameter-Sweep method in which the upper and lower bound filter variables were swept across a range of values between 5 to 95%, and -5 to -95%, in intervals of five, respectively. Identification of neighborhoods satisfying the socio-economic characteristics was the main indicator of success of filter selections. The highest accuracy was obtained at a lower bound of -10% and an upper bound to +10%, equal to a total margin of 20%. Adjustments were made as the SRS has some outspoken socio-economic characteristics because of its small sample size compared to the neighborhoods in Stockholm.

The households in the SRS research were primarily highly educated, with 97% of the residents having a post-secondary education. This would be the highest percentage in the complete Stockholm dataset. Therefore, the Parameter-Sweep method was applied again, resulting in a 20% extra margin on the lower bound. Moreover, the reformatting of household types (couples, singles, and families) arguably decreases the reliability of this characteristic. Therefore, an extra 5% was accounted for to address possible errors.

Table 3: Overview of upper and lower bounds for the nine household characteristics in the Stockholm Royal Seaport case study, based on the Parameter-Sweep method.

	Lower bound	Upper bound
Average salary	-10%	+10%
Percentage couples	-15%	+15%
Percentage singles	-15%	+15%
Percentage families	-15%	+15%
Percentage children	-10%	+10%
Percentage working age	-10%	+10%
Percentage Elderly	-10%	+10%
Percentage post-secondary education	-30%	+10%
Average surface area	-10%	+10%

Stockholm case study: results and discussion

Step 6: Interpretation and analysis

A variety of maps visualize the different household characteristics in Stockholm. These maps provide direct insights to where and to which extent specific household characteristics are present in neighborhoods. Figures 2, 3 and 4 demonstrate single filter maps based on income, household composition, and age. Figure 5 presents a multi-filter map that displays neighborhoods conforming to the multiple characteristics examined in the Nilsson et al. (2018) study.

Single-filter maps

Figure 2 shows the areas with the highest household income in the Stockholm region. Referring to the findings of the literature review in Section 2 (Hayn et al., 2014; Matsumoto, 2016; Podgornik et al., 2016), a possible explanation could be that households in this area own a lot of electrical appliances as well as more smart appliances than the average income household. Households that own more smart appliances might be more interested in implementing DR programs since their smart appliances could potentially be connected to the system. High-income residents will also be more likely to be able to afford solar panels or electric vehicles, where a DR program can become essential for the residents. From the results in Section 4.2, it was also discovered that high-income people have a different lifestyle behavior than low-income. High-income households live more dynamic lives and can afford to travel or eat out more frequently (Matsumoto, 2016). Therefore, a DR program could be beneficial for high-income residents especially when it is well connected with all household appliances and remotely accessible for its occupants.

Figure 2: The average salary in SEK is depicted from low (dark orange) to high (dark blue).

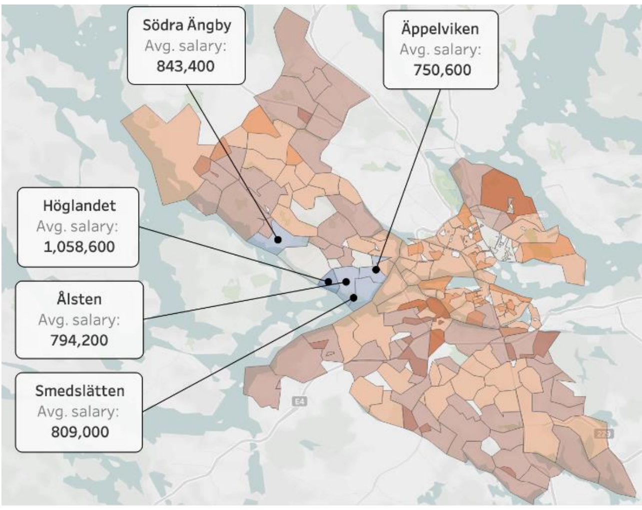


Figure 3 shows the top five areas with the highest concentration of families. The literature review indicates that households with families consume most electricity, primarily due to the fact that they tend to own and use more energy consuming electrical appliances such as washing machines and dishwashers. Teenagers and children also spend more time watching television and on computers (Jones & Lomas, 2015). Studies also show that families spend more time at home leading to an increased use of household electricity (Bedir & Kara, 2017). Regarding efficient use of energy, families tend to be less efficient than other household compositions, which could be because children are less conscious of consuming energy and less concerned over financial implications (Jones & Lomas, 2015). A DR program with only environmental and financial incentives might not therefore be optimal for a family. A strategy would be to implement some sort of gamification to increase child engagement. Nevertheless, as mentioned previously in Section 2, as age increases, children tend to use resources more sustainably (Gifford & Nilsson, 2014). Another strategy could therefore be to have a DR program that can adapt to different ranges of age.

Figure 3: The percentage of Family households is depicted from small (dark red) to large (dark green).

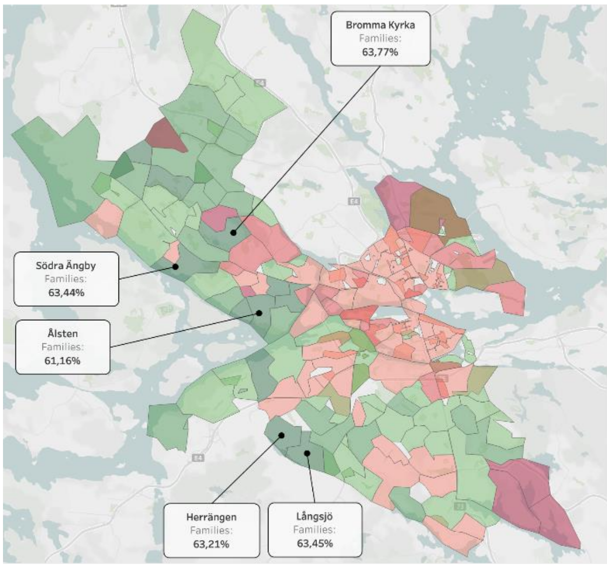
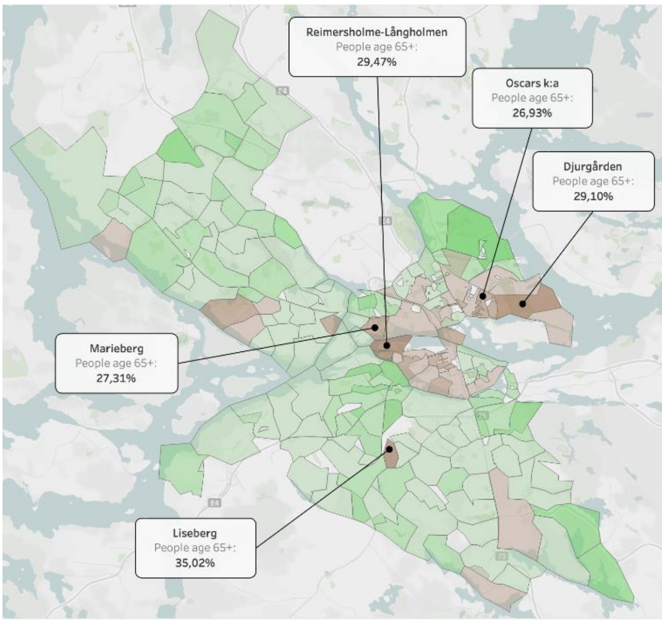


Figure 4 shows the areas where most elderly people live. Elderly residents are those households that consume most electricity per capita, as they tend to live in single households, spend more time at home (Hayn et al., 2014; Matsumoto, 2016), and have less energy-efficient appliances (Jones & Lomas, 2015). A strategy before installing DR programs in elderly households would be to implement some more efficient, smart appliances connected to the DR program, initiating a more efficient DR program. Elderly people enjoyed receiving energy feedback on displays more because it was easier to use (Vassileva et al., 2012b). A strategy would be for DR programs to adapt an interface that is more compatible for the elderly.

Figure 4: The percentage of people above 65 is depicted from small (dark blue) to large (dark green).



Multi-filter maps

The upper and lower bounds in Step 5 are now applied to filter neighborhoods for each household characteristic dataset. The resulting dataset will only contain the `filtered` neighborhoods, which are visualized on a map. All six characteristics were applied in figure 5, i.e. household income, composition, education, surface area, age, and employment status. Nilsson et al. (2018) desires to upscale in a neighborhood similar to the SRS as described in Step 5. The boundary conditions, as depicted in Table 3 filter out all neighborhoods except for Mariehäll, Stadshagen, and Hjorthagen-Värtahamnen. Figure 5 shows these five neighborhoods. It is expected that deployment of a DR program in these neighborhoods would result in similar outcomes, challenges and opportunities as the Stockholm Royal Seaport, based on their household characteristics.

Figure 5: Neighborhoods that display most similar household income, composition, education, surface area, age, and employment status to the

Stockholm Royal Seaport after layering all maps created with their respective boundary conditions.

By changing the boundary conditions in Table 3 according to the preference of the stakeholder, different neighborhoods can be identified as the most suitable places for future projects. In the case of the Stockholm Royal Seaport, future research in different neighborhoods with similar characteristics yet with a significantly lower level of education, could be targeted. Västra Matteus, with more than 50% of its population not having any post-secondary education, could be a potential neighborhood to do such research in. Similarly, Kälvesta is a neighborhood relatively similar to the SRS yet the percentage of family households is much larger. Therefore, a study focussing on the differences in DR programs in family households could be suitable in Kälvesta. The analysis showed that layering multiple household characteristics on a map filtered by the boundary conditions for specific neighborhoods using DR programs can be beneficial for finding areas for future research and upscaling.

Discussion

This study contributes to previous research as it proposes a conceptual framework which can be used to efficiently identify *where* future DR programs and projects could be suitable. The conceptual framework assists researchers, policymakers, housing developers, and energy companies in future works.

First, researchers can find (new) areas to upscale and study DR programs, as it is a simple and replicable method. Different visualization tools can be used for this framework, since it is not limited to a specific software. This study focuses on electricity consumption and efficient use of DR programs; nevertheless, this framework can be used for any studies that examine the relation of household characteristics and the use of different resources, e.g. water consumption or waste management in different locations.

Second, policy makers on all national, regional, and local levels have goals to reduce their energy consumption or emissions. However, not all policy makers have the same level of expertise on what projects to develop, and *where*. This conceptual framework can help identify neighborhoods with a specific potential for DR related programs in a variety of neighborhoods. Especially in areas with building development projects, it can provide insights in what approaches are useful to enable an energy efficient built environment. The framework provides guidance in decision making processes when planning future energy reduction and DR strategies. Policy makers can in this way address lower income areas in an optimal way, depending on the other characteristics.

Third, energy and utility companies need to market products more effectively and appropriately. Industries commonly use customer segmentation to divide customers into various groups depending on characteristics. Currently, several utility and energy companies are starting to sell and implement different DR programs in order to control and save energy for customers (ABB 2020; E.ON 2020; Siemens 2020; Vattenfall 2020). However, as this study confirms, different consumers have different patterns that affect the use of DR programs. The conceptual framework presented in this study can therefore assist energy and utility companies in targeting potential customers. Similarly, energy utilities can combine these maps with transmission lines and identify and target neighborhoods optimally with specific DR strategies to decongest and reduce potential investments in the grid.

In this study, several considerations should be made. It should be noted that this study was conducted prior to the COVID-19 pandemic; data collection can vary depending on lifestyle changes due to the pandemic and where the study is conducted. Some corporations and organizations have different policies which can cause hindrances to accessing data, which can lead to incomplete results. Additionally, the framework does not identify the absolute optimal places for the implementation of DR programs; it will only provide stakeholders with insights that could potentially help them determine the optimal location for implementing and upscaling DR programs. Finally, the household characteristics that are used in the study are generalized at a neighborhood scale. Although this study acknowledges the differences within neighborhoods (each individual household is different than the neighborhood), these are not considered for simplicity reasons. Moreover, the study acknowledges that the household characteristics used in the analysis are not exhaustive, and therefore could be expanded upon.

Future work regarding this framework should be in applying this framework on more cases to validate several assumptions. In particular, validating the effects of characteristics in different settings, and the extent to which a household characteristic has an impact on effectiveness of a DR program. Moreover, the extent to which the characteristics are interrelated is often unknown. While many studies point out the correlation between different characteristics, it is hardly discussed whether a specific combination of household characteristics requires a different DR strategy than the individual strategies for each individual characteristic combined. However, combining household characteristics in so-called lifestyle profiles is not something new, and already used in, for example, the (Ons Water, 2020) from the Dutch government. Here, they successfully developed different water saving campaigns for different groups of people based on demographic characteristics (Ons Water, 2020). A similar approach can be taken as a next step in this framework. Lastly, it would be valuable to look at different sizes of neighborhoods or blocks. Neighborhoods represent the average of the sum of different blocks and streets in the area, creating a less representative area to assess and address. The optimal balance between a large enough size to roll out a DR program and the homogeneity of an area could be explored in the future.

Conclusions

The six step process presented in Section 3 first analyzes and identifies the household characteristics which impact electricity use and behavior that affects the use of demand response, which in this study is demonstrated in Section 2. Through geographic and numeric data collection of the identified household characteristics, the data is then visualized in single- and multi-filter maps which geographically pinpoints the location of various household characteristics either solely or combined. If DR program designers (e.g. researchers, DSO's) and implementers (e.g. housing developers, governments) need to deploy a specific DR strategy, they can use the single- or multi-filter maps to identify where this research can further be assigned. As demonstrated in Section 4, the framework can also be applied to previous research and assist it in further upscaling research that previously was limited to a smaller scale. This was demonstrated by applying the framework in Stockholm and to the research study Nilsson et al. (2018). If research and deployment of DR strategies can be expanded and used more efficiently, the DR can become a more efficient flexibility solution.

The framework has limitations in taking into account the complex interrelation between different household characteristics. Future work should validate the presented insights and could further explore the interrelatedness of the characteristics to provide more resilient and holistic recommendations for DR strategies. Moreover, this framework could be applied for the studies that examine other relations of household characteristics with the use of different resources, e.g. water or waste management in different locations.

Potential outcomes of the proposed framework increase the effectiveness of DR programs, user interaction, and could help households become more conscious about their energy consumption. Ultimately, this study contributes to creating a more flexible and low-carbon smart grid by leveraging demand response.

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259 Plastic-free Tourism and Hospitality on Dutch Wadden Islands: Multi-level Design Approaches and Experiences

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Abstract

The Dutch Wadden islands Vlieland and Terschelling, as part of the greater Waddensea area in The Netherlands, Germany and Denmark, experience conflicting interests. On the one hand, as Natura 2000 area as well as UNESCO World Heritage area, nature preservation and biodiversity are very important. On the other hand, tourism is the main source of income on both islands, which is contributing to pollution, increased traffic, building activities and disturbance on the islands. Triggered by the MSC Zoe container loss incident in 2019 which led to littering with (amongst others) plastic products, plastic beads and polystyrene packaging on the beaches and in the dunes, the topic of reduction of plastic waste is high on the agenda of tourism and hospitality stakeholders on both islands and beyond. The research group Open Innovation of NHL Stenden University, Leeuwarden, is involved in several concerted approaches and activities during 2019 – 2021 towards the goal of plastic free tourism and hospitality, often in cooperation with other research groups of NHL Stenden: 1) Plastic free Vlieland: a set of connected pilot cases with tourism and municipal actors on Vlieland 2) Plastic free Hospitality project on Terschelling: cooperation with the main hotels on the island to have plastic free terraces and reduction and circularity in their kitchen and transport plastic waste 3) Project 'Wad of Value" biobased product alternatives for the Wadden islands 4) participation in the national Beach clean-up tour 2021 to measure the impact of the actions taken by beach restaurants involved in the tour 5) participation in the Community Plastic-free Waddensea to communicate all results with a larger group of actors, and 6) research proposal to measure and minimize the additional use of plastics in hospitality companies due to additional hygienic measures for COVID19. This paper analysis the results of these concerted and coordinated efforts on four elements: Multi-level design, circularity strategies, stakeholders involved and actual level of achievement. First results show that there is ample room for improvement in this sector. 1) Having plastic free terraces, restaurants and rooms is relatively easy. 2) However, plastic free kitchens, cleaning and transport is much harder to attain, and a combination with reuse and recycling of plastics is

required. 3) The islands also need new dedicated systems for recycling and (more so after the transition towards biobased materials) composting. 4) More and more biobased alternatives are becoming available, whereby the total environmental footprint is often worse than that of well recycled non-degradable plastics. However, littering and potential microplastics effects are usually not part of these assessments. 5) Impact measurement, especially for littered plastics, is still cumbersome and needs to be improved. 6) And lastly, due to COVID the use of plastics in the hospitality sector has increased, and it remains to be seen what the post-COVID situation will be due to changed hygienic attitudes of customers. By performing a concerted set of multidisciplinary projects and by involving many stakeholders along the way, synergy effects between the projects have been achieved.

Keywords: Circular, Plastic-free, Tourism, Hospitality, Multi-level design

Introduction

To the North of The Netherlands the Dutch Waddensea area is located, as part of the greater Waddensea of The Netherlands, Germany and Denmark. This area is the largest unbroken system of intertidal mud and sand flats in the world, and one of the last remaining of such systems where natural processes continue to function undisturbed. Not surprisingly, it is designated as UNESCO World heritage Area (UNESCO, 2021). The Dutch Waddensea area is also designated as protected Natura 2000 area (Dutch Ministry of Agriculture, 2021). Nature preservation and sustained biodiversity are very important for this area. In the municipalities of the Dutch Wadden Islands, tourism and related hospitality are the main economic activities, next to agriculture and maritime sectors. Nature and landscape are the key pull factors for tourism on the islands, and at the same time tourism contributes to negative environmental impact because of waste production, building activities, traffic and disturbance. Therefore, tourism development and nature conservation need to be closely aligned and tourism needs to be developed sustainably (Revier, 2013).

The emerging issues of plastics pollution, including the topics of plastic soup, littering of plastics on beaches and in nature area, and microplastics pollution have been drawing attention for some years now. On the Dutch Wadden islands, the attention for these topics rose sharply after the MSC Zoe container loss incident in January 2019. A total of 3.200 Tonnes of products and materials spilled from the damaged containers ended up in the North Sea and Waddensea, and part of it washed to shore on the islands Vlieland, Terschelling, Ameland and Schiermonnikoog. Among these were plastic products, plastic beads and packaging materials such as polystyrene (Strietman et al. 2020). Normally, beachcombing after spillage is an exciting and profitable activity for inhabitants of the islands, but the sheer size of this disaster changed their attitude into concern for the environment and critique on the risk taken by the shipping company. Policy makers, tourism companies and inhabitants on the islands were triggered by the disaster and have since then strengthened their resolve to tackle plastic waste problems, supported by regional and national organisations. Next to taking action on plastic litter found at shores and in nature areas on the island, attention is also focused on the use and waste management of plastics in tourism and hospitality companies, in the villages and in households on the islands.

Dutch policy for the transition towards a circular economy has been in place since 2016 and is aiming at a fully circular economy in 2050, with a milestone of 50% reduction in 2030 (Rijksoverheid 2016). For plastics, a National Transition Agenda has been set with the same targets (Rijksoverheid 2018). A recent study estimates that it should be feasible to at least recycle 87% of plastic materials in 2050 (TNO 2020). A national execution program with a variety of projects has been started. Emphasis in Dutch policy programmes and projects is still on recycling of plastics (Ogink and Crul 2019, Partners for Innovation 2020). Based on the general gradation of circularity strategies made in literature (Kirchherr et al. 2017) recycling is less preferred compared to for instance refuse, reduce, and reuse strategies. Specifically for packaging plastics, of which most of the plastic waste from tourism and hospitality companies consists, a framework has been developed for innovative circularity, focusing first on elimination and reuse of plastics before applying recycling approaches (Ellen McArthur Foundation 2020).

The research group Open Innovation of NHL Stenden University of Applied Sciences has been extensively involved in projects with Wadden island communities over the years, especially on the islands of Vlieland and Terschelling. Together with the research groups Circular Plastics, International Tourism, and Sustainability in Hospitality and Tourism, and with students from several educational curricula, initiatives on plastic-free and circular plastics in tourism have been executed over the last three years. Six of these initiatives have been selected for analysis in this paper. In table 1, a brief overview of these is presented.

Table 1: Plastic-free and circular initiatives on Dutch Wadden Islands

Name of initiative	period	Brief description
(1) Plastic-free Vlieland	2019	4 design pilot cases with tourism and municipality actors on the island.
(2) Plastic-free hospitality Terschelling	2020-2021	Project with main hotels on the island on plastic-free terraces and reduction and circularity of plastics ‘behind the counter (kitchen, logistics)

(3) Wad of Value	2020-2022	House of Design project on developing new replacement products from locally produced biodegradable materials
(4) Beach clean-up tour	2021-2022	Information campaign for beach cafes on plastic-free terraces and circular plastics
(5) Community Waddensea Plastic-free	2019-ongoing	Community with website, regular meetings and workshops in which all actor groups around this theme are gathered.
(6) Workshops with Tourism companies	2020-2021	Workshops and meetings with Tourism companies on sustainable welcome package, and on COVID impact on plastic use

For these initiatives, this research is focused on the different levels where change and innovation are needed. For instance, to reduce the use of plastics in a tourism company, changes are needed on different levels: Change or redesign of the product itself, so by the plastic product producer, changes in the supply chain towards the tourism company, changes in the materials used by plastic supplier or other industry, changes in the waste management systems of the company, municipality and region, and other societal changes such as preferences from users (guests of the hotel) and policy incentives and regulations by local, national and European governments. As an example of the last category, the ban on certain single use plastic products as of 2021 (EU 2019) has a direct impact on the purchasing choices of individual tourism companies. The application of such a multi-level design framework is described in the methods chapter below.

Methods

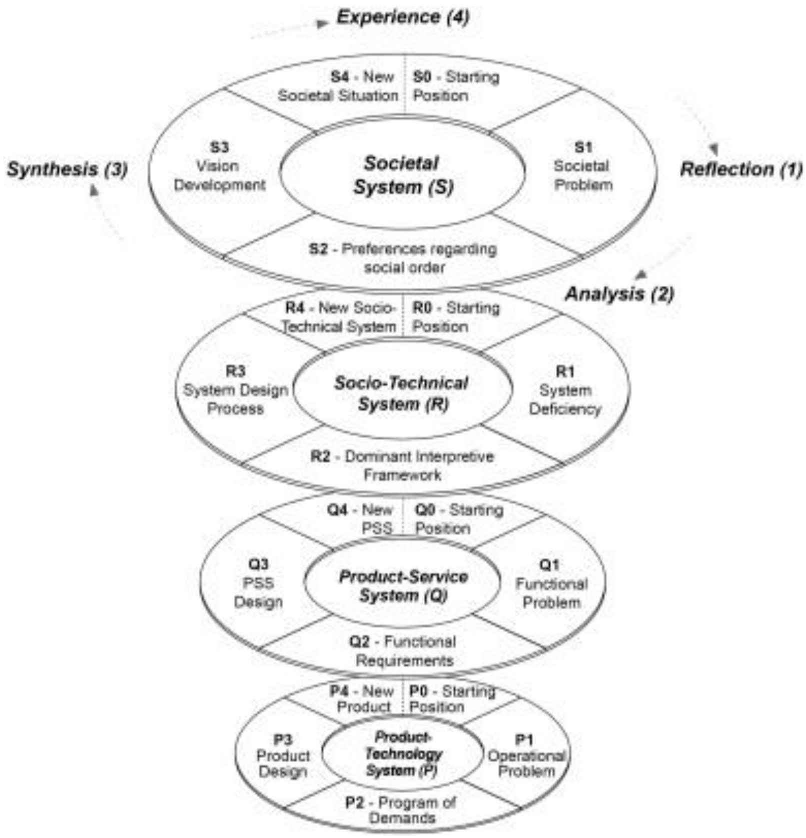
To be able to analyse the impact, effectivity, and efficiency of the presented initiatives on the circularity of plastics in the tourism sector on Dutch Wadden islands, a multi-pronged framework is developed based on the following four elements:

- Multi-level design elements used (1)
- Gradation of circularity strategies deployed (2)
- Diversity of stakeholder groups involved (3)
- Actual level (TRL estimate) of results achieved (4)

(1) For analysis of the innovation levels of the initiatives, the multi-level Design Model or MDM (Joore and Brezet 2015) will be used which was developed specifically for the analysis of complex societal transitions such as the transition to circularity, where

products, services, systems and policies have to be changed and (re)designed on all levels simultaneously. The model describes the design cycles in four different connected levels of systems, the product-technology system (P), the product-service system (Q), the broader Socio-technical system (R) and the overall societal system (S) as depicted in figure 1. For the analysis of the plastic-free initiatives, it will be identified which levels of the model were tackled.

Figure 1: Multi-level Design Model (Joore and Brezet, 2015)



(2) To determine the *strategies for circularity* that were used in the initiatives, a representation of the 9R hierarchical gradation has been adapted for circular plastics (see figure 2), allowing for replacement of plastics by biodegradable materials, now included as the fifth strategy.

Figure 2: 9R hierarchy of circular design strategies (adapted from Potting et al, 2016)

(1) Refuse: preventing the use of raw materials;

(2) Reduce: reducing the use of raw materials;

(3) Reuse: product reuse (multiple use, second-hand, sharing of products);

(4) Repair: maintenance and repair;

(5) Replace: use alternative (biodegradable) materials

(6) Remanufacture: creating new products from (parts of) old products;

(7) Repurpose: product reuse for a different purpose;

(8) Recycle: processing and reuse of materials;

(9) Recover energy: incineration of residual flows.

(3) Since circular design in complex societal settings can only be achieved when all relevant stakeholders are involved directly in the process (Crul et al, 2019) a description of the number of relevant *stakeholder groups* is made for the initiatives, whereby the following categories are counted for each initiative: companies (F), consumers/customers (C); supply chain partners (S); researcher/designer/consultants (R); municipalities (L) , regional/national authorities (N), environmental/circularity organisations (E).

(4) Last, for each initiative the *actual realisation* is assessed. In many of the type of projects described in this paper, pilot projects are performed with companies and other stakeholders, where design processes are delivered up to a certain point, for instance the developing of a working prototype or new system. The actual introduction to the market of a product or actual implementation of a technical, logistic or social system is often not part of the project itself but left to commercial partners to follow up. To measure this, as a first estimate the TRL (Technology readiness Level) of the initiative is estimated, whereby TRL 1-3 = discovery, TRL 4-6 = development, TRL 7-8 = demonstration and TRL 9 = market deployment. In case of social or societal change, the TRL measure is used in that sense.

Results and Discussion

Narrative results

A short narrative summary of the results of each initiative is provided in box 1 – 6.

Box 1. Results Plastic-free Vlieland

Student group projects from the Master programme Design Driven Innovation and a BSc Graduation project Industrial Design were executed with various stakeholders on the island. (1) An awareness programme for children and their families on avoiding plastic waste was developed, starting with the ferry journey to the island. (2) A collection and composting system for the village was developed, anticipating the increase in biodegradable materials when substituting for plastics. (3) An entrepreneurs platform (support website and information system) for tourism companies was developed on use of and alternatives for plastic packaging (DDI 2019) (4) a new reusable transport packaging for tomatoes for hotels and restaurants was designed, avoiding single use packaging (Gort 2020). Working prototypes were developed in all these cases, no actual implementation of the systems was achieved up to date.

Box 2. Results Plastic-free Hospitality Terschelling

Eight hotels and restaurants on Terschelling joined the project to eliminate single use plastics on terraces and in the rooms, and to reduce plastics use in kitchens, maintenance, and logistics. Joint workshops were organised to exchange information and good practices. Guidelines were developed to take actions in the companies (Crul and Obinna, 2020). Actions feasible at short term were implemented, including plastic free terraces, largely required by the EU SUP directive (EU 2019). It should be noted that the paper and cardboard alternatives that are chosen often have a higher total environmental footprint than the plastic product used before. Reason for the replacement would then be the avoidance of plastic litter which is not biodegradable and the avoidance of microplastics. Plastic-free kitchens and logistics are harder to attain due to food safety and logistic requirements. A combination with transition to reusable plastic products and better recycling of the remaining materials is required. Parallel to this, workshops were organised with other stakeholders on the island on additional activities with the Tourist Information Office. A new information and awareness system was prototyped, using plastic waste from the beach for its token sign, the island's lighthouse (Dijkstra 2021). The project is still ongoing in 2021.

Box 3. Results Wad of Value

The research group is one of the partners of this project, together with other educational institutes, sector organisations, consultancies and companies, managed by House of Design. Its purpose is to develop and put on the market replacement products for plastic ones that end up in the Waddensea and on the beaches frequently. Selected products that are redesigned from biodegradable materials are fishermen's gloves and food containers. The project is ongoing. More and more of these biodegradable alternatives are becoming available. Also in this case, it is advisable to check on the total environmental footprint of the alternative and make an informed decision on its application.

Box 4. Beach Clean-up Tour

This is a yearly public clean-up event for all North Sea beaches in The Netherlands, several stages of which are at the Wadden islands (Beach clean-up tour 2021). This year it is proposed to be coupled with an information and workshop programme for beach bars and restaurants on plastic-free terraces and reduction of other plastics use. As a starting point an inventory will be made of plastic waste found at the beaches and dunes, and the impact of plastic reduction actions by beach bars will be measured. In the preliminary research, it became evident that measurement of total littering is still cumbersome and needs to be improved. This part of the project has not yet started and has no results to show yet.

Box 5. Results Community Waddensea Plastic-free

The Community is an active group of many stakeholders involved in initiatives concerning a plastic-free Waddensea. Stakeholders include knowledge institutes, local, regional and national governments, companies and consultants, societal organisations like museums and environmental/circularity groups. Next to a website, regular meetings and workshops, joint projects are developed and executed between the members (Plastic-free Wadden, 2021)

Box 6. Workshops with Tourism companies

As part of a project of the Research Group Sustainability in Hospitality and Tourism, workshops took place on plastic waste reduction and the development of a sustainable, plastic-free welcome package for tourism companies. Also, in the framework of proposal development, interviews were held on the effects of COVID19 measures on the use of plastics in the companies. There was an increase reported because of stricter hygienic measures and requests from guests, although the actual effect on prevention of virus infection because of increased packaging is not proven. This is preliminary information from interviews which is not yet substantiated by quantitative data.

Multi-level design elements used

The initiatives are analysed for the multi-level design levels included in the activities. The different levels product-technology system (P), product-service system (Q), broader Socio-technical system (R) and overall societal system (S) have been identified for each initiative. The results are presented in table 2.

Table 2. Multi-level design levels included in initiatives

Name of initiative	Multi-level design elements used P,Q,R,S
(1) Plastic-free Vlieland	P: Product development; Q: collection and composting system municipality; awareness raising campaign
(2) Plastic-free hospitality Terschelling	P: Product development; Q: Supply chain management; awareness raising campaign
(3) Wad of Value	P: Product development; Q: Supply chain management
(4) Beach clean-up tour	P: Product replacement; Q: Awareness raising campaign
(5) Community Waddensea Plastic-free	Q: project initiatives S: Overall societal system involvement and influence
(6) Workshops with Tourism companies	Q: Product-service development

As can be seen in table 2 the focus of the initiatives is on Product (P) and Product-service (Q) development (including awareness raising campaigns). The Community (5) is also touching upon the wider societal changes (S) since all relevant actor groups are involved and are exerting influence on national policy making. Missing level is the broader socio-technical system (R), which for instance would involve the overall plastics production and collection systems with the intention to divert the use to other materials and other types of product-services. This would involve an international, production and supply chain approach which is not included in the current projects that are more locally and regionally focused on the tourist companies as users of the plastic products.

Circularity strategies deployed

The initiatives are assessed for circularity strategies used by the 9R strategies system outlined in the methods section. The results are presented in table 3.

Table 3. 9R circularity strategies deployed in initiatives

Name of initiative	9R circular design strategies - see methods section
(1) Plastic-free Vlieland	(R1) single-use plastic-free terraces (R3) Reusable tomato packaging (R5) (R9) collection and composting system for biodegradable materials
(2) Plastic-free hospitality Terschelling	(R1) single-use plastic-free terraces (R2) reduction of kitchen plastics (R3) reuse of logistics plastics (R8) recycling improvement and use of recycled plastics of beach litter plastics
(3) Wad of Value	(R1) refuse of plastic products (R5) replacement by biodegradable products
(4) Beach clean-up tour	(R1) single – use plastic-free terraces (R8) collection for recycling
(5) Community Waddensea Plastic-free	Connection to all of the above projects and others on (R1) (R2) (R5) and (R8)
(6) Workshops with Tourism companies	(R1)(R3)(R5) for welcome Package; Intention to focus on (R2) reduction of use of additional packaging due to COVID hygienic measures.

A clear focus on preventing and reduction raw materials, especially for single use plastics, change-over to reusable products and replacement by biodegradable materials can be seen in the initiatives. Next to this, improvement of recycling and product from recycled materials is also part of some of the initiatives.

Stakeholders involved

The initiatives are analysed for their stakeholder groups involved, being companies (F), consumers/customers (C); supply chain partners (S); researcher/ designer/ consultants (R); municipalities (L), regional/ national authorities (N), environmental/ circularity organisations (E). The results are presented in table 4.

Table 4. Stakeholder groups involved in the initiatives

Name of initiative	Stakeholders involved
(1) Plastic-free Vlieland	(F) tourism companies (R) researcher + student groups (L) Municipality Vlieland (C) guests, tourists
(2) Plastic-free hospitality Terschelling	(F) hotels and restaurants, Jutfabriek (R) research groups + students (E) Circulair Friesland, Milieujutter
(3) Wad of Value	(F) material companies (R) research, consultants,

	education (E) Circulair Friesland
(4) Beach clean-up tour	(F) beach restaurants (S) to some extend- supply chain (C) tourists (R) researchers, consultants (L) municipalities (E) Stichting Noordzee
(5) Community Waddensea Plastic-free	Multiple (F)(R)(L)(N)(E)
(6) Workshops with Tourism companies	(F) hotels (S) supply chain (R) research groups (E) Circulair Friesland

In all initiatives combined, there is a broad involvement of all relevant stakeholder groups. Involvement of supply chains partners, which are considered relevant for structural change is limited to two initiatives.

Actual realisation

The initiatives are analysed on their actual realisation impact by means of an estimate of the TRL (Technology Readiness Level), whereby TRL 1-3 = discovery, TRL 4-6 = development, TRL 7-8 + demonstration and TRL 9 = market deployment. This is also used in the social and societal sense where applicable. The results are presented in table 5.

Table 5. Actual realisation level of initiatives by TRL stage

Name of initiative	**Actual realisation level (TRL stage 1-9)**
(1) Plastic-free Vlieland	TRL 5 Prototypes presented and partially tested. TRL6 working prototype for tomato packaging.
(2) Plastic-free hospitality Terschelling	TRL9 First market deployment for plastic free terraces; TRL7 Demonstration of plastic use reduction in kitchen/logistics TRL 6 Working prototype for awareness programme sign
(3) Wad of Value	TRL3-4 discovery and development of biodegradable products
(4) Beach clean-up tour	TRL9 First market deployment for plastic free terraces; TRL 5 development of alternative products
(5) Community Waddensea Plastic-free	Not applicable directly in Community work
(6) Workshops with Tourism companies	TRL 4 development welcome package TRL1-2 discovery plastic reduction COVID hygienics

In the initiatives full realisation is achieved primarily with the introduction of plastic-free terraces in tourism companies. Most other initiatives show results in development (prototypes) or early demonstration phases.

In table 6, all results on the four analytical elements are presented combined for the initiatives. Please refer to tables 2-5 for the abbreviations used.

Table 6: combined impact analysis for initiatives

Name of initiative	Multilevel	9R strategies	Stakeholders	TRL phase
(1) Plastic-free Vlieland	P,Q	R1,R3, R5,R9	F,C,R,L	TRL5 TRL6
(2) Plastic-free hospitality Terschelling	P,Q	R1,R2,R3,R8	F,R,E	TRL6 TRL7 TRL9
(3) Wad of Value	P,Q	R1,R5	F,R,E	TRL3-4
(4) Beach clean-up tour	P,Q	R1,R8	F,C,S,R,L,E	TRL5 TRL9
(5) Community Waddensea Plastic-free	Q,S	R1,R2,R5,R8	F,R,L,N,E	N A
(6) Workshops with Tourism companies	Q	R1,R2,R3,R5	F,S,R,E	TRL4, TRL1-2

The scores on the combination of initiatives shows a wide and relevant coverage for the requirements identified for different impact aspects.

Conclusions

Six initiatives on plastic-free and circular tourism companies on Dutch Wadden islands, ranging from a community of practice to implementation projects. were analysed on their joint impact on multi-level design, circularity strategies, stakeholder involvement and level of achievement. It can be concluded that for this sector, there is still ample room for improvement in this area. Plastic-free terraces, rooms and restaurants ('before the counter') are relatively easy to achieve, although the requirements for hygienic measures for COVID19 have again increased the amount of plastics used. It remains to be seen whether this is a temporary situation or hygienic attitudes of customers have changed. Plastic reduction in kitchens, maintenance, and logistics ('behind the counter') is harder to achieve but steps up in circular use of the materials is certainly possible on the short term. For all these changes, actions on all levels of the system are necessary. The projects mainly dealt with the levels of product-technology system and product-service system design. More emphasis and activities are needed on the higher levels of the broader socio-technical system and overall societal system. For this, other stakeholders need to be involved such as plastics industry, recyclers and national and European government. Up to now, a good mix of regional and local stakeholders has been involved. This has made the projects successful, but at the same time the opportunity for higher level impacts is lacking.

Circularity strategies deployed were ranging from refusal, direct reduction and reuse of plastic products to replacement by biodegradable products and recycling. The latter strategies require a good understanding of the total environmental impact of the changes made, since these alternatives or recycling systems often have a higher total impact. However, littering and potential microplastics effects are usually not part of these assessments. In general, this assessment is not considered enough. Although several of the initiatives show promising implementation of innovative measures, these are often 'low hanging fruits', and more costly and/or complex solutions are only piloted or one-time demonstrated. More follow-up projects on actual market implementation and supply chain building are necessary.

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108 The resource reduction index – evaluating product design's contribution to a sustainable circular economy

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Abstract

Primary resource consumption is a main driver for global environmental change, including the climate crisis. Hence, reaching climate targets requires material production to change significantly. For the global scale, we have developed the Ecological Resource Availability (ERA) method quantifying primary resource budgets. If those budgets are respected, major Earth system boundaries are not transgressed with high confidence. Product design and the implementation of circular strategies have the potential to reduce the pressure on these limited resources significantly. Nevertheless, the question, *how much* a product needs to reduce its environmental impacts to reach a sustainable level and respect planetary boundaries remains open. In the present contribution, we define and introduce the resource reduction index (RRI) to answer this question. RRI quantifies and evaluates the degree to which a specific product design respects planetary boundaries. RRI is designed as an absolute and generally applicable indicator, which is able to show the achievements of resource reduction targets on different levels (products, companies, sectors, countries). It is therefore relevant also beyond product and service design. Its applicability is shown here with a case study of a circular jacket, which is designed for an almost perfectly closed material loop. Different scenarios – from a prototype to an industrial scale utilizing the full circular potential – show that circular strategies effectively reduce the pressure on limited resources and the environment. However, only the most advanced scenario, combining multiple and fully implemented circular strategies, can achieve absolute sustainability respecting planetary boundaries.

Keywords: Ecodesign, resource pressure, ecological resource availability, absolute sustainability indicator, planetary boundaries

Introduction

How much better is good enough? In environmental assessments, this question remains usually open due to a lack of suitable methods quantifying the absolute sustainability of an activity (Bjørn et al., 2020). However, it is necessary to provide designers and decision makers with a reference to the scale of the improvements that are necessary to create truly sustainable products, services and other anthropogenic activities. Up to now, all this remains a fundamental challenge, as allocating shares of global environmental boundaries to individual products or activities is at the one hand very influential on the assessment and on the other hand subjective.

In this contribution, we propose a different way of measuring the effects of design improvements on reaching absolute sustainability, which is based on the translation of planetary boundaries to resource budgets, called ecological resource availability (ERA) (Desing et al., 2020). The ERA method calculates the annual primary production amount of each resource, which is available to be used in the economy without violating any of the considered environmental boundary conditions. It necessitates to allocate Earth system boundaries to resource segments (e.g. plastics) and to define the relative share of production for resources (e.g. PET) within each segment. Following the original publication, we use here results generated with the grandfathering allocation approach, i.e. all resource segments may generate impacts in the same proportion as in the past and the relative share of production stays constant on today's level (Desing et al., 2020). Other allocation approaches reflect different societal priorities.

The global use of resources must not exceed the respective resource budgets to be sustainable. As most current resource uses are beyond their resource budgets, the global economy needs to reduce primary resource consumption significantly and/or change the way resources are produced. One-way to achieve this is redesigning products and services to put less pressure on the environment and its resources. Circular economy strategies can reduce primary material input and final losses and their effectiveness can be measured by the resource pressure method (Desing et al., 2021b). This method is an easy-to-use tool quantifying the environmental pressure products cause on planetary boundaries. In this method, the effect of circular strategies reducing resource pressure are considered through the following parameters: reducing the mass of the products $m_{in\,product}$, reduce manufacturing losses γ_m (material efficiency), increasing lifetime t_L, reducing primary material content α', as well as increasing recyclability η_R and cascadability η_C (Desing et al., 2021b). Additionally, primary resource consumption can be reduced through reducing production or resource budgets enlarged through changing material production processes (e.g. hydrogen steel (Bhaskar et al., 2020)). However, the goal of this study is to measure the effectiveness of design improvements through circular strategies on the absolute sustainability of a product in line with planetary boundaries.

Methods

The resource pressure τ is itself already an absolute sustainability indicator (Desing et al., 2021b). If the global sum of all τ_r for a specific resource r is larger than one ($\sum\tau_r > 1$), more of this resource is used than is sustainably available. In this case, the resource use is unsustainable. As straight forward the analysis appears on a global level, as difficult it gets when we want to assess the absolute sustainability of a single activity, be it a product or entity. In one way or another it needs to be determined, how much a single activity is allowed to contribute to the total resource pressure; in other words, how much a single product can utilize from a resource budget.

The first possibility is to allocate resource budgets to the activity under investigation. Such an allocation is however difficult to define (e.g., how much steel, and any other material, is a washing machine allowed to use?) (Ryberg et al., 2018). Alternatively, we can define resource reduction targets for global resource consumption. As several Earth system boundaries are violated today (Rockström et al., 2009; Steffen et al., 2015), it is necessary to reduce the primary resource production to sustainable levels or introduce more environmentally friendly production processes (Desing et al., 2020). For any new product, we can define an equal contribution to this collective effort as a benchmark. Reaching this benchmark on a product level, the product can be considered absolute sustainable in the sense that "if every product provides the same contribution while demand is constant, we will be sustainable collectively." However, not every sector or product type can contribute equally to the global target, as for some this is much harder to achieve. In addition, some activities may be more relevant to society, thus deserving priority and therefore lower reduction obligation.

For this reasons we can combine the former two approaches by allocating resource budget to a defined entity (e.g. product group, industry, company or country as e.g. defined by the science based targets (Pineda et al., 2015) for industries in regard to climate targets) and then specify resource reduction targets for all products and activities contained within. An example for the logic of this combined approach are emission reduction targets in the car industry. These targets are specific for the sector and have to be reached as the average of the fleet of cars sold by a manufacturer.

The approach we present here can be applied to the latter two. However, we show it for global reduction targets as an example. It is a two-step procedure: first, defining the reduction target for each resource necessary for a product (or service) within a defined entity. Second, measuring how well this target is achieved in a specific product.

Reduction target

To illustrate the method and for simplicity, we define and use a global reduction target. Such a reduction target for a resource κ_r can be established by simply dividing the reference global production rate of resource r by its respective resource budget ERA_r.

Please note, ERA budgets are influenced by societal choice, i.e. allocation principles (Desing et al., 2020), and thus will be the reduction target.

$$\kappa_r = \frac{\dot{m}_{prim,r,ref}}{ERA_r}$$

As reference year for the production amount, the latest year is chosen for which data are available and this year is preferably the same as for the reference product. The value of κ_r indicates how much the primary production of resource r in today's global economy needs to be reduced in order to be environmentally sustainable. Values of $\kappa_r < 1$ indicate, that the resource budget is higher than current production and thus production of that material can increase. Values $\kappa_r > 1$ indicate a need to reduce the primary resource intensity of the global economy for this resource or change its production process (e.g. phase out fossil fuels).

When using sub-global entities (e.g. industries, countries or companies), ERA budgets have to be allocated to the respective level and current primary production volume used on that level for the reference year. This results in reduction targets for each resource used within a specific sector.

For products requiring multiple resources, a single reduction target κ_p can be defined by aggregating reduction targets of individual resources used in the product. We propose to aggregate the reduction targets of the resources weighted by the respective resource pressure $\tau_{r,p}$:

$$\kappa_p = \frac{\sum_r \kappa_r \cdot \tau_{r,p}}{\sum_r \tau_{r,p}}$$

In this way, the higher the resource pressure (meaning the less favourable for the environment), the more important the reduction target of the specific resources and it thus weights more in the overall reduction target for the product. This increases the incentive for the product designer to substitute resources with high reduction targets κ_r or focus on the reduction of their resource pressure $\tau_{r,p}$.

Resource reduction index

The resource pressure for a new product can be compared with a reference product from the same year as the primary production data used in the definition of the reduction target. The aim shall be to reduce the resource intensity of the new product at least by κ_p (or κ_r, if only one resource is used or investigated) compared to the reference product. Progress towards this goal is measured by the primary *resource reduction index* (RRI). RRI measures the extent to which the primary resource reduction target for a product κ_p is reached.

$$RRI_p = \frac{\frac{\tau_{cum,p,ref}}{\tau_{cum,p}} - 1}{\kappa_p - 1}$$

It can be evaluated for single materials, products or higher entities (e.g. companies, households). Designs containing different materials can be compared on a product level when comparing the cumulative resource pressure $\tau_{cum,p}$ of the reference product and the new design with the reduction target of the new design κ_p.The RRI equals one when the resource intensity reduction of the product equals the required resource reduction target κ_p. If $RRI > 1$, the reduction target is overachieved and an increase in demand is possible. If $RRI < 1$, the reduction is insufficient to reach sustainability. RRI is zero, if the resource pressure of the reference product is equal to the reference, e.g. when no reduction/change in production processes took place. The reference product shall represent the global average product fulfilling the same function. For example, for a washing machine the reference product is the market share weighted average of the resource pressure exerted by sold washing machines worldwide (see figure 1). Note, for a product creating new demand no reference products exist and therefore the RRI cannot be calculated.

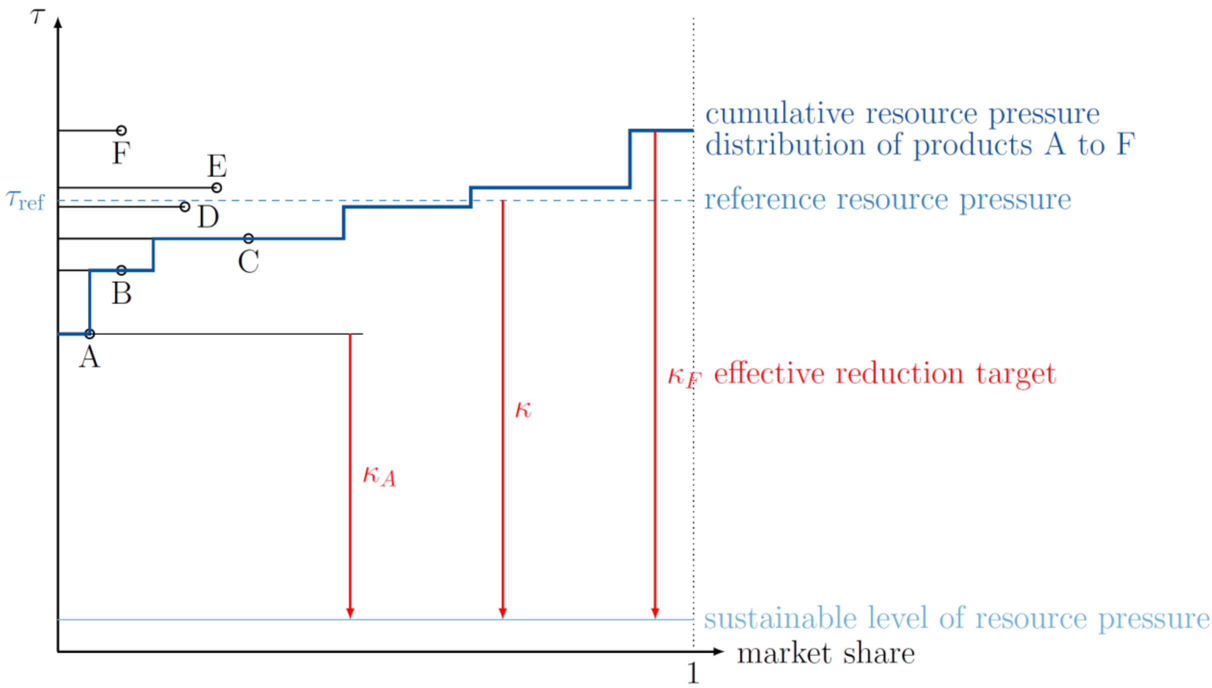

Figure 1. The reference resource pressure τ_{ref} can be calculated as the market share weighted average of the products on the market (A to F). Product A, which has a lower resource pressure than the reference, also has a lower effective reduction target κ_A as part of the reduction is already achieved. On the contrary, product F has a higher reduction target as its resource pressure is larger than the reference.

RRI can be increased by the product design by decreasing the resource pressure of the new design and by avoiding resources with high reduction targets κ_r. Additional to products, the indicator can be applied on different levels, e.g. on company, sector, country and global levels.

Case study

RRI is applied in an illustrative case study of an innovative circular textile product designed by the wear2wear™ consortium (www.wear2wear.org). The product under investigation is a work-wear jacket integrating several circular economy principles. The jacket itself is made of few and easily separable materials to enable a straightforward recycling process at end-of-life (EoL). An innovative sewing yarn is used for the seams, which dissolves in boiling water. In this way, the zipper can easily be separated from the jacket at EoL and reused up to three times. To ensure that the jacket returns for recycling, it is rented out – not sold – to the costumer. During the use-phase, an industrial washing service is provided. The polyester jacket is regranulated in a polymer melting process and the recycled granulate is again spun into new filament fibers. Overall, the jacket consists of a three-layer laminate (outer material, membrane, lining), a zipper, yarn, pocket magnets, shanks and buttons. For more information regarding the design of the product system, please see the respective Life Cycle Assessment (LCA) carried out by Braun et al. (2021). The mentioned LCA study compares the circular jacket to a linear reference jacket to understand the improvements/ deteriorations of designing a textile with circular elements. Therefore, the fictive linear jacket contains the exact same components. However, it does not include the recycling and reusing elements and is in fact incinerated at EoL. The results of the LCA show a reduction potential of the circular jacket of 1/3 in terms of greenhouse gas (GHG) emissions compared to a linear one.

Figure 2. The wear2wear production loop. Starting from the light green field, the fibres are spun either from virgin PES or recycled granulate. The fabric is a three layered laminate just made of PES to guarantee optimal recycling at the EoL, where new fibres are made again from remolten granulate *(*wear2wear™, 2020*)*.

In this study, we use the same two products and compare them based on the resource pressure method and RRI. In total, five scenarios are investigated in detail, comprising varying parameters for the circular jacket. Each scenario is compared to the linear reference case (scenario *Linear*). A detailed description of the scenarios is given in Table 1.

Table 1. Parameters for the resource pressure method for each scenario of the linear and circular jacket. Each parameter is the sum of the different product components. The *Linear* scenario includes no recycling/ cascading activity at the EoL (instead incineration with energy recovery) and manufacturing losses are low. The manufacturing losses of all circular scenarios are assumed equal to the *Linear* version except for the first *Circular* scenario, which represents the prototype manufacturing process with higher losses. The primary material input reduces with an increasing value for recyclability/ cascadability. Moving from *Circular* to *Circular R+*, the primary material input decreases due to less manufacturing losses. The *Circular R++* scenario goes one-step further and assumes that even manufacturing losses are recycled (and thus increasing the recyclability value). In the Circular optimal scenario, it is additionally assumed that everything that is not recycled (due to quality issues), is cascaded and all material inputs are taken from secondary production.

Scenario	Linear	Circular	Circular R+	Circular R++	Circular optimal
Resource budget (kg)	6.28E+08				
Mass in product (kg)	0.39				
Manufacturing losses (kg)	0.23	0.29	0.23	0.23	0.23
Lifetime (years)	4				
Primary material input (kg)	0.62	0.42	0.36	0.15	0.02
Recyclability (kg)	-	0.26	0.26	0.47	0.47
Cascadability (kg)	-	-	-	-	0.11

The ERA budgets and the mass in product are the same for each scenario, because each jacket contains the same amounts of the same materials. The manufacturing losses for the "original" circular jacket (scenario *Circular*) are higher compared to the other scenarios. This is because at the point of data collection, the wear2wear production system was still in its prototyping phase, which results in higher manufacturing losses. Reflecting industrial scale production, the same amount of manufacturing losses are assumed in scenario *Circular R+*, *Circular R++* and *Circular optimal* as for the linear jacket. Note, that manufacturing losses summarize all losses along the entire supply chain (from fibre spinning to the manufacturing of the final product). The lifetime is assumed equal for all jackets. The primary material input is higher for the linear compared to the circular jacket. It decreases with a higher recyclability. Recyclability is divided into two categories: first, for material that is recycled at EoL of products and second, for manufacturing losses. In the scenario *Circular*, no recycling of manufacturing losses is assumed, as during the prototyping phase this was not the case. In scenario *Circular R+* and onwards, recycling of manufacturing losses is assumed with a recyclability of 95%, as these materials are pure and can be easily recycled. Materials are not cascaded (i.e. downcycled) except in scenario *Circular optimal,* where everything that is not recycled is assumed to be cascaded (except for glue & yarn). Additionally, the *Circular optimal* scenario assumes that all materials are made from secondary production (cascaded materials from higher quality, e.g. food-grade PET bottles).

We calculate in the next chapter the resource pressure for all materials contained in the jacket and neglect the contributions from all auxiliary materials (e.g. washing detergents) and energy (i.e. for production, use and recycling). ERA budgets are calculated following the grandfathering allocation approach as presented in (Desing et al., 2020). Environmental impact data for plastics are taken from ecoinvent v.3.6 (Wernet et al., 2016) and production amounts for 2015 from (Ryberg et al., 2019). ERA budgets and production amounts for metals are taken from (Desing et al., 2020).

Results and Discussion

Before the RRI can be calculated for all scenarios, the reduction targets must be set. We defined the reduction targets for our case studies based on a comparison between the resource budgets with today's production. This is a simplification and it would be best to define Science-based Targets (Pineda et al., 2015) for individual materials, industries, or countries to account for differences in the production processes, maturity of the technologies applied, etc. The reduction targets and the resulting RRI for each scenario are presented in table 2. Our current way of setting the reduction target would require all scenarios to decrease the resource pressure equally by a factor of 32.

Based on these input parameters the resource pressure of each product in the above-mentioned scenarios is calculated. Figure 3 compares them to each other. The resource pressure for the linear jacket is highest. The resource pressure of the *Circular* scenario is about half the linear one; while the reduction for the *Circular R+* scenario is 2.2 times, the *Circular R++* scenario 2.6 times and the *Circular optimal* scenario 35 times lower than the linear version. Comparing the circular and linear scenarios, the reduction of resource pressure (1/2) is somewhat higher than the reduction of greenhouse gas emissions (1/3) found in the original LCA by Braun et al. (2021). This is due to the above mentioned simplifications made for the analysis of the resource pressure.

Table 2. Resource pressure, reduction target and RRI for each scenario. Small changes in reduction targets are due to different resource pressures for each component in the various scenarios.

Scenario	Linear	Circular	Circular R+	Circular R++	Circular optimal
Resource pressure	5.56E-09	3.16E-09	2.66E-09	9.85E-10	8.22E-11
Reduction target	31 – 33				
RRI	0	0.03	0.04	0.05	1.1

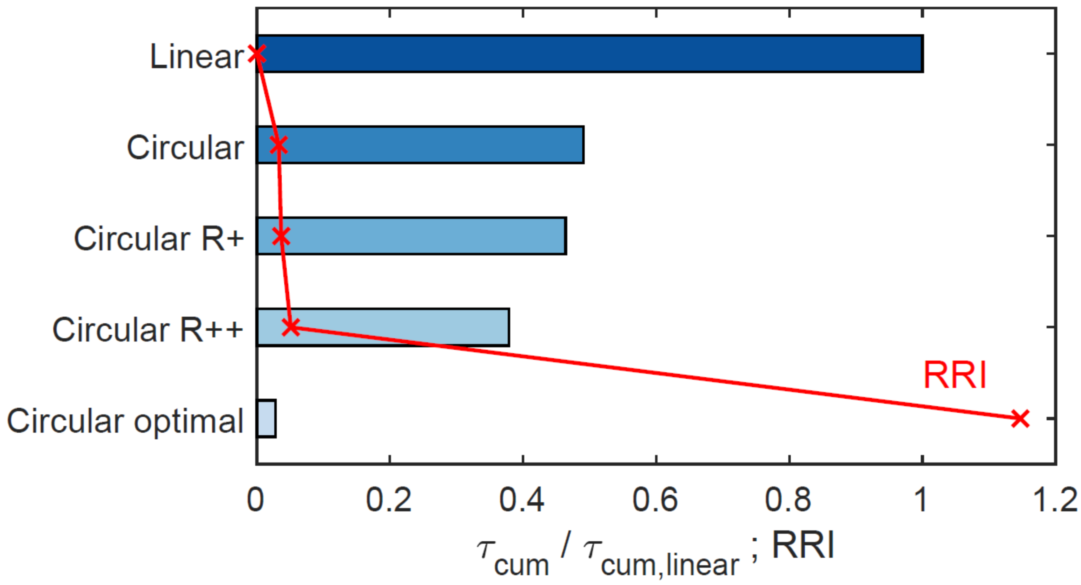

Figure 3. Resource pressure of each product in each scenario (blue bars) and RRI in each scenario (red line). The *Circular optimal* scenario reduces the resource pressure the most – 35 fold – and thus overachieves the reduction target (RRI>1).

The RRI indicator is for the first three scenarios far below one and only for the last scenario >1. That means that the circular textile in the *Circular optimal* scenario has sufficiently reduced its resource pressure to be considered absolute sustainable within planetary boundaries. All other scenarios fall short of the reduction target, therefore the circular strategies of *refuse* and *reduce* (Reike et al., 2017) decreasing the production amount would need to be applied in order to stay within planetary boundaries. The RRI increases with the improvements in the scenarios. As the RRI is proportional to the reduction factor, large initial reductions in the resource pressure τ_r

result in a low increase of the RRI (e.g. from *Linear* to *Circular* scenarios), while additional reductions in τ_r have a stronger effect on RRI (e.g. from *Circular R++* to *Circular optimal* scenarios). The reason is explained by a simple, fictive example: if τ_r is reduced by 50% - meaning that a product has decreased its environmental impacts from 1 to 0.5 (minus 0.5), the reduction factor is 2 – still far away from the reduction target of 32. If the product's impact can be further reduced in a second step from 0.5 to 0.05 (minus 0.45), the reduction factor now is already 20, even though the impact has only been reduced by 0.45 (compared to 0.5 in the first step). In other words, the RRI reacts most strongly for small improvements closer to the reduction target, whereas large improvements around the reference resource pressure value have a small effect on the RRI. This can be justified by the extra efforts that need to be taken for additional reduction on an already low level of resource pressure. For our textile product *Circular R++* scenario, many improvements have been assumed compared to the scenario *Circular* (reduction of manufacturing losses by 0.06 kg, decrease of primary material input by 0.27 kg, increase of recyclability by 0.21 kg) with a resulting RRI improvement of 0.02. In comparison, when moving from *Circular R++* to *Circular optimal* (primary material input decreases by 0.13 kg, cascadability increases by 0.11 kg) the RRI increases by 1.1. This sharp increase can be traced back to eliminating most primary material input and final losses in combination with the already implement circularity in the previous scenario, thus reducing the resource pressure significantly. In the *Circular optimal* scenario it is assumed that every material for the jacket is delivered by secondary production (e.g. cascaded from PET bottles) and that everything that is not recycled at the EoL will be cascaded. That means, no primary materials are required as an input to the product system (except for the glue & yarn) and everything leaving the system is recycled or cascaded. The combination of these measures leads to the drastic reduction in the resource pressure indicator (and thus increasing RRI) which is in line with the idea of the methodology itself (Desing et al., 2021a). Implementing the *Circular optimal* scenario in practice will require extraordinary efforts in comparison to the other scenarios, therefore also the "award" by the RRI is reasonable.

Moreover, there are certain limitations to the RRI for the moment. We show here the application of the RRI indicator on global reduction targets. This would require all industries to reduce their resource pressure equally. However, as some products and services are more necessary (e.g. food) than others (e.g. racing cars), it will be more relevant to define reduction targets on the level of product groups or industries. Furthermore, to determine the RRI indicator, we must compare the new design to a reference product. This choice is critical for the result as a reference product with high environmental impacts allows achieving the reduction target easier than a reference product with low impacts. We propose that the reference product should represent a global average product with global average values for the parameters in τ, because resource budgets (Desing et al., 2020) are based on global averages as well. For new products that fulfil similar functions as existing products, the average of existing products can be taken as a reference. However, for innovation creating a new demand, no reference exists and therefore RRI cannot be determined. Additionally, in the case that materials are substituted in the design in regard to the reference (e.g. use of paper instead of plastic for shopping bags), the RRI indicator is not fully consistent, as the reduction target is set by the materials of the new design. However, it still provides guidance on the question, if the design can reduce the resource pressure more effectively and thus ensure a higher utility of the sustainably available materials to society. All these limitations are potential areas for further development of the RRI.

Conclusions

In this contribution, we introduce the Resource Reduction Index (RRI) and show its application in a case study of a circular textile product. RRI measures to what extent the target for reducing primary resource consumption can be fulfilled with the circular redesign of a product or service. Reaching the target (i.e. getting a RRI≥1) through reducing the resource pressure in the activity under investigation by circularity measures means that the demand for this activity can be kept constant and still be environmentally sustainable. Not reaching the target (i.e. getting a RRI<1) means that either circular strategies of "refusing" and "reducing" the demand are necessary or that the production process of materials themselves must be redesigned (to cause less environmental impacts and thus increasing their resource budgets) to reach absolute environmental sustainability. RRI is indicating to the designer and business developers how much circular design improvements can help in reaching a sustainable level of resource consumption. However, absolute environmental sustainability cannot be analysed and guaranteed by a focus on a single activity alone, but must be assessed and respected on a global level at all times.

RRI contributes an easy-to-handle indicator for measuring absolute sustainability of products and services to the ongoing scientific effort. Before implementing the RRI, a discourse on "desirable" resource budgets is necessary (Desing et al., 2020). This includes to explore different allocation principles (Kulionis et al., 2021; Ryberg et al., 2020) and their effect on global resource budgets, while ensuring to provide basic needs for a decent life globally (Millward-Hopkins et al., 2020; Rao and Min, 2018). It further requires an international harmonization and agreement on resource budgets and their distribution among countries and industries (Pineda et al., 2015), so that resource reduction targets can be applied consistently to all products and services.

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204 CheckS – Check Sustainability as a new tool for identifying materiality following the SDGs

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CheckS helps to classify sustainability topics

One of the central requirements of sustainability reporting and of nearly all standards like GRI, DNK – the German Sustainablity Code or ISO 26000 is the definition of a materiality analysis. With the CheckS B.A.U.M. has developed a tool, which makes it easier to identify materiality following the framework of the 17 Sustainable Development Goals (SDGs). The material topics form an ideal basis for developing a solid sustainability strategy.

Keywords: Sustainable Development Goals, materiality analysis, sustainability strategy, Boston-I portfolio, matrix of results

SDGs: background and involvement of business

Defining materiality is difficult not only for SMEs. The question on which topics to concentrate within the core business as well as the consideration of the outside-in (relevant for the company) and the inside-out (relevant for sustainability) perspective and the stakeholders' views are inevitable steps to be taken towards a systematic materiality analysis. B.A.U.M has seen the chance to "translate" the complexity of sustainability to companies by relying on the internationally acknowledged SDGs. Therefore a catalogue of 188 "practical" questions, which makes the SDGs better understandable for companies as embedded in their day-to-day business was developed. So for example under "SDG 1 - no poverty" questions refer to salary structures of the company, fixed employment contracts, company pension scheme and opportunities for advancement etc.

The 17 Sustainable Development Goals (SDGs) were agreed upon in September 2015 by 193 countries at the United Nations General Assembly. They are addressed to everyone: politicians, civil society, business, science and each and every individual. At the political level, they provide the framework for policy action, and government delegations report annually to the UN High Level Political Forum on progress. The pivotal role of enterprises for a sustainable development, however, was underlined from the beginning. "The private sector is an indispensable partner for achieving the Sustainable Development Goals. Businesses can contribute as part of their core business. We therefore call on companies around the world to measure the impact of their actions, set ambitious targets and communicate their progress transparently." Ban Ki-moon, former Secretary-General of the United Nations.

An interesting aspect was given by Prof. Dr. Johan Rockström, Head of the Potsdam Institute for Climate Impact Research, shown in figure 1 also called "wedding cake", in which the ecological SDGs form the basis and all other SDGs build on them (Diering, 2020). Whereas common concepts of sustainability consider all three dimensions equally important emphasized e.g. by the geometry of the sustainability triangle, Rockström's perspective is about the priority of planetary boundaries. "There are different opinions on the weighting of the dimensions. In addition, there are often conflicts of objectives, i.e. two objectives are difficult to reconcile or are even mutually exclusive. In such cases, it is necessary to weigh things or set priorities" (Kropp, 2019).

We will later describe in the evaluation of 43 CheckS enterprises from different branches and sizes whether in their results Rockström's theory is reflected.

Figure 1. Rockström et al 2015.

CheckS workshop method and design

In a workshop with the top management the relevance of each of the 17 goals is discussed along 188 questions including the perspective of stakeholders and evaluated together by considering the experts' view from B.A.U.M. The results are recorded in an adapted Boston-I-portfolio. The workshop design is set up rather "haptic", as the 17 SDG cubes can be moved by the participants to and fro on the table and along the portfolio. At the end of the day company representatives get an excellent overview which of the goals are material and which ones are relevant for only one part (enterprise or stakeholder) or not relevant.

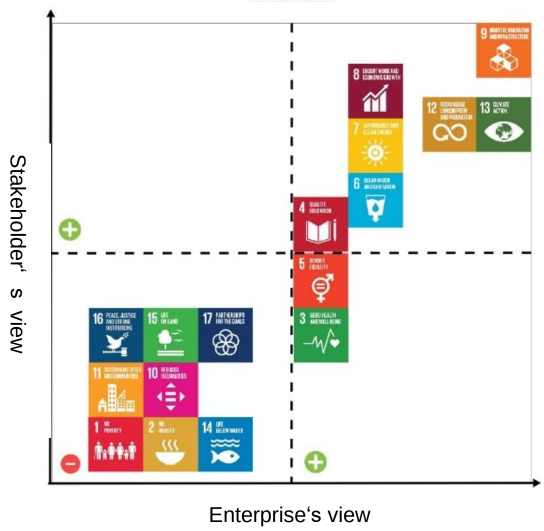

Figure 2. I-Boston portfolio with 7 material topics.

In the same process step weather symbols are used to assess the performance of the company in each of the material and relevant goals – from sunshine to tempest a four-point scale is used. As a warm-up the workshop starts with a SWOT-analysis regarding sustainability which perfectly supports risk definition, another important requirement of sustainability standards.

The effects and results of the CheckS are manifold: companies get a reliable materiality analysis with a list of strategical directions of impact with first goal derivations as a basis of a sustainability strategy. An assignment of sustainable activities and projects as well as the assessment of the existing sustainability performance in a "matrix of results" comprising a table of implemented and planned measures are built up like it is shown in Figure 4. CheckS also is an effective awareness rising tool, a communication model as well as a good starting point for a more sustainable business model.

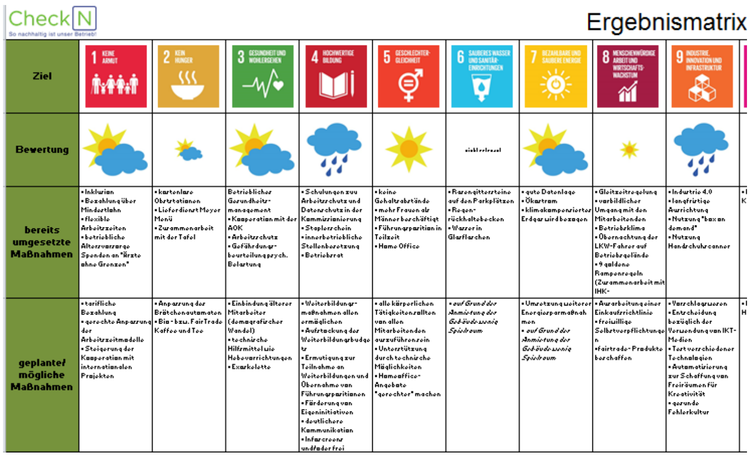

Figure 3. matrix of results.

CheckS develops sustainability into strategy

While carrying out numerous CheckS workshops with different companies B.A.U.M. has developed a modified type of CheckS because especially big enterprises want to focus stronger on the strategic direction offered by the CheckS. So the process of discussion why a goal has been rated material and what it means in the strategic context (what does this SDG mean for us and what does it not mean?) is more important than summing up implemented and planned projects shown in fig.3. To underline the strategic dimension of the CheckS, B.A.U.M. has matched the SDGs with the megatrend-map (zukunftsinstitut, 2021) in order to develop a future oriented company strategy which perfectly integrates sustainability and the "deep currents of change" represented by the megatrends.

Figure 5. matching SDGs with megatrends.

Evaluation of CheckS: materiality and performance

Altogether 43 companies have to date carried out CheckS workshops together with B.A.U.M starting in March 2019. For each of them a report was written, a Boston I-portfolio was drawn and analysed, recommendations for follow-ups were given. Furthermore, a matrix of results assessing performance in each material or relevant goal was built up. Additionally, the participants have obtained a certificate.

The evaluation of all 43 CheckS has shown, that each of the 17 goals was covered by at least one company, the "top material SDG" being no. 4 "quality education", followed by SDG 9 "industry, innovation and infrastructure" and followed ex aequo by SDG 13 "climate action" and SDG 3 "good health and wellbeing" as shown in table 1.

Table 1. Material SDGs by numbers.

Overview - material SDGs - distribution - all CheckS companies to date (n = 43)																	
	SDG 1	SDG 2	**SDG 3**	**SDG 4**	SDG 5	SDG 6	SDG 7	SDG 8	**SDG 9**	SDG 10	SDG 11	SDG 12	**SDG 13**	SDG 14	SDG 15	SDG 16	SDG 17
Material	24	8	**30**	**39**	16	13	26	24	**32**	10	15	27	**30**	2	10	12	17

Looking at the overall results which comprise also the relevant goals, i.e. the ones important for the company or for the stakeholders as well as the performance in each goal considering the weather symbols, the following figure 6 was drawn.

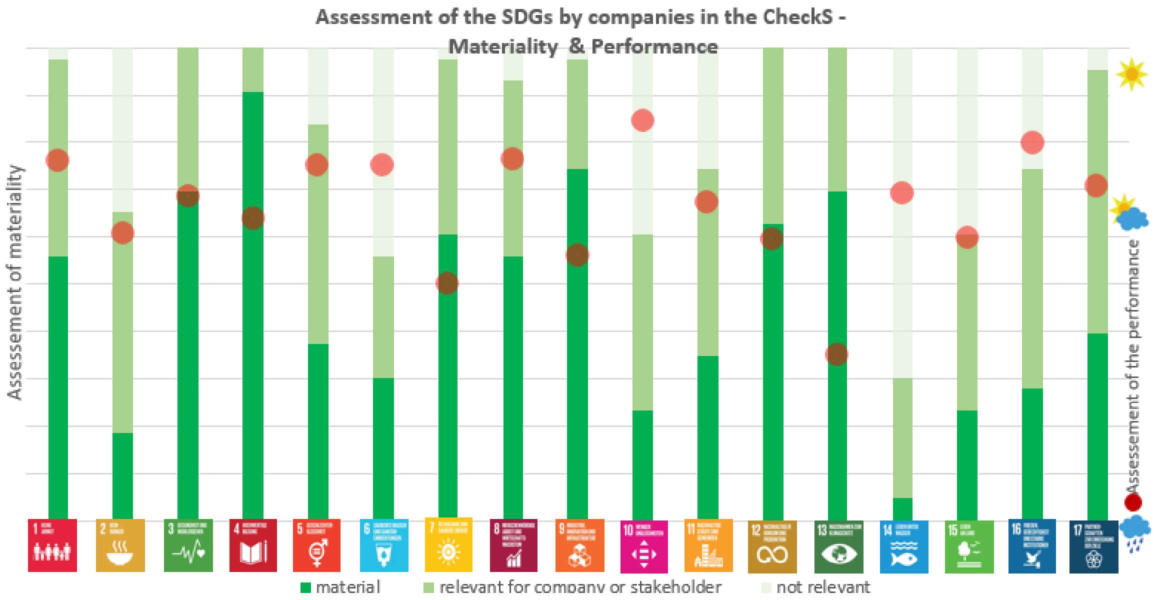

figure 6. overall evaluation of SDGs by 43 companies.

When we come back to Rockström and the necessary basis represented by biosphere and planet boundaries with reference to the SDGs no. 6, 13, 14 and 15 our evaluation in table 1 shows, that goal no. 13 "climate action" is considered by 30 out of 43 of the companies as material and goal no. 6 by 13 out of 43, 15 by 10 out of 43, whereas goal no.14 seems of little relevance to the companies. Overall higher rated by companies are the social SDGs like 3, 4 and 1.

We assume that more enterprises already promoted environmental topics while the social dimension of sustainability has been under-represented to date. As 74% percent of the CheckS companies are ECOPROFIT® companies in possession of an environmental management certificate they are "ecology leaders" who assess their performance in ecological goals rather high. The major role of SDG 9 points out that innovation is understood as a driver of sustainability by a big number of enterprises (30 out of 43).

The evaluation considers also differences between ECOPROFIT® companies and others and between producing and non- producing enterprises with more interesting results.

Conclusions

The instrument of CheckS is well accepted by enterprises of different branches, sizes and with or without previous sustainability experience offering both an overview and introduction in sustainable practices as well as concentration and in depth dealing with this topic. Materiality analysis, assessment of the status quo, a summary of implemented and planned measures as well as a good basis for building up a sustainability strategy are the manifold applications of CheckS. The SDGs as future oriented agenda 2030 propagating the 5 Ps - **P**lanet, **P**eople, **P**erformance, **P**rosperity and **P**eace - represent a good framework not only for countries and regions but - if translated to business and it's requirements – also for companies and institutions.

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262 Impacts of the level of details, shadowing and thermal zoning on urban building energy modelling (UBEM) on a district scale

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Abstract

In order to address the building sector energy efficiency improvement at the urban scale, a new Urban Building Energy Modelling (UBEM) generation is described, following a bottom-up physical model-based workflow. It is built over a shoebox paradigm to address all kind of buildings with as much data as possible, still complying with high samples of simulation to run. As a first step before calibration and using the UBEM tool for large scale energy conservation measure's impact, this study proposes to address three basic assumptions of the modelling process. The Level of Detail on the geometry side of each building is studied through the impact on the energy heat needs for LOD 1.2 and LOD 1.3, the thermal zoning resolution is compared from coarse assumption of single zone for heated and non-heated volumes up to core and perimeter zones for each floor's building. Finally, the impact of surrounding shadowing environment is computed. Two districts are considered for the three aforementioned points, both in Stockholm County, Sweden. Stockholm typical year weather file is used from IWEC. Analyses are done through the energy needs for heating only. Results show that the scale of analyses makes the differences. At the building scale, all three elements have important impact whereas at the district scale, quite few differences are obtained depending on the thermal zoning resolution or the Level Of Details on the geometry of each building. The surrounding shadowing environment is still important

as up to 10% of difference is computed at the district level for on eof the two studied areas.

Keywords: Urban Building Energy Model, UBEM, Level Of Detail, Shadowing, Thermal zoning.

Introduction

The building sector is responsible for one-third of total final energy use and greenhouse gas emissions (IEA, 2016). Hence, it is one of the key areas to be addressed in order to meet 1.5°C scenario. There is a wide range of interventions available, including decarbonisation of supply, renovation of the existing building stock, low-energy requirements to new buildings. However, the current pace of energy transition for buildings is much lower than what is required to meet national and local climate commitments. In order to address the challenge of making the building sector improve its overall efficiency, new paradigm and tools are needed. There is a strong need for integrated models and tools that would allow assessing the benefits and drawbacks of each urban energy intervention in a holistic way to all involved stakeholders. Urban Building Energy Modelling (UBEM) has emerged recently as a bottom-up approach to city-scale building energy modelling (Reinhart and Cerezo Davila, 2016). A number of attempts to address the issue of scale for UBEMs have been done (Ferrando et al., 2020), including different approaches to align the models with measured data at the urban scale through automated calibration (Sokol et al., 2017; Wang et al., 2020). It is different from a simple aggregation of building energy models (BEM) as it imposes automated creation of simulations involving larger amounts of structured data and simplified representation of individual buildings. In the UBEM field, physicssbased, multizone dynamic models, are still required to evaluate detailed urban design scenarios as well as urban scale building rhetoric analyses, even though such models could be seen as too detailed for such scale of analyses, (Reinhart and Cerezo Davila, 2016). However, multizone dynamic thermal simulation can be time-consuming when too high thermal zoning resolution is needed, besides the amount of available data might be a bottleneck for introducing higher spatial resolution in the energy modelling.

Therefore, a balance between required data and model accuracy is a key issue for UBEMs. Many studies utilize archetypes (representative building for a group of similar buildings) to diminish the number of simulations needed on a city scale (Cerezo et al., 2017, 2015; Pasichnyi et al., 2019).

However, quite a few studies investigated the basic assumptions for the mandatory UBEM inputs. Particularly, three aspects are regularly highlighted to have a crucial impact on the quality and applicability of the derived UBEMs, namely a) level of detail (LOD) of buildings' geometry (Biljecki et al., 2016), b) shadowing effect of the surrounding environment (Nikoofard et al., 2011) and lastly, c) the thermal zoning (Chen and Hong, 2018). This study aims to explore the impact of these three factors on the accuracy of district-level UBEMs based on preliminary learnings from modelling two districts in Stockholm, Sweden.

Regarding previous studies, the main novelties given from this new generation UBEM come from 1) the methods used to catch the surroundings shadowing environment for each building and 2) the ability of the workflow to automatically generated Functional Mock-up Unit (FMU) from each building in order to address, at a district scale operation issues on either electrical or heating networks. Co-simulation is mandatory in such cases and FMU is one of the easiest ways to make model communicate at each time step along the simulation period.

Three core steps could be distinguished in the overall process: 1) the data gathering process, 2) the 3D geometry construction, including external shadowing surfaces, its conversion in dedicated file format (GeoJSON) and 3) the energy modelling parts which has to comply with all kinds of building and data embedded in the main input GeoJSON format file. One file is computed for an entire urban area to be modelled.

In the following section, the new generation UBEM workflow is presented in detail, trying to be as close as possible to a shoebox paradigm, to comply with all kinds of building and equipment, followed by the two studied areas to address the three aspects mentioned above. The gathering data process, which is a key part of the UBEM workflow, is presented within these two areas to give insights of different sources used to gather the required data for the energy modelling parts.

UBEM Workflow

Bottom-up physical based UBEM workflow is about how can input data form large open-source database be embedded in a general and common framework to model all buildings in a given urban area. At such scale, the energy modelling of buildings can be subdivided into two levels: the building level and the zone level. The first one requires at least a geometry description, surrounding environment, thermal zoning, and some elements that enable to represent the building envelope performance. The related inputs could be seen as the static ones for the UBEM workflow (like envelope materials, number of floors, surrounding environment, for example). The zone level requires occupancy related inputs and indoor elements that have dynamic impact on the energy needs. In a same way, the related inputs could be seen as the dynamic ones for the UBEM workflow. Considering an entire building, equipment units for heat or cool production are allocated at the zone level, as several types can be present in the same building. Following the same paradigm, envelope leaks are assigned at the zone level as these have time dependent impacts and can be differently addressed depending on the type of zone (heated or non-heated).

The current UBEM workflow is compatible with either building per building simulation approach or archetype from building segmentation approach. In both approaches, a physics-based model needs to be defined with as many elements as possible to represent either the building or the archetype (representation of a sample of buildings). This current UBEM workflow is based on Python 3 and EnergyPlus respectively for the structuring process and the thermal core engine. All processes (input ASCII files and dynamic thermal simulations) take benefit of multiprocessing capacities. The entire process is freely available in https://github.com/KTH-UrbanT/MUBES_UBEM. The UBEM workflow is presented in the following section respectively to the two aforementioned levels – building and thermal zone.

Building Level

This level is about geometry definition, envelope characteristics, thermal zoning and surrounding environment. Each are presented separately in the following sections.

Geometry definition

Buildings are defined though polygons for each external surfaces, these are gathered from photogrammetric point cloud approach. Some filtering processes are done at this stage and two methods can be designed for either making LOD1.2 or 1.3 in the 3D building model considering the classification proposed in (Biljecki et al., 2016).

What is the main pros and cons of making either LOD1.2 and 1.3 (the approaches that we called 2D and 2.5D). it has to be linked to the results section where LOD1.3 can bring valuable aspect on computing the energy needs (shape factor can be strongly affected)

In the results section, the impact of dividing one building into several blocs (LOD1.2 to LOD1.3) is quantified for one specific district.

Envelope characteristics

Building envelope is simplified into two components for the two main thermal effects that are insulation or inertia, respectively. All constructions are supposed to be composed of one or two layers maximum, thus, giving the ability of simulating either lightweight materials or heavy ones and with either external or internal insulation. This simplification is compatible with the UBEM levels as there is no need to get into several layers with small effect. The counter part is that the input database should consider equivalent material for typical constructions methods depending on the year of construction or specific renovation action for each building. The equivalent material definition shall follow the resistance/capacity paradigm from similarities with electricity, for layer in series as 1D conduction is still considered. The layers are thus composed by one single material for which the three main thermal properties, aside from the thickness, are required (density (kg/m3), the thermal conductivity (W/K/m) and the calorific capacity (J/K(kg)). Surface's radiative properties can also be defined at this stage if specific effect is to be considered like special paintings or metallic surface layers. Windows are part of the envelop. The input of windows to wall ratio (wwr) is used to automatically compute the height of windows. Window spreads from both sides, on each external facade.

Thermal zoning

Several options of thermal zoning are proposed form the single zone for heated and non-heated volumes up to the multizone option on each floor, splitting the area into a core zone and as much as perimeter zones as required. In case of single zones for heated and non-heated volumes, the inputs are corrected to still consider the entire heated floor areas using floor-multiplier factor. An automatic algorithm has been developed to ensure the multizone definition. Depending on the perimeter depth, perimeter zone definition is automatically realized starting from each edge delimiting the core zone. A threshold on the resulting edge length, defined by default as half of the perimeter depth, is integrated to the core zone perimeter. This enables to avoid having to too narrowed zone angles or too small zones. Then, triangle zones (having a single vertex on the external polygon) is not allowed except for the last perimeter zone definition, closing the loop over the core's edges. Thus, perimeter zones with more than one edge in common with the core zone are allowed. The perimeter depth starts at 3m by default and is reduced by half if some issue is encountered in the process. Figure 1 present the thermal zoning option and its relation to the perimeter depth on two types of building. The process could be optimized further as non-convex zones are currently allowed (all external non-convex surfaces are still split into convex ones for the sake of shortwave multireflection, see Surrounding environment below). Nevertheless, non-convex zones are mandatory only if internal shortwave multireflection is requested, which are out of UBEM field of interest. Besides and still linked to the building scale, no internal architecture is available in any available database. The core and perimeter zone would be needed only to better catch discrepancies between southern and northern oriented surfaces. In such multizone definition, partition walls shall be defined but without adding any inertia nor limitation in the heat transfers at the floor scale. The current workflow has been developed using EnergyPus 9.1 for which the common definition of partition airwall is done through a thin highly conductive material. A new object is introduced in version 9.2.0 and will be implemented in the following release of the UBEM workflow. Nevertheless, the results with the partition assumption used show very close results for the different thermal zoning option as shown later in the results section.

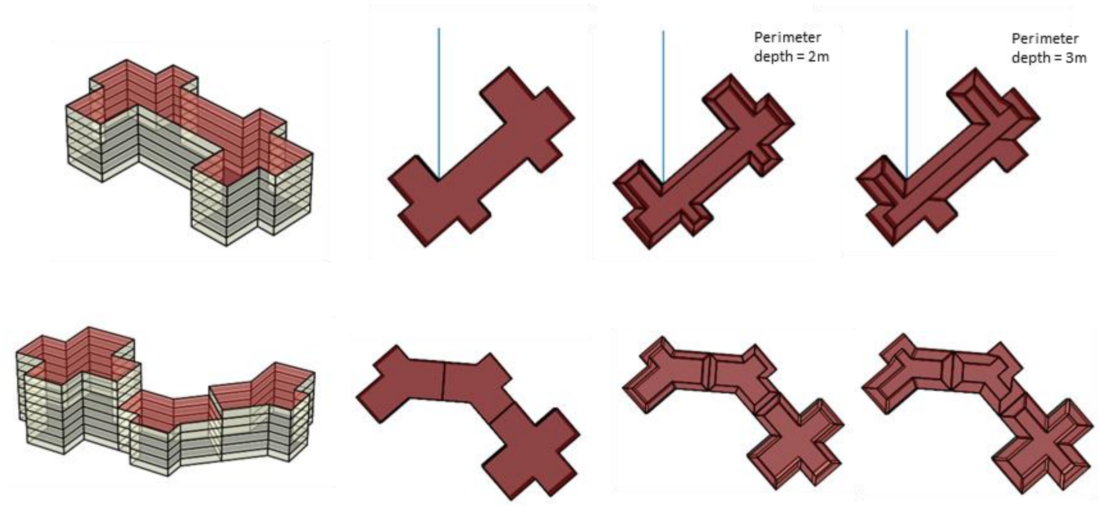


Figure 1. Thermal zoning, single zone and core perimeter zone with 2m and 3m of perimeter's depth. Example for LOD1.2 case (top) and LOD1.3 case (bottom)

Surrounding environment

Even though each building is modelled separately, the surrounding environment is considered through its shadowing impact on each building. The shadowing is automatically dealt in EnergyPlus for external surfaces defined as shadowing elements. External surfaces can receive and reflect shortwave radiation. Long wave radiation is not taken into account as it should require computing the view factors between each surface of the building and the surrounding ones before simulation and then to use an iterative approach to catch the heat fluxes between surfaces at each time step. Some proposal of iterative method have been done by (Luo et al., 2020) and maximum effect of 3.6% of decreasing effect on the heat needs is observed upon different locations in US. In the current UBEM workflow, all external surfaces of each building are considered one after the other and all visible surfaces belonging to other building are reported. Then, depending on a distance's threshold form the building's centroid, all surfaces closer than the limit are kept and modelled as shadowing surfaces in EnergyPlus. Figure 2 illustrate for one random building the effect of the distance threshold on the modelling process.

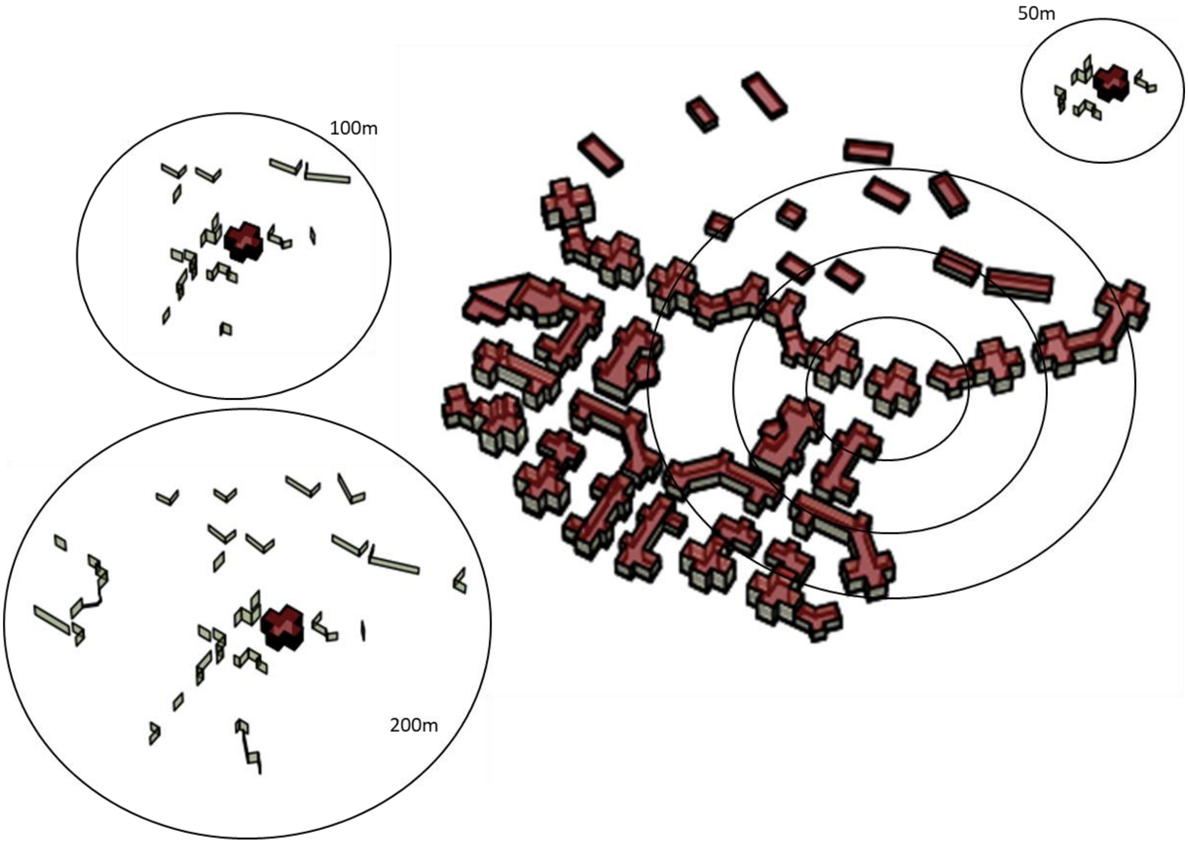


Figure 2. Shadowing effect of the environment based on a distance threshold (50, 100 and 200m around a random building).

At a district scale, the effect of surrounding cannot be estimated for each building thus some systematic threshold should be considered for all buildings. Parametric simulations for two different districts are reported in the results section.

The Zone Level

This level is about all local elements that has impact in the energy balance of each zone, at each time step. Thus, even if some element could be linked to the building, like envelope leakage, these are included here as depending on the over whole external envelope areas of each zone. Figure 3 represents the different required inputs at the zone level. Each of these are presented separately in the following sections.

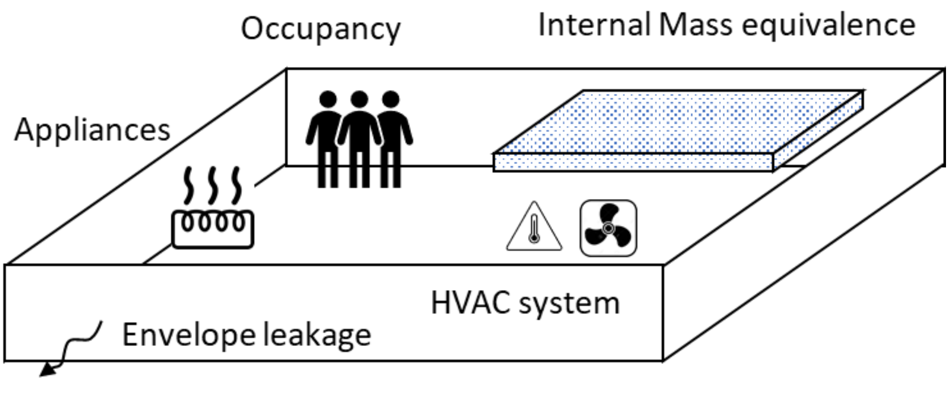


Figure 3. Schematic inputs representation at the zone level

Internal Mass equivalence

Internal mass is the effect of indoor furniture and partition walls on the indoor temperature dynamics. These are of greater importance in UBEM assumptions as internal architecture is not modelled. All floors are fully open spaces in which area-based elements are to be defined. Internal mass is defined through a material with classic thermal properties, a weight per square meter and a surface of exchange with the current zone. The default values used in the current UBEM takes 40kg/m2 of an equivalent material with thermal conductivity of 0.3W/K/m, density of 600kg/m3 and specific heat of 1400 J/kg/K. The surface is automatically computed to be twice the specific area taken form the volume divided by the thickness of the material (taken at 0.1m by default). This definition uses the floor-multiplier in case of single zones for heated and non-heated zones.

Envelope leakage

Envelope leakage is an important parameter, that is influenced by thermal gradient and the zone's height (hydrostatic pressure gradient, thus considering stack effect). EnergyPlus infiltration model with flow coefficient enables to consider several elements as influenceable factors, such as stairwells, urban area density and building's height. In the current process, the equivalent value given in l/m2 at 50Pa is converted using a value of 0.667 on pressure exponent value in the power law. The influenceable parameter are given in the EPC's templates in Sweden.

For non-heated zones, being generally below ground level, an air change rate is defined per volume as no outside boundaries does not refer to external environment (but contact with ground temperature).

HVAC System

The Heating, Ventilation and Air Conditioning (HVAC) system is limited in the UBEM workflow to the used energy. This means that the energy carriers and their production and distribution efficiencies are not taken into account in the zone level, but rather in the post-treatment and calibration process as described further. On the opposite, the different ventilation systems, being either fully exhaust or balanced with heat recovery, are taken into account through the amount of incoming fresh air as these are direct sinks in the energy balance. Thus, the equivalent *shoebox* HVAC model is considered as an Ideal Load Air System that computes, for each zone, the needed energy to matches the internal temperature set point. Figure 4 presents a schematic view of such system. If heat recovery system is to be modelled it will raise the temperature of the incoming fresh air. Thresholds, if available, either in the supplied air temperature or compensation mass flow rates of the overall supplied power, can be given as inputs to better catch the heat needs of each zone. The heating and cooling supply will correspond to the external needed energy, at each time step, for this zone to comply with its temperature set point. The temperature set point can be defined as constant or can follows fixed schedules with day and night times or can be defined through external files on an hourly basis. In the current UBEM workflow, each zone has an HVAC system. The different inputs for the *shoebox* HVAC model are gathered from the database. Heat recovery is only considered through sensible heat exchange.

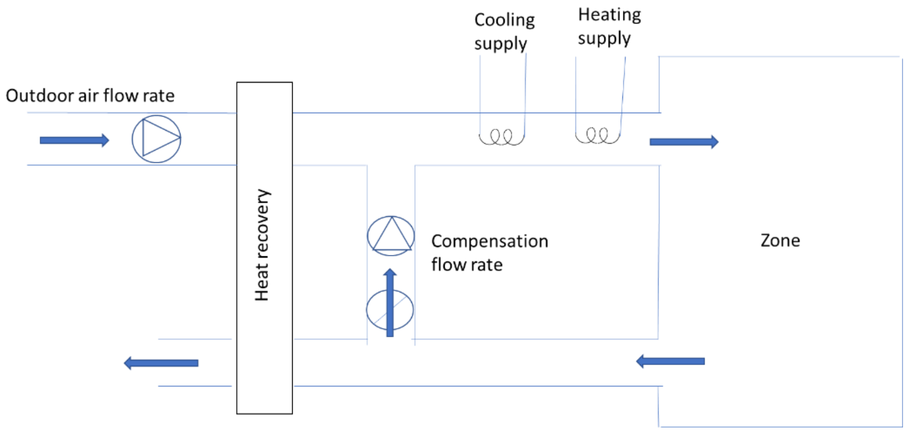


Figure 4. Schematic view of the Ideal Load Air system

Occupancy

In the current UBEM workflow and as domestic hot water needs are considered in the post processing stage (presented in a dedicated section further), occupancy rate usage is limited to non-residential types of buildings. All but residential type of buildings generally has extra air change rates based on the number of occupant and in these, the heat released by occupant (taken constantly at 70W per occupant in the current UBEM) raises above levels that are no more negligible. In residential type of building, occupancy's impact can be embedded in the appliance's energy needs presented further. The number of occupants is based on occupant density defined for the different occupancy types (except residential). Two options are available using either the maximum density or an hourly random beta distribution-based number of occupants. Time schedules are also implemented for all but residential occupancy types. Opening hours are defined as inputs to compute the number of occupants.

Appliances

The energy needs and thus released by internal appliances is of great importance to compute the building heating and cooling needs. On a yearly basis, these can be defined as internal loads in W/m2 but as energy needs are dynamically computed, there is a need to define a higher resolution for internal loads. Several options are available to define either constant needs (the loads will remain the same for each time step for the entire simulation period), or seasonal based needs with variable slope possibilities. The appliances energy consumption is modelled as fully electric equipment and thus all the loads are injected as internal heat gains in the different zones. Figure 5 presents the different profiles computed form the year basis consumption. Depending on the input database, yearly electric consumption can be gathered. In such case, internal load profiles are computed with respect to this yearly data.

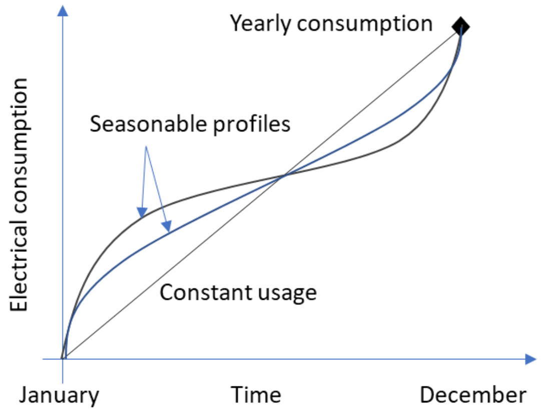


Figure 5. Internal appliances profiles

Domestic Hot water

The current UBEM workflow assumes no strong coupling between the domestic hot water (DHW) network and the building energy balance. Thus, the requirement for modelling DHW is given by potential available measured data, that would embed DHW needs with heating needs, for calibration. In such case, the related energy needs for DHW are modelled through a simple water use equipment. The hot water temperature supply is fixed to 55degC (can be define in the database), incoming cold district water temperature is still given as a time series input (or taken constantly) as well as the water taps resulting in the energy needs for DHW. As DHW might me considered only for the calibration stage, the FMU's option (see co-simulation environment section further) of the current UBEM could be worth of interest to compute the water taps the diminish the discrepancies between measured and simulated energy needs in non-heating periods.

Calibration

Even if UBEM is not a simple aggregation of BEM, the calibration process remains mandatory. The calibration process that bests fit with UBEM constraints might be the probabilistic calibration. Indeed, even though simplifications are realized compared to BEM, many inputs are still needed and with higher uncertainties than for BEM. The UBEM process needs to address all the different buildings with the same process. Even though missing inputs could be more or less the same for a full sample of building, the calibrated inputs will definitely be different. Among the probabilistic calibration, the Bayesian iterative process is promising as it can automatically adjust the exploring ranges of missing inputs to each building.

The UBEM workflow described above is fully compatible with probabilistic calibration. It offers the option of making numerous of simulation with Latin Hypercube Sampling (LHS) of any input parameter for the sake of either sensitivity analyses or calibration process. Such a calibration method has been applied for Hammarby district with hourly measured data. Nine parameters from both static and dynamics inputs were considered.

Co-simulation environment

The current UBEM workflow is aimed to be used either for making district-city energy analyses of current state, retrofitting actions, generating sample of simulations for the sake of calibration but also to analyses, at a district level option, different operation strategies on either the electric or heating network. In order to make co-simulation, functional moke-up unit (FMU) are to be built and used in a dedicated environment. The FMU toolkit for Energy plus is embedded in the UBEM workflow and enables to automatically create FMUs of each building in the input file. Of course, as specific inputs / outputs will have to be defined in the process that matches with the controlled parameters ones want in the co-simulation. Two examples of co-simulation process are proposed in the UBEM workflow using the indoor temperature set point and the DHW taps as inputs at each time step. The environment used to make the co-simulation is FMI++.

In the following sections, parametric simulations, using the above described UBEM workflow, are presented to highlight the impact of the level of detail in the geometry process, the thermal zoning impact and the shadowing impact of the surrounding environment. Two different districts in Stockholm County are taken for the sake of illustration. A first sections section presents the two districts, followed by the database construction process to gather as much element as available for these two districts. The results from the simulation are presented in a last section.

Case study

Two different districts of considered in the following to make the parametric simulation. Both districts are mainly residential but most of the building include some small percentage of non-residential occupancy type. After a brief description of the two districts, the data gathering is presented. Results from parametric simulation are finally presented.

District’s presentation

Minneberg district and a part of Hammarby Sjöstad are composed of 33 and 45 buildings, respectively. Figure 6 Presents the two districts used as studied cases with current the UBEM workflow. Only Minneberg is used for the impact of level of details while both are used for the thermal zoning impact and the surrounding shadowing impact on the energy heating needs (EHN). For both districts, the same database workflow is used to gather the available information needed to build the cases in the UBEM workflow.

After presenting the data gathering process, the results are presented and discussed.

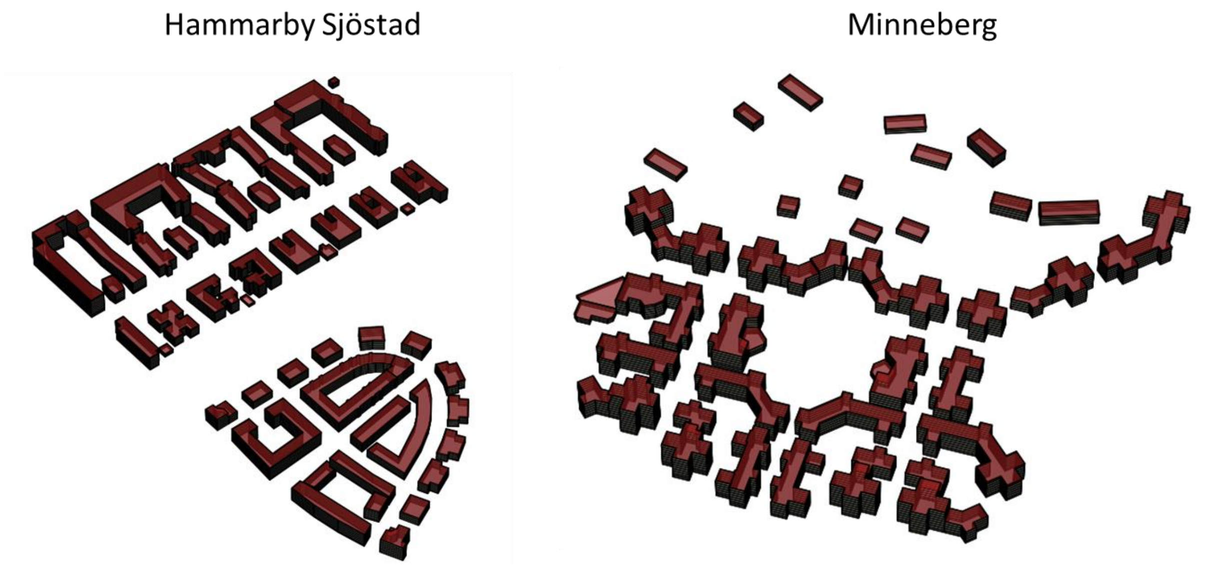


Figure 6. Districts considered in the parametric simulations.

Data Gathering process

As said earlier, data scarcity remains the most difficult part of any UBEM tools. The most related database to UBEM remains the energy performance certificate. Being mandatory since a few decades now, the amount of available data continuously growth among years. Different levels of information are available in EPCs for different countries. In Sweden, EPCs are required every 10 years with one full year of measured data on the energy consumption for the different needs (heating, cooling, domestic hot water, electricity, subdivided into collective and private areas). These are generally obtained by installed meters for the purpose of the EPCs while some other could be done using the yearly purchased energy through invoices analyses from the energy suppliers. Thus, EPCs include measured energy consumption and some details on the geometry, the occupancy type, the installed equipment and the energy carriers. A counterpart is small renovation either in the building envelope, or its equipment might create discrepancies between the available information and the real situation of each building.

This main database, from EPCs is cross checked and enriched by other sources. Building and property cadastres, 3D city models and national climate database are also considered in the overall input database for the current UBEM workflow.

The urban area of interest, including geometry and all gathered properties, are compiled into GoeJson files. Python is used for the building process of the input files and launch Energy Plus for each building defined in the GeoJson file. Both input file and simulation processes are using the multiprocessing capacities of python.

Level of detail impact

In this section, Minneberg district is particularly used to illustrate the impact of level of detail in the building geometry. The climate of Stokholm, Arlanda airport is used from IWEC typical year database form ASHARE. Level of detail LOD 1.2 and LOD 1.3 are considered. These two require different point cloud approaches and cleanings before being able to be integrated in the UBEM workflow. Figure 7 presents two examples to illustrate the differences between LOD1.2 and LOD 1.3. Even though EHN are generally divided by the heated area, the external envelope's surface and the solar gains are different in the two assumptions leading to different heat gains and losses.

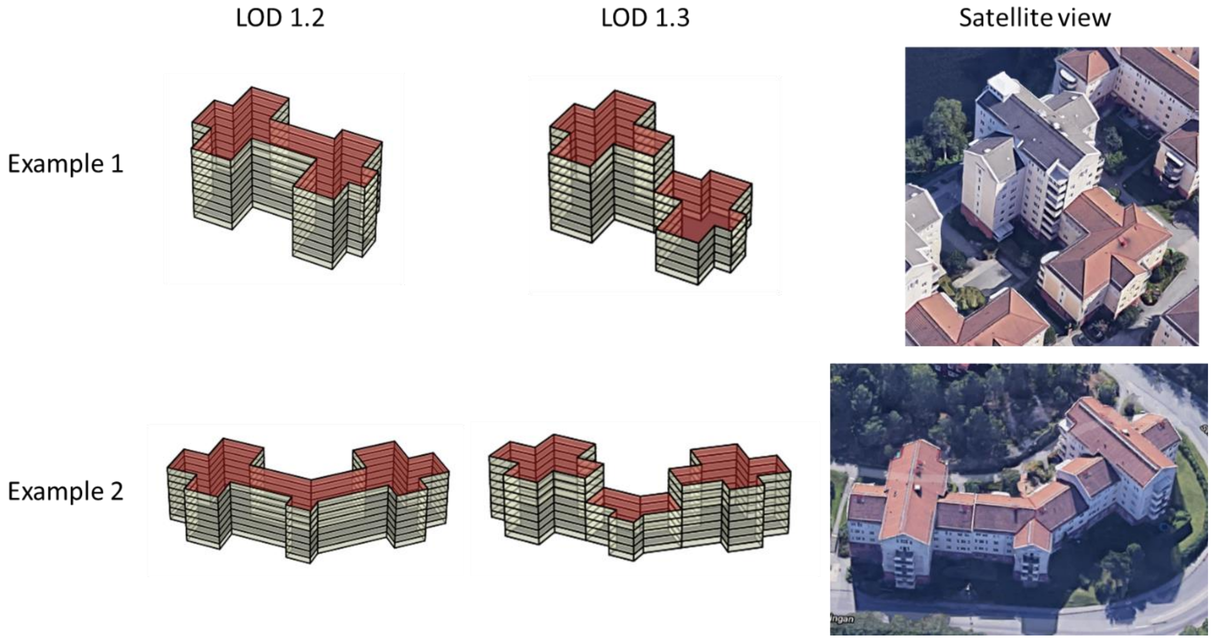


Figure 7. Examples of LOD 1.2 and LOD 1.3 models compared to satellite views.

Figure 8 presents the relative error between LOD1.2 and LOD 1.3 for Minneberg district (LOD 1.2 being the reference). Only 23 buildings are present in the comparison as some were not available in the LOD1.2 format. Nevertheless, results show that even though the majority of discrepancies remain below 4%, some specific buildings show up to 10% higher heat needs with LOD1.3 than for LOD1.2 (buildings 8 and 9 in Figure 8). The two highest differences are observed with around 20% higher shape factor for the same buildings (**Figure 9**). Thus, at the UBEM scale, keeping LOD1.2 could lead to 10% extra discrepancies in the EHN of some buildings. But the on the overall district, the difference remains below 1% (0.76%). Thus, the level of details might be irrelevant at the UBEM scale. But the extra effort catching LOD1.3 is worth of interest in the context of computing impact of ECMs or in the calibration steps as these 10% of extra EHN should have been compensate by wrong calibrated inputs.

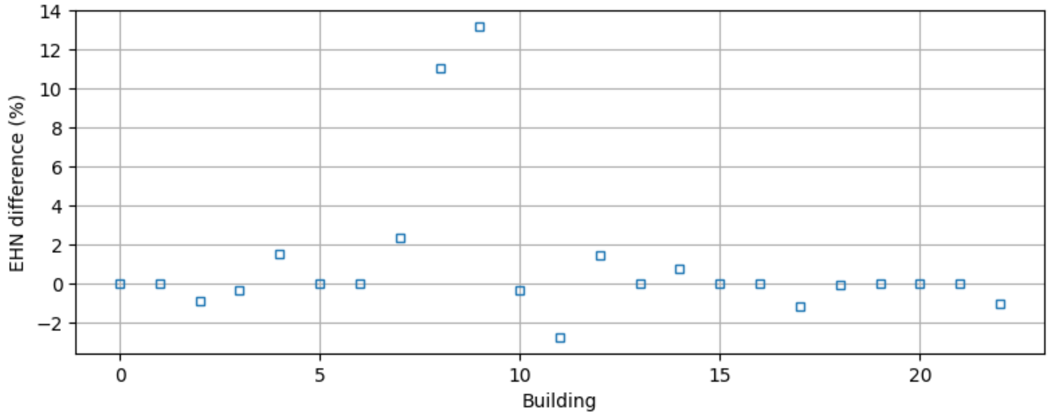


Figure 8. EHN differences between LOD 1.2 and LOD1.3 taking LOD 1.2 as a reference.

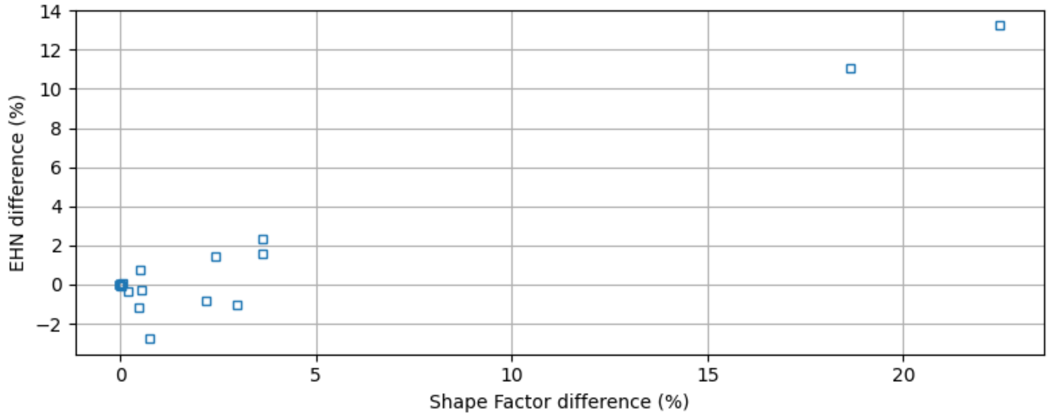


Figure 9. EHN differences between versus shape factor difference of LOD 1.3 versus LOD 1.2 taking LOD 1.2 as a reference.

Thermal zoning impact

This section present, for the two districts described above, the impact of different thermal zoning resolutions. For illustration, Figure 10 present the different options available in the UBEM workflow on a simple building.

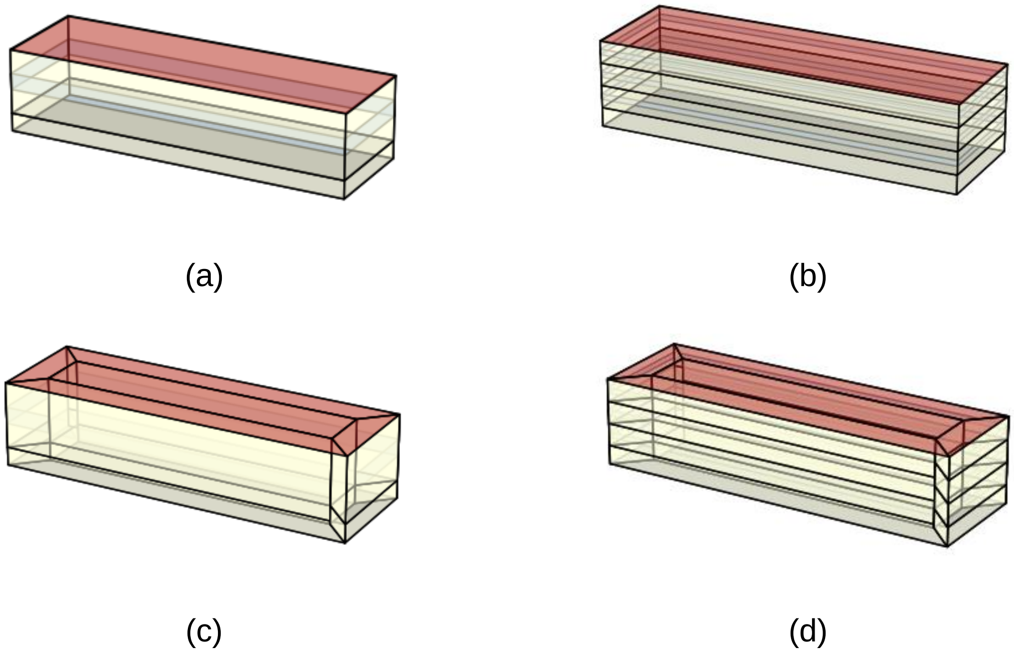


Figure 10. Four thermal zoning option, applied on a simple building with 3 storey and 1 floor basement: (a) Single zone for heated and non-heated volumes (b) single zone per floor (c) Core and perimeter zones on (a) configuration and (d) core and perimeter zones on (b) configuration.

The same paradigm of floor multiplier is applied as in (Chen and Hong, 2018) for option (a) and (c). The core and perimeter zone definition follows the algorithm presented above. All element but the thermal zoning remains the same among the different simulations presented below. Impact of thermal zoning is illustrated regarding the EHN.

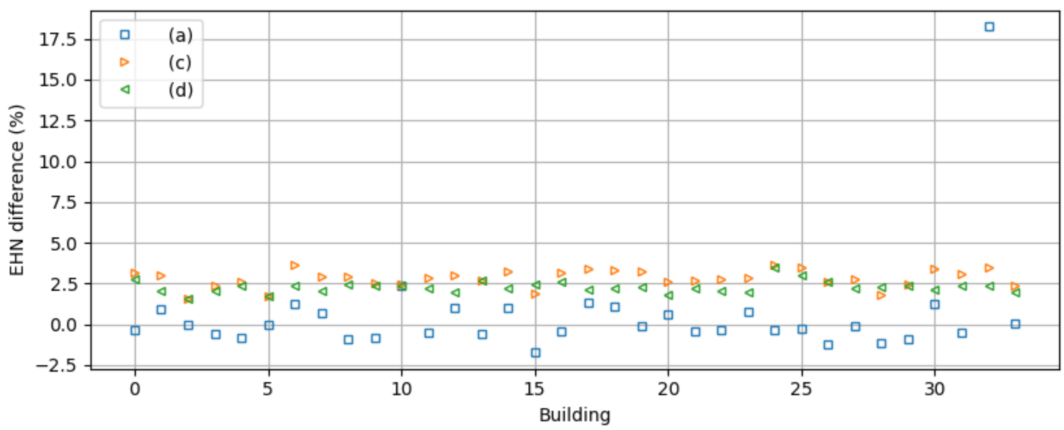


Figure 11. EHN differences based on thermal zoning option (b) and for Minneberg district in LOD1.3 geometry modelling option.

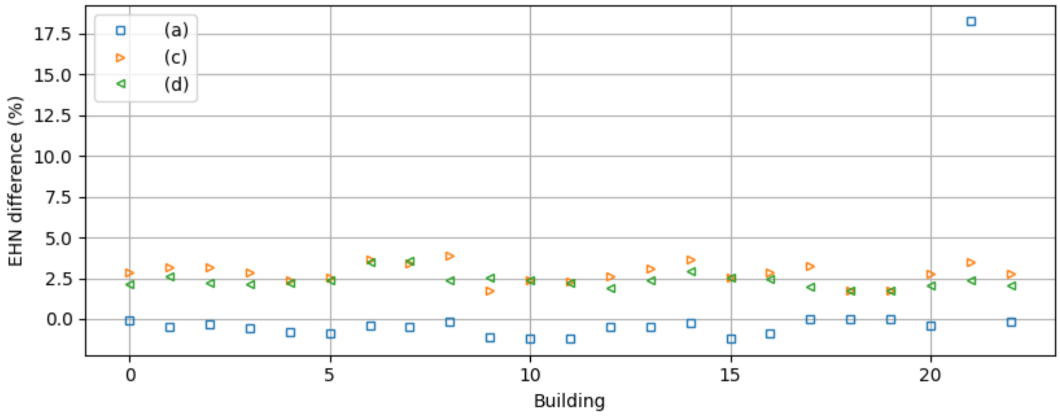


Figure 12. EHN differences based on thermal zoning option (b) and for Minneberg district in LOD1.2 geometry modelling option.

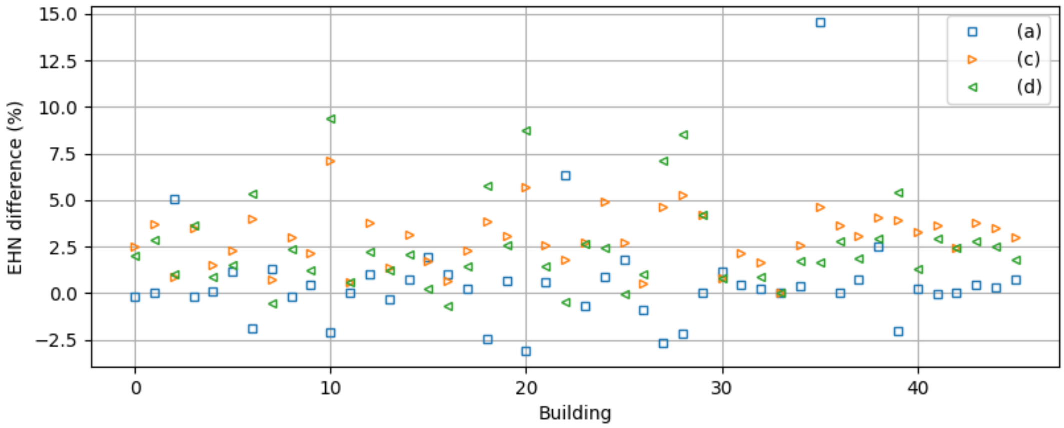


Figure 13. EHN differences based on thermal zoning option (b) and for Hammarby district in LOD1.3 geometry modelling option.

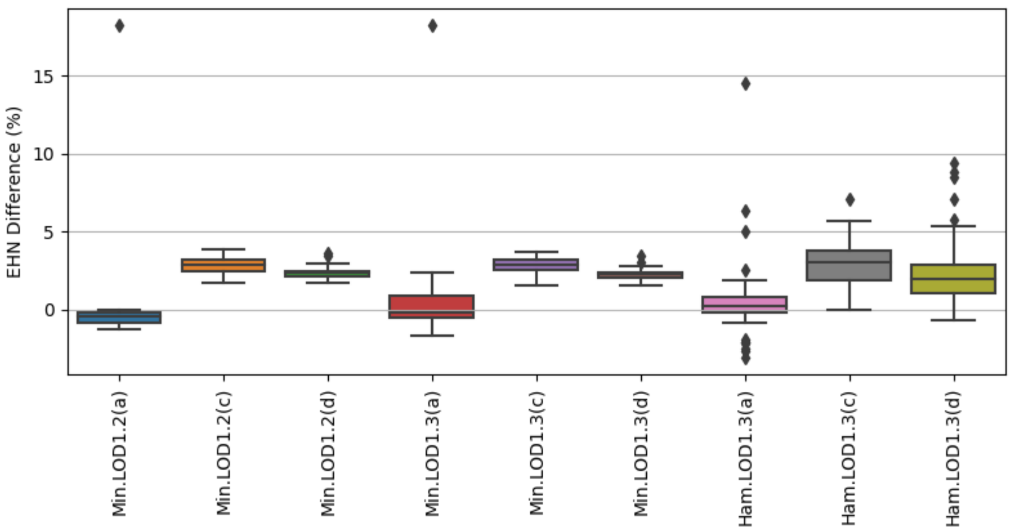


Figure 14. Box plots of the EHN difference for the three cases

Table 1: EHN difference on the cumulative demand at the district scale

	Min. LOD 1.2 (a)	Min. LOD 1.2 (c)	Min. LOD 1.2 (d)	Min. LOD 1.3 (a)	Min. LOD 1.3 (c)	Min. LOD 1.3 (d)	Ham. LOD 1.3 (a)	Ham. LOD 1.3 (c)	Ham. LOD 1.3 (d)
Total EHN differences (%)	0.5	2.7	2.3	0.7	2.8	2.2	0.9	2.7	2.0

The different figures, for the three cases (two districts and LOD1.2 and LOD 1.3) shows the same trends. The configuration with single zones for heated and non-heated volumes remains to the configuration with one zone per floor configuration, the core and perimeter zone raises the EHN by a small amount. These results match with earlier obtained results for similar studies (Chen and Hong, 2018).

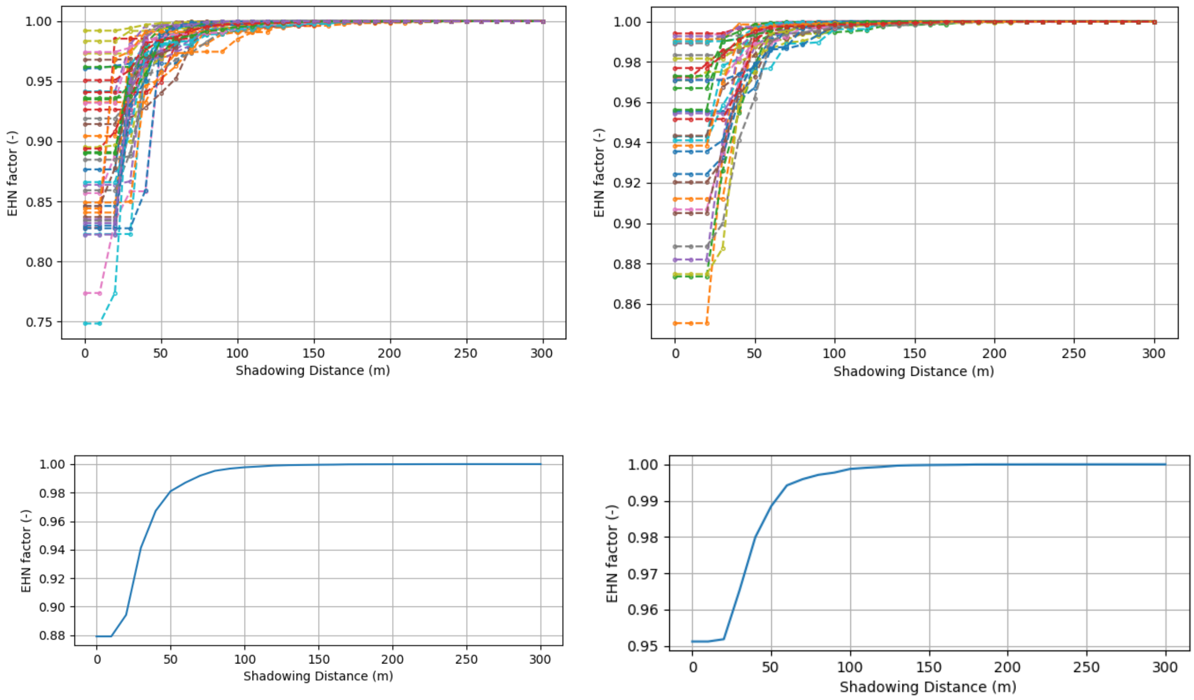
Here again, at the district level, considering the different option might be strictly equivalent and not worth of interest. But the strong discrepancy that remain for some building is still of concerns for either catching retrofitting aspect or just calibrating missing inputs for these specific buildings. While large extra time were required for the core and perimeter zone on each floor, the one zone per floor or the core and perimeter zone with the floor-multiplier are suggested for UBEM studies.

This particularity on specific buildings has not been explained from now, why this building especially was different from the others…

Surrounding shadowing environment

As presented in the building level's presentation section above, a threshold can be defined above which surrounding building are no more taken into account. For the two described districts with LOD 1.3 and one zone per floor configuration (option (b)), parametric simulations are realized for all the buildings in each district.

Results on EHN are presented for each building and aggregated at the district scale. The EHN factor represents the ratio of the EHN for each shadowing distance over the maximum EHN computed for all shadowing distances. As expected, as more shadowing impact are considered as more EHN is computed. From **Figure 15**, even though for both districts, some building shows an important dependency on shadowing effect of surrounding environment, aggregated results at the district level are quite different. 5% of difference can be found for Minneberg while 12% of EHN difference is computed for Hammarby at the district scale. Some threshold for both districts could be held form those results. Difference below 2% could be computed with all shadowing surfaces within 50m from building's centroid while all surfaces farer than 150m does not seem to have any effect on the district level, at the building level a threshold of 200m could be kept.



(a) (b)

Figure 15. Shadowing distance threshold impact for each building in the 2 considered districts (a) Hammarby, (b) Minneberg and all building (top) entire district (bottom)

Conclusion and discussion

A new generation UBEM workflow has been presented. It has been developed under python environment for the management process and uses EnergyPlus as the thermal core engine. The gathering data process includes the geometry photogrammetric point cloud methods. The UBEM process undertake physical building energy modelling, thus, following a building per building approach at the district scale. Data are organized into a GeoJson structure file with polygons for all building's external surfaces and different properties gathered from several database. It tries to follow as much as possible a shoebox model all along the process as shown for the HVAC system, in order to comply further with other format of data file. The UBEM workflow has been used to highlight the importance of level of details on the geometry side, the impact of thermal zoning and shadowing effect of surrounding environment. From the two districts considered in this study, the following conclusions can be held:

On the level of details: the LOD 1.2 and LOAD 1.3 can lead to quite different shape factors for each building and might be worth of interest as its impact on the EHN might be not negligible on the building level. On the district level, and depending on some district typology, LOD1.3 might not be required. For the specific studied district, the overall difference at the district level remains below 1% even though up to 10% could be computed for some specific buildings. As extra effort to compute LOD1.3 might not be important, the authors would still advice to keep as much as possible this level of modelling geometries.

On the thermal zoning: As shown also by earlier studies, the thermal zoning effect at the district level remains below 5% of difference despite some strong effect for some specific buildings. The single zone option for heated and non-heated volumes is still to avoid as is not recommended by any standard. Applying a core and perimeter zone can lead to closest results to a classic one zone per floors option.

On the surrounding shadowing environment: for two districts with quite different types of building geometries, up to 12% of EHN differences could be computed, with the lowest EHN the lowest shadowing distance threshold. At the district scale, EHN difference below 2% were observed for shadowing environment up to 50m to the building's centroid and surfaces farer than 100m does not seem to have any effect at the district scale on both studied areas. At the building's scale, this threshold is raised to 200m. As extra computing time is negligible, the authors would advice to keep 200m for all simulation.

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192 EURECA-PRO, The European University on Responsible Consumption and Production: An Alliance for Sustainability

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Abstract

In recent years, the implementation of sustainability has gained importance in all areas of global societal development as science has proven that climate change is a human induced and inevitable future circumstance if nothing is done to avert it. With strategies and frameworks such as the UN Sustainable Development Goals and the EU Green Deal, it has become clear which direction research and education will take in the future, towards an interdisciplinary and excellence-based approach to systemically solve today's societal challenges for a better ecological and social future. Innovation, education, research and societal cooperation, known as the knowledge square, are key factors in reaching these goals. The framework of the European Universities offers an opportunity that can integrate all these factors, in promoting cooperation across borders, languages, and disciplines thereby being an ideal vehicle to address societal challenges of our time and related skills and knowledge shortages faced in Europe.Within the ERASMUS+ and H2020 Framework Programmed seven higher education institutions located in six different EU member states, namely Montanuniversität Leoben (Austria), Technische Universitaet Bergakademie Freiberg (Germany), University of Petrosani (Romania), University of León (Spain), Technical University of Crete (Greece), Silesian University of Technology (Poland) and Mittweida University of Applied Sciences (Germany) joined forces and created a strong and unique European University in the field of Responsible Consumption and Production as defined in Sustainable Development Goal 12 of the United Nations: **EURECA-PRO** – The **E**uropean **U**niversity on **RE**sponsible **C**onsumption **A**nd **PRO**duction. Its mission is a two-fold one: on the one hand, it aims at contributing creatively to the European Higher Education Transformation Agenda to stimulate seamless education and cooperation within Europe. On the other hand, it aims at becoming the European core excellence hub for responsible consumption and production converging all European and global activities, be it scientific, industrial or social, as well as all stakeholders in this field. Since Fall 2020 the consortium works on its goal to ultimately create a research and education agenda that systemically integrates all necessary interdisciplinary knowledge (technological, ecological, policy, economic, societal

aspects etc.) to solve today's pressing questions regarding consumption and production patterns and the transfer of solutions into society and industry. This is done by taking into consideration new technologies and processes that integrate material and resource flows towards responsible impact flows as well as complimentarily focusing on consumption behaviors and the factor human being in relation to these flows, thus putting the manifold influence factors in harmony to each other and the surrounding environment.

Keywords: Sustainable Development, Responsible Material Flows, European Universities, European Higher Education Area, European Research Area

Introduction - The Europe of the Future

The creation of the European Union was aimed at putting an end to the numerous bloody wars between neighboring countries that resulted in World War II. Since 1950, the European Coal and Steel Community has been the beginning of the economic and political unification of European countries to ensure lasting peace (Europea.eu, 2020). The European Union is thus in principle the biggest peace project in history.

There are two very important aspects regarding the design of the European Union which shape its development in a more profound way than other areas, namely the European Higher Education Area (EHEA) and the European Research Area (ERA). They generate what we need for a stable society: capable and skilled Europeans that are culturally connected and work for the interest of future generations.

The European Higher Education Area (EHEA)

The European Higher Education Area (EHEA) is a unique international collaboration on higher education. The main goal of this initiative is to increase staff and students' mobility and to facilitate employability of graduates, increase social inclusion, civic engagement, innovation and environmental sustainability (European Commission, 2021). It is the result of the political will of 49 countries with different political, cultural and academic traditions. It is based on structural reforms and joint commitments as well as a common set of key values– such as freedom of expression, autonomy for institutions, independent student unions, academic freedom and free movement of students and staff (Bologna Process Secretariat, 2021). Through this process, all stakeholders of the area continuously adapt their higher education systems making them more compatible and strengthening their quality assurance mechanisms.

The European Research Area (ERA)

The Lisbon Treaty defines the European Research Area (ERA) as a unified research area open to the world and based on the Internal Market. The ERA enables free circulation of researchers, scientific knowledge and technology. The objectives of this

initiative are to improve the coordination of research activities on European level, to develop human resources, and to increase the attractiveness of European research to the best researchers from all over the world. (Austrian Federal Ministry of Science and Research, 2021). Why is this important? To strengthen the EU's scientific and technological bases, its competitiveness and its capacity to address grand challenges collectively.
Both areas have undergone significant development over the last twenty to thirty years. With the introduction of the ERASMUS program, in which to date more than 4 million students have been supported to study abroad, and the initiation of structural alignment through the Bologna Process a new era was entered in Europe (Schulze-von Laszewski, 2017). At first it was deemed absurd and undoable to send students abroad within their studies and now it has become a standard that has changed the way we think and approach education. Over the last two decades also in the ERA "a wide range of related policy reforms and initiatives have been successfully implemented" (Austrian Federal Ministry of Science and Research, 2021), contributing towards its overarching objective. The EU needs a strong EHEA and ERA to compete in every aspect on an ever stronger and competitive world stage which is facing a key period for transformation. Therefore, continuous development and world leadership is key in being a part of changing the planet and positioning the European Union as leader and role model.

Already in November 2018, research ministers confirmed the need to improve ties between the EHEA and the ERA, one major aspect of which are the European University Networks (Austrian Federal Ministry of Science and Research, 2021). With the foundation of the European Universities Initiative a huge leap forward was thus taken in further developing the areas. "The aim of this initiative is to bring together a new generation of creative Europeans able to cooperate across languages, borders and disciplines to address societal challenges and skills shortages faced in Europe" (European Commission 2021). The foundation of the alliances are not solely projects to be worked on and put into a drawer upon completion. They aim at a much higher goal, namely a changed future – through structural reform to contribute to the EHEA and ERA but in this specific case also through jointly addressing the most pressing societal challenge and positively developing it, namely *Responsible Consumption and Production - EURECA-PRO*.

It is a commonly understood fact that today's world is characterized by unprecedented environmental stresses. All anthropogenically induced negative Earth system trends (for example: biodiversity loss, terrestrial biosphere degradation, temperature rise, land alteration etc.) have accelerated in recent decades (Steffen et al., 2015). The reasons for this can be simply summarized as an explosion in global population growth, an increase in global wealth, both especially since the industrial revolution, and a huge concomitant increase in material use. Since the start of these developments global contribution to this development has been unevenly spread. It seems that "in 2010 the OECD countries accounted for 74 % of global gross domestic product GDP but 18 % of the global population" (Steffen et al., 2015). Thus, it becomes obvious that "most of the human imprint on the Earth System is coming from the OECD world". This trend seems to be changing, however, as indicators are starting to stabilize in OECD countries and much of the increase of activity and impact can now be detected in the fast-growing economies of the BRICS countries and the rest of the world (Steffen et al., 2015), making the future development of the trajectory of the Anthropocene largely dependent on urban development in Asia and Africa. The human influence, as it results in negative effects for the planet, delivers positive dynamics for individual human lives, however. Since the mid-twentieth century many millions of people have been helped out of deprivation through economic development, resulting in countless people who are the first generations in their families to ever "lead long, healthy and educated lives, with enough food to eat, clean water to drink, electricity in their homes, and money in their pockets and for many, this transformation has been accompanied by greater equality between women and men, and a greater political voice" (Raworth, 2018). It must be welcomed that the social development of the world is heading in such a positive direction as it is well known from the past that the world used to be a mostly unfavorable place for the majority of human realities. Fortunately, the long sought-after utopia of Cockaigne has already become a reality for most people today (Bregman, 2018). In terms of enabling these social and economic trends and sustaining this population growth, an ever-increasing amount of raw materials to supply the population with biomaterials, fossil energy, metals and construction materials is used for industrial activity. Especially demand and supply for bio materials, for food and construction materials for shelter have been strongly on the rise. Indeed, demand for raw materials corresponds directly with population growth and gross national incomes (Krausmann, et al. 2018). Globally, the consumption of raw materials increased from 6 billion tons per year at the beginning of the 20th century to 84 billion tons per year in 2015 (biomass, fossil fuels, metallic and non-metallic minerals). Projections predict a further increase to up to 182 billion tons per year in 2048 (European Innovation Partnership on Raw Materials EIP, 2018).

Methods

Each material has a specific environmental impact due to the way it is produced and how it is used and disposed of in the post-consumption phase. A stated target of the UN Sustainable Development Goals (SDG) is to decouple the production of materials from its environmental impact, as well as the required material use, from economic growth (United nations Environmental Programme UNEP, 2011). However, a mere reduction in material use, i.e. its quantitative decrease, does not automatically mean the qualitative improvement of its environmental sustainability and thus in many situations will not result in the urgently necessary environmental impact decoupling.

The matter of material flows, cycles and applications is a very complex interplay between many stakeholders and aspects and hence needs to be scrutinized in many interconnected dimensions in a systemic way. Circular economy, in-stock use, recycling, elements and substitution, thermodynamics, energy and exergy, consumer demand, production sustainability are just a few of the countless concepts that feed into this grand challenge.

Montanuniversität Leoben (MUL, AT), the Technical University Freiberg (BAF, DE), the University of Petrosani (UP, RO), the University of León (ULE, ES), the Technical University of Crete (TUC, GR), the Silesian University of Technology (SUT, PL) and Mittweida University of Applied Sciences (HSMW, DE) joined forces to create a strong and unique European University Alliance in the field of Responsible Consumption and Production (RCP) - EURECA-PRO - to address these challenges.

By creating such an alliance, a commitment was made by these seven European institutions to jointly change from within and to take on the challenge of systemically bringing together all the mentioned concepts and shed light on their systemic interplay to seek solutions. EURECA-PRO is getting ready for the new future. The human resources of the alliance include 54.500 students, 9.400 members of staff and 60 departments/faculties, supported so far by 24 associated partners from all over Europe with growing interest for associated partnership. Currently, EURECA-PRO activities are funded under ERASMUS+, H2020, the Austrian Exchange Service OEAD and other national ministries and agencies of the partner countries, amongst others the DAAD, Bundesministerium für Bildung und Forschung (D), Ministerul Educatiei (RO) and the Ministry of Science and Higher Education (PL) in the respective countries.

Mission and Vision

Vanessa Debiais-Sainton, Head of Higher Education Unit in the European Commission, is known to state that “This is not a project. It is a long-term vision on what the Alliance and the European Education (and Research) Area could look like in 2030 or even 2040“. In this way, EURECA-PRO follows a two-fold vision according to its mission statement. On the one hand, it aims at transforming the EHEA.

- It is a role model for civic engagement, equal participation and transparent joint governance as well as shared fundamental philosophies, common values and solution-oriented approaches regarding social cohesion, responsible citizenship and humanhood.
- The Alliance has established all necessary mechanisms to ensure academic freedom and development of free mobility throughout Europe. It has implemented effectively all necessary communication channels, dissemination and science communication measures to reach out to society.

On the other hand, it aims at transforming the ERA and society.

- By 2025 EURECA-PRO is well-known throughout Europe for its competence as an educational core hub and interdisciplinary research and innovation leader in qualitative environmental and social framework development for sustainable consumption and production of goods as well as responsible systems design.
- It is a major innovation contributor to the realization of the EU Green Deal and develops new technologies and processes that integrate primary and secondary resource material flows and efficient resource use in the sense of a Circular Economy. It delineates responsible consumption behaviors that are aligned with societal expectations as well as the Planetary Boundaries.

The overall approach of the alliance is thus to effectively contribute to solve the societal challenge of responsible consumption and production, specifically in the field of materials and their flows as they form the basis of the way we develop and define our societies. Building everything around this vision and mission, the alliance contributes to developing the EHEA as the two-fold missions perfectly complement and need each other. EURECA-PRO establishes shared governance, administration and content structures that allow for complementary collaboration and production of results. Students, society, industry and other external stakeholders are integrated into the creation of structures and contents to make EURECA-PRO inclusive, authentic and relevant.

Project structure

In the first three-year funded period, EURECA-PRO has set itself the goal of establishing joint structures in Research, Education, Innovation and Third Mission and is thus based on the knowledge square (integration of Research, Education, Innovation and Society) thus signifying high impact on environment, economy and society. Furthermore, the alliance will implement a strong governance basis in terms of joint administration and future collaboration phases. With the set targets of 13 milestones and 130 deliverables the alliance aims high. However, only delivering the defined agenda will not be enough to become a synergetic institution. For this the people, topics and mind-sets need to grow together which requires an immense amount of dedicated time for people work. Coordinating the incredible amount of human resources is a grand task that seems to expand everyday as the joint work penetrates the institutions more and more.

Research

The key to EURECA-PRO's strength in research is its interdisciplinary set-up. Each university brings into the alliance a different set of competencies that enable a systemic point of view in each approach to a challenge. This comprises technological, ecological, economic, societal, legal and policy aspects and their transfer into society and industry as illustrated in Figure 1. The first step taken in the research work was the creation of a *Scientific Framework Charter* that defines how the work is organized

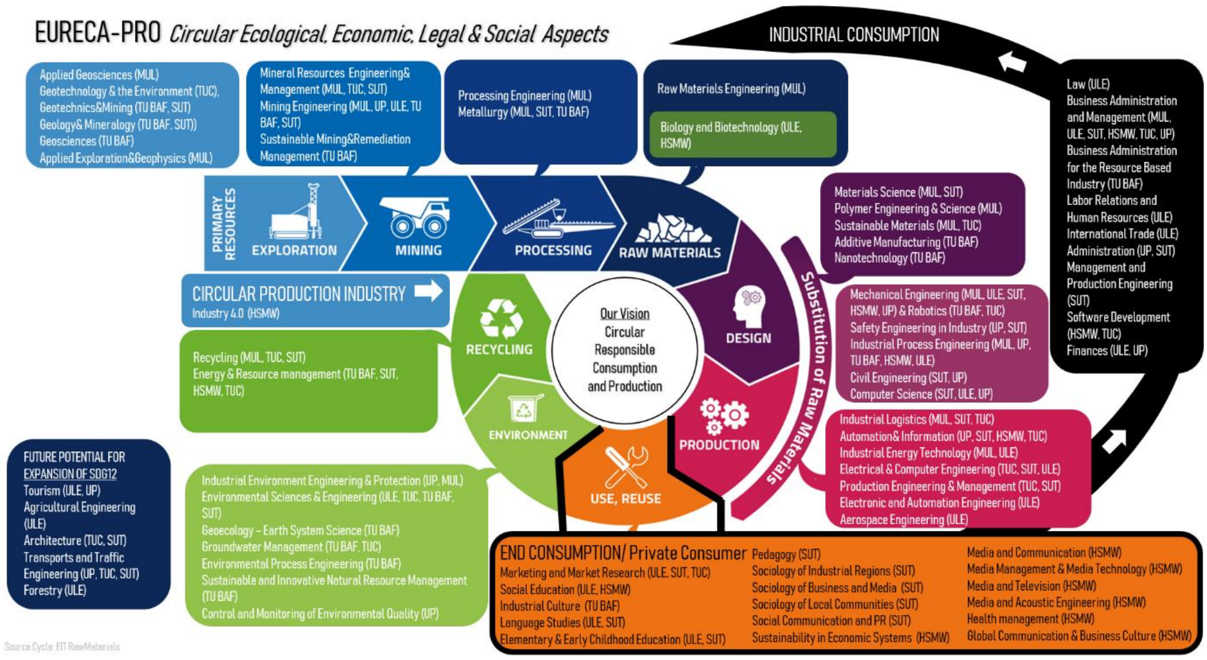

Figure 1 - Interdisciplinary competencies of EURECA-PRO (Moser et al. 2021)

in the research branch of the alliance and who is involved. The operative arm of the research branch is the *Research Task Force* (RTF). With the present competencies *Research Lighthouse Missions* regarding responsible consumption and production are established that address the most pressing current issues. It is the RTF that leads its members towards a common definition of the first three lighthouses from which then extended joint interdisciplinary research teams will be set-up to develop and work on the topics systemically and in depth. All the expertise that may be missing in the core consortium is sought after with the associated partners and Global Knowledge Alliances that will be formed. Currently, a common inventory of SDG12 related work is being set-up and the notion points towards desired work in responsible material flows, sustainable materials and products, environment and water as well as advanced energy technologies. The establishment of systemic responsible consumption and production models is of course a necessary task encompassing all topics. The final decision which lighthouses will be worked on is made in October. Once the sub-groups have created substantial content, this will be directly fed into definition and deduction of education contents. Society and industry are actively involved in the knowledge creation process through regular community building and open science events.

A crucial aspect of the research work is the commitment of EURECA-PRO to an open access policy. The knowledge created shall be openly accessible by all members of society. It will do so by building a common platform and uniform formatting for documents and on the production of FAIR (findable, accessible, interoperable and re-usable) data. Furthermore, following the *European Open Science Agenda*, the alliance will raise awareness among its research community through training on the importance of *Open Science*. All existing open repositories of the partner institutions will therefore be merged into a common repository, which will be a thematic repository on responsible production and consumption. In the shared infrastructure, the *European Open Science Cloud* (EOSC) platform launched in 2018 will be implemented and used as both producer and consumer. A relevant task force to realize this process is already operative.

Education

The alliance defines education as an agent of change for the global sustainability challenges and driver of fundamental societal transformation processes, therefore as a central element in its work. Education is constantly in systemic interaction with knowledge creation and knowledge transfer. Therefore, the research work created directly flows into the alliance's educational formats. The operative arm of the education activities is the Education Council, consisting of the Deans and other education related members of the alliance's universities. They jointly implement EURECA-PRO's goals into their own institutions. The general structure of the work is to create a three- cycle education program in *European Studies* with the implementation of the EURECA-PRO PhD studies in October 2021, for which most of the legal work and structural processes have been completed, and following this the implementation of the EURECA-PRO Master and Bachelor Studies in October 2023.

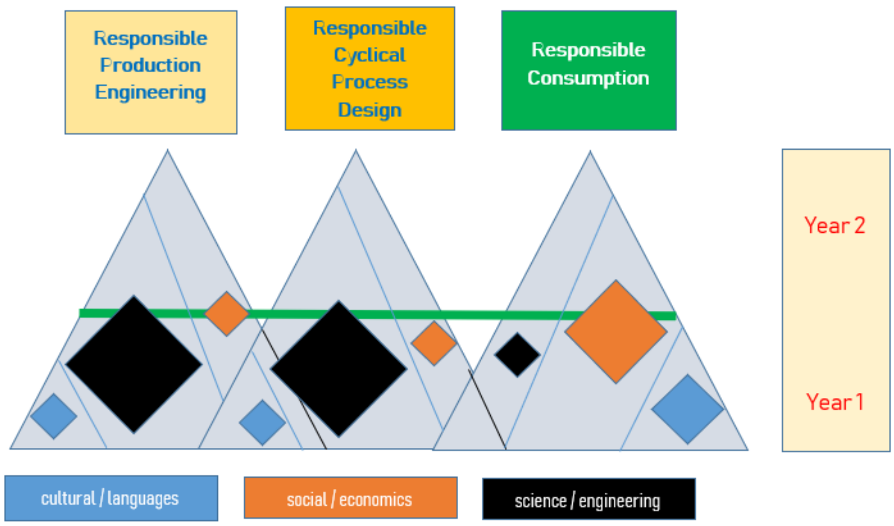

Figure 2 - Example of possible paths in Master of European Studies

This may sound almost conventional, however, the tracks designed for the students will be flexible as they allow for different fields of emphasis yet addressing the same overall area. Furthermore, students will be required to have a higher degree of mobility than in a regular student exchange, as well as additional transversal skills work (intercultural skills, languages and citizen action – digital language spaces, virtual exchanges and European identity courses, digital skills – digital management tools, STEM skills – STEM project-based learning activities and courses, policies, incentives and outreach for enhanced inclusion of women in STEM, employability skills – leadership and related skills training). Moreover, the educational approach will include alternative didactic concepts such as a strong emphasis on problem-based learning (PBL) approaches but also training for teaching staff (teaching methodologies and didactics – teacher workshops and training, sustainability and social awareness, sustainability communication, social entrepreneurship) or the development of a digital platform for pedagogics and education (PEdPlat), online pedagogical training activities as well as the provision of guidance materials (e.g. MOOCS, electronic manuals and infographics) for implementation of the models in other HEIs. So far, the alliance has already successfully implemented the 14-lecture series "Responsible Consumption and Production", partnered in the summer school "Digital CirCOOL – The Aluminium Cycle" and is holding the summer school "Responsible Consumption and Production for digitized Higher Education". In 2022 together with the UNESCO Competence Center of Mining Engineering Education Austrian Branch, EURECA-PRO will hold a lecture series on the "Planetary Boundaries" with globally recognized experts.

Innovation

The educational aspect of EURECA-PRO also encompasses the innovation sphere through the implementation of joint innovation and entrepreneurship training courses. Students of EURECA-PRO have a required number of credits to complete as innovation and entrepreneurship courses to nurture their creative thinking ability and further a shift in their mindset through an amalgamation of creativity, experiential learning and skill building. It engrains in participants business basics, widens the understanding of packing ideas into business concepts, market basics, problem-solution thinking, business plan orientation and leadership skills. Creating consolidated value chain innovation services and pipelines such as idea camps, jump starter competitions, booster workshops and accelerator pipelines is an important means to give students the chance to foster their responsible consumption and production ideas into real businesses and thus promote start-up related activities. This is the most significant tool to create spin-offs from EURECA-PRO and put into practice what students and scientific staff learn in the innovation trainings. Through the outreach to industry and the formation of new alliances to the existing ones, capacities for internships for EURECA-PRO students is created. Moreover, by connecting existing and developing *Knowledge Transfer Offices* and their services, continuing education courses, summer courses and seminars on responsible consumption and production will be provided. Target groups will be: industry, government agencies and services and the community at large.

However, not only educationally innovation and knowledge transfer play an important role but also in the upscaling and marketing of EURECA-PRO solutions. For this, joint structures are implemented through the creation of an *Innovation Academy*, the connection of existing and developing innovation and entrepreneurship centers as well as the creation of connected knowledge transfer centers. This will contribute to the diffusion of research and technology results through the development of university spin-off companies or patent licensing well beyond the geographic areas of each individual institution. The knowledge transfer will be facilitated not only by the use of the universities' physical facilities (libraries, scientific laboratories, computer facilities, and so on), but also through the creation of the virtual campus. This will have a synergistic effect on knowledge transfer at community/regional scale, since all universities involved are of similar academic nature and operate in regional areas with wide geographical diversity.

Third Mission

Today universities have to engage with cultural expectations, societal needs and economic development under the umbrella of ecological pressures to benefit society. Especially in the case of responsible consumption and production this is of utmost importance as it represents a pressing and highly topical interrelated cultural, societal and economic challenge. Through coordinated communication measures with the three stakeholder groups mentioned, a structured dialogue can be established, linking the university's activities with societies' own socio-economic context.

Measures to include local community involve: open science knowledge creation events, digital discussion forums, open house and STEM days, visits from schools and to schools in order to promote information flow towards the primary/secondary levels of education, newsletters/flyers, information sessions with the community at large (with presentation and Q&A from audience), newsletter/social media updates, community events and workshops on topics related to alliance theme.

In order to enhance the external image, science outreach also targets wider society and citizens with the aim to communicate scientific results, generate interest, establish trust and increase credibility. EURECA-PRO will show and explain the wide spectrum and diversity of sustainable developments in responsible consumption and production via project/problem-based learning (PBL), EURECA-PRO website content "for Society" and short videos about scientific findings/results, children asking professors as well as interviews with professors, as well as other dissemination channels.

Governance

The alliance understands that a solid governance structure is the key success factor to a functioning institution. EURECA-PRO has therefore developed a short-term and a long-term governance structure. The long-term plan foresees a four-phase development plan until 2040 when the vision is a complete intertwining of all

participating institutions to become a supra-institution.

- Phase II 2024-30 - Introduction of virtual administration
- Phase III 2031-40 - Deep demonstration of structures

- Phase IV (beyond 2040)

Phase I of this governance structure is concerned with setting scene or as such charting the way towards this vision which happens from 2020-2023. Within the first phase the governance layout is concerned with creating the basic structures such as the boards, councils and other related groups and underpinning the way they function. All partners contribute by seconding staff and students to the relevant boards and creation groups established. A very important committee in this respect is the *Student-Centred Co-Creation Group* that allows volunteer students of all the institutions to participate in the design of the new education, research and transversal programs. Furthermore, a legal situation analysis specifically with regards to a legal form, joint admission and automatic credit recognition as well as a funding screening to tap other funding sources will be made.

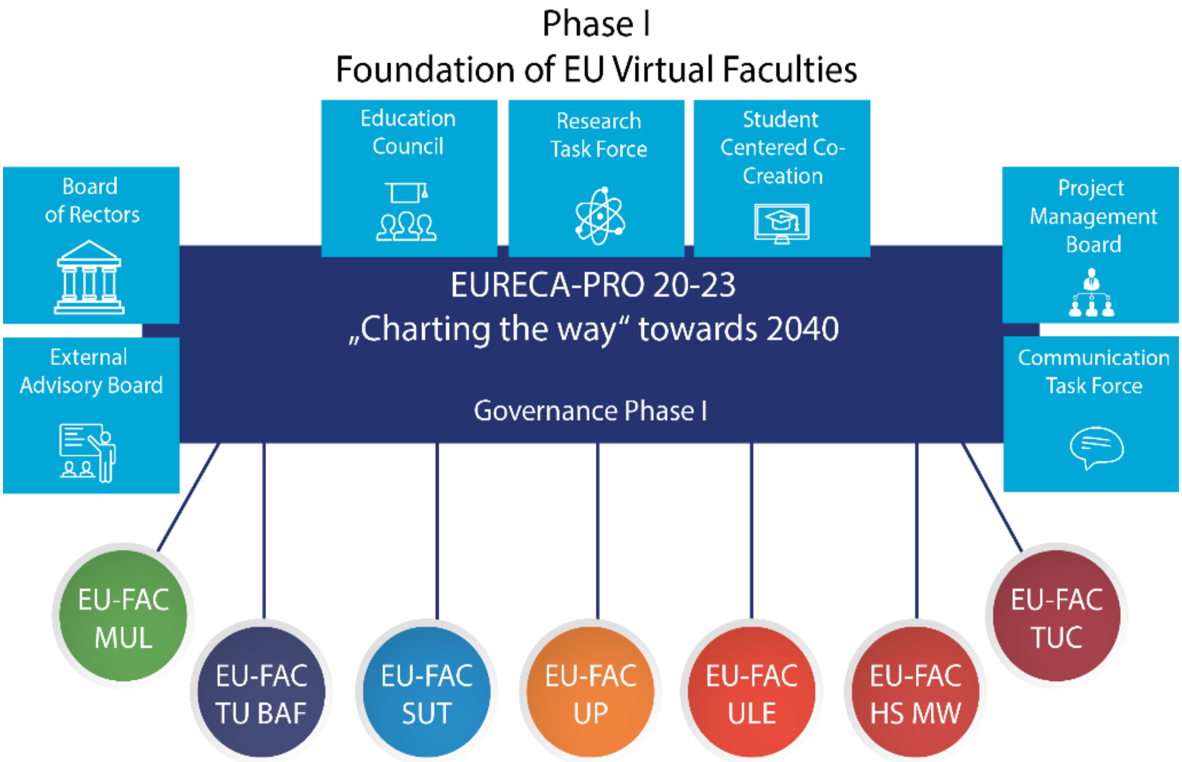

Figure 3 - Governance structure of EURECA-PRO (Moser et. al 2021)

Additionally, each partner designates EURECA-PRO spaces in their institutions to ensure shared work, education, research and infrastructure for transversal training for all participating students, researchers and staff that are constantly moving between the institutions (work space, lab infrastructure, housing, social etc.).

The digital platform and shared spaces

With regards to collaboration over distances, it is crucial to implement a system that allows for seamless collaboration for which digitalization is a key factor. Each of the partners will implement virtual spaces that are shared with one another. All partners are equally contributing structurally through the establishment of joint digital

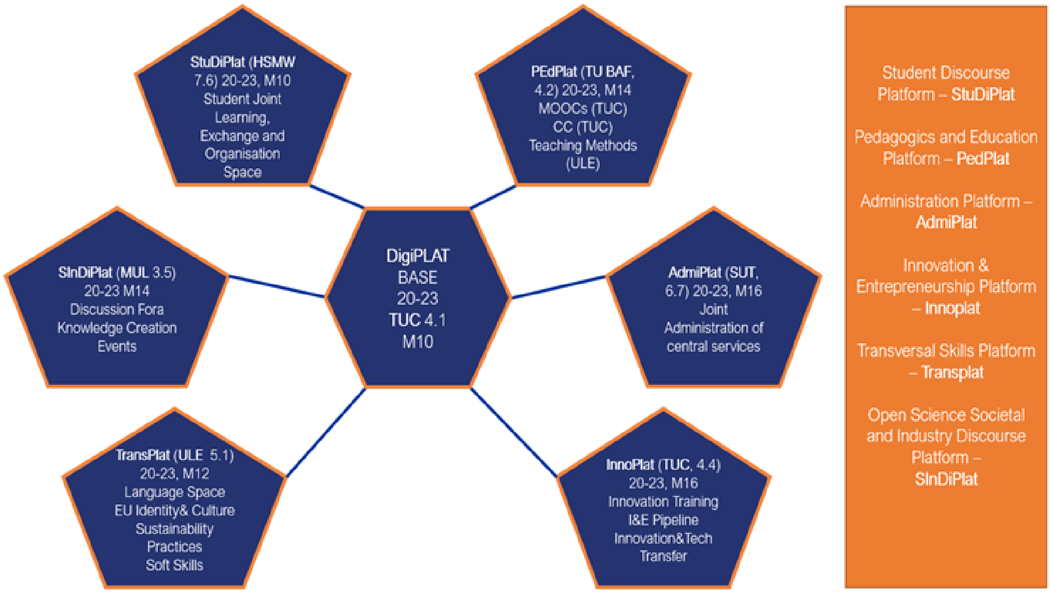

Figure 4 - Digital platforms of EURECA-PRO (Moser et al. 2021)

services that are then utilized by everyone. A digital master platform is currently being implemented as the software basis (DigiPLAT) for many individual platform branches that service each area of interest. Within the project period sub-platforms for open science, societal and industry dialogue and outreach (SInDiPlat), for staff and student training of transversal skills (TransPlat), for pedagogics and education (PEdPlat) and an innovation and entrepreneurship platform (InnoPlat) are implemented. In a subsequent governance phase after the first project period this is complemented by a student discourse and service platform (StuDiPlat) and a joint administration platform (AdmiPlat). The development of content is shared amongst partners. Communication structures, strategies and database design are carefully planned and implemented to guarantee maximum usability, efficiency and outreach.

EURECA-PRO following its two-folded vision will strengthen the excellence and completeness of the EHEA and ERA by addressing the highly cultural, societal and economic challenge of Responsible Consumption and Production, specifically in the field of materials and their flows as they form the basis of the way we develop and define our societies. Its developments include the complex matter of material flows, cycles and application which has to be looked at in an interdisciplinary and systemic way.

Results and Discussion

The implementation of EURECA-PRO has only started less than a year ago and it has become clear that the bold 2040 vision of being a key leader in the structural changes of the EHEA and the ERA as well as being a key leader of the sustainable development of the EU, both at the same time, has a dimension that in this way has not been anticipated. The changes to be realized manifest themselves in grand challenges, huge bundles of tasks and everyday they branch out more into the structures of the university by involving more and more people and becoming more and more detailed. The originally planned goals require a great deal of detailed work when broken down into actually feasible chunks. Nevertheless, the realization of the work as described has been fairly efficient so far and the collaboration rather smooth. It seems as though the partners are a good fit and all up to the challenge. It has become more than clear, however, that this alliance will not become a European University in the anticipated sense if the people themselves do not grow together on a personal level. It would be fairly simple to just deliver all the work packages of the first three years and nothing else. According to project management standards this would suffice. However, this is not what will make the essence of the alliance or what will be the glue to hold it together. Every partner and every individual of each partner has a slightly different understanding of how what has been envisioned will be achieved. It is of essence to constantly be in dialogue with all the partners, in and across all levels and groups, to align the common understanding of the way forward, to forge friendships and shape the narrative that defines the social cohesion and collaboration within the alliance members. As the start of the alliance and its work fell right into the COVID-19 pandemic which forced the members to grow together solely on an online basis it is believed that the ties have not been forged yet to a level that they usually would have been. It is hoped though that the future outlook on this will be positive. All in all, it has become obvious that the successful management of all these aspects and developments on a supervisory level is a crucial aspect not to underestimate and to plan and carry out very thoroughly thought through. Without a comprehensive overview of how the branches of this tree grows it may quickly take on an unwanted shape.

Conclusions

EURECA-PRO following its two-fold vision will strengthen the excellence and completeness of the EHEA and ERA by addressing the highly cultural, societal and economic challenge of *Responsible Consumption and Production*, specifically in the field of materials and their flows as they form the basis of the way we develop and define our societies. Its developments include the complex matter of material flows, cycles and application which has to be looked at in an interdisciplinary and systemic way.

The *European Universities Initiative* itself is a game changer for the EU and EURECA-PRO is the “responsibility” part of it. Within this alliance there is the potential to transform the educational system and internal *Higher Education Instituions*’ structures, research in an interdisciplinary manner on crucial topics of global interest and prepare well-educated, open-minded, critical and transversal skilled leaders of tomorrow.

With this alliance a contribution to creating a new future is made in which our sons and daughters have educational opportunities past generations did not have, where they grow up as true European citizens with a true European mindset in a socially and ecologically sustainable environment where they and their children can thrive.

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240 Resilient cities in practice

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Abstract

In the focus of sustainable development, resilience is one of the main characteristics that modern and liveable city should have in the 21st century. Currently, we are facing serious global problems, including climate change, social inequalities, resource scarcity, pandemics and related healthcare system challenges, cyber insecurity, etc. All those problems are representing complex risks and require complex system solution approach. Even if Europe is not the most vulnerable region in the globe, consequences of our changing climate are significant and new challenges emerge constantly. As core components of the current system, cities represent major contribution to greenhouse gas emissions and they serve as centres of population, decision-making and institutional power. For these factors, cities have a special role in sustainable development processes. Despite a wide range of sustainability approaches and solutions, there are still plenty of obstacles that slow down the process of development. These obstacles are especially peculiar in cities, as a consequence of high population density, limited space and limited availability of affordable housing, dependency on external food supply and water supply etc. The aim of the paper is to highlight the differences between the theoretical and the practical approach in the case of closing the gap between expectations and achievable development. It follows a practice-oriented approach to examine whether a locally, well-planned complex development chain could achieve a significant improvement in the inhabitants' life, according to social, economic and environmental indicators. The purpose of the study is to provide potential good practice examples to the recent field of smart solutions, related to climate change mitigation and adaptation. Trough specific small-scale solutions the involved fields and the smart, complex system-oriented modifications and their effects will be presented. The applied methodology is case study analysis, which aims to assess the resilience of an 8000 inhabitants' settlement in Europe. Results of the paper show that with a determined, multidisciplinary, complex, solution-oriented approach an appreciably higher resilience can be achieved, by affecting different fields of challenge (such as energy sector, heating, social awareness) and simultaneously target climate adaptation and mitigation. Contribution of the paper to its field, is the approach that the analysed case represents and the evidence that even a small city'

effort can be resilient and contributes to tackling climate change and sustainability challenges.

Keywords: Climate Change, Resilience, Complexity, Small Scale Solutions, Smart Solutions

Introduction

The potential limits of both uncontrolled and sustainable growth and development have been in the focus of scientific research for decades. The potential stocks of available natural resources, the consequences of demanding human activities and, last but not least, the intensifying overpopulation put significantly huge pressure on the Earth' ecosystem and our institutions alike. Currently we are facing seventeen identified and monetarized global challenges, defined by the United Nations (United Nations, 2021), such as poverty, famine, deterioration of health and well-being, different quality of education, gender inequality, sanitation difficulties, access to affordable energy, not inclusive economic growth, inequality, vulnerability and unsustainable cities, irresponsible consumption and production, climate change, vulnerability of life below water and on land. All these problems are representing interrelated challenges. However, one of them, Climate Change, is outstanding as it has strong relationship with all the other sixteen and its impacts affect all of them. This is one of the most complex risks, that is globally observable and the perceived consequences are often independent from the origin of the emission.

According to the WEF's Global Risks Report 2020 (WEF, 2020), the Top 5 global risks in terms of likelihood in 2020 were extreme weather, climate action failure, natural disasters, biodiversity loss, and human made environmental disasters. All of these climate change related environmental risks have strong connections with social risks (such as food and water crisis, infection diseases), geopolitical risks (such as interstate conflict, state collapse), economic risks (such as growing unemployment rate, fiscal crisis, energy price shock), and technological risk, (namely IT infrastructure breakdown) (WEF, 2020). The forecast of WEF for the year of 2021 is more dispiriting, while the indirect consequences of uncontrolled climate change became even closer. However, still climate action failure is seen as the driving force of the other potential global risks, the respondents of the WEF survey noticed infection disease and livelihood crisis (probably related to the COVID-19 pandemic) as the most critical threats in a short run (0-2 years), beside extreme weather events, cybersecurity failure and digital inequality. In medium term (3-5 years), the negative economic consequences are expected such as asset bubble burst, price instability, commodity shocks and debt crisis, combined with IT infrastructural difficulties and breakdowns. Finally, in a long run (5-10 years) serious geopolitical consequences are prognosed such as weapons of mass destructions and state collapse (WEF, 2021).

The role of climate change in shaping our future is undeniable. For appropriate mitigation and adaptation measures and actions to avoid reaching the tipping point of irreversibility, the biggest emitters are identified, their monthly/yearly CO_2 equivalent emissions are monetarised, and environmentally friendly innovations are internationally promoted. The focus from an only top-down approach has been shifted to a broader point of view, where the local, small scale innovations (bottom-up) are valued and lifted up as best practice in the international level. The need of well-designed local actions and the use of the two approaches on parallel to reach global sustainable development became globally accepted (Bulkeley and Betsill, 2003).

Although cities are representing just 2% of the Earth's surface (United Nations, 2020), they contribute to 80% to the global GDP (United Nations, 2018) and they are major contributors to climate change by consuming 70-78 % of the world's energy and produce more than 60% of the global greenhouse gas emissions, according to optimistic estimation (United Nations, 2020) which mainly stems from energy generation, transportation and emissions related to buildings (UNEP, 2021). Less optimistic estimations calculate with 75% (UNEP, 2021) or even 80% (Hoornweg, et al., 2020). Furthermore, cities, in developed and in developing countries, megacities and small cities, rich and poor ones, with high or low population density, represent more than 55% of the world population in total, which number is estimated to increase up to ~ 60% for 2030 (UN-Habitat, 2020). These facts put cities into a central position, how they could increase resilience and tackle climate change during urban development. In this paper, resilience is analysed along sustainable climate change mitigation and adaptation potential, from the perspective of a smaller Central-European city and examines how smart solutions connect and contribute to the urban development.

Our paper includes a literature review, where the role of cities and the importance and literature of urban resilience are interpreted, and the most important definitions are stated. The literature review is followed by a case study. In the chapter of Methods, the applied qualitative methodology is presented, the case study of the development projects and the investigated fields of the settlement, Tamási in Hungary. In the chapter of Results and Discussion, the accomplished developments of Tamási and the achieved improvements are presented and evaluated, from the point of view of sustainability. Finally, a summary and conclusions are given.

Literature Review – Urban Resilience

Cities are the centre of services, development, institutions and industrial activities by the potential to control resources such as natural resources, financial and human capital and act as a platform for insure flow of capital, people and information. With all of the advantages that cities could provide their inhabitants, there are significantly high risks which concentrates in these locations. Cities should enhance their resilience not just but mainly the consequences of climate change, and urbanisation, land consumption, dependence of hinterland, pollution, heat islands effect, waste and water management, housing and infrastructure capacities (Meadows, et al., 1972), (United Nations, 1987), (United Nations, 2012) , (OECD, 2010), (UN-Habitat, 2011), (Revi, et al., 2014), (Kocsis, et al., 2016), (Kovács, et al., 2017). Although, cities represent significant share in consumption of energy and production of waste, they have the local authorities, which can also control these segments (energy use, waste generations, transportation, etc.) by keeping in focus of sustainability and climate mitigation or adaptation (Angel, et al., 1998), (Collier, 1997), (Collier and Löfstedt, 1997), (DeAngelo and Harvey, 1998), (Feldman and Wilt, 1993), (Harvey, 1993), (Lambright, et al., 1996), (McEvoy, et al., 1999), (Wilbanks and Kates, 1999).

The appearance and the spread of the phenomenon of 'Urban Resilience' (UR) started in 1973 (Holling, 1973), which highlight the need of persistence in the case of human and ecology relation. The number of articles and research which was published in the last, less than 50 year in this topic was significantly lower than the parallelly developed usually gradated phenomenon 'Urban Sustainability' (US). The significant increase in the publications of UR has been started in the 2000s (Zhanga and Li, 2018). According to Zhanga and Li (2018), Table 1., the research priorities across global, regional, city, community and facilities levels of 'Urban Resilience' are different. While in the global level UR puts more focus on the self-protection and the after-crisis restoration, until then at a regional level the diversified, stable urban economic structure is the target. On the city level, policy management and institutions get larger consideration, until in the facilities level the reliability and the fast and efficient applicability of the built infrastructure are the priorities.

Table 1. Research scale of Urban Resilience.

Scale	Items	Scale	Items
Global	Ecological environment protection	Urban/city	Urban governance
	Resource protection and utilization		Urban system
	Population and health		Urban Security

Regional	Regional economic structure	Community	Residents’ demand
	Regional resource flow		Neighbourhood
	Regional resource carrying capacity		Community management
Facilities		Infrastructure management	
		Transportation	
		Building	

Source: own edition based on (Zhanga and Li, 2018, p.143).

‘Urban Resilience’ or ‘Resilience’ have not had one globally accepted definition, but this phenomenon is over-weaved by disciplines and scientific fields. Two waves of the approaches could be identified. In the first one, one thing is common, the flexibility, which is needed to cope with the unexpected, the emergency recovery capabilities. In the field of **psychology**, ‘resilience’ is seen once as the ability to effectively cope with inner (development imbalance) and external (major losses) stresses (Werner, 1982), or “reflect the capacity for recovery and maintained adaptive behaviour that may follow initial retreat or incapacity upon initiating a stressful event” (Garmezy, 1991) or as a concept of a “combination of serious risk experiences and a relatively positive psychological outcome despite those experiences” (Rutter, 2006), (Shean, 2015).In the field of **engineering science**, ‘resilience’ is implemented to the system to reduce once potential failure, secondly consequences of faults and finally, the recovery time (Bruneau and Reinhorn, 2006, p. 1), (Bahadur, et al., 2013). In the field of **economics**, ‘resilience’ has been applied in micro, meso and macro level to internalised the motivation of private and public sector policies to contribute to the system recovery from a shock (Rose, 2004), or as a business management approach as a strategy to handle difficulties in the business flow or disaster impacts (Webb, et al., 2000) (Bahadur, et al., 2013). According to **social scientists**, ‘resilience’ is rooted in ecological theories, while cross- and multi- disciplinary methods are needed to adapt. This approach generated the socio-ecological system (SES), which involves both fields equally during the analysis (Folke, 2006). “Urban Resilience is the passive process of monitoring, facilitating, maintaining and recovering a virtual cycle between ecosystem services and human wellbeing through concerted effort under external influencing factors” (Zhanga and Li, 2018, p. 145). Finally, in the field of **ecological science**, ‘resilience’ is measured by the persistence and the ability of systems to absorb fluctuation and maintain previous status (Holling, 1973), (Hassler and Kohler, 2014).

In the second wave of the definition’s development, parallel interpretations exist, which are in common by highlighting the role of uncertainty. According to (Martin and Sunley, 2015) there are three different approaches of ‘resilience’, which differ from each other in reactivity and resistance (Prisi, 2019): technological, ecological and adaptive resilience. ‘Resilience’ according to the technological approach is the return to the stabile status of a system between the timeframe of the external impact and the recovery. According to the ecological approach, ‘resilience’ describes the highest possible external shock that the system can resist without any consequence or any permanent damage. The followers of the adaptive approach see ‘resilience’ as an ability to adapt to the new circumstances that occurred due to the external change. This is a shift in the past system and is hardly measurable.

Despite of the different definitions and approaches, the most common, main characteristics of the phenomenon of resilience are the following (Bahadur, et al., 2013):

- High diversity;
- Effective governance and institutions;
- Acceptance of uncertainty and change;
- Non-equilibrium system dynamics;
- Community involvement and inclusion of local knowledge;
- Preparedness and planning;
- High degree of equity;
- Social capital, values and structures;
- Learning;
- Adoption of a cross-scalar perspective.

In this article, the adaptive approach and the **IPCC** definition are followed, while they are found to include all the relevant prospects from the different fields. According to the IPCC (2014), ‘resilience’ is “the capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation” (IPCC, 2014, p. 5).

Methods

The classification of a country-, region-, city- or even household-level of resilience can be calculated according to several different indices (quantitative method), such as the examination of the labour market, population density, literacy rate, education level of the dwellers, added value of the private sector and so on. In case of the quantitative analysis, the number of the applied indices are varied from one (Drobniak, 2017), or 52 (CRI, 2018) up to even 139 (Wang, et al., 2018), (Nagy, et al., 2020).

However, the adaptive resilience can be hardly measured by indices because it represents a shift in a complex system (Prisi, 2019). For that reason, a qualitative research, the case study method is applied to present the importance of resilient thinking even in a small-scale city development.

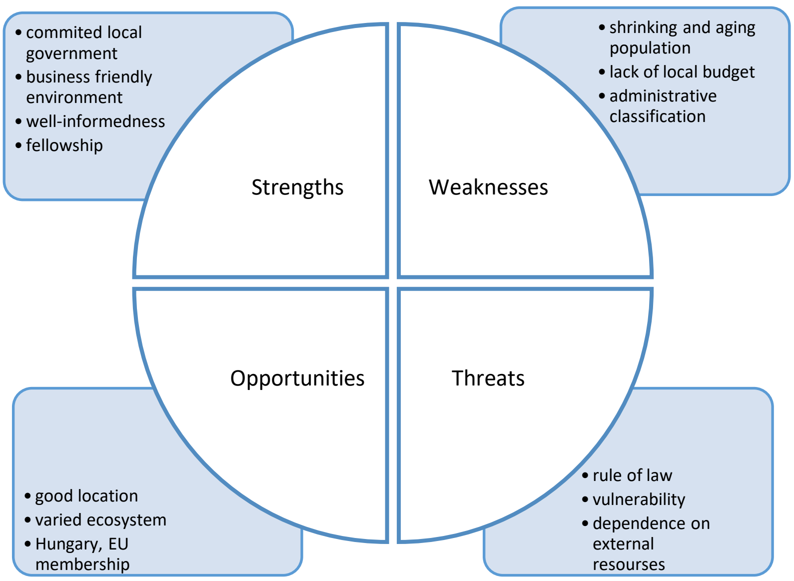
Tamási, a city in Tolna county and the centre of Tamási district in Hungary, was selected to the analysis of resilient thinking, as consequently determined city management goals and significant bottom-up developments have been set, followed and achieved in this city in the last 15 years. The local government is committed to build up a complex, interconnected city management system, which makes Tamási capable to cope with significant challenges as a consequence of social and /or environmental and economic changes.

During the analysis, the complexity and the involved fields of the adapted projects are examined. The aim of the research is to present the potential development that have been achieved through complex and resilient thinking, and to assess its features in the light of sustainability.

Results and Discussion

As a basis for the evaluation of resilient thinking, a SWOT analysis was made for Tamási.

Figure 1. SWOT analysis of Tamási.



Source: own edition

Tamási's environment has varied terrain and provides thermal spa facility, which is the base of the region tourism. It is located near to Lake Balaton and it is just one hour away from Paks, which city currently has one of the biggest investments and developments in Hungary. The local government of the city is determined to the sustainable, climate resilient development which consider nature and social well-being beside economic efficiency, as well. The development projects usually mixed financed from either or both local, national budget and from EU funds. While, the city has shrinking and aging population, in January 2020, 7.852 dwellers in 11.195 hectares (KSH, 2020), which data determines its administrative classifications and the available resources and the projects.

Tamási as regional best practice

In Tamási, the local government sets its development projects' planning and their implementations according to three leading factors to create an integrated city management system. These factors are environmental, economic and social factors, where environmental and economic factors are inseparable from each other, and their sustainability is key during the decision-making process. The environmental awareness comes from once the local heritage and the small city status dependence, while the economic cost-efficiency, sustainability connected to the limited available resources and the common sense. In Tamási, during the last decade, an integrated city management system has been built up through relevant development projects and conscious new project implementations with the use and integration of smart technology. The projects and the management system increase the resilience and sustainability of the city (Hallegatte et al., 2020):

- by identifying medium and long-term purposes according to local abilities and needs, concluded in Tamási City Development Strategy (Dulicz, 2016) and in Tamási's Climate Strategy (Tamási Municipality, 2020);
- following their strategy, the main goals were broken down into manageable targets, development projects;
- the development projects were prioritised according to local needs (current, medium, long-term);
- during the development, the inclusivity of local dwellers has been increased;
- the “plan – implement – monetarize – intervene” steps were followed;
- the capability of immediate modification has enhanced by the integrated systems to prevent or lighten external shocks,
- efficient natural resources utilization has been adapted;
- the environmental footprint of the city has shrunk;
- the city infrastructure has been improved;
- the efficiency of the public services has been developed
- the engagement between citizens and local government improved;
- and finally the city never stops developing.

Those, previously mentioned projects, which helped to increase the resilience of the city are the following (Széles, 2017), (Széles, 2018):

The first significant project in this development was the **geothermic heating system**, which is based on the main natural, tourist attraction of the location, the use of the 47 Celsius hot, thermal and curative water. Based on this natural opportunity a heating system was established provide heating service for 17 service points in 4,7 km long. Through the integrated smart operational system the whole process is adjustable, a necessary intervention can be made in any point and during the whole operation data is collected that provide information for intermediate interventions or future optimalization. While this system used in public facilities, such as dormitories, government offices, police station etc., different heating curves are set, which fits to the need of the service points. By using the natural heat of the thermal water 70 percent expenditure saving could be achieved. The remaining 30 percent of cost, which comes from the use of gas-based heating was replaced, through another project, by using **biomass-based heating** from the locally collected green waste. Currently this heating system is only using renewable energy. Through this project, the city could increase its energy efficiency, by separating from an unsustainable energy resources and utilize its natural resource in a sustainable way by not causing any harm in it. This intervention decreased the emitted greenhouse gases, the amount of the used energy and changed the resource of it. Beside the economic advantages of the project, such as reduction in the system's maintaining and heating expenses and the reduction in green waste handling fee, the project increased the self-sufficient ability of the city by using renewable energy, which is generated by locally and by distributing the natural resource more consciously the gas consumption has dropped.

Since 2018, the locally abundant **green waste** is collected separately and its pass at the collection point is free of charge to ensure the needed biomass and the fundamental treatment of the green waste. Those who contribute to the biomass with green waste, receives extra point in the city card system, which could be transfer for discount in the local shops or for services. With this movement, the local government tried to approximate to circular economy and increase the citizens environmental awareness and engagement to the development. By the use of green waste, the number of households burning dropped, which caused better air quality and smaller air pollution, including GHG emission as well.

The next project is the improvement of the **public lighting system**, 1.445 pieces of old public lightnings were replaced by new LED streetlights, which includes SIM cards, operates online with Citytouch management system and communicates on LORA. Through this solution, each and every lamp in the grid could be controlled separately from the others, through the remote control the luminous intensity could be set, and the streetlamps could be switch on or off according to the need of different residential areas. Additionally, the system could send instant feedback about possible breakdown with the details of the failure, the location and number of the lamps. According to this push notification, the reparation can accelerate, which can increase the satisfaction of the inhabitants with the public service. As the benefits of this project the nominal energy use dropped by 40 percent, and 20 percent drop could be achieved by the control over the luminous intensity. With this more energy efficient solution the city greenhouse gas (GHG) emission, energy usage and energy expenses decrease, the traffic-safety increases, and new administrative divisions, peripheries, received infrastructural development by installing the old lamps, which generated higher social inclusivity. This LED public lighting system provide further development potential such as installing cameras for security reason, traffic counting, traffic lights control, traffic control system to optimise public transportation, parking systems, air pollution measurement etc., but its main advantage is the network that can connect tools, collect and analyse data and become main part of the city management system. Through this, the decision-making of the location can become more valid and grounded.

Based on this project in 2017, 20 **thermometer sensors** were installed in 20 elderly dwellers' home, who were the most vulnerable for the winter stress. These sensors monitor the daily temperature in the houses and send alert if the temperature drop under a critical value. This simple service can increase the inclusion of the marginalised people, social responsibility, through the collected data the provided social services during wintertime could be optimized.

Considering the challenges of the local dwellers, an **intelligent wastewater pump** system was built, which in case of a blockage, cleans itself without any stoppage in the service. This system has been integrated and in the first year prevented almost 150 cases and up to now almost 400 cases. That is resulted a significant expenditure saving (wages, stop in the operation during fieldwork, disinfection, lower maintaining expenses, etc.) Connected to this topic, Tamási has a **smart rest room** at its main bus station, which is 100 percent accountable, sends push notifications when the fundamental tools are out of stock or immediate intervention is needed. These developments are economically sustainable, decrease health risks and related expenses. These projects serve as a good example for considering the essential need of the inhabitants and find smart sustainable solutions for them.

To further increase the energy efficiency of the city, they use **solar cells** in office – school - police buildings as part of the 'smart building' development and **sensors** for monetarize water usage and identify water leakage. During the COVID-19 pandemic, the establishment and the use of **e-administration** options have been improved and increased to ensure safety during administration.

Conclusions

The local government of Tamási sees the city as an excellent testing platform for experiments with new technologies to eliminate the early defects of the innovations and through this living lab form, the innovations and the best practices, that are technologically developed in place, can increase the sustainability and resilience not just locally, but could be adapted by bigger and more complex cities, regions. Tamási has the essential motivation, sustainability centred attitude and the capability to take this stakeholder position.

As it is showed through the diverse development projects in Tamási, the resilience of a city can be increased by deliberate city management, complex interconnected network-based approach, involvement of the community to identify the areas of improvements, considerations of the local capacity and challenges and finally openness to learning.

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121 An analysis of the Sustainability in the Engineering degree in Industrial Design and Product Development

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Abstract

Education for the Sustainable Development Goals (ESDG) in universities calls teachers to become agents of change, capable of training graduates on the challenges that the Agenda 2030 arises and to qualify students with the needed SDG competencies. Being able to conduct an analysis that maps the current situation in a degree is the starting point to tackle such a challenge, by helping to become aware of which gaps and opportunities exist and might be addressed. The EDINSOST2-SDG project, involving 8 Spanish universities, sets the framework for this study. This paper shows the results of diagnosing the presence of the sustainability competencies and the SDG at the undergraduate engineering degree in Industrial Design and Product Development at the School of Engineering of Vilanova i la Geltrú of the Universitat Politècnica de Catalunya. The methodology developed and applied to measure the presence of sustainability and the SDG in the degree has been piloted in a previous phase of the case study. Results showed how using official documentation and study guides as information sources implied depending on the validity of these documents, which are not always updated. In this phase, data is obtained through the questionnaires for teachers designed at EDINSOST2-SDG and compared to previous results to validate and further develop the methodology. First step is detecting which subjects should be prioritized for conducting the analysis and developing a strategy to gather information. Second step is developing a Sustainability Presence Map, that shows the percentage of presence per degree, semester and subject, of the 4 sustainability competencies proposed by the Conference of the Presidents of the Spanish Universities (CRUE). Third step is to obtain an SDG Presence Map, which provides information about the presence of the SDG according to the UNESCO SDGs learning objectives. Step 4 is comparing the results of both phases of the case study and discussing which sources are more reliable and why this methodology can be useful for the higher education industry.

Keywords: Education for sustainable development, Sustainability in engineering degrees, Curriculum design, Sustainability competences.

Introduction

Political and social background

In 2015, the United Nations adopted the Agenda 2030 for Sustainable Development. To stimulate actions over the next few years, the resolution proposes 17 Sustainable Development Goals (SDG) and 169 associated targets to facilitate the balance between the three dimensions of sustainable development: the economic, the social and the environmental. SDG4, Quality Education, affirms that by obtaining a quality education one sets the foundation to improve people's lives and sustainable development. Universities are called to work towards this goal when considering its target 4.7; «By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, gender equality, promotion of a culture of peace and non-violence, global citizenship and appreciation of cultural diversity and of culture's contribution to sustainable development» (United Nations, 2015).

In May 2021, the UNESCO World Conference on Education for Sustainable Development gathered participants form governments, international, intergovernmental and non-governmental organisations, civil society, youth, the academic community, the business sector and all spheres of teaching and learning. All of them adopted the Berlin declaration of Education for Sustainable Development asking for urgent action regarding the «dramatic and interrelated challenges that the world is facing, particularly, the climate crisis, mass loss of biodiversity, pollution, pandemic diseases, extreme poverty and inequalities, violent conflicts and other environmental, social and economic crisis that endanger life on our planet» (UNESCO, 2021).

The 20th may, the Spanish government published the law on climate change and energy transition, specifying that «The Government shall encourage universities to review the treatment of climate change in the curricula leading to the award of official university degrees where it is coherent with the competencies inherent to them, as well as training of university teaching staff in this field» (Ley 7/2021, de 20 de Mayo, de Cambio Climático y Transición Energética., 2020). In addition, at a local level, the 14th of May of 2019, the Catalan Government declared the Climate Emergency. Climate movements criticized its process and content, denouncing a lack of participation and clear goals. As a response, the movements redacted a document gathering 11 urgent policies to face the climate emergency. In relation to education and training, the article number 10 of the document urged to «revise the current curriculum so that within a maximum of 3 years, the education system addresses the state of climate and ecological emergency in both regulated education and social education programmes, incorporating rigorous knowledge about the seriousness of the problem, the causes, the false solutions and the urgent policies that need to be undertaken to address the drastic reduction of greenhouse gas emissions». The urgent policy also demands continuous training programmes for primary, secondary, high school and university teachers and, for the coming academic year and as a first step, including the subject of climate emergency in secondary schools and teacher training in universities (Xarxa climàtica, 2020).

Considering this background, a new scenario is open to promote changes in the Spanish education system. To accelerate Education for the SDGs in Universities 5 main steps should be followed. Step 1, Mapping what a university is already doing; step 2, building capacity and ownership for ESDGs; step 3, identifying priorities, opportunities and gaps; step 4, integrating, implementing and embedding SDGs and step 5, monitoring, evaluating and communicating (Australia/Pacific SDSN, 2017).

The EDINSOST2-SDG framework

EDINSOST2-SDG is a project aimed at integrating SDGs into sustainability training in Spanish university degrees and continues with the achievements of the project EDINSOST. It is financed by the Spanish Ministry of Science, Innovation and Universities (MCIU), the State Research Agency (AEI) and the European Regional Development Fund (Sánchez-Carracedo et al., 2020; Segalàs Coral & Sánchez Carracedo, 2019). The project provides a set of tools that allow to map the learning of sustainability and the SDGs in a degree, which contributes to accomplish step 1 of the 5 steps recommended by the SDSN. Even so, a methodology has not yet been developed to exploit these tools for obtaining tangible results, a fact that sets the objective of this paper. The tools applied in this case study are the following:

- Engineering Sustainability Map (ESM)

The ESM is a matrix containing a common Sustainability Map for all engineering degrees which summarizes 53 learning outcomes related to the 4 transversal sustainability competences proposed by CRUE (CRUE, 2012) and the SDGs' learning objectives proposed by UNESCO (UNESCO, 2017). The 4 CRUE competencies are operationalized in 4 possible dimensions (social, economic, environmental and holistic), 7 competency units, 3 domain levels (according to the Miller's pyramid) and end up in 53 learning outcomes.

- Sustainability Presence Map (SPM)

The SPM is a matrix that shows how a subject or group of subjects fulfils the learning outcomes of the ESM. Each cell relates each learning outcome proposed by the ESM to each subject that is being taught in the degree.

- Questionnaire for professors

The questionnaire for professors was designed to complete the Sustainability Presence map. Previous research pointed out that using official documentation and teaching guides as information sources did not offer truthful results, as those sources are not always up to date. The survey, consisting of 22 questions and 53 sub-questions, was designed to obtain information about the accomplishment of the 53 learning outcomes of the ESM, according to the teacher's perspective.

- SDG Presence Map (SDGPM)

The SDGPM is a matrix that shows how a subject or group of subjects fulfils the SDG based on the learning objectives of UNESCO.

Context of the case study

This case study is piloted in the bachelor's degree in Industrial Design and Product Development Engineering that is being taught at the UPC Engineering School of Vilanova i la Geltrú (EPSEVG). The degree provides the student with the skills to become an industrial engineer and a product developer. The school management team has shown interest in improving the presence of sustainability and the SDGs in their degrees and has encouraged teachers to participate in this study.

To organise the acquisition of skills among the student body, the UPC defines four types of competences in their educational system:

- Transversal competences: competences that are common to all students at the UPC, regardless of the degree they are pursuing (ANECA, 2012).
- Basic competences: competences that are common to most degrees but are adapted to the specific context of each degree. (ANECA, 2012).
- General competences: competencies that are intended to provide students with useful knowledge, skills and attitudes to function in their professional field. (ANECA, 2012).
- Specific competences: competences specific to a degree that are oriented to the achievement of a specific graduate profile (ANECA, 2012).

Competencies are distributed throughout the subjects of the degree by curriculum designers and end up configuring the degree structure. Figure 1 Shows the curriculum containing the common framework of the degree in Industrial Design and Product Development Engineering, the specific optional subjects related to itineraries and the cross curricular electives. The degree has a study load of 240 ECTS [7]. These are distributed in 60 basic education credits (10 subjects), 126 compulsory credits (21 subjects), 30 optional credits (5 subjects) and a final degree project worth 24 credits. A total of 51 subjects configures the degree.

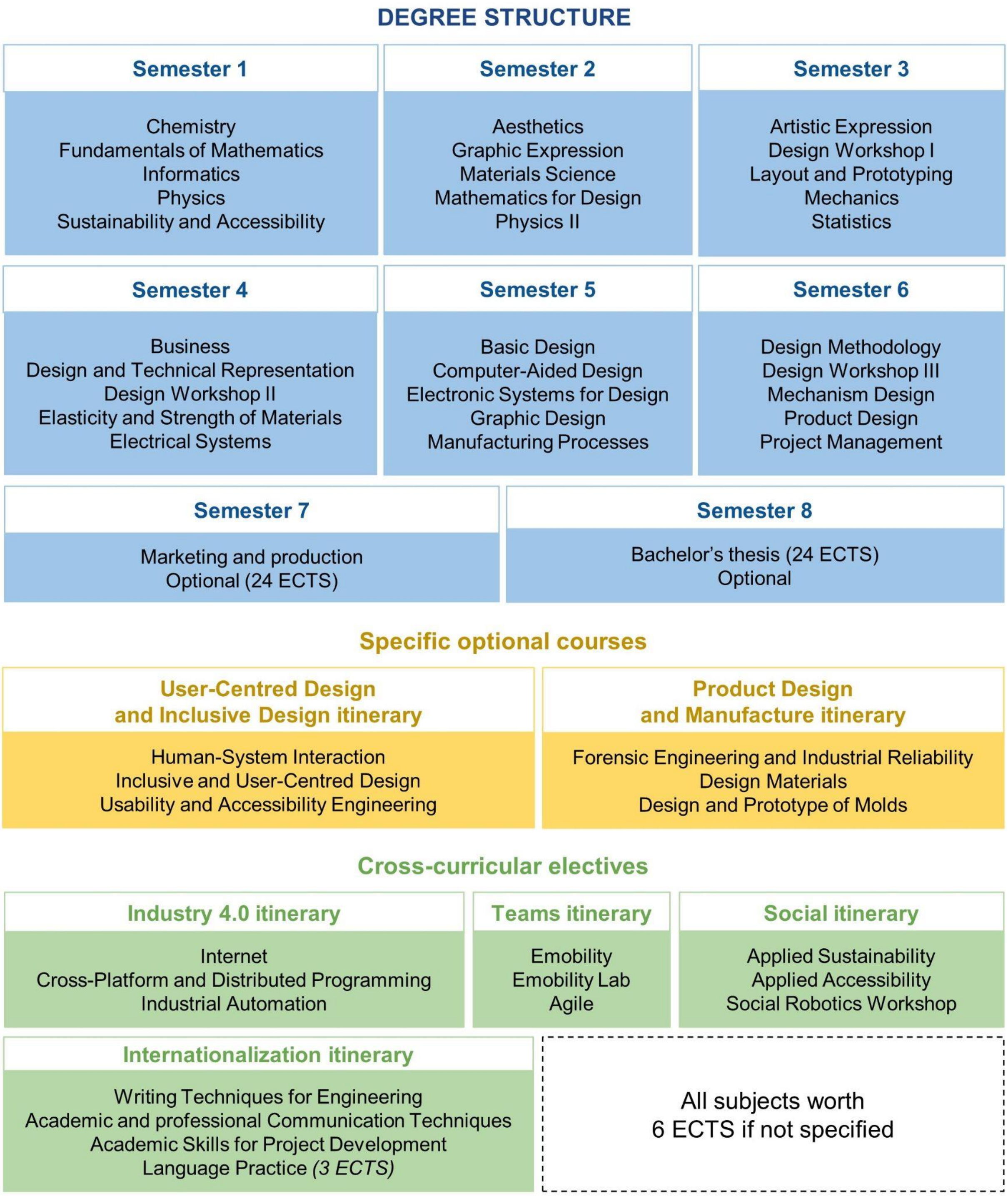

Figure 1. Structure of the undergraduate degree in Industrial Design and Product Development Engineering at EPSEVG.

Methods

This paper presents the piloting of a methodology to evaluate the presence of sustainability and the SDGs in Engineering Degrees, using tools provided by EDINSOST2-SDG. The methodology is piloted as a case study to the Engineering Design degree taught at EPSEVG of the Universitat Politècnica de Catalunya.

First step is to provide the questionnaire to the teaching staff. The questionnaire has to be answered by the professor who is responsible for the subject and each subject requires a minimum of one answer to be evaluated. Convincing teachers to participate in the process is crucial. Identifying which subjects are more likely to address sustainability issues is helpful to be aware of which teachers should be prioritised in case of need. This study also counted with the school management support, a fact that encouraged teachers to contribute to the research.

Second step is to apply the answers of the questionnaire to the Sustainability presence map (SPM). The questions of the survey are directly related to the presence of the 53 learning outcomes of the Engineering Sustainability Map (ESM) in a subject. Subsequently, to convert the answers of the questionnaire into a numerical score in the SPM, it is necessary to pay attention on which questions are related to each learning outcome of the ESM. The criteria to score the corresponding learning outcomes implies that those answers marked with “Nothing” equal “0”; “Little” equal “1”; “Quite a bit” equal “2” and “A lot” equal “3”. Table 1 shows the layout of the SPM. In case that a subject has more than one coordinator, the scores of the answers of the questionnaire have been averaged and the final score for each learning outcome has been rounded up to fit the scoring criteria.

Table 1. SPM layout when applying the answers of the questionnaire.

Applying the answers of the questionnaire to the SPM		Competences of the degree		
		Subject 1	Subject …	Subject n
ESM learning outcomes	Learning outcome 1	*3, 2, 1 or 0*	*3, 2, 1 or 0*	*3, 2, 1 or 0*
	Learning outcome …	*3, 2, 1 or 0*	*3, 2, 1 or 0*	*3, 2, 1 or 0*
	Learning outcome n	*3, 2, 1 or 0*	*3, 2, 1 or 0*	*3, 2, 1 or 0*

Third step is to convert the score of the SPM into percentage. Eq. (1) must be applied in each cell of the SPM to obtain a percentage that considers the operationalisation of the ESM. The results that can be obtained through this formula will show information about the presence of the 4 sustainability competences. To obtain information about the competency units, the final results of competence 2 need to be multiplied by the number of competency units that are related to the competence, which are 4 (CU2, CU3, CU4 and CU5).

$$SPM[\%] = \frac{100 * SPMscore}{nDIM * nCU * nL * nPr} \quad (1).$$

SPMscore: cell score in the SPM; ***nDIM:*** number of possible dimensions of a competence; ***nCU:*** number of competency units related to the dimension; ***nL***: number of learning levels related to the competency unit; ***nLO:*** number of learning outcomes related to the level; **n*Pr:*** number of possible results according to the SPM scoring criteria. Scoring 0 will always mean a 0% of presence. Therefore, it is not considered as a possible result that distributes weight of the percentage.

Once the SPM [%] is completed, adding up the results of each subject according to the operationalisation of the Engineering Sustainability Map, allows to gather information at different levels, i.e., the percentage of presence according to each Competency Unit or to each of the 4 CRUE competencies. To analyse the presence of Sustainability in a set of subjects, for instance, to obtain information related to a specific itinerary, a semester or a degree, the scoring of each learning outcome of the subjects will be averaged. This process will generate a new column which can provide results with the same format as the analysis of a subject.

Fourth step is completing the SDG Presence Map (SDGPM), which allows to obtain the presence of SDGs in a degree. As table 2 illustrates, it is a matrix set for each subject of the degree showing the presence [%] of each SDG (columns) in relation to each learning outcome (rows). To calculate the presence of each SDG in a subject, the percentage of presence of each SDG related to a learning outcome has to be multiplied by the percentage of the SPM[%] of the corresponding learning outcome. Multiplying the two results allows to calculate to what extent the percentage of SDGs are being covered through the scoring of a learning outcome.

Table 2. SDGPM layout.

SDGPM of a subject		Competences of the degree		
		SDG1	SDG …	SDG17
ESM learning outcomes	Learning outcome 1	*SPM[%] * SDG[%]*	*SPM[%] * SDG[%]*	*SPM[%] * SDG[%]*
	Learning outcome …	*SPM[%] * SDG[%]*	*SPM[%] * SDG[%]*	*SPM[%] * SDG[%]*
	Learning outcome n	*SPM[%] * SDG[%]*	*SPM[%] * SDG[%]*	*SPM[%] * SDG[%]*

The sum of each column containing the score of each learning outcome synthesizes the results of the presence of each SDG in a subject. To combine a set of subjects, the scoring of each learning outcome of the different subjects will be averaged. This operation will allow us to obtain 17 new columns gathering an average score for each learning outcome in relation to each SDG. As a final step, the percentage of each column will be summed, obtaining an average score of the presence of each SDG in the set of subjects to be calculated.

Results and Discussion

Results of the diagnosis

First aspect to discuss is the scope of the analysis. Data has been obtained from 20 subjects which did not allow an analysis of the entire degree yet. Even so, the methodology applied in this case study has shown interesting results that will be completed as more teachers are convinced to participate in the analysis. The information that has been collected involved the following subjects: *Physics, Sustainability and Accessibility, Materials Science, Layout and prototyping, Business, Basic design, Manufacturing processes, Electronic systems for design, Mechanism design, Design methodology, Inclusive and User-Centred design, Design and prototype of moulds, Marketing and production, Human-System interaction, Multiplatform and distributed programming, Mechanics, Mathematics for design, Electrical Systems, Applied Sustainability* and *Usability and Accessibility Engineering*.

The methodology presented in this article provides two types of results. It is possible to obtain data about the presence of the 4 competences in sustainability defined by CRUE and results according to the Competency Units featured on the Engineering Sustainability Map. Results can be presented either by grouping subjects together or by analysing each subject individually. The diagnosis also provides information about the presence of the SDGs, considering the UNESCO learning objectives and their relation to the 53 learning outcomes of the Engineering Sustainability Map.

Results are synthesized in a graphical format to ease the communication of the diagnosis outcomes. Spider charts show how competences or SDGs are covered. Visualizing the presence of sustainability and SDGs in a degree raise awareness of which aspects could be improved in a curriculum. A diagnosis of a cluster of subjects, which could be an analysis including an itinerary, semester or degree, shows an average presence, which helps to highlight which are the less (or most) sustainability-aspects being addressed. Considering the results of a specific subject provides hints on which competencies could be further developed and therefore enhancing the whole itinerary, semester or degree results.

The next figures are examples of the information that can be obtained. Figures 2 and 3 represent the average percentage of presence obtained when clustering the results of the 20 surveys that were answered. Figure 2 shows the results according to the 4 CRUE competencies, related to sustainability. Results show a balanced percentage in competences 1, 2 and 4 (C1, C2, C4) while competence 3 (C3) has a lower presence. By observing figure 3, which shows the results according to competency units (CU), CU2, CU3 and CU6 appear as the ones that are being less addressed. Consulting which learning outcomes of the Engineering Sustainability Map are related to these competencies may help to develop a strategy to add new content in this set of subjects to improve the presence of the 4 sustainability competences. To understand the results, it is important to bear in mind that the concept "presence" used when considering the presence of the sustainability competencies, refers to the percentage of accomplishment of the learning outcomes of the ESM proposed by EDINSOST2-SDG. A group of subjects would very rarely score a 100% of presence but the methodology offers results that expose which competencies are being prioritized and which none.

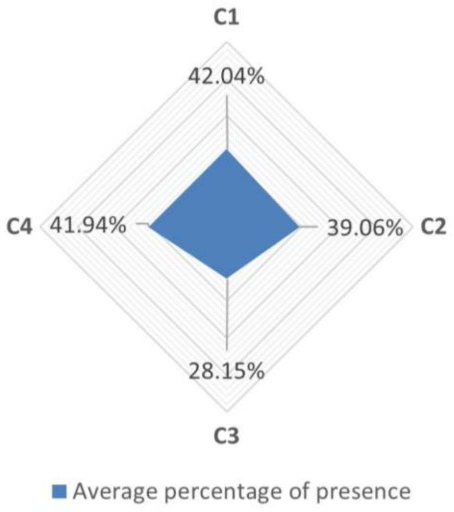

Figure 2. Average percentage of presence of the 4 CRUE competencies of the whole range of subjects.

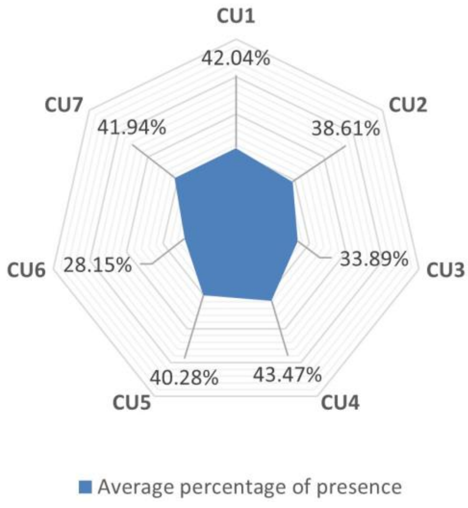

Figure 3. Average percentage of presence of the Competency Units of the whole range of subjects.

Figure 4 and 5 show results of the analysis at a more specific level. Figure 4 shows the spider diagram related to the percentage of presence of the 4 sustainability competencies in the subject Materials Science. Results clearly indicate how C1 and C4 are being prioritized. Figure 5 shows the results of the same subject related to the competency units. CU1 and CU7 show the highest percentage of presence. In this case, as an example to understand the potential of the analysis, it could be useful to discuss how to improve the presence of C2 which is related to the sustainable use of resources and prevention of negative impacts on the natural and social environment. C2 is disaggregated in CU2, CU3, CU4 and CU5 which include concepts such as circular economy or environmental impact that can be related to the subject. On the other hand, C3 and CU6 might be less likely to be associated with the subject materials science, since these are related to participation in community processes that promote sustainability.

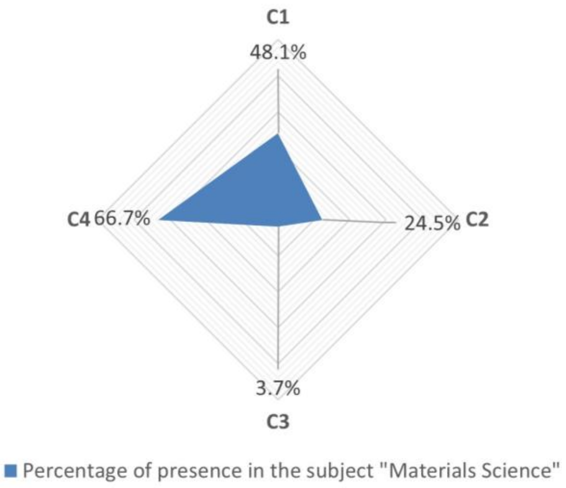

Figure 4. Percentage of presence of the 4 CRUE competencies in the subject Materials Science.

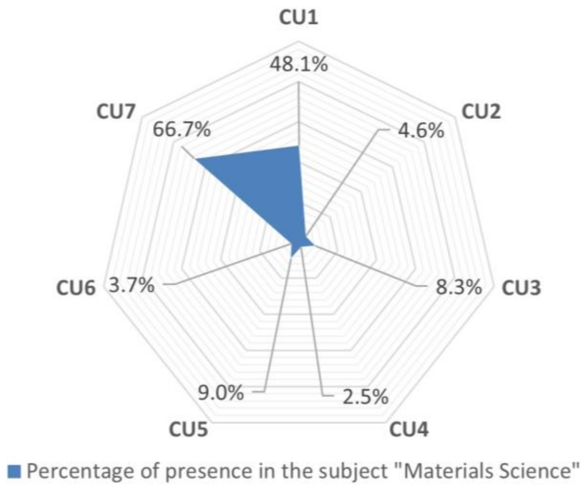

Figure 5. Percentage of presence of the Competency Units in the subject Materials Science.

Figures 6 and 7 show the results of the analysis in relation to SDGs. To interpret the charts, it is needed to notice that the concept "presence" used when analysing the presence of the SDGs, is related to which SDG learning objectives are related to the Engineering Sustainability Map. Some of the SDGs learning objectives are not related to any of the 53 learning outcomes and therefore, SDG2 (No hunger), SDG14 (Life below water) and SDG15 (Life on land) will always score 0. The EDINSOST2-SDG project is currently working on finding further relations between the learning outcomes and the SDGs. Due to this fact and considering that SDGs are indivisible and interrelated, it has been decided to include all SDGs in the results of the analysis anyways.

Figure 6 shows the average percentage of presence of the SDGs in the group of subjects analysed in this study case. Results show a certain homogeneity, but a desired scenario should show how SDGs related to product engineering stand out from the rest. Results show, in example, how SDG7 (affordable and clean energy), SDG9 (Industry, innovation and infrastructure) and SDG12 (Responsible consumption and production) may have room for improvement, considering their close relation to the topic.

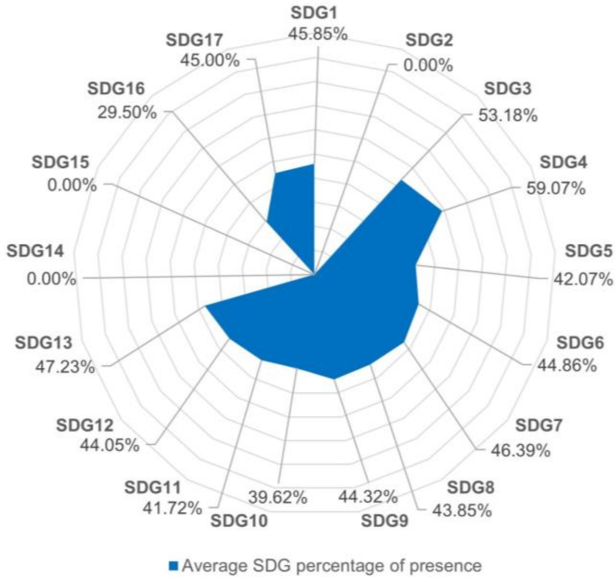

Figure 6. Average SDG percentage of presence of the whole range of subjects.

Figure 7 shows the SDG percentage of presence in the subject Materials Science. In the same way as the analysis of the 4 Sustainability competences in a subject, deepening into a more specific level of presence shows more accurate results. In this case, SDG3 (Good health and well-being) and SDG4 (Quality Education) stand out, letting us know that the subject is oriented to aspects related to health and includes an important amount of learning outcomes related to education. As an example to consider SDGs aspects to include in the subject, SDG6 (Clean water and Sanitation) is a SDG interesting to discuss with the teacher by relating it to water pollution caused by the production and disposal of specific materials. On the other hand, SDG9 (Industry, innovation and infrastructure) and SDG12 (Responsible consumption and production) are also likely to be discussed as long as they should be very present in the degree.

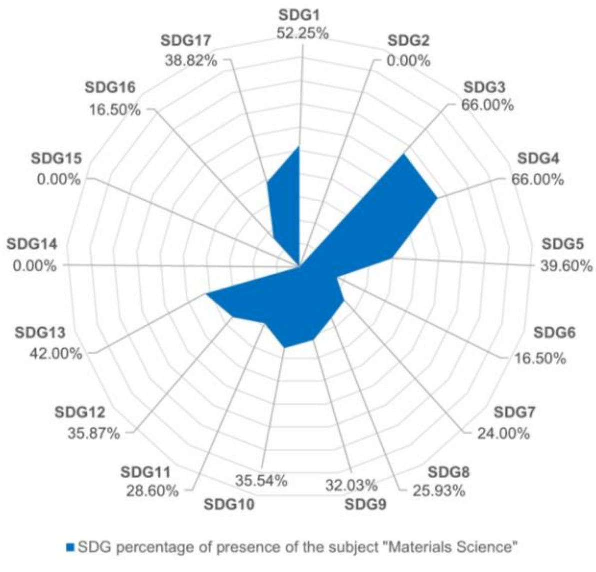

Figure 7. SDG percentage of presence of the subject Materials Science.

Comparison of the data sources

A comparative analysis has been carried out to demonstrate how the results may vary depending on the sources of information, which can be the official documentation of the degree, the study plans or the questionnaires.

The first aspect to discuss is the scope of the analysis. In this comparative study, only those subjects with available data from the three data sources were taken into consideration. The information has been limited by the number of questionnaires answered by the teachers. Thus, the comparative analysis considers the same subjects as the previous diagnose. These 20 subjects are *Physics, Sustainability and Accessibility, Materials Science, Layout and prototyping, Business, Basic design, Manufacturing processes, Electronic systems for design, Mechanism design, Design methodology, Inclusive and User-Centred design, Design and prototype of moulds, Marketing and production, Human-System interaction, Multiplatform and distributed programming, Mechanics, Mathematics for design, Electrical Systems, Applied Sustainability* and *Usability and Accessibility Engineering*.

Second aspect to discuss is the capacity of gathering information through each source and their validity. Official documentation and study guides provide information about a higher number of subjects (62 and 72 subjects, respectively) while questionnaires gather less data by far (20 subjects).

The official documentation distributes competencies in a non-truthful manner, i.e., by distributing the same competencies for all the elective subjects or including subjects which do not exist in the current degree structure, questioning whether the documentation is up to date.

Study guides provide information about a slightly higher number of subjects in comparison to official documentation and those subjects are up to date. Regarding the validity of the source, competencies in study guides are not distributed exhaustively i.e., by skipping types of competencies or adding competencies that do not match with the official documentation. This lack of coherence is critical since the methodology to analyse the presence of CRUE competences and SDGs through official documentation and study guides depends on the competencies related to each subject.

Obtaining information through questionnaires has proven to be challenging as it depends on the predisposition of each teacher to participate in the study or not. Obtaining information about each subject of the degree would allow a precise analysis of the presence of CRUE competencies and SDGs at an itinerary, semester or degree level. The validity of the information does fit the content of the subject, but data contains a bias, as the answers are based on the teacher's opinion, their knowledge in relation to sustainability, their attitude when completing the questionnaire, etc. To overcome this bias, critical thinking related to sustainability should be included in further steps to introduce sustainability in a degree, specifically when developing teacher training courses. This will contribute to flattening the learning curve of the teaching staff when using the questionnaire as a tool to conduct future diagnoses.

In relation to the results that can be obtained from the 3 data sources, Figures 8 and 9 exemplify some of the differences. Figure 8 shows the results of the diagnosis when clustering the whole set of subjects. The average percentage of presence of the 4 CRUE competencies are represented in blue, red and yellow to distinguish the source from where the results are coming. As expected, the results vary considerably directly affecting the interpretation of the analysis and the further discussion of which actions should be taken.

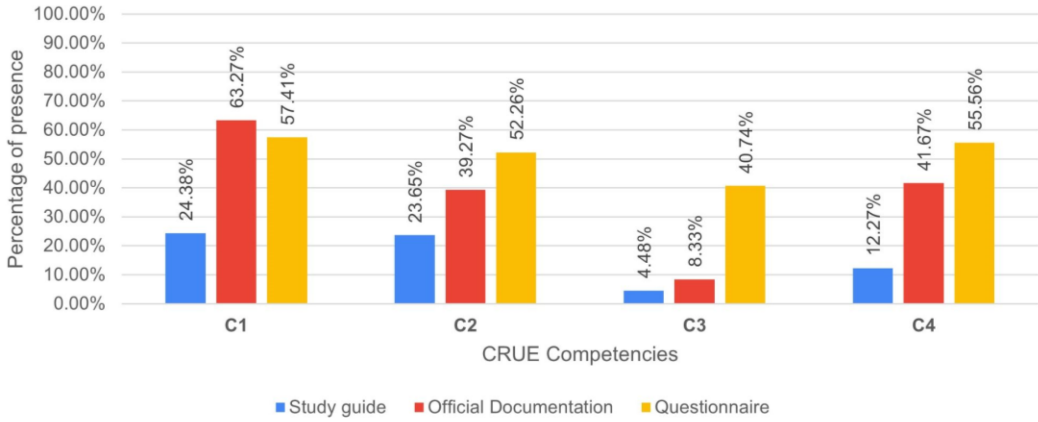

Figure 8. Average percentage of presence of the Competency Units of the whole range of subjects. Comparison of the results obtained using study guides, official documentation and questionnaires as sources of information.

Figure 9 shows these differences in a more precise way, as it shows the presence of the 4 CRUE competencies in a specific subject, Manufacturing processes. The results vary drastically depending on the source. This pattern is repeated when analysing the results of the other subjects of the study.

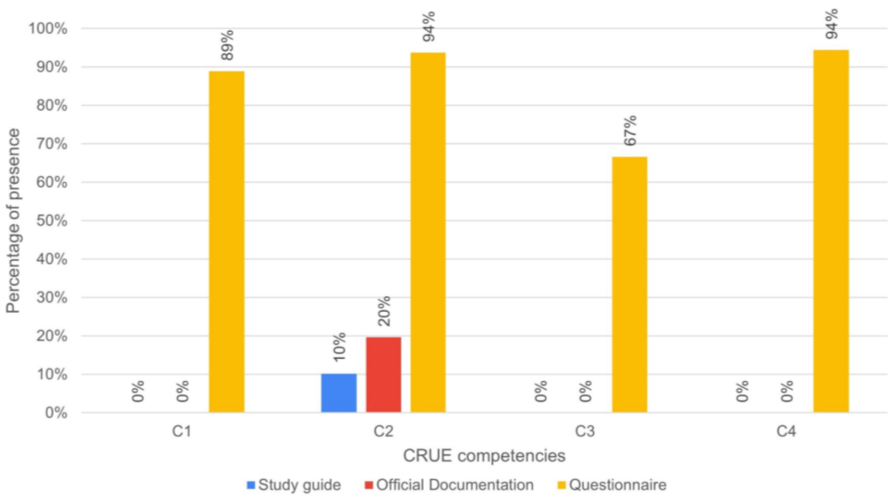

Figure 9. Percentage of presence of the 4 CRUE competencies in the subject Manufacturing Processes. Comparison of the results obtained using Study guides, Official documentation and Questionnaires as sources of information.

Conclusions

In this article, we have introduced a methodology allowing to map the current situation of a degree regarding the presence of the 4 Sustainability competences proposed by CRUE and the presence of the SDGs based on the SDGs learning objectives and the learning outcomes proposed in the project EDINSOST2-SDG. The methodology has been applied to the Engineering Degree of Design at the EPSEVG of the UPC. Performing such an analysis in a degree contributes in clearing the path to building capacity among the teachers, identifying opportunities and gaps to integrate sustainability and SDGs in a subject or cluster of subjects (itinerary, semester, degree…) and it also directly contributes to evaluating and communicating how sustainability is being addressed in a degree.

A comparative analysis has been conducted to explore which data sources are more reliable to analyse the presence of the 4 sustainability competences and the SDGs in a subject or degree. Results have shown how official documentation and study guides are not to be trusted when applying this methodology but conducting an analysis through these sources is useful to become aware of the coherence of these documents and could help university staff to generate future versions of these documents. Using questionnaires as a data source has turned out to be an optimal method to provide results that are more in line with the classroom's reality. As this is a new type of analysis thought to be implemented in universities, it should be noted that it involves a learning curve, not only for those who are conducting it, but also for teachers who answer the questionnaire and are eager to introduce sustainability in their subjects. It is expected that as more analyses are carried out, the results will be more accurately adapted to reality. A step further to confirm the validity of the results could involve gathering teachers' opinions through in-depth interviews and the students' learning progress related to sustainability and the SDGs.

Available results show how sustainability is being embedded in 20 subjects of the degree. Engaging teachers to participate in the study is a key aspect to analyse the whole degree since results can show how sustainability is being addressed in a subject, itinerary, semester, degree or any other possible cluster of subjects, but the data availability depends on the teacher's willingness to participate in the study.

Further steps to complete the scope of the analysis should include more connections between the 53 learning outcomes of EDINSOST2-SDG and the SDGs. Another interesting aspect to explore is the possibility of providing an easy and intuitive way to perform the analysis. Refining the way results are communicated is also an opportunity for improvement, i.e., by showing the results while providing recommendations on which learning outcomes could help to achieve desired scenarios.

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290 Empowering Communities in the light of the Maximum Ordinality Principle. Selected case studies well beyond energy scarcity

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Abstract

The present paper aims at showing how Empowering Communities may progressively increase their role by adopting the Maximum Ordinality Principle (MOP) as basic reference criterion. This is because its adoption on behalf of a given Community generates an increasing sense of being a real Community, together with its correlative responsibilities. This aspect will preliminarily be shown in the case of adverse conditions, such as for instance energy scarcity. However, the process becomes much more intensive when the MOP is adopted to deal with aspects that go well beyond energy scarcity. In such a perspective, we assumed as Reference System five European Countries (Italy, France, Spain, Germany, Austria), which were modelled as a unique and sole Self-Organizing System, that is understood as being a Real Community. In this way, after having preliminarily shown the increase of Resistance and Resilience of such an Ordinal Community adverse energy scarcity, immediately after the paper will present the most appropriate modalities for the research for new energy sources, always with reference to the same Ordinal Community. However, as a further significant contribution of the MOP, the paper will then show how the considered Countries can even more increase their consciousness of being a real and proper Community. Not only with reference to their Ordinal Relationships within themselves, but also, and especially, in terms of their Ordinal Relationships with all the other surrounding Countries, and even with the Environment. All these aspects, in fact, can become an effective reality precisely because, as previously anticipated, the adoption of the MOP as Reference Principle represents a valid choice for analyzing both "non-living", "living" and "conscious" Self-Organizing Systems.

Keywords: Empowering Communities, Maximum Ordinality Principle, Incipient Derivative

Introduction

The Ostensive Example adopted as an introductory case study is a System made up of five almost adjacent European Countries (Italy, France, Spain, Germany, Austria). Such countries, considered in the light of the MOP, were modelled as a unique and sole Self-Organizing System, in order to successively analyze, as already anticipated in the abstract, several and diversified aspects which go well beyond the energy scarcity. To this purpose, it is then preliminarily worth recalling the physical and conceptual bases of the MOP and its correlative formal language.

The Reference Principle adopted for the abovementioned analysis and its correlative formal language

The Maximum Ordinality Principle (MOP), presented in 2010 at the 6th Biennial Emergy Conference, Univ. of Florida [12], is a Principle that is apt to describe the "Emerging Quality" of Self-Organizing Systems. Its verbal enunciation asserts that "Every System tends to maximize its Ordinality, including that of its surrounding habitat", and it is formulated by means of two fundamental equations, which are so strictly related to each other so as to form a Whole ([15], [16],[17])

The First Fundamental Equitation

It is formulated as follows

$$(\underline{\tilde{d}/\tilde{d}\,t})_s^{(\tilde{m}/\tilde{n})}\{\tilde{r}\} \overset{[\rightarrow}{=} \{\tilde{0}\} \qquad (1) \qquad (\tilde{m}/\tilde{n}) \rightarrow Max \rightarrow \{\tilde{2}/\tilde{2}\} \uparrow \{\tilde{N}/\tilde{N}\} \quad \textbf{(1.1)}$$

Where $\{\tilde{r}\}$ is the *Relational* Space of the System under consideration (see Appendix 2), while $(\tilde{m}/\tilde{n})$ represents its corresponding Ordinality, which reaches its *maximum* when it equals $\{\tilde{2}/\tilde{2}\} \uparrow \{\tilde{N}/\tilde{N}\}$ (as indicated in Eq. (1.1)).

In this respect, it is worth noting that:

i) The underlined symbol $(\underline{\tilde{d}/\tilde{d}\,t})_s$ explicitly indicates that the Generative *Capacity* of the System (more appropriately termed as *Generativity*), is "*internal*" to the same System, precisely because it is the one which gives origin to its Self-Organization as a Whole;

ii) The symbol "$\overset{[\rightarrow}{=}\{\tilde{0}\}$" represents a more general version of the simple *figure* "zero", as the latter systematically appears in the traditional differential equations. In fact it now represents, at the same time:

- the specific "*origin and habitat*" conditions associated to the considered Ordinal Differential Equation (1);

- while the symbol "$\overset{[\rightarrow}{=}$" indicates that the System, during its Generative Evolution, is persistently "adherent" to its "origin and habitat" conditions.

The Second Fundamental Equitation

It is formulated as follows

$$(\tilde{d}/\tilde{d}\,t)^{(\tilde{2}/\tilde{2})}\{\{\tilde{r}\}\circledR(\tilde{d}/\tilde{d}\,t)^{(\tilde{2}/\tilde{2})}\{\tilde{r}\}\}\overset{[\rightarrow}{=}\{\tilde{0}\}\quad \textbf{(2)}$$

and it can be considered as representing a *global* Feed-Back Process of *Ordinal Nature*, which is *internal* to the same System. Equation (2), in fact, asserts that the *Relational Space* of the System $\{\tilde{r}\}$, which "emerges" as a solution from the First Equation, interacts in the form of the Relational Product $\circledR$ (defined in Appendix 2) with *its proper Generative Capacity* $(\tilde{d}/\tilde{d}\,t)^{(\tilde{2}/\tilde{2})}\{\tilde{r}\}$ In such a way as to originate a *comprehensive* Generative Capacity which, *at any time*, is always adherent to the origin and habitat conditions of the Second Fundamental Equation.

The correlative Formal Language

As previously shown, the MOP is formulated in terms of a *new concept of derivative*, that is, the "Incipient Derivative", whose definition is recalled in Appendix 1. Its introduction is directly referable to the fact that Self-Organizing Systems always show an unexpected "excess" with respect to their phenomenological premises [29],[30],[31]. So that they usually say: "*The Whole is much more than its parts*".

Such an "excess" can be termed as *Quality* (with a capital Q) because it cannot be understood as being a simple "property" of a given phenomenon. This is because it is *never reducible* to its phenomenological premises in terms of traditional mental categories: *efficient causality, logical necessity, functional relationships*. Consequently, it cannot be described in terms of the traditional derivative that, at the level of *formal language*, represents the perfect reflex of such "a priori" mental categories [34].

This evidently suggests a *radically new* gnosiological perspective and, *in adherence*, the adoption of *"new mental categories": Emerging Causality, Generative Logic, Ordinal Relationships.*

These "*new mental categories*" can no longer be termed as "pre-suppositions", because they are not defined "a priori" (as in the case of the Traditional Approach). In fact, they are adopted "a posteriori", that is only on the basis of the "Emerging Quality" previously recognized. "*Emerging Causality*", in fact, refers to the capacity of a Self-Organizing System to manifest an "irreducible excess"; "*Generative Logic*" correspondently refers to the capacity of our mind to draw "*emerging conclusions".* That is "conclusions" whose information content is much higher than the information content corresponding to their logical premises, although they are persistently "adherent" to the latter. "Ordinal Relationships", in turn, refer to particular relationships of *genetic nature*, like in the case of "brothers". The latter in fact are termed as such not because of their "*direct* reciprocal relationships" (e.g. because they love each other, they respect each other, etc.), but because of their *direct reference* to *the same genetic principle*: their father (or their mother or both) [ib.].

Such new mental categories, in turn, suggest the development of a completely *new formal language*, in order to formulate a *Reference Principle*, the Maximum Ordinality Principle, so that the description of Self-Organizing Systems might result as being faithfully conform to their "Emerging Quality".

This is why *a new concept of derivative* was introduced, whose definition, as already said, is given in Appendix 1.

Description of the System analyzed

As anticipated in the Introduction, the Ostensive Example adopted as a case study is a System made up of five almost adjacent European Countries (France, Italy, Germany, Spain, Austria). Consequently, in order to analyze the problem of energy scarcity, at least as a simple *preliminary* aspect, the most appropriate characteristics assumed as basic reference are shown in Tab. 1.

Table 1 Basic Reference Characteristics (data from World Bank 2020)

Progressive Number	Nation	Imported equiv. oil per person (ton) 1	Imported equiv. oil per person/ Occupational level (%) 2	GDP ($) per person /1000/ Occupational level (%) 3	Occupational level(%) 4	GDP($) per person 5
1	France	1.8	2.53	0.570	71.0%	40.494
2	Italy	2.0	3.21	0.533	62.3%	33.228
3	Germany	2.4	3.03	0.586	79.2%	46.445
4	Spain	2.5	3.81	0.452	65.5%	29.600
5	Austria	2.5	3.35	0.734	75.0%	55.050

From the data of Tab. 1 it is possible to recognize that, in face of a progressive incidence of imported oil on behalf of the various Nations (column 1), Italy and Spain present a higher incidence of their imported energy on the respective occupational level (column 2).

At the same time, both Italy and Spain present a lower value of GDP (per person) with respect to that of the other Nations and, in particular, when GDP is referred to the national percentage of the occupational level (column 3).

The first trend fundamentally depends on a more reduced occupational level in Italy and Spain (column 4), while the second mentioned trend principally depends on a more reduced value of the correlative GDP per person (column 5).

Now, by assuming as reference the data shown in Tab. 1, we will develop a deeper analysis, essentially based on *the first three Indicators.*

Such a choice is not simply due to the fact that the five Indicators are strictly related between them, but it is a choice mainly referable to the same *Ordinal Perspective* we are going to adopt in our analysis. In fact, with specific reference to a "Conscious" System, it is advisable to take *three* Indicators that could possibly (and adequately) represent the way of "*Thinking, Decision Making*, and *Acting*" on behalf of the same considered Conscious System [15]. Obviously, the three Indicators should be each time selected with specific reference to *the field of analysis* under consideration .

Consequently, in the specific context of *energy supply*, Indicator 1 surely represents the reference Indicator to elaborate a *general strategy* to reduce the incidence of imported energy, especially in the cases of its higher levels. Indicator 2, in turn, may suggest *the most appropriate decisions* to reduce, above all, the correlative incidence of energy supply on the occupational level. Indicator 3 may finally suggest those specific *operative actions* that could actually improve its corresponding values, especially with reference to its lower values.

Reconfiguration of the System in Ordinal Terms, so that it might become a real "Community" of Nations

The Reconfiguration of the System was obtained by means a Simulator, termed as EQS (Emerging Quality Simulator), based on the *explicit solution* to the MOP (shown in Appendix 2), and thus it is not conceived as a traditional computer code that operates in functional terms, but on the basis of Ordinal Relationships between the various parts of the System. The specific Ordinal Reconfiguration of the System, modelled (as previously said) as a Self-Organizing System, was researched for in such a way as to keep substantially invariant both the minimum and maximum values of the three selected Indicators. This is because, at a preliminarily stage of the analysis, the Requalification of the System is contextually finalized to estimate the minimum *costs and times* of the same Ordinal Requalification Process. The Ordinal properties of the System, after such an Ordinal Reconfiguration, are shown in Tab. 3, from which is possible to recognize that the minimum and maximum values of the Indicators are substantially equal to the corresponding values shown in previous Tab. 2.

In this respect, it is worth explicitly pointing out that the Ordinal Reconfiguration represented in Tab. 3 was obtained through three intermediate passages:

a) A preliminary representation of the System in terms of “couples” of Nations
b) The research for the maximally similar Reconfiguration by means of the Simulator EQS, in terms of Ordinal “Duets”
c) Finally, the disarticulation of the Ordinal “Duets” in order to obtain the Reconfiguration in terms of “single” Nations.

This procedure simply reflects the fact that in *an Ordinal context* there are not, properly speaking, “single” parts of the System, because all its various parts are related to each other *in Ordinal terms*, and the corresponding minimum level of Ordinality is precisely that represented by Ordinal “Duets”.

The Relevance of the Ordinal Requalification Process

At this stage one could ask: why is it worth requalifying a System of Nations in Ordinal Terms? The answer is very simple: such an Ordinal Process, in fact, does not only increase the Resistance of the System against *adverse events* such as, for example, energy crises, as we will show as a *preliminary* aspect in the next paragraph. But it will also increase its correlative Resilience. In fact, the Ordinal Requalification Process also represents, in all cases, the Basic Reference Criterion for “Empowering Communities” in order to address all the other aspects that surely go “well beyond” energy scarcity, as we will see in the subsequent paragraphs.

Without forgetting that, in addition, any considered System, by increasing its correlative Ordinality level, can adequately and progressively enhance its specific Role, both with respect to the Ordinal Relationships *within itself* and, even more, with respect to its surrounding *Habitat*.

Table 2 Basic Reference Characteristics of the System (taken from Tab. 1)

Progressive Number	Nation	Imported equiv. oil per person (ton)	Imported equiv. oil per person/ Occupational level (%)	GDP ($) per person /1000/ Occupational level (%)
1	France	1.8	2.53	0.570
2	Italy	2.0	3.21	0.533
3	Germany	2.4	3.03	0.586
4	Spain	2.5	3.81	0.452
5	Austria	2.5	3.35	0.734

Table 3 Ordinal Requalification of the System after Disarticulations of "Duets"

Progressive Number	Nation	Imported equiv. oil per person (ton)	Imported equiv. oil per person/ Occupational level (%)	GDP ($) per person /1000/ Occupational level (%)
1	France	1.8	2.53	0.570
2	Italy	2.0344	3.1509	0.6111
3	Germany	2.1391	3.3803	0.6522
4	Spain	2.2907	3.4197	0.6933
5	Austria	2.5000	3.3500	0.7345

Table 4 Ordinal Requalification of the System in operative terms

Progressive Number	Nation	Imported equiv. oil per person (ton)	Imported equiv. oil per person/ Occupational level (%)	GDP ($) per person /1000/ Occupational level (%)
1	France	1.8	2.53	0.570
2	Italy	2.0 *(-)	3.21 *(-)	0.533 *(+)
3	Germany	2.4 *(-)	3.03 *(-)	0.586 *(+)
4	Spain	2.5 *(-)	3.81 *(-)	0.452 *(++)
5	Austria	2.5	3.35	0.734

Description of the considered *energy crisis* and its potential effects on the System of Nations

The evaluation of the Resistance of the System was obtained by simulating by means of EQS, and in conformity to Eq. (2), the Ordinal Inter-Action between the System in its Requalified Ordinal Configuration and the Ordinal Configuration of the same System after the estimated effects due to a foreseeable energy crisis.

In adherence to the MOP, the analysis was performed by modelling both the two configurations of the System in terms of "couples" of elements (or "Duets") for the same reasons previously recalled. Consequently, the Reference Ordinal Structure of the System is now that one represented in Tab. 5, where the values of Duets are referred, by difference, to Nation 1.

As far as the *energy crisis* is concerned, this is thought as an *energy scarcity*, which may be due either to a reduction of fossil fuels production or to an increase of their prices (or both) and, as a work hypothesis, it was supposed characterized by an "incidence" of the order of 20% on the values of Indicator 1.

The incidence on the values of the other two Indicators is strictly correlative to the Ordinal Reconfiguration of the System (shown in Tab. 5). Consequently, the corresponding effects on the System, simulated by means of EQS, and represented in Tab 6, in this case show an incidence of the order of 10% on the values of Indicator 2 and an incidence of the order of 5% on the values of Indicator 3.

More precisely, while the resulting "incidence" on the values of Indicator 1 is equal to 20%, as precisely supposed by hypothesis, the correlative "incidence" on the values of Indicator 2 is equal to 9.75%, while the "incidence" on the values of Indicator 3 evenly ranges from 5.10% and to 5.16%.

Formal Translation into EQS of the Inter-Action previously described

The evolution of the process described by the two fundamental equations (1) and (2) of the MOP was represented by means of EQS through three distinct successive processes:

a) The simulation of the Ordinal Reconfiguration of the System in its original integrity, as it appears in Tab. 5, that is considered in the absence of any external effects, and specifically structured in terms of "Duet" elements, as previously said;

b) The simulation of the Inter-Action of the System with its Habitat conditions, represented by the hypothesized *energy scarcity* and its consequential reconfiguration, still in terms of "Duets", as represented in Tab. 6;

c) The simulation of the Ordinal Inter-Action between the configuration of the System under condition a) and the System under condition b). This is because such an Inter-Action is precisely that which reflects the proper meaning of Eq. (2).

In fact, the Inter-Action between the Initial System (in its original integrity) and the System after the effects of the considered *energy scarcity*, gives origin to a *New* Ordinal System, whose final configuration is represented in Tab. 7

Tab. 5 - Ordinal Requalification of the System considered as being made up of 4 couples of Nations

I	BI	CI	EI	$\rho_{1j(t0)}$	$\phi_{1j(t0)}$	$\theta_{1j(t0)}$	$\mathring{\rho}_{1j(t0+\Delta t)}$	$\mathring{\phi}_{1j\ (t0+\Delta t)}$	$\mathring{\theta}_{1j\ (t0+\Delta t)}$
1	1	0	3,3416	0,2344	0,6209	0,0411	0	0	0
2	1	0	6,2831	0,3391	0,8583	0,0822	0	0	0
3	1	0	9,4247	0,4907	0,8897	0,1233	0	0	0
4	1	0	12,5664	0,7100	0,8499	0,1645	0	0	0

Captions: BI, CI, DI are internal control parameters of the Simulator EQS
$\rho_{1j(t0)}$, $\phi_{1j(t0)}$, $\theta_{1j(t0)}$ represent the *actual* Relational Space {now represented by Indicators 1, 2, 3} pertaining to each Duet at the initial time
$\mathring{\rho}_{1j(t0+\Delta t)}$, $\mathring{\phi}_{1j\ (t0+\Delta t)}$, $\mathring{\theta}_{1j\ (t0+\Delta t)}$ are their corresponding Incipient Derivatives

Tab. 6 - Ordinal Requalification of the System as a consequence of the hypothesized energy scarcity

I	BI	CI	EI	$\rho_{1j(t0)}$	$\phi_{1j(t0)}$	$\theta_{1j(t0)}$	$\mathring{\rho}_{1j(t0+\Delta t)}$	$\mathring{\phi}_{1j\ (t0+\Delta t)}$	$\mathring{\theta}_{1j\ (t0+\Delta t)}$
1	1	0	3,1416	0,1875	0,5604	0,0390	0	0	0
2	1	0	6,2831	0,2713	0,7746	0,0781	0	0	0
3	1	0	9,4247	0,3926	0,8030	0,1172	0	0	0
4	1	0	12,5664	0,5680	0,7399	0,1562	0	0	0

Captions: BI, CI, DI are internal control parameters of the Simulator EQS
$\rho_{1j(t0)}$, $\phi_{1j(t0)}$, $\theta_{1j(t0)}$ represent the *actual* Relational Space {now represented by Indicators 1, 2, 3} pertaining to each Duet at the initial time
$\mathring{\rho}_{1j(t0+\Delta t)}$, $\mathring{\phi}_{1j\ (t0+\Delta t)}$, $\mathring{\theta}_{1j\ (t0+\Delta t)}$ are their corresponding Incipient Derivatives

Tab. 7 - Final Reconfiguration of the System and correlative "mitigation" of the energy scarcity effects

I	BI	CI	EI	$\rho_{1j(t0)}$	$\phi_{1j(t0)}$	$\theta_{1j(t0)}$	$\mathring{\rho}_{1j(t0+\Delta t)}$	$\mathring{\phi}_{1j\ (t0+\Delta t)}$	$\mathring{\theta}_{1j\ (t0+\Delta t)}$
1	1	0	3,1416	0,2109	0,5919	0,0400	0	0	0
2	1	0	6,2831	0,3052	0,8182	0,0801	0	0	0
3	1	0	9,4247	0,4416	0,8482	0,1202	0	0	0
4	1	0	1,3490	0,6390	0,7816	0,1603	0	0	0

Captions: BI, CI, DI are internal control parameters of the Simulator EQS
$\rho_{1j(t0)}$, $\phi_{1j(t0)}$, $\theta_{1j(t0)}$ represent the *actual* Relational Space {represented by Indicators 1, 2, 3} pertaining to each Duet at the initial time
$\mathring{\rho}_{1j(t0+\Delta t)}$, $\mathring{\phi}_{1j\ (t0+\Delta t)}$, $\mathring{\theta}_{1j\ (t0+\Delta t)}$ are their corresponding Incipient Derivatives

Analysis of the results of the simulation of the previous Inter-Action Processes

The results in Tab. 7, which refer to the Final Configuration of the System as a consequence of the hypothesized energy crisis due to *energy scarcity*, show that such an Ordinal Exit is a clear manifestation of the *recovery*, on behalf of the System, of its *Internal Stability*, as explicitly foreseen by Eq. (2) of the MOP.

In fact, it is easy to recognize the corresponding *reduction* and *mitigation* of the effects due to the reduction of imported energy, with reference to all the values of the three Indicators, both with respect to their maximum and minimum values.

For the sake of brevity, but also for clarity, the corresponding "mitigations" of the effects are reproduced here below in the form of percentage changes:

Maximum Value of Indicator 1:	the incidence of	-20.00 %	becomes	-10.0 %
of Indicator 2:	the incidence of	- 9.75%	becomes	- 4.67 %
of Indicator 2:	the incidence of	- 5.16 %	becomes	- 2.18 %
Minimum Value of Indicator 1:	the incidence of	-20.0%	becomes	- 10.10 %
of Indicator 2:	the incidence of	- 9.74 %	becomes	- 4.67 %
of Indicator 3:	the incidence of	- 5.10 %	becomes	- 2.67 %

It is also evident that an organic picture of the results can easily be obtained through a more articulated comparison between the values in Tabs 6 and 7, respectively. Nonetheless, the previous results unable us to surely affirm that the System manifests a higher Resistance with respect to the corresponding conditions characterized by a total absence of an Ordinal Requalification.

At the same time, it is also possible to recognize a correlative increase of its Resilience. In fact, in the presence of a *prior* Ordinal Requalification, the System, after having mitigated the effects of the energy scarcity, still keeps an Ordinality level sufficiently high to adequately and progressively reacquire its specific *Role*, both in terms of Ordinal Relationships *within itself* and, even more, with respect to its Ordinal Relationships with its surrounding *Habitat*. As we will see in the next paragraphs.

Conclusions with specific reference to the considered aspect of *energy scarcity* previously analyzed

The conclusions of the previous analysis can be synthesized as follows:

- In view of a possible *energy scarcity* (or, more in general, energy crises), any System of Nations should provide, in advance, to improve its Ordinal Requalification, appropriately commensurate to the "foreseeable" energy crises pertaining to its specific case;
- This is because, from such an Ordinal Requalification, it will result a "*Rebound*" of its "Resistance" and at the same time, of its correlative level of "*Resilience*". This evidently becomes even truer, for example, in the case of the European Community (made up of 27 Nations) and, even more, in the case of USA (made up of 50 States), with particular reference to their relevant specific Role in the World.

In these cases, in fact, there is a progressive increase of the corresponding *Ordinality* of the Systems, because associated to the increasing number of their States, as clearly shown by Eq. (1.1), which is formulated, of course, in Ordinal Terms.

Strategic Methodology based on the MOP for analyzing some specific cases that go well beyond energy scarcity

After having preliminarily shown the increase of Resistance and Resilience adverse energy scarcity, and the correlative increase of consciousness of the "Empowering Community" involved, since the latter aspect is directly related to its corresponding increase of Ordinality, now we will present the most appropriate modalities to take *strategic decisions* in cases that go well beyond energy scarcity. We will then start by considering the aspects concerning both *energy saving* and the research for *new energy sources*.

Energy saving and renewable energy sources. The Smart Grids

The two aspects mentioned in the title represent, in a certain sense, two sides of the same coin.

In fact, in accordance with the previous analysis, *energy saving* should not be realized *unilaterally* by each single Nation. This is because, in the contest of Self-Organizing System, once Requalified in Ordinal Terms, the amount of energy saving corresponding to each Nation should always be in conformity to those of all the other Nations, that is, according to the Harmony Relationships (2.5) shown in Appendix 2. Consequently, the "actions" of the various Nations should be *coordinated* between them, because always referable to a *unique and sole* Self-Organizing System. In particular, because of the correlative benefits to its GDP, but also for the associated benefits due to the reduced "vulnerability" of the System to energy scarcity.

The same concept is equally valid inside the territory of each single Nation. This is because within any single Nation it is possible to re-propose the same analysis previously shown in the case of five Nations. In this particular case, the analysis should be performed with reference to the various Regions (or Federal States) pertaining to each Nation (18 Regions for France, 20 for Italy, 16 for Germany, 17 for Spain, 9 for Austria). Consequently, also in this case the energy saving corresponding to each Region (inside the same Nation), should always be *in adherence* to those of all the other Regions (of the same Nation), according to the previously recalled Harmony Relationships.

Smart Grids

An analogous concept is equivalently valid even when the energy saving is obtained by means of the recourse to Smart Grids. In fact, said in more explicit terms, the same diffusion of the Smart Grids should be uniform between the various Nations and, contextually, among their pertinent Regions, always for the respect of the above mentioned Harmony Relationships and the correlative reduction of the “vulnerability” to energy scarcity.

However, one could ask: how is it possible to realize a wide diffusion of Smart Grids, given their well-known intrinsic instability and consequential frequent blackouts?

The answer, once again, can be found on the basis of the MOP. In fact, the problem can easily be solved by modelling a Smart Grid in the light of the M.O.P. [20]. This is because, as pointed out by P. Anderson (Nobel Prize in Physics 1977): “A complex aggregate of electrons shows properties that are not reducible to their sum” [1]. In other words, “a complex aggregate of electrons”, although “forced” by some generators into electrical circuits, always tends to behave as a “Self-Organizing System”.

Consequently, the distribution of the N Generators (and their related connections) should not be designed in functional terms. On the contrary, they should topologically be distributed in such way as the Voltage ($\tilde{V}_i$), Current ($\tilde{I}_i$) and Phase ($\tilde{\Phi}_i$) of each generator satisfy, at any time t, the Harmony Relationships pertaining to the Smart Grid under consideration, according to Eq. (2.5) in Appendix 2

$$\{\tilde{V}_{1,j+1}, \tilde{I}_{1,j+1}, \tilde{\Phi}_{1,j+1}\}_t \stackrel{*}{=} (\sqrt[N-1]{\{\tilde{1}\}})_j \circledR \{\tilde{V}_{12}, \tilde{I}_{12}, \tilde{\Phi}_{12}\}_t \qquad j = 1,3,......N-1 \qquad (4)$$

where the index “12” refers to an arbitrary couple of generators assumed as reference, while $(\sqrt[N-1]{\tilde{1}})$ represents the N-1 Ordinal Roots of Ordinal Unity ($\tilde{1}$).

In this way the Smart Grid will result, in actual fact, as being intrinsically stable, because the specific “weight” of its internal cardinalities (always understood as a Whole) will result as being much higher than the quantitative contributions (in number and intensity) of the most frequent disturbances and, especially, in the case of unforeseeable cyber attacks.

At the same time, this example also suggests a possible “transposition” to a higher level of analysis: the Economics Stability of a System of Nations.

Economics Stability of a System of Nations and their increasing consciousness as being a real Community

The research for equilibrium conditions in a free-market economy, generally in a progressive development, but also in the case of potential crises, can be obtained once again by means of a *specific strategy* based on the MOP, because in such a case the latter allows us to solve the famous *The three-good two factor Problem* of Neo-Classical Economics. The latter in fact, in spite of its wide theoretical diffusion, is characterized, from its same origin (at the beginning of the XX century) by such an unsolvable problem, which has never been solved up to now ([27], pp. 247-252).

This Problem, as its same "title" clearly states, consists in the fact that, given three goods, in a free market economy, characterized by two productive factors (Kapital and Labour), such three goods do not reach an equilibrium condition.

This result clearly shows that a free market economy cannot be considered as being a simple "mechanism".

A free market, in fact, as shown in [20], is characterized by "Initiative", "Inventiveness" (understood as a "continuous development of new products"), without considering that any transaction always generates "Extra" Benefits of Ordinal Nature [11], which are irreducible to a traditional description in terms of causality, necessity, functionality.

All these conditions suggest that a free market between Nations can be more appropriately modelled as a "Self-Organizing System". In fact, when "The three-good two factor Problem" is interpreted in the light of the MOP, the Problem can be solved for an arbitrary number of goods (N_g), in the presence of Three Productive Factors: Capital (K), Labour (L) and Natural Resources (N) [14],[20].

In particular, in the case of a System of Nations, the number of goods (N_g) is precisely represented by the number of Economies of the considered Nations, while Capital (K) stands for GDP, Labour (L) for occupied workers, while Natural Resources (N) refer to both internal and external resources pertaining to each considered Nation.

As widely shown in [20], the corresponding "Emerging Solution" is given by the following Harmony Relationships (ib.)

$$\{\tilde{K}_{1,j+1}, \tilde{L}_{1,j+1}, \tilde{N}_{1,j+1}\} \overset{*}{=} (\sqrt[N-1]{\{\tilde{1}\}})_j \circledR \{\tilde{K}_{12}, \tilde{L}_{12}, \tilde{N}_{12}\} \qquad j = 1,3,......N_g - 1$$

(5),

where the index "12", represents an *arbitrary* couple of Nations assumed as a reference, while the term $(\sqrt[N-1]{\{\tilde{1}\}})_j$ represents the $N_g - 1$ Ordinal Roots of Ordinal Unity $\{\tilde{1}\}$ (see also Appendix 2).

On the basis of such a result, a System of Nations that adopts an Economics Policy in conformity to the previous strategic solution, will surely increase its sense of consciousness of being a real Community. This is particularly important not only for the System of five Nations previously considered, but even more, for example, in the case of the European "Community", made up of 27 States (or Nations).

Increase of Ordinality and Consciousness of a "Community" both in its Internal and External Relationships

The examples previous considered also suggest an even higher level of analysis for strategic decisions, always based on the MOP, with particular reference to the surrounding Habitat.

In fact, the verbal enunciation of the MOP asserts that:

"Every System tends to maximize its Ordinality, including that of its surrounding habitat".

This means that, if for example the European Community has reached its maximum level of Ordinality, characterized by its corresponding internal Stability, and consequently it has reached a much deeper consciousness of being an effective Community, all these aspects can have a direct reflex on the improvement of its Ordinal Relationships. Both internal to the single Nations and between them. In addition, a further improved level of Relationships can manifest when such Communities will establish New Ordinal Relationships with other countries.

For example, let us consider the European Community. It may further increase its already reached level of Ordinality because it can surely play, always on the basis of the MOP, a particular "leading role" with respect to those Nations that, for example, would like to become part of the same European Community and which, at present, represent only its Habitat.

Something similar, or even more significantly, can be asserted with reference to United States of America (made up of 50 States), especially for their extremely important role and their relevant "influence" at Mundial Level.

The abovementioned aspects also suggest, on the other hand, that any considered Ordinal System of Nations could also play a decisive role in the respect of the Environment, by assuming strategic decisions always in the light of the MOP.

Environment. Climate change forecasts. The Sea Level Rise over the Period 1900-2000

In this case, the "Empowering Communities" may manifest their increase of consciousness and their particular role with reference to the Environment, only in the respect, however, of the following conditions:

a) The "prior condition" is that they have reached a sufficiently high level of Ordinality as Self-Organizing Systems, by adopting as a Reference "Guide" the Maximum Ordinality Principle;

b) Afterwards, they know very well the Environmental Phenomenology pertaining to the aspects of specific interest;

c) This means that they are able to recognize the "Emerging Quality" of the processes they are going to deal with;

d) And, as a fundamental aspect, they are systematically oriented at the research for a possible Syntony with such an "Emerging Quality";

e) Finally, even in the case of potential adverse events, they can mitigate the associated undesired "effects", always in adherence to the MOP.

In order to illustrate the importance of the previous conditions, let us consider, as an ostensive example, the Sea Level Rise over the Period 1900-2000, as described in [22], [33].

It is evident that such a process is difficult to contrast if its "origin" is not deeply known.

At a first glance, in fact, the process seems to be inexplicable, because the correlative "causes" are still unknown [26].

However, as clearly shown in [20], this is simply due to the fact that the specific "causes" are systematically researched for in terms of efficient causality, logical necessity, functional relationships, that is they are researched for as the various processes involved were pure "mechanisms" (as illustrated at par. 2.1).

In reality the process of Sea Level Rise can be analyzed in the light of the M.O.P. by means of its associated Ordinal Simulator EQS (ib.), which faithfully represents the various Harmony Relationships between all the different physical Systems involved in the process (sea, ice, hearth, sun, etc.). Such Inter-Actions in fact, because of their Ordinal Nature, are precisely those that represent the real "generative cause" of that registered "unexpected" trend. Which, according to such an interpretation, is nothing but an "Emerging Exit" of a unique "Self-Organizing System".

Consequently, "Empowering Communities" should correspondently modify their way of "Thinking, Decision Making, and Acting" so as to research for the maximum Syntony (and possibly Harmony) with the "Emerging Quality" shown by the considered Processes, so as to minimize both present and future effects with respect to the Environment [13].

Conclusions

We have shown how various forms of Communities, although substantially different among them for their Ordinality Level, may progressively become more intensive

"Empowering Communities" by adopting as reference criterion the Maximum Ordinality Principle (MOP).

This is because its adoption, on behalf of a given Community, generates an increasing sense of Community and a higher level of correlative responsibility, as it has been preliminarily shown with reference to adverse conditions associated to energy scarcity. However, the same process becomes even more intensive when the MOP is adopted to deal with aspects that go well beyond energy scarcity.

In such a perspective, we have preliminarily assumed as Reference "Community" that one made up of five European Countries (France, Italy, Germany, Spain, Austria) which were modelled as a unique and sole Self-Organizing System, so that it could be considered as being as a real Community. In this way, after having preliminarily shown the increase of Resistance and Resilience of such an Ordinal Community adverse energy scarcity, immediately after we showed the most appropriate modalities for the same Ordinal Community to research for new energy sources.

As a further and more significant contribution, we also showed how the considered Countries can even increase their consciousness of being a real Community, especially with reference to their Ordinal Relationships with all the other surrounding Countries, in particular, in the case of European Community and the United States of America.

In such a general context, we have also shown how such progressively "Empowering Communities" can also improve their Ordinal Relationships with the Environment.

All these aspects, in fact, can always be realized on the basis of the Maximum Ordinality Principle, when the latter is adopted on behalf of any Conscious System in all the various cases of interest, as a preferential "Guide" for its way of "Thinking, Decision Making, and Acting"[15].

In this way any Community, understood as Self-Organizing Conscious System, can progressively maximize its proper Ordinality, so as to reach the maximum Syntony (and possibly Harmony) with the "emerging Quality" which is specific of any surrounding Habitat, included the same Environment.

In particular, this becomes possible because the MOP precisely represents a valid Reference Principle for analyzing both "non-living", "living" and "conscious" Self-Organizing Systems [16].

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241 Quantities, units and their symbols in production and consumption

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Abstract

The International System of Quantities (ISQ) shall be used in education and textbooks, in scientific and engineering journals, in conference papers and proceedings, in industry, etc. The names of quantities together with their symbols and units are being published by the International Organization for Standardization – the standard ISO 80000 Quantities and units, composed of 14 parts. Mathematics and natural sciences (physics, light and radiation, acoustics, physical chemistry, atomic and nuclear physics, condensed matter physics) compose most of the parts. Also, some engineering disciplines (mechanics, thermodynamics, electromagnetism), and characteristic numbers are covered. The units are based on the International System of Units (SI). Unfortunately, chemical and process engineering as well as environmental engineering and engineering economics are not dealt with in the standard. In this paper they will be proposed as an additional part of the ISO standard with a tentative name Chemical and environmental engineering.

The additional part of the standard is proposed to include a) reaction and separation engineering together with mass transfer and reaction kinetics, b) process design, control and optimization, c) process economics, mathematical modelling, operational research, and d) environmental engineering with climate change, pollution abatement, increase of resource efficiency, zero waste and circular economy. The number of quantities is planned but not limited to about 70 – the average of ISO 80000 parts. Each quantity item contains a quantity name and definition (including an equation if suitable), SI unit and remarks (running number will be added later). The rules are defined in ISO 80000-1 General rules, and practice of the other ISO 80000 parts is respected; the quantities already included in the other parts are not repeated. Also, the IUPAC (International Union of Pure and Applied Chemistry) Green Book rules are respected. The literature used included Ullmann's Encyclopedia, Perry's Chemical Engineers' Handbook, and some traditional textbooks from the chemical engineering and environmental fields. Some common mistakes in printing symbols of quantities and units are mentioned.

Keywords: chemical engineering, quantities, standard, symbols, units

Introduction

After the letters, numbers and units, the system of quantities was the last one developed and standardized globally. Quantity is a property of a phenomenon, body, or substance, where the property has a magnitude that can be expressed by means of a number and a reference (unit). The first international organizations trying to standardize chemical and physical quantities have been the International Union of Pure and Applied Physics, IUPAP (established in 1922) and the International Union of Pure and Applied Chemistry, IUPAC (formed in 1919). IUPAP prepared its first edition of Symbols, Units and Nomenclature in Physics in 1961 (IUPAP), for official use only; its 1987 revision is available online (Cohen). IUPAC published the first edition of the Manual of Symbols and Terminology for Physicochemical Quantities and Units in 1969 (McGlashan). After the 3rd edition they changed the title of the manual and published it as a Green Book, again with three editions (IUPAC, 2007). The Green Book is available on Internet, too.

In 1988, the International Organization for Standardization, ISO, in cooperation with International Electrotechnical Commission, IEC, published the first edition of international standard ISO 31 Quantities and units in 13 parts (ISO, 1978), and ISO 1000 SI units and recommendations for use (ISO, 1981). In 1992 a new version of both standards was published. In 2009 the two standards have been substituted by ISO 80000 Quantities and units containing 14 somewhat reorganized parts; the last edition was published in 2019, the exception being the parts mentioned in parentheses (the parts 1 and 6 are planned to be updated in the year 2021):

1) General (2009)
2) Mathematics
3) Space and time
4) Mechanics
5) Thermodynamics
6) Electromagnetism (2008)
7) Light and radiation
8) Acoustics (2020)
9) Physical chemistry and molecular physics
10) Atomic and nuclear physics
11) Characteristic numbers
12) Condensed matter physics
13) Information science and technology (2008)
14) Telebiometrics related to human physiology (2008)

The general part contains information about quantities and units, printing rules, rules for terms in names for physical quantities, rounding of numbers, and logarithmic quantities. In parts 3–14, the quantities of each subset are listed, including item number, quantity name, symbol and definition, unit symbol, and eventual remarks. Since 2019, each part has an alphabetical index of quantities at the end to enable searching for the items. Three further parts, 15–17 (Logarithmic and related quantities, Printing and writing rules, Time dependency) are under development (ISO/IEC, 2021).

As can be seen from the above cited list of ISO 80000 parts, chemical and process industries (CPI) are not included although they are very important in many respects (turnover, profit, investments, employment, research, etc.). Besides the chemical industry, CPI is involving pharmaceuticals, cellulose and paper, metals, ceramics, textiles, food and beverages industries, etc. The area is including process, plant and equipment modelling, design, construction, analysis, optimization, operation, control, process economics, safety, hazard assessment, transport phenomena, etc.

There is also no standard on environmental science and engineering although we are in the climate change/crisis, facing species extinction, pollution, and raw-materials scarcity. Paris agreement, European Green Deal, Net Zero by 2050, Sustainable Development Goals are some of the most frequent buzzwords which we are facing every day. They are dealing with greenhouse gas emissions, renewable sources, critical raw materials, biodiversity, resource efficiency, zero waste, circular economy, etc. Therefore, it is necessary to define internationally agreed names, symbols and units for the quantities used in the area.

Methods

Literature search included chemical and environmental engineering textbooks, handbooks, encyclopaedias, lexicons, manuals, standards, and Google searches. As the number of items is limited, the most important quantities have been selected according to the importance and frequency of their usage.

The proposal starts with chemical engineering quantities, continues with process economic ones in design, and finishes with the environmental ones. Some common mistakes in symbols of quantities and units are mentioned, they can also be found in literature (Glavič, 2021).

The proposed terms will be discussed at the ERSCP 2021 meeting – after an improvement they will be sent to the EFCE (European Federation of Chemical Engineering), the AIChE (American Institute of Chemical Engineers), the IChemE (British Institution of Chemical Engineers), and the DECHEMA (Deutsche Gesellschaft für chemisches Apparatewesen). After their approval they will be asked to send the proposal to the Technical Committee ISO/TC 12 Quantities and units.

Results and Discussion

Chemical and process engineering quantities are very exhaustive as they cover many topics based on chemistry, physics, mathematics, economics that deal with a very broad range of materials, methods, and equipment, e.g. (Ullmann, 2000; Perry, 2007):

- principles of fluid and particle dynamics, heat and mass transfer, chemical thermodynamics and kinetics, statistics, and optimization methods
- very diverse reactions – homogeneous liquid or gas ones, gas-liquid, or gas-liquid solid ones, using blast, or rotary furnaces, fixed or fluidized beds, heterogeneous gas catalysis, electrolysis, photo-, or plasma-chemistry, etc.
- unit operations like size reduction and classification, transportation and storage, mechanical, magnetic, electric separations, mixing and conveying, heating,

cooling, adsorption, absorption, extraction, ion exchange, distillation, evaporation, sublimation, refrigeration, crystallization and drying
- process design, construction, operation, control, and development with modelling, costing, simulation, optimization, process safety, pollution, energy integration, waste management and reuse, circular economy, renewable energy.

Therefore, an ISO standard about quantities and units is truly needed. Besides it, a similar edition as a Green Book in chemistry (IUPAC et al., 2007) would also be welcome.

Basic chemical engineering principles and unit operations

Some basic quantities that are not included in other parts of ISO 80000 are presented in Table 1. Values of constants are taken from BIPM (2019) and CODATA (2018).

Table 1. Basic chemical engineering quantities

Name	Symbol	Definition	Unit	Remarks
Avogadro constant	N_A	$N_A = N/n$	mol^{-1}	$6.022\,141\,76 \times 10^{23}$
Boltzmann constant	k, k_B		$J\ K^{-1}$	$1.380\,649 \times 10^{-23}$
Faraday constant	F	$F = eL$	$C\ mol^{-1}$	$9.648\,533\,212 \times 10^{4}$
Henry's law constant	k_H	$k_{H,B} = (\delta f_B/\delta x_B)_{x_B = 0}$	Pa	
fugacity coefficient	ϕ	$\phi = f_B/p_B$	1	
2nd virial coefficient 3rd virial coefficient	B C	$pV_m = RT(1 + B/V_m + C/V_m^2 + \ldots$	$m^3\ mol^{-1}$ $m^6\ mol^{-2}$	$pV_m = RT(1 + B_p p + C_p p^2 + \ldots$
Stefan-Boltzman constant	σ	$M = \sigma T^4$	$W\ m^{-2}\ K^{-4}$	$5.670\,374\,419 \times 10^{-8}$
Planck constant	h	$H = E/f$	J s	$6.626\,070\,15 \times 10^{-34}$
coefficient of mass transfer	k_c	$k_c = q_n/A\Delta c_A$	$m\ s^{-1}$	
specific surface area	s	$S = A/m$	m^2/kg	
logarithmic-mean temperature	ΔT_{lm}	$\Delta T_{lm} = (\Delta T_2 - \Delta T_1) / \ln(\Delta T_2/\Delta T_1)$	1	

Chemical Reaction Engineering

Chemical reaction is the heart of chemical engineering activity – reactants are flowing into a reactor where they react, and products are flowing out of the reactor. Therefore, amount flow rates must be discussed first. The symbol F is used in English literature (Levenspiel, 1999), $\dot{n}$ in German one (Fitzer and Fritz, 1989). Mass flow rate, q_m (kg/s), and volume flow rate, q_V (m^3/s), are defined in ISO 80000-4-30.2 and 4-31 but amount (of substance) flow rate is not; it is not defined in the Green Book (IUPAC, 2007), either. By analogy, q_n (mol/s), could be used (Table 2). ISO 80000-4 defined mass flow, $\boldsymbol{j}_m$, too; therefore, amount flow, $\boldsymbol{j}_n$, is also included in the list.

Table 2. Chemical reaction engineering quantities.

Name	Symbol	Definition	Unit	Remarks
amount flow	$\boldsymbol{j}_n$	$\boldsymbol{j}_n = cv$	mol m^{-2} s^{-1}	c – concentration
amount flow rate	q_n	$q_n = \iint \boldsymbol{j}_n \cdot \boldsymbol{e}_\mathrm{n}\, \mathrm{d}A$	mol s^{-1}	$\boldsymbol{e}_\mathrm{n}$ – normal vector
(fractional) conversion	X_B	$X_\mathrm{B} = (n_\mathrm{B} - n_\mathrm{B0}) / n_\mathrm{B0}$ $= 1 - c_\mathrm{B} / c_\mathrm{B0}$	1	n – amount (of sub.) $\mathrm{d}X_\mathrm{B} = \mathrm{d}c_\mathrm{B}/c_\mathrm{B0}$
selectivity	σ_P	$\sigma_\mathrm{P} = \mathrm{d}c_\mathrm{P} / (\mathrm{d}c_\mathrm{P} + \mathrm{d}c_\mathrm{S})$	1	
(fractional) yield	φ Φ	$\varphi = \mathrm{d}c_\mathrm{P} / (-\mathrm{d}c_\mathrm{A})$ $\Phi = c_\mathrm{Pf} / (c_\mathrm{A0} - c_\mathrm{Af})$	1 1	instantaneous over-all, f – final
rate of conversion	ω	$\omega = \mathrm{d}\xi / \mathrm{d}t$	mol s^{-1}	
specific rate of conv.	r_m	$r_m = (1/m)\,(\mathrm{d}n_i/\mathrm{d}t)$	mol kg^{-1} s^{-1}	
areic rate of conv.	r_A	$r_A = (1/A)\,(\mathrm{d}n_i/\mathrm{d}t)$	mol m^{-2} s^{-1}	
volumic rate of conv.	r_V	$r_V = (1/V)\,(\mathrm{d}n_i/\mathrm{d}t)$	mol m^{-3} s^{-1}	V – reactor volume
rate of reaction	r_c r_p	$r_c = (1/\nu_\mathrm{P})\,(\mathrm{d}c_i/\mathrm{d}t)$ $r_p = (1/RT)\,(\mathrm{d}p_i/\mathrm{d}t)$	mol m^{-3} s^{-1} mol m^{-3} s^{-1}	for liquids for ideal gases
rate constant	k	$r = k\Pi_\mathrm{B} c_\mathrm{B}^{m_\mathrm{B}}$	$(m^3/mol)^{m-1}/s$	m – order of reaction
residence time distribution, RTD	$\boldsymbol{E}$	$\int_0^\infty \boldsymbol{E}\, \mathrm{d}t = 1$	1	age distribution at reactor exit
space-time	τ	$\tau = V_\mathrm{r}/q_{V,\mathrm{F}}$	s	
space-velocity	s	$S = 1/\tau$	s^{-1}	
recycle ratio	R	$R = q_{V,\mathrm{r}}/q_{V,\mathrm{f}}$	1	r – recycled, f – final

Conversion is the next quantity to be defined. It is often called fractional conversion (Umsatzgrad). The ISO 80000-9 and the Green Book cite extent of reaction, ξ (mol), and the Green Book also rate of (absolute) conversion, $\dot{\xi} = \mathrm{d}\xi/\mathrm{d}t$ (mol/s). In American textbooks X_A, or x_A, or f_A are used for conversion of a reactant A, while U_A (Umsatz) is used in German ones. X_A is adopted here. Subscripts A, B, C, etc., are used for reactants, and P, R, S, etc. for reaction products. Selectivity, σ_P is the amount ratio of desired product P to all products S formed. The definition in Table 2 is appropriate for reactors with constant volume. For selectivity calculation of a batch reactor, amounts of product P and reactant A are used, $\sigma_\mathrm{P} = n_\mathrm{P} / (n_\mathrm{A0} - n_\mathrm{A})$. For continuous reactors amount flows are needed, $\sigma_\mathrm{P} = q_{n,\mathrm{P}} / (q_{n,\mathrm{A0}} - q_{n,\mathrm{A}})$. Yield (Ausbeute) is the amount ratio of desired product P to reactant A fed. It can be instantaneous, φ, or overall, Φ. Yield is always the selectivity times the conversion, $\varphi_\mathrm{P} = \sigma_\mathrm{P} X_\mathrm{A}$.

The name 'rate of reaction' is used with constant volume fluids or with ideal gases, only. In other cases, the rate of conversion for any species i is proposed to be used; the specific rate of conversion is applied in cases of solid in fluid-solid systems. The areic rate of conversion is suitable for interfacial surface in two-fluid systems and in surface of solid catalyst in gas-solid systems. The volumic rate of conversion is based on volume of a reactor, not the volume of a fluid; it could also be named rate of production, but this name is used in the case of selectivity, $q_{n,\mathrm{B}} = \Phi q_{n,\mathrm{A0}} = \sigma_{\mathrm{B}} X_{\mathrm{A}}\, q_{n,\mathrm{A0}}$.

Equilibrium constants are described in ISO 80000-9, space time, space velocity and yield are not. Space-time, τ (s), is the time required to process one reactor volume of feed at specified conditions. Space-velocity, s (s^{-1}), is the space-time reciprocal. Recycle ratio, R (1), is the quotient of the volume flow rate returned to the reactor entrance and the one leaving the system.

Only a few quantities from reaction engineering are presented in Table 1. Single and multiple (series or parallel) reactions, elementary and nonelementary are known, number of molecules (molecularity with different orders of reaction) can differ and influence the rate equation. Temperature and pressure effects can vary, reaction can be exothermal or endothermal. Also, we know different type of reactors – batch, plug flow, mixed flow, recycle ones. Flow patterns and contacting can be ideal or non-ideal; in the last case dispersion, convection, or earliness of mixing must be accounted for. Finally, fluid-fluid (liquid or gas), fluid-solid, catalytic, and various biochemical (enzyme or microbial) reactors exist – heat and mass transfer become important in these cases, too. It will be difficult to standardize all od the quantities used in one standard. Especially so because process control, economics, and optimization influence the design of reactors.

Regarding axial dispersion, the dispersion coefficient, $\boldsymbol{D}$ (m^2/s), mean time of a passage, $\bar{t}$ (s), and variance, σ^2, are important quantities; probability distribution, statistics and uncertainties are described in the Green Book (pp. 151, 152). In the case of catalytic systems, the rate of conversion equations from Table 1 can be used; they can be based on volume of voids in reactor, mass or volume of catalyst pellets, catalyst surface area, or total reactor volume; activity of catalyst, $\boldsymbol{a}$ (1), may also be important. For heterogeneous reactions with two or more phases, the standard could contain some other quantities like interfacial area density, a (m^2/m^3), effectiveness factor ($\mathcal{E}$ or η, 1), mass transfer coefficient of the gas film, β, or k_{g}, liquid film, k_{l} (m/s), H (Pa m^3 mol^{-1}), Thiele modulus, M_{T} (also h_{T}, ϕ in German literature), Wagner or Weisz modulus, M_{W}, and Hatta modulus, M_{H} (the unit 1 for all).

Other unit operations

Unit operations are numerous and differ very one from another. Let us take distillation as an example. It is normal to write amount flow rates (mol/s) with a symbol of a flow rate name – F for feed flow rate, D for distillate flow rate, S for side stream flow rate, V for vapour flow rate, etc. F could be used as a quantity symbol with a subscript denoting different flow rates, $q_{n,\mathrm{F}}$, $q_{n,\mathrm{D}}$, $q_{n,\mathrm{S}}$ and $q_{n,\mathrm{V}}$ in this case. The second disrespect of ISO 80000 rules is the name "duty" for the heat flow rate (W), e.g., condenser duty, reboiler duty while their symbol, $\dot{Q}$ is in accordance with the ISO one. Also, void fraction, ε is not well defined – volume fraction of voids is the right name, and φ the right symbol. Some other proposals for quantities of unit operations and their symbols are presented in Table 3.

Table 3 Quantity names, symbols, and units in separation units

Name	Symbol	Definition	Unit	Remarks
amount flow	$\boldsymbol{j}_n$	$\boldsymbol{j}_n = q_n/A$	mol m^{-2} s^{-1}	
external reflux ratio	R	$R = q_{n,\,N+1}/q_D$	1	$q_{N+1}/V_N = R/(1 + R)$
vapor-liquid equilibrium ratio	K_i	$K_i = x_i/y_i$	1	
relative volatility	α_{ij}	$\alpha_{ij} = K_i/K_j$	1	
fugacity coefficient	ϕ_i	$\phi_i = f_i/p$	1	$\phi_i = 1$ for ideal gas
volume fraction of voids	φ_V	$\varphi_V = V_V/V_{tot}$	1	
efficiency of batch experiment	η_b	$\eta_b = 1 - e^{-kt_b}$	1	t_b batch mixing time
efficiency of a continuous process	η_c	$\eta_c = k\theta/(1 + k\theta)$	1	θ total liquid residence time

Process development and design

Process development data which can be internal or external, process evaluation which is including capacity determination, and economics, process optimization and decision making are important. Table 4 is presenting the most frequent quantities in process engineering optimization using mathematics and economics. Statistics is well covered in ISO standards; therefore, it will not be regarded here. Economics on the other side is not standardized, and often acronyms are used instead of symbols; it also lacks international coordination (Couper, 2003).

Table 4. Chemical and process engineering design economics

Name	Symbol	Definition	Unit	Remarks
cost	C		EUR, USD, …	cost index
investment	I		€, $, …	fixed capital
interest rate	i		%	V_p – present value
future value	V_f	$V_f = V_p\,(1 + i)^N$	1 (% = 10^{-2})	N – number of years
net sales, revenue	S_n	$S_n = S_g - O_c$	€, $, …	S_g - gross sales
turnover ratio capital ratio	r_{to} r_c	$r_{to} = S_g/I$ $r_c = I/S_g$	1 1	reciprocals
production rate	q_m	$q_m = m/t$	kg/s, t/a	capacity dependent
operating expenses	O	$O = O_d + O_i$	€, $, …	
depreciation	D	$D = I/N$	€/a, $/a, …	with no salvage value
gross income	P_g	$P_g = R - O - D$	€/a, $/a, …	gross profit
net income	P_n	$P_n = Pg\,(1 - t)$	€/a, $/a, …	net profit, t – tax rate

Name	Symbol	Definition	Unit	Remarks
income tax	T	$T = \tau(R - O - D)$	%	τ – tax rate
net profit after tax	P_n	$P_n = Pg\,(1 - \tau)$	€/a, $/a, …	net income
cash flow rate	q_c	$qc = P_n + D$	€/a, $/a, …	
return on investment	R_{oi}	$R_{oi} = P/I \times 100$	%	internal rate of return
payout time	t_{po}	$t_{po} = I/P_n$	a	payout period, years

The most used cost indices are Marshall and Swift (M&S, since 1926), Chemical Engineering (CE, since 1958), and Nelson-Farrar (since 1946) ones. Capital investment is including equipment cost, instrumentation, piping, insulation, electrical and engineering costs without any contingency; contingency is about 15–20 % of capital investment – when added to capital investment, the battery-limits capital investment is obtained. Working capital is including the fund for wages and salaries, purchase raw-materials, supplies, etc.

Operating expense is the sum of expenses for the processing of a product plus general, administrative, and selling expenses. They can be grouped into direct, indirect and product expenses; direct expenses are raw-materials, utilities, labour, maintenance, supervision, payroll charges, operating supplies, clothing and laundry, technical service, royalties, and environmental control ones. Indirect expenses include depreciation and plant indirect costs. Total manufacturing expense is adding packaging, loading, and shipping expenses to the operating expense. Revenues are the net sales received from selling a product to a customer. The value added to the product is the difference between the raw material expenses and the selling price of that product.

Time value of money, the expected interest rate that capital should or would earn, is diminishing because of the inflation. The present value of money, V_p, is lower than the future value, V_f. When a company loans money, a charge is made for the use of borrowed funds – the interest rate includes inflation expectation, the borrower's cost and his desired profit. The cost of capital is what it costs the company to borrow money from all sources (loans, bonds, stocks); it is expressed as an interest rate.

Besides the term depreciation, the quantity amortization is often used – there is a slight difference between them. If the period of life is known exactly, the annual expense is called amortization. If this time is estimated, it is called depreciation.

Rate of return and its variations are known by various names, e.g., internal rate of return, interest rate of return, discounted cash flow rate of return.

Environmental quantities, units, and symbols

Sustainable development with its three pillars (environmental, social, economic ones) is gaining importance and so is the Paris agreement with the 17 sustainable development goals (SDGs). The most problematic is the climate crisis caused by greenhouse gas (GHG) emissions with global warming. Table 5 presents some of the most important quantities in this area, starting with GHG emissions and climate change.

Table 5 Environmental quantities with symbols and units

Name	Symbol	Definition	Unit	Remarks
amount fraction of CO_2 equivalent	$x(CO_{2,eq})$	$x_B = n_B/\sum_i ni$	μmol/mol	in atmosphere
electricity, emissions coefficient	$E_e(CO_{2,eq})$	$E_e = m/W$	kg/(kW h)	not factor
travel, emission coefficient	E_l	$E_l = m/l$	g/km	various forms
carbon footprint per user	F_c	$F_c = m/t$	t/a	per person, …
ecological footprint	F_e	$F_e = A_{eq}$	ha	not gha
water footprint	F_w	$F_w = V/t$	m^3/a	
amount fraction of air pollution	$x(SO_2)$	$x = n_{SO_2}/\Sigma n$	nmol/mol	not ppm
mass concentration of particulate matter pollution, $d \leq (2.5, 10)$ μm	$\gamma_{PM2.5}$ γ_{PM10}	$\gamma = m_{PM}/V$	$\mu g/m^3$	in air
number concentration, microplastics	C	$C = N/V$	m^{-3}	in lake, ocean
mass concentration, heavy metal	$\gamma(Hg)$	$\gamma = m_{Hg}/V$	μg/L	in water
mass fraction, heavy metal	$w(Pb)$	$w = m_{Pb}/\Sigma m$	mg/kg	in soil
waste generation per capita	q_m	$q_m = m/t$	kg/a	mass flow rate
mass fraction of waste recycled	w_r	$w_r = m_r/m_w$	1, %	not recycl. rate

GHGs contain the most dangerous gases: water vapour, H_2O, carbon dioxide, CO_2 and methane, CH_4, and also nitrous oxide, N_2O, ozone, O_3, chlorofluorocarbons, CFCs, and hydrofluorocarbons, HFCs; they are recalculated into CO_2 equivalents. The literature is usually writing about their concentrations in ppm (parts per million) as a unit. The quantity is not concentration (mol/m^3) but rather amount fraction (μmol/mol). The units, ppm, ppb (part per billion), etc. are not recommended by IUPAC, therefore, amount (of substance) fraction with the symbol x and unit μmol/mol is used.

GHGs originate from burning of fossil fuels in transportation, energy production, industry, residential areas, from fermentation of waste and in agriculture. The $CO_{2,eq}$ emissions can be expressed in different ways, e.g., as mass per energy produced (kg/kW h, or mg/J), mass per volume of fuel (mg/l), mass per distance travelled (g/km), mass of CH_4 per agricultural area released or absorbed(kg/ha). They can be calculated per person, per company, per city, per country, or per world. No special names and symbols are available now. Many mistakes can be observed in statistical collections and in literature, e.g., by including CO_2 formula, or the words “per person” or “per capita”, into the units.

In Table 5 some tentative symbols for quantities and units regarding emissions are proposed by analogy with the ISO 80000 rules. According to these rules "emission factor" is switched to "emission coefficient". Using the proposed names, symbols and units, different forms of travelling (car, train, plane, etc.) or different users of carbon footprint can be addressed and compared. Ecological footprint uses a special name for land and water area unit name – global hectare with a symbol gha (GFN, 2009). According to the ISO rules, the name 'global' is a part of the quantity name (global area) and its symbol (A_g), and not of the unit one (hectare, ha). Many other footprints have been developed (water, land, nitrogen, phosphorus, material, biodiversity, chemical, plastic, energy, etc.); the environmental footprint family, relating to the nine planetary boundaries and their connection with SDGs is being developed (Vanham et al., 2019).

Pollution of air, water, soil with chemical substances, heavy metals, particulate matter, noise, electromagnetic radiations, etc., is the second major problem of the modern society. Accepted terminology and symbols can be used for them but are usually not applied. An international standard could improve their usage. Waste minimization, recycling and circular economy are becoming more and more important. "Waste generation" (per capita) actually means an abbreviated name for "mass flow rate of waste generated". "Recycling rate" means mass flow rate of recycled material (q_m, kg/a) what is a different quantity; therefore, the name is substituted by the "recycling fraction" in %.

Conclusions

Chemical and process engineering as well as environmental science and engineering are not represented in the 14 parts of ISO 80000 standard on quantities and units. The chemical industry sales alone (3.66 TEUR – trillion euros, 10^{12} EUR) reach 5.4 % of the world's GDP (gross domestic product, 68.10 TEUR). It is very interdisciplinary and specialized, and different from the manufacturing industry. It is also very important in the area od sustainable engineering, especially in environmental sustainability. Therefore, it deserves a special part in the standardization of quantities and units. The literature review has shown that there are many names of quantities and units that are not in accordance with the ISO 80000 rules. Even worse is the situation with quantity symbols and units – many symbols of quantities are not coherent with the international system ISQ, and many units do not respect the SI rules. Acronyms cannot be used as quantity symbols, and SI units may not be intermixed with quantity specifications.

This paper tried to discuss and propose some of the most important quantities in the areas of chemical and environmental engineering, and process economics. Regarding the names and symbols selected, the rules accepted in the systems ISQ and SI were tried to be obeyed. The choice of quantities is of course just an illustration of names and symbols to be included in the proposal. Health and safety, management and quality were not discussed as standards for them exist, but this does not mean that a review of quantity names, units and symbols in those standards is not needed. Also, basic concepts of statistics, process modelling, simulation, synthesis, design, integration, and optimisation were not included, yet.

The area is too broad and complex for the definite selection of quantities, their names, and symbols, but every journey starts with a single step. The proposal with proposed quantities, their names, symbols, and units must be discussed in national and international associations as well as the International Organisation for Standardization. Environmental and economic quantities could also be discussed as separate standards because their importance is broader than the chemical and process industries area.

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132 Nutritional life cycle assessment for sustainable diets and agri-food production: A regionally-explicit global case study

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Keywords: nutritional-life cycle assessment, sustainable food, environmental impacts, planetary health, nutrition security

Accounting for the multi-functionality of food

Optimizing food systems from both a production and consumption perspective requires the inclusion of nutritional, health, and environmental sustainability dimensions. However, to accomplish this, we need innovative methods; one such option is nutritional life cycle assessment, which is the integration of nutrition and health into environmental life cycle analysis (Green et al. 2020). In this assessment, we explored the applications of nutritional life cycle assessment with a case study that covered over 200 countries and food items, in addition to identifying methodological and data challenges. Specifically, we focused on nutritionally-invested environmental footprints because our food system is not only responsible for environmental impacts like climate change and freshwater scarcity but also for hidden hunger and noncommunicable diseases like diabetes (Green et al. 2021). However, currently, most life cycle assessment studies are measured using a mass-based functional unit, which does not holistically reflect the multi-functionality of food.

Methods

For this study, we used regionally-explicit nutritional (Smith et al. 2016) and environmental data (Poore and Nemecek 2018; Poore 2018) to calculate trade-weighted nutritional metrics of food supply and food products and their associated environmental impacts. We analyzed six impact areas; namely, greenhouse gas emissions, water use, land use, arable land use, pasture land use, and eutrophication. For nutritional metrics, we calculated novel and existing nutrient indices, which measure nutritional adequacy for food products and food supply, as well as nutrient diversity metrics that assess how diverse a national food supply is on a nutritional basis. For this, we accounted for 23 nutrients relevant to food consumption and human health.

Results and Discussion

Overall, we found that using nutritionally-invested environmental impacts revealed new insights and trade-offs and that methodological choice influenced results. One main case study result was that the relative rankings of environmental footprints change when considering the nutritional value of the food product or national food supply. For example, for the greenhouse gas emissions impact category, 67 percent of food groups changed ranking spots. In such cases, a food item that has an environmentally-friendly water footprint when measured on a kg basis may have a relatively higher footprint compared to other food items when accounting for nutrient density. We also saw that these trends, for the same food group, varied depending on the region. The relevance of these findings varied according to country-specific emission intensities and current nutrient adequacy ratios; we saw that of the 23 nutrients examined only the requirements of five nutrients were met in all countries. Methodological challenges that we identified and addressed included the use of disqualifying nutrients, energy standardization, capping nutrient scores, and a lack of harmonized LCA data. The choice of how and when to apply these methods altered the final nutritionally-invested environmental impact results.

Conclusions

Overall, our results have implications for how money should be allocated when designing sustainable food systems. Consequently, more research should explore the area of combined nutritional and environmental analyses via nutritional life cycle assessment.

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120 Circular Design Standards for Plastic Packaging – A Comprehensive Analysis

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Abstract

From the second half of the 20th century on, plastics started to gain relevance as a prime packaging material for both food and non-food products. Through packaging innovation, long shelf-life, great freedom of design, and high convenience in handling were achieved. However, the extensive use of plastic packaging paired with their typically short lifetime leads to increasing waste volumes. Often, these plastic wastes are incinerated, end up in landfills or leak into the environment rather than finding their way back into the economy via reuse or recycling. The problem of low circularity of plastics is increasingly being addressed by various circular design standards for plastic packaging from the corporate, non-governmental, and institutional sectors. According to the standards, plastic packaging designed for recycling is the key to overcome current barriers in the recycling value chains and to implement a Circular Economy (CE) of plastics. In contrast to a linear economy (take, make, dispose), a CE can be considered a more sustainable form of production as products shall be cycled in closed technical loops (reuse, repair, recycle) and/or in biological loops (composting, digestion), hence preventing the generation of waste. To fit into one of these loops, packaging must be designed in a way to be compatible with several closed material loops. For this paper, we analysed seven design standards such as the Designing for a Circular Economy, the Circular Packaging Design Guideline - Design Recommendations for Recyclable Packaging, or the Cradle to Cradle Certified Products Standard. We compared these standards by means of a qualitative content analysis. The analysis focuses on the type and number of packaging design elements addressed in each guideline as well as on potential conflicts between the design recommendations and the basic packaging functions defined in the literature. Further categories of evaluation were the elimination of certain formats, materials, and substances and the technical feasibility of the recommendations from a polymer engineering perspective. The individual analyses as well as the overall comparison revealed that most guidelines propose a similar packaging design. The topics of packaging design, technology, and input requirements for mechanical recycling are covered by almost every guideline. Thus, they seem to meet CE targets without seriously conflicting the basic packaging functions. However, the topics of polymers science and the toxicological profile of the output material from recycling processes remain mostly untouched in the standards. This leads to the conclusion that the currently available packaging design standards contribute to reducing the share of plastic packaging typically considered as non-recyclable at the end-of-life. However, for really closing the loop of plastic packaging by re-introducing recycled materials at the highest possible quality level into production, existing standards should incorporate more substantive specifications with regards to material science and toxicological profiles of substances and their effect on recycled material quality.

Keywords: Circular design, Circular economy, Design for recycling, Eco design, Plastic packaging

Introduction

In recent years plastics have attracted increasing attention especially because of improper disposal paired with their slow degradation in nature. While more and more plastic waste is entering the environment and thus endangering whole ecosystems, plastics are still an integral component in many products and industries. However, one type of plastic product is subject to serious criticism: packaging (Silpa Kaza et al., 2018, 1ff).

Packaging products account for around 40% of total plastics consumption which is the largest share and even twice as much as the second-largest share; building and construction (PlasticsEurope, 2017, p. 22). Worldwide, only 14% of plastic packaging waste is collected for recycling, the rest is incinerated (14%), ends up in landfill (40%) or leaks into the environment (32%) (WORLD ECONOMIC FORUM, 2016, p. 13). Today public and legal pressure force the plastics industry to set counteractions to the negative externalities of plastic packaging.

From a regulatory perspective, the European Commission (EC) is particularly ambitious in promoting plastics recycling. While some of the EC's efforts in this context are more general such as the target to bring 10 million tons of recycled plastics into new plastic products annually by 2025 (European Commission) or the substantially increased recycling target for plastic packaging wastes of 55% per weight by the end of 2030 (*Directive (eu) 2018/852 of 30 may 2018 amending directive 94/62/ec on* *packaging and packaging waste.* 2018), others are specifically impacting product design. As a matter of fact, the so-called Single-Use Plastics Directive (SUP) of the EC (European Commission 2019) not only foresees market restrictions and reduction targets for certain plastic products. In its article 6, it also imposes concrete product requirements. Caps and closures of plastic beverage bottles must remain attached to the bottles in future and beverage bottles made of PET have to contain at least 25% recycled content by 2025 (European Commission 2019). Moreover, the EC's Strategy on Plastics in a Circular Economy (European Commission, COM(2018) 28 final) contains the explicit statement that all plastic packaging placed on the EU market shall be reusable or easily recyclable by 2030. The EC's 2020 New Circular Economy Action Plan (European Commission 2020a) further strengthens this plan by demanding that recycling all (plastic) packaging put on the EU market shall be possible in an "economically viable way". In that sense, a particular focus is being put on the reduction of (over)packaging, the promotion of design for re-use and recyclability including restrictions on the use of certain packaging materials, and reduction of packaging materials complexity (European Commission 2020b, COM2020 98 final). Furthermore, a revised version of the Ecodesign Directive is envisioned to more comprehensively integrate diverse aspects of circularity for a wider range of products (European Commission 2020b).

This concerted regulatory pressure on the design of plastic packaging and products has stimulated quasi-voluntary commitments of members of the plastic packaging value chain such as the Ellen MacArthur Foundation's Global Commitment (Ellen MacArthur Foundation 2020) or private sector design guidelines. Several organizations published packaging development standards with the goal of a sustainable packaging future. These are mostly protocol-type models specifying voluntary design principles and evaluation-type models (interactive tools) (Koeijer et al. 2017, 446ff). These standards could support a transition towards a CE by specifying clear targets for packaging developers.

Packaging design standards face a difficult task. They must take into account proper cycling that safeguards high material quality and volumes over several life cycles (Koeijer et al., 2017) while still maintaining all necessary packaging functions. These functions set the boundary conditions for the transition from linear to circular. If the content of a guideline conflicts with the basic packaging functions, the practical relevance of the standards decreases. However, analyzing packaging design standards and their role for a transition towards a CE has been so far neglected (Koeijer et al., 2017). We address this gap by the following research questions: W*hich circular packaging design standards exist and where do they guide us? How do the packaging functions affect circular packaging design?*

Considering the specific functions and the short lifecycles of packaging, the recycling loop receives the most attention. Recycling in terms of a CE starts at the product design stage and has to take into account all related processes and value chain steps (Paletta et al., 2019). Recycling processes are often hampered by inseparable (polymer) composites, opaque materials, unnecessary use of additives, and the use of substances of concern (Paletta et al., 2019). Keeping plastic packaging in closed material loops can lead to the accumulation of hazardous chemicals in material streams (Aurisano et al., 2021; Groh et al., 2019; Zimmermann et al., 2019). Impurities, caused by both intentionally added substances (IAS) (monomers used to make the polymer, additives added to the polymer to impart a desired property or function, and other chemicals intentionally used during manufacturing such as solvents or processing aids), and non-intentionally added substances (NIAS) *(contaminations, reaction by-products, and breakdown products* (Groh et al., 2019)) can jeopardize proper recycling. To "fully close polymer loops, recovered plastic materials need to be recycled into new products at the same or similar quality levels as the original plastic product, that is, within applications comparable to the original products" (Eriksen et al., 2019). However, to date, knowledge on packaging composition is in general inaccessible for actors in the packaging value chain. This complicates circular packaging development and proper recycling (Kramm et al., 2020). Hansen and Schmitt (2021) provide an example of how a material transparent circular packaging development based on a requirement standard can work throughout the value chain. Along with these information barriers, several other barriers to packaging circularity exist. These stem from the political landscape (Bening et al., 2021), the plastic value chain (Paletta et al., 2019), the complex material science of polymers, and recycling technologies (Martens and Goldmann 2016, 271ff). Effective circular development standards will have to address all of these points.

Methods

The methodological approach is a qualitative and comparative analysis of recent packaging design standards with a focus on plastic packaging. The candidates were selected based on a set of criteria. To become part of the review, a standard must first, directly address plastic packaging; second, be directed towards a CE; third, focus on design elements of plastic packaging; forth, be based on the publisher's research; fifth, be available in English or German; and sixth, be published in or after 2015 (ensure up-to-date information)

We identified seven standards to fulfill our criteria for review (CEFLEX, 2020; Cradle to Cradle Products Innovation Institute, 2019; Ellen MacArthur et al., 2017; EverMinds - Borealis AG, 2019; FH Campus Wien, 2020; RecyClass, 2019; WRAP et al., 2018). Most of them are guideline standards but also one certifiable requirement standard

(Cradle to Cradle Certified) and interactive tools passed the qualification. A list of final candidates with their publishing institution and their date of publication can be found in Table 1.

Table 1 Overview of analysed circular design standards

Title of Standard	Publisher	Type of Standard	Latest Update
Polyolefin Packaging Design – 10 Codes of Conduct for Design for Recyclability	Borealis AG	Guideline Standard	2019
Circular Packaging Design Guideline - Design Recommendations for Recyclable Packaging	FH Campus Wien	Guideline Standard	2020
Rigid Plastic Packaging - Design Tips for Recycling	WRAP	Guideline Standard	2018
Design for Recycling Guidelines by RecyClass	RecyClass	Guideline Standard	2020
Designing for a Circular Economy – Recyclability of Polyolefin-based flexible Packaging	CEFLEX	Guideline Standard	2020
The New Plastics Economy – Catalyzing Action	Ellen MacArthur Foundation	Guideline Standard	2017
Cradle to Cradle Certified Product Standard	Cradle to Cradle Products Innovation Institute	Requirement Standard	2021

To review and compare the standards, an analysis grid was developed focusing on design elements that set a circularly designed package apart from a conventional one, and on the conflicts with the basic functions of packaging, which occur because of the recommended changes in packaging design. The analysis grid can be understood as a set of checkpoints to drive the reviews and comparisons of the standards. It enables compact delivery of the generated findings and ensures comparability in terms of content and scope.

In the first step of the analysis, we identified the circular packaging design elements from the conventional packaging design literature (e.g. Geueke et al., 2018, p. 493). We compared these design elements with those the circular packaging design standards propose for redesigning a package. These elements are the choice of the main material such as PE (polyethylene), PP (polypropylene), or PET (polyethylene terephthalate), additional substances for the material formulation such as stabilizers, plasticizers, or any kind of coloring agent, additional layers or coatings such as EVOH (ethylene vinyl alcohol) barrier layers, the size and shape of the product, the material density, product decoration (e.g. labels, sleeves or direct printing), and product features like closure systems. So, we not only got "true or false" statements that show whether a design element is considered by a guideline or not but also descriptive models of the ideally cyclable package according to the respective guideline.

Second, we analyzed the standards with regard to the basic functions of packaging. The packaging functions are containment, protection, preservation, information & merchandizing, facilitating convenient handling, being economically friendly, and environmental responsibility (e.g. Coles et al., 2003, pp. 8–9; Emblem & Emblem, 2012, 24ff; Lindh et al., 2016, 230ff). All of them might be affected by changes in product design. Despite the need for higher cycling rates, it must be ensured that the products do not lose their purpose and functionality at the cost of circularity. Today, even so-called conventional packages are already highly efficient engineering products providing a maximum of functionality with a minimum of resource consumption. Consequently, we pointed out the links between the standards and the packaging functions. We especially concentrated on conflicts between the functions and the design recommendations. Conflicts between the recommended design changes and the functionality of packaging decrease the practical relevance of the standards and thus hinder the transformation to a more circular economy. Pointing out these conflicts in design changes might help packaging designers and authors of future standards to solve certain conflicts by providing better alternatives.

Third, we visualized the relations between the design elements and packaging functions. Therefore, we developed a grid, see table 2, that shows which design elements cause what conflict.

After reviewing the standards individually for design elements and packaging functions, we compared them to each other and performed overall evaluations. Those enabled us to highlight the strengths and weaknesses of the standards and to deduce recommendations for further development.

Results and Discussion

Our analysis led to the following results.

Design Elements

Summary of recommended design elements

Main-Material: The analysis has shown that the average recommended packaging design includes a significant reduction in the variety of used packaging materials, however, plastics per se are not affected by that claim directly. The standards treat all polymer grades (PE, PP, PVC etc.) as individual materials. Among them are some polymers that should be replaced by other polymers but the substitution of polymers with non-polymeric materials never was recommended by any guideline. Some polymers even are treated as the number one choice for many products if they fulfill two barrier conditions. First, the packaging system must be realized as a mono-material structure. Second, the chosen polymer should be one of the following: PE, PP, or PET.

Additives: A major influence on the recyclability of plastics is caused by additives. It appears that most authors know little about polymer additivation. For example, “reducing additivities to a minimum” is a frequently read recommendation. In fact, correct additivation is strongly polymer- and application-specific and sometimes the reduction of additives causes a decrease in recyclability instead of an increase. This is especially the case for stabilizing additives in polyolefins. Polyolefins tend to undergo radical degradation during service life and (re)processing, which can be prevented through correct and enough additivities.

A special kind of additives are pigment-based or liquid-based coloring agents. While the material color does not necessarily have an influence on the packaging functions, it can negatively affect sortability and always causes a price reduction of the resulting recyclate which cannot be deliberately colored anymore. Especially carbon black is a barrier to recycling since it strongly absorbs electromagnetic radiation and thus cannot be sorted through NIR (near infrared).

Layers and coatings: To improve the preservation ability of packages, they are often equipped with barrier layers or barrier coatings. Many barrier materials are not stable as mono material structures because they are very cost intensive, unable to fulfill other requirements than barrier functions (e.g., load carrying capacity) or are sensitive to environmental influences like humidity. So, they are usually sandwiched between layers of the main material. Since this makes a 100% sorting rate impossible, barrier layers are addressed by all the candidates. They usually recommend the transition from polymeric, metallic, or paper barrier layers to plasma coatings. Barrier layers are much thicker than plasma coatings and consequently, the disturbing effect of plasma coatings on the recycling process is minor.

Size and shape of the product: These aspects are cycling relevant since some automated sorting facilities are not able the handle all sizes of input waste. Especially very small formats are problematic since sensor-based sorting techniques require the pieces of waste to be at least some centimeters long. But packages can also be too large to be handled by sorting machines. Thus, some standards recommend an upper volume limit of five liters for plastic packaging. Concerning the shape, many standards recommend a packaging design which enables full drainability.

Density: The density of polymers can be easily adjusted through certain processing principles or fillers. Density modification becomes problematic when sorting facilities use swim sink separators to separate polyolefins from other polymers or contaminants. So, most standards feature a section on material density. While some of them recommend preventing all density-changing activities, others specify their recommendations by allowing lowering the density of polyolefins and rising the density of other plastics.

Decoration: Labels, sleeves, and direct printing are used for packaging communication. Of course, here the potential for disturbing the recyclability is huge since it includes various product parts and colors. The average recommendation of the standards is to minimize the size of all forms of decoration, to use washable inks, and to use labels and sleeves made of the same material as the main body.

Other features: many packages have practical features like reclosable closure systems, ziplines, dosing systems, etc. In this case, the standards either recommend manufacturing all parts of the main body material or using parts with a significant difference in density that is easily decomposable at the same time.

Comparisons and evaluations of design elements:

Basing on the individual analysis of the standards, we compared the content of the standards with to draw overarching conclusions. The findings of the individual evaluation charts were entered in a calculation tool and graphically edited. Individual, as well as all-encompassing strengths and weaknesses of the candidates were revealed this way.

The number of addressed design elements corresponds to the conclusiveness of the standards. In detail, our analysis grid includes 14 different design elements. Figure *1* shows how many of them are addressed by which guideline. It appears that all but two of the candidates address at least eleven elements. The *Circular Packaging Design Guideline* by FH Campus Wien and *Designing for a Circular Economy* by Ceflex stand out as they are the only standards addressing all design elements of the analysis grid. Nevertheless, two candidates lie far behind the others. These are *The New Plastics Economy* and the *Cradle to Cradle Certified Product Standard*. Both candidates stand out as they have a style which is significantly different from the others. They are not pure packaging design standards. *The New Plastics Economy* is about a whole transformation of the economic system of packaging. Packaging design is only one of many topics that are subject to the framework. The *Cradle to Cradle Certified Product Standard* is a certifiable requirement-standard that applies to all product groups – the first with the explicit aim to foster a transition to a CE through product innovation. Its new version 4.0 contains a specific section with specifications for packaging (C2CPII, 2021) The broader focus of these two standards are assumed to be the reason for the weak focus on design elements.

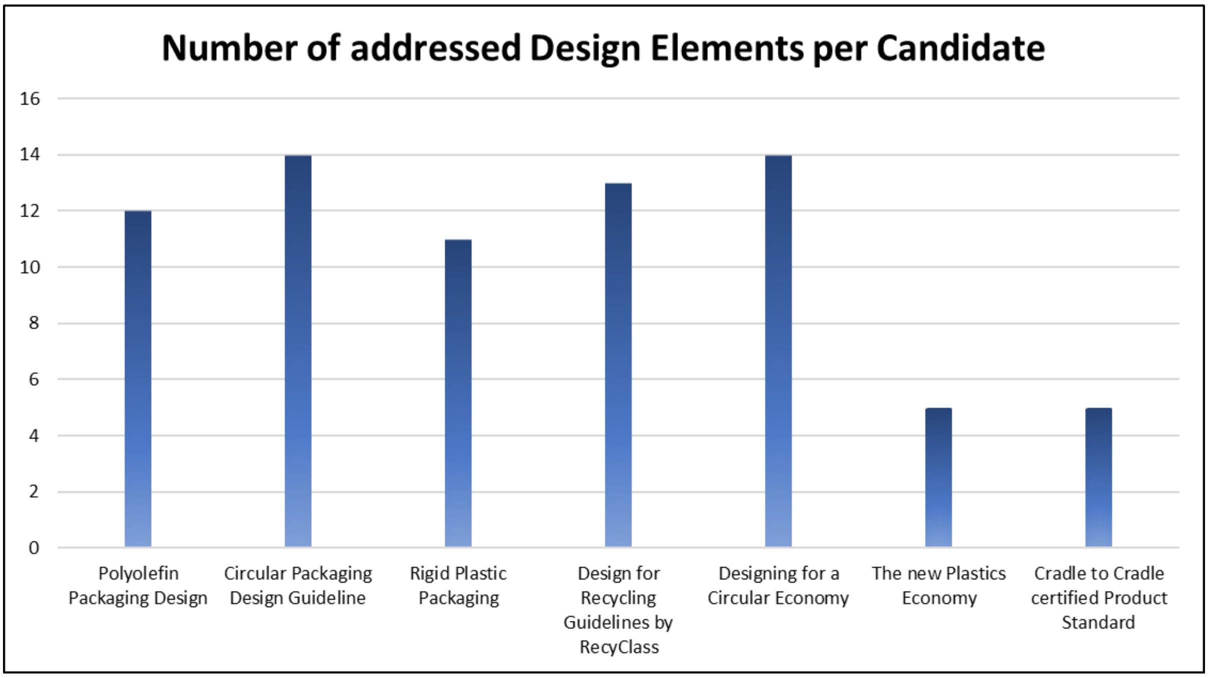

Figure 1: Number of addressed design elements per standard

Figure 2 shows how often the 14 design elements were addressed in total by all standards. It shows which design elements the packaging industry is generally aware of, and which elements still need to be made known. The choice of the main-body material stands out as it is the only design element addressed by all candidates. On the other hand, stabilizing additives are addressed three times and recommendations that go beyond product design are addressed only twice. General weaknesses can be identified in the field of full drainability of the package and its format design too.

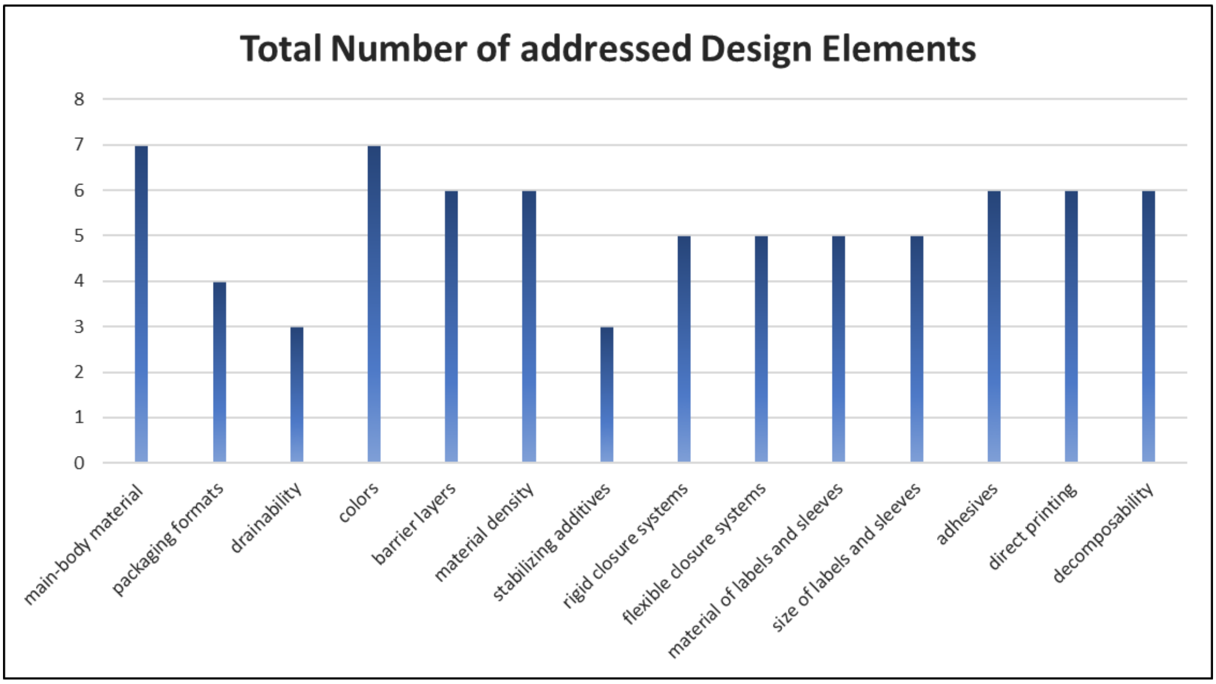

Figure 2: Total number of addressed design elements

Packaging Functions

Summary of packaging functions

Containment: as mentioned before, the standards offer recommendations concerning the size and shape of the products. Since creating sellable units is part of the function containment there is conflict potential. According to the recommended limitations, it would not be possible anymore to pack small products like bonbons individually or to sell beverages in units of more than 5 liters.

Protection: we did not find any recommendation within the standards conflicting with the function of mechanical protection.

Preservation: The analysis showed that keeping the preservation function will be an extensive part of the transition from linear to circular packaging design since this function faces many conflicts. First, there is the recommendation of avoiding well-established barrier materials such as aluminum or EVOH. Second, the standards recommend avoiding well-established sealing materials like PVC. Both recommendations conflict with a proper barrier against gases and humidity. Third, the standards recommend using clear packages. Since many products such as milk or meat require protection against (UV) light, this claim is problematic. Alternative light protection using full-size printings or labels is not recommended because of the claim for proper sortability. Fourth, at least one guideline recommends scaling up compostable packaging materials. Packages are usually designed to prevent interactions between the good and the environment and thus degradable plastics are badly suited to preserve goods unless they are highly modified with stabilizers.

Information and merchandizing: This function conflicts with the claim for reducing all forms of decoration. At least some standards mention washable inks or labels made of main body material as cycling compatible alternatives.

Facilitating convenient handling: This function generally conflicts with recommendations that shorten the shelf life like eliminating barrier layers, and with recommendations that require a more challenging waste sorting at home. An example is the recommendation of scaling up compostable packages.

Being economically friendly: Alternative solutions that cost more than conventional solutions will always have difficulties competing on the market. So, recommended changes in product design that cause a significant increase in cost are in conflict with this function. Again, this is for example the recommendation of scaling up compostable packages.

Comparisons and evaluations of packaging functions

The number of conflicts with the basic packaging functions corresponds to the practical relevance of the guideline. Conflicting with some of the functions is not the problem per se. The analysis even shows that most candidates propose recommendations that are in conflict with some of the basic functions. But as long as the standards also offer a feasible solution to the conflict, the practical relevance is maintained. Figure 3 shows how many conflicts each candidate faces (blue bars) and how many conflicts remain unresolved (red bars). It can be seen that most conflicts are resolved through alternative recommendations in the respective guideline. All but one of the standards have none or a very low number of remaining conflicts. The only guideline with more remaining conflicts is *The New Plastics Economy*. This guideline offers a high number of approaches but on cost of conclusive and meaningful description. It can be concluded that as a design-aid, it is rather unsuited.

Figure 4 shows the total number of conflicts with each packaging function. It represents the critical aspects of redesigning plastic packaging. Most conflicts are linked to the function of preservation. *Preservation* even faces more than twice as many conflicts as *information and merchandising*, which is the function with the second most conflicts. It can be concluded that the conventional way of preserving products is not suited for a recyclable packaging design. Enabling a recyclable way of *preservation* (offer a barrier against gases, humidity, and radiation) is a central challenge of redesigning plastic packaging. On the other hand, the function of *protection* (prevent product loss due to mechanical stress) does not cause any issues with a recyclable packaging design. Attention must also be paid to *information and merchandising*. Since reducing the information on packages would perhaps not be accepted by brand owners, recyclable alternative ways of packaging communication must be established.

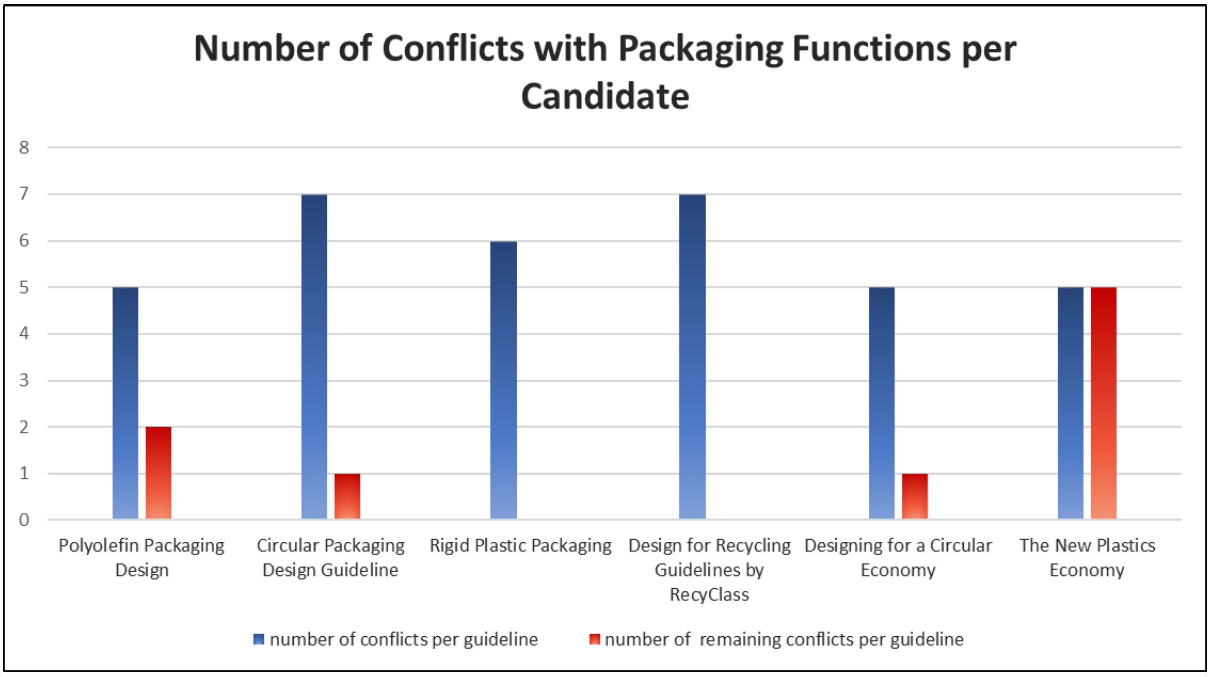

Figure 3: Number of conflicts with packaging Functions per standard

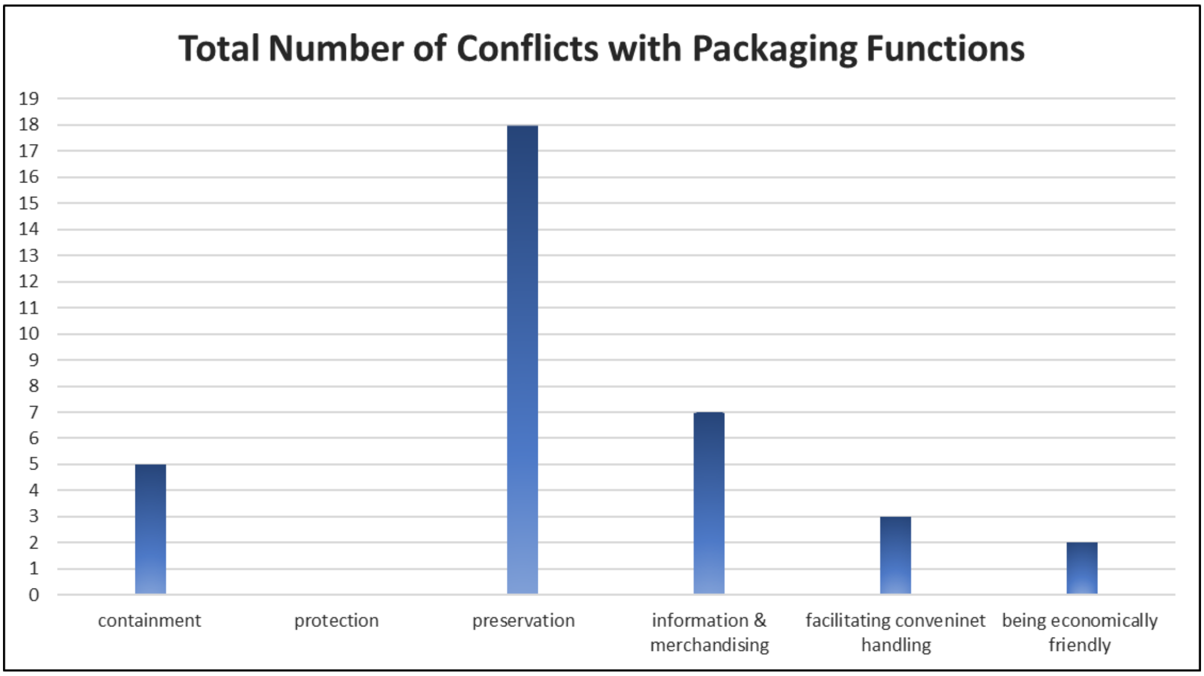

Figure 4: Total number of conflicts with packaging functions

Relations between design elements and packaging functions

After having analyzed the content of the standards for their recommendations regarding design elements and packaging functions, Table 2 summarizes our findings on the relations between both aspects. The column of protection is empty because no conflicts were found with this function in any of the reviewed standards (see figure 4).

Table 2 Relations between design elements and packaging functions

	Main material	***additives***	***Layers and coatings***	***Size and shape***	***Material density***	***decoration***	***Product features***
Containment				*Limitations in the freedom of creating sellable units*			*Limitations in the way of enclosing due to the avoidance of well-established sealing materials like PVC*
Protection							
Preservation		*Limitations in preventing quality losses due to radiation because of the avoidance of coloring agents*	*Limitations in preventing quality losses due to gases, humidity, and radiation because of the avoidance of established barrier layers like EVOH, PA or aluminum*			*Limitations in preventing quality losses due to radiation because of the avoidance of non-translucent coatings*	*Limitations in preventing quality losses due to gases, humidity because of the avoidance of well-established sealing materials*
Information and merchandizing						*Limitation in packaging communication due to minimization of labels sleeves and direct printing*	
Facilitating convenient handling	*Limitations in convenient storage because of the claim for degradable materials that have rather poor barrier properties*	*Difficult to get high quality recycled due to the avoidance of stabilizers*	*Limitation in convenient storage because of the avoidance of established barrier layers*				*Limitations in convenient use due to the avoidance of small parts like opening zippers*
Being economically friendly	*Limitations because of the claim for more expensive materials like degradable polymers*	*Limitations because of material losses due to too less stabilization*	*Limitations because of product losses because of too week barrier properties*				

Strengths and weaknesses of the standards

The circular packaging design as it is recommended by the standards is intended to bring along ecological and economic benefits. But is the knowledge from the standards enough to get the plastic issue under control? The general answer to this question is: No. Besides the human cooperation along the value chain of packaging, the impact of the standards is also limited by the recycling-capability of polymers. Studies with various types of polymers show that continuous cycling of polymers is linked to various technicalities. This is due to degradation mechanisms in polymers. Degradation means that at least one of the following effects occurs: change in molecular weight due to chain scission or crosslinking, or formation of oxygenated and unsaturated compounds. The degradation effects are triggered by mechanical-, thermal-, thermo-oxidative and photochemical stresses and lead to changes in material properties and process conditions. The stresses mainly occur at the reprocessing stage during shredding, washing, and extrusion.

The degradation mechanisms lead to several changes in the polymer behavior. A study, that addresses the effects of degradation was for example conducted by Jin et al., (2012). They showed the effects of extensive recycling on the properties of PE. With an increasing number of cycles, the mean molecular weight decreases for PE. This indicates chain scission because the shorter the average chain length, the lower the mean molecular mass. The molecular weight affects many other polymer properties such as viscosity. However, it is important to mention that the behavior of PE does not represents other polymers too. In fact, all polymers respond differently to recycling. While some tend to undergo chain scission due to heat and shear, other tend to crosslink instead.

However, the study of Jin et al. (2012) is idealized because it does not consider the use phase of the samples. The cycles of the study include shredding, melting, and regranulation while aspects that are linked to recycling such as mixing of polymer fractions, contaminations through waste or organic substances, aging during the use phase, or washing were neglected. So, the study shows the influences of reprocessing and not recycling. Moreover, it uses one defined material grade and thus neglects the effect of mixing differently modified PE grades.

To sum up, it can be said that sticking to the standards is not enough to close the loop on plastic packaging. Deeper competencies in polymer science are required to keep the product quality under control and to supply the industry with innovative approaches. Since it is difficult to prevent degradation, mixing, and contamination, a pragmatic suggestion from a recycler's point of view would be coping with these effects using special design from recycling principles (Ragaert et al., 2018, 528ff). An often-discussed attempt is sandwiching the recycled content between virgin surface layers to maintain the surface quality while simultaneously utilizing a significant amount of recycled material in the core. The feasibility of sandwiching contaminated PP between virgin material in transport boxes was already reviewed by Gall et al (Gall et al., 2021, 1ff). They concluded that not all product properties suffer under the use of recycled content and that the potential of this technique lies in design approaches, that include fracture mechanical methods. So, the feasibility and the limitations of design from recycling principles can be explored for potential applications.

The standards reviewed in this paper, help to organize the waste treatments and to establish a clear base for further developments, which of course is a key element in closing the loop on plastic packaging but not the only one. The consequent addition to the design for recycling-approach of the standards would be a design from recycling approach.

References to substances of concern within the standards

Material-toxicity can be described as a measure of a material's ability to harm living organisms. Establishing material-health, as the C2C standard terms it, means going for a saver product chemistry and thus reducing the harmful effects of the material. As such, material-health is the central element of C2C Design. Material toxicity or health must be discussed for plastics because various plastic products are suspected to contain substances of concern and researchers have already proven their presence and toxicological effects. For example, (Zimmermann et al., 2019, 11467ff) tried to benchmark the toxicological effects of several polymers used in consumer products like packaging using in-vitro-bioassays and nontarget high-resolution mass spectrometry. They detected baseline toxic effects in almost 3/4 of their probes. These toxicological effects can be endocrine disruption, steroidogenesis, neurotoxic, genotoxic, or oxidative stress etc. (Beach et al., 2013, 1613ff). But it appears that substances of concern are an uncommon topic among the analysed standards. In fact, in most of the standards, is the toxicological profile of substances not mentioned at all. At least some standards refer to regulatory standards like EuPIA (European Printing Ink Association 2020) or REACH (European Commission 2006). The guideline from Ceflex recommends eliminating the substances of very high concern according to REACH, the standards from RecyClass and FH Campus Wien recommend eliminating toxic printing inks according to EuPIA and the standard from the Ellen MacArthur Foundation generally recommends eliminating substances of concern. An exceptional case is the Cradle to Cradle Certified Product Standard. This standard is the only guideline in the analysis referring to a restricted substances list that was developed by the Cradle to Cradle Certified Products Innovation Institute itself. Apart from this framework, the topic of material toxicity is a general weakness of the analysed standards. With its focus on its purposive choice of materials and substances C2C can be regarded a specification of circularity. It must be discussed whether the topic of substances of concern is underestimated by the other standards or whether there are other reasons for the absence of the topic.

The strategy of Ceflex allows a prediction of a possible future scenario for plastics coming closer to the C2C concept. Ceflex perceives its current campaign for establishing a cyclable packaging design as the first phase of their two-phase transition strategy. Phase two shall be about improving the cycling strategies and getting rid of substances of concern in materials. Ceflex separated the phases because they need knowledge from testing programs that have just been started for the second phase.

Conclusions

This paper analysed current circular packaging design standards for their conclusiveness and practical relevance. The focus was on design elements, conflicts with the packaging functions, reductions and eliminations of formats, materials, and substances, and the technical feasibility of the recommendations. The analysis and comparisons showed that most of the candidates reach a high level of conclusiveness as they address a high number of relevant design elements. The preservation function turned out to face the most conflicts with the recommendations of the standards. It can be concluded that keeping the preservation function requires explicit attention to the redesigning of plastic packaging for a CE. Toxins in existing packaging basic materials is a minor topic of the standards. It is difficult to say whether the standards underestimate the importance of the topic or whether they lack knowledge because of the difficulties when accessing and assessing information on material toxicity. In any case, just following the standards is not enough to completely close the loop on plastic packaging. Polymers are complex materials whose performance depends on many influences. During processing, in particular, polymers are exposed to high shear stress and a high temperature. Both factors lead to degradation and negatively affect the polymer’s property portfolio even if the package follows all design-recommendations of the standards. Of course, the standards help to control and organize the handling of waste, but to close the loop, further material and processing innovations in the field of plastic recycling are necessary. After these analyses and comparisons of packaging standards, the next step should be a collection and homogenization of the design-recommendations. This would result in a more conclusive and reliable packaging guideline. The key here is to connect design *for* recycling and design *from* recycling in a genuine design for circularity. Future guideline- and requirement standards might rather set focus on specific use cases of packaging such as guidelines for foils or beverage packages to provide unerring guidance. The to date voluntary standards could also be a valuable base for developing mandatory standardization on basic materials and additivation.

Not only knowledge should be harmonized, but also the waste treatment systems. Waste treatment systems are still different in many countries and consequently, the applicability of packaging design standards is locally limited. With a homogenous waste treatment system, giving recommendations that are internationally valid and at the same time precisely formulated would be much easier. Creating incentives for packagers to keep to the recommendations of the standards might also be helpful. The C2C Products Innovation Institute demonstrates that this incentive can be a product certificate for example. Also, governmental directives or the popularity of the standards among the consumers can be an incentive.

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124 Clothing Circulator - Data to extend the lifetime of garments

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Abstract

Fashion industry is the second largest polluter in the world. To tackle the environmental crisis globally, we must minimize the environmental impact of fashion industry. The extension of garment lifetimes leading into smaller number of garments produced and sold has been identified essential towards sustainable fashion. This requires novel business models substituting volume-based fashion business. The purpose of this study is to investigate, how data can be used to promote the reuse of clothing and sustainable fashion. The first result is a state-of-the-art review focusing on clothing reuse. An integrative literature review method was used to examine the consumer challenges, current services and technologies. Previous research has identified challenges on reuse of different products as well as usage of consumer-to-consumer marketplaces to be on selling and buying experience, trust on the marketplace as well as quality of the product, and difficulties in finding the required size and style. The review provides a logical starting point for the second result, which is a multifaceted description of the Clothing Circulator concept. The concept presents a novel data-driven solution for extending the garment lifetimes and it was created as a multidisciplinary collaboration between fashion, consumer, service and technology researchers during a series of 7 workshops. Holistic, transparent view on the garment lifecycle from design to material recycling is the essence of the concept, which describes stakeholders and their roles, data sources in different phases through the garment's lifecycle, key enabling technologies and consumer aspects that are relevant for the clothing circulator solution. The consumer gets tools to curate wardrobe with a stylish and sustainable selection of garments. It helps in reselling the underused items and estimates the value of the underused garments based on big data from the marketplaces. For the brands the concept provides data on usage of the garments: how often the items are used, how long the items are kept as part of the wardrobe, what kind of combinations are created with the brand items, what type of customers seem to like/dislike the items, what is the resale value of the items and finally, how the items are recycled in the end of the lifecycle. Based on these insights, the brands can

base the design choices on measured data, which optimally leads to diminished waste of unsold items as the design and production would meet better the consumer expectations. This research is a first step towards data-driven approach to support reuse of garments, and hence extending garment lifetimes and more sustainable fashion. In the sustainable fashion research, the data-driven solutions to support reuse or decision-making in the design and production phases have not been extensively studied, even if sustainable consumption is a rising trend among “early adopter” consumers, especially in younger age groups. In the future, the research community should study the topic from a multidisciplinary perspective involving e.g. consumer, technology, data and business research together with the industry, targeting at the development of successful data-intensive solutions to support sustainable fashion.

Keywords: Clothing reuse, Data-driven solutions, Sustainable fashion, Garment lifecycle, Future consumer

Introduction

The environmental impact of fashion industry is remarkable on global scale considering the use of resources (Niinimäki et al, 2020). It is considered to be the second largest polluter in the world (UN News, 2019). To tackle this, we must find ways to minimize the environmental impact of fashion industry. Currently most of the research and development activities in fashion industry are targeted at development of more sustainable materials and improvement of working conditions aiming at ethical manufacturing. Even if both these topics are highly relevant, the extension of garment lifetimes leading into smaller number of garments produced and sold has been identified essential towards sustainable fashion. This requires a transformation from current volume-based fashion business to novel business models offering sustainable options. One of the main challenges is the underutilization of produced pieces of clothing: consumers tend to efficiently use only a portion of their clothing and often many clothes end up in hanging in the wardrobe or being disposed early as waste (Laitala and Klepp, 2015; Maldini et al., 2018). The textile and clothing industry are more and more under radar by the regulators and there is a burning need for improved services supporting consumers in their choice of clothing (no false purchase decisions) and C2C sharing (lending, renting and selling) of extra clothes, which can enhance the use of clothes in their first form. Luckily, today’s consumers are increasingly motivated to make environmentally friendly choices. The purpose of this study is to investigate, how data can be used to promote the reuse of clothing aiming at novel sustainable fashion services.

Methods

The first phase of this work is a state-of-the-art review focusing on clothing reuse for extending the lifetime and improving the utilization rate of garments. An integrative literature review method was used to examine the consumer challenges, current services and technologies. The review provides a logical starting point for the second phase, which is the definition of the “Clothing Circulator concept”, which presents a novel data-driven solution for extending the garment lifetimes. The concept was created as a multidisciplinary collaboration between fashion, consumer, service and technology researchers during a series of 7 workshops.

Fashion reuse market and consumer perspective

Trade of used goods between people has a long tradition. People have commonly been selling services and goods to other people for example, in flea markets, which have a history of several hundreds of years. This activity is at the core of consumer-to-consumer (C2C) commerce, which has become increasingly popular during the recent years. C2C commerce inherently supports the principles of sustainability and circular economy as it extends the life of the product. The change is global, as indicated by e.g. a Japanese study that presents a clear growth of fashion reuse market in Japan (Yano Research Institute Ltd., 2020). The Covid-19 pandemic also had an impact on the reuse market. For example, in Finland the coronavirus has also increased rapidly C2C sales as between March and May 2020, the amount of C2C parcels delivered by the Finnish postal service rose by almost 70% compared to the same period previous year (Posti Group, 2020). Generally, Covid-19 has also made consumers think more about reuse and environmental impact in the context of fashion and clothing (Statista, 2020a).

As a traditional business-to-consumer (B2C) commerce requires a business to consumer relationship, in C2C commerce a role of business is more facilitating the environment that enables trade between the consumers. Traditional physical (offline) environments, such as self-service flea markets, are still popular among consumers, but consumers are increasingly moving to using different types of online e-commerce platforms. In practice, these platforms provide a digital marketplace for selling and buying used goods. Selling products in these environments is typically based on auction or fixed price sales. Many of these C2C e-commerce platforms are providing a wide array of different product categories (e.g. Craigslist, eBay) and a part of the platforms provides service to both C2C and B2C sectors. In addition, some C2C e-commerce platforms focus on a specific product sector, such as fashion and clothing. At its best, these fashion e-commerce platforms can have tens of millions of unique visitors every month. (Statista, 2020b). There are also platforms that have focused especially on fashion and clothing and enable online trading of used clothing between the consumers (e.g. Zadaa). In practice, these companies base their business on taking care of all activities from collecting the clothes to delivering them for consumers.

Typically, the revenue is based on a commission-based model in which the company charges a pre-agreed share of the products sold.

Previous research has identified manifold challenges on reuse of different products as well as on usage of C2C marketplaces. Many times the product does not meet the consumer expectations (Armstrong et al., 2016; Lang et al., 2019). The consumers have also doubts on hygiene of the clothing (Armstrong et al., 2016; Becker-Leifhold and Iran, 2018). Not all the consumers feel comfortable to use clothing that has been previously used by others (Lang et al., 2019). Regarding the C2C marketplaces the challenges are related to buying and selling experience (e.g. sales process, logistics) and trust regarding the platform as well as payment processes (Armstrong and Park, 2020; Becker-Leifhold and Iran, 2018; Leung et al., 2019).

However, there are also various issues supporting the usage of C2C marketplaces and reuse of garments. According to a UK consumer survey, consumers do not use 20% of the garments in their wardrobe (WRAP, 2013). Similar findings on unused garments are reported in other studies as well (Jorgensen and Jensen, 2012; Rathinamoorthy, 2019). On the other hand, the consumers have a need to renew the content of their wardrobe regularly and to avoid being seen rewearing the same clothes (social norms) (Harris et al., 2015; Jorgensen and Jensen, 2012; Klepp, 2001). The impulse buying behaviour often in relation to sales in fast fashion can lead to mistake purchases and to need for resale of garments (Klepp, 2001; Park et al., 2006). In worst cases, the mistake purchases and little-used garments end up as waste (Jorgensen and Jensen, 2012). Thus, there is potentially at least 20% of all the garments in our wardrobes, which could be resold to improve the utilization rate and increase the lifetime of garments.

Often the reuse of garments could be enhanced with repair, customization and refashion services. However, in many cases there is lack of repair skills and the costs are considered to be high (Diddi and Yan, 2019; Gwift, 2014; Laitala et al., 2018). The services can also be difficult to find and in the end the repair, customization or refashioning service is not economically feasible due to the poor quality of the garment (Goworek et al., 2012; Mclaren and McLauchlan, 2015).

Clothing Circulator concept

The Clothing Circulator concept (Figure 1) defines a novel data-driven solution for extending the garment lifetimes and it was created as a multidisciplinary collaboration between fashion, consumer, service and technology researchers. The concept aims at providing a holistic, transparent view on the garment lifecycle from design to material recycling and ideas for data-driven services to support efficient usage of garments.

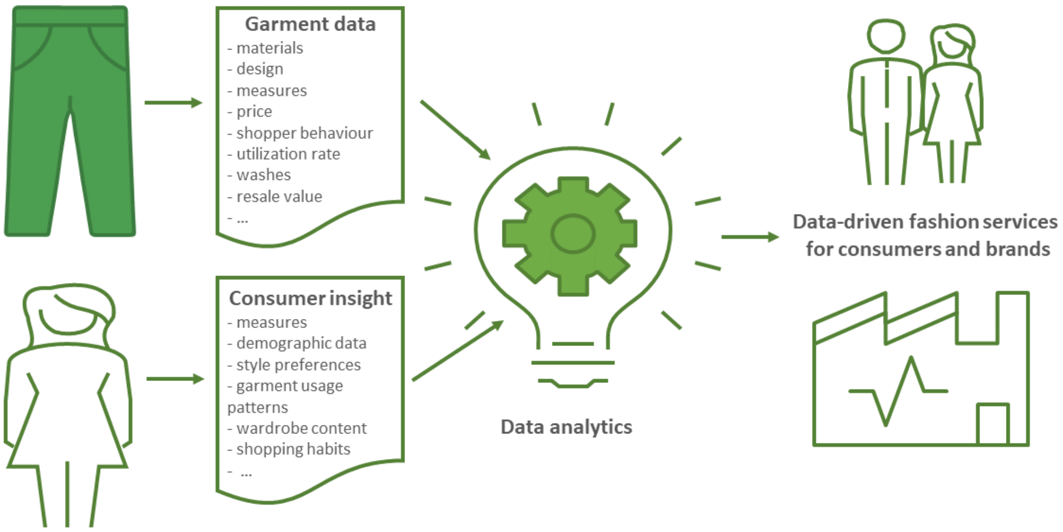

Figure 1 The Clothing Circulator concept

For the consumer it provides tools to curate their wardrobes with a stylish and sustainable selection of garments. The Clothing Circulator services help in resale of the underused items and estimate the value of the underused garments based on big data from the marketplaces. For the brands, the concept provides information on actual usage of the garments, which can be used to optimize the design and production processes.

As the Clothing Circulator is based on exact data on a specific garment along its lifetime, from the design and usage to recycling phase, new technologies for identification, tracking and data collection are needed. This study is based on the assumption that the current research and development activities targeted at item specific garment tracking technologies will provide a solution able to store and share the data along the lifecycle of the garment. The Clothing Circulator concept is focused on defining the potential of garment data and data-driven services.

Data describing the garment and its lifecycle

Currently the garments contain relatively simple information such as materials used (typically main fibres used in the fabric), country of production and sizing. The information is most often attached to the garment in production phase using a fabric tag and the information is not updated in anyway during the garment lifetime. However, there is a lot more information, which would be essential in data-driven fashion services. For example, in the design phase, the brands have more detailed information on measures of the garment, style, usage and characteristics of the target user. The marketing operations create product descriptions and multimedia presentations to support the sales of the product. The retailers use the product and marketing information provided by the brands, and could collect data on sales process: the actual price of the product, time required for selling, demographic information or the customer segment of the buyer of the garment, online/offline shopper behaviour related to the garment etc. From the usage phase, it would be possible to acquire data on number of times the garment is worn, combinations of garments worn together, number of washes required and other information describing garment usage, maintenance and user. The C2C marketplaces supporting the resale of garments can collect detailed information on condition of the garment after the usage phase, the usage time before resale phase, the resale potential and pricing as well as time required to complete the C2C sales process. The recycling operator can record the end of the lifecycle collecting data on the actual lifespan of the garment and the condition the garments are discarded as waste.

The lifecycle described above is simplistic and the actual lifecycle of a garment contains a larger number of stakeholders such as brands, designers, material producers, garment producers, logistics services, packaging providers, online and brick-and-mortar retailers, consumers, C2C and second hand marketplaces, repair and refashion services and recycling operators. All these stakeholders could be both creators as well as users of garment data, which - due to the collaboration of the operators along the garment value chain - gets updated and more detailed during the lifetime of the garment.

Data-driven wardrobe curation services for the fashionable consumer

The fashion consumers are starting to look for not only stylish and comfortable garments, but also truly sustainable choices. As the previous research has shown, consumers often have a large quantity of unused items in their wardrobes. Often the consumers are not willing or able to invest time required for efficient usage of C2C or second hand services to redistribute their unused items or buy used garments instead of purchasing new products. The Clothing Circulator concept in practice for the consumer is a digital style assistant, which tracks the usage of different items in the wardrobe, learns in time the consumer’s preferences and analyses the background information related to the preferences. It also identifies the unused garments and can suggest new purchases (from C2C marketplaces, second hand stores or retailers) to complement the wardrobe content to create new variating outfits. The digital style assistant can provide information on maintenance of the garments and suggest refashion options. It knows the updated resale value of the garments and can suggest ways to sell the unused items. It could even identify a potential new user for an unused garment based on the usage and preference data collected from other users. In total, the digital style assistant will make the garments in the wardrobe move either to be worn more or sold to new users supporting the targets of the Clothing Circulator concept to increase the utilization rate and extend the garment lifetimes.

From the technology perspective, the Clothing Circulator concept at home requires solutions to automatically track the usage as the services should be very easy and enjoyable for the end user to use. For example, RFID tags integrated to the garments to identify a specific item and readers to collect information on usage and washes. The data collected is delivered to a background system, which is able to analyse it and interact with the consumer to guide on the garment usage and wardrobe curation.

Data to enhance the sustainability of fashion industry

Adoption of garment tracing and data collection technologies along the lifecycle of a garment in large scale would enable usage of novel data analytics and artificial intelligence methods to guide the decision-making for example in design, production and distribution of garments. Utilizing the big data on garments and their lifecycle it would be possible to predict more accurately the demand or to define the necessary marketing activities to increase the product awareness in the identified target user group.

For the brands, the garment data would provide objective insight, which is not currently available from any source, on actual usage, reuse and end-of-life of the garments:

- how often the brand products are used,
- how long the garments are kept as part of the wardrobe,
- what kind of combinations are created with the brand garment,
- what type of customers seem to like or dislike the garments,
- what is the resale value of the brand products and finally,
- how the items are recycled in the end of the lifecycle.

Based on these insights, the brands can make their design choices using measured data, which optimally can lead to production of garments meeting better the consumer expectations. This way the brands will both save notably on costs and resources as the amount of unsold items discarded as waste will diminish. In addition, the customer experience on brand products will improve.

The evolving database of garment specific information described above could be used to create services enhancing the sustainability of fashion industry not only for consumers and brands, but also for other stakeholders in the garment value chain. For example, using more detailed information on the garment measures, material and style in combination with data-based insight on consumer preferences and measures, the Clothing Circulator services could diminish the number of mistake purchases tackling the problem of product returns in e-commerce.

Results and Discussion

This study is merely the first step towards a data-driven approach to support reuse of garments extending garment lifetimes and aiming at more sustainable fashion industry. In the sustainable fashion research, the data-driven solutions to support for example reuse of garments or decision-making in the design and production phases have not been extensively studied yet, even if sustainable consumption is a rising trend among "early adopter" consumers, especially in younger age groups. In the future, the research community should study the topic from a multidisciplinary perspective involving e.g. consumer, technology, data and business research together with the industry, targeting at the development of successful data-intensive solutions to support sustainable fashion.

The adoption of data-driven solutions in fashion industry in practice requires collaboration of different actors in the industry to enable collection and sharing of relevant data along the lifetime of the garment. A standard format for garment data should be defined and agreed globally. The basic technology building blocks are already available for garment tracking and creation of data-driven services. The economic feasibility of a Clothing Circulator service implementation is however depending on the overall data-driven garment lifecycle management as the tags should be integrated into the garment in the production phase and the brands as well as other stakeholders should provide the detailed garment data to support the functionality of Clothing Circulator services.

The transformation towards sustainable fashion services necessitates also changes in current volume-based business models and operational models in fashion industry. For example, the quality of the garments should be high enough for enabling higher utilization rates and longer lifetimes of garments. High quality clothing also would make repair and refashion services economically feasible and raise the potential resale prices of used garments accelerating the development of C2C marketplaces and second hand fashion markets. Adoption of sustainable business models and development of data-driven fashion services opens up new possibilities for technology savvy operators as well as for third party companies entering the fashion business with novel service offering targeted at consumers, brands or other fashion industry stakeholders.

Conclusions

The purpose of this study was to research and innovate on the potential related to extensive data collected and shared along a garment lifecycle from design and production to material recycling aiming to enhance the sustainability of fashion industry. The first phase of the work produced a review of consumer challenges related to extending the lifetime of garments and usage of C2C marketplaces. In the second phase, the Clothing Circulator concept was defined to describe a novel data-driven solution for extending the garment lifetimes and decreasing the usage of resources. The Clothing Circulator concept provides a holistic view on the data along the lifecycle of the garment and ideas for innovative data-driven services for consumers, brands and other stakeholders of fashion industry. Finally, the implications for both data-driven solutions in fashion industry as well as novel business models moving away from volume-based business are discussed from research and industry perspective.

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282 Harnessing the economic potential of ocean thermal energy conversion in Indonesia with upscaling scenarios

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Abstract

Ocean Thermal Energy Conversion (OTEC) produces electricity using the temperature difference between warm surface and cold deep seawater. Despite a gigantic theoretical potential of up to 44 PWh worldwide, OTEC is still at an early development stage and many countries cannot benefit from OTEC's clean and predictable baseload power yet. In a series of papers, the economic potential of OTEC was studied at an unprecedented depth. First, practically suitable sites for OTEC are mapped with a novel *Geographic Information Systems (GIS)* methodology. Then, the economic potential of OTEC at these sites was simulated with an upscaling scenario model that scales up OTEC from small pilot plants to full-scale commercial plants until 2050, considering the cost-reducing effects of technological learning and economies of scale. Indonesia is used as a case, the country with arguably the best prerequisites for OTEC in terms of ocean thermal resources and electricity demand. Including criteria like seawater depth and temperature as well as conservation zones, more than 1,700 practically suitable sites for OTEC are detected in Indonesia. Under the consideration of upscaling and economies of scale, the economic potential ranges between 6–41 GW_{net}. Among the studied upscaling scenarios, the highest aggregated *Net Present Value (NPV)* from OTEC is US$(2018) 24 billion in 2050. In that scenario, OTEC would have a significant impact on Indonesia's energy transition, with more than 8% of national electricity demand being covered in 2050. OTEC could be cost-competitive against any other energy technology in Indonesia. Notwithstanding these promising outlooks, this work also shows OTEC's challenges. Cost optimisation is essential from day one and learning effects must be strong and continuous over multiple decades. To which extent this is possible in practice is still unclear, but this paper shows that further development of OTEC is worthwhile, not only for Indonesia, but for many other countries worldwide.

Keywords

Ocean Thermal Energy Conversion, Economic Potential, Upscaling, Technological Learning, Indonesia

Introduction

Ocean Thermal Energy Conversion (OTEC) produces clean electricity with the temperature difference between warm surface and cold deep-sea water (Fujita et al., 2012; Vega, 2012). Despite a massive global resource potential of up to 44 PWh per year (IRENA, 2020), OTEC is still at an early development stage with small-scale pilots. Much is still uncertain about OTEC economics and a critical literature review (Langer et al., 2020) revealed seven knowledge gaps in contemporary literature, namely (i) absence of spatial economic analyses, (ii) omission of natural external influences on real power output, (iii) uncertainty of system and component cost, (iv) operational uncertainty, (v) impact of various risks on interest and discount rate, (vi) omission of technological learning, and (vii) omission of further economic assessment tools. Hence, it is unknown how much of the global resource potential can be tapped practically and economically, especially once OTEC has been scaled up from small-scale pilots to commercial large-scale systems. Tackling these knowledge gaps could be worthwhile, as OTEC could provide stable and affordable baseload to tropical regions and thus boost the energy transition there. This is especially relevant for Indonesia, the arguably most interesting country for OTEC in terms of ocean thermal resources (Asian Development Bank, 2014; Langer et al., 2021a), oceanography (GEBCO Compilation Group, 2020), and electricity demand. The world's largest archipelago is still dependent on domestic fossil fuel resources to meet the strongly growing national electricity demand (ESDM, 2020) and could thus benefit from OTEC as a renewable alternative.

This paper presents the methods and results of a series of studies (Langer et al., 2021a, 2021b, 2020) that shed light on six of the seven knowledge gaps above with the following research question:

Where are practically suitable sites for OTEC in Indonesia and what is OTEC's economic potential there considering upscaling and technological learning?

Knowledge gaps (i) and (ii) are addressed by mapping practically suitable sites for floating closed-cycle OTEC plants using a novel *Geographic Information System (GIS)* methodology. Knowledge gaps (iii) and (v–vii) are treated with upscaling scenarios until 2050 using a range of possible *Capital Expenses (CAPEX)* and *Operational Expenses (OPEX)*, cost-reducing technological learning rates, and economic assessment tools like *Levelized Cost of Electricity (LCOE)*, *Net Present Value (NPV)*, experience curves, and cash flow diagrams. This work contributes to the OTEC research field by shedding more light on OTEC's economic feasibility beyond today's state of the art. Recent discussions focus too much on current costs without taking into account that these costs will decline once the technology moves towards maturity. But since this process does not happen overnight, this paper also elaborates on the technical and economic prerequisites that have to be met for the upscaling scenarios shown here. The broader social relevance of this work comes from raising awareness about OTEC as an interesting option for the global energy transition for policymakers, renewable energy developers, and relevant institutions.

Methods

Mapping of practically suitable OTEC sites

This study follows the methods proposed by Langer et al. (2021a). Five years of daily seawater temperature data in Indonesia and its *Exclusive Economic Zone (EEZ)* are downloaded as point data from the *HYbrid Coordinate Ocean Model (HYCOM)* in a horizontal resolution of 27.8 km at depths of 0 m and 1,000 m. At these depths, the warm surface seawater and cold deep-sea water are extracted to drive an *Organic Rankine Cycle (ORC)* with ammonia as the working fluid. The horizontal resolution was chosen to limit local thermal degradation at the seawater exhaust pipes and the potentially negative ecological implications arising from it (Lockheed Martin, 2012; Nihous, 2010). Each data point is assumed to represent one OTEC plant. Then, the mesh of data points is projected over a map of Indonesia in the QGIS interface together with restrictive layers where OTEC cannot be implemented. These restrictions include water depth, average seawater temperature, and marine protected areas. Regarding water depth, areas with depths smaller than 1,000 m are excluded, as OTEC plants must extract sufficiently cold water from this depth to maintain the ORC. Moreover, sites with depths larger than 3,000 m are excluded to account for current technical limits of mooring lines (Ahmed Ali et al., 2019; Xu and Guedes Soares, 2020). At each point, the five-year temperature data is averaged and points with a temperature difference between surface and deep seawater of less than 20 °C are excluded. Lastly, points within marine protected areas (Direktorat Konservasi Kawasan dan Jenis Ikan, 2013) are removed as well. The output of this filtering process is a point layer that contains all practically suitable sites for OTEC. These practically suitable sites are then connected to adequately populated onshore connection points via marine power cables. In this study, the onshore connection points are regency capitals in Indonesia. Besides the distance from plant to connection point, the applicable electricity tariff at the connection point is assigned to the data points. In Indonesia, renewables are currently remunerated based on a *Power Purchase Agreement (PPA)* scheme, for which the maximally receivable tariffs for OTEC varied regionally between 5.87–18.18

US¢(2018)/kWh in 2018 (ESDM, 2019). These tariffs are assumed to stay constant throughout the upscaling scenarios.

Upscaling scenarios with technological learning

After obtaining the set of practically suitable sites, a model scales up OTEC from small pilots to large-scale systems over 30 years until 2050 (Langer et al., 2021b). At each year, an installation target is declared based on a growth rate chosen by the user, in the following called *OTEC growth rate*. The model tries to achieve the target by selecting favourable sites for OTEC deployment based on a (1) close distance to shore, a (2) high local electricity tariff, and a (3) sufficient electricity demand at the connected province. The electricity demand at the province is updated annually with a user-defined *demand growth rate,* which is assumed to be 6.4 % per year based on past records (ESDM, 2020, 2010) and official future projections (Presiden Republik Indonesia, 2017). If a province temporarily does not have demand for a new OTEC plant, it is not considered by the model until there is enough demand again in later years. In the upscaling scenarios, no other generation technologies are considered to meet the demand. In the beginning, the implementation targets are small and at OTEC's early development stage, only small-scale plants in the range of 10 MW_{net} are initially available to meet them. But with each year, the available plant sizes grow as it is assumed that plants can be built gradually bigger with growing experience. In this study, the maximum reachable system size is 100 MW_{net}, which is often used as a representative size for commercial, full-scale systems (Banerjee and Blanchard, n.d.; Martel et al., 2012; Oko and Obeneme, 2017; Vega, 2012).

For the techno-economic analysis of the scenarios, the LCOE is calculated for each plant that is deployed by the model using equation (1). To account for the high uncertainty of costs in contemporary literature, this study uses *Low-Cost (LC)* and *High-Cost (HC)* assumptions drawn from literature (Langer et al., 2020). The cost approximation functions for location-independent and location-dependent components are listed in Table 1. Additional techno-economic assumptions are listed in Table 2. Technological learning during the upscaling scenario is included by adjusting the CAPEX, OPEX, and discount rate of each implemented plant with a learning rate of 7% (Avery, 2003; Martel et al., 2012) with equations (2–5). Applying the learning rate to the discount rate is a novelty of this work. This assumes that technological learning will not only reduce investment and operational costs over time, but also financing costs as can already be observed for solar PV (GrantThornton, 2018). In this study, a learning rate of 7% lead to a decline of discount rate from initially 10% (Langer et al., 2021a) to 5% in 2050, a rate which harmonises with the ones of today's mature technologies (Rubin et al., 2015). However, comparing discount rates only by technology would exclude myriad other financial and socio-political influences (Bloomberg, 2015). Hence, the concept suggested here needs further validation.

$$LCOE_h = \frac{CRF_h * CAPEX_h + OPEX_h}{E_h} \quad (1)$$

$$with\ CRF_h = \frac{DR_0 * \left(\frac{P_{inst,h}}{P_{inst,0}}\right)^{-b} * \left(1 + DR_0 * \left(\frac{P_{inst,h}}{P_{inst,0}}\right)^{-b}\right)^N}{\left(1 + DR_0 * \left(\frac{P_{inst,h}}{P_{inst,0}}\right)^{-b}\right)^N - 1} \quad (2)$$

$$CAPEX_h = CAPEX_0 * \left(\frac{P_{inst,h}}{P_{inst,0}}\right)^{-b} \quad (3)$$

$$PR = 2^{-b} \quad (4)$$

$$LR = 1 - PR \quad (5)$$

Inputs

b: Learning Coefficient
PR: Progress Rate
LR: Learning Rate
N: Project Lifetime
CAPEX: Capital Expenses
OPEX: Operational Expenses
P: Installed Capacity
CRF: Capital Recovery Factor
DR: Discount Rate
LCOE: Levelized Cost of Electricity

Indices

0: Starting Year
h: h^th Implemented Plant
inst: Installed
H: Total Number of Implemented Plants

Table 1 Cost Functions in US$ (2018) Million. ∆*T*: seawater temperature difference [°C], *d:* distance from plant to connection point [km], P_{net}: nominal plant size [MW_e]. Adapted from (Langer et al., 2021a).

Cost Component	Location-dependent?	Scale Curves/ Approximation functions	
		LC-OTEC (Vega, 2010)	HC-OTEC (Martel et al., 2012)
Platform & Mooring	No	$(39.6 * P_{net}^{-0.418}) * P_{net}$	$(51.8 * P_{net}^{-0.315}) * P_{net}$
Power Generation			
Water Ducting			
Deployment & Installation			
Others			
Heat Exchangers	Yes, seawater temperature difference (Martel et al., 2012)	$(1.97 - (\Delta T - 20\ °C) * 0.19) * P_{net}$	$(5.82 - (\Delta T - 20\ °C) * 0.56) * P_{net}$
Power Transfer	Yes, distance to connection point (Martel et al., 2012; Vega, 2010)	$(0.0497 * d + 0.304) * P_{net}$	

Table 2 Techno-economic assumptions regarding OTEC plants. Adapted from (Langer et al., 2021a).

Parameter	Value [Unit]		Reference
	LC-OTEC	**HC-OTEC**	
OPEX	5% of CAPEX per year	3% of CAPEX per year	(Martel et al., 2012; Vega, 2010)
Nominal Size	10 – 100 MW_e		
Lifetime	30 Years		(Bluerise, 2014; Martel et al., 2012)
Capacity Factor	91.2%		(Jung et al., 2016; Martel et al., 2012; Vega, 2012, 2010)
Discount Rate	10%		(Harrison, 2010; Zhuang et al., 2007)
Transmission Efficiency	(100 – $2*10^{-4} * d^2$ – $1.99*10^{-2} * d$) %		(Langer et al., 2020; Martel et al., 2012)

After calculating the LCOE for each deployed OTEC plant, the aggregated NPV is determined with equation (6).

$$NPV = \sum_{h}^{H} \sum_{i}^{i+N} \frac{E_h * (PPA - LCOE_h)}{\left(1 + DR_0 * \left(\frac{P_{inst,h}}{P_{inst,0}}\right)^{-b}\right)^i} \quad (6)$$

Inputs
i: Year of Plant Implementation
NPV: Net Present Value
PPA: Tariff from Power Purchase Agreement

The NPV is used in this study to estimate the economic potential of OTEC. If an upscaling scenario returns a positive aggregated NPV, then the economic potential encompasses the installed capacity of all deployed plants in that scenario, even the ones with a negative NPV. With this, it is assumed that the experience gained from these unprofitable plants contribute to reduce the costs of follow-up plants, which then are profitable.

In this study, it is first assessed which OTEC growth rate yields the highest aggregated NPV while leaving all other scenario parameters unchanged. For the optimal OTEC growth rate, a techno-economic analysis is conducted with outputs like a cash flow diagram, plant distribution across Indonesia, and experience curves that show how the LCOE develops throughout the scenario timeframe. However, the goal of this study is not to find *the* optimal scenario, but to indicate the impact of individual variables on the upscaling scenarios and the key outputs like NPV and LCOE. This is done with a sensitivity analysis for the discount rate, learning rate, and demand growth rate.

Results and Discussion

Mapping of practically suitable OTEC sites

Based on the filtering process in the previous section and Figure 1, a total of 1,704 suitable OTEC sites are identified within Indonesia and its EEZ. If all sites were occupied with a 100 MW_{net} plant each, the total practical potential would be 170.4 GW_{net}. Note that these numbers differ from an earlier work (Langer et al., 2021a), because not only the marine provincial borders but also the EEZ outside provincial borders were included. As seen later in Figure 4, most practically suitable sites are situated in East Indonesia, which is not as economically developed as the economic centres of Java and Bali. Therefore, OTEC could be an interesting technology to boost socio-economic development and to provide clean, stable baseload power to hitherto disadvantaged communities. Regarding the exclusion criteria, the water depth of less than 1,000 m is the most effective one with 3,840 removed sites. Moreover, 3,006 sites are removed with a depth of more than 3,000 m. This is a valuable insight as the local water depth is not always included in spatial OTEC resource assessments (Asian Development Bank, 2014; Lewis et al., 2011; Nihous, 2010). The impact of a maximum water depth is especially noticeable for the Banda Sea in the East, where the water can be as deep as 7,000 m. The minimum seawater temperature difference of 20 °C only removed 25 sites, which can be explained by Indonesia's highly favourable climatic conditions for OTEC. Nonetheless, this exclusion criterion is still essential, especially in other regions suitable for OTEC with less favourable thermal resources.

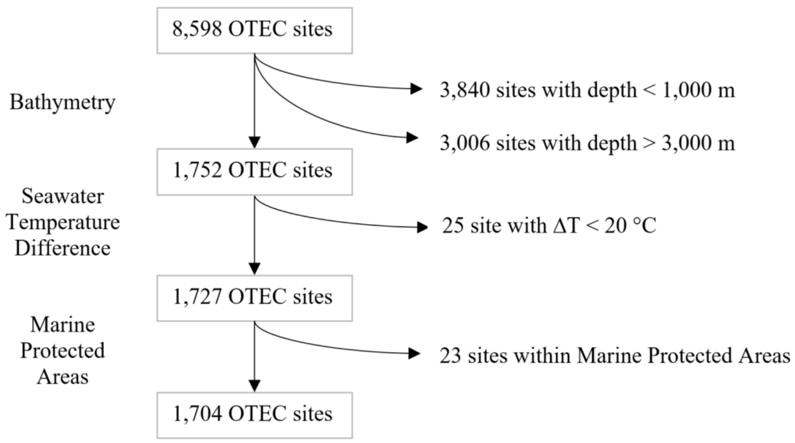

Figure 1 Filtering process for OTEC site selection. The 1,704 sites form a practical potential of 170,4 GW_{net} in Indonesia. Adapted from (Langer et al., 2021a).

Upscaling scenarios with technological learning

Whether a practically suitable site is actually used for OTEC deployment strongly depends on how the upscaling process takes place as presented in this section. Figure 2 shows how the impact of OTEC growth rate on (a) final installed capacity, (b) final aggregated NPV, and (c) average LCOE.

In Figure 2(a), the aggregated installed capacity rises with the OTEC growth rate until reaching a plateau at 45 GW_{net}. The initial exponential increase of aggregated installed capacity is not maintained, because supply growth is eventually higher than demand growth. Consequently, the regions that are suitable for OTEC become maximally saturated with OTEC. Then, an even higher growth rate only leads to a faster saturation without increased aggregated capacities.

Figure 2(b) shows that OTEC could be profitable in the long run even if initial CAPEX are high. The aggregated NPV peaks at 26% for low-cost assumptions and at 28% under high-cost assumptions. The total installed capacities at such OTEC growth rates are 9 GW_{net} with US$ 3 billion with aggregated NPV and 16.5 GW_{net} with US$ 23 billion, respectively. The NPV reaches zero at growth rates between 24% and 32% and lead to an economic potential of 6–41 GW_{net}.

The LCOE reaches a minimum of 8.5–12.8 US¢/kWh at an OTEC growth rate of 30% in Figure 2(c). At higher growth rates, the LCOE rises again, as fewer large plants can be implemented without oversupplying the respective provinces. Consequently, more small- to mid-sized plants are implemented with weaker economies of scale and thus higher LCOE.

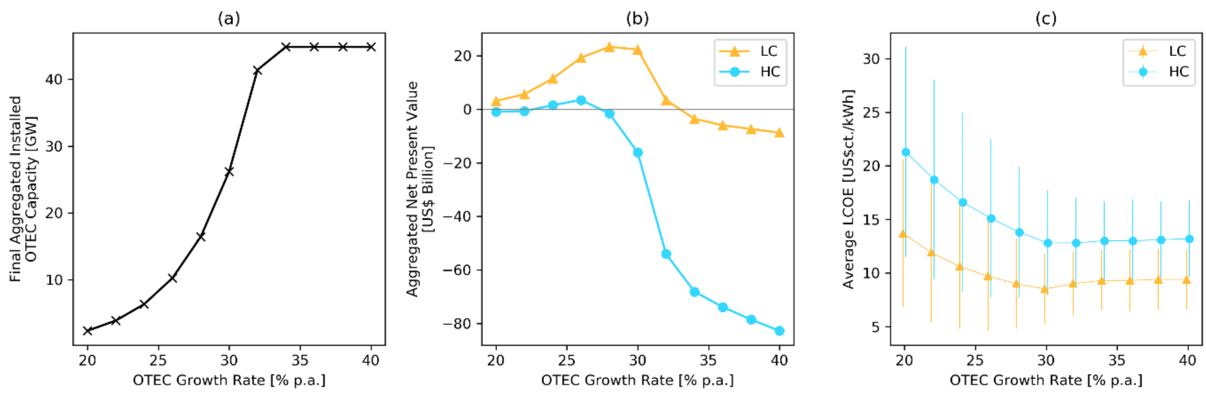

Figure 2 The influence of the OTEC growth rate on (a) aggregated installed capacity, (b) aggregated net present value after 60 years, and (c) average LCOE (error bars show standard deviation). Adapted from (Langer et al., 2021b).

For a NPV-optimal OTEC growth rate of 28% per year, the results of the upscaling scenario are presented in more detail with Figure 3. In Figure 3(a) shows that OTEC could be as important to Indonesia's future power system as already established renewables like geothermal (Presiden Republik Indonesia, 2017). OTEC implementation occurs without limitations by electricity demand, reaching a final aggregated capacity of roughly 16.5 GW_{net}.

The first 100 MW_{net} OTEC plant is implemented after 16 years. This is reasonable as the main priorities in the first decade could be the collection of operational data and the monitoring of pilot plants. With the experience gained from these initial projects, larger systems could follow at lower costs. This is a new perspective to the upscaling period to full-scale 100 MW_{net} plants of 5–6 years in literature (Martel et al., 2012; Vega, 2012). Of course, full-scale OTEC could be achieved faster than projected here, but at the technology's current stage no final conclusion can be drawn.

The decline of LCOE with time and cumulated capacity can be seen in the two experience curves in Figure 3(b). Initially, the LCOE ranges between 33.5–49.9 US¢/kWh for the first pioneer plant and decreases to 9.0–13.8 US¢/kWh in 2050 at full scale. However, the LCOE does not drop indefinitely. After an initial decline to a minimum of 6.2 US¢/kWh, the LCOE rises again. High-quality sites close to shore and with high PPA tariffs become more scarce and instead gradually economically less attractive sites are selected. This is in line with practical observations made in the offshore wind industry. There, the trend of going further offshore also led to increased CAPEX, although this probably stems more from the motivation of utilising the higher wind speeds further offshore for higher electricity yield than from the depletion of implementation sites (Rodrigues et al., 2015).

Figure 3(c) depicts the aggregated NPV, where LC-OTEC breaks even after 19 years and reaches US$ 24 billion after 60 years. Before the breakeven point, negative cash flows of pre-maturity plants accumulate to a total of US$ 378 million. This sum could be understood as the total financial support required for OTEC contractors to reach profitability. In contrast to LC-OTEC, HC-OTEC does not break even, as many full-scale projects remain unprofitable late into the scenario as seen in Figure 3(d). For HC-OTEC to reach a positive final aggregated NPV, the OTEC growth rates indicated in Figure 2(b) are necessary.

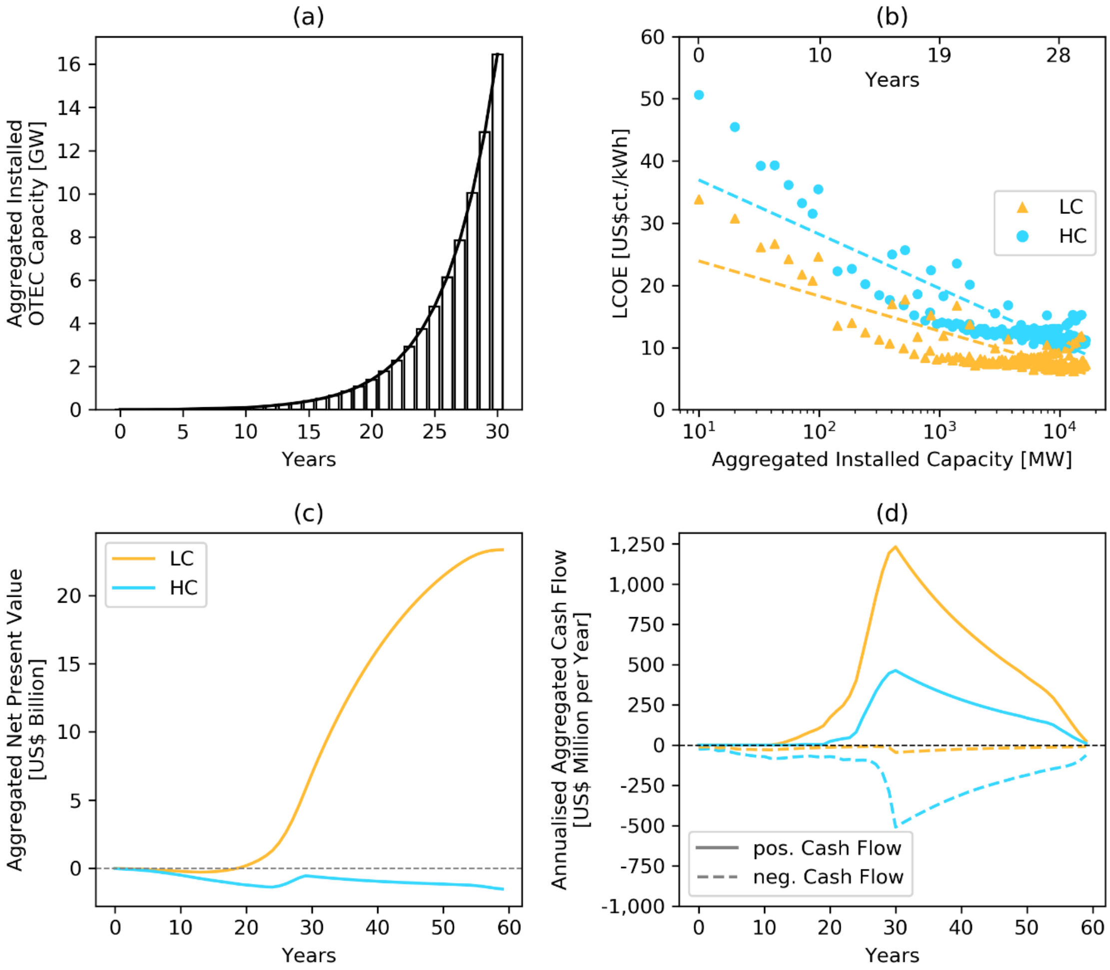

Figure 3 Results of the economically optimal scenario. (a) Aggregated installed capacity. (b) Experience curves. (c) Aggregated NPV. (d) Annualised aggregated cash flows. Adapted from (Langer et al., 2021b).

With a OTEC growth rate of 28% per year, OTEC could cover 44.3% of all supplied provinces and 8.4% of national electricity demand, respectively. Table 3 shows how both average LC- and HC-LCOE are below the average local PPA tariff, thus implying the cost-competitive supply of up to 99% of local electricity demand. In this scenario, 184 sites or 11% of the practically suitable sites are occupied with OTEC plants. Especially the sites far from shore and at provinces with very low electricity tariffs like Java are only occupied at higher OTEC growth rates. Figure 4(a) shows the distribution of OTEC plants and their sizes across Indonesia in the NPV-optimised scenario. Small-scale OTEC is primarily implemented in provinces like Maluku and Maluku Utara, while large-scale OTEC is deployed nationwide, including economic centres like Sumatera and Bali. This is because the upscaling model focusses primarily on the economics of the plant, which could be perceived as a limitation. In practice, the upscaling strategy might be different and pioneer OTEC plants are implemented in the economic centres of Indonesia where the necessary infrastructure like roads and harbours are already given. At an early stage, profitability might not be the highest priority and an easy access to the site for installation, operation, monitoring, and maintenance might be more important. Once enough experience is gained, the OTEC industry could diffuse from the West to the East with a stronger focus on profitability. Therefore, the model presented here could benefit from a multi-criterion decision-making logic that incorporates the aspects above and more.

Table 3 Key results of the economically optimal scenario per province. The PPA tariff is weighted based on installed capacity. Adapted from (Langer et al., 2021b).

Province	Aggregated Installed Capacity [MW_{net}]	Weighted Average PPA Tariff [US¢/kWh]	LCOE [US¢/kWh] $\bar{x} \pm \sigma$		Supply of Electricity Demand [%]
			LC	HC	
Sumatera Barat	2,300	13.5	8.1 ± 1.4	12.1 ± 1.3	79.3
Aceh	2,092	11.7	7.4 ± 0.1	11.7 ± 0.3	98.8
Sulawesi Selatan	1,500	8.3	6.9 ± 0.3	10.6 ± 0.3	33.4
Nusa Tenggara Barat	1,400	18.1	7.8 ± 0.4	12.2 ± 0.6	96.1
Sulawesi Utara	1,354	13.9	9.1 ± 5.2	14.6 ± 7.4	99.5
Sumatera Utara	1,300	19.6	9.0 ± 1.3	13.0 ± 1.1	14.9
Sulawesi Tengah	900	19.2	7.8 ± 0.3	12.2 ± 0.7	94.0
Sulawesi Tenggara	700	16.6	8.0 ± 0.7	12.9 ± 1.3	94.0
Papua	689	17.2	8.8 ± 3.4	12.9 ± 4,7	92.3
Nusa Tenggara Timur	667	20.4	9.6 ± 1.8	15.4 ± 2.8	88.3
Bali	600	6.9	6.7 ± 0.2	10.6 ± 0.1	14.0
Bengkulu	600	7.5	6.8 ± 0.2	10.7 ± 0.1	80.8
Maluku	481	21.0	17.1 ± 8.1	25.5 ± 11.8	99.1
Kalimantan Timur	400	10.6	7.6 ± 0.2	11.1 ± 0.1	13.3
Papua Barat	400	16.8	7.5 ± 0.6	11.7 ± 0.7	85.9
Gorontalo	300	13.5	7.3 ± 0.0	11.3 ± 0.2	72.7
Maluku Utara	273	20.2	12.5 ± 5.8	19.5 ± 8.7	83.0
Lampung	200	7.3	6.9 ± 0.2	10.6 ± 0.1	5.7
Sulawesi Barat	200	8.3	6.8 ± 0.5	11.4 ± 1.1	71.6
Kalimantan Utara	100	10.6	8.0 ± 0	11.4 ± 0	65.4
Total	**16,456**	**14.5**	**9.0 ± 8**	**13.8 ± 12**	**44.3**

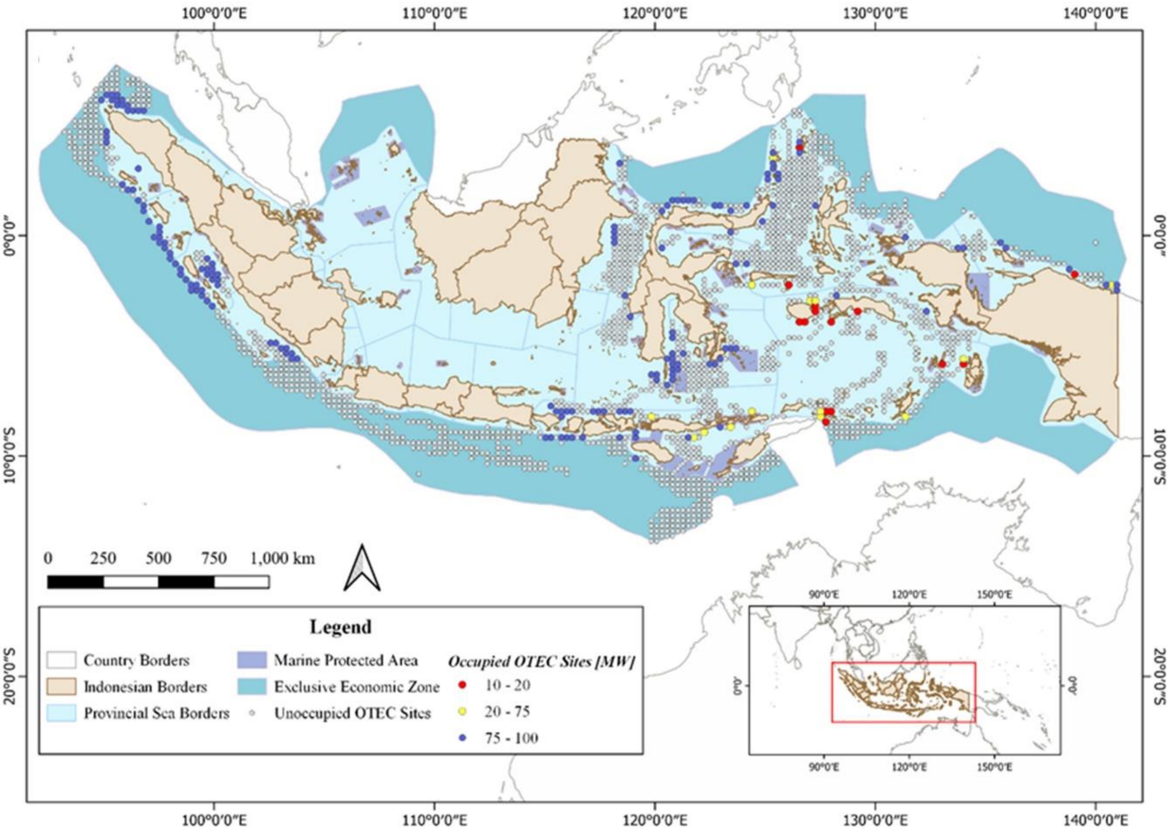

Figure 4 Map of practically suitable and occupied OTEC sites including system size for the economically optimal scenario. Adapted from (Langer et al., 2021b).

Another key result is OTEC's economic viability within Indonesia's electricity mix. As seen in Figure 5, large-scale OTEC could be cost-competitive against all other currently deployed energy technologies in Indonesia. This harmonises with Vega (Vega, 2012), who estimated cost-competitiveness of OTEC for a range of 50–100 MW_{net}. Note that Figure 5 implicitly implies that the LCOE of all competing technologies will not change during OTEC's upscaling. But unlike OTEC, these competitors have been on the market for several decades and have benefitted from cost reductions. Furthermore, fossil fuels like coal are currently heavily subsidised by the Indonesian government (Maulidia et al., 2019). With these aspects in mind, Figure 5 is still useful to project OTEC's competitiveness in terms of LCOE.

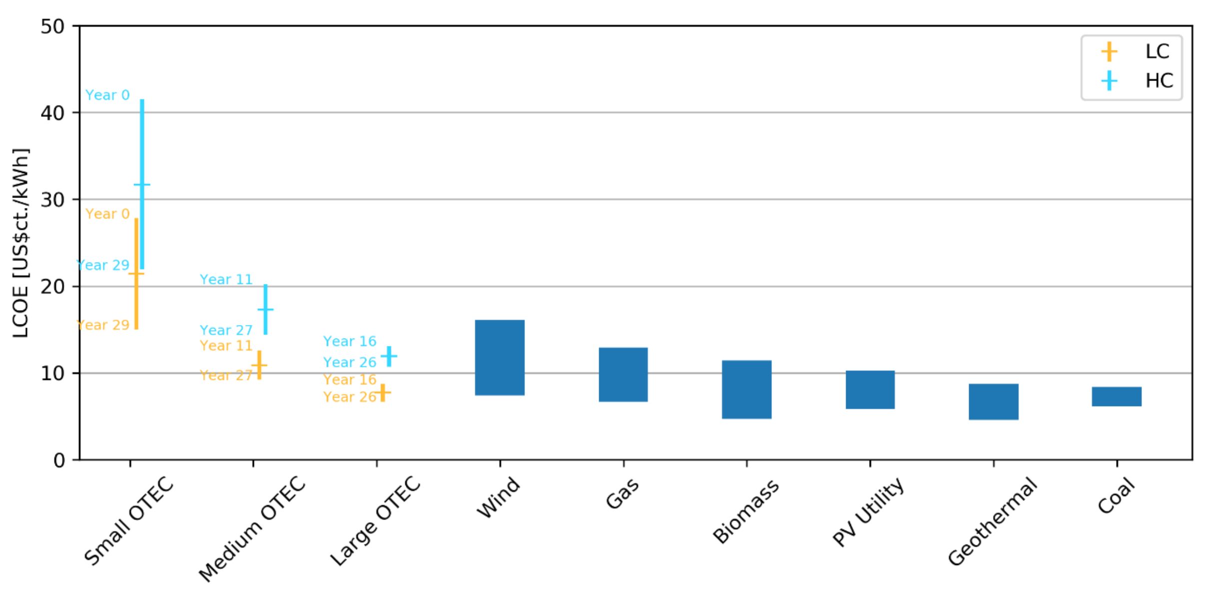

Figure 5 OTEC's competitiveness against other energy technologies (IESR, 2019) **in Indonesia. Error bars show standard deviation. Adapted from (Langer et al., 2021b).**

As explained earlier, a novel feature of the upscaling model is the use of a dynamic discount rate. Not only CAPEX and *Operating Expenses (OPEX)* will decrease with experience, but also the cost of finance, represented by the discount rate, as risks associated with the technology will gradually decline.

With this assumption, Figure 6(a) shows that OTEC could be profitable even at high initial financing costs, as long as these costs decline at later stages. If the financing costs remain static, a discount rate of 5–13% is required to break even with costs in 2050, while the range changes to 10–20% with a dynamic rate. Figure 6(a) also illustrates how the effects of discount rate dynamisation become less prominent with the increase of the initial discount rate. In the case of HC-OTEC, a high dynamic discount rate even leads to a worse NPV compared to a static one.

Figure 6(c) and (d) illustrate the strong impact of the learning rate on OTEC's profitability. A doubling of learning rate from 7 to 14% increases NPV by almost a fourfold. While LC-OTEC could collectively break even at a learning rate of 4%, HC-OTEC requires a rate slightly above 7%, which supports the observation in Figure 3(c), where HC-OTEC was just shy from breaking even at a learning rate of 7%.

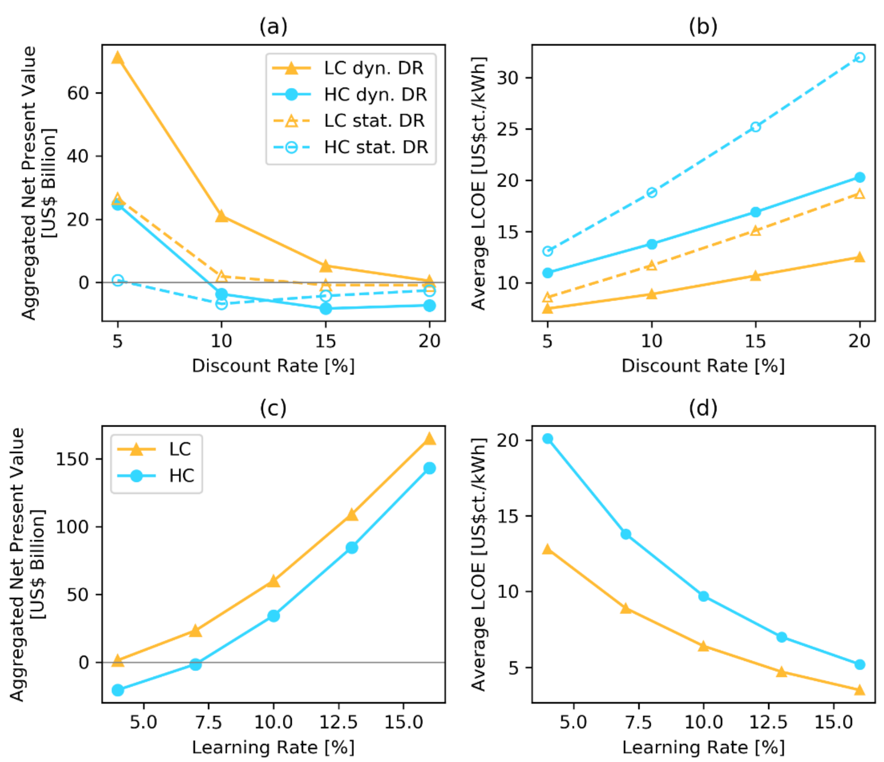

Figure 6 Impact of discount rate on (a) aggregated NPV and (b) average LCOE and impact of learning rate on (c) aggregated NPV and (d) average LCOE. Adapted from (Langer et al., 2021b).

The relationship between electricity supply and demand is depicted in Figure 7. At too high OTEC growth rates, supply eventually outpaces demand and implementation slows down. Then, an increase in electricity demand growth provides more room for OTEC implementation and at a certain point allows unhampered upscaling, as depicted in Figure 7(a) for a 32% p.a. OTEC growth rate.

Figure 7(b) shows once more the detrimental economic effects of a too high OTEC growth rate. At low to moderate demand growth rates, the aggregated NPV is lowest at a 32% p.a. OTEC growth rate, because the model resorts to small- and medium-scale plants at low-PPA-tariff locations to meet the implementation targets. This growth rate only becomes economically viable if it is matched with a high demand growth. For the 32% p.a. case, breakeven is achieved at a sustained annual demand growth of 6–9%.

Then again, if demand growth is higher than OTEC growth, NPV as well as LCOE stabilise as shown in Figure 7(c). At a sufficiently high demand growth, the model locks in on few provinces with high availability of close-to-shore sites and high PPA tariffs. Eventually, an optimum implementation configuration is reached and a further increase of demand growth has no effect on OTEC implementation.

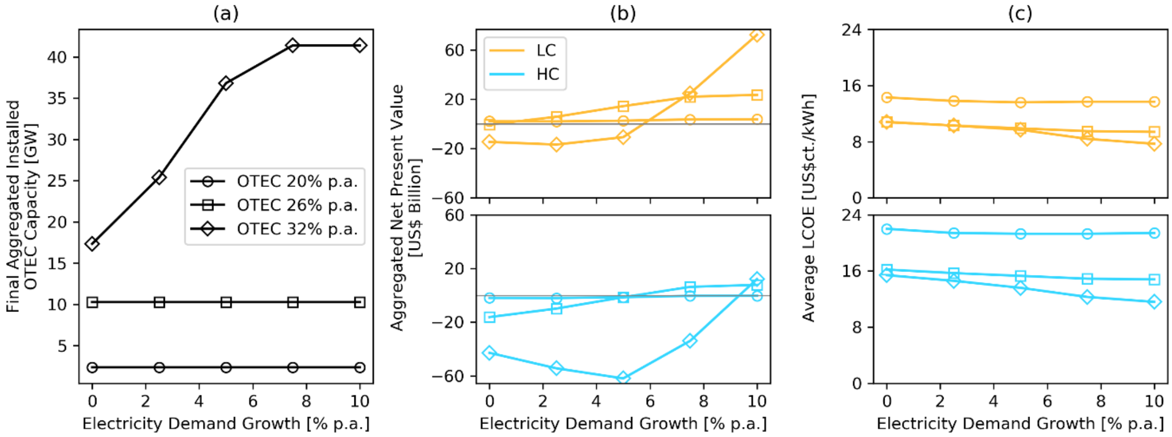

Figure 7 Impact of electricity demand growth on (a) installed capacity, (b) aggregated NPV, and (c) average LCOE. Adapted from (Langer et al., 2021b).

Conclusion

This paper provides an overview of a series of studies that shed light on where practically suitable sites for *Ocean Thermal Energy Conversion (OTEC)* are located in Indonesia and what the economic potential of OTEC is considering upscaling and technological learning. By using a novel *Geographic Information System (GIS)* methodology, more than 1,700 practically suitable sites could be mapped within Indonesia's marine provincial area and *Exclusive Economic Zone (EEZ)*. Most of these sites are located in the economically less developed East of the country, which underlines OTEC's potential of fostering socio-economic development by providing clean, reliable, and continuous baseload. However, OTEC must be scaled up from current small-scale pilot plants to large-scale commercial systems. This study shows that technological learning and economies of scale significantly boost OTEC's economic feasibility, with an economic potential ranging between 6–41 GW_{net}. Until 2050, OTEC could provide clean, affordable electricity and serve more than 8% of Indonesia's electricity demand at *Levelized Cost of Electricity (LCOE)* as low as 6.2 US¢./kWh. Full-sized OTEC plants could be cost-competitive in less than 20 years against all currently deployed energy technologies in the country. Therefore, this paper presents OTEC as an interesting alternative for Indonesia's energy transition. However, our studies also show the challenges OTEC might face on its way to maturity. Cost optimisations are essential from day one and the conservative cost assumptions found in literature must be avoided. OTEC will also require strong, continuous learning over several decades to drive down costs at a sufficiently high rate. To which extent this is feasible in practice is still unclear, given that some components like turbine and generator are already mature. Then again, OTEC's costs mainly consist of components with lots of room for innovation, for example the cold water pipe and the heat exchangers. Another challenge will be to match the abundantly available OTEC resources in many countries with the local electricity demand. For Indonesia, the upscaling scenarios showed that the regions with the highest economic potential for OTEC are often in regions with low electrification rates and limited socio-economic development. This insight can easily be translated to a global perspective, as OTEC is often seen as an interesting technology for small island developing states. Then again, there are also countries suitable for OTEC with sufficient electricity demand like Japan, South Korea, and the USA, so OTEC could still be developed profitably on a global scale. With these aspects in mind, this paper provides reasons why the further development of OTEC is worthwhile despite the challenges ahead. After all, not only Indonesia, but many other countries worldwide could benefit from OTEC.

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213 Sustainable and inclusive digital mobility services in times of Covid: a case study of Barcelona

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Abstract

In the transport and mobility sector, developments such digitalisation, smart applications, local-based digital services, are radically altering mobility patterns, offering a whole range of mobility innovations that meet the fast-changing lifestyles of Europeans. Nonetheless, while transport public services and products become more interactive and are increasingly offered solely online, different societal groups do not fully benefit from these new opportunities offered by digitalization. In fact, the lack of a proper digital literacy can lead to situations of exclusions from many transport services and facilities, as most of them move online or integrate digital elements. The most vulnerable people experiencing mobility exclusion are mainly linked to situations of multiple social disadvantages related to physical impairment, material deprivation (low income, migrants), cultural issues (ethnic minority background), and demographic variables (elderly). National legislation addressed to ensure access to essential mobility services and products has often a limited reach, since technological advances are faster and permeating the mobility ecosystem. Therefore, the design of inclusive mobility solutions has a key role in maximising social inclusion and improve the user experience.

The research presented is part of the DIGNITY project – Digital Transport in and for Society (https://www.dignity-project.eu/) – a research European H2020 initiative, aims at promoting a sustainable, integrated and user-friendly digital travel eco-system, which improves accessibility and social inclusion, travel experience and the daily life of all citizens. This, in turn, will foster the use of public transport system, helping the transition towards more sustainable mobility solutions. The project approach combines analysis with concrete actions to make digital mobility services inclusive over the long term, connecting users' needs and requirements with the provision of mobility services.

The key challenges addressed in the project are: i) understanding how the needs and characteristics of all end-users are considered in the design of digital mobility solutions and ii) supporting policymakers to plan long-term strategies to reduce the digital gap in transport innovations, considering vulnerable groups and gender issues.

Four case studies (pilots) have been selected in five EU partners countries – Spain, Italy, Belgium, the Netherlands and Germany – based on their ambitions for working towards inclusive sustainable mobility solutions (https://www.dignity-project.eu/pilots/). This contribution specifically addresses the case study based in Barcelona, one of the leading cities undergoing a smart city transformation. The propensity to use digital transport information and services in the Barcelona Metropolitan Area (BMA) has been assessed through a quantitative survey. The results discuss the habits of Barcelona citizens in current local mobility characterised by Covid-19 pandemics, as well as the need of promoting more inclusive digital solutions, specifically in public transport.

Keywords: Mobility, Social inclusion, Inclusive digital solutions, Sustainable mobility

Introduction

Digital transformation has a great impact on the daily lives of people. Public products and services are becoming more interactive and are being increasingly offered online. Nevertheless, some groups in society do not fully benefit from the opportunities of digitization (Groth, 2019; Loos et al., 2020), (for instance, women, people who are older or have functional impairments, low education, low income, as well as short-term migrants and ethnic minorities) and are more likely to be excluded from many services and facilities (Durand and Zijlstra, 2020).

Furthermore, the last technological advances in the transport and mobility sector, such as digitalization, availability of smart applications, and local digital services are radically altering mobility patterns and offer a range of mobility innovations that respond to rapid changes in lifestyles. New mobility concepts include a wide variety of elements, such as novel products, data-based processes, and services inspired by new transport dynamics e.g., Mobility as a Service (MaaS) or on-demand public transport, as well as new business models. However, many services are offered currently as an "online" mode or incorporate digital elements, and the lack of adequate digital literacy or of specific competencies/skills can be expected to generate situations of exclusion. This may exacerbate the conventional structural disadvantages due to the emergence of new systems and modes of transport that are not accessible to people with low digital sovereignty. This digital divide in mobility mainly affects citizens at risk of exclusion and encompasses different social dimensions which often accentuate situations of poverty and social injustice, such as: gender, poverty, low education level, age, reduced mobility, migrant status, ethnic minorities, etc. Until now, technology has not yet contributed to universal access and most of the new transportation technologies have more greatly benefited a specific demographic: urban, young, tech-savvy, and usually well-off (Vandycke, 2018).

Therefore, commuting and mobility produces new challenges for the political agendas and the development of the public and private sectors, with a strong presence of information and communication technologies. In this context, there are synergies appearing that can produce social exclusion in the field of mobility and the use of new technologies. Different studies are examining the digital divide and transport poverty in greater depth (Kuttler and Moraglio, 2020). Nevertheless, the growing relationship between mobility and the use of new technologies, as well as the tendencies of governments and companies to move towards digitization, require further studies relating the two concepts and give a precise overview of social exclusion and situations of inequality that are being generated in this area.

The opportunity of the DIGNITY project

Digital mobility services should be based on and promote inclusivity, taking into account the attitudes, skills and capabilities of users that might not fully benefit from mobility digital services. Understanding the aspects related to the integration of inclusiveness in digital mobility services is one of the research objectives of the DIGNITY project (DIGital traNsport In and for society, 2020, https://www.dignity-project.eu/) a European initiative funded as part of the European Union's Horizon 2020 research and innovation programme. The overarching objective of DIGNITY is to foster a sustainable, integrated, and user-friendly digital travel ecosystem that improves accessibility, social inclusion, travel experiences, and daily life of all inhabitants. DIGNITY aims to contribute to the development of a transport system that is inclusive, digital, and interconnected, and that meets the needs of all residents. The project has fourteen partners from six European countries and selected four pilot studies in five EU partners' countries (Spain, Italy, Belgium, the Netherlands, and Germany) for their innovative proposals in sustainable and inclusive mobility solutions.

The project thoroughly examines the digital mobility ecosystem to understand the full range of factors that could lead to disparities in the adoption of digitized solutions for different user groups in Europe. Its aim is to propose solutions for an inclusive digital transport system that takes into account the needs and characteristics of all sectors of society, with particular attention to digitally excluded groups. The idea is to support public and private mobility providers in their conception of general digital products or services, to make these accessible and usable by the largest possible number of people, regardless of their income, location, social or health situation, or age. The challenges of digitisation are analysed from the perspective of users and suppliers, through a new approach that connects users' experiences with the available products and services, while analysing how transport policies and strategies can support a more inclusive digital transition. Four case studies on implementing inclusive mobility solutions have been selected as pilot projects, based on their ambition of working towards these types of solutions: Ancona (Italy); Barcelona (Spain); Flanders (Belgium), and Tilburg (the Netherlands).

This paper is specifically based on the case study of the Barcelona Metropolitan Area (BMA). The objectives are to: i) characterize the context of digital exclusion with respect to mobility in the BMA, and ii) to understand the patterns of use of digital technologies by residents for their daily mobility. The research work is partially based on a Master's Thesis conducted by one of the authors of this article (Wybraniec, 2021), under the direction of the first and the last author.

Methods

The research applied a mixed-method approach, combining a literature review and a quantitative survey data analysis. The review of literature has been carried out by investigating challenges and trends in the context of sustainable mobility, with special focus on the new digital services, inclusive design and related problematic of digital exclusion (Hoeke et al. 2020) and mobility poverty (Kuttler and Moraglio, 2020). It was found that the great part of the research done till now in those matters has been focused on each of the topics separately and there is still lack of literature addressing digital gap in mobility in particular. As a result, the literature review has allowed to identify the most adequate scheme for analysis of the survey data and interpret them properly thanks to the previous contextualisation of the main concepts relevant in the studied domain.

A scheme marked out in Durand & Zijlstra (2020) has been used as a framework for understanding the digital gap related to the new mobility services in the context of the BMA. The three principal areas of the analysis are digitalisation, social exclusion and mobility, along with the intersections between each of them. As shown in Figure 1, the target and core focus of this study is the central point formed by an interconnection of those main topics, namely digital inequality in transport services and its potentially exclusionary effects. Applying this approach is considered well-founded and reasonable as a great part of the past studies are mainly focused on one of those realms individually and there is still lack of scrutiny that would integrate the aforementioned themes. In addition, previous research has tended to focus on singular aspects of digital mobility exclusion, such as specific determinants that may cause and exacerbate mobility-related disadvantages of a particular vulnerable group. In contrast, this work takes a wider perspective by analysing those three interrelated areas and looking at a range of factors across the population as a whole. What is more, the fact that people at risk of exclusion typically belong to more than one specific group has to be taken into account. Therefore, it enables to consider digital exclusion and mobility poverty as a complex, interrelated and multi-layered phenomena, which requires in-depth research in order to be able to understand the nuances affecting it.

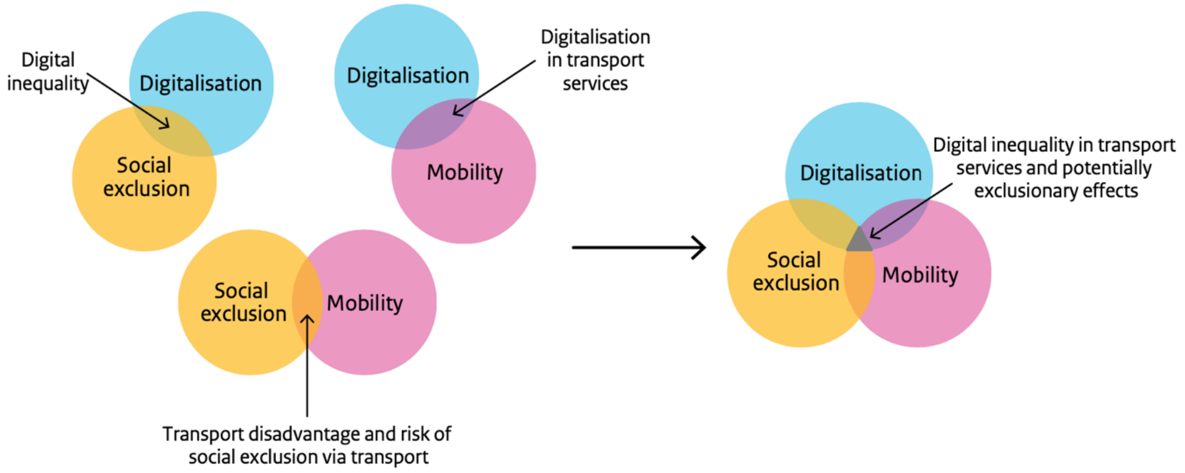

Figure 1. Project scheme/framework. Source: adapted from Durand & Zijlstra, 2020.

User survey in the Barcelona Metropolitan Area

The user survey used in this study forms part of the work done within the DIGNITY project (DIGNITY, 2020). The survey aims at improving the understanding of the patterns of use of digital technologies among the resident population in the BMA. The survey was conducted in Barcelona and other pilot cities. In the BMA, the fieldwork of collecting interviews was entrusted to the GESOP (Gabinet d'Estudis Socials i Opinió Pública - Cabinet of Social Studies and Public Opinion), an independent market and opinion research institute from Barcelona, who carried out a population-representative survey (n=601) conducted at the end of 2020. The survey questionnaire was adapted from a previous questionnaire examining digital exclusion (Goodman-Deane et al., 2020). It contains 96-questions/variables, divided into eight parts, each of which addresses specific issues related to; users' access to and use of digital technology, their digital capabilities, attitudes towards technology, current use of and attitudes to digital transport services and limitations in their regular mobility. Specifically, the survey objectives are to:

- measure level of accessibility and use of different technologies;
- measure use of digital mobility services;
- analyse characteristics that affect how a person interacts with the technologies;
- analyse daily mobility habits and its changes due to the pandemic.

Apart from that, this study provides an additional insight about the impact of the COVID-19 pandemic on the mobility patterns of the BMA residents and public opinion regarding measures for future urban planning.

The work presented here is mainly focused on specific topics of the survey:

- Technology access and use: related to the access to and frequency of use of different devices;

- Technology for public transport: addresses issues related to the use of digital public transport services;
- Demographics: describes characteristics of the population (e.g., social, educational, residential, etc.);
- Questions about daily mobility.

Although two subsamples were defined (one for the city of Barcelona, and the other for the remaining metropolitan area), this article only presents grouped data. Interviews were stratified by district, and the potential interviewees were selected randomly after taking into account quotas of gender, age, nationality and type of place of residence.

Results and Discussion

The results of the survey highlight interesting characteristics in the use of digital technologies and services related to mobility, as well as the main limitations and concerns of the main groups analysed in the BMA. The next paragraphs provide analysis based on the quantitative data gathered through the questionnaire and outline general gaps and trends among the studied population.

Digital inequality

First of the analysed intersection is the digital inequality, which comes as an effect of digitalisation processes and could aggravate already existent social exclusion. This creates disadvantages for vulnerable groups which cannot take advantage out of new technological solutions in daily life because of lack of access and/or skills to use the ICTs.

According to the results, in the context of the metropolitan area of Barcelona, the Internet is the most accessible technology, with almost 93% of the population connected. This confirms the results presented in a recent report of Barcelona City Council (Ajuntament de Barcelona, 2020). This set the digital divide in Barcelona of about 7% of the population. If we extrapolate this percentage to the total of about 3,3 million of residents living in the BMA (Ajuntament de Barcelona, n.d), we will get more than 200.000 people without access to the digital world and, consequently, without the possibility to benefit from the digital mobility services.

Subsequently, the categories of Smartphone (85.2%) and Computer (77.4%) are reported to be available among the citizens, which is compatible with the current trends observed in the society. Finally, less than 50% of the interviewees (45.9%) answered that has access to the tablet, which demonstrates that use of these kind of devices is not that popular in comparison to those mentioned earlier.

Moreover, analysing the differences in the access to the different technologies among different socioeconomic groups, factors such as age and education level are the ones that, in general, influence the level of population access to the ICTs. In fact, the younger and the better educated, have better access to all kind of the analysed technologies, apart from the tablet, which is the most popular among the middle-aged group. Finally, results show non-significant differences in the level of access to technologies between males and females.

It should be noted that the access to the different technologies does not mean that people use them on a daily basis and/or without any limitations. There are numerous factors influencing the appropriate use of digital solutions resulting in different use patterns among the population.

Taking into account that the Internet and smartphone are accessible to more than 85% of the BMA population, and that in order to use new digital mobility products and/or services it is usually required the use of a smartphone to access the Internet, survey results on the frequency of technology use point out that:

- Internet: 84% of people uses the Internet every day or almost every day. 6.2% uses it at least once a week and 2,8% never uses it.
- Smartphone: 84,9% uses a smartphone every day or almost every day. Just 1% uses it at least once a week and the 12,3% never uses it.
- Accessing the Internet on a smartphone: the data proves that the uptake in that case is less frequent, with about 80% of people using it every day or almost every day. What is more, 3.8% of the interviewees answered that they used it at least once a week and 13.6% that they have never done it. This proves that on a daily basis, about 1 out of 5 individuals doesn't use a smartphone to access the Internet, for example to rent an on-street bike or check an alternative route for a journey while being on the move. This gap puts in question inclusiveness of the current transport services, and marks the needs of future work, especially thinking about future multimodal mobility.

Digitalisation in transport services

The second intersection to be analysed is the digitalisation in transport services. As mentioned before, the new digital mobility services usually require the use of a smartphone with access to the Internet. Therefore, this section considers it the most relevant in the context of digital mobility services use, as well as the attitudes towards technologies and the uptake of innovative digital solutions in mobility.

Another important factor in the uptake of the new mobility solutions are the attitude and capabilities of users for whom they are designed. Although some groups have access to technologies and use them regularly, a large part of them is not aware about availability of new mobility products, feel insecure while using them, and/or experience limitations while planning (before the trip) and during the journey, related for example to the handling capacity of electronic devices.

The results highlight that big part of the population could be exposed to difficulties while using innovative digital solutions in transport or trying benefit from new mobility services. Specifically, regarding the confidence to plan successfully an unfamiliar, local public transport journey using the Internet or an app on a smartphone, results show differences among different target groups:

- Gender: higher percentage of men answered that they are highly confident to plan such a trip (67.7%) comparing to women (60.9%). Besides, only 8.3% of men reported feeling low confident in contrast to higher proportion of women (19.6%). This point out that gender gap should be considered when it comes to attitudes towards use of the technologies in mobility. However, this doesn't mean that women have fewer digital skills.
- Age groups (16-29; 30-64; 65 and more): there is a higher distrust among older people in the use of digital services for trip planning; 40% of older people feel insecure about planning a trip on public transport using the Internet or an application on a smartphone, and only about one out of them feel very secure about that. On the contrary, less than 1% of the people aged 16-29% and just 8,4% aged 30-64 feel insecure planning a trip using the internet.
- Education level (low; medium; high): about 25% of people with lower, 14.4% with medium and only 4.4% with high level of education answered that they have low confidence when planning a trip using a smartphone. On the contrary, the highest level of confidence was observed in the case of people with high educational attainment levels (80,9%), followed by 65.1% of those with medium and 44.9% with low attainment levels.

Again, the observed tendencies are similar to the ones outlined in the previous paragraphs; feminine gender, older age and low education level are risk factors for digital exclusion, here, influencing the proper uptake of new mobility solutions.

Regarding the use of digital transport services, the survey results revealed that, in general, new digital solutions are still little used. The highest percentages are reported for digitally booked taxi services and digital payment for parking, although still much lower than 25% even considering longer period of time than 3 months before carrying out the interviews. Furthermore, the use of carpooling, car sharing or on-street scooter/motorbike hire services is very low, which shows that these new forms of shared transport remain unpopular among the general population.

Transport disadvantage and risk of social exclusion via transport

Lastly, the third intersection within the marked methodology will be analysed, focused on transport disadvantage and risk of social exclusion via transport. In this section, the main means of transport used by the population in their regular mobility will be studied and comparison between the target groups will be made. Afterwards, the main motives for regular travel (work, studies, leisure etc.) among general population, as well as within various groups will be analysed.

The three main means of transport indicated by the respondents as primarily used for their daily displacements are active mobility, public transport and private vehicle. Overall, active mobility, which include walking, riding a bicycle, scooter or other low-speed transportation mode, is the most popular mean of transport for the daily displacements of the BMA residents (52.2%). Secondly, up to 30% uses public transport as the main mode for the daily displacements. Finally, about 18% of the population moves in private vehicle to reach their daily destinations. Similar results, were obtained in the EMEF 2019 (IERMB, 2020) – the reference report regarding regular mobility conducted annually in the BMA. However, changes provoked by the pandemic should be taken into account while analysing this distribution.

Splitting general results by target groups offers interesting results. Specifically:

- Gender: the difference in active mobility is not significant (52.2% of women and 51.4% of men). In the case of public transport, 35.3% of women and 22.9% of men make use of it, while men use more often private vehicles (10.9% of women and 25.3% of men) in their daily journeys. These results prove that gender gap in mobility still exists in the BMA, especially regarding private mobility use, a fact reported also in other recent studies (Cubells, 2020). These differences are also consequence of the social roles and distinct mobility patterns of both genders. In fact, women's daily mobility is usually more complex, diverse and sustainable since they tend to look for a workplace closer to home in order to be able to undertake home responsibilities (Ortiz, 2019).
- Age groups (16-29; 30-64; 65 and more): older people tend to move around actively (76.3%), and primarily by foot, much more often than the ones aged 30-64 (45.5%) and 16-29 (44.5%). Furthermore, public transport is the first choice to commute for 42.7% of younger people, followed by the middle aged (30.3%) and the elderly (16.3%). Finally, data show that people aged 30-64 are principal users of private vehicle (23.9%), while only 12.9% of young people and 5.9% of the older ones use this mode of transport on a daily basis.
- Education level (low; medium; high): active means of transport are used in large part by people with lower attainment levels (60.5%), followed by the individuals with high (54.9%) and medium (42.6%) education levels. Public transport use, instead, is more common by those with medium education levels (34%), while less people with high (27.2%) and low (27%) education levels reported that they use this mode of transport. Finally, 23% of the interviewed with medium attainment levels answered that they commute in private vehicle, followed by 18% of individuals with high and 11.4% with low education levels.

Finally, the interviewees had to answer to the question: thinking about your regular travel within this region, to what extent do you feel limited in your travel by the following aspects? The concept of “limitation” in this question is defined as ‘wanting to travel more but feeling unable to’.

Regarding perceived limitations in regular mobility, safety of transport services and cost of the travel are indicated as the most significant limitations, respectively with 44,7% and 43,2. Next, limited availability of transport services and limited availability of infrastructure are the motives that limit users to some extent up to 39% and 33% respectively. Overall, the lack of digital skills required for planning travel, as well as during trip are not indicated as one of the most significant limitations (about 20%). Finally, difficulties using the available transport due to special needs or disabilities were indicated as the reason that limits the least part of the respondents (up to 16%).

COVID-19 Impact, public opinion

Adding to the already present issues in urban mobility and its diverse users’ needs, the COVID-19 pandemic has brought new challenges for future-proofing urban mobility planning. Post-lockdown studies, for instance the one issued by EIT Urban Mobility (2021), report on the main trends: changes in mobility demand, shift in user requirements, and decreases in investments in mobility. However, questions still remain on how the pandemic has impacted the users’ attitudes per se, and to what extent the observed changes in mobility demand will continue after this crisis. This paragraph will present the survey results regarding the changes of users’ daily mobility patterns, as well as public opinions on the importance of promoting some selected actions for future mobility in the Barcelona metropolitan area.

The questionnaire results reveal that, due to the pandemic, a great number of the population increased their use of active mobility modes, and especially walking, which is good news in regard to future sustainable mobility within more liveable cities. However, some interviewees reported switching to private vehicle use. The most worrying fact is that around half of the respondents decreased their use of public transport. Furthermore, those changes in daily mobility varied depending on the age group and/or education level: in general, the well-off, better educated, and younger groups could afford to change to alternative modes of transport, while some less-advantaged individuals were forced to maintain or even increase use of some transport modes (such as public transport) despite concerns related to social distancing or risk of contagion.

New digital mobility services include carpooling, which aims to be an alternative for private car use and an option for integration into public transport. However, the results show that the great majority did not use, or decreased their use of those digital solutions due to the pandemic crisis. This demonstrates that reduced use of public transport and lack of alternatives could lead to changes towards private transport use and further aggravate the negative effects related to this mode.

Specifically, the results (Figure 2) show that, due to the pandemic, 41.1% of the people resident in the metropolitan area of Barcelona increased their active mobility modes, with 35.8% walking more and 12.1% more frequently riding a bicycle, scooter or other low-speed transportation mode. Conversely, 14% of respondents increased their use of a private car. Moreover, over half (50.2%) of the respondents have decreased their use of public transport. Notably, these changes differed amongst people within different socioeconomic groups.

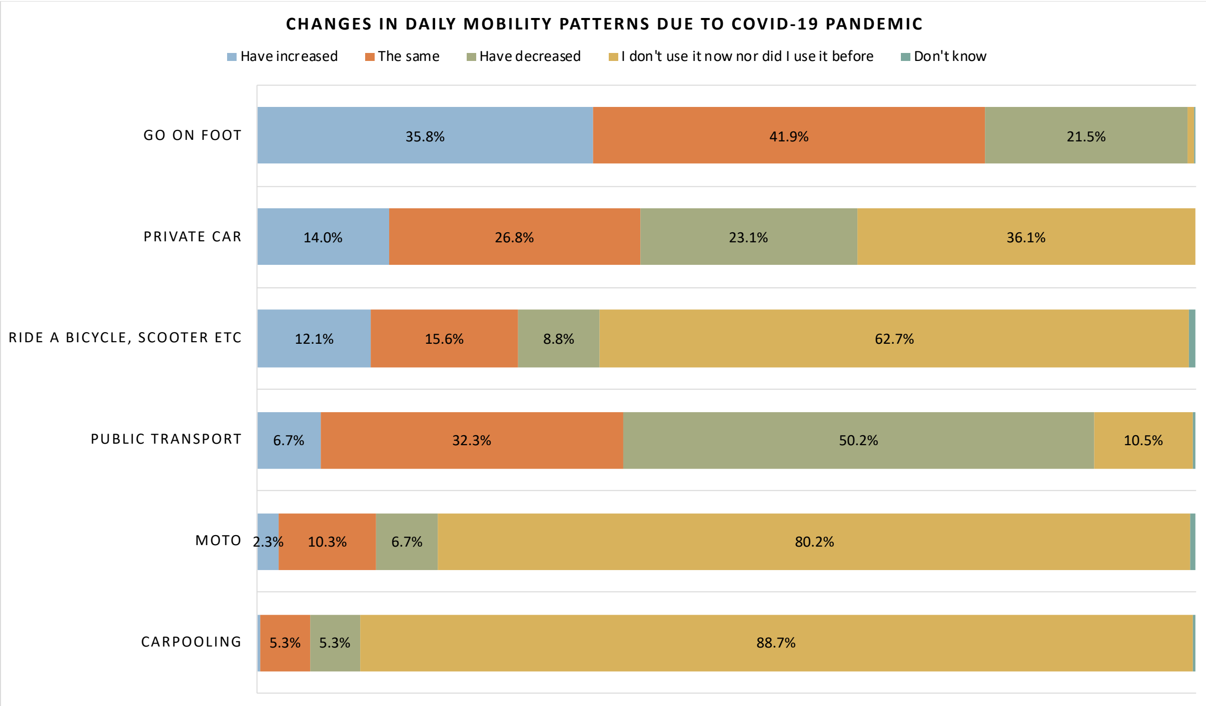

Figure 2. Changes in daily mobility patterns due to the COVID-19 pandemic. [n = 601, error margin ±4%, significance level = 95%] Source: own elaboration.

The survey also collected information about the importance that the interviewees assigned to the promotion of different actions for the future, taking into account the crisis of COVID-19. An increase in the provision of public transport to avoid congestion stands out amongst the measures indicated as the most important. This is mainly related to perceived safety at the health level and concerns about the risk of contagion; these are important issues from now on in the context of public transport that have to be addressed with adequate measures, in order to regain the trust and reliability of this fundamental public service, which is essential for a sustainable urban ecosystem. Other future actions indicated as highly relevant were those addressing working conditions: specifically, the flexibility of working hours and an increase of teleworking. Less importance was assigned to measures such as the expansion of bike lanes or the promotion of new shared electric vehicle systems. Finally, the measure with the lowest perceived importance is the ease of driving to work by car.

These insights are very relevant for the post-pandemic life, as they can help authorities to make appropriate decisions on the way to recovery and to transition towards future sustainable mobility. However, the remaining question is how those perceptions will evolve in the longer-term, and to what extent they will shape our future cities.

Regarding the importance that the interviewees assigned to the promotion of different actions in the future (Figure 3), the post-COVID measure highlighted as the one most needed was an increase in the provision of public transport to avoid congestion (83.5%). Other measures considered as highly important were related with working conditions—specifically, the importance of having flexibility of working hours (75.7%) and increased teleworking (73.2%). The promotion of the implementation of contactless transport tickets or the expansion of pedestrian areas were also considered important for the future of cities, with percentages above 60%. The expansion of bike lanes (54%) and the promotion of new shared electric vehicle systems (51.4%) were also considered important, while less importance was given to the ease of driving to work by car (40.4%).

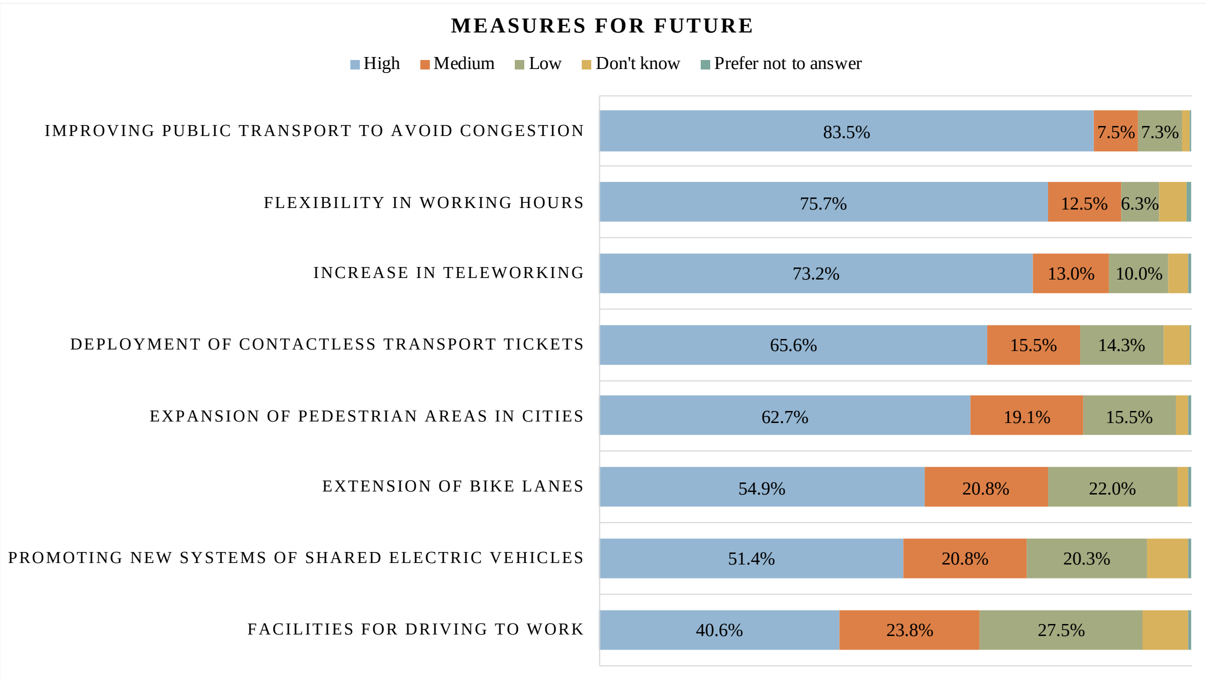

Figure 3. Measures for future. [n = 601, error margin ±4%, significance level = 95%] Source: own elaboration.

This case study gives a first overview of the changes in daily mobility of citizens of BMA during the pandemic. Public attitudes towards different actions give context-based insights to address future mobility policies for a sustainable transport ecosystem. The study provides interesting insights for policy- makers and transport operators with respect to what measures are considered important by the metropolitan population—valuable information for designing citizen-focused, future-proof urban mobility systems and crucial for sound strategic planning of transport policies.

The case study confirms the information reported in other works regarding changes in mobility demand, and especially, the strong decrease in public transport use. One lesson to be learned that should be highlighted is that shifts in regular travel during the pandemic did not affect all collectives equally and could have aggravated the already existent transport disadvantages amongst different socioeconomic groups.

Interestingly, the feedback regarding the importance of promotion of different actions in the future shows that the great majority of respondents indicated that an increase in the provision of public transport to avoid congestion was important. This proves that, despite the strong decline in mass transit during the COVID-19 crisis, the citizens consider this mode of transport as valid, as long as its high level of safety, good quality, and good provision are guaranteed. Moreover, measures enhancing working conditions were considered more important than those related to promotion of new shared mobilities or contactless ticketing.

Conclusions

The project results allow a better understanding of factors leading to the existing digital gap between mobility service provision and uptake, by different users' groups, within the current digital travel ecosystem.

The literature review pointed out that the great part of the research done until now regarding the matters in question has been focused on each of the topics separately and there is scarce literature addressing digital divide in mobility in particular.

Furthermore, the analysis of the qualitative information from the user survey confirmed the problem of potential exclusion related to the mobility in the BMA. The identification of several digital gaps proves that there are large parts of population that cannot access the digital world or lack required knowledge and skills and, consequently, they are not able to take advantage of novel transport services. Consequently, very low levels of digital mobility services' uptake were observed which proves that solutions such as carpooling, carsharing etc. are accessible mainly for small part of the society; usually younger, tech-savvy and well-off individuals. Therefore, in the process of urban mobility planning and design of digital services, it is important to take into account that, apart from access to the technology, provision of appropriate mobility options and awareness of their availability, the final user needs confidence and digital skills in order to make proper use of them. It should be taken into account that there are diverse individuals with different needs, patterns of use and attitudes towards digital technologies in mobility. Hence, adaptable solutions, as well as non-digital and low-tech alternatives are needed that would meet specific person's requirements and make mobility ecosystem more inclusive and sustainable.

Furthermore, main groups at risk of digital mobility exclusion have been identified. In the context of the BMA, older people and people with low level of education have been found to be the most affected groups with regard the access to the ICTs and their use, and consequently, the changes that may result from the development of new modes of transport. In addition to that, gender may be an aggravating factor for digital mobility exclusion since women indicated feeling less confident in using technology, and they tend to use more sustainable modes of transport, which is linked with the social roles and distinct mobility patterns of both genders.

On that account, a better understanding of the relationships among digitalisation in transport services, digital inequality and mobility poverty is required in order to address the exclusion situations that different vulnerable groups might experience. The identified gaps affect the groups that could be the main beneficiaries of new innovative products/services such as transport on demand or shared mobility. However, these solutions are not accessible to vulnerable persons or in excluded areas, but are mostly addressed to general public with digital skills and available in urban areas with a wide range of mobility. Without adequate measures to make new digital means of transport accessible to greater parts of the population exposed to transport related disadvantages and/or mobility poverty and to empower the most vulnerable, new technological solutions will continue to increase the digital dichotomy between sustainable mobility and social inclusion.

In addition, urban mobility needs adequate actions for future, taking into account its current challenges, as well as the COVID-19 pandemic impact. In this sense, it will be important to address certain aspects, such as improvement of public transport, with particular attention to categories such as women and older persons, who represent a significant percentage of users. Regaining the trust and reliability of this fundamental public service is essential for a sustainable urban ecosystem since reduced use of public transport and lack of alternatives could lead to changes towards private transport use and further aggravate the negative effects of externalities related to this mode. Other important measure for future is the promotion of working conditions that recognize the flexibility of working hours and the possibility of working remotely. These factors will in turn lead to important changes in the design of services to be offered and in the conditions of provision of the public transport service.

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116 Danish municipalities support to the cultivation and consumption of legumes through public procurement strategies

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Abstract

This paper will, with point of departure in the situation in Denmark, investigate how to speed up the use of grain legumes within the municipal food basket, applying the theoretical approach of municipalities being ‘consumers’, ‘regulators’ and ‘facilitators’. Through public procurement strategies (‘regulator’), Danish municipalities have previously for example requested the use of organic food produce within municipal kitchens (kindergartens, elder people’s homes, etc.), and hereby been an important user and pull-market (‘consumer’) agent for an increase in organic food produce. Grain legumes like fababeans, lentils, peas and chickpeas have traditionally been a part of our diet, as being a healthy inexpensive source of protein, substituting for example meat produce, while playing an important role in the traditional crop rotation systems providing Eco System Services (ESS). Within the EU, political focus is currently on the cultivation of grain legumes for both animal fodder and human food, with the purpose of substituting imports of soy for livestock feed and increasing direct human food plant protein consumption. Various organizations are engaged in this transition including grain legume suppliers, retail markets and citizens. Presently, the market for domesticated grain legumes is developing fast. Through the theoretical lens described above - combined with case study analysis of four Danish municipalities, as well as a chickpea producer and a legume retailer both seeking a market entry - we will analyze how Danish municipalities can be important actors in developing a market for gain legumes. We find that especially larger Danish municipalities are very active within the area, having developed politically decided municipal food and meal strategies that includes grain legumes, where some even require supply of locally produced grain legumes. Others again, are merely starting up emphasizing grain legumes in their municipal food supply, but have on the other hand, supported (‘facilitated’) business cooperation between a grain legume producer and retailer within the local community. Thus, the analysis reveals the current patterns of support from municipalities, provided by the cases, but also reflect on the future not yet harvested support mechanisms.

Keywords: Agriculture, case study, legumes, municipalities, public procurement

Introduction

Global decline in legume cultivation

The development of more EU-grown plant proteins is required to meet the farm to fork's strategy objectives. Countries in the developed world are consuming unfavorable amounts of animal proteins primarily based on imports causing environmental and social challenges (FAO, 2018). Natural and semi-natural habitats are consequently and increasingly being converted into arable land, with severe impact on soil quality, climate change and biodiversity (Nemecek et. al., 2008). Denmark imports around 1.8 million ton of fodder protein annually, where 80 % is utilized for pig fodder, and the remaining as feed for dairy cattle, poultry and egg producing hens (IFRO, 2012; 2014). Over the last five decades the global average grain yield has almost doubled, but the cultivation of legumes dramatically declined - for fababean with about 56 % (Jensen et. al. 2010). This means reduced Eco system Services (ESS) beyond protein quality provided (Jensen, et. al. 2010; Zander et. al. 2016).

Consumption of legumes in Denmark

After years of decline in the consumption of legumes within the EU and globally, as mentioned above, it now seems that the development is slowly changing in a Danish context. Livestock farmers are increasingly utilizing e.g., fababeans as animal fodder, especially within organic farming, and a market for leguminous produce for human food are being requested by supermarkets and thus consumers (Landbrugsavisen.dk, 2020; Økologisk Landsforening, 2021a). By 2050 it is estimated that approximately 50.000 and 100.000 ha cultivated farmland in Denmark will be composed of legumes for human food and animal fodder respectively, and that the farmland area dedicated to cultivation of animal fodder will be reduced from 1.77 million ha to 1.22 million ha within the same period (Rådet for Grøn Omstilling, 2020). Fewer livestock, and livestock feed by e.g., grass clover and proteins extracted from grass clover, will be some of the means to reach this. Increases in consumption of legumes for human food are not only based on traditional legumes being costumed to the Danish climate, where pea for example is popular (Landbrugsavisen.dk, 2020b). Also, lenses, chickpea and lupine are requested by consumers, and many stakeholders would like to support a local market where these types of legumes not are based on import (Landbrugsavisen.dk, 2020a).

Within some Danish municipalities legumes have also become popular, and some such local governments are now including legumes in their Public Procurement (PP) strategies, as they included organic produce some 20 years ago (Sørensen et. al., 2016; Smith et. al., 2016). Legumes are a more climate friendly and protein rich substitution to the consumption of e.g., meant, and many municipal kitchens would like to utilize new types of protein sources (Møller, 2021; Petersen, 2021; Dahl, 2021). But how is the purchase of legumes being supported within municipalities, and what type of legumes are being requested? How are municipalities developing tools and support mechanism to be able to select specific locally cultivated sorts of legumes instead of legume imports? And which barriers and opportunities exist within the supply part of the value chain to be able to deliver the legumes requested in the municipal food basket? This paper investigates, how legumes are being supported by Danish municipalities emphasizing their role as ‘consumer’, ‘regulator’ and ‘facilitator’, and how PP and other means of tools being developed can be utilized as a lever to support the cultivation and consumption of locally cultivated legumes. We will elaborate on this in the following.

Public procurement

There are many approaches to Public Procurement (PP) as the concept has developed and matured during the years alongside societal changes and policy adaptation. The European Commission (EC) (2008) defines Green Public Procurement (GPP), as *“A proses whereby public authorities seek to produce goods, services and works with a reduced environmental impact throughout their lifecycle compared to goods, services and works with the same primary function that would otherwise be produced”* (EC, 2008:4). Again, Sustainable Public Procurement (SPP) goes beyond e.g., ecolabeling, environmental management systems and efficiency in energy uses, entailed within the GPP strategy (Rainville, 2018), and are defined as follows: *“A process by with public authorities seek to achieve the appropriate balance between the three pillars of sustainable development - economic, social, environmental - when producing goods services or works at all stages of the projects”* (EC, 2020). Thus, both green and social criteria are included in SPP strategies, as for example environmental criteria formulated in contracts and Corporate Social Responsible (CSR) demands regarding companies use of labor (Andrecka, 2017).

Innovative Public Procurement (IPP) is, on the other hand, the strategic purchasing of goods and services which do not currently - or only to limited extend - exists on the market, hereby stimulating new product development within geographical confined markets to meet demands (Morley, 2021). According to Kristensen et. al. (2021) IPP can be connected to three mechanisms, being i) pre-commercial procurement, ii) public procurement innovation solutions, and iii) innovation partnerships. Thus, IPP is interpreted as a tool used for demand side policies creating supply side innovations (Rolfstam, 2009; Rolfstam et. al., 2010; Iossa et. al., 2018). In our research of municipal case studies, we will emphasize the above mechanisms to illuminate how PP are operationalized to integrate more legumes in the municipal food basket. Finally, the newest PP strategy is Circular Public Procurement (CPP), which has its roots in the European Commission’s (EC) emphasis on circular economy (EC, 2020) and require integration of for example environmental issue, social initiatives, new processes, and organizational thinking that integrate and merge PP strategies, thus not merely applied as addons. As emphasized by Kristensen et. al. (2021) the CPP is a challenging and difficult procurement strategy, and by being relatively new the principles of CPP is yet immature and hard to adopt.

PP within the OECD countries account for between 13 % to 20 % of the Gross Domestic product (GDP), and reaches 17 % in the EU alone (Evans et. al., 2010). Within developing countries, the figures are even higher and reaches levels of 30 % to 70 % of the GDP, thus public money utilized to purchase goods and services (Perera, 2012). Within the EU this figure is estimated to account for 16 % of the GDP (Iossa et. al., 2018). When it comes to public sector food procurements it mainly happens at the municipal level (regional and sub-regional level), and account for approximately 63 % of all food related public purchases within the OECD countries (OECD, 2019). Emphasizing on Denmark alone, the annual budget expenses on public procurement, primarily composed by the 98 municipalities, is approximately 300 billion DKK, or 40 billion Euro (Lundsgaard et. al., 2020). Emphasis on PP is therefore not to be neglected, as the purchase volume is high and thus a potential driving factor for new produce to be included in the municipal food basket (Kristensen et. al., 2021).

Research focus

In this empirically based research paper, we investigate how PP are utilized to promote the cultivation and consumption of legumes within four case municipalities in Denmark. We will identify which power and strategies the municipalities are using to promote legumes, and which mechanism that are hampering or stimulating more locally based legume business models to develop. Field case study analysis of a legume producer and a retailer will also highlight, whether the supply chain (producers) is hampered by e.g., lack of knowledge, appropriate machinery, and legume seeds appropriate for cultivation in a Danish context. And again, are supply chain stakeholders (retailers) meet by adequate support and favorable tender procedures from municipalities? And do they possess a general willingness, to engage in an increased distribution of legumes by including such options in their bidding proposals?

No previous studies in Denmark sheet light on these issues emphasizing the adaptation of legumes in the food basket of municipalities through PP strategies. Various studies however have emphasized the promotion of organic food produce in PP strategies to be included in municipal diets (Lindström et. al., 2020; Sørensen, et. al., 2016; Morgan, 2015). Thus, this study provides new information revolving legume based PP strategies and point to areas where this could be emphasized more strongly in the future with special emphasis on local produce. We will shed light on how legumes are, and can be, included in the municipal diets by *Innovation Public Procurement (IPP)*, emphasizing *Public Procurement Innovation*

Partnerships (IP), as discussed by for example Timmermans and Zabala-Iturriagagoitia (2013), Uyarra (2016) and Iossa et. al. (2018), with roots in the procurement directive of the EC (EC, 2014). We interpret municipal PP revolving legumes, as innovation towards a transition of Danish food consumption, thus IPP, and new types of cooperation between municipalities, producers, and retailers etc., thus IP.

Methodology

Analytical approach

This study combines the theoretical approach described in the following section with primary and secondary empirical data to be able to describe the landscape of municipal support to the cultivation and consumption of legumes. Suggestions to future initiatives will hence be provided and included in the discussion section of the paper, which entails knowledge from the interviews and field studies analyzed, as well as additional knowledge from scientific literature, reports, etc. This research is primarily based on explorative empirical studies (Andersen, 1990) investigating a new arena to be embraced by PP, where lack of existing literature exists to compare and discuss our findings. This research study should therefore be seen as initial studies and inspiration for other researchers to conduct investigations within the field of legumes.

Theoretic framework

The theoretical framework applied is inspired by Bulkeley and Kern (2004) and Corfee-Morlot et. al. (2009) and their findings of how e.g., municipalities can influence various sectors as for example the local energy consumption as being ‘consumers’, ‘regulators’ and ‘facilitators’ of energy services. This understanding was for example applied by Lybæk and Kjær (2015) in their analysis of how municipalities can support the development of the Danish biogas sector. This paper however will apply this theoretical lens to describe and understand how municipalities can support the cultivation and consumption of local legumes through such mechanisms and adopted into the municipal PP strategies (Thai, 2009; Li and Geiser, 2005).

Danish municipalities have previously supported a development of specific municipal diets by utilizing their role as ‘consumers’, ‘regulators’ and ‘facilitators’ by for example including organic food produce in the supply of ingredients to the food basket of municipal institutions. By constituting a market (‘consumer’) an adequate amount of food consumption or ‘a market’ could hence be guaranteed, and the requirement of such food supply were made viable by municipal political agreements (‘regulator’). Various activities and support to kitchen personal, using the lever of education and training, were then provided (Lenny, 2015; Sørensen, et. al., 2016) to ease the transition to the use of organic food and hence lower amount of meat in the municipal food basket ('facilitator'). This paper emphasizes how Copenhagen, Århus, Odense and Slagelse municipalities are adopting legumes in their municipal diets; how they currently promote this, and which barriers and opportunities can be identified in the value chain.

When looking at the municipal role as 'consumer' we will emphasize how many units (municipal institutions) are included in the municipal food diets, and the target group being e.g., young, or older citizens or both. We will also emphasize what type of legumes the municipality are requesting in their consumption of such food stuff. Within the area of municipalities being 'regulators' we further identify whether or not concrete targets and political statements are developed to support the cultivation and consumption of legumes. This can for example be the formulation of food and meal strategies emphasizing legumes, climate related policies, and other means of future tools and data needed that can encourage or stimulate the cultivation and consumption of legumes. The municipalities as 'facilitators' are investigated through activities, or levers, supporting a further purchase and use of legumes targeting e.g., kitchen personal, school activities, etc. In the discussion part emphasis on how to strengthen relevant areas identified through the empirical studies, which entails reflections to other relevant studies.

Choice of case municipalities

In our empirical data collection, we have chosen four municipalities, each representing a main part of Denmark. On the largest island in Denmark, named Zealand, the capital of Copenhagen has been chosen, also being the largest city in Denmark. Also, Århus, which is located on the mainland connecting Germany in the South, has been selected being the second largest city in Denmark. Finally, in the middle, located on the island of Funen, the town of Odense has been chosen being the fourth largest city after Ålborg. Besides the selection of three of the largest cities in Denmark, we also emphasized initiatives taken within more rural areas of Denmark, here represented by Slagelse Municipality located on West Zealand. This case represents not only a rural Danish community, but also a legume producer (Kragerup Mansion) and a retailer (Grøn Fokus), who have received support from Slagelse municipality's Business Center in developing their legume business model currently applied. Below, in Table 1, we have collected some main data to provide a short description of the four Danish municipalities.

Table 1. Characteristics of case municipalities (Danish Statistics, 2021).

	Copenhagen	Århus	Odense	Slagelse
Number of citizens	632.340	353.354	204.182	79.073
Area (km2)	292,50	467,90	305,6	568
Citizens/km2	7.082	728	662	139
CO2 emissions from the city (t/y)	1.021.820	1.326.779	765.000	840.000
CO2 emissions from municipal activities (t/y)	51.000	38.925	23.768	17.000
CO2 reduction targets for the city (by year)	2025	2030	2030	2030

Data collection

Field case studies (Maaløe, 20022; Yin, 2013) and semi-structured interviews have been applied, relying on methods described by Kvale and Brinkmann (2015) and Andersen (1991). Besides primarily empirical data, presented below, also secondary empirical data and literature have been collected and utilized to broaden the discussions further.

Interviews

Interviews with municipal stakeholders dealing with food planning and purchase activities, etc. has been conducted within Copenhagen, Århus, Odense and Slagelse municipalities, with the following actors:

- Copenhagen Municipality: Astrid Dahl - Children and youth department of Copenhagen municipality & Anya Huntberg - Municipal procurement department.
- Århus Municipality: Bente Kramer Møller - Contract manager in the procurement and bidding department.
- Odense Municipality: Gitte Breum - Chef for food department & Claus Brandstrup - municipal kitchen responsible.
- Slagelse Municipality: Mette Lücke Petersen - Environment, planning and technical department of Slagelse.

Field case studies
Also, several field trips to Kragerup Mansion have been conducted in 2020 and 2021 to provide information about the cultivation, species, and yield of the chickpea production, and the establishing of and current corporation with Grøn Fokus and their dialogue with Business Center Slagelse.

- Kragerup Mansion: Olav Ditlevsen - Farmer & chickpea producer.
- Grøn Fokus: Stefan Skov-Jespersen - Legume retailer.
- Slagelse Business Center: Per Madsen - Head of the business center.

Results and Discussion

In the following sections, we will *firstly* present the data from case interviews emphasizing municipal support to legumes, being ‘consumers’, ‘regulators’ and ‘facilitators’, and then *secondly* turn to the field case studies of a legume producer and a retailer seeking a larger market entry for chickpea. We will thus investigate how local legumes cultivation are - or can be - supported, and which opportunities and barriers exist within PP tendering processes to support the consumption of legumes and which value chain barriers there currently exists in the producer and retailer supply part. At the end of this section, we will, *thirdly*, provide further reflections on how to strengthen the municipal support mechanisms for legumes.

Case study Copenhagen, Århus, Odense & Slagelse municipality

We present our four municipal cases with emphasis on their supporting mechanisms to include legumes in their municipal food basket, emphasizing their role as being ‘consumer’, ‘regulator’ and ‘facilitator’.

Copenhagen municipality

Consumer
Within the city of Copenhagen 1.200 municipal units (schools, kindergartens, old people’s home, etc.), who all apply to the ‘Food and Meal strategy’ (Copenhagen Municipality, 2019), serve approximately 70.000 meals daily. The main target group for emphasizing more legume consumption in the municipal diet is young people (age 0-18) and not so much older people, due to their food preferences and the fact that it is more important that they like the food and get enough nutrients daily. In the future, the consumption of legumes will likely be older types of spices that are unprocessed, meaning that legume flour and different types of processed or frozen ingredient’s will not be emphasized in the municipal diet (Dahl and Huntberg, 2021).

Regulator

Strategies for reducing food waste and a goal of 90 % of the food being organic have already been adopted within the municipal policies for several years now (Lenny, 2015). And in the 'Food and Meal strategy' targets are set to lower the CO2 footprints connected to the food purchase by 25 %. The municipality hence recommend all units to purchase more green food ingredients, and thus explicitly mention legumes in the diets for the future. As of now Copenhagen municipality cannot require procurement of certain legume produce from specific producers and retailers due to the restrictions entailed by the public tendering process. But if more scientific data were available, as e.g., Live Cycle Analysis (LCA) showing the environmental impact of different legume species (import v. local produced, older spices v. modern species like quinoa). Having such data, the municipality could require certain purchases following such knowledge, and maybe be able to support local producers and specific legume species. Thus, more data are needed to be able to prioritize differently (Dahl and Huntberg, 2021).

Facilitator

The levers applied by Copenhagen municipality is to educate and train kitchen personal to utilize legumes in their preparing of diets. Also, school project is adopted, like school-gardens and open-school programs, where ingredients and cooking are emphasized and the basis for a good and healthy food-culture established. In the future, the municipal would like to provide more assistance to kitchen personnel to increase the overall legume purchase, and to emphasize more on the climate impacts connected to this purchase (Dahl and Huntberg, 2021).

Århus municipality

Consumer

Within the city of Århus around 550-600 units (30.000 meals) are served daily, and as opposed Copenhagen municipality the emphasis is also here on the older generation, as they, according to Bente Kramer Møller (2021) *"also tend to like the legume dishes if they taste good and are presented nicely"*. Moreover, the older generation are demographically growing, and it is therefore important to include them in the legume diets as well.

Regulator

Targets of 1/3 reduction in food waste and the use of 60 % organic food in the diets are already politically decided. A 'Food and Meal Strategy 2017' has been launched targeting diets for children between the age 0-18, and addresses schools, kindergartens and after school activity centers, etc. (Århus Municipality, 2017). Only implicit emphasis on legumes crops in the strategy are formulated, as a protein source substituting meat produce. Politically decided targets of 25 % CO2 reduction connected to the food purchase have been agreed upon, but the use of more regulation and rules are not interpreted as favorable to support a further consumption of legumes. It is, according to the municipality, more favorable to 'tell a good story' about legumes being a nutrient rich and climate friendly crop, but at the same time does not provide too much information as to avoid tiring people and face resistance. One aspect to include in this narrative could be the ESS benefits of legumes, as this knowledge is underrepresented, and the climate impacts of food purchase most often only connected to the CO2 emissions of e.g., transportation (Møller, 2021; Brandstrup, 2021).

Facilitator

The levers applied are to educate kitchen personal, but this is applied as a peer-to-peer process in within the municipality, as they do not have financial resources to provide courses and the like. In Århus, they will support the cultural changes, which the municipal food diets are undergoing in these years, by providing good stories and narratives (Møller, 2021).

Odense municipality

Consumer

Around 86 units or 5.000 meals are served daily within Odense municipality. The target group for legume diets are children between year 0-18, and the main legume species emphasized is fababeans, lenses and peas (Breum and Brandstrup, 2021).

Regulator

Besides the politically decided targets of 60 % organic food and reduction of food waste, Odense will during 2021 formulate target for CO2 emission reductions connected to food purchase. The current 'Food and Meal strategy, 2016' (Odense Municipality, 2016) emphasize how important healthy food is and have an ambition that Odense shall become a food-city. In the strategy no explicit requirements of legume crops are however mentioned, but implicit included as alternative protein source to meat. The target group for legume diets are children between year 0-18. As opposed to Copenhagen and Århus, Odense municipality require that 30 % of their food purchase must come from the local community, thus Funen and the small islands in the South. In this way it has been possible to impact the retailers and make them do an effort to deliver the food ingredient that Odense municipality requires. It is however important to pose the demands in a pace where the producers can keep up with the demand. Retailers are also asked to go back in the value chain and let the producers know that there *is* a market for their produce (Breum and Brandstrup, 2021).

Facilitator

The levers have for example been to develop recipes with legumes that are tasteful and nicely to increase the deployability of legume dishes. Besides this they are currently seeking to develop an IT tool that can calculate the carbon footprints of the menu's put together by the kitchen personal. In this way they will easily be able to see what consequence it has as far as CO2 footprint, when substitute a certain part of the ingredients with another part (Breum and Brandstrup, 2021).

Slagelse municipality

Consumer

The municipality do not serve food for children between year 0-18, but only to elders in the old people's home and within some activity centers, as well as within three canteens connected to the city hall, adding up to 10 units (Trummer, 2021) equal to 600 meals per day. The Mayer has just recently requested two meat-free days a week at the city hall's three canteens. But, as pointed out by the municipality, many companies, educational institutions, and businesses are located within the municipality and hence pose a large market for utilization of legumes in their canteen food in the future (Petersen, 2021).

Regulator

Currently, there are no Food and Meat strategy, nor politically decided targets for reducing food waste, and CO2 emission connected to purchase of reduction target are not yet decided upon. There are however CO2 emission reduction targets for the city, just as silver and bronze target levels of organic food are served in the 10 units within Slagelse municipality. However, in 2022 a new climate strategy will be finalized and will include the topic mentioned above. A new Sustainable Development Strategy, which include issue like biodiversity, circular economy, and climate, has newly been finalized but do not include the benefits of legumes as far as ESS and biodiversity. It would, according to Petersen (2021) be beneficial, if such issues could be addressed in future policies related to biodiversity, as Slagelse is a rural community where the politicians are keen on emphasize initiatives supporting the agricultural sector.

Facilitator

The main lever in Slagelse is a very energetic kitchen chef who are keen of utilizing legumes in the preparation of food within the municipality. Otherwise, no activities as teaching or courses etc. are undertaken. In the future, however, the municipality would like to support the use of locally cultivated legumes in their food diets. This could be done by undertaking local development contracts and in this way promote agriculture and business within the local community, and hence a supply of local produce (Petersen, 2021). All data from the explorative study of the four municipalities are depicted in Table 2 below.

Table 2. Summary of findings: Existing and future support mechanism.

	Consumer	Regulator	Facilitator
Copenhagen	-Municipal units:1.200 (70.000 meals per day). -Target group: Children 0-18 years. -Legume type: Unprocessed and preferably old and native species.	-Food and Meal Strategy, 2019 explicit emphasizing legumes. -Food waste reduction targets. -Share of organic food in diets 90 %. -Require 25 % CO2 reduction connected to food purchase. -Public bidding process hamper emphasis on the use of locally cultivated legume. -LCA analysis of carbon footprints of different legumes could favor the demand for specific types of legumes and producers from the local area.	-School gardens, open school education & upgrading of kitchen personal to handle legumes. -Would like to strengthen assistance to kitchen personal in regard to the climate impact of their legume purchase.
Århus	-Municipal units: 550-600 (30.000 meals per day). -Target group: All ages.	-Food and Meal Strategy, 2017 implicit emphasizing legumes. -Food waste reduction targets. -Share of organic food in diets 60 %. -Require 25 % CO2 reduction connected to food purchase. -No more regulation needed, but a need to 'tell the good stories' of legumes, e.g., ESS benefits.	-Peer-to-peer upgrade of kitchen personal to handle legumes. -Legume storytelling in focus.
Odense	-Municipal units: 86 (5.000 meals per day). -Target group: Children 0-18 years. -Legume type: Fababeans, lenses and peas.	-Food and Meal Strategy, 2016 implicit emphasizing legumes. -Food waste reduction targets. -Share of organic food in diets 60 %. -CO2 reduction connected to food purchase will be required ultimo 2021. -Require that 30 % legumes purchase must origin from the local community.	-In the process of developing an IT tool to help kitchen personal in climate friendly purchase of food ingredients. -Currently kitchen personal is provided with data on food carbon footprints from the retailers, but more data is needed. -Develop recipes of how to make dishes including legumes.
Slagelse	-Municipal units: 10 (600 meals per day). -Target group: Elder people's home, activity centers, and three canteens connected to the City Hall.	-No policies supporting the use of legumes are currently in place. - Silver and bronze target levels of organic food are served. -In 2022 a Climate Strategy will be effectuated and include: Targets for food waste & CO2 reduction targets connected to the municipal food purchase. -A Sustainable Development Strategy has been decided upon and could in the future deal with benefits of legumes related biodiversity.	-A very energetic chef supports the use of legumes within the municipal kitchens. -The municipal seeks to support local producers and retailers connected to legumes, when possible.

Field trip Kragerup, Grøn Focus & Slagelse Business Center

In the following, we present Kragerup Mansion & Grøn Fokus, and Slagelse Business Centers' support to the development of their business model. We emphasize on which additional support the Business Center can provide, being requested by the involved stakeholders.

Actors in developing the legume business model in Slagelse.

Kragerup Mansion

The farm is located in West Zealand in Slagelse municipality (borders directly up to

Kalundborg municipality) and is a 1.200 ha large farm estate with hotel, conference, meeting and wedding facilities, etc., as well as Go-High activities (high tree climbing) and other recreational activities, as mountain bike tracts and football golf, etc. (Ditlevsen, 2020). The farm primarily cultivated cereals but have in the last couple of years also emphasized on legumes, as for example fababeans, lenses, millet, chickpea, and lupine, where the latter two initially were utilized within the Kragerup mansion's restaurant by the kitchen chefs (Ditlevsen, 2020). According to Ditlevsen (2021) the white lupines looks like small quail eggs, which the restaurant costumer's like as garnish, just like they value the fresh and locally cultivated chickpea utilized in the restaurant dishes. The ground plan for 2021 is to cultivate 40 ha fababeans, 9 ha chickpea, intercropping 39 ha mixed dog grass & pea, and a same size area with white clover & barley, and well as several smaller parcels with lenses, lupine etc. Besides this most of the farmland will be cultivated with cereals (Ditlevsen, 2021).

Grøn Fokus

Around 15 km from the Kragerup Mansion, within the city of Slagelse, the company Grøn Focus are situated, which is a retailer dealing with organic produce. Grøn Fokus began their business in 1999, with an emphasis on buying and selling organic produce from Denmark, which later also included produce from outside Denmark (www.gronfokus.dk & Facebook. com/gronfokus). The company primarily supply the Danish market, and very little to e.g., Sweden, Iceland, and the Faeroe Islands. The company mostly deliver organic and bio-dynamic products to professional large-scale kitchens. The company supply around 2.500 different products, whereof Skov-Jespersen (2020) estimates that 100 products are a sort of legume in any kind of form (processed or non-processed, etc.) (Skov-Jespersen, 2020).

All sorts of legumes (fresh, dried, or canned) are distributed by the company and mainly imported, as for example the chickpeas that are cultivated in Turkey. Grøn Focus purchase their products from middle traders, and they are certified organic. The market for legumes is increasing and the chefs in the kitchens are asking for more organic legumes to include in their food preparation. It is especially chickpea, quinoa, lenses, and millet from Denmark that the costumers would like to purchase (Skov-Jespersen, 2020).

Slagelse Business Center - Initiating cooperation between actors

Due to Slagelse municipals' emphasis on supporting the cooperation between actors in the local area to support agricultural business opportunities (Petersen, 2021), Grøn Fokus and Kragerup Mansion were introduced for each other by the Slagelse Business Center (Madsen, 2021) under a busines award event in the region (Ditlevsen, 2021) - and were later established as more formal business meeting between the stakeholders (Madsen, 2021). Besides establishing the contact between the two parties Slagelse Business Center do not provide any other facilitating service to companies etc., but they will continue to try to identify potential corporation in the municipality between various types of businesses and the agriculture (Madsen, 2021).

Grøn Focus would initially like to cooperate with Kragerup Mansion as they wanted to increase their share of locally cultivated chickpea. This due to job creation, the environment and the community-based issue revolving around *“producing ‘things’ in the local community”* (Skov-Jespersen, 2020). The company would like to brand their products more for being cultivated locally. They are willing to expand they current value chain, by taking a financial risk together with Kragerup Mansion to achieve a domestic production of chickpea. Grøn Fokus hence hope for lager chickpea yields on Kragerup Mansion in the future to phase out some of the imported of chickpeas from Turkey (Skov-Jespersen, 2020).

The motivation for Kragerup Mansion to cooperate with Grøn Fokus was rooted in a market entry opportunity. Thy would like to brand their legume produce more, but it is difficult as the knowledge is low, and the market still limited and immature. People do for example not, according to Ditlevsen (2020) know about ESS benefits of legumes, and thus do not recognize what he is doing with his soil, the local environment, and on the farm. Young people might know about soybean from South America and avoid supporting this by eating local produce. But their knowledge stops there. *“People need to be more food-educated and know about legume dishes, as well as raw materials cultivation and soil”* (Ditlevsen, 2020).

Grøn Fokus and Kragerup Mansion appreciate the cooperation facilitated by Slagelse Business Center, but they would like to see additional supportive mechanisms. For example, financial support to machinery that e.g., efficiently rinses the chickpeas, as such processing machinery are difficult to identify, or it could be help to applications for governmental funding for purchase of machinery or other types of processes or experiments e.g., refined seeds, which could support a larger market entry for cultivating chickpea. Thus, more support connected to the financial and regulatory support, based on political mandates from municipal politicians. Finally, Slagelse municipality are suggested to begin to purchase chickpeas from Kragerup Mansion to secure a larger and stable market, which could be utilized within the municipal kitchens, etc. (Ditlevsen, 2021).

Also, new business opportunities within other types of plant-based food supply could be pointed out and facilitated by Slagelse Business Center. Grøn Fokus, for example, sees great potentials in cooperation with the diary company Arla - situated just across the street from them - and a potential production of new types of plant products, as e.g., oat-milk, which Grøn Fokus would like to be a part of. Thus, more facilitating initiatives from the

Business Center are requested (Skov-Jespersen, 2020). A summary of the data from the explorative study is provided in Table 3 below.

Table 3. Summary of findings: Existing and future support mechanism.

	Consumer	Regulator	Facilitator
Slagelse Business Center	-Should identify new market opportunities, e.g., oak-milk production by Arla.	-Acquire political mandate to support legumes by supporting purchase of rinsing machinery financially.	-Previously established the meeting between Grøn Fokus and Kragerup Mansion. -Should assist in applying for funding, etc. -Must be more active in facilitate cooperation between local companies, e.g., Arla and Grøn Focus on the production and distribution of new products, as for example oak-milk.
Slagelse Municipality	-Suggested to begin purchase of chickpea from Kragerup Mansion for their kitchens to secure a larger and stable market.		

Strengthen the municipal support mechanisms - reflections

According to our empirical data legume strategies and targets could be included as a ***regulator*** element in municipal biodiversity plans in the future due to the many ESS benefits of such legume crops (Petersen, 2021; Møller, 2021), and hence support the agricultural sector and the environment within municipalities. According to Møller (2021) it is however also important to inform and educate citizens about legume ESS, than e.g., adopting new policies and goals on paper. Thus, by integrating grain legumes in strategic plans legume crops will achieve an additional platform for policy engagement, and by appropriate narratives knowledge can be disseminated within the society. This also account for the food strategies, where legumes should be mentioned more explicitly in the municipal Food and Meal strategies to underpin the importance of legumes being an important part of the food transition.

Emphasis on mechanisms that assist kitchen personal in addressing the use of legumes in the food basket could be strengthen by various IT tools calculating CO2 carbon footprint of various food ingredient choices, etc. Emphasizing consumption of legumes from local producers can be ***facilitated*** by LCA tools identifying the environmental impacts of local produce compared to imported produce. According to Huntberg (2021), municipalities underlying tender processes, will then have a scientific and legitime platform to make purchase requirements on, meaning that they can support special types of legumes, if the LCA supports this. This could facilitate a ***consumer*** role in which municipalities support a larger market for legumes being specific sorts from certain locations (Ibid.). But what are the obstacles and opportunities in the value chain for increasing the municipal consumer role? We will shed light on this in the following section.

Lack of knowledge in the legume value chain and support mechanisms

Legume producer's capability to cultivate and hence deliver legumes at an adequate amount of to the municipalities, are currently a barrier for municipalities being a stronger ***consumer.*** According to Brandstrup (2021) and Ditlevsen (2021), a balance is currently needed between the municipal demands and the capabilities of supplier, as new farm systems must be deployed, unless the legumes required are e.g., green pea and fababean, which Danish farmers are costumed to cultivate. Lenses, lupine, chickpea etc. need to increase in yield just as the quality must be improved for some legumes to be appropriate for human food (Bertelsen, 2021). This has for example been the case for fababeans which solely have been cultivated in Denmark for use as animal feed with high levels of tannin (bitter taste) and the need for heat treatment to enhance the protein (amino) uptake. New more refined seeds are however available now appropriate for human food. For chickpea variations in size and color are still normal, which needs to be addressed to reach a larger market (Ditlevsen, 2021).

As for the case of Kragerup Mansion there is also technical obstacles for an increased production of chickpea, as rinsing and sorting machinery are not readily available. Inexpensive and non-advanced sorting machinery has been purchased from Poland, and efforts has been made to identify companies that could provide such service, which was found to be unfavorable expensive (Ditlevsen, 2020; 2021). At Kragerup Mansion better chickpea seeds are also requested. Seeds being refined for the Danish context and climate, with more stable yield as far as t/ha, color, and size (Ditlevsen, 2021). Economic support and help with funding application work are thus questioned. In the retailer part of the value chain, Grøn Focus already emphasize on organic farm produce hereunder legumes, but the need to evolve further into other types of vegetable businesses are hampered by lack of engagement in the local community, and the capability of seeing business opportunities between local companies. Thus, more emphasis on stakeholders assisting or getting involved in this area, are requested (Skov-Jespersen, 2020).

Emphasis on legumes through PP tendering and negotiations

The empirical data showed that some municipalities would like to emphasis the use of specific local legume species and even on specific producers in their purchase of legumes and thus apply *innovation public procurement* (IPP) to provide a market and a transition of the municipals food basket to include domestic legumes as a new produce. Municipalities thus not only look to pea and fababean in their emphasis on legumes, however being the most cultivated legume crops (Bertelsen, 2021; Økologisk Landsforening, 2021).

Municipalities are however challenged by the public tendering process, which PP within government institutions are subject to. In the following, we emphasize this issue.

Cooperation between local stakeholders could, however, be stablished through *innovation partnerships* (IP) to facilitate and secure the cultivation and consumption of local legume produce, which are not available or not adequately available on the market (EU, 2021). This could be done by larger municipalities that apply to tendering regulation (EC, 2007), where they e.g., engage in a partnership with a producer and apply experiments in the cultivation of a certain e.g., local old sort of legume, and where the municipal kitchen staff seek to develop tasteful and nicely presented dishes using this specific legume (Petersen, 2021). Such innovative partnership could be financed by a e.g., public business fond (erhvervs-pulje) (anonymous informant).

When the specific bulk of legumes are large enough from the producer, and found relevant as a food basket ingredient, it will be something the municipality could include in their tender formulation for the next bidding period (anonymous informant). Hereby, retailers will be asked to, and thus must include the specific sort of legumes in their bidding proposals to be competitive and develop their portfolio of produce (Brandstrup, 2021). This is what Rosell (2017) defines as retailers: *"….. being awarded by means of a negotiated procedure"*. Within smaller municipalities not applying to tendering regulation - due to lower threshold purchases and with an aim of for example supporting small and medium sized enterprise's (SME's) - they could engage in a negotiation with retailers being awarded in this way, hence not being obliged to tender (EC, 2007; Rosell, 2017).

Conclusion

Currently, there is a growing interest in Denmark for the consumption of legumes for human food, but most of the grain legumes are imported (Økologisk Landsforening, 2021; Bertelsen, 2021) besides pea and fababeans, which danish farmers are costumed to cultivate, and where the latter have been improved for the Danish context by adopting to better seeds (boxer & figuero) (Bertelsen, 2021). There exists both barriers and opportunities for a further uptake of legumes in the municipal food basket, exemplified in the following. The empirical data hence shows that Danish municipalities and retailers like Grøn Fokus - but also for example Hørkram, Fynsk Psykologi and Biogan (Brandstrup, 2021; Økologisk Landsforening, 2021) - are interested in supporting more local produce including older sort of legumes, which for example includes lenses, chickpea, and peas, being more popular legumes for human consumption compared to fababeans and lupine (Landbrugsavisen.dk 2020b; Bertelsen, 2021). The yield and quality of for example lenses, chickpea and lupine are however still to be developed further (Ibid.). Municipalities' support to the promotion of such legumes through various PP strategies - *innovation partnership* and *negotiations partnerships* - is extremely valuable, as emphasized in this paper, but however not enough to increase the yield and quality over a short period of time, as simply increasing the demand for certain legumes is not sufficient.

As the empirical data shows, support to refining seeds, machinery to deal with sorting and pealing etc. must also be supported, developed, and disseminated. Economic support and knowledge transfer to farmers must also be provided, as these types of legumes are more difficult to cultivate than traditional legumes like e.g., pea and fababeans (Landbrugsavisen.dk, 2020b; Bertelsen, 2021). Research supports the need for capacity building in a Danish context regarding appropriate technology and knowledge of cultivation practices (Legvalue, 2020). Thus, the 'consumer', 'regulator' and 'facilitator' role of municipalities within legume PP are a strong mechanism to support the consumption of legumes by various means, but must additionally be supported by national initiatives, like economic support, knowledge interventions and capacity building on a larger scale. This is especially important when it comes to the more challenging legumes, here lenses, chickpea, and lupine, as opposed to for example pea and fababeans, where adequate knowledge seems to exist.

Acknowledgment

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154 Behavioural Insights into Personal Electronics Repair in Sweden

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Abstract

Sweden is actively seeking to scale up repair activities as part of its strategy to reduce waste, transition to a circular economy, and achieve zero net emissions by 2045. In the last couple of years, several new policies to promote consumer repairs have been adopted or proposed in Sweden. However, very little is known about the socio-cultural factors that shape people's decision to repair their personal electronics. This study addresses this gap by applying consumer behaviour theory to study the factors shaping and influencing people's decision to repair their personal electronics. A mixed-method research approach was used, involving 19 semi-structured interviews and an online questionnaire answered by 190 participants. The interviews and questionnaire targeted Swedish residents and were based on Triandis' theory of interpersonal behaviour. The study revealed that intention and habits determined repair behaviour and that social norms, attitudes, and feelings about repair determined participants' intention to repair. Moreover, the interviews and the questionnaire uncovered that, in general, attitudes and social norms about repair do not encourage repair behaviour and that the physical environment is filled with barriers that discourage people from repairing their broken electronics. Therefore, the study concluded that to scale up repair activities, it is essential to improve the perceived individual benefits of repair, strengthen social norms to make repair the expected solution for broken personal electronics, shape repair habits, and lower contextual barriers. Based on these findings implications and specific policy recommendations are discussed.

Keywords: Repair, Electrical and Electronic Equipment, Theory of Interpersonal Behaviour, Circular Economy, Sweden.

Introduction

There is sound evidence to assert that electronic products (e-products) are causing significant environmental impacts in our natural world (Laurenti et al., 2017; Lavers Westin et al., 2019). In fact, in Sweden alone, e-products are hot-spot products of urban consumption responsible for between 14 and 58 percent of the total urban emissions causing climate change, acidification, eutrophication, ozone formation and resource use (Lavers Westin et al., 2019). For most e-products, the most significant environmental impact happens in the extraction and manufacturing phases, therefore extending their life through repair will generally result in environmental gains (Bachér et al., 2020; Bakker & Schuit, 2017; Parajuly et al., 2019; Rudenauer & Prakash, 2020).

Beyond the environmental benefits, repair also promises to boost local economies (EC et al., 2018; King et al., 2006; Llorente-González & Vence, 2020; Mitchell & Morgan, 2015) and bring back a lifestyle centred on caring for our belongings (Bovea et al., 2017; Montalvo et al., 2016). Therefore, promoting repair and product repairability are coined as essential strategies to mitigate the environmental impacts of e-products and meet environmental goals such as the transition to a circular economy (CE) (Almen et al., 2020; Bakker & Schuit, 2017; EEB, 2019; Wieser & Tröger, 2018).

Both in policy and academia, repair is increasingly referred to as an important strategy to extend the life of electronics and achieve circularity. Especially at the European Union (EU) level, there has been a boom in repair-related policies, including introducing repairability standards for product design, and regulations to publish repairability information, make spare parts accessible, and improve legal guarantees (Svensson-Hoglund et al., 2021). In the specific case of Sweden, the Government has introduced tax deductions to promote the repair sector (Almen et al., 2020). The key EU-level legislation addressing repair include the Ecodesign Directive, the Sales of Goods Directive, the Waste Framework Directives, The Waste Electrical and Electronic Equipment Directive, the EU Ecolabel, and Green Public Procurement.

In academia, repair gained attention along with the concept of the CE, with the first publication appearing in 2010 and a boom that started in 2018 with over 50 publications (Niskanen et al., 2021). However, despite the increased interest in repair demonstrated by the surge in both policies and publications on the subject, existing research has not paid sufficient attention to how attitudes, social factors, affective appraisal, and habits influence an individual's decision to repair electronic devices (Ackermann et al., 2018; Cerulli-Harms et al., 2018; Raihanian Mashhadi et al., 2016; Scott & Weaver, 2014; Wieser & Tröger, 2018). Moreover, very little is known about the Swedish case. Instead, existing literature has overwhelmingly focused on understanding contextual barriers to repair, such as cost, access, product design, information provision, and guarantees (see Lopez Davila, 2021, for a review of the literature on electronics repair).

When analysing the existing legislation, it appears that repair policies that target consumer behaviour are reduced to information provision through manuals and eco-labels, hinting at a neoclassical economics understanding of the individual as a rational decision-maker that corrects his or her behaviour based purely on information. However, research shows that behaviour is complex and multidimensional, governed by norms, emotions, habits, attitudes, and context (Jackson, 2005; Triandis, 1977). Thus, information provision alone is unlikely to be effective, and a more comprehensive conceptualisation and understanding of the factors that shape behaviour is needed to successfully design effective behaviour-change policies that promote the repair of electronic devices.

This study addresses this research gap by applying behaviour theory to gain behavioural insights into personal electronics repair. In this study, personal electronics are defined as computers, tablets, printers, electronic watches, music equipment, calculators, mobile phones, televisions, projectors, digital cameras, electric toys, videogames, and sports machines. The use of behaviour theory is key since it provides the possibility of exploring repair behaviour more comprehensively and of testing the strength of the different factors that influence repair decisions. The findings of the study would enable policymakers to understand the factors that influence repair behaviours and identify concrete intervention points to incentivise Swedish residents to engage with this practice effectively, and promote the environmental objectives of Sweden.

The next section introduces the theoretical framework, followed by a section on methods. This is followed by an overview of the main results and a discussion section. The paper ends with policy recommendations and the conclusions.

Theoretical framework

Behaviour theories have been widely applied to explain and predict environmental behaviours such as upcycling (Sung et al., 2019; Terzioğlu, 2021), product care (Ackermann et al., 2018), sustainable food consumption (Shin & Hancer, 2016; Vermeir & Verbeke, 2008), waste recycling (Chan, 1998; Chan & Bishop, 2013), and travel mode choice (Bamberg & Schmidt, 2003; Domarchi et al., 2008). To understand the complexity of environmental behaviours, many of these researchers have proposed modifications to existing behaviour models such as Ajzen and Fishbein’s theory of planned behaviour (TPB) or Schwartz’s value-belief-norm. A common factor of these modified models is that they include elements that are part of the Theory of Interpersonal Behaviour (TIB), such as habit, self-concept, and affect.

TIB has been recognised for its wide applicability and explanatory power in studies investigating upcycling behaviour (Sung et al., 2019), travel mode choice (Bamberg & Schmidt, 2003; Domarchi et al., 2008), hand hygiene behaviour (Kupfer et al., 2019), and ethical decision-making (Li et al., 2020). Moreover, in a comprehensive review of consumer behaviour and behaviour change models, Jackson (2005) found that although TPB is the most widely used model in the study of environmental behaviours, it has failed to measure actual behaviour. Similarly, Bamberg and Schmidt (2003) argue that there is increasing evidence that TPB fails to explain all kinds of social behaviours. In contrast, Jackson (2005) and Bamberg and Schmidt (2003) argue that TIP captures many of TPB's criticisms and thus is a better framework to study social behaviours. Thus, given the broad applicability and comprehensive conceptualisation of behaviour, TIB is considered as the most appropriate framework to investigate repair behaviour.

Triandis' Theory of Interpersonal Behaviour

Triandis proposes that behaviour is shaped by three overarching factors: Intentions, the strength of habits, and the facilitating conditions that enable or hinder a behaviour (Triandis, 1977). Moreover, he proposes that there are three factors that influence intention: Attitudes, social factors (such as norms, self-image, and roles), and affect (i.e. emotions) associated with the behaviour (Triandis, 1977) (see Figure 1).

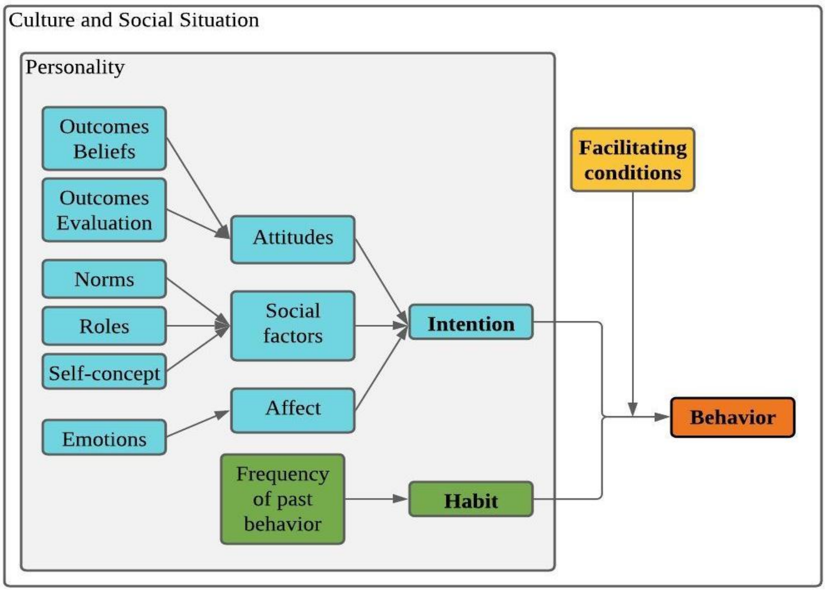

Figure 1. Triandis' Theory of Interpersonal Behaviour
(Source: adapted from Jackson, 2005 and Page & Sherif, 1980)

Triandis theorises that depending on the type of behaviour, situation, or person, the weights of the components of his model shift (Triandis, 1977). For example, for new, unlearned social behaviours, intentions determine a behaviour. However, once the behaviour has been repeated multiple times and has been rewarded or punished, the behaviour becomes automatic and is determined by habits (Triandis, 1977). Moreover, the influence of habits and intention on behaviour is moderated by the presence or absence of facilitating conditions (Triandis, 1977).

Methods

This study used a mixed-methods exploratory sequential research design. Guided by Triandis' TIB this study commenced with a qualitative data collection and analysis phase, which informed the second phase of quantitative data collection and analysis. The qualitative data collection consisted of 19 semi-structured interviews with Swedish residents. The purpose of the interviews was to understand the residents' past experiences, intentions, habits, and the facilitating conditions that influence their decisions to repair personal electronics. The interviewees were selected using non-probability quota sampling to provide a wide range of perspectives and opinions. NVivo10 software was used to conduct thematic analysis on the qualitative interviews.

Also based on TIB and guided by the findings of the interviews, quantitative data collection consisted of an online questionnaire answered by 190 Swedish residents (see Lopez Davila, 2021, for an overview of the demographic characteristics of the questionnaire sample and the list of the interviewees). The questionnaire gathered individuals' opinions and experiences repairing personal electronics. Participants were selected through non-probability convenience sampling based on the author's network. The software IBM SPSS 27 was used to conduct descriptive statistics, Spearman's rank-order correlation analysis and binomial logistic regression on the questionnaire data.

To adequately test Triandis' TIB model, correlation and regression analyses were conducted in two steps: Step 1 examined intentions to repair, and Step 2 frequency of repair behaviour. See logic in Figure 2.

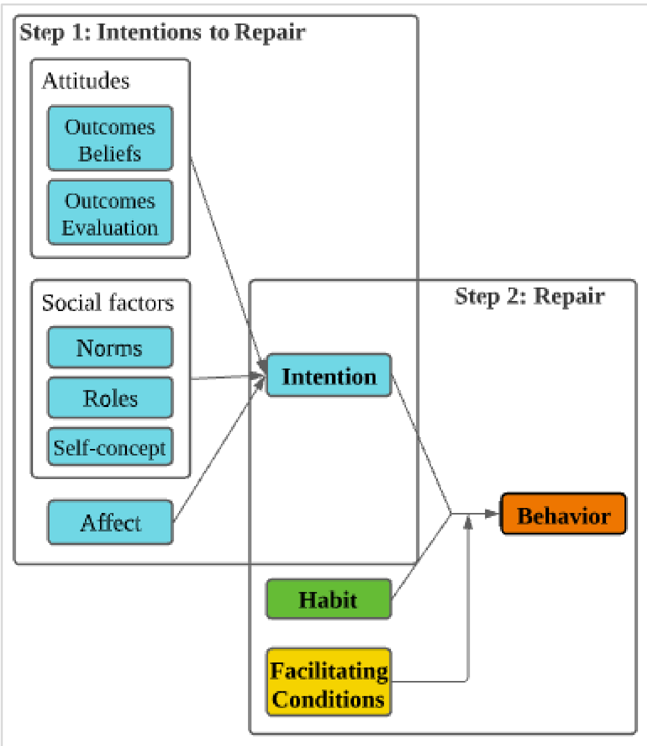

Figure 2. Correlation and regression analysis steps

Results and Discussion

This section presents the findings in the following way: 1) factors that shape repair behaviour revealed by qualitative analysis and descriptive statistics, and 2) factors that explain repair behaviour uncovered by correlation analysis and logistic regression.

Factors that shape electronics repair behaviour

The decision to repair a broken personal electronic device is shaped by intricate individual, social, and contextual factors. The following findings are presented following Triandis' TIB, starting with intention and its related factors, then with habits, and finishing with facilitating conditions (see Figure 1).

Attitudes towards repairing e-products

Repair has a tainted image. Although people think repair is beneficial for the environment, the economy, and society, they think it is complicated, time-consuming, and expensive.

The most mentioned benefits of repairing personal electronics where environmental (19 out of 19 interviewees) and economic (8/19): *"Repair is necessary for sustainable development. We are overconsuming and repair helps to slow consumption, and also the environmental and social aspects of mining"* (P7), and "*We save some money because [repairing] is not really exactly as expensive as buying a new one"* (P3). Moreover, building emotional connections and encouraging a lifestyle of caring were also mentioned as benefits of repair by some interviewees (5/19).

However, more than half of the interviewees perceived repair as an inconvenient, complicated, lengthy, and hard thing to do (13/19): *"It's the opposite of easy but I don't mean just difficult but more like a lengthy process that feels a little bit overwhelming and expensive. I don't really know if it's worth it"* (P3).

When it came to the cost of repair, twelve participants expressed that repair services were generally expensive in Sweden but that the real problem was that they felt they did not get their money's worth when repairing their personal electronics: *"Will it be more economic in the long term to buy a new phone? if I repair, would it last? because repair may be a bit cheaper but then it may not last long. You cannot guarantee a reparation in the same way you can guarantee a new phone"* (P16).

The majority of interviewees (11/19) also described repair services as time-consuming in two ways. On the one hand, it takes time to investigate where to go and what is a fair price. On the other hand, the wait time to get a device repaired can be long, which is especially problematic with devices such as computers and phones: *"There is downtime when you have a phone and you have to replace something which is not available immediately and you have to ship it from wherever then you have to wait for three days and three days without a phone in Sweden is really problematic"* (P19).

The survey findings mirrored the interview findings. The questionnaire showed that there was overall agreement among participants that repairing electronic devices was good (90%), beneficial (86%), and worthwhile (73%) but also hard (68%), time-consuming (65%), and expensive (50%). Opinions about whether repair was frustrating or satisfying were divided (see Figure 3)

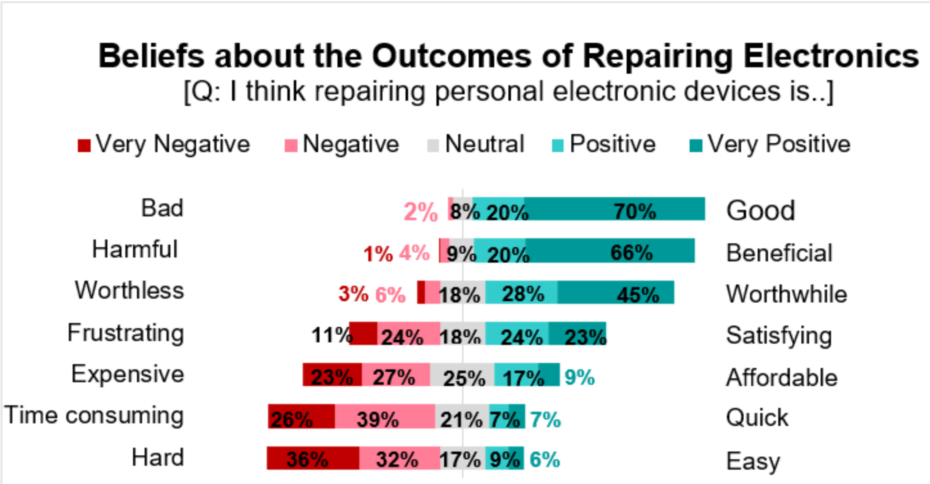

Figure 3. Respondents' beliefs about the outcomes of repairing electronics

Moreover, most participants strongly agreed or agreed that repairing electronic devices when they break helps protect the environment (87%), makes them feel proud (83%), is *not* a waste of time (71%) or money (63%), is a good deal (60%), and will result in their device working as well as when it was new (58%). On the other hand, the slight majority of participants strongly disagreed or disagreed that repairing electronics makes them uncomfortable (48%) and that repairing a device signals it will continue to break (42%) (see Figure 4).

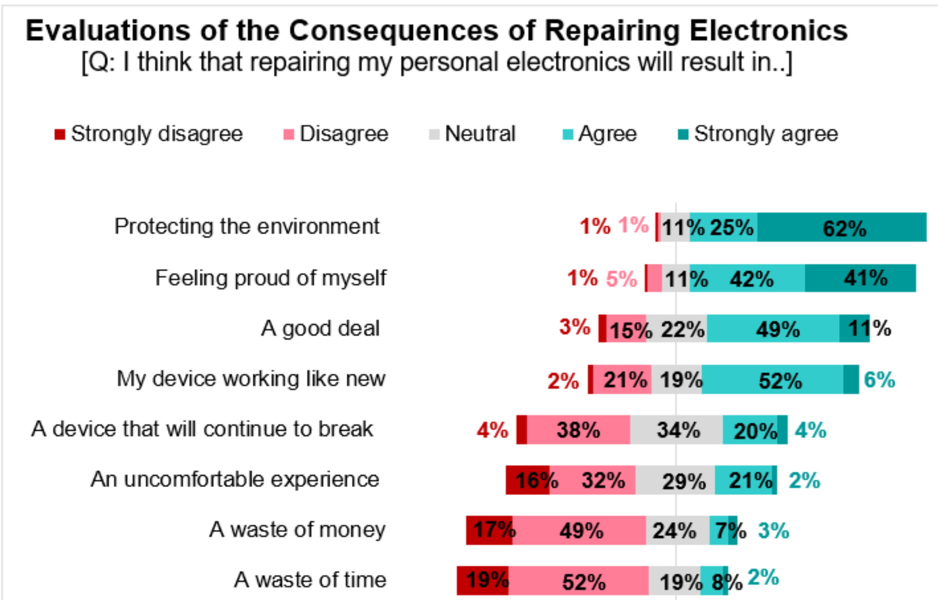

Figure 4. Respondents' evaluations of the outcomes of repairing electronics

Social Factors

Repairing broken personal electronics is seen as something people “should” but not as something they “must” do. Most participants (17/19) perceived that the normal thing to do when an electronic device breaks or malfunctions is to replace it. There were some discussions (6/19) about how there is a growing expectation to donate or recycle old devices and consensus that repair is more common for high-quality, expensive electronics. The interviews revealed two plausible explanations for this finding.

First, some participants mentioned that the current paradigm of consumption favours replacing over repairing personal electronics. The popular Swedish say “slit och släng” (“use it and throw it away”) was brought up to describe the current norms around e-products. Interviewees explained that repairing things, including electronics, was the norm in Sweden for a long time, but it began disappearing at the turn of this century. This change was in part attributed to the Government, who back in the 1970s believed consumption needed to be accelerated *“for the health of the country”* (P17).

During this time Sweden experienced a few key incidents. First, there were nationwide efforts to mainstream “slit och släng” through actions such as the televised discussions. At the same time, globalization generated the well-known “race to the bottom” effect, which resulted in increasingly cheaper electronics becoming available in Sweden. Meanwhile, the cost of labour in Sweden kept on rising. All these factors contributed to repair becoming increasingly unpopular and expensive.

In this new paradigm of consumption, the norm became one where *“you should replace your whole living room every year*” (P10), as eloquently said by one interviewee: *“That's the era we are living in now [slit och släng], it’s a lot cheaper to buy new than to repair and it is actually quite cheap to buy new electronics […]. It’s the cultural norm and expectation so then it really feels like you're swimming upstream if you want to do something different”* (P18).

Another reason mentioned by most participants (15/19) to explain why repair culture is not the norm in Sweden, was that contrary to buying new, the process and outcome of repair is uncertain, and Swedes prefer certainty over uncertainty: *“Swedes, they say we like safety, we have insurance, security, bells in the cars. We are very much about control and security you know. We really want to know what we're getting so maybe that's part of it as well, you want to be sure. If you go ‘there’ maybe they won't repair it and it feels really bad not getting what I want or not being sure of what I'm getting”* (P8). Some participants (9/19) highlighted that some Swedes can be conflict-averse, which could explain a preference for replacing over repairing: *“I think people in general in Sweden avoid conflict. So that means that when we buy a product, we don't want to go back and say: ‘hey, this is not what I expected I want you to fix it’ we don’t want that conflict, I think.”* (P3).

When it comes to societal roles, being a working professional or a parent was consistently described as being *"time poor"* (P11) hence not having time to repair. In contrast, students identified themselves as perfect candidates for repair as well as for the second-hand market: *"We tend to repair things. But also buy second hand. At least in the student world it works like that a lot. Those two things before buying new"* (P14).

Regarding self-concept, the majority of participants (12/19) described themselves as environmentally aware and talked about making intentional choices to live their lives sustainably such as buying second hand, taking bags into the supermarket, and eating less meat-based products. However, during the interview, many (5/19) reflected that repair was not something they had thought about too much: *"I mean when it comes to other aspects of living sustainably, I feel that I go much longer in order to live right, or do the right thing"* (P1).

The questionnaire findings were consistent with the interviews and revealed that most participants (49%) do not see personal electronics repair as something they are expected to do. Interestingly, the opinion on whether people think they should repair broken personal electronics was somewhat divided with a slight inclination towards thinking that repair is something others think they should do (39% strongly agreed/agreed versus 33% strongly disagreed/disagreed). Also aligned with the interview findings, most participants think it is acceptable to replace a device that still works if it is recycled/donated (54%) or replaced with a second hand device (51%) (see Figure 5).

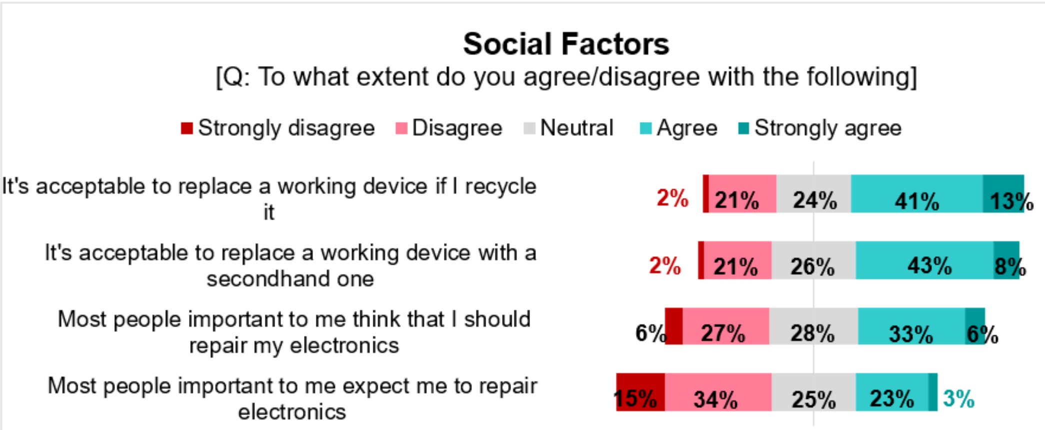

Figure 5. Perceived norms around what to do when personal electronic devices break or malfunction

Affect

Professional repairs are associated with negative emotions such frustration (4/19): *"There are so many steps that you just get angry"* (P13); discomfort (5/19): *"I know that I always get a little bit apprehensive in situations that I'm not really comfortable with and since I don't really know much about electronics I feel like I could be fooled"* (P5); and uncertainty (4/19):"*I feel a bit insecure. In Sweden we have this say: 'you buy a pig in a sack' you pay for something but it's not transparent, you don't really know what* *you get"* (P8). Conversely, emotions for those who self-repair are more optimistic, including excitement, fun, and satisfaction.

Unlike in the interviews, the reported feelings about repairing electronics in the questionnaire were mixed between positive and negative emotions, with no clear trend. Participants reported feeling pleased (50%), unsure (45%), nervous (43%), comfortable (38%), confident (35%), relaxed (29%), annoyed (29%), and uncomfortable (27%) (see Figure 6).

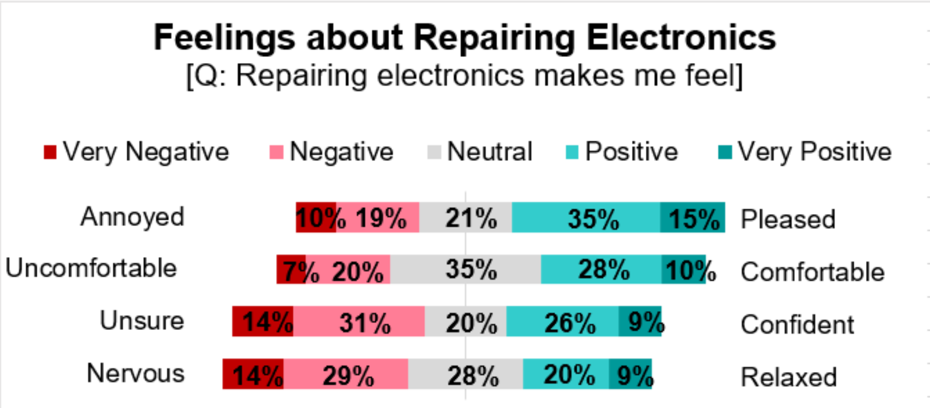

Figure 6. Respondents' feelings about repairing electronics

Habits

Most interviewees (11/19) said they usually don't repair broken electronics. In contrast, more than half of the questionnaire participants (57%) claimed to try to repair their personal electronics when they break. Most participants (7/19 and 58%) said they remember growing up in households that repaired electronics when they broke.

The most frequently cited reasons for replacing a device instead of repairing it were that the device was at the end of its useful life and hence not worth repairing (4/19): *"When those phones reached three years and started malfunctioning, you don't even consider repair, you just go for replacing"* (P12); that the device couldn't be repaired (3/19): *"Actually it has been so broken that it can't be repaired. The repairer told me that its more costly to repair than to buy new"* (P15); or simply that they did not think about repair (8/19): *"We ended up buying a new one. There wasn't even a question of trying to repair it"* (P6).

Of those who repaired their electronics (8/19), only a minority talked about using guarantees to pay for repairs (3/19); the rest repaired their devices outside of the guarantee period. The participants that reported "doing nothing" usually cited doing so because their device was functioning well enough (5/19): *"I recently dropped it so the screen crashed a little, but it works still so I can continue to use it for a while"* (P1).

Facilitating conditions

To create the optimal conditions to repair personal electronics, interview participants would like the following facilitating conditions in place:

Contextual. Repair should be as easy and convenient as buying new. Repair shops should be more visible (5/19), the entire repair process should happen online (8/19), and repair technicians should be more encouraging (5/19). The cost should be transparent, lower than the cost of replacing (11/19), and the guarantees should be as good as those of new devices (5/19). Consumers should know what to expect upfront and have access to information about repairability and maintenance (7/19).

Cultural. To increase their engagement with repairing personal electronics, participants want others to be doing it (5/19). They want society to tell them it is important to repair and encourage them in the same way they have been encouraged to buy second hand (e.g. clothes), eat less meat-based products, bring their bags to the supermarket, and take the train instead of the plane (8/19). They want to know their friends and colleagues are more engaged in repairing and to hear about their experiences and get their recommendations about reliable repair shops.

> *" I just think it has to get the attention and become commonly known. A great example is with plastic bags, like it's incredible that you would skip-go to ICA if you don't have your plastic bag rather than just buy a new one for 6 SEK. Like 6 SEK is nothing compared to what you're getting at the store but you still, sometimes I say, 'oh I didn't bring my plastic bag, I'll just go shopping some other time'"* (P6).

When it comes to the questionnaire, participants were asked to report their perceived barriers to repair. The majority reported that the following factors have impeded them from repairing their broken electronics to a considerable or a great extent: the cost of repair being higher than the cost of buying a new item (72%), not having a way to easily compare repair prices (66%), not knowing the cost of repair up-front (56%), not having access to instructions on how to maintain and repair electronics (55%), not having a device covered by a guarantee (55%), and not knowing where to go to repair their electronic devices (54%). Slightly less than half of the participants (43%) reported that not having the time to figure it out was a factor that prevented them from repairing their devices either to a considerable or great extent. In addition, about one-third of the respondents reported not trusting the repair service will do the job right (37%) and not trusting that the repair service is being transparent (31%) as considerable or great barriers (see Figure 7).

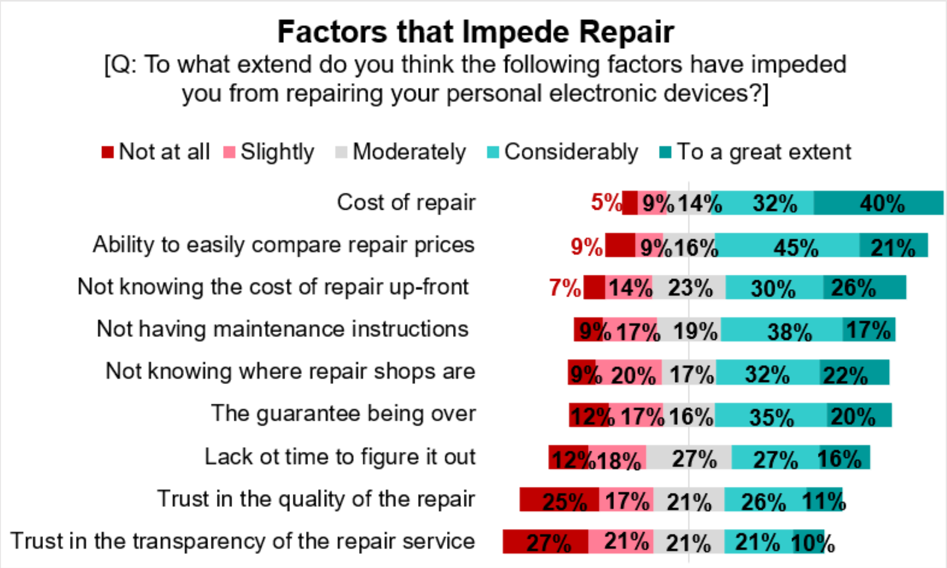

Figure 7. Factors that impede repair

Factors that explain electronics repair behaviour

Step 1: Intention to repair

Spearman's Rank Order Correlation was conducted to investigate whether the determinants of intention are correlated with intention to repair. The analysis revealed that all the determinants of intention are positively correlated with intention to repair with a moderate-size effect (r = .30 and .49). This means that on average, the more positive a participant response was on all items of the questionnaire (attitudes, affect, norms, etc.), the higher the intention to repair broken electronics they reported. The analysis also revealed that beliefs about repair outcomes helped explain 23% of the variance in respondent's reported intention to repair while roles helped explain 22% of this variance. See results in Table 1.

Table 1. Spearman's rho between determinants of intention to repair and intention

Variable	Correlation coefficient	Determination coefficient
Beliefs about outcomes	.477**	23%
Evaluations of outcomes	.374**	14%
Attitudes	.421**	18%
Norms	.300**	9%
Roles	.470**	22%
Self-Concept	.357**	13%
Affect	.345**	12%

**. Correlation is significant at the 0.01 level (2-tailed).

Moreover, binomial logistic regression was used to assess the effect of the intention factors on the likelihood that respondents intended to repair their devices next time they break. The model to explain intention to repair had six predictors and was statistically significant $x^2(6, N=158) = 81.699$, $p< .001$, indicating that the model was able to distinguish between respondents that reported positive intention to repair and those that did not. The model explained between 40.4% (Cox & Snell R2) and 72.9% (Nagelkerke R2) of the variance in intention to repair and classified correctly 93% of the cases. Sensitivity, or true positives, was 95.6% and specificity, or true negatives, was 77.3%. Positive predictive value, or the percent of true positives predicted was 96.29%, and negative predictive value, or the percent of true negatives predicted was 73.91%.

Three predictors made a unique statistically significant contribution to the model: norms, affect, and outcomes evaluation. The strongest predictor was norms with an odds ratio of 82.48 followed by affect with an odds ratio of 0.03, and by outcomes evaluation with an odds ratio of 28.86. This means that participants who believed that they were expected to repair were 82 times more likely to report that they intended to repair their electronics. Participants who had positive beliefs about the consequences of repair were 29 times more likely to report intention to repair than those who did not. Conversely, those that reported positive emotions were 34 times less likely to report intention to repair than those that reported neutral or negative emotions (see Table 2).

Table 2. Logistic regression explaining the likelihood of reporting intention to repair electronics with beliefs about outcomes, evaluation about outcomes, norms, roles, self-concept, and affect variables

Predictor	**ß**	**SE B**	**Wald's x^2**	***Df***	***P***	**Odds ratio**
Beliefs about outcomes	20.160	3729.37	.000	1	.996	569322802.7
Evaluation of outcomes	3.363	.955	12.392	1	.000	28.862
Norms	4.413	1.423	9.620	1	.002	82.487
Roles	.941	.820	1.318	1	.251	2.563
Self-Concept	1.586	.913	3.014	1	.083	4.883
Affect	-3.530	1.096	10.364	1	.001	.029
Constant	-1.675	.675	6.157	1	.013	.187
Test			**x^2**	***Df***	***P***	
Omnibus tests of model coefficients			81.699	6	.000	
Hosmer and Lemeshow test			2.352	7	.729	
Model summary and classification						
Pseudo R square statistics		.404 (Cox & Snell R^2)			.729 (Nagelkerke R^2)	
Overall percentage correct						93.0

Step 2: Frequency of repair behaviour

The extent to which habits, intention, and facilitating conditions are correlated with frequency of repair behaviour were examined using Spearman's Rank Order Correlation. The analysis revealed that frequency of repair is positively and strongly associated with both repair habits (r= .585, p< .001) and the intention to repair (r= .501, p< .001). No significant association was found between frequency of repair and facilitating conditions. The analysis also revealed that repair habits helped explain 34% of the variance in the respondents' reported frequency of repair while intention to repair helped explain 25% of this variance. See results in Table 3.

Table 3. Spearman's rho between determinants of behaviour and behaviour frequency

Variable	Correlation coefficient	Determination coefficient
Repair habit	.585**	34%
Intention to repair	.501**	25%
Facilitating conditions	.085	-

**. Correlation is significant at the 0.01 level (2-tailed).

Furthermore, binomial logistic regression was used to assess the effect of the factors of repair behaviour on the likelihood that respondents repaired their devices when they broke. The model to explain frequency of repair included three predictors and was statistically significant x^2(3, N=160) = 46.787, p< .001, indicating that the model was able to predict which respondents reported repairing frequently and those who did not. The model explained between 25.4% (Cox & Snell R2) and 33.9% (Nagelkerke R2) of the variance in frequency of repair and classified correctly 73.1% of the cases. Sensitivity was 79.2%, specificity 68.8%, positive predictive value 67.06%, and negative predictive value 80%.

As shown in Table 4 below, only intention to repair and habit were statistically significant. The strongest predictor was intention with an odds ratio of 8.85 followed by habits with an odds ratio of 6.02. This means that participants that reported intent to repair electronics were almost 9 times more likely to report high frequencies of repair behaviour, while participants that reported strong habits were 6 times more likely to report high frequency of repair behaviour than those who did not.

Table 4. Logistic regression explaining the likelihood of reporting relatively more frequent electronics repair with intention, habit, and facilitating conditions variables.

Predictor	ß	SE B	Wald's x^2	*Df*	*p*	Odds ratio
Intention to repair	2.181	.789	7.633	1	.006	8.855
Habits	1.795	.395	20.619	1	.000	6.020
Facilitating conditions	.304	.501	0.368	1	.544	1.355

Constant	-3.284	.800	16.830	1	.000	0.037
Test			X^2	***Df***	***p***	
Omnibus tests of model coefficients			46.787	3	.000	
Hosmer and Lemeshow test			1.620	4	.805	
Model summary and classification						
Pseudo R square statistics		.254 (Cox & Snell R^2)			.339 (Nagelkerke R^2)	
Overall percentage correct						73.1

The results from logistic regression are visualized in Figure 8 below.

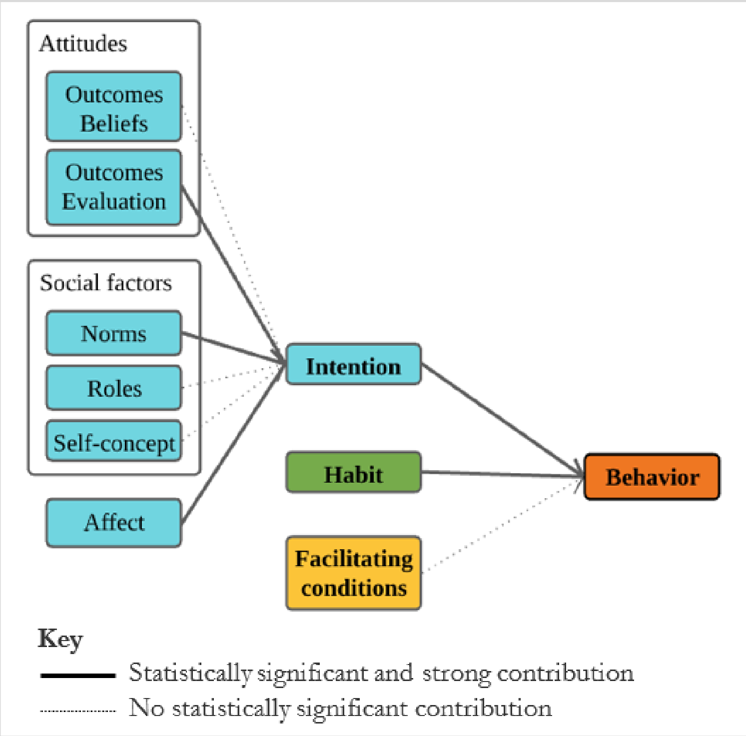

Figure 8. Logistic regression findings

Discussion

Triandis' theory of interpersonal behaviour proved to be a powerful model for understanding and explaining repair behaviour that can guide interventions for scaling up repair of personal electronic devices. Altogether the qualitative findings suggest that repair has an unfavourable image. Attitudes and feelings about repair are both positive and negative, with a slight inclination towards being negative. Most people agree that repair results in societal and environmental benefits. However, there are mixed thoughts about the personal benefits of repair, with people thinking it could be a good deal but also that it is complicated, time-consuming, and expensive. Social norms around broken electronics favour replacing devices over repairing them. Repair habits are still existing although they seem to have declined over the past decades. Lastly, the physical environment of repair is filled with barriers and disincentives.

The finding that attitudes do not favour repair behaviour suggests that for repair to be scaled up, attitudes about the personal benefits of repair need to be improved. Moreover, the fact that social norms about consumption of personal electronics may be influencing people's decision to repair their personal electronics to a greater extent than norms about repairing, indicates that strengthening norms and social expectations of repair cannot happen without addressing existing consumption norms. Repair needs to be understood not as a standalone practice but as part of electronic device consumption. Some organizations such as iFixit have understood the importance of placing electronics repair in the context of consumption and are actively working on inviting people to reflect on their consumption levels and use their community and repair resources to fix their products and 'hang on to last year's model' (Wiens, 2010). This study suggests that iFixit is on the right track, and their approach should be studied and supported by actors that wish to scale repairs.

Quantitative findings generally confirmed the qualitative analysis and suggested that norms are fundamental in the decision-making equation when a device breaks or malfunctions. The findings uncovered that intention to repair and habits shaped participants' repair behaviour, while facilitating conditions were not a determining factor. In addition, data revealed that norms, attitudes, and affective appraisal shaped participant's intentions to repair. Moreover, all the determinants of frequency of repair behaviour and intention to repair, except affect, are positively related, meaning that an increase in any of the determinants increases intention or frequency of repair behaviour. When it comes to affect, findings revealed that positive affect decreases intention to repair.

The result that intention is a direct predictor of behaviour have been corroborated by studies on upcycling (Sung et al., 2019), travel mode choice (Bamberg & Schmidt, 2003), and recycling (Chan & Bishop, 2013). However, the intention-behaviour gap in pro-environmental behaviours has been highly debated in academic literature, with studies finding no link between the two (Carrington et al., 2010; Hassan et al., 2016). This study contributes to this debate by confirming Triandis' position that behaviour is partly determined by controlled processes and suggesting that repair is partly an intention-driven behaviour. Moreover, the finding that habits are a direct predictor of behaviour has been documented in two studies on travel mode choice (Bamberg & Schmidt, 2003; Domarchi et al., 2008). Triandis' position is that for new, unlearned social behaviours, intentions determine a behaviour. However, once the behaviour has been repeated multiple times and has been rewarded or punished, the behaviour becomes automatic and is determined by habits. This position is confirmed by this study and suggests that repair is partly a habitual behaviour.

The result that affective appraisal is a direct predictor of intention to repair has also been found in travel mode choice (Domarchi et al., 2008), and ethical decision-making in the health sector (Li et al., 2020). Triandis' position is that affective response towards a behaviour makes some behaviours more appealing than others and thus influence people's intention to behave. The correlation analysis confirmed this position but not the regression analysis, which revealed that neutral and negative emotions towards repair increase the repair odds and not the other way around.

A plausible explanation is that those who reported both frequent repair behaviour and neutral or negative emotions about the repair process may have limited means and therefore see repair as the most viable alternative to consuming personal electronics. Having the latest version of a product is strongly associated with feelings of success in life, positive self-image and social identity (Cox et al., 2013), therefore maintaining a faulty and outdated product through repair could lead to negative emotions. Moreover, negative or neutral emotions can be linked to the "let-down" or false anticipation of how long consumers expect a product would last before it breaks (Cox et al., 2013). Consumers usually rely on proxies such as brand and price to formulate judgements about how long a product will last (Cooper, 2004), therefore a broken product (either due to accident or premature obsolescence) can affect people's emotion even in the event of a minor repair. The functional reliability of a product (i.e. performing without breaking down regardless of how long it is built to last) is deemed crucial for consumers, even for products expected to be kept for a short time (Cox et al., 2013). Nevertheless, further research on the role of affective appraisal on repair would be necessary to identify complementary explanations to this phenomenon.

Finally, the finding that facilitating conditions are not a predictor of repair behaviour was documented in an upcycling study (Sung et al., 2019). This lack of association and predictive value is not surprising given that the literature review and interview findings revealed that there are more substantial barriers than drivers to electronics repair. Therefore, it could be that those who repair are not doing it because "it is easy" (or rather, "less hard"). The questionnaire revealed that 65% of the participants tried to repair the last device that broke. This suggests the study sample is overrepresented by those who choose to repair in today's barrier-ridden context and indicates that it is norms and attitudes, and not facilitating conditions, that influence the decision to repair for this group of people. However, this finding does not imply that lowering the barriers to repair would not increase the number of people who chose to repair; instead, it suggests that mainstreaming and improving the image of repair would. This last thought is supported by Triandis' TIB, which posits that "even if the intention is high, the habit well established, and the affect optimal, the behaviour might not happen if the environment renders the behaviour impossible" (Page & Sherif, 1980, p. 198).

Policy Recommendations

Based on these findings, policymakers should consider the following measures:

Make repair the norm for broken personal electronics. Efforts to promote repair need to focus on normalizing repair activities. Examples of interventions that could contribute to establish repair as an expected behaviour include: fund and develop media campaigns to promote repair; introduce principles of electronics repair to high school curriculums; regulate advertising to ban the promotion of early renewals and promote longer use (HOP, 2020); introduce mandatory repairability and durability labels in personal electronics (HOP, 2020); and adopt the repairability criteria proposed by the European Union green public procurement guidelines.

Adopt regulations to increase the perceived value in personal electronic repairs. Policymakers need to step in to create a conducive environment for repair services to flourish and thus change the current perception that there are not many individual benefits to repairing personal electronics. Some recommendations include: require producers to create repair funds as part of anti-waste laws (HOP, 2020) and to revise Extended Producer Responsibility contributions to take repairs into account – on top of recovering and recycling of products; push for adopting and implementing 'the right to repair' legislation; instil consumer confidence in repairs by mandating quality labelling for repairs (Gåvertsson et al., 2020); revise the taxation regime regarding repair services (Milios, 2021); and extend Ecodesign regulations to address a larger number of personal electronic devices and include criteria to limit software obsolescence (HOP, 2020).

Introduce habit-shaping interventions: These should establish: 1) context cues that trigger the desired habit, 2) incentives to encourage the desired actions, and 3) conditions that promote memory associations between the action and the environment. For example: work with repair businesses and waste management organisations to establish repair shops in recycling centres (Milios & Dalhammar, 2020); distribute repair vouchers to lower the price of repairs (Piringer & Schanda, 2020); and regulate the application of warrantees to prioritise and enable repair over replacement when products fail (Dalhammar et al., 2021).

Design tailored interventions based on consumer profiles: Conduct a market segmentation study to categorise consumers of personal electronics based on their willingness and readiness to engage with repair. Use this typology to develop public policy interventions that cater to their needs and characteristics.

Conclusions

This study aimed to gain behavioural insights into personal electronics repair in Sweden to provide recommendations for scaling this behaviour and accelerating Sweden's transition to a CE. This was achieved through a mixed-method research design involving semi-structured interviews and an online questionnaire based on Triandis' theory of interpersonal behaviour.

This study expands on our understanding of the behavioural factors shaping and explaining Swedish resident's decisions to repair personal electronics. It is the first study to explore repair behaviour using Triandis' TIB, which demonstrated that norms, affect, and evaluations of the outcomes of repair play a considerable role in shaping intentions to repair and that intention and habits shape the frequency of repair behaviour. It also highlights context-specific issues which help in developing a more nuanced understanding of repair behaviour in Sweden. In addition, this study contributes by suggesting how this new knowledge can be used to scale repair behaviour in Sweden.

The generalizability of this study is limited since the sample is not representative of the Swedish population. This is particularly important to highlight in the case of the questionnaire since the sample is primarily composed of students and young professionals. However, it can be argued that this segment of the population will be more affected by environmental degradation, and thus, increasing repair activities in this group is most important. Therefore, although not generalizable, the findings of this study are relevant and valuable in guiding the design of policies and interventions to scale up repair of personal electronics in Sweden.

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281 Environmental assessment of power, district heating and district cooling geothermal generation for a neighborhood in Southern Italy

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Abstract

Global energy consumption has been characterized by rapid growth over the last decades, as a side effect of technological development and increased life style of some countries. Even though the recent COVID-19 pandemic set a fall of 5% in 2020, global energy demand is projected to reach pre-pandemic levels at the beginning of 2023 and to show a growth of 9% by 2030. Furthermore, the energy sector is one of the most relevant in terms of greenhouse gas (GHG) emissions, with electricity and heat production representing the largest contributor to global emissions (about 15 billion t in 2016). This framework advocates for solutions capable of addressing the global growing demand of energy with much reduced environmental impacts. The energy demand presents different rates worldwide, with a declining trend in advanced economies and an increased request in developing economies. However, energy inequality is still dramatically spread globally, with large dissimilarities both among countries and among income groups, with the top 10% earners consuming about 20 times more energy compared to the bottom 10%. The much advocated energy transition discourse from fossil-based to zero-carbon is led by the use of solar photovoltaic (PV) energy, representing the main driver of growth within the share of renewable energies. However, this change in the electricity sector translates in an additional pressure in the use of reliable supplies of crucial minerals and metals, as well as within the production, and the disposal of storage elements, such as accumulators and batteries.

Geothermal is a kind of energy always available in loco to be used through suitable plants. In this work, a geothermal system is proposed as a feasible addition for the generation of power, by means of an Organic Rankine Cycle (ORC), and for the generation of district heating and cooling for buildings. The presented case study is the evaluation, by means of the Life Cycle Assessment (LCA) method, of a grid designed for the supply of heating and cooling to eight buildings in the city of Naples (Italy) and for the generation of electricity with a reduced generation of environmental impacts.

Keywords: Geothermal energy, Energy grid, Life Cycle Assessment, Organic Rankine Cycle, District Heating and Cooling

Introduction

One of the main worldwide aims, in order to counteract the current environmental pressure, is a global reduction of anthropogenic greenhouse gases (GHG) emissions, as discussed within the United Nations Sustainable Development Goals (SDGs) (UN, 2018), the Intergovernmental Panel on Climate Change (IPCC) report (IPCC, 2018) and the United Nations Climate Change Conference of the Parties (COP) (UN, 2019). The document produced after the Rio+20 Conference, the Future We Want, highlights climate change as "an inevitable and urgent global challenge with long-term implications for the sustainable development of all countries" (UN, 2012). As set forth within the document, Member States acknowledged the importance of the ever growing emissions of GHG, in particular by developed countries, and the direct exposure to the problem and to the related dangerous effects of all countries, particularly developing countries. Therefore, Member States advocated for the cooperation and participation in significantly addressing the urgent issue of climate change. As part of the European Green Deal, the European Commission proposed a target of at least 55% reduction of GHG gases compared to 1990 by 2030 (EC, 2019). A significant part of the global GHG emissions, comes from the energy sector (Figure 1), making it the most important target to acknowledge for addressing the issue. The global production of electricity and heat have been responsible for the emission of about 15 million tonnes $CO_{2\ eq.}$ in 2016 (Ritchie and Roser, 2020a).

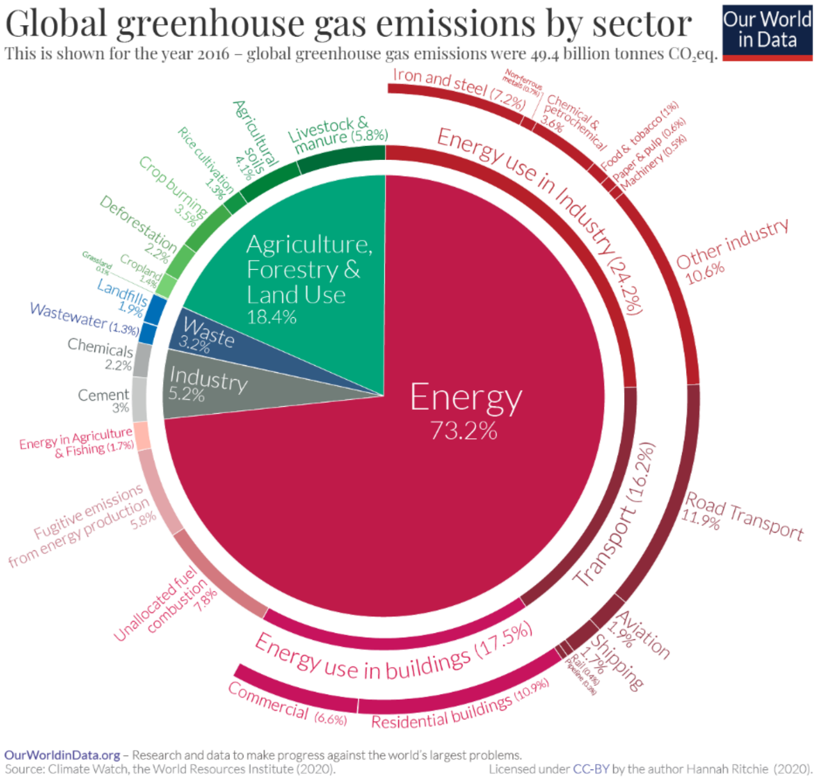

Figure 1. Global 2016 GHG emissions by sector (source: https://ourworldindata.org/emissions-by-sector).

In the last half century, energy consumption has been growing yearly, with a fast raising trend in regions where incomes and population are growing, and actually declining trends in richer countries (Ritchie and Roser, 2020b). The global energy demand dropped of about 5% in 2020 because of the current COVID-19 pandemic, with a projected rebound to pre-pandemic levels at the beginning of 2023. In a scenario in which the pandemic is gradually controlled following the current policy objectives, the global energy demand is expected to grow by 9% within 2030 (IEA, 2020). Large relevance, to reach the decarbonization objective, is given to photovoltaic (PV) systems. Global PV capacity is expected to grow, from a current installed capacity of about 655 GW (IEEFA, 2019), to an expected 4500 GW by 2050 (IRENA, 2016). This will cause 78 million tons of PV waste by 2050, a figure which the vast majority of the global countries are unable to deal with, from a material and a regulatory point of view (Ghosh and Yadav, 2021). Even though a minimum level of energy consumption is a fundamental requirement for an adequate wellbeing, energy inequality is still dramatically spread across countries and income groups, with many people suffering from energy deprivation and very few consuming far too much, as the final energy consumption of the top 10% income earners is equal to roughly 20 times more compared to the lowest 10% (Oswald et al., 2020).

This situation calls for energy sources simultaneously capable of addressing these environmental, social and economic issues.

In this work, a geothermal system, namely the GEOGRID system, for the generation at low environmental impacts of electric energy delivered to the national electricity grid and of district heating, cooling and domestic hot water delivered to eight buildings in the Municipality of Napoli is proposed and assessed by means of the Life Cycle Assessment (LCA) method. The system, proposed under a R&D project funded by Campania region with EU funding, addresses the sustainable use of geothermal energy in Southern Italy.

Materials and methods

The investigated case study is a geothermal plant for the production of electricity by means of an Organic Rankine Cycle (ORC) system, and the production and delivering of district heating, cooling and domestic hot water to 5 residential buildings and 3 office buildings in a neighborhood in the municipality of Naples, Italy, by sustainably exploiting the geothermal energy available (Figure 2). The geothermal fluid extracted is directed to a first heat exchanger, for the ORC system, and then to a second heat exchanger, for the district heating and cooling grid. Cooling energy is generated by means of an absorption chiller. Heating and cooling energy is delivered to the buildings with dedicated pipes. The geothermal fluid is reheated to adequate levels by using excess heat from the system before reinjecting it in the underground. The entire system is able to generate 43800 MWh of electric energy, 50868 MWh as heating, 80562 MWh as cooling and 96000 MWh as domestic hot water over the course of 20 years. The heating and cooling energy production is based on the energy demand of the served buildings, however the investigated system would be capable of supplying energy to additional buildings connected to the grid.

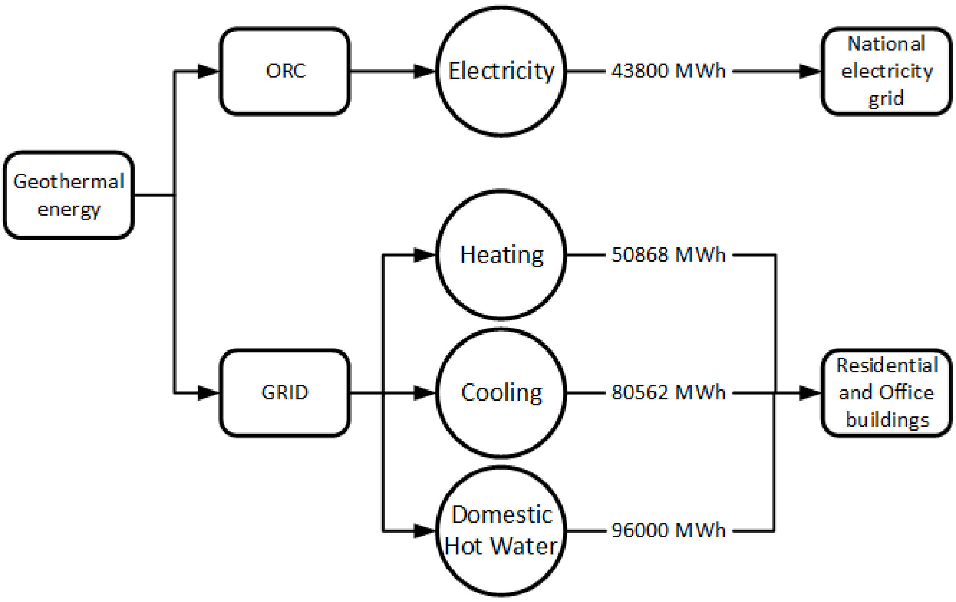

Figure 2. Flow chart of the GEOGRID system.

The environmental assessment of the impacts and use of resources of the investigated system over its the entire lifespan, estimated in 20 years, has been performed by means of the LCA method. LCA is a four-step tool for the assessment of human driven transformation activities (ISO, 2006a, 2006b), standardized as: 1) goal and scope definition: the boundaries and functional unit (FU) of the study are defined; 2) Life Cycle Inventory (LCI) analysis: the inventory of all input and output flows is defined; 3) Life Cycle Impact Assessment (LCIA): impact and resource use indicators for the selected case study are calculated; 4) Interpretation of results.

This study has been conducted using the SimaPro v.9.1.1.1 software (https://simapro.com/), the Ecoinvent v.3.6 database (Wernet et al., 2016) and the ReCiPe 2016 v1.04 Midpoint and Enpoint impact method (Goedkoop et al., 2009; Huijbregts et al., 2017).

Results and Discussion

ORC system

The ORC system inventory has been built based on Wang et al. (2020), considering an installed power of 0.5 MW, with a cooling tower modeled following Schulze et al. (2019), and heat exchangers, modeled based on technical specifications (inventory in Table 1).

Table 1. LCI of construction and operation of the ORC system.

#	Item	Quantity	Unit
	Input		
1	Geothermal wells (× 2)	80	m
2	Excavation operation	1075.5	m^3
3	Filling	1640774	kg
4	Cement	44.5	m^3
5	Steel	17909.5	kg
6	Stainless steel	1651	kg
7	Aluminum	438	kg
8	Copper	297.5	kg
9	Rock wool	443.5	kg
10	High density polyethylene	219.8	kg
11	Polyvinylchloride	143.2	kg
12	Water	452050	kg
13	Titanium	296.5	kg
14	Glass fiber reinforced plastic	1277.5	kg
15	Refrigerant	5780	kg
16	Cooling tower	1	item
17	Disposal of end-of-life materials		
18	Geothermal energy	438000	MWh
	Output		
19	Electricity	43800	MWh
20	Thermal energy returned to environment	44045	MWh

In Table 2, the ReCiPe Midpoint characterized results are reported for the generation of 43800 MWh of electric energy over the timespan of 20 years. These numbers are largely due to the extraction and processing of metals used within the machinery involved.

Table 2. ReCiPe 2016 v1.04 Midpoint characterized results for the generation of 43800 MWh from the ORC system.

Impact category	Unit	Quantity
Global warming	kg CO_2 eq	2.5E+05
Stratospheric ozone depletion	kg CFC11 eq	3.9E+00
Ionizing radiation	kBq Co-60 eq	1.1E+04
Ozone formation, Human health	kg NO_x eq	6.8E+02
Fine particulate matter formation	kg PM2.5 eq	4.4E+02
Ozone formation, Terrestrial ecosystems	kg NO_x eq	7.1E+02
Terrestrial acidification	kg SO_2 eq	8.8E+02
Freshwater eutrophication	kg P eq	9.0E+01

Marine eutrophication	kg N eq	9.0E+00
Terrestrial ecotoxicity	kg 1,4-DCB	2.1E+06
Freshwater ecotoxicity	kg 1,4-DCB	4.2E+04
Marine ecotoxicity	kg 1,4-DCB	5.3E+04
Human carcinogenic toxicity	kg 1,4-DCB	3.6E+04
Human non-carcinogenic toxicity	kg 1,4-DCB	5.6E+05
Land use	m^2a crop eq	5.5E+04
Mineral resource scarcity	kg Cu eq	4.5E+03
Fossil resource scarcity	kg oil eq	4.7E+04
Water consumption	m^3	3.1E+03

Figure 3 shows the normalized results for the ORC electricity generation compared to the same amount of energy from the Italian national grid of electricity. The impacts of the ORC generation of electricity are about 95% lower than the impacts from the Italian electricity mix on average across the impact categories, highlighting the higher impacts of an electricity production heavily relying on the combustion of fossil fuels as the Italian mix, composed for about 40% by the combustion of natural gas and for about 10% by the combustion of coal, among other contributions.

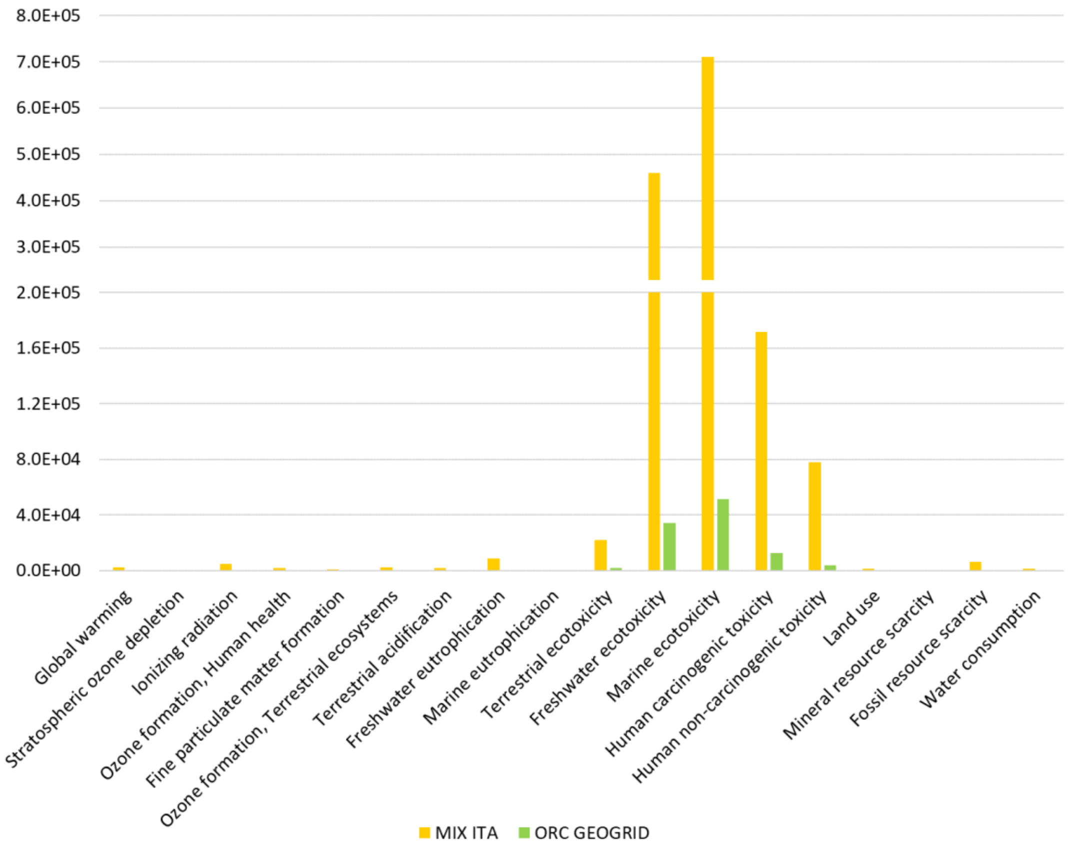

Figure 3. ReCiPe 2016 v1.04 Midpoint normalized results for the generation of 43800 MWh from the ORC system and from the Italian mix of electricity.

From an Endpoint perspective (Figure 4), the impacts of the investigated ORC system on human health are equal to the 2% of those from the Italian mix, the impacts on ecosystems are 1.3% of those from the Italian mix, while the impact of resources of the investigated system is represents the 0.8% of that related to the Italian mix of electricity.

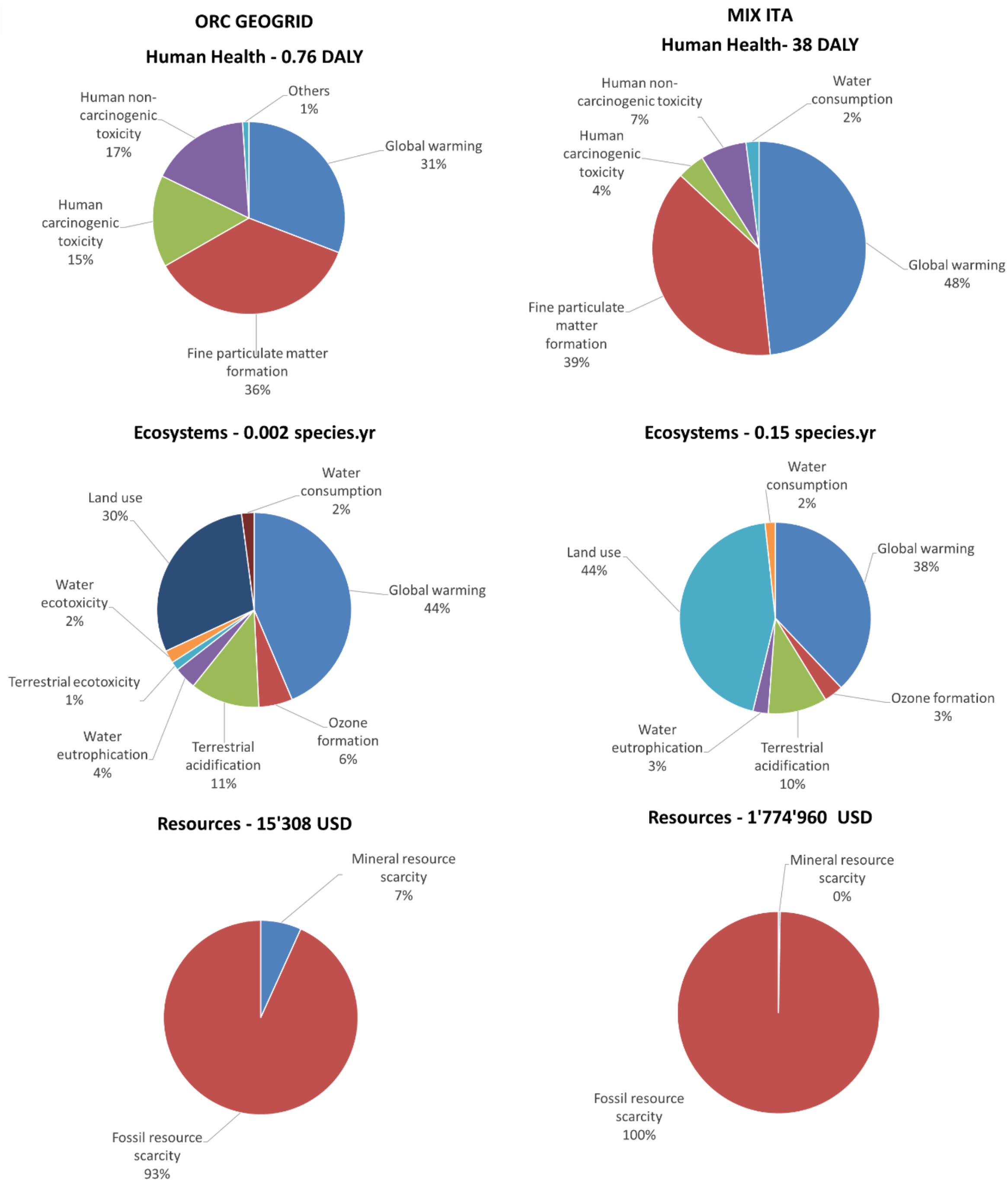

Figure 4. ReCiPe 2016 v1.04 Endpoint impacts for the generation of 43800 MWh from the ORC system and the Italian electricity mix.

Grid for district heating, cooling and domestic hot water

The proposed grid (GEOGRID) would provide 3 office buildings and 5 residential buildings with heating and cooling energy and with domestic hot water, following their energy demand. The system is designed with extraction and re-injection wells shared with the ORC system, a 10 MW heat exchanger, a 7.5 MW absorption chiller, a cooling tower, 1.6 km of insulated PVC pipes, a substation with three heat exchangers for each served building and an adequate number of fan coils within the buildings (Table 3).

Table 3. LCI of construction and operation of the grid system.

#	Item	Quantity	Unit
	Input		
1	Geothermal wells (×2)	80	m
2	Steel	14842	kg
3	Cooling tower	1	item
4	Absorption chiller		
	Steel	11340	kg
	Copper	4860	kg
	LiBr solution	2280	kg
5	Grid pipes	1600	km
	PVC	128.32	kg/m
	Bitumen	81	kg/m
	Insulator	7.54	kg/m
	Excavation	4.2	m^3/m
6	Fan coil	1159	item
	Steel	17.38	kg/item
	Copper	3.92	kg/item
	Aluminum	1.4	kg/item
	PVC	0.3	kg/item
8	Building pipes	22.25	km
	HDPE	4.5	kg/m
9	Geothermal energy	696000	MWh
10	Water	7507.3	m^3
11	Disposal of end-of-life material		
12	Wastewater treatment	6209.2	m^3
	Output		
13	Heating	50867.8	MWh
14	Cooling	80561.8	MWh
15	Domestic hot water	96000	MWh
16	Thermal energy returned to environment	3650	MWh

Residential buildings are served with 3.5E+4 MWh as heating, 5.6E+4 MWh as cooling and 6.0E+4 MWh as domestic hot water, over the considered lifespan of 20 years. The midpoint results reported in Table 4 are largely due to the extraction and processing of metal (≈60% of impacts) and plastics (≈15% of impacts). The larger impacts, about 39%, are related to the cooling energy.

Table 4. ReCiPe 2016 v1.04 Midpoint characterized results for the energies used by the residential buildings in 20 years.

Impact category	Unit	TOTAL	Heating	Cooling	Domestic hot water
Global warming	kg CO_2 eq	1.2E+06	2.8E+05	4.4E+05	4.6E+05
Stratospheric ozone depletion	kg CFC11 eq	6.9E-01	1.6E-01	2.6E-01	2.7E-01
Ionizing radiation	kBq Co-60 eq	8.0E+04	1.9E+04	3.0E+04	3.1E+04
Ozone formation, Human health	kg NO_x eq	2.5E+03	5.9E+02	9.3E+02	9.4E+02
Fine particulate matter formation	kg PM2.5 eq	2.2E+03	5.4E+02	8.5E+02	8.2E+02
Ozone formation, Terrestrial ecosystems	kg NO_x eq	2.6E+03	6.1E+02	9.6E+02	9.8E+02
Terrestrial acidification	kg SO_2 eq	4.9E+03	1.2E+03	1.9E+03	1.8E+03
Freshwater eutrophication	kg P eq	5.7E+02	1.4E+02	2.3E+02	2.0E+02
Marine eutrophication	kg N eq	2.3E+02	5.3E+01	8.4E+01	8.9E+01
Terrestrial ecotoxicity	kg 1,4-DCB	1.7E+07	4.2E+06	6.7E+06	5.6E+06
Freshwater ecotoxicity	kg 1,4-DCB	3.2E+05	8.3E+04	1.3E+05	1.1E+05
Marine ecotoxicity	kg 1,4-DCB	4.1E+05	1.1E+05	1.7E+05	1.4E+05
Human carcinogenic toxicity	kg 1,4-DCB	1.1E+05	2.7E+04	4.1E+04	3.9E+04
Human non-carcinogenic toxicity	kg 1,4-DCB	4.5E+06	1.1E+06	1.8E+06	1.6E+06
Land use	m^2a crop eq	5.0E+05	1.3E+05	2.0E+05	1.8E+05
Mineral resource scarcity	kg Cu eq	1.5E+04	3.8E+03	6.0E+03	5.5E+03
Fossil resource scarcity	kg oil eq	4.4E+05	1.0E+05	1.6E+05	1.7E+05
Water consumption	m^3	2.1E+04	5.0E+03	8.0E+03	8.4E+03

Office buildings are provided 1.6E+04 MWh as heating, 2.5E+04 MWh as cooling and 3.6E+04 MWh as domestic hot water. The midpoint impact results are listed in Table 5. 43% average of impacts are related to the cooling energy, and the contributions are in line with the contributions to the energy for residential buildings, mostly coming from the metal and plastic materials used.

Table 5. ReCiPe 2016 v1.04 Midpoint characterized results for the energies used by the office buildings in 20 years

Impact category	Unit	TOTAL	Heating	Cooling	Domestic hot water
Global warming	kg CO_2 eq	8.2E+05	1.8E+05	2.9E+05	3.4E+05
Stratospheric ozone depletion	kg CFC11 eq	4.6E-01	1.1E-01	1.8E-01	1.7E-01
Ionizing radiation	kBq Co-60 eq	5.7E+04	1.4E+04	2.2E+04	2.1E+04
Ozone formation, Human health	kg NO_x eq	1.8E+03	4.5E+02	7.0E+02	6.4E+02
Fine particulate matter formation	kg PM2.5 eq	1.8E+03	5.1E+02	7.9E+02	5.3E+02
Ozone formation, Terrestrial ecosystems	kg NO_x eq	1.9E+03	4.7E+02	7.3E+02	6.7E+02
Terrestrial acidification	kg SO_2 eq	4.3E+03	1.2E+03	1.9E+03	1.2E+03
Freshwater eutrophication	kg P eq	5.7E+02	1.7E+02	2.7E+02	1.3E+02
Marine eutrophication	kg N eq	1.4E+02	3.0E+01	4.7E+01	5.8E+01
Terrestrial ecotoxicity	kg 1,4-DCB	2.0E+07	6.5E+06	1.0E+07	3.5E+06
Freshwater ecotoxicity	kg 1,4-DCB	4.0E+05	1.3E+05	2.0E+05	7.1E+04
Marine ecotoxicity	kg 1,4-DCB	5.1E+05	1.6E+05	2.5E+05	9.1E+04
Human carcinogenic toxicity	kg 1,4-DCB	9.2E+04	2.6E+04	4.1E+04	2.5E+04
Human non-carcinogenic toxicity	kg 1,4-DCB	5.0E+06	1.6E+06	2.5E+06	1.0E+06
Land use	m^2a crop eq	4.9E+05	1.5E+05	2.3E+05	1.1E+05
Mineral resource scarcity	kg Cu eq	1.4E+04	4.2E+03	6.5E+03	3.4E+03
Fossil resource scarcity	kg oil eq	3.0E+05	6.7E+04	1.0E+05	1.3E+05
Water consumption	m^3	1.3E+04	2.9E+03	4.6E+03	5.5E+03

Figure 5 shows the normalized impacts for the energies delivered by the geothermal grid. The larger impacts are within toxicity related categories (marine ecotoxicity, freshwater ecotoxicity, human carcinogenic and non-carcinogenic toxicity and terrestrial ecotoxicity), and are due to the extraction and processing of materials used, with the office energies being slightly larger because of the high number of fan coils used in the office buildings (970 fan coils in office buildings on a total number of 1159).

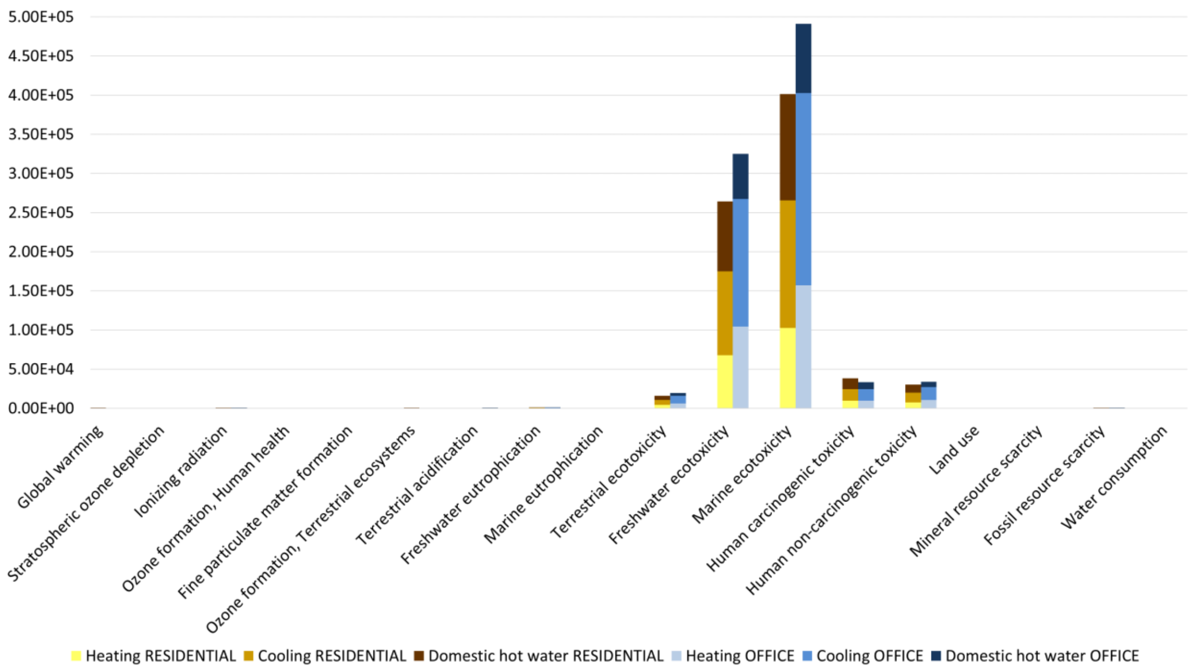

Figure 5. ReCiPe 2016 v1.04 Midpoint normalized results for the heating, cooling and domestic hot water energy to residential and office buildings in 20 years.

The obtained results for the designed grid have been compared to some scenarios for the delivering of the same amount of energy to the considered buildings.

Scenario 1: the current situation, with boilers for heating and domestic hot water and air conditioning for cooling in residential buildings, and heat pumps for heating and cooling and boilers for domestic hot water in office buildings.

The investigated geothermal grid shows impacts reduced of average 82% in residential buildings and 74% in office buildings compared to Scenario 1, with the avoided emission of 52000 tons of $CO_{2\ eq.}$, 25 tons of PM2.5, 300’000 m^3 less water used and 16’000 tons less $oil_{eq.}$.

Scenario 2: in both residential and office buildings, heat pumps are used for heating and cooling and boilers are used for domestic hot water.

Impacts of the geothermal grid are 86% and 74% lower for respectively residential and office buildings, with less 49000 tons of $CO_{2\ eq.}$, 30 tons of PM2.5, 406’000 m^3 less water used and 14’500 tons less $oil_{eq.}$.

Scenario 3: same configuration as Scenario 2, but with PV electricity powering the heat pumps and biogas used in the boilers.

In this scenario, the geothermal grid shows 90% less impacts for the residential buildings and 84% for the office buildings, with avoided 32000 tons of $CO_{2\ eq.}$, 20 tons of PM2.5, 1.5 million m^3 water used and 1500 tons of $oil_{eq.}$. Scenario 3 show reduced impacts in terms of use of fossil resources and emission of CO_2 compared to Scenario 1 and Scenario 2, but higher impacts on the other categories because of the mainly agricultural operations providing the biomass for biogas generation.

Figure 6 shows the normalized impacts related to the entire energy production from the proposed geothermal grid, and from the three developed scenarios, highlighting the environmental benefits delivered by the GEOGRID system.

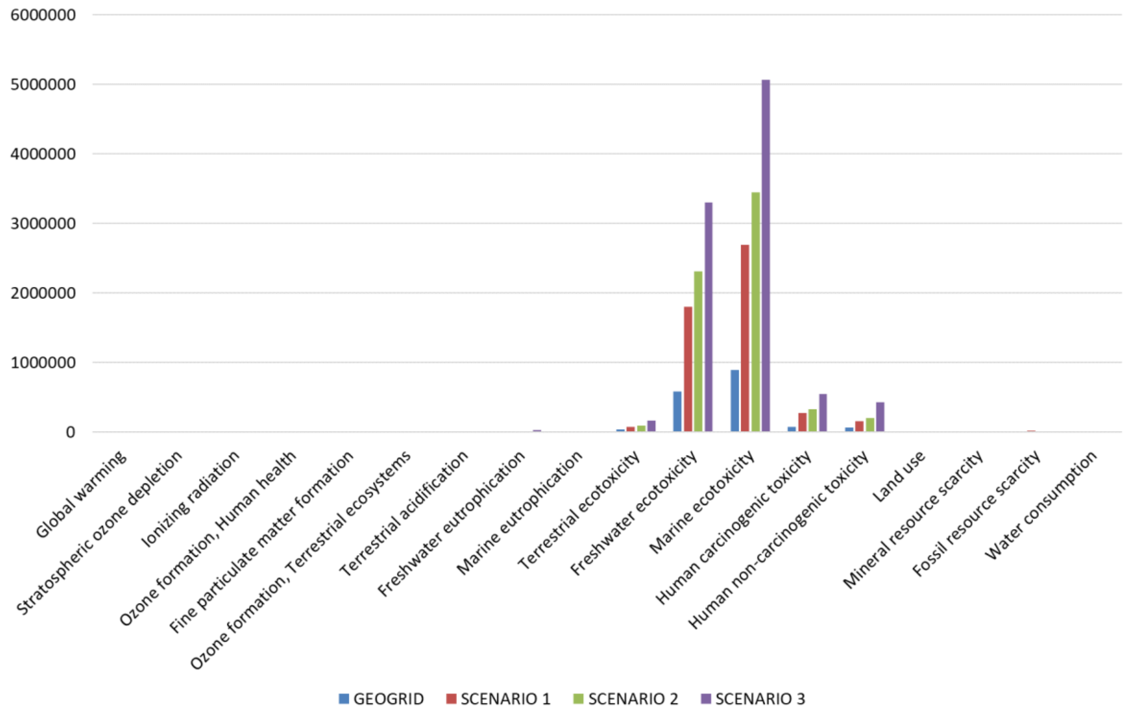

Figure 6. ReCiPe 2016 v1.04 Midpoint normalized results for the proposed geothermal grid, Scenario 1, Scenario 2 and Scenario 3.

From an endpoint perspective, the comparison among the GEOGRID system and the developed scenarios (Figures 7a and 7b) shows the difference of a system within which energy is not generated by the combustion of resources, both renewable and non-renewable. As already said, the impacts of the GEOGRID system are related to the extraction and processing of materials (metals and plastics) used in the plant and machinery, while the three scenarios are affected by a high reliance on combustion processes, even when PV electricity is involved, because of the activities of production of PV systems. Human health effects of the proposed grid are 1/10 of those of the developed scenarios. Ecosystems effects are 1/10 compared to Scenario 1 and 2 and 1/20 compared to Scenario 3. Resources impacts of the GEOGRID system are 5% compared to Scenario 1 and 2 and 38% compared to Scenario 3.

Figure 7a. ReCiPe 2016 v1.04 Endpoint impacts for the energies generated in 20 years by the GEOGRID system and the same amounts from SCENARIO 1.

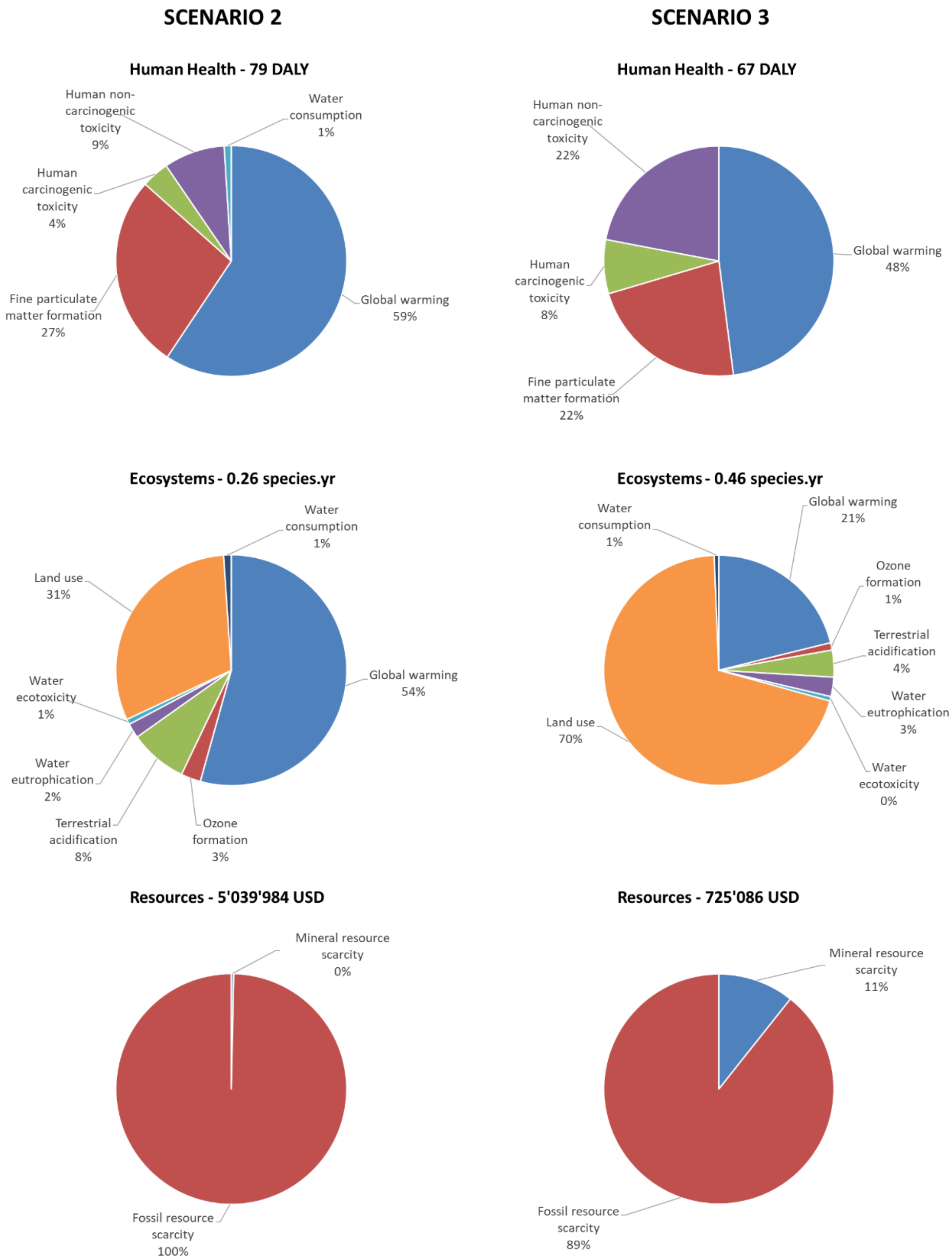

Figure 7b. ReCiPe 2016 v1.04 Endpoint impacts for the generation in SCENARIO 2 and SCENARIO 3 of the same amount of energies generated by the GEOGRID system in 20 years.

Conclusions

The proposed GEOGRID system for the sustainable use of the geothermal resource at low and medium enthalpy for the generation of electric energy, district heating, cooling and domestic hot water has been assessed as a feasible way of ideally addressing pollution, climate change, energy scarcity and energy inequality issues at the same time. Being characterized by the total absence of combustion processes and a by stable availability of the energy source (i.e. the geothermal fluid), it showed a reliable energy source at low environmental impacts, when compared to current and improved energy sources. Furthermore, if taking in consideration the economic aspects too, it would be important to consider that the served buildings could be interested by interventions for their improvements in terms of thermal insulation, renewal of air conditioning systems and energy efficiency, among others, under the incentives contained in the Italian regulation D.L. 34, active from the May 19th, 2020 (DECRETO-LEGGE 19 maggio 2020, n. 34, 2020). These interventions are estimated at around 4 million € in total for the residential and office buildings involved in the investigated system. The construction of the considered buildings dates back to around the 1960s and 1970s, thus presenting a short residual lifespan of around 20 years, which is not allowing for a complete amortization of the investment. A rough estimate of the implementation of the GEOGRID system is calculated at 2 million €. Therefore, the advantage would be represented by the halved cost for a system that will continue to stay in place delivering energy even if the connected buildings will theoretically be replaced. Furthermore, the energy generated as district heating, cooling and district hot water has been assessed based on the demand of the involved buildings, but the system is theoretically capable of producing additional energy for additional buildings to become part of the grid, configuring as a real energy community.

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178 Dress and the city: a comparative study of clothing and textiles environmental policy in five European cities

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Abstract

European clothing consumption has increased dramatically in recent decades, leading to a current average of 26 kg of textiles annually purchased per capita (EEA, 2019). While garments (and most of clothing's environmental impacts) are produced in other parts of the world, European municipalities face a problem of increasing volumes of textile waste. Moreover, the revised waste directive of 2018 specifies that European Union countries will be obliged to collect textiles separately by 2025. This study investigates how these phenomena are affecting city-level policy and strategy, including but not limited to textile waste management. It builds on a comparative analysis of official documents informed by interviews with policy makers and waste management authorities in five European cities.

The research points out that, in these cities, clothing environmental policy and other public initiatives are at varied levels of development. The paper identifies three kinds of measures, namely (a) improving separate collection, (b) waste prevention, and (c) consumption reduction. Reducing the share of textiles disposed of in general household waste (and therefore increasing separate collection) has been a central aim in cities where textiles fall under local waste regulation. The waste directive mentioned above makes separate collection of all textiles compulsory for EU members, leading to revisions in some cities' collection systems. Some municipalities have gone one step further in preventing these textiles from reaching waste streams by supporting local initiatives for repair and reuse. The most advanced and recent approach is aiming at reductions in new clothing demand through citizen campaigns and monitoring the effect of repair and reuse actions in consumption levels.

The comparative analysis leads to recommendations for future policy and strategy including developing the three approaches mentioned above simultaneously, further exploring measures for consumption reduction, and the integration of more concrete targets and monitoring plans, so that the most effective paths in social and environmental terms can be identified.

Keywords: Clothing, Textiles, Environmental policy, Municipalities, European cities

Introduction

The environmental impact of clothing production and consumption has received increasing public attention in recent years, following rapid growth in the quantity of clothing in circulation. Euromonitor estimates that the volume of clothes sold globally doubled between 2000 and 2015, while population increased by approximately 20% (Ellen McArthur Foundation, 2017). Most of these textiles and garments are manufactured in Asia, where the main environmental impacts associated with water and chemical use, and carbon emissions, occur (Niinimäki et al., 2020). In Europe, the environmental problems of clothing overflow are visible through rising volumes of used clothing and textile waste; but these consumption-intensive countries are also responsible for and affected by the impacts of the whole chain.

Approximately 5.8 million tons of textiles are disposed of by European households each year, equivalent to 11.3 kg per person. Between 1.7 and 2.1 million tonnes of used textiles are separately collected annually throughout the European Union (EU). The majority of the remaining 3.3 to 3.7 million tonnes are thought to be discarded in mixed household waste, with a much smaller amount being stored in increasing stockpiles in households (Beasley and Georgeson, 2014).

In European cities, separate textile waste collection is managed by commercial and charity organisations in different ways, as well as by public authorities. For instance, in the Parisian region, there are more than 300 textile collecting terminals for textiles of any quality, managed by various organisations and supported by city policy (City of

Paris, 2019). 20 of these points are connected to the Refashion program; an industry-led initiative supported by the state promoting circularity including reduction, reuse and recycling of textiles (Refashion, 2020). Notably, this initiative follows pioneering Extended Producer Responsibility in France, where clothing producers are responsible for collection. Recently, some textile retailers such as H&M also began to offer take-back systems elsewhere; they collect used textiles in their stores to recycle them in the future (e.g. Ellen MacArthur Foundation, 2017). Recycling textiles is yet a challenge. For instance, blended fibers, which can have a positive effect on the resilience or functionality of the garment (a common example is polycotton), have so far been difficult to separate and thus complicate recycling of such textile waste. Currently 73% of global textile waste is being landfilled (Ellen McArthur Foundation, 2017). Therefore, prevention of waste is a central condition for a sustainable textile sector.

The challenge of reducing textile waste volumes has led to policy initiatives at different levels including EU, national, and city leves. Cities play a central role, because in most European countries, municipalities are accounted as responsible parties for textile waste collection (e.g. Brieger et al., 2021, Watson et al., 2018). Samie (2021) has argued that textile waste is a “social phenomenon of the urbanised city”. On the other hand, the concept of “waste” in this sector is somewhat ambiguous, because post consumer textiles may fall under waste legislation or not depending on the national context, the way they are collected, and their destiny (Watson et al., 2018).

It is predicted that about 68% of the population globally will live in cities by 2050 (UN, 2018), where clothing consumption per capita is bigger than in rural areas. For instance, people living in Oslo or close by buy more clothing pieces and their total consumption is larger than the average for Norway (Laitala and Klepp, 2020). In the Netherlands, people living in cities own more garments and more clothes that are not actively used (Maldini et al., 2017). Therefore, cities are key in fostering sustainable consumption, including but not restricted to waste prevention. Reductions in the volume of clothing produced and consumed are, as the primary source of this waste, a central challenge (e.g. Iran and Schrader, 2017; Maldini, 2019; Levänen et al., 2021), also because production is the most impactful phase of the clothing lifecycle (e.g. Roos et al., 2015; van der Velden et al., 2014).

There is certain consensus that for achieving sustainable consumption, not only individual consumers should become active, but also government interventions are necessary (e.g. Newell, et al., 2021; Prothero et al., 2011; Wolff and Schönherr, 2011). European governments have tried to promote sustainable consumption through developing strategies and policy instruments that “mostly focus on technological improvements in production and products” while paying less attention to the consumption side (Wolff et al., 2017, p.457). The consumption side “has been addressed mostly by strategy papers and communicative instruments such as labels or campaigns aiming to inform, educate, appeal to, or ‘nudge’ consumers towards more sustainable behaviours” (Wolff et al., 2017, p.457). Accordingly, Dawkins et al. (2019) highlight that there is still a lack of research on the factors influencing successful implementation of sustainable consumption interventions at the local government level. Without having an understanding of such factors, authors argue, it is difficult to determine the role of local government in fostering and facilitating sustainable consumption (Dawkins et al., 2019).

Therefore, for local governments to plan and implement successful interventions for fostering sustainable consumption, it is necessary that they thoroughly evaluate the existing instruments as well as drivers and barriers to their success (Wolff and Schönherr, 2011). In this paper, we focus on the role of cities and municipalities in developing policy and strategies to tackle challenges regarding the environmental impact of clothing and textiles consumption. To this end, the paper explores current programs and future plans of municipalities in dealing with and reducing these impacts in different European cities. Moreover, the level of development of city level policies and strategies regarding textile waste are compared between five cities: Amsterdam, Belgrade, Berlin, Geneva, and Oslo. The analysis goes beyond reporting differences in textile collection strategies to focus on how cities and municipalities have approached textile waste prevention and eventually reduction in new clothing consumption.

Methods

For the purpose of this research, a qualitative comparative study has been conducted in five different European cities. Besides being located in various European sub-regions, these cities are different regarding their level of engagement with clothing, environmental policy, and textile waste treatment and prevention. The next section discusses some of these differences. Moreover, they vary greatly in size, ranging from approximately 500,000 inhabitants (Greater Geneva) to 3.7 million (Berlin). Lastly, the countries where they are located have different relations with the EU, with implications for policy: Norway and Switzerland are not EU members, Serbia is in the process of integration to the EU, and Germany and the Netherlands are established members.

Given this variety in context, the study compares the approach to and development of clothing environmental policy in these cities, exploring the following questions:

- How do these cities and their local authorities deal with the environmental challenges of growing clothing consumption and textile waste volume?
- What city policies and strategies (if any) have emerged in this context and how are these affected by national and EU policy?
- Which city policy and strategy recommendations can we provide based on this comparative study?

The methods used include reviewing official documents (EU, national, and city level policy and strategy documents relevant for the five studied cities) and conducting semi-structured interviews with local authorities, charity organizations, and textile waste specialists in these locations. The study is exploratory in nature and, therefore, has limitations in terms of the completeness of the collected data and its accuracy, as respondents are often those designing and implementing the strategy analysed here. Still, this study addresses a research gap on the topic of textile related environmental policy in European cities and highlights measures that are being implemented and others that could be developed in the future.

Results and Discussion

Table 1 shows an overview of the national and city documents reviewed in this study. Notably, the Circular Economy framework is frequently used for national and city policy in line with European strategy. The relation between different policy levels is not to be understood only as a top-down one, as municipalities lobby at a national and European level. For instance, the Oslo Municipality has participated in, among others, the EU's Urban Agenda Partnership for the circular economy and the EUROCITIES city network.

Despite the common points in the policies summarized in Table 1, the ambitions and focus of these programs vary greatly, as does the significance of clothing and textile environmental policy in local sustainable consumption policy. For instance Geneva has an advanced policy in food waste prevention (Geneva Waste Management Strategy, 2021), but there is no specific mention of textile waste prevention and treatment in city documents. On the other hand, the Municipality of Amsterdam has chosen textiles as one of the three consumer goods value chains to focus on, and the Amsterdam Economic Board is working on textiles as the main consumer goods sector within their Green Deals program (Amsterdam Economic Board, 2021).

Another noticeable characteristic in Table 1 is the number of policy documents that are recently released or expected to be released in the coming period, suggesting that at least some governments are working hard on issues that have gained rapid public attention. For instance, Oslo is working on their Circular Economy Strategy, and a new Waste Strategy, which in line with existing national and city policy are expected to include specific measures for textiles (Oslo Municipality, 2020). Another reason for recent development of textile-specific measures may be new requirements such as the European Waste Directive, where EU member states are obliged to have a system in place for separate collection of textiles, not only re-wearable garments, by 2025. In Serbia, in the process of integration into the EU, the national government accepted the

European Waste Directive in April 2020, suggesting an upcoming revision of Belgrade collection systems in the next few years (MEPS, 2020).

Separate textile collection can be considered the entry point to clothing-related environmental policy in cities. The issue of re-wearable and non-rewearable grades - and their implications in terms of waste regulation, economic viability of the actors involved in collection, sorting and trade, etc. - has been dealt with differently across states and cities.

In the Netherlands, post consumer textiles are collected in above-the-ground containers assigned by municipalities. These containers are managed by charitable organisations that used to pay a fee to municipalities to operate. Regulations introduced in 2009 oblige these organisations to collect all textiles and accessories regardless of their quality and to make that clear in their communication to citizens (Maldini et al. 2017). As a result, all collectors need to be registered as waste organisations (Watson et al. 2018). In 2020, many municipalities withdrew their fees as a result of the economic challenges suffered by collectors - which were accentuated with the COVID-19 pandemic. The Amsterdam Municipality manages the location and permits of the 370 containers run by the charitable organisation Sympany. However, city authorities are currently conducting a pilot to collect on-demand at households. The new system is expected to replace Sympany's containers by February 2022, resulting in higher quality materials collected (avoiding contamination) and more control over them (Interview with Stef Le Fevre, Amsterdam Municipality).

In Serbia there is no discrimination between rewearable and non rewearable grades either. Municipalities and small businesses are involved in textile collection, which is carried out weekly through containers. However, containers are still available in a limited number, mainly in urban areas. As per available data gathered in 2017, in that year Belgrade had 34 textile collection containers available and set up through the city (EASD, 2018).

In the Federal States of Germany, the context varies greatly between regions. In Berlin, all waste must be handed over to the main waste collection organisation (BSR) in accordance with Section 7 of the Closed Substance Cycle Waste Management Act. Paragraph 18 in this section, however, specifies that other collectors can also collect waste with a notice, if they prove that the waste is disposed of properly and in a harmless manner. As BSR does not have the capacity to collect textiles in Berlin at the moment, other organisations are allowed to collect for the time being; therefore, many organisations are active in collection, regardless of the quality of textiles (e.g. Forbig et al., 2020).

Table 1: National and city level documents considered in this study

	Amsterdam	Belgrade	Berlin	Gene
National environmental policy concerning consumer goods and textiles	Dutch policy programme for circular textiles 2020-2025 Waste to Resource, 2014	Roadmap for the circular economy in Serbia 2020 The Rulebook on criteria for defining by-products (Official Gazette of Republic of Serbia, no. 76/2019)	Waste Management Concept 2020-2030 National Programme on Sustainable Consumption (2016)	Program Sust Textiles Switz
City environmental policy and strategy documents concerning consumer goods and textiles	Amsterdam Circular 2020-2025 strategy	The 2030 Sustainable Urban Development Strategy of Belgrade and other cities in Serbia.	Re-Use initiative Waste Management Concept	Geneva Waste Management S (2021) City of Genev Textiles

In Switzerland, there is no dedicated federal-level policy for separate textile waste collection and there are different collection systems in terms of actors involved in different cities. In Geneva, the municipality is responsible for general waste collection and treatment and provides space for containers for separate textile collection, although local authorities are not involved in the actual process of textile collection or treatment. Rewearable textiles (including shoes, accessories, and household textiles) are collected by *Coordination pour la récupération* des *textiles à Genève* (CRT), an association of local charities (including CSP, Croix Rouge, Caritas, Emmaus, and Terre des Hommes Suiss) and TEXAID, a Swiss textile recycling company. There are around 3,000 tons of used textiles collected in Geneva annually via approximately 250 boxes (TEXAID, 2017, Interview with Typhaine Guihard, Vestiare Sociale; Interview with Sophie Pichon, Croix Rouge).

Norway has different collection systems for rewearable and non rewearable grades. In 2018, charitable organisations collected 79% of all separate textiles, while municipal waste companies and private organisations collected 13% and 8%, respectively. In Oslo, post consumer textiles for reuse are collected by charities and private organisations, although this fraction also includes some non-reusable textiles. The Municipality is involved by appointing city space for collection boxes and approximately 350 boxes administered by the charities (Fretex and UFF) are placed all over the city (Oslo Municipality, 2017). Other post consumer textiles (not suitable for reuse) are collected only at main recycling stations (Watson et al. 2020). The Municipality is now looking into alternatives and doing pilot studies in cooperation with charities for collecting waste either in separate collection boxes, or in separately labeled bags together with textiles for reuse (Frimann, 2021).

Increasing separate collection of textiles is an aim in all cities. However, some have moved beyond this target to focus on improving the quality of collection systems in order to ensure quality in the material collected. For example in Belgrade, communicating the value of textile recycling to citizens is a central activity of the city government, while Amsterdam and Oslo have a well established culture of separate textile collection and municipalities are now rethinking their collection systems as discussed above.

Table 2 shows the latest available information about separate post consumer textile collection volumes to our knowledge, and their destiny. Information is available at a national - rather than a city - level. In general terms, countries are making efforts to increase separate textile collection, but the destiny of these textiles is a result of market dynamics. Serbia is a particular case within the cities studied here, as it imports used garments for local consumption, and the low volumes of materials collected separately are not considered for reuse. In the other countries, textiles considered suitable for reuse are sold at a higher price and therefore reuse is prioritized by sorters. However, demand plays a big role in sorting decisions. For example, sorters are more flexible with children's clothes and their rewearable qualities, because they are in higher demand internationally. The fact that the market determines the destiny of these textiles means that they are not always processed in the most environmentally or socially beneficial way. As the table shows, only a small share of discarded or donated garments are reused locally. What is exported for reuse abroad (mainly to African countries) sometimes does not fit local needs (e.g. winter clothes) and ends up being a burden rather than an asset in the global south (see e.g. OR Foundation, 2021).

City governments and waste authorities are aware of these challenges and they are trying to enable more positively impactful processes for discarded textiles. Having more control over the collection and sorting process is one way to ensure better uses for the collected material (see pilots developed in Oslo and Amsterdam above), but not all municipalities and waste management organisations have the capacity to do so (e.g. BSR in Berlin and CRT in Geneva). A hybrid solution, perhaps, is the one developed in the Netherlands at the moment, where Extended Producer Responsibility measures will help finance collection, recycling, and re-use of post consumer textiles, with city authorities remaining responsible for the management of textile collection, even if that is handled by other organisations. It is expected that this mechanism will enable better destinies for the collected material in social and environmental terms.

Given difficulties in regulating international markets, an overall approach of municipalities has been that of facilitating initiatives for local reuse and repair, complementing more traditional downcycling and second hand international trade. Table 3 summarizes initiatives aimed at preventing materials from reaching more established waste streams. Although they are mostly in their infancy and do not seem to have a significant impact yet, as the popularity of second hand consumption and environmental concerns about the fashion industry are growing in Europe, we may see rapid growth in their effects in coming years. In some cities, these efforts are carried out in line with city policy aimed at promoting local reuse and reductions in overall local clothing consumption, as a primary source of waste prevention.

In the initiatives listed in the second row of Table 3, it is visible how collaboration with other parties is currently central in waste prevention. Some policy and strategy documents promote reuse and repair and these intentions translate into support to emerging initiatives with physical spaces, linking and promoting existing premises through maps and platforms and promoting access to and collaboration among grassroots initiatives. This approach is different to the more established (container-based) waste management systems described earlier in this paper. It promotes product life-extension (e.g. through repair) and the localisation and de-centralisation of reuse, with increasing control over the final destiny of the garments traded and their social implications. It is still unclear if the current growing popularity of second hand consumption in Europe has negative or positive social and environmental implications in the areas where post consumer textiles traditionally flow to, but the simplification of these flows enables assessment of their effects locally. Moreover, by preventing these materials from reaching waste streams, municipalities reduce the textile volumes that are under their responsibility.

The policy documents reviewed show an interest of municipalities in promoting circular strategies but remain vague in terms of the targets set, and the monitoring of environmental and social impacts. It is unclear how significantly repair and reuse practices are expected to grow and if reductions in new clothing consumption are anticipated. For instance, the environmental targets of Oslo Municipality include reductions in food waste by 30 percent in 2025 and by 50 percent in 2030. For plastics, there is a goal to phase out unnecessary disposable plastic items completely (Oslo City Council, 2019). However, local textile targets are more vague and indicators are in development.

The specific aim of consumption reduction has been incorporated very recently in policy, and it remains limited. Research in sustainable clothing consumption continues to show that longer lifetimes, reuse and collaborative consumption may not have any environmental advantages if they do not substitute the purchase of new clothes (e.g. Iran and Schrader 2017, Maldini, 2019, Levänen et al., 2021). From this perspective Oslo and Amsterdam have mentioned reduced consumption of new garments as a goal in the city strategy. In Norway, the national government has stated that it will "assess how the textile industry and consumers can be challenged to reduce consumption and environmental impact from textiles" (Norwegian ministries, 2021), and the municipality of Amsterdam is committed to reduce its own consumption via public procurement by 20% in 2025. Moreover, Amsterdam is planning a communication campaign promoting reduced clothing consumption among citizens. These measures are pioneering when compared to other cities but they have not been yet translated into specific targets for overall consumption reduction. Geneva has developed campaigns to eat local and less meat, but no communication campaigns for sustainable consumption of textiles. Oslo is studying opportunities to reduce the advertising pressure for meat and unhealthy food in municipal advertising areas. Applying restrictions in fashion advertising and season sales are promising next steps in policy aimed at reducing clothing volumes, but such measures have not been yet undertaken by governments in the cities studied here.

Table 2: Post consumer textiles separately collected

	Netherlands	Serbia	Germany	
Post consumer textiles collected separately per capita	In 2018, approximately 8 kg of textiles were collected per person. 45% of the total post consumer textiles disposed of or donated.	In 2010 20 kg of textiles per capita were disposed of in household waste and therefore incinerated. In 2017, 0.05 kg per capita were separately collected in Belgrade.	Estimates indicate an annual textile collection volume of 15.3 kg per capita. 88% are collected through containers, 9% in the streets, and the rest through other methods such as collection in stores.	Ro tex se na ca Ge
Destiny of textiles collected (suitable and non-suitable for reuse)	53% of separately collected textiles (including shoes), are sold for reuse abroad (e.g. Africa and Eastern Europe). 33% are sold for recycling in Europe (as cleaning cloth or pressed fibres) and India or Pakistan (further sorting, fiberization and processing into yarns). The rest is incinerated.	Collected textiles are downcycled into wiping and polishing rags, towels and mops for industrial usage.	In 2015, 54% was collected for reuse, 17% garnetted stock industry, 21% downcycling, 6% substitute fuel, 2% burned. Only 4% are sold within Germany. 44% remained within the EU and in the former Soviet states. 28% were sold in Africa. Another 10% in India and Pakistan. 14% were exported to other regions	Ch ca co (lo the inc for ne 7% sh so Mo so Af an do po sh

Sources	Ffact, 2020	Statistical office of the Republic of Serbia, 2012	Forbrig et al., 2020	Sw Th Int Gu TE

Table 3: Overview of waste prevention city targets and initiatives

	Amsterdam	Belgrade	Berlin	Gen
Targets and initiatives in city policy beyond collection	The Amsterdam Circular 2020-2025 Strategy includes measures for consumption reduction: an awareness campaign aimed at citizens, and measures to reduce consumption by the Municipality itself in 20% by 2025 and implement 100% circular procurement by 2050. Support for repair and reuse initiatives.	The current focus is on developing new and improved textile waste management policies, and textiles sorting systems, and communicating the value of separate collection to citizens.	The initiative Re-Use of the Berlin Senate Department for the Environment, Transport and Climate Protection promotes the increased reuse of used goods, less waste and more ecological production cycles. The overall aim is to achieve zero waste in Berlin.	Agenda 21 (Geneva) run initiatives su GE:Repair, w repair cafes repair atelier the city. GE: development information a options for d consumer go city, including second hand shops.
Municipalities' collaboration with other city initiatives for sustainable clothing consumption (reduced consumption, reuse, repair, etc)	Initiatives from the Municipality and the Amsterdam Economic Board include: a series of multi stakeholder meetings including companies, knowledge institutions and the local governments leading to green deals focused on textiles. Municipal support for initiatives such as a clothing brands' shared repair facility in the city, neighborhood swap shops, discount card for low income citizens to be used in local repair shops	There are privately organized clothes resale, and clothes swap events in the city, but involvement by the Municipality could not be identified. Remarkable perhaps because second hand garments are imported but the city doesn't stimulate local reuse. Other cities in Serbia have a stronger involvement of municipalities in collection and other initiatives.	Department stores "of the future" are developed with the waste collection organisation of Berlin (BSR), public, private, non-profit and charitable organisations. These include resale of products, refurbishment, repair and upcycling facilities, providing educational opportunities. See already operating stores of this kind below. The city organised the competition "circular fashion" in 2020, the winning proposal (Smart Guide Textilien: a map and platform linking all	Besides runn own initiative 21 financially other projects the G'Innove One of the pr funded by the explores alte fast fashion i and aims to policy recom to transition t sustainable f consumption 2022.

			existing textile-related initiatives) was funded and will be implemented by the city.	
Initiatives mentioned above	Amsterdam Metropolitan region's Green Deals The swap shop Repair shared service center Amsterdam discount card		Noch-Mall (2020) B-Wa(h)renhaus (2020) Reuse Zentrum (2021) Circular Fashion competition	Agenda 21 GE: REPARE

Conclusions

In light of the growing volumes of discarded post consumer textiles, city governments that are responsible for dealing with residential waste have been increasingly confronted with the environmental challenges of clothing in recent years. Cities with more established collection systems for re-wearable textiles are now improving collection of non-rewearable grades (e.g. Oslo). Following the example of France, the Netherlands has decided to assign responsibility to the companies producing and selling new clothes in the first place. However, producers are expected to finance collection and processing of post consumer textiles while municipalities keep responsibility over the process and, therefore, certain control over the environmental and social effects.

The EU European Waste Directive, where member states are obliged to have a system in place for separate collection of all textiles by 2025, is pushing some cities that are late in this process, like Belgrade, to get up to speed. However, not all cities have developed clothing-focused environmental policies. For example, Geneva has not introduced textile specific measures in city waste management policy, and separate collection - the entry point of clothing-related measures - remains a challenge. These shortcomings are partially explained by the fact that post consumer textiles are not included in local waste regulations.

Interest in reducing the volumes of materials that are municipal responsibility, concerns about the environmental and social effects of global post consumer trade, along with interest in enabling healthier urban ecosystems have motivated city authorities in developing local repair and reuse policies and strategies for consumer goods, including clothing and textiles. For example, in Berlin, the focus of the Re-Use policy is to promote access to second hand goods, recreating a similar experience to that of purchasing new products. That is the purpose of their "Department Stores of the future" which include repairing facilities and education. Despite the limitations mentioned above, the Municipality of Geneva has developed programmes promoting access to existing repair and resale facilities through official maps and platforms and also runs its own repair workshops. Norway offers a similar map at a national level. What is remarkable in the efforts summarised in the second row of Table 3, is that municipalities are acknowledging the importance of collaboration and grassroots initiatives, supporting and enabling their actions, rather than redesigning local post consumer textile flows from scratch. Still, a thorough assessment of the social and environmental effects of local reuse in Europe and their implications for the people and places traditionally involved in global post consumer trade are recommended while prioritizing this path.

Lastly, reduced consumption is starting to receive some attention as a source of waste prevention. Moreover, in targeting consumption reduction, municipalities acknowledge the environmental responsibility of consumption-intensive countries. However, current policies lack concrete targets and monitoring programs, or are at their nascent stages. For instance the City of Oslo is currently working on developing indicators for sustainable and reduced consumption for textiles in collaboration with Oslo Metropolitan University.

Based on this comparative study, we recommend city policy and strategy to tackle strategies at all three levels mentioned above simultaneously, including:

- Improving separate collection. Increasing separate collection of post consumer textiles volumes and safe processing of these materials in social and environmental terms; questioning not only the quantity of post consumer textiles that are and could be separately collected but also the environmental and social effects of their destiny.
- Waste prevention Prevent used textiles to reach more established post consumer streams by facilitating local repair, exchange, and reuse and empowering local initiatives. This can be done, for instance, by facilitating physical spaces in the city or promoting collaboration between different local organisations.
- Consumption reduction. Tackle new clothing demand as the primary source of waste, by setting up targets and developing initiatives that focus on both citizens' purchasing habits and companies' practices that lead to overconsumption and overproduction. Regulation of advertisement and season sales are some examples of measures that have not been yet applied and could deliver overall reductions. More advanced measures can be considered in the design of commercial areas in city planning, discouraging overlaps between leisure and purchasing activities.

In considering all the strategies described above, municipalities can learn from each other, as textile-focused policy is at different stages of development in these and other cities. Moreover, we encourage more concrete, iterative cycles of target setting and impact measuring, so that the most effective paths can be identified. In most of the policy documents reviewed, the overall intentions are stated, but it is unclear how these are expected to change the overall impact of local clothing consumption and how they are going to be evaluated. We note that local knowledge institutes can help in developing concrete goals and monitoring programmes, as a way to bridge rapidly advancing knowledge in the field of sustainable clothing consumption and the interest of citizens and local governments in enabling more sustainable cities and ways of living.

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233 Estimation of marginal costs at anaerobic digestion

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Abstract

Anaerobic digestion (AD) is commonly used to treat organic waste due to its robustness and ability to recover energy and material. During its operation, the incoming waste treated by an AD can change either in quantity, composition, or both. This change can have economic implication at which the average cost of treating waste will change. This paper provides means to assess the economic consequences of waste diversion with regards to existing AD. The method was then applied to a case study including AD with co-generation of heat and power. Baseline and four scenarios were developed to assess the economic impact of waste diversion using dairy manure, municipal food waste (MFW), and biosludge as feedstock. The feedstocks for baseline were dairy manure and municipal food waste. There were two waste diversions involving the reduction of manure input and MFW input with the application of six scenarios in regard to this diversion. Negative marginal costs (-6.95 to -4.56 €/ton diluted waste) were obtained in S1 and S4 at which the reduction of certain type of waste was not compensated by other type of waste. Positive marginal costs (2.39 to 2.53 €/ton diluted waste) were found when the input reduction was compensated by other type of waste to produce same amount of methane as shown in baseline scenario. The results implied that the quantity and composition of the incoming waste affected the marginal cost differently. Calculating marginal cost can provide comprehensive view concerning waste diversion and new waste management solution that mainly includes only environmental assessment. This can be used as well for future reference to support decision making and adjusting gate fee.

Keywords: Cost, anaerobic digestion, biogas, waste diversion, waste management

Introduction

There is a paradigm shift in municipal waste management that initially focused on maintaining public health and protecting the environment to resource recovery (Vergara & Tchobanoglous, 2012). In Europe, improved waste management has reduced the amount of waste going into landfill despite the increase in waste generation (Evangelisti, Lettieri, Borello, & Clift, 2014). It includes sourced-separated collection and applying suitable technology that can treat different type of waste safely resulting material and energy recovery as well as volume reduction. One of the technologies is anaerobic digestion (AD) that has been used to treat organic waste. Biological process involving different types of bacteria with the absence of oxygen occurs in AD so that organic matter is converted into biogas and digestate. AD provides benefits due to its robustness in handling high organic loading rate, its ability to treat waste without pre-treatment, and its products such as biogas and digestate (Appels et al., 2011). Biogas generated by AD contains methane for around 65% making it suitable for renewable energy source whereas the digestate has high nutrient and can be used as fertilizers (Appels et al., 2011; Evangelisti et al., 2014).

Although AD provides benefits in treating biowaste, the technology requires high monetary investment with a long technical lifespan (Edwards, Burn, Crossin, & Othman, 2018). During its operation, progress can occur in the society and government causing changes in the socio-economic condition, regulation, and environmental requirement. For example, regulation change such as landfill ban can prevent food waste from being landfilled and it must divert to existing AD. These changes will alter the quantity and composition of organic waste treated by AD implying an economic implication in the post-design costs of AD. Post-design cost including marginal costs and average cost. The first one refers to the supplementary cost related to additional quantity of something (e.g., the change in total cost of AD to treat an extra ton of waste), while average cost represents the cost resulted from dividing total cost in running AD facility by total waste input (Martinez-Sanchez et al., 2016; Massarutto, 2015).

As a suitable technology to treat organic waste, AD is widely used as shown by the increase in total capacity in Europe. Its capacity was 120000 ton per year in 1990, and it has increased into almost 9 million tons per year in 2015 (European Bioplastics, 2015). It shows the importance of AD and the economic consequence regarding its operation should be understood. To anticipate the unexpected cost with regards to waste diversion, this study aims at developing an approach to calculate economic consequences of waste diversion in existing AD facilities that can be used as basis in decision making. The applicability of the approach is tested using a hypothetical case study of AD facility. The aim of the study is achieved through specific objectives: i) define cost item of AD facility, and ii) identify marginal costs related to diversions of different waste composition.

Materials and methods

The basis of marginal cost concept at existing waste facilities was adopted from work developed by Martinez-Sanchez et al. (2016):

a. Assessing the average costs of baseline situation of AD based on waste parameter. The cost items were defined as fixed costs, effluent handling costs, energy and consumable costs, and revenue.
b. Defining marginal change that was represented by different scenarios. These scenarios illustrating various waste quantity and composition.
c. Assessing the average costs of various scenarios where marginal change occurs.
d. Estimating the marginal cost as the difference between average costs in baseline situation (a) and the alternative scenarios (c).

Case study

This hypothetical case study was used to illustrate the financial implication of waste diversion at AD. The AD was assumed to have maximum throughput of 88000 ton/year with its design of 12% total solids (TS), 20 days of hydraulic retention time (HRT) and operating period of 8000 hours per year. Pre-treatment facility that has throughput of 22000 ton/year was used for MFW. Figure 1 shows the sketch of AD digestion flow that produce heat, electricity and biosolids to sale (dashed boxes). Table 1 shows elemental composition, total solids (TS), and volatile solids (VS) of dairy manure (Akyürek, 2019; Chen, Rojas-Downing, Zhong, Saffron, & Liao, 2015; Tsai, Huang, & Lin, 2019), MFW (Arafat & Jijakli, 2013; Zhang, Lee, & Jahng, 2011), and biosludge (Nielfa, Cano, & Fdz-Polanco, 2015; Saarela, 2018).

Table 1 composition of the feedstocks

Feedstock	Dairy manure	Municipal food waste (MFW)	Biosludge
C (% dw)	33.07	44.99	5.4
H (% dw)	4.87	6.43	9.1
O (% dw)	58.53	28.76	36.4
N (% dw)	2.9	3.3	0.6
VS (g/kg)	79	170	56.9
TS (%)	13	31	20

The baseline scenario comprises of dairy manure and MFW as feedstocks, and waste diversion will cause the input of dairy manure decreasing for 5%. The scenarios to illustrate marginal cost were: i) no reaction to the waste diversion (S1), ii) increasing the input of MFW (S2), iii) using biosludge to replace dairy manure (S3). Another diversion involved the decrease amount of MFW input by 12% causing the CH_4 production equalled with 5% reduction manure input. The scenarios regarding the second diversion were: i) no reaction to the diversion (S4), ii) increasing the input of dairy manure (S5), iii) using biosludge to replace MFW (S6). In the scenario S2, S3, S5, and S6 the addition of MFW, dairy manure or biosludge would maintain the CH_4 production at the same level as baseline scenario.

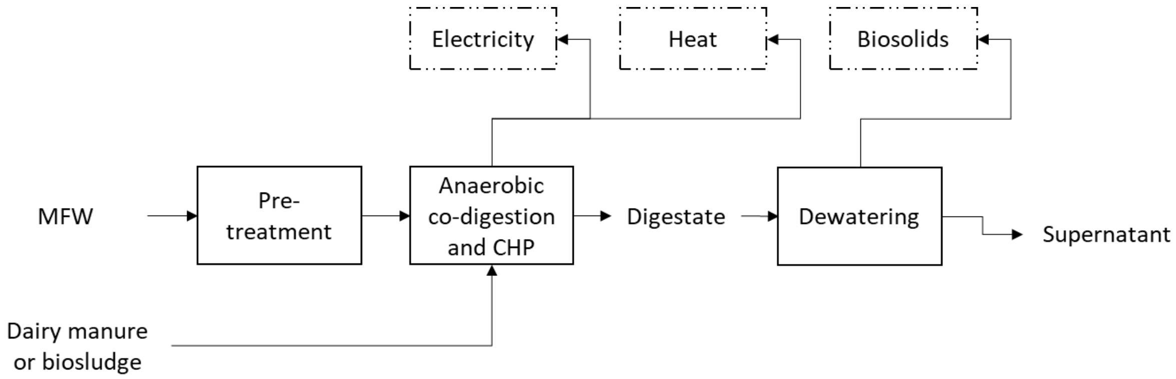

Figure 1 The sketch of AD flow

Cost model

The average cost calculation consisted of fixed cost (FC), effluent handling cost (EC), energy consumption and consumables cost (ECC), and revenue (Rev) as shown by equation (1). The cost was then divided by usage rate (UR) which equalled to the annual waste input that has been diluted for digestion process. The reference year was 2020 and the result was expressed in monetary unit per ton diluted waste (12% TS) in the AD (€/ton diluted waste). The cost unit for each parameter was based on Finnish or European condition.

$$Average\ cost = \frac{FC + EC + ECC + Rev}{UR} \quad (1)$$

Fixed cost

Annual fixed cost included amortisation of capital cost (CAPEX), annual maintenance cost (MC), annual insurance cost (IC), and annual labour cost (LC). CAPEX comprised of land cost, planning and design, building and civil work, process equipment and other contingency cost for pre-treatment facility and AD facility (Martinez-Sanchez, Kromann, & Astrup, 2015). The amortisation of CAPEX was obtained by converting the total capital cost into annuities using interest rate (4.6%) and the lifetime of the technology (25 years). It was reported that an AD (300000 ton/year) and a mechanical pre-treatment facility for municipal organic waste (30000 ton/year) cost for about 20.6

M€ and 5.8 M€, respectively (Martinez-Sanchez et al., 2015). To adjust the known cost of a facility into a specific capacity, the rule of 0.6 can be used as shown by equation (2) (Serna, 2018):

$$\frac{Cost_1}{Cost_2} = \left(\frac{Cap_1}{Cap_2}\right)^{0.6} \qquad (2)$$

where Cap_1 and Cap_2 are the capacity of first and second equipment meanwhile $Cost_1$ and $Cost_2$ are the cost of first and second equipment, respectively. Adjustment to reference year may be needed and can be performed using the Marshall and Swift index as shown by equation (3):

$$\frac{C_1}{C_2} = \left(\frac{I_1}{I_2}\right) \qquad (3)$$

where $C_{1,}$ and $C_{2,}$ show the calculated cost at year 2020 and the reference price, whereas I_1 and I_2 are the index at year 2020 and at the reference year, respectively.
Annual insurance and maintenance costs were assumed to be 1.5% and 3% of CAPEX, respectively (Martinez-Sanchez et al., 2015). The number of employees were assumed to be 8 and the average salary was 25 €/hour. Equation (4) shows the formula of fixed cost (FC):

$$FC = CAPEX + MC + IC + LC \qquad (4)$$

Effluent handling cost

The effluent cost (EC) was related to the handling of supernatant and biosolids as shown by equation (5). Cost in treating supernatant was a product of supernatant (m_{sp}) and price of treating a unit mass of supernatant (P_{sp}). Meanwhile, the cost of handling biosolids was obtain by multiplying biosolids (m_{bs}) and price of treating a unit mass of biosolids (P_{bs}).

$$EC = m_{sp}.P_{sp} + m_{bs}.P_{bs} \qquad (5)$$

The system has TS reduction rate of 50% and water content in biosolids of 17% (Chen et al., 2015; Remy, 2018), whereas the price in treating supernatant and biosolids are 0.68 €/ton supernatant and 26 €/ ton biosolids, respectively (Edwards et al., 2018).

Energy consumption and consumables

Energy consumption and consumables (ECC) comprises of expenses for the electricity, natural gas, water, and activated carbon as shown by equation (6) . The water consumption related to the dilution was required to adjust the TS of the waste into 12%. The consumption of electricity and natural gas were 0.031 % of biogas produced and 0.036 % of biogas produced, respectively, with additional electricity of 9.16 kWh/ton feedstock was required for dilution of MFW due to its high content of TS (Evangelisti et al., 2014). Activated carbon required by MFW was about 0.0082 ton/ton feedstock, whereas manure and biosludge consume 0.0015 ton/ ton feedstock (Chen et al., 2015).

$$ECC = W.P_w + AC.P_{ac} + El.P_{el} + NG.P_{ng} \qquad (6)$$

$$W = Waste\ diluted\ weight - Feedstock\ weight$$

$$Waste\ diluted\ weight = Feedstock\ weight.\frac{TS_{act}}{TS_d}$$

where $W, AC, El,$ and NG are the consumption of water, activated carbon, electricity, and natural gas, respectively. Meanwhile $P_w, P_{ac}, P_{el},$ and P_{ng} refer to price of water, activated carbon, electricity, and natural gas. It was estimated that: electricity costed 0.066 €/kWh, natural gas costed 0.032 €/kWh, activated carbon costed 0.94 €/kg, and water costed 0.4 €/m^3 (Ecoinvent Centre, 2019; Eurostat, 2020a, 2020b). To calculate the water required for dilution, estimation of the weight of diluted waste was needed. It could be calculated using the information regarding the feedstock weight, the actual TS of the feedstock (TS_{act}) and the TS design (TS_d)

Revenues

The revenues were obtained from the sale of heat, electricity and biosolids (pressed digestate). The amount of heat and electricity generated depend on CH_4 produced. To estimate CH_4 potential, laboratory test is usually performed. However, the process takes time and can be costly. This study employs stoichiometric equation based on elemental composition of the feedstocks by taking into account carbon (C), oxygen (O), hydrogen (H), and nitrogen (N). Boyles equation shows the chemical reaction occurred as shown by equation (7) (Nielfa et al., 2015):

$$C_nH_aO_bN_c + \left(n - \frac{a}{4} - \frac{b}{2} + \frac{3c}{4}\right) H_2O \rightarrow \left(\frac{n}{2} - \frac{a}{8} - \frac{b}{4} + \frac{3c}{8}\right) CH_4 + \left(\frac{n}{2} - \frac{a}{8} - \frac{b}{4} + \frac{3c}{8}\right) CO_2 + cNH_3$$

$$BMP_{th} = \frac{22.4\ \left(\frac{n}{2} + \frac{a}{8} - \frac{b}{4} - \frac{3c}{8}\right)}{12n + a + 16b + 14c} \qquad (7)$$

with BMP_{th} indicates theoretical methane generated by certain feedstocks in AD. The constant of each element such as n, a, b, c are obtained from dividing the mass of each element in grams (**Table 1**) by its relative mass.

Additivity method was applied to estimate the total theoretical methane production by estimating methane potential from individual feedstocks and summing them up. The value of 0.8 was used to adjust the methane production model under ideal condition to the realistic condition (Achinas & Euverink, 2016). This method did not take into account synergistic or inhibitory effect that may potentially occur in co-digestion process. Holliger, Fruteau de Laclos, & Hack (2017) reported that the difference of methane potential in laboratory experiment between mixed substrates and additivity of individual substrates were not significant.

The energy recovery system employs CHP assuming that electricity efficiency was 32%, heat efficiency was 50% (Evangelisti et al., 2014),and the energy content of methane was 10 kWh/m^3 (World Nuclear Association, 2016). Equation (8) shows the revenue from AD.

$$Rev = Electricity. SP_{el} + Heat. SP_h + Biosolids. SP_b \quad (8)$$

where SP_{el}, SP_h, SP_b are selling price of electricity (0.066 €/kWh), heat (0.027 €/kWh) and biosolids (5 €/ton), respectively (Corden et al., 2019; Eurostat, 2020a; Helen ltd, 2021).

Marginal costs

The marginal cost is defined as the additional cost in treating organic waste using AD with regards to a change in waste quantity. The change in waste quantity was represented by different scenarios, and the marginal cost was calculated using equation (9).

$$Marginal_{cost} = \frac{Average\ cost_{scenario} \cdot m_{scenario} - Average\ cost_{baseline} \cdot m_{baseline}}{m_{scenario} - m_{baseline}} \quad (9)$$

at which $m_{scenario}$ and $m_{baseline}$ indicate the quantity of waste treated (diluted to 12% TS) in various scenarios and baseline, respectively.

Sensitivity analysis

Sensitivity analysis was performed to identify the consequences of input parameters on the results. It was carried out by applying perturbation analysis at which each input parameter was increased by 10% one at a time while keeping other parameters as the same as the baseline values. The results of perturbation analysis was used to calculate (SR) which indicated the ratio of two relative changes as shown by equation (10) (Clavreul, Guyonnet, & Christensen, 2012).

$$SR = \frac{\frac{\Delta\, result}{initial\ result}}{\frac{\Delta\, parameter}{initial\ parameter}} \tag{10}$$

Results and Discussion

Average cost of anaerobic digestion

Calculation on methane potential using elemental composition and stoichiometry showed that dairy manure, MFW, and biosludge could generate for about 178.37 ml CH_4/g VS, 458.29 ml CH_4/g VS, and 267.81 ml CH_4/g VS, respectively. The total methane generated in the baseline scenario was about 1.26 Mm^3 in a year. It was translated into average cost of treating waste using AD for about 27.62 €/ton diluted waste (Table 2), meanwhile the gross costs were around 33.36 €/ton diluted waste. The major costs contribution was from fixed cost. Within fixed cost, the highest contributions were from labour costs and annual capital costs for about 66% and 33%, respectively. The costs related to energy consumption, water and consumables were minor compared the whole cost items, meanwhile the total revenue from selling electricity, heat, and biosolids brought revenue for about 5.74 €/ton diluted waste.

Table 2 Average cost of baseline system

Cost item	Value (€/ton diluted waste)
Annual fixed cost:	
• Labour cost	19.76
• Insurance cost	0.15
• Maintenance cost	0.29
• Amortization capital cost	9.79
Energy consumption, water, and consumables	0.89
Effluent handling	
• Supernatant handling	0.6
• Biosolids handling	1.88
Revenue	
• Electricity sale	-3.28
• Heat sale	-2.1
• Biosolids sale	-0.36
Total average cost	27.62

The average cost of treating waste using AD was correspond well with other studies, such as ones performed by Edwards et al. (2018) and (WRAP, 2018). The denominator unit in other study might be different, because the other study seemed to use monetary unit per ton waste input instead of diluted waste, nevertheless, our results were still similar and fell in between their ranges.

Marginal cost

Waste diversion was illustrated by decreasing dairy manure input for about 5% and in another case, decreasing MFW input by 12%. In S1 and S4 where there were no reaction to the decrease, energy production would decrease as well. Meanwhile in S2, S3, S5, and S6 there were additional input of different feedstocks to maintain the energy production as equal as baseline scenario. The study assumed the use capacity of the AD was not 100% but ranging from 88-96%. Table 3 summarises the input and output of all scenarios.

Table 3 Summary of inputs and outputs for each scenario

Scenario	Feedstock (ton/year)			Use capacity (%)	Energy produced (MWh)		Diluted waste (ton)	Biosolids (ton)
	Dairy manure	MFW	Biosludge		Electricity	Heat		
Baseline	63522	4701	0	92	4036.3	6306.7	80960	5853
S1	60346	4701	0	88	3893.1	6082.9	77519	5604
S2	60346	5275	0	90	4036.3	6306.7	79003	5711
S3	60346	4701	2937	94	4036.3	6306.7	82414	5958
S4	63522	4126	0	90	3893.1	6082.9	79476	5745
S5	66699	4126	0	94	4036.3	6306.7	82917	5994
S6	63522	4126	2937	96	4036.3	6306.7	84371	6099

Although energy production in S2, S3, S5, and S6 were the same as baseline, the quantity of feedstock input and diluted waste were varied. It was affected by different TS and CH_4 potential in each of the feedstock. Higher TS will require more water to dilute the waste in order to achieve the TS design (12%). Meanwhile, feedstock with higher CH_4 potential will limit the input due to its high energy content.

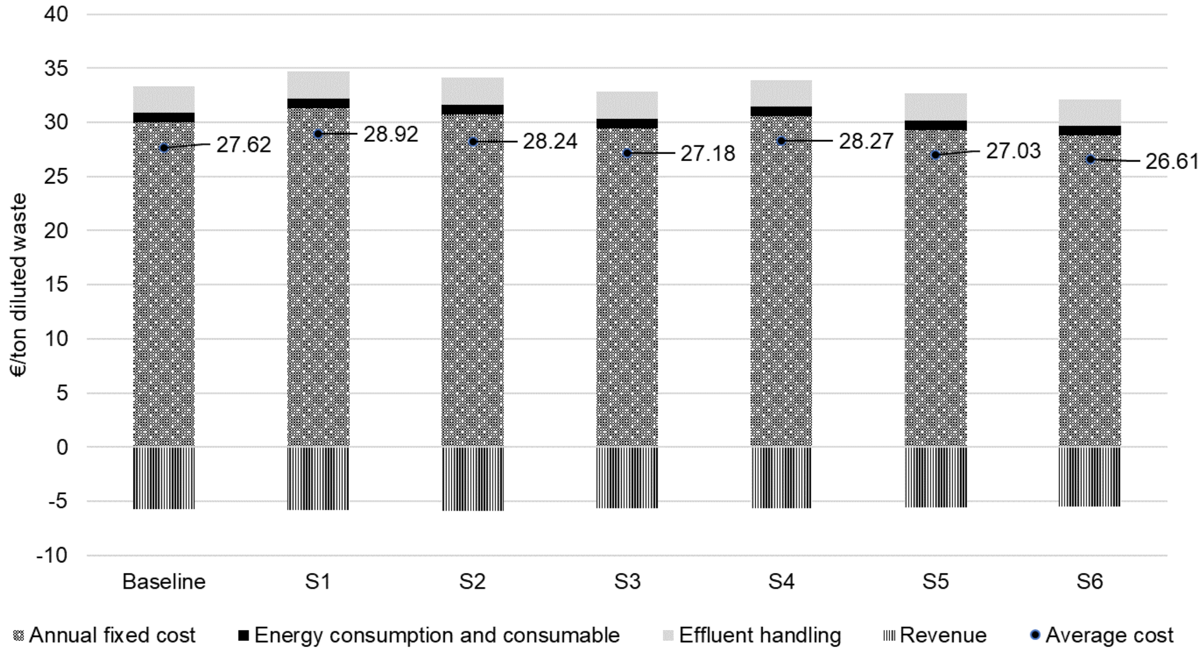

Figure 2 Average cost of baseline and alternative scenarios

Figure 2 shows average costs of baseline and alternative scenarios. S1, S2, and S4 resulted higher average costs compared to the baseline, meanwhile S3, S5, and S6 produced lower average costs. The average costs and the quantity of the waste were used to estimate marginal costs as shown in Figure 3. For the marginal cost, same pattern occurred in the case of reduction of manure input and MFW. The marginal costs were negative when the diversion was not followed by reaction (S1 and S4), and the marginal costs were positive when the diversion was followed by the reaction through additional waste input (S2, S3, S5, S6). When the manure input was reduced by 5% and the MFW input was reduced by 12%, the CH_4 generation was the same for around 1.21 Mm^3 CH^4. However, the value of marginal costs was different at which reducing MFW resulted lower cost for about 78% than reducing manure input. The reduction of manure input corresponded to a decrease of 3176 ton manure feedstock that is relatively higher compared to diversion of MFW that was translated into a reduction of 574 ton MFW feedstock. This stark difference was caused by the content of CH_4 in the feedstocks.

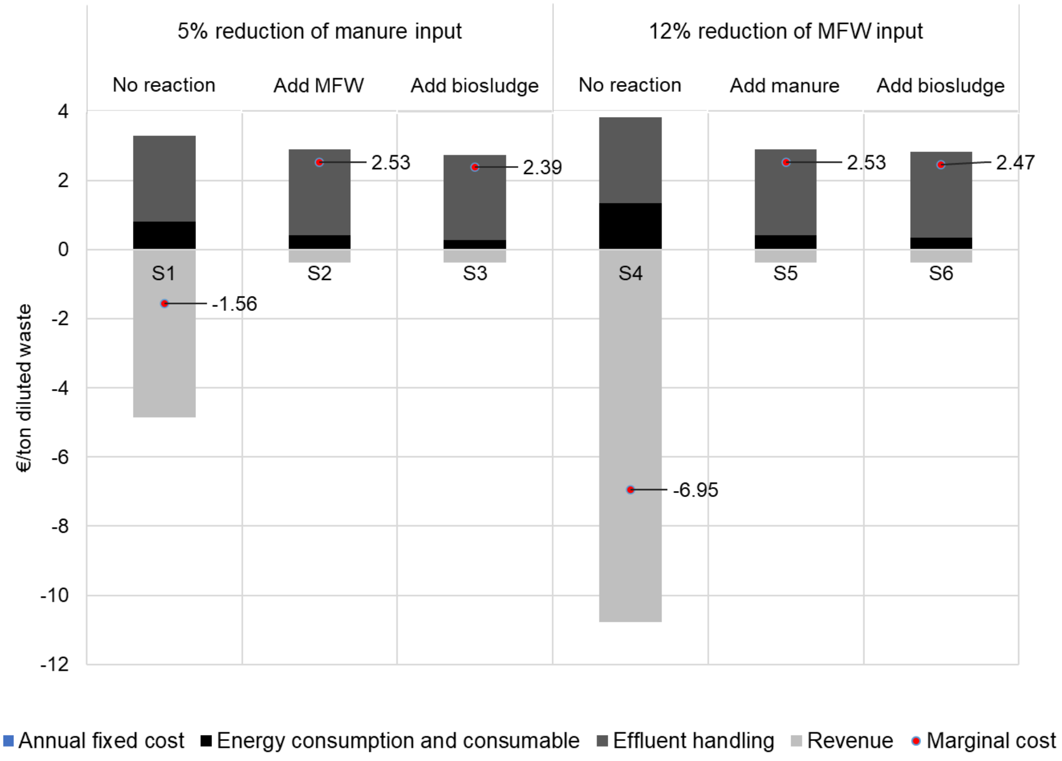

Figure 3 Marginal cost of waste diversion in AD

S2 and S5 resulted same marginal cost. The proportion of dairy manure and MFW in S2 and S5 were 84:16 and 87:13, respectively. Nevertheless, the production of CH_4 was equal and feedstock types were similar. This might explain the similarity in the marginal cost values. In S3 and S6, to maintain CH4 production, the diversion was aided by biosludge addition for about 2937 ton in both scenarios. These additions resulted positive marginal costs that were only slightly different in between S3 and S6.

Sensitivity analysis

Figure 4 shows the results of perturbation analysis with x axis indicates the SR. The parameters included were only the ones that gave results larger than ± 0.025. If an SR has value of 0.025, it shows that when the value of parameter is increased by 10%, the result will increase by 2.5%. The SR results ranging from -0.18 up to 0.72. Positive SR indicates linear correlation at which an increase value of the parameter will drive the cost higher, whereas the opposite correlation is indicated by SR with negative values. For the positive SR, the most sensitive parameters were number of employee and labour cost (0.72) followed by interest rate (0.37) and CAPEX (0.35). For the negative one, 10% increase in LHV of CH_4 will drive down the cost by 18%

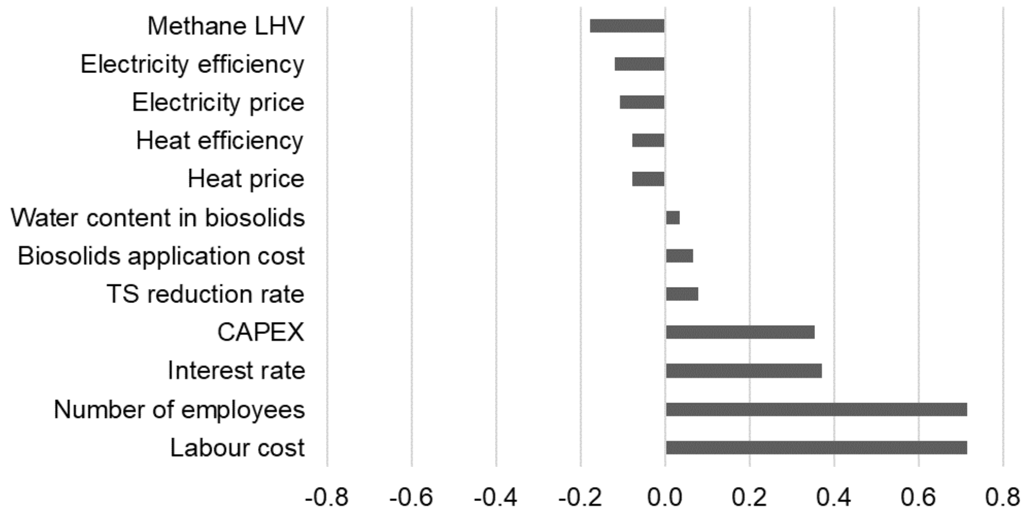

Figure 4 Sensitivity ratio among input parameters

Limitations and implications

The study on the marginal cost of existing AD was done using secondary data. Assessing CH_4 potential through experiment can provide more accurate results although it takes time and can be expensive. Meanwhile, the use of secondary data and stoichiometry are quicker. Although it can result more uncertainties, conducting CH_4 assessment using stoichiometry can gauge the potential economic consequences and anticipate it when diversion strategy is applied.

Gate fee is levied to usually offset cost of opening, operating, and closing the facility. The value may change based on the cost incurred regarding the facility. The marginal costs due to waste diversion may be aided by an adjustment of gate fee, accordingly, this study did not include gate fee as one of cost items.

The results of S1 and S4 showed the importance of waste composition. The marginal cost of diverting waste in both scenarios were difference although S1 and S4 producing the same amount of CH_4. Each waste type has different level of TS and methane potential that limits the input quantity into the AD. This study only simulated few scenarios that limit the knowledge on how the system will behave, whereas many other waste types can be treated and diverted to and from AD.

Conclusions

This study developed marginal costs estimation caused by waste diversion in AD. The model was then applied in case study showing its applicability. This study illustrated that costs calculation involve various costs items that can be categorized into fixed costs, energy and consumables, effluent handling, and revenue. The variety of cost items can affect the result and increase uncertainty of the study. The case study showed that marginal costs can be positive or negative depending on the waste being diverted and a reaction towards the diversion. It was also shown that marginal and average costs were highly influenced by waste quantity and types. The approach used in this study can be applied to assess cost change with regards to waste diversion that will help waste strategy development.

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207 The Impact of the Urban Environment on Consumption-Based Carbon Footprints of Climate Concerned Urban Dwellers

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Abstract

The Nordic countries are held as green due to their low-carbon energy systems. However, their global climate impacts are among the highest when the emissions are allocated based on consumption, particularly that of the urban residents. The purpose of this study is to examine and test methods to study if different types of urban environments influence on the consumption of the citizens of Helsinki metropolitan area. It is known that the urban environment has an affect on consumer behaviours and that climate concern might be related to lower carbon footprints. In this study the aim is to better understand how consumption is related to local urban characteristics and how it could be studied, how strong these connections might be and could climate concerned citizens consume differently based on the characteristics of their living environment. Could some urban environmental characteristics support low-carbon lifestyles of their residents, and could this connection be found by using our methods? In this study we are testing our methods by utilizing our carbon footprint pilot survey data, to later study consumption of climate concerned urban dwellers in different types of urban environments by using our upcoming carbon footprint survey data. Novel statistical approaches in the research field are used in this study, such as a factor analysis to study different climate change concern variables as well as GIS analyses to study the spatial aspects. The main source of data is our carbon footprint pilot survey, executed in Finland. As the sample size is limited, exploring and testing the methods for our future studies remains as the main purpose of this paper. The results are going to show if it seems like the urban environment could have an impact on consumption habits of urban dwellers in addition to their climate concern and if these connections can be found by using the methods of this study.

Keywords: Carbon Footprints, Sustainable Cities, Climate Change Concern, 1.5 degrees

Introduction

The current climate change is one of the biggest threats of our times, getting close to transgress our planetary boundaries (Rockström et al. 2009; Steffen et al. 2015). Stopping the global warming at 1,5 degree Celsius level would require both rapid and radical changes from humans (IPCC, 2018). Consumption-based carbon footprints are a tool to quantify the impacts of the current globalized trade exchange and to reduce those impacts. Cities, being the centres for economic growth, can be seen as the main drivers for global warming (Edenhofer et al. 2014; Glaeser & Gottlieb 2009; Glaeser & Kahn 2010). As the centres of consumption, cities are driving three quarters of the global greenhouse gas (GHG) emissions directly or indirectly (Satterthwaite, 2008; Kennedy et al. 2012). Urbanization as such seems to increase environmental burdens when the indirect impact of the consumption is allocated to the final consumers in the cities (Ottelin et al. 2019; Wachsmuth et al., 2016; Heinonen & Johannesson, 2019; Heinonen et al., 2013 a-b; Wiedenhofer et al., 2013).

In this study, the aim is to examine if climate concerned urban dwellers could have significantly different GHG emissions of consumption on different types of urban living environments. Could some urban environmental characteristics support low-carbon lifestyles of their residents more than others? On the global scale, Nordic countries are among the highest polluters when it comes to GHG emissions form consumption. Hence, studying the consumption in Nordic contexts provides a great base to study these differences and the possible impact of the living environment. The purpose of this paper is to test our research questions and our methods to later study the topic more comprehensively by utilizing our upcoming carbon footprint survey data and methods and research questions presented in this paper.

This conference paper provides a preliminary overview on how the consumption patterns and carbon footprints of climate concerned urban dwellers may differ on city centres and other urban localities in Helsinki metropolitan area, based on our pilot data of our upcoming carbon footprint survey. As the pilot data provides us with a smaller sample size than the upcoming survey, we are going to separate our analysis of variance of climate change attitudes (Chapter: “Climate Change Attitudes Results and Discussion”) from the spatial analysis of the individual GHG emissions of consumption of goods and services of the urban dwellers (Chapter: “The Impact of the Urban Environment on Consumption Based GHG emissions of Climate Concerned Urban Dwellers”). Due to the limited sample size, exploring and testing the methods for our future studies remains as the main purpose of this paper.

Methods

The carbon footprint survey pilot data is used to study consumption, living place and climate change concern of urban consumers who participated to our survey's pilot round in Finland. The carbon footprint survey pilot data covers 60 responses, which does not yet allow us to interpret all the statistical approaches we are planning to use to further study this topic. However, the research question can already be tested on a simple two-class zoning in Helsinki metropolitan area by combining the spatial information with the carbon footprint survey pilot data and some supportive carbon footprint data. These are presented in detail in this Methods Chapter.

Carbon Footprint Survey Pilot Data

Our upcoming carbon footprint survey will provide us with detailed information about the consumption, lifestyles, climate change attitudes and behaviours of consumers living in Nordic countries. The survey will be executed in Iceland, Finland, Denmark, Sweden and Norway and it includes an inbuilt carbon footprint calculator and consists of 113 questions. However, for this study only the pilot survey data of this carbon footprint survey can be utilized.

Most of the pilot survey participants (60) live in Helsinki metropolitan area. Pilot survey questions about climate change attitudes (12 questions) and "Where do you live?" (OpenStreetMap, where the pilot survey participants mark their home location on a map with up to 200 metres accuracy) and the questions about diet and consumption of goods and services (see in further detail in Chapter: Calculating the GHG emissions of Consumption) are utilized in this study.

Pilot survey participants who live in the Helsinki metropolitan area (Helsinki, Espoo, Vantaa and Kauniainen) are separated from the pilot survey data by using an overlay analysis in GIS. From these, the climate concerned urban dwellers are selected to further studies by excluding those who answered "(1) not at all" or "(2) slightly" to the survey question "How worried are you about climate change?" Therefore, only participants who live in the Helsinki metropolitan area and are "(3) moderately", "(4) very" or "(5) extremely" worried about climate change are included in this study. After these measures, the sample size is 46.

As our carbon footprint pilot survey includes 12 different questions about participants' attitudes towards climate change, a preliminary factor analysis on climate change variables is also conducted and included in this study but due to low sample size it is not included in spatial analysis.

Calculating the GHG Emissions of Consumption

To get some indications about the consumption-based carbon footprints of our pilot survey participants, the greenhouse gas emissions of their consumption of goods and services is calculated. This includes their consumption of food (diet) and the following consumption categories: Alcohol & Cigarettes; Clothing & Footwear; Interior Design & Housekeeping; Health; Recreation, Sports & Culture; Restaurants; Hotels; Electronics; Other Goods & Services. Housing and transportation were excluded from these pilot data based analyses but will be included in our future studies. All the other relevant consumption categories are included, and they are based on the Classification of Individual Consumption by Purpose (COICOP) categories (United Nations, 2018).

In our pilot survey, the participants were asked to estimate how much money they consume in these different consumption categories mentioned above, and to choose one of the following diets: vegan, vegetarian, pescatarian or omnivore. If they chose omnivore, the conditional question about “Please estimate which one of the following options best describes your daily/weekly meat consumption” is shown, among the following answer options to choose from: At least once or twice a day (300 g/day); Almost everyday (150 g/day); Two to three times a week (70 g/day); Maximum once or twice a week (50 g/day).

The greenhouse gas emissions resulting from the consumption of the pilot survey participants (excluding diet) is calculated by using Exiobase 2015, extrapolated model of Exiobase 2011 (Tukker et al. 2014). Exiobase category combinations are based on the paper of Ottelin et al. (2020) and are defined in Table 1. Exiobase basic prices are transformed to purchasers’ prices and, in the case of Finland, the territorial GHG emissions are upscaled to match the total emissions in 2015 as reported by Statistics Finland (see Ottelin et al. 2021 for details). The fixed Exiobase coefficients used in this study are shown in the Table 1.

Table 1. Exiobase consumption categories and GHG coefficients used in this study.

Category	Exiobase codes and calculations	kg CO2e/€
Alcohol & Cigarettes	([CP021&CP012] + [CP022])/2	0,15
Clothing & Footwear	[CP052, CP0311&CP0313]	0,09
Interior Design & Housekeeping	([CP054] + [CP0721 & CP055] + [CP0561])/2	0,37
Health	([CP123&CP061] + [CP124&CP063&CP062]) / 2	0,18
Recreation, Sports & Culture	([CP094] + [CP095])/2	0,15
Restaurants	[CP11]	0,16

Hotels	[CP11]	0,16
Electronics	[CP0914, CP0912, CP0911, CP082]	0,26
Other goods & services	[CP127, CP1211, CP0923, CP0915, CP0562, CP0533, CP0513, CP0444, CP0432, CP0322, CP0314])	0,11

Consumption of food is calculated separately to include the different climate impacts of different diets. To define the GHG coefficients for different diets, we use values based on the diagrams of Saarinen et al. (2019), accompanying one additional category for even higher meat consumption (300 g/day). Highest meat consumption has a coefficient value which is derived from the previous diet coefficient values from Saarinen et al. (2019). The values used to calculate the diet emissions are presented in Table 2.

Table 2. Greenhouse gas coefficients used to calculate the yearly climate impact of an individual's diet (Saarinen et al 2019).

Diet	Kg CO2e/2200kcal/day (Saarinen et al 2019)	kg CO2e/year
Vegan/vegetarian	3,1	1132
Pescatarian	3,5	1278
Omnivore 50g meat/day	4,2	1533
Omnivore 70g meat/day	4,6	1679
Omnivore 150g meat/day	6,9	2519
Omnivore 300g meat/day	(2519-1132)/2+2519	3213

Spatial datasets

The Finnish Environmental Institute's spatial datasets (2013; 2018) describing urban form are utilized in this study when analysing the connection between an urban form and consumption of climate concerned urban dwellers. The selection of the spatial dataset has a crucial role when studying the urban environment inside the city –

Helsinki's suburban districts for example are often considered as urban but at the same time they are sparsely populated when compared to city centres. Therefore, they can be divided into quite opposite regional categories depending on the dataset. In this study, the spatial dataset of city centres (Finnish Environmental Institute, 2018) is used to separate the cite centre-like urban environments from other urban localities, leading to two categories: urban localities and city centres. In this study, urban localities is a class for an urban area without city centre-like characteristics, which in Helsinki's context could be referred as suburban districts as well, after the city centres are separated from it.

The dataset used to identify the city centres in this study is based on a criterion that there is a mixture of jobs, residences and different services within a walking distance (Rehunen et al. 2014). Therefore, city centres do not only cover the actual, spoken language, city centre of Helsinki but also city centre-like urban environments in Helsinki metropolitan area. This kind of spatial dataset is ideal in a study like this where we specifically want to study the possibly different urban consumption environments. The two spatial datasets are presented in Figure 1, where these regions are also combined to some results from our carbon footprint pilot survey.

For the analysis of this paper, climate concerned urban dwellers are divided between these two regional classes by using an overlay geoprocessing tool in GIS, leading to 19 samples in urban localities -class and 25 in city centres -class. Two climate concerned pilot survey participants are left out from this study, as they are not overlapping with neither urban localities nor city centre areas but are not forming a big enough sample to include a third urban environment class either.

Results and Discussion

This chapter is divided into two separate chapters. First, we will go through our preliminary results about the impact of the urban environment on consumption based GHG emissions of climate concerned urban dwellers accompanying some discussion. Then, we will explore in further detail the climate change attitude questions and their potential in future analyses about the topic.

The Impact of the Urban Environment on Consumption Based GHG emissions of Climate Concerned Urban Dwellers

A minor difference between consumption related GHG emissions of climate concerned residents of Helsinki metropolitan area is shown from the carbon footprint survey pilot data when GHG emissions of the residents are compared between city centres and other urban localities (Figure 1). The average consumption related GHG emissions of the residents of the city centre region are 2084 kg CO2e/year while the average consumption related GHG emissions of the residents living in the other urban localities is 2150. Only those who answered "(3) Moderately", "(4) Very" or "(5) Extremely" to the question “How worried are you about climate change?” were included in this analysis. Of them, the city centre area had an average value of 4,6/5 in “How worried are you about climate change?” answers, while other urban localities had an average value of 4,4/5. If the sample were larger, a conclusion could be drawn that the residents of city centres are more worried about climate change and consume less than those who live in other urban localities in Helsinki metropolitan area.

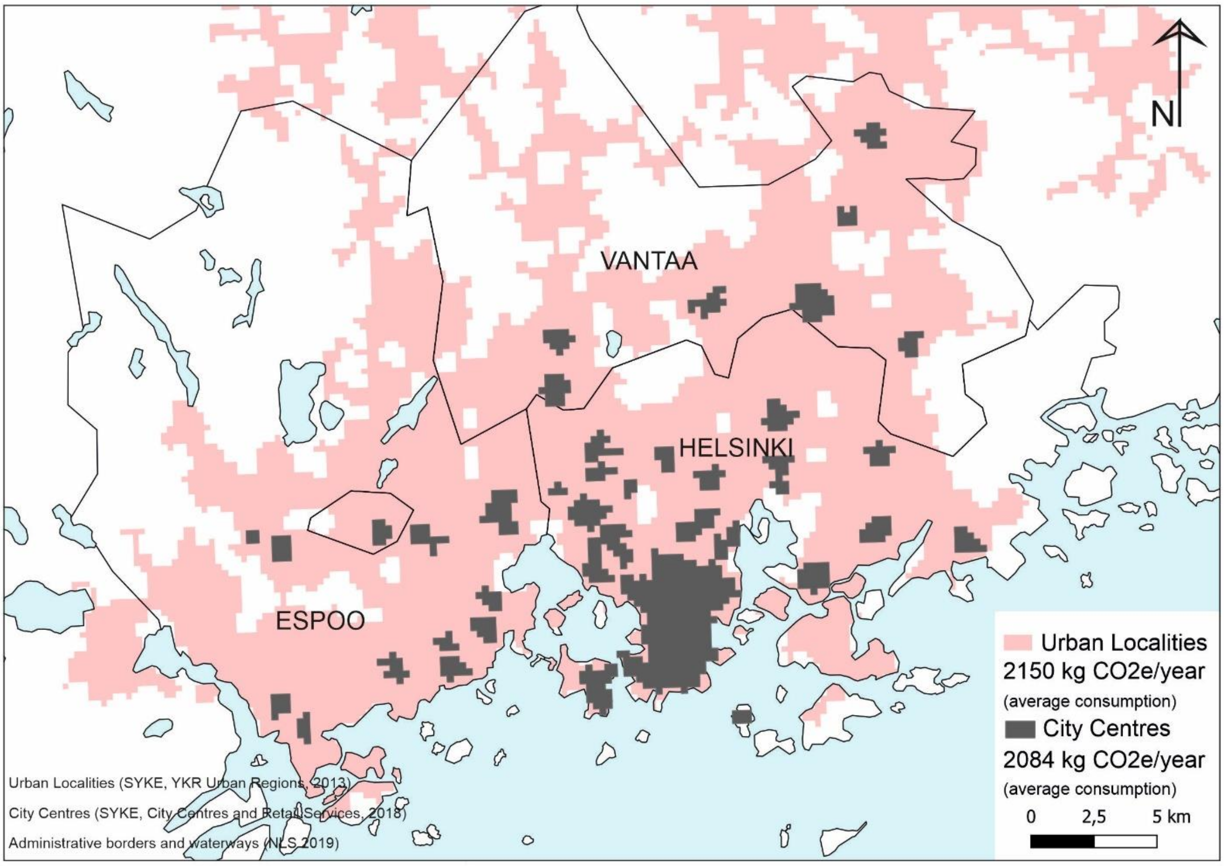

Figure 1. GHG emissions of consumption of goods and services by climate concerned urban dwellers on Helsinki Metropolitan Area’s city centres and urban localities. Only consumers who are moderately, very or extremely worried about climate change are included. Average consumption of climate concerned urban dwellers in city centres is 2084 kg CO2e/year while in urban localities the average consumption is 2150 kg CO2e/year.

However, these differences are so small, as is the sample size of our carbon footprint pilot survey, that no conclusions can be drawn to either direction. Equally, it could be very possible that the results of the upcoming carbon footprint survey will show an opposite pattern. A correlation between climate concern and higher GHG emissions have been found in previous studies for example related to trips abroad (Czepkiewicz et al. 2019). Ottelin et al. (2015) have shown that the residents of inner urban areas have higher carbon footprints while smallest carbon footprints were found in newly built outer and peri-urban areas, also when income level differences were taken into account.

While our upcoming carbon footprint survey will cover also the GHG emissions from housing, vehicle, local and long-distance travel, second homes and pets, this pilot data-based study is limited to include only the consumption of goods and services with a limited sample size – Hence, we cannot yet draw conclusions, but we can ask: Could climate concern predict lower carbon footprints? And on the other hand: Could living in a certain type of urban region predict higher carbon footprints?

Climate Change Attitudes Results and Discussion

As our carbon footprint pilot survey includes 12 different questions about participants' attitudes towards climate change, a preliminary factor analysis on climate change variables was conducted (Figure 2). As the data violated assumptions of normality, principal axis factoring with promax rotation was used. Based on the results, three factors, presented in Figure 2, were identified for the analysis. The 12 climate change attitude questions in the carbon footprint pilot survey are the following, with an answer scale from 1 to 5 (1 = not at all, 5 = extremely):

hwy= How worried are you about climate change?

hfg= How much do you think climate change will harm future generations of people?

hyp= How much do you think climate change will harm you personally?

hip= How important is the issue of climate change to you personally?

hai= How likely do you think it is that your actions will influence others to behave in ways that reduce greenhouse gas emissions resulting from their lifestyles?

hwc= How likely do you think it is that large numbers of people will voluntarily change their lifestyles to try to mitigate climate change?

imc= How important it is to mitigate climate change?

cfl= How climate sustainable would you think that your own lifestyle is?

kib= Do you feel that you are knowledgeable about the climate impacts of your consumption choices?

pcf= In your opinion, how important are the following in mitigating climate change? [Lifestyle changes to reduce one's personal carbon footprint]

gmm= In your opinion, how important are the following in mitigating climate change? [Governmental/municipal measures (limitations, regulations, funding allocations etc.)]

ted= In your opinion, how important are the following in mitigating climate change? [Technological development]

PAF	PA1	PA2	PA3	Comm.
hwy	0.02	0.24	0.53	0.53
hfg	0.04	0.10	0.78	0.76
hyp	-0.01	-0.15	0.89	0.63
hip	0.66	0.36	-0.01	0.84
hai	0.79	-0.14	0.00	0.51
kib	0.62	0.03	0.03	0.43
imc	-0.07	0.99	0.04	0.94
gmm	-0.02	0.88	-0.07	0.69
p. var	0.19	0.26	0.22	
c.var				0.66

Figure 2. Climate attitude factors. Factor loadings and communality values of climate change attitude variables of the carbon footprint pilot survey.

Since the sample size of the pilot data is low, the communality values for different variables remain relatively low as well. Out of 12 climate change attitude questions, 8 were included in the factor analysis and four were left out due to exceptionally low communality values. However, Figure 2 shows that after the implementation of the upcoming carbon footprint survey, the bigger sample sizes will most likely allow us to conduct and interpret the results of variance and linear mixed effect models analyses of climate concern and attitudes. Then, the results can be combined to consumption-based carbon footprints and urban form in the similar manner as we now used just a single “How worried are you about climate change?” question to include only climate concerned individuals to our spatial carbon footprint studies (Figure 1).

With bigger data samples, also more detailed spatial classifications could be used. The suburban districts could be separated to various other regional categories, e.g., in Helsinki the more sparsely built forest suburbs built in 1950s and 1960s could be separated from the newer, densely built suburbs built after 1970s and representing a relatively different urban environment which could be connected to climate change attitude factor analysis results as well. And, when including only extremely concerned urban dwellers, could the carbon footprints differ between city centres and other urban localities or even between sparsely and densely built suburbs?

Conclusions

This study presents some important research questions, methods and possible future results of the possible impacts of the urban environment on consumption-based carbon footprints of climate concerned urban dwellers by utilizing the pilot data of our upcoming carbon footprint survey.

The study implicates that those possibly significant differences between consumption-based carbon footprints on different types of urban environments among climate concerned urban dwellers can be determined by further processing the methods and practices we utilized in this study by applying them to our upcoming carbon footprint survey data. With a larger data sample, even more detailed regional classifications in GIS can be connect to statistical analyses of climate change attitudes. Most importantly, GHG emissions from diet, housing, vehicle, local and long-distance travel, consumption of goods and services, second homes and pets can be included into our calculations of the consumption-based carbon footprints of the participants.

This kind of comprehensive study with a large data will also allow us to connect the results to the remaining global carbon budget for halting global warming to 1.5 degrees to see if some types of urban environments are supporting sustainable lifestyles more than others. This paper set the methodological framework for our future studies of the topic.

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167 Community participation in deciding on local renewable energy projects

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Abstract

Citizen participation in local renewable energy projects is often promoted as a panacea for the difficulties that are involved in the energy transition process. Quite evidently, it is not; creating a stakeholder participation process presupposes that there is a wide variety of perspectives and stakes in the energy transition process; and indeed, we can all observe this wide variety. However, conflicting viewpoints will not vanish miraculously by a participation process.
In this paper, we aim at developing insight in what participation might achieve. We will first sketch the substance of local conflicts on renewable energy projects. Afterwards the paper analyses three case studies on local participation processes. The success of participation is not identical to the acceptance of local renewable energy projects: it is reaching a joint decision on a pathway for the future. Such decisions are not impossible. The paper will finally argue that a good citizen participation process can be organized if the process is open and fair, and citizens are not addressed as opponents or greedy subjects, but as responsible partners in the energy transition.

Keywords: Participation, Bottom up initiatives, Wind turbine, Solar Park, Noise Screen

1. Introduction: Why citizen participation in local sustainability projects?

Progress in the development of renewable energy projects and their implementation is too slow. Various procedures, objections, legal requirements and the process of decision making take much time. The causes that prohibit rapid local action are often misunderstood:

- *'If we could show all people that sustainability is the only way to go, the problem would soon be solved'.* Of course, it would be helpful if more people would learn why sustainable development is needed. But even if the idea of SD could be explained to each and every one, adapting lifestyle, adapting professional behaviour, adapting jobs, and adapting institutional frameworks might take much time especially if it brings no individual gains
- *'If polluters would pay for ecological destruction and resource depletion, a new economy would emerge'*. Industrialized economies are so deeply entrenched in ecological destruction that immediate drastic reforms would imply economic destruction, and probably trigger revolts and a reversal of power.
- *'A strategy for a sustainable development should be agreed upon at global level, and afterwards be implemented top down'* ('Eco-authoritarianism' (Beeson 2010) or 'a green dictatorship') Nobody has the wisdom, the modesty and the self-sacrifice to act as a single global decision maker a10.3217/978-3-85125-842-4-42nd implement decisions under various local conditions. Dictators are not immune for narrow mindedness, mass hysteria, and psychiatric diseases.

Calling opponents of local sustainability projects 'NIMBYs' is in line with eco-authoritarianism: It prohibits a serious discussion on the pros and cons of a project. In 1980, Livezey introduced the 'not in my back yard (NIMBY)' phenomenon (Livezey 1980). He made 'NIMBY' the brand of people that rejected common interest projects, only to optimise their own private interests. NIMBY was thereby a negative term that referred to selfishness and the uncompromising pursue of the own sake. Branding opponents as 'NIMBY' was an effective weapon to derail their public legitimacy. It also made 'compensation' the main instrument to make individuals and/or communities accept projects, instead of persuading citizens to contribute to common interest goals. Policies that are only focussing on compensation are democratically dangerous as there is a thin line between 'offering justified compensation' and 'buying political support'.
Finally, one should realise that Sustainable Development is not a single goal but it encompasses many goals. Implementing global policies at the local level means balancing these global goals. Many of the global goals might be contradictory at the local level: fossil free energy takes space and materials, it could also imply some pollution, harm to wildlife, less space for food production, and local nuisances. So there is always scope for debate regarding the implications of renewable energy projects for the local situation (Mulder, Ferrer et al. 2011). Local debates are required and such debates are crucial for the support of a local community. Many community members might have 'blocking power'. Only by actively involving local stakeholders in decision-making, a lasting progress can be achieved. Local debates need preparation, and so they need time. People need time to consider new ideas and to become accustomed to those ideas. That is 'muddling through' at local level (Lindblom 1959). However, how to organise a successful participation process?

2. The problem of developing Renewable Energy

2.1. Climate Policy from global to local action

The 2015 Paris agreements have created ambitious goals for reducing the emissions of greenhouse gases. This necessitates drastic measures: reduction of energy consumption by energy frugality, developing renewable energy sources and transformations of energy systems in order to cope with different energy carriers, provide storage for the annual and daily fluctuations of renewable energy sources and deal with this revolution in energy business conditions. These transformations do not just affect the energy sector. They will transform the rural and urban landscape, and affect everybody's daily life. Moreover, the transformation of energy systems will lead to a considerable loss of fixed assets, of consumers, industry and energy companies. As in every largescale transformation, there will also be new business opportunities.
At the global level, the world has recognised the interrelation of environmental and equity issues: conflicting interests of rich and poor, underdeveloped and developed nations and regions, fossil fuel producers and -consumers, potential climate change victims and regions with considerable resilience towards climate change, regions with rich renewable energy assets, and regions that are poor in this respect. The concept of Sustainable Development created a milestone on this pathway of promoting integrated policies (World Commission on Environment and Development 1987).
However, the implementation of new policies targeting renewable energy is still predominantly governed by traditional planning. Like there are equity issues at the global level, so there are equity issues at regional level: there are poor and rich areas, ruined landscapes, i.e. wastescapes (Amenta and van Timmeren 2018) and areas of natural beauty, spatial claims for various incompatible economic activities, leisure and nature. Renewable energy activities are a new issue in this force field. Renewable energy generation often create nuisances for local inhabitants, while owners/operators and consumers elsewhere reap the benefits. Landowners are sometimes compensated quite generously, in order to ensure their cooperation. However, is it fair not to offer any compensation to non-landowners?
Besides the variety of interests among its members, a local community might question the necessity of their contribution. Should rural communities accept the nuisances of wind turbines, solar parks or hydropower dams, in order to provide for cities? (Wolsink 2007). In addition, even beyond that, people might question the resilience of their local ecosystems, but also the global climate system, to cope with change. Perceptions of natural systems have deep roots in the socio cultural beliefs that are foundational for main ideologies (Schwarz and Thompson 1990). Hence, local renewable energy projects might give rise to local controversy.
The successful local implementation of renewable energy policies depends on the support of the local social fabric. While at one-hand policies to construct wind turbines or solar parks in specific regions trigger local resistance, the lack of such policies, or policies that obstruct local renewable energy action, might also create local controversy.

2.2. From 'acceptance' to 'participation'

Controversies on 'siting' decisions have occurred manifold. For example, the siting of nuclear power facilities in the 1970s was a politically sensitive issue; if local resistance was strong, final decisions could be delayed considerable. However, the argument of local employment could sometimes persuade the local population to accept a nuclear power station near their community. Studies showed that local 'acceptance' was not just an issue of economic advantages versus negative impacts: local history and its social conditions, and local economic conditions were quite important as well (Byrne and Sucov 1977).
Stakeholders not only determine their position regarding a local project by their assessment of costs and benefits for themselves: values, ideologies and religion might play an important role in assessing new technologies or large-scale operations in local communities. Mapping such issues was helpful in preparing policy makers (Mulder 1996).
Could local acceptance be measured unambiguously, in order to decide what is acceptable in a local community, and what is not? Or to decide at what site a facility would meet acceptance? There are large difficulties in developing such a tool:

- In interview/survey research, the subject and object are interdependent, a general social science phenomenon. Gathering data in a local community will generate interest, and might make the inhabitants feel 'special' and/or it will stimulate them to consider issues that they would not have considered otherwise.
- Local residents might act strategically; they will emphasize issues and downplay others, as to serve their values/interest concerning what they perceive as the aim of the study.
- The image of the analyst making the 'acceptance' study is of major importance. Citizens might refuse cooperating with companies or agencies that represent a specific interest. Scientists are more often regarded as independent and neutral, but local residents might distrust them if they are 'hired brains'. Experiences might also create distrust.
- Any assessment of issues is influenced by general issues of the moment. Recent external events, like catastrophes, conflicts of the region with national government, or other issues that temporarily dominate the media, influence the judgment of local residents (Gamson and Modigliani 1989).
- 'Acceptance' might even be an issue of ignorance, regarding impacts. Such 'acceptance' might be flushed away if unfavourable facts become known.

Local projects aimed at reducing greenhouse gas emissions might be perceived differently by various local stakeholders, might affect local assets and local values, and might trigger conflicts of interest. Ignorance might play a considerable role among all stakeholders, as some might be unaware of the impacts of renewable energy technologies, while others have no idea of the implications for the local community. For these reasons, local decision making on renewable energy projects might be a challenge of

- Providing insight into the need to implement renewable energy technologies (in relation to measures elsewhere)
- Assessing the local impacts of renewable energy technologies
- Balancing the cost and benefits for various stakeholders
- Achieving the project goals at acceptable costs.

Hence, local decision making on the introduction of renewable energy technologies is a learning process to:
- Understand the potential impacts for the community, both positive and negative,
- To develop changes in behaviour/organisation in order to deal with the impacts, optimise opportunities and prevent harm.
- To negotiate compensation and/or mitigating measures for the balance of positive and negative impacts

This means 'second order learning' in order to adapt behaviour and organisation of the community (members) to the new options and new barriers (Cf. Bloom, Krathwohl et al. 1984). Important in second order learning is not just conveying knowledge on new local phenomena, such as wind turbines, solar parks, or hydropower dams, but also facilitating discussions and creativity, in order to reach understanding for conflicting views. So besides learning on the direct implications of renewable energy technologies, processes of social learning are a crucial element for local communities in order to strengthen local democratic decision making, prevent conflict, and to discuss compensation for specific actors that might fear negative impacts of a renewable energy technology. Careful decision making, being 'fair' to all members of the community, giving regard to various viewpoints and interests is an important element of local decision making on renewable energy technology.

2.3. Different Perceptions of Renewable Energy in a local context

Local renewable energy projects cause many local impacts: renewable energy is to be harvested from the landscape, and so there are landscape effects. What are these impacts? Hydropower disturbs river flows and the river aquatic ecosystems, especially migratory fish. It also affects recreation and water management(Mulder, Parandian et al. 2012). Geothermal energy might create induced seismicity (Deichmann and Giardini 2009). In the remainder of this paper, only impacts of wind turbines, solar parks, and PV on noise screens in the Netherlands will be discussed, as those impacts will be dealt with in three case studies.

2.3.1. Wind turbines

In various regions of the Netherlands, wind turbines are by far the most controversial renewable energy technology. What are the contested impacts?
In September 2013, the 12 provinces of the Netherlands and the national government agreed on a distribution of the wind turbine capacity that is required to work towards a national renewable energy system. In 2020, wind turbine capacity on land should be 6000 MW. The five coastal provinces would be responsible for the major part of this capacity. Each province would be responsible for siting of the assigned wind turbines, and for all accompanying measures that were required.
The pathway to this goal proved not really to be smooth for the provinces. In 2020, 3300 MW of wind power capacity had been created and 700 MW was still under construction (Interprovinciaal Overleg n.d.).
At various sites, the provincial implementation of the plans created conflict. Negative impacts of wind turbines that played a role in these conflicts:

a. Landscape. The large wind turbines affect the image of the landscape. In order to compromise, the Friesland province, right from the start, embarked on a policy of concentrated wind parks, and aimed at preventing the construction of single wind turbines (van Houten 2011). In this way, landscape deterioration was confined to a few spots.
    i. However, this concentrated wind park policy also created conflict. For example in the village of Roordahuizen, a village cooperative produced electricity by a single wind turbine. It had been successful for about 15 years, but needed to replace its wind turbine. In order to stay competitive in respect to the electricity prices of the national grid, the villagers needed a somewhat larger wind turbine. However, the Friesland province refused a licence. The municipality supported the villagers, and long lasting legal procedures commenced (van den Berg 2016). After3 years, the High Court of Appeal for Government Decisions decided against the villagers. Meanwhile, however, the Friesland province was governed by a new coalition that was willing to compromise with the villagers (Omrop Fryslan 2019). Besides these bottom-up initiatives, also farmers were victims of this wind turbine concentration policy. During the years, novel small scale wind turbines were introduced that were ideal for farmers: they were profitable, required no changes to the farm's electricity grid connection, required little maintenance, and as these wind turbines were about as high as the highest trees, there were hardly landscape objections. However, farmers in Friesland could not get a licence for these wind turbines and felt disadvantaged as compared to their colleagues in other provinces.
    ii. The areas that were determined to be the location for wind turbines felt as scapegoats. Ultimately, the main contribution to fulfil Friesland's obligations was achieved by constructing a large wind park in the large lake Ijsselmeer, which triggered resistance from national environmental organisations (Anonymous 2018).

b. Disadvantaged Regions. Provincial siting decisions for wind- and solar parks are for a major part determined by perceptions of landscape value. Valuable landscapes need protection. Industrial areas and reclaimed land are preferred locations for wind turbines. The reverse side of this argument, i.e. that locations for wind parks are branded as having no landscape value, is not helpful in communicating the siting decision to that region: inhabitants identify themselves with their region. As a result the inhabitants of regions that have to accept wind parks, not only are 'losers of the political game'; they are also sad inhabitants of an 'ugly region'.

c. Noise. Noise production by wind turbines is proportional to wind speed. However, the normal noise of wind increases similarly, and this creates a 'natural mask' for wind turbine noise. However, this does not apply under all conditions. Wind turbines might produce much more noise than expected, especially during low winds at night (Van den Berg 2006).

d. Annoying visual effects: shadows, flicker, and night (flash) lights. These are considered a nuisance and disturb wildlife (Pennewaard 2016). Wind turbines can be put on halt to prevent annoying shadows (Kingdom of the Netherlands n.d.).

e. Bird mortality. The wings of wind turbines move at high speeds (maximum about 200 km/hr), in relation to the speeds of most migratory birds (about 40 km/hr). The wings might knock the birds out of the sky. For this reason, conservationists have been opposing wind turbines in and near conservation areas. Bird mortality can be limited by not placing turbines at migratory bird routes, or by putting the turbines on hold in the migration season (ter Steege 2019)

f. Space use. Wind turbines need limited space. A relatively small, 1 MW turbine produces about 1,5 million KWh annually. This is sufficient electricity for 450 households. Except for the construction phase, space use of a wind turbine is negligible. In order to generate a similar amount of energy by a solar park, more than 20.000 m^2 is needed. Citizens often argue that PV should first cover roofs. An average supermarket is about 1000 m^2, which means that 20 supermarkets have to cover their roofs with PV in order to generate a similar amount of electricity as a 1 MW wind turbine. Larger buildings are often not designed to carry the weight of PV panels. Insurance costs of these buildings will rise. The minimal use of space is for farmers often an argument to prefer a wind turbine.

g. Real estate value. As people experience nuisances from wind turbines, prices of nearby real state might fall (Droes and Koster 2019). This again might trigger resistance of those fearing to lose part of their assets.

h. Employment and economic benefits. The local employment impacts of a wind park are generally small (Munday, Bristow et al. 2011) The turbines are remote controlled and have low maintenance. However, there are investors that seek green power as an important asset for their company, both for security of energy supply and for their green image (Rengers and Houtekamer 2020)

There might be additional income for a region. Landowners are compensated for land use. In 2014, the NWEA, Netherlands Wind Energy Association, recommended its members to make a 0,40-0,50 euro/MWh per annum deposit in a local development fund. This might amount to about 3000 euro/annum per wind turbine. Under the pressure of local conflict, some wind parks pay already much higher contributions (van der Laan 2020).

i. Necessity of wind turbines in the region. As there is plenty of space for off shore wind turbines in the North Sea, why should a region accept wind turbines? (Wolsink 1988)

Nowadays, the societal need for renewable energy is not an issue. Even in an area where a large controversy had occurred regarding wind turbines (The area of the 'N33' and 'Drentse Monden-Oostermoer' wind parks in the North of the Netherlands), 65% of the inhabitants wanted more wind energy (25% opposed) to provide renewable energy, even if turbines would have to be placed in their region (Brandsma 2019).

2.3.2. Wind turbines and 'fairness'

However, apart from the separate issues, and how they work out for various stakeholders, there is a general issue: Is the distribution of costs and benefits of a new local wind turbine, or a wind park, fair? In other words: are there stakeholders that benefit, without much risk, and are there stakeholders that suffer without any compensation? Lack of 'fairness' hurts: A wind park does not just need the consent of main local stakeholders, and a licence of the appropriate authorities. It needs a location without residents in its vicinity, to minimise/prevent nuisances. Landowners need to allow the placement of a wind turbine. In general, farmers own such sites. Moreover, they often live between their parcels. Hence, they are the ones that might object to the noise and visual impacts of wind turbines. For this reason, farmers as key actors for wind park developers and are offered substantial compensations for accepting wind turbines. The inhabitants of rural villages do not benefit from local wind turbines. Noise, visual hindrance and falling real estate prices are not individually compensated. For example in Meeden local protestors used the slogan *'Boeren slapend rijk, onze huizen dalen in waarde'* (Farmers become rich without any effort, while the prices of our dwellings fall'). *"In this way, a division is created between farmers and citizens* (*Op deze manier zaai je verdeeldheid tussen de boeren en de burgers*).'' (Brandsma 2019). Hence, resistance against wind parks could be perceived as a conflict regarding a fair distribution of costs and benefits, and not as a selfish attempt of some groups to refuse to cooperate in achieving a common goal.

2.3.3. Solar Parks

Discussions on solar parks have in some respects a similar character. Sometimes solar parks are regarded as alternative for wind turbines, and sometimes, wind turbines are promoted as alternatives for solar parks.

The main objection against solar parks is the harm they do to the landscape: solar parks take considerable space and many people detest the view of large fields with shiny plates. Everybody agrees that roofs, especially the large ones of commercial buildings, are to be preferred as locations for PV panels. However, after PV panels turned out to have been the cause of a large fire in 2019, insurance costs for PV on industrial halls sharply increased. Investors preferred meadows as locations for solar parks (Keukenkamp 2019). The attempts to create solar parks created several local conflicts. In several cases investors tried to persuade municipalities to accept solar parks, by promising to take measures to prevent landscape deterioration (E.g. a girth of trees and shrubbery surrounding the park). However, such a promise should be legally solidified in spatial plans and/or contracts (Zurhake 2019). In another case, a field that was part of a Natura 2000 natural reserve area was planned to become a solar park (van Rootselaar 2019). This caused negotiations between environmental organisations and the PV industry. In a covenant of November 2019, they agreed that natural reserve areas would not be used for PV unless it would be clearly beneficial for the area. This could be the case if there would be a low number of PV panels per surface area. In that case, grazing cattle and other small animals could potentially create a richer ecology (Straver 2019).

Besides the landscape, also agriculture played a role: farmers rejected withdrawing good soil from agricultural food production, as it would be an economic threat and a risk for food security. In the municipality of Hilvarenbeek Kronos Solar presented a good landscape plan for a solar park. However, villagers protested: 'One should first cover roofs of stables and commercial enterprises' (van Hest 2019). This argument can be heard everywhere. However, for many roofs, PV panels are technically no option or too expensive by high insurance costs.

Like the siting issue of wind turbines, 'fairness' is an important issue for solar parks:

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Large investors from elsewhere make a profit by their solar park, but the landscape in the village deteriorates, and local farms are closed down. Dominique Doedens, an advisor for local energy projects: *"The problem is that project developers own the solar park. They use some so-called 'participation', i.e. local people can buy a share. However, the large profits leave the local community, often the profits go abroad. The burden remains in the local community."* (Laconi 2018)
So in fact, the problem is similar to the one that was described above for wind turbines: some inhabitants of a local community gain (by having shares, by renting out their land, etc.) but the others are worse off as the landscape deteriorates and the value of property is declining. The resistance of the local population against renewable energy projects is neither an issue of support for fossil fuels, nor a sign of 'NIMBY-ism': An important underlying issue is that of a fair distribution of costs and benefits of this intervention in the landscape.

3. Case Studies: participation in local renewable energy projects

3.1. Wind Park 'Drentse Monden/Oostermoer'

In January 2008, a new national enhancement policy for renewable energy started. This policy comprised incentives for new renewable energy generation projects. As a result, landowners considered building wind turbines on their premises. In the Northern province of Drente, farmers, generally the more wealthy ones that owned land and had the means to invest, formed a group to consider creating a wind park. This group was active in the so called 'peat colonies', an agricultural region that remained after 17-19th century peat digging. As the landscape is flat, with few trees, it is suitable for wind turbines. The group lobbied at the provincial authorities to get their plans accepted, but in vain: the provincial authorities only regarded the large 'peat colonies' in the South East of the province as suitable for rather limited wind energy plans of 60 MW. The rest of the province, including the area of this group of farmers, was off limit. But the farmers did not give up: investments in wind turbines had become very attractive. In 2009, they contacted the Ministry of Economy Affairs, that is responsible for the renewable energy plans. Their plans were well received at this department as the plans fitted into the policies for expanding 'wind on land'. In 2010, the new Crisis & Recovery Act offered the option to national government to take over all licence procedures from provincial and municipal authorities if it concerned a project of national interest. For energy generations, this implied a generation capacity larger than 100 MW. The farmers submitted an application to the ministry to apply this new law to their wind turbine plans: They aimed at building 225 MW of wind turbines in their regions. Other investors also showed interest in the region. In the meantime, the provincial authorities were under increasing pressure: Their spatial planning policy plan was criticized by left wing parties for not having sufficient options for renewable energy. The Christian Democrats, that represented many farmers, joined this criticism. Under this pressure, the provincial authorities accepted 200 MW of wind turbines for their province, and they extended the 'search area' for wind turbines to all of the 'peat colonies' of the province. By this sudden move, the population and the municipalities of the area had not been consulted on wind turbines, and was unable to submit any objections or alternatives. Moreover, the provincial council rejected the cap of 200 MW, which implied that there was no upper limit for wind turbine plans. As a result, various investors started developing wind turbine plans, and the farmers group raised their application to 500 MW of wind power. Moreover, the group requested national government to take control of procedures by applying the new Crisis & Recovery act. National government agreed and the provincial authorities and municipalities were side-lined. Within three months, two municipalities changed from being off limits for wind turbines, to being a wind turbine area, without any limit. The message wat communicated informally to civil servants of the municipalities, probably in an attempt to get their support. The attempt was in vain; it marked the start of years of harsh regional conflict (De Haan 2019).
National government had set an important condition for the group of farmers and their wind turbine plans: 'developing local support'. However, after such an administrative affront, the whole idea of local support seemed hilarious. Public administration of the region had fallen victim of a hostile takeover. Although the municipalities and provincial authorities were side-lined, they decided to cooperate at a minimum level in order to be able to influence the course of events.
In 2011, a national covenant assigned Drente 285 MW of wind turbine capacity, of which 255 MW would be in the area. The Drente province aimed at reducing this number and finally succeeded in 2014 when national government accepted 150 MW for the 'peat colony' area. The reduction is probably due to the fierce protests:

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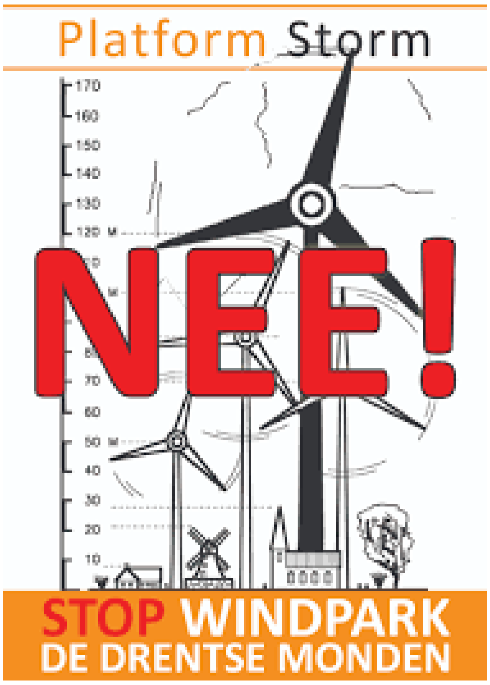

Inhabitants started creating protest groups. In 2011, 'Storm' was created in the municipality Borger-Odoorn, and several other groups soon followed. The anti-wind turbine groups cooperated in 'Tegenwind' (headwind)[1].

National government handled 'participation' at the minimum required level, with no other purpose than fulfilling legal obligations. For the population involved, it was striking that the first information meetings for citizens (February 2012) were not even organized within the territory of the municipalities involved: either The Hague civil servants did not know their geography, or they did not care…..

The atmosphere in the region became grim. 80 % of the population was clearly opposed to wind turbines and the initiating farmers group became socially isolated. *'Fucked by our neighbours'* was the text of a banner at a junction in the area. Farmers complained that villagers publicly insulted them. They held the municipalities responsible for the discord (Bouma 2016). However, the municipalities were still sidelined. Protestors showed up in every public meeting that had the word 'energy' in its announcement. The situation became even worse; as the protests did not have the desired impact, there were anonymous threats of violence against farmers and (wind turbine) constructors. Farmers suffered from destruction of machinery. A barn went on fire. But, there were also threats the other way.

The protestors did not have any desired impact, not politically, and not in court. When minister Kamp was questioned in parliament regarding the lack of support for the plans in Drente, he replied that there was sufficient support: a national covenant that included many parties among which all provinces and the Union of Netherlands Municipalities (VNG); if parliament wanted another energy policy, well, he was open for suggestions(de Haan 2019).

Politicians and companies received threats, their pictures showed up marked with swastikas, meetings had to be cancelled, as people no longer dared to speak up. In December 2018, the regional situation really got out of control when asbestos was dumped at two sites in the North of the Netherlands. Later, two persons were arrested and convicted. The wind energy protestors lost public credibility and political support. The construction of the wind turbines proceeded and they will start production by the end of 2021. However, the local situation in the 'peat colony area' is still tense. Recently new conflicts emerged regarding the 'area fund': A fund that has been created to compensate the area for losses due to the wind turbines. The fund is filled by 0,5 euro/MWH from the wind turbine production and by a government donation. It might take years before the social divides created by the wind turbine conflict are healed.

3.2. Solar Park 'Heeten'

The village of Heeten is located in the central-East part of the Netherlands. It has 3500 inhabitants that partly work in agriculture, or commute to the nearby larger towns. A bottom up initiative from the village created a solar park, and a local energy cooperative Endona to supply the inhabitants with electricity. September 21st 2018, the solar park started powering the village. The surface area of the park is 4,5 hectares, of which 3 hectares is covered by 7200 PV panels, with a maximum output of 1.8 to 2.0 MW. The remaining part of the park is used for landscape measures: The solar panels are sunken, and a earth wall with hedges hides the PV panels from sight (Eelerwoude 2021). Although there were objections to the solar park, the way they were handled did not lead to controversy.

The first initiatives for the solar park were taken in 2011. Villagers contacted their municipality, and first ideas were discussed and evaluated. In 2014, the initiators considered to have a feasible idea and created a group to study social acceptance of their idea within the community. Door to door, villagers were approached to inquire what their ideas were regarding a village solar park. Resistance was met from the agricultural community that feared loss of scarce farmland. Another fear that surfaced was the threat to the arcadic pasture surrounding the village.

[1] See: http://www.tegenwindveenkolonien.nl/index.html

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In further defining the project, the worries of the stakeholders were taken seriously. The process of communication was handled carefully: a number of walk-in evenings was organised and there were contact persons for each street that guaranteed that villagers could discuss the subject with a knowledgeable neighbour. The plans were adapted in such a way that the solar park would not be visible, and that the land would be dual used, for solar energy and agriculture. These agreements were fixed in a document in order to safeguard the interests of all stakeholders. Moreover, a stakeholder platform was created to discuss the further design of the solar park, and its landscape embedding. This was carried out by a number of design sessions.

In this phase, the applications for legal permits were discussed between the initiators and the stakeholder platform.

In 2015, the initiators created local energy company ENDONA that would own and manage the solar park, and would sell the energy to its members. Members could by a certificate for which they would receive a fixed interest. Additional profits would be transferred to public interest causes of the village, to be determined by the members of ENDONA.

A few objections remained, but they were rejected by a court decision in 2016. When the construction started in 2017, ENDONA started issuing newsletters and maintained a website with detailed information.

In 2018, the solar park was opened. 7700 PV panels supplied electricity for 600 dwellings. The park was sunk to make it invisible for its neighbours; Sheep were grazing between the panels. Additional efforts were put into the surrounding hedges, to make them contribute optimally to local biodiversity. The park was designed to be able to host batteries in the future, and to deal with electric vehicles.

Endona received the municipal prize for local initiatives, Heeten was determined the most sustainable village of their province, and Endona is developing additional solar parks. However, they embarked on a course for smaller solar parks as these were better adaptable to the requirements of stakeholders: ‘Many little ones also create a large one’. In this way Endona clearly distinguish itself from a threat that many villagers feared: plans announced by investors to created solar parks of up to 40 hectares in their region (Laconi 2018).

3.3. Solar Panels on Railway Noise Screens: NEWRAIL

NEWRAIL is a project initiated by ProRail (the organisation that manages the national railway network infrastructure). The project aimed at designing and evaluating options to mount PV panels on railway noise screens. In the Netherlands, measures limiting noise of (rail-) traffic are strictly regulated by chapter 11 of the Law on Environmental Management. Based on this legal framework, the national government initiated an investment program aimed at noise reduction at ‘hotspots’: Any dwelling that was subjected to noise in excess of 65 dB (motorway) or 70 dB (main railroad) would be ‘remediated’. Legally, it was prescribed that noise reduction measures with highest efficiency (i.e. noise reduction per euro) should be applied, which implies that mathematical models decide whether the façade of a building will be treated, noise reduction measures will be applied in the railroad track/road surface, or noise reduction screens be built (Rijksoverheid nd). Noise measures are therefore no ‘negotiable solutions’: they are prescribed by law in case noise levels are too high. Noise walls need to fit spatial plans of municipalities. As noise reduction only applies in the built environment, deterioration of the natural landscape is hardly an issue. Aesthetics is important and therefore, municipalities sometimes do not allow noise screens. Citizens consider noise walls as ugly for two reasons:

- The walls are dull and grey, and attract graffiti. Plants and flowers can cover the external side of the wall but that takes additional budgets for maintenance. The walls could be painted, which might be cheaper, but less effective in preventing graffiti.
- Noise walls create a visual barrier in a residential area. As people do not see their fellow villagers anymore (i.e. across the railroad track), they perceive the local community as being split up by a noise screens.

Local protests against railway noise screens often occur, for example in Heiloo (NH Nieuws 2017), Tricht (Bijl 2011), Gouda (Peters 2017). Also in Germany, railway noise screens are often controversial, like e.g. in Hohenlimburg (Bremshey 2019) and Vilshofen (Glas 2020). In principle, there are options to reduce railroad noise without applying high screens. Besides adapting the railroad tracks, railroad noise can be reduced by lower walls that are placed close to the tracks . However, this solution affects railroad safety (in case of a train evacuation), and railroad maintenance becomes harder (Prorail 2018). Hence, for a local community railway noise screening is not a simple benefit; It has costs and benefits, and the issue is not just health, but also involves the aesthetics of the village and community life.

3.3.1. Railroad noise in America

America is a village at the Eindhoven-Venlo railroad, and part of the freight connection between Rotterdam and the Ruhr area/Southern Germany. The village is therefore confronted with rail nuisances. In 2016, ProRail published the "Remediation plan for railway tracks" for the Southern Netherlands: Noise measures were required a.o. in America. The measures to be taken should be determined by further studies. The municipality of "Horst aan de Maas', to which America belongs, prepared an urban development vision in July 2017. This vision emphasized source measures to combat noise and noise barriers no higher than 1.5 meters. Consultations regarding this vision took place in the autumn of 2017. In America, the village insisted on 3 meter screens on the north side of the tracks, of which the top 1.5 meters would preferably be transparent. Villagers held various opinions regarding measures to be taken on the south side of the tracks (screens max. 1 or 3 meters high). In view of the reactions of the population, the municipality decided to allow ProRail to place 3 meters high noise screens along the tracks in America. Based on this vision, ProRail made a noise reduction plan which encompassed 3 m high noise screens. The final plan was published in june 2020.
However, in the meantime ProRail had started the project to study mounting PV panels upon noise screens. The America location seemed very suitable to test the ideas because:
- The railroad through America was oriented east-west.
- The length of the noise screens to be installed was not too long.
- Based on the information from the urban development plan and discussions with the municipality, there appeared to be support for 3 m high noise screens that offered options for PV.

As ProRail quickly needed data on the technical and economic feasibility of solar panels on noise screens, it would imply that noise screens in America would be constructed several years earlier than initially planned.

3.2. Participation process

The project consortium NEWRAIL carried out the studies regarding PV on noise screens. The local energy cooperative Reindonk Energie would take over the exploitation of the solar panels after the test period of two years. Residents of America could participate in the decision making on these PV panels and the design of the screens, by a three stage process: First there would be a 'questions/information session', afterwards a 'discussion session' and finally there would be design sessions. On May 27 2020, NEWRAIL and the village working group had an 'questions/information' session. Villagers had various doubts regarding noise effects of solar panels on noise screens. Moreover, participation in PV electricity generation was a complex issue. The NEWRAIL team would gather the required information, and it was decided that NEWRAIL and the village working group would jointly organise an open participation meeting on September 23. Moreover, the village working group was introduced to an independent expert regarding their question if model calculations of noise levels were reliable.
On the 9th of july, ProRail's noise reduction plans for America had been published, and especially the 3 meter high noise screens on both sides of the railway tracks had created unrest. Some villagers were submitting legal objections to the plan. Alderman Eric Beurskens tried to ease the situation: *'The residents need not worry about this. The residents who live on the church side have already made very high hedges, so they probably won't even see the screens. On the other side, the dwellings are a bit further removed, so their view will be less affected…. village and municipality have jointly decided in favour of these screens'*.
For the open discussion meeting on September 23rd, Frank Elbers (noise consultancy dBVision) was invited to introduce the issue of noise screening, the impact of PV panels on noise screens, and to answer any questions from the participants. Moreover, the financial participation in the solar panels was explained. Although the noise screens as such were not part of the agenda, it soon turned out that this was the main issue for the villagers. A number of participants spoke out emphatically against the "Berlin Wall" through their village. There was, however, understanding for the noise nuisances that some residents experienced. The village opted for a low screen on the south side, and a high transparent screen on the north side. In fact, the conclusion of the evening was that the questions regarding the influence of solar panels on noise reduction had been answered adequately and that there were no concerns left. Those present had much more concerns about the negative influence of the noise screens on the appearance of the village. As a result of the participation meeting, regional newspaper 'De Limburger' wrote on October 30 *"America does not want a 'Berlin wall' that splits the village in two"*.
NEWRAIL decided to make a number of visual impressions that would show the villagers how the railway zone would look with various noise walls and PV panels:

1. Noise screens as provided for in the noise remediation plan, made of wood fiber concrete
2. Noise screens as provided for in the noise remediation plan, top 2 meters of glass
3. Noise screens as provided for in the noise remediation plan, with glass panels around the railway crossing

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These were visuals were shared with the village working group. The village working group added two alternatives without visualization:

4. No noise screens
5. Noise screens of 1 meter high on the south side and 3 meters high on the north side, of which the top 2 meters are transparent,

and presented these on their website to the villagers

Figure 2 Example of a visualization: transparent screens at railway crossing

The village community could respond to these alternatives. Most respondents preferred alternatives 4 or 5.
On 19 November 2020, the ProRail noise reduction plans for America were approved by national government. The America village group decided to appeal, as its objections were overruled. The appeal procedure will take approximately 1,5 years, which implies that NEWRAIL cannot carry out its PV tests in America, as the project has to finish earlier. Another test site was found, with no residents nearby. All noise screen solar power plans for America were cancelled.

4. Reflexion

4.1. Conflict in local energy projects

Debates on local renewable energy projects generally focus on what actors that initiate project ideas, are allowed to do; i.e. on the harm that projects bring to the local inhabitants. If nobody suffers from a project, there should not be any objections. This has been the traditional base for environmental law: not inflicting harm to others (Reynard 2002). However, this criterion has lost its clarity. What about harm to wildlife, what about visual impacts, what about the increasing utilisation of public infrastructures, and what about (low) noise levels? The harm of these impacts is often not very clear, in terms of loss of health or economic opportunities. However, such projects cause loss of enjoyment of life. The decline of real estate value near wind- en solar parks is a clear indication for that (Dröes and Koster 2016, Droes and Koster 2019). The implication is that projects should not just fulfil legal requirements in terms direct harm. Decisions on projects should also be based on ‘fairness’; fairness in regard to the sum of costs and benefits for the location, and fairness in regard to the distribution of those costs and benefits between stakeholders. In that case, decision-making is neither on the direct impacts of various renewable energy technologies as such, nor on what citizens are obliged to accept: it is on fair decisions. And what is fair is not determined by legal rules, scientific evidence, or standard financial compensation rules. History plays a role as old feelings of being disadvantaged, both at individual and at group level, might re-emerge in such debates. In fact in all three case studies simple norms regarding ‘measurable impacts, did not prevent conflict.

4.2. Levels of embedding of renewable energy plans

Thus far, renewable energy production is hardly carried out just for its economic benefits; it is carried out to prevent climate change and fossil fuel depletion. These issues are of a global nature, and therefore handled at supranational level. National governments have translated these objectives in national renewable energy plans for which they might have developed a support base. In our cases, there are national policy plans for wind energy and for stimulating local initiatives. These plans have been developed interactively with provincial governments and the energy sector. However, the resulting covenant on wind energy encompassed a clause against those provinces that would not deliver: National government would overrule them, and take control (Environment and Affairs 2014). Enforcing national consensus on the provincial levels could perhaps be legitimated from by the need for climate action, but it takes time. Building up a substantial level of regional/local consensus takes even more time and serious efforts. From the Heeten case, we can see what efforts it takes to reach a local consensus. No matter how many national organisations support national plans, local consensus does not trickle down from the national level.

4.3. The paradox of a good start

In participation processes, the start is decisive for the further process. If the start is respectful and friendly, and the viewpoints of citizens are valued, the further interaction might be productive. However, if it is made clear that:
- no matter what citizens say, the project idea will not be affected, or
- no matter what officials say, the project idea is non-negotiable

the atmosphere to work out a joint solution is absent.
The consequences of both ways of starting interaction are not always very clear at the beginning. In the case of the wind park, the national government almost immediately took away all power from local officials. It created one of the ‘worst case practices’ (Bröring 2017) of renewable energy decision making.
In the beginning of decision making, it might be tempting to streamline procedures, and not to be slowed down by what might seem ‘pointless meetings’. One might hope ‘to get away with it’ or that determination might scare off opponents. However, such a decision cannot be undone. Later, when such damage is clear, there is no way to forge a solution and any decision will only be finalized after legal battles. Nobody will be really satisfied, and relations might be damaged for decades. The wind power case is a clear example, but also the course of affairs in the noise wall project makes clear that small decision against stakeholder in the early phases of a project might resurface later: rejection of a requirement of citizens in the beginning was the cause of terminating the PV on noise wall project much later.
Therefore, in general, strategies aimed at sidelining an opponent, either by outsmarting them or by execution of power are not smart in the end. Quick action before anybody is aware what is at stake will not contribute to a productive dialogue. For example in 2011, the municipality of Boxtel issued a licence to the British gas company Cuadrilla, to start exploratory drilling for shale gas in their territory (Persson 2011). Only after the permit was issued, the media payed attention to this application. Inhabitants got worried, and started studying the issue. Internationally, there were growing worries about the impacts of shale gas fracking, which were highlighted in the film ‘Gasland’, by Josh Fox (Fox 2010). Especially after this film was broadcasted on Netherlands national television, the local population got worried. A local committee appealed against the permit and the court annihilated the permit (ANP/Redactie AD 2011), which became the start of a legal battle. This controversy was terminated in 2018, after the minister of Economic Affairs announced in parliament that there would not be any shale gas drilling in The Netherlands (van Mersbergen 2018).
Outsmarting opponents, like getting a licence before opponents are aware, is a risky strategy as project initiators might lose their investments and public credibility.

5. Towards consensus oriented participatory decision making

During the 1990s, various attempts started to revitalise procedures for public participation in local decision-making. Until the 1990s, participation had been confined to public hearings regarding infrastructure decisions. Such hearings did not really contribute to creating consensus among stakeholders. On the contrary, they generally triggered a process in which contestants were entrenched in fortified positions. Moreover, decision making processes were much delayed by this process, as parties were adding studies to support their own vision (Bruning 1994). In reaction, there were various attempts to introduce new procedures to involve stakeholders in public decisions (De Rooij 1994, van Enthoven and de Rooij 1996). Generally, a more open interaction with stakeholders, before problems were defined, and pathways towards solutions entered, was the basis of these new approaches.
In the beginning, decision makers feared that the new procedures would create conflict between stakeholders and the responsible politicians. However, it turned out that by a good participation processes, decision makers might learn, and take better decisions. Participatory decision-making does not erode the position of elected bodies, on the contrary. Political parties can actively determine their own position by actively following the participation process and make themselves less dependent on the information provided by the executives.
Participation should definitely not be confused with promoting "acceptance". If "creating support" or "acceptance" is limited to informing citizens, there is nothing wrong with this, but if this clearly aims to win citizens over for already established government policies, this degenerates into propaganda with all its negative consequences. Citizens recognize propaganda and mistrust is reinforced rather than removed (Cf. Wolf 2020).
Participation sometimes leads to disagreements. That is not a problem, it might even be considered a precondition for participation as it is a sign that there are crucial issues at stake for local communities; or in other words: if there is nothing "at stake", then there are no "stakeholders", and decision-making is of no interest. Citizens' participation in decision-making actually makes sense only if there are public issues and arguments "in favour" and "opposed". Specific ‘Interests’ of citizens might be good arguments, as long as stakeholders equally respect the interests of others. Debates become problematic if a difference of opinion leads to a "controversy":
- a difference of opinion is based on different values or interests and arguments derived from them; in a controversy. New arguments might create changes of position.
- in a controversy opinions have become fixed, and contestant select arguments to support that opinion (Nelkin 1974, Nelkin 1979, Mazur 1981, Mulder 2012).
Hence, in a controversy new arguments will not convince any opponent. A difference of opinion can eventually be bridged in a debate, or the debate can reveal a deeper layer from which the difference of opinion arises. This is impossible in a controversy.

Participation, How?

Especially scientists and engineers perceive the root cause of problems of local renewable energy decision making as ignorance: a lack of understanding of the challenges of climate change, the depletion of fossil fuels, and what it takes to replace the current energy system by one that is fuelled by renewable sources. However, local decision-making is on values (landscape, wildlife, nature) and on ‘fairness’, in the context of local factors and a local history. Much attention has been focussed on international decision making regarding climate change policies(Akerboom 2018), it is time to shift our attention to the local level in order to successfully implement measures.
Participation processes might have various aims. Stakeholders should be clearly informed on those aims, as it might easily turn into a source of conflict. Aims of such a process might be:
- Informing the population.

- Consult the population.
- Jointly shaping a decision with authorities
- Inviting stakeholders to develop a joint plan.(Edelenbos 1999)

In order to achieve these highest forms of participation, a high level of trust among stakeholders is required, and an open and transparent process is required. Mission driven agencies are not the proper organisations to run a participation process. Their mission prohibits an open and transparent local process, and might lure them into early shortcuts that have devastating effects. Local actors might be much better equipped to manage such a process.

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144 Development of a Sustainable Steel Cluster in Iran through Industrial Symbiosis

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Abstract

Sustainable industrial development aims to increase living standards of people while providing solutions for environmentally and socially sound industrialization. Clustering is one of the main industrialization patterns in today's economies, and in order to define sustainable development of industrial clusters, the concept of Industrial Symbiosis (IS) has been defined for decades. Industrial clusters are complex systems in which the formation of IS is influenced by internal (e.g., technical characteristics of the plants and actors' previous collaborations) and external factors (e.g., energy prices and environmental limitations). Using a social-technical perspective, this paper will explore which symbiotic exchanges are more likely to occur in a cluster under various technical and institutional arrangements. The research was conducted in three main steps. First, the technical potential of IS was assessed by mapping the cluster technical structure, exploring the availability of waste flows for recovery, and finding matching demands for recovered flows. Second, based on a survey amongst the main actors of the cluster an institutional analysis was conducted. This analysis provided insight into current inter-industry collaborations, institutions guiding those collaborations, and drivers and barriers for extending them in the form of IS. Third, based on the collected data and information of the two first steps, the socio-technical structure of the cluster was modelled in Linny-R, a Mixed Integer Linear Programming software developed in Delft University of Technology. The conceptualization of the linear modelling is based on decomposing complicated industrial systems into a set of simple processes and products. The method was applied to a case of the Persian Gulf Mining and Metals Special Economic Zone (PGSEZ) in Iran. The results indicate that the presence of a coordination body in the cluster, does not guarantee collaboration between companies. The institutional analysis showed a discrepancy between stakeholders' preferences and governing legislations for future IS collaboration. Financial stimulation and infrastructure provision highly motivate stakeholders for IS, but institutional statements are unclear and ineffective in this regard. Bounding the economic parameters with technical and institutional conditions showed that symbiotic exchanges could result in higher cash flow and less electricity consumption of the whole cluster in case of an

increase in the grid electricity price or restrictions on its supply. Examining the flows between unit operations resulted in higher temperature waste heat and increased its quantity by 8%. Encouraging all actors to participate in the exchanges and governmental investment could boost the opportunities. As literature has rarely investigated industrial symbiosis cases in the Middle East, this study provides insight for future regional comparative studies. This conceptualization could be adjusted for any industrial cluster and its application is not limited to industrial symbiosis.

Keywords: industrial symbiosis, socio-technical perspective, cluster development, MILP

Acronyms and Symbols

Almahdi Aluminium Complex	AAC
Bandar Abbas City	BAC
Direct reduction plant	DRP
Electric arc furnace	EAF
Hormoz Power Plant	HPP
Hormozgan Steel Complex	HOS
Investment cost	IC
Iranian Mines and Mining Industries Development and Renovation Organization	IMIDRO
Kish South Kaveh Steel Company	SKS
Mixed integer linear programming	MILP
Operation cost	OC
Persian Gulf Mines and Metals Special Economic Zone	PGSEZ
Persian Gulf Saba Steel Company	SAB
PGSEZ management	PGM
Steelmaking plant	SMP

Introduction

Waste material or energy exchange among nearby industrial plants, which aim to gain a collective economic or environmental benefit, is defined as Industrial Symbiosis (IS) (Chertow, 2007). IS results in more sustainable production processes by recovering and utilizing one industry's waste flows in other industries. The geographical proximity of industries in clusters offers favorable conditions for IS implementation. A system-level approach is needed to study IS formation in an industrial cluster considering its technical, social, and economic conditions, since industrial clusters are complex socio-technical systems.

The first step in IS implementation on industrial clusters is to assess if a technical potential for IS exists. IS is based upon a material or energy exchange between a source and a sink in which the source is a waste flow. In a cluster, material and energy are exchanged between unit operations, plants, and companies. However, there is no consistency in the literature about the source and sink exploration. Most IS studies have examined plant outlet flows (Boons et al., 2016; Kastner et al., 2015; Notarnicola et al., 2016), while some recent IS studies have examined flows inside the plant for IS purposes. The latter approach overlaps with process integration methods. Moreover, in the sink exploration, IS possibilities in future cluster development are overlooked. Here is a need for a multi-level IS potential assessment method to explore sources and sinks for symbiotic at different levels.

The next consideration in IS assessment is to gain insight into actors' willingness to engage in IS collaboration. In the literature, previous collaborations (Spekkink and Boons, 2016), the existence of an anchoring actor (Sun et al., 2017), and a range of drivers are acknowledged to encourage actors in future IS collaborations (Ashton and Bain, 2012; Mortensen and Kørnøv, 2019; Yu et al., 2014). Besides, actors' behaviour in a socio-technical system is guided by shared visions, social norms, and legislations, called institutions collectively (Crawford and Ostrom, 1995). The linguistic expression of institutions is referred to as institutional statements. ADICO grammar of institutions, introduced by Crawford and Ostrom, is a powerful tool to investigate and interpret institutional statements, which has not been used in the IS field before. On the other hand, economic circumstances influence actors' investment decision on waste recovery exchange. This paper aims to understand how technical, social, institutional and economic conditions influence formation of IS in an emerging industrial cluster in the long term. Thus, all these aspects are incorporated in a mixed integer linear programming (MILP) model. For this purpose, Linny-R software, developed in Delft University of Technology (Bots, 2021), is used.

This paper proposes a systematic approach to identify possible IS collaborations in an industrial cluster considering its technical, social, and economic conditions. The methodology is elaborated in the case study of Persian Gulf Mines and Metals Special Economic Zone (PGSEZ). IS implementation in this industry could result in more sustainable industrialization. The case study implementation focuses on waste energy flows, although the methodology applies to both material and energy.

The paper is structured as follows: The methods section introduces the case study and four main steps toward IS assessment. Then, the results of different steps are presented and discussed. Finally, the conclusions and contribution of this work to IS studies are elaborated.

Methods

Figure 1 demonstrates the system-level approach implemented in this paper to investigate IS formation in an industrial cluster. First, we assessed internal and external technical, collaborative, institutional, and economic conditions that influence IS. Then, all these aspects were modelled together in Linny-R. Optimization procedure in Linny-R resulted in production level of different processes, and consequently their consumption and generation rates and actors' cash flow. Investment in waste recovery plants and other actors' decisions to buy recovered flow resulted in symbiotic exchanges.

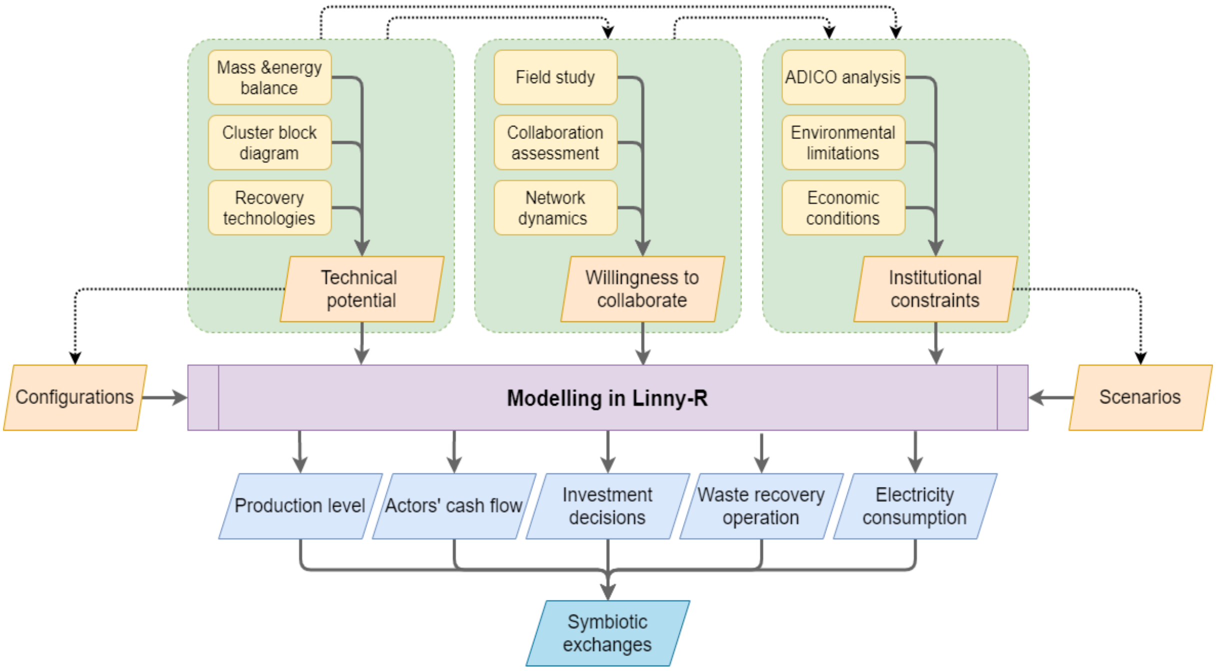

Figure 1 System-level approach implemented in this paper to study IS formation in a cluster

The case study

The method was implemented on the case study of PGSEZ in Iran. PGSEZ is located in the south of Iran, 14-kilometers from Bandar Abbas city (BAC), to utilize the advantage of proximity to the South Pars natural gas fields in developing energy-intensive metal processing industries. PGSEZ is an iron and steel-based industrial cluster located in the south of Iran. The iron and steel industry is one of the growing industries in emerging economies. World crude steel production has doubled during the last three decades, mainly by a steep increase in emerging economies. With 29 million tonnes yearly production, Iran stands in 10th place in world crude steel production (WSA, 2021), with plans to reach 55 million tonnes capacity soon (SEAISI, 2017). However, steel production generates a wide range of pollutants (SEAISI, 2008; Villar et al., 2012). Six percent of global CO_2 emissions and eight percent of energy-related emissions belong to iron and steel production. The cluster is managed by the state-owned corporation of Iranian Mines and Mining Industries Development and Renovation Organization (IMIDRO). PGSEZ management (here called PGM) is responsible for coordinating activities and providing shared infrastructure for industries. PGSEZ has several development plans either inside existing companies or establishing new industries. However, industrial development in Iran suffers from water scarcity (Madani, 2014; Madani et al., 2016), high CO_2 emissions (Global Carbon Project, 2016), and sanctions. Active companies in PGSEZ are three steel production (SKS, HOS, and SAB), an aluminum production (AAC), and one gas turbine power plant (HPP). An under-construction pelletizing plant was not considered in this study.

Table 1 Companies and plant located in PGSEZ with their production capacities

Company	Plant	Type	Capacity
Kish South Kaveh Steel Company (SKS) (sksco.ir/)	P1	Midrex direct reduction	1,850,000 t/year
	P2	EAF steelmaking	1,200,000 t/year
Hormozgan Steel Complex (HOS) (hosco.ir/)	P3	Midrex direct reduction	1,650,000 t/year
	P4	EAF steelmaking	1,500,000 t/year
	P5	Cold Briquetting	75,000 t/year
Hormoz Power Plant (HPP) (pgsez.ir/)	P6	Gas turbine power plant	160 MW
Persian Gulf Saba Steel Company (SAB) (sabasteel.co)	P7	Midrex direct reduction	1,000,000 t/year
Almahdi Aluminum Complex (AAC) (almahdi.ir/)	P8	Anode Baking	93,000 t/year
	P9	Hall-Héroult Aluminum Refining	172,000 t/year

Technical potential assessment

Industrial networks can be presented as a collection of sources and sinks (Kastner et al., 2015). In IS context, sources are waste flows, and sinks are processes or plants which consume these sources. A previous study (Noori et al., 2021) has proposed a method to uncover technically possible symbiotic exchanges which have not become functional yet. The methodology was based on identifying sources and sinks and matching between them considering recovery technologies. For this purpose, first, all incoming and outgoing material and energy flows of every plant were mapped. Flow rates were gathered during site visits or obtained from literature or calculated based on mass and energy balances where field data was not available.

As stated in the introduction, the system boundaries for source and sink exploration have not been defined in the literature explicitly. We explored sources and sinks at different levels to investigate the effect of boundary settings on perceived technical potential. For source exploration, we first looked up plant outflows. Then, these flows were traced back inside plant boundaries for any processing before disposals, such as cooling and dilution. In sink exploration, first, we searched for energy demand inside the cluster. Then, utilization possibilities in the nearby urban area or future cluster development were explored. In the end, the technology ranking framework developed by Oluleye et al. (2017) was implemented to select the most suitable heat recovery options based on source temperature and sink type (heating, cooling, or electricity).

Social readiness for IS

To get insight into cluster social readiness for IS formation; a previous study (Noori et al., 2020) was conducted on two grounds: A field study to understand the internal social structure of the cluster and institutional analysis to investigate national or regional rules and regulations governing IS implementation in Iran.

Collaboration assessment

For the field study, a three-part questionnaire was distributed among managers and deputies of the companies. In the first part, called the collaborations matrix, the respondents were asked to indicate if they have had previous collaborations that could lead to future symbiotic exchanges. Such activities are called pre-emergence collaborations (Spekkink and Boons, 2016). Asked pre-emergence collaborations in the questionnaire were technical advice and consultation, supervision and project management, product trade, by-product trade, utility supply, and joint investment. In the second part, the structure of successful collaborations was studied in terms of involved stakeholders and their roles. In the last part, IS drivers from the literature were ranked by respondents to uncover which drivers are the most dominant in this cluster.

ADICO institutional analysis

ADICO grammar of institutions is a systematic approach to study institutional statements (Basurto et al., 2010). Five ADICO components are attribute (A), deontic (D), aim (I), condition (C), and or else (O). To implement ADICO in IS field, we adapted it to IS dynamics framework introduced by Boons et al. (2016) (Table 2). Attributes were classified to the industry, cluster management, and government and governmental organizations. Aims were also categorized into nine IS-related topics. For this purpose, as the first step of institutional analysis, regulations governing development, environmental protection, and energy efficiency in the industrial sector were chosen among national documents. The list of selected law books and procedures was checked with experts in the cluster to ensure all currently effective regulations are considered. Then, all clauses, paragraphs, and notes were separated and copied to an excel sheet, complicated parts were broken into simple ones. The investigation scope narrowed down to IS-related statements (e.g., cluster development, waste management, and energy recovery). Subsequently, five ADICO components were distinguished for each statement. Not every institutional statement includes all components. Rules incorporate all five components, norms do not declare penalties or sanctions, and shared strategies are composed of an attribute, aim, and condition only.

Table 2 ADICO grammar linked to IS dynamics (Noori et al., 2020)

Attribute	Deontic	Topic	Condition	Or else
Government/ Governmental Organisation Cluster Management Industries	Obligation Permission Prohibition	Pricing Eco-efficiency improvement Infrastructure provision Market brokerage Knowledge development and awareness Economic stimulation Industrial and Cluster development Regulatory and legislation Environmental monitoring and assessment	When Where If Unless	Penalties Sanctions

Economic conditions

In general, waste heat must be recovered before utilization in other plants. Starting a new waste recovery plant (WR) has investment and operation expenses and influences the actor's cash flow. Therefore, all costs associated with the operation of existing plants and future WRs were estimated. It was assumed that existing plants have been paid off already. Therefore, investment cost was assigned to WRs only. Capital cost for different waste recovery technologies was obtained from literature and adjusted by Middle East location factors. The equivalent annual cost was calculated assuming an interest rate of 10% and a lifetime of 20 years (Equation 1 and 2). Annualized cost was calculated based on Equation 3 and was deducted from actor's cash flow in case WR came into operation. Domestic and industrial electricity and natural gas prices were obtained from a previous study (Noori, 2020), raw material and product prices were collected from publicly available price lists, and operation costs obtained from similar plants, adjusted by location factors (Rubin et al., 2021).

$$CRF = \frac{R}{1 - (1+R)^{-n}} \quad \text{(Eq. 1)}$$

$$EAC = Capital\ cost \times LF_{inv} \times CRF \quad \text{(Eq. 2)}$$

$$AC = EAC + (O\&M_{fixed} \times LF_{labour}) \quad \text{(Eq. 3)}$$

Where:

AC: annualized cost

EAC: equivalent annual cost

CRF: capital recovery factor

R: interest rate

n: lifetime

$O\&M_{fixed}$: fixed operation and maintenance cost

$O\&M_{var}$: variable operation and maintenance cost

LF_{inv}: Investment cost location factor (material cost factor x contingency factor)

LF_{labour}: labour cost location factor (labour productivity factor x labour cost factor)

Cluster modelling in Linny-R

Linny-R is a diagram-based MILP modelling tool for techno-economic analysis and optimization of industrial systems. The building blocks of a Linny-R model are products and processes. Linny-R also accepts non-physical processes and flows, which provides the opportunity to incorporate non-physical activities such as buying, selling, contracting, or willingness in the model. Constraints and prices can be assigned to non-physical processes in the same way as physical ones.

To study IS formation; the current structure of the cluster was built in Linny-R first. Each production plant modelled as a process and its incoming and outgoing flows as products. Production capacities and flow rates were obtained from the integrated cluster block diagram, and process expenditures and revenues were collected during economic inventory. Then, designated waste recovery units and possible exchanges were added to the model to investigate which collaborations could shape in the cluster under given technical, social, and economic conditions. Modelling period was selected to be 20 years with time steps of one year. The main Linny-R functionalities regarding waste recovery and exchange are elaborated in this section.

Conceptualizing waste recovery and exchange decision

Figure 2 shows how symbiotic exchanges were conceptualized in this study. The conceptualization has three pillars: decomposing IS to a set of physical and non-physical activities, applying system constraints to processes and products, and giving actors the opportunities to select among different routes in each step. In this conceptualization, actors decide for waste recovery and exchange based on their economic benefit and willingness to collaborate. Waste flow W, which is generated by actor k, could be sent to waste disposal (WD) or recovered in waste recovery (WR) in the form of $R'_{recovered}$. In general, $R'_{recovered}$ could be used internally by actor *k* or sold to the other actors. On the other hand, actor *h* could buy resource R' from the market or actor *k*. IS shapes when actor *k* chooses WR over WD, and actor *h* selects $R'_{recovered}$ over R'_{market}. This conceptualization represents self-organized IS in which two actors collaborate without intervention or facilitation by the cluster management or governmental organizations.

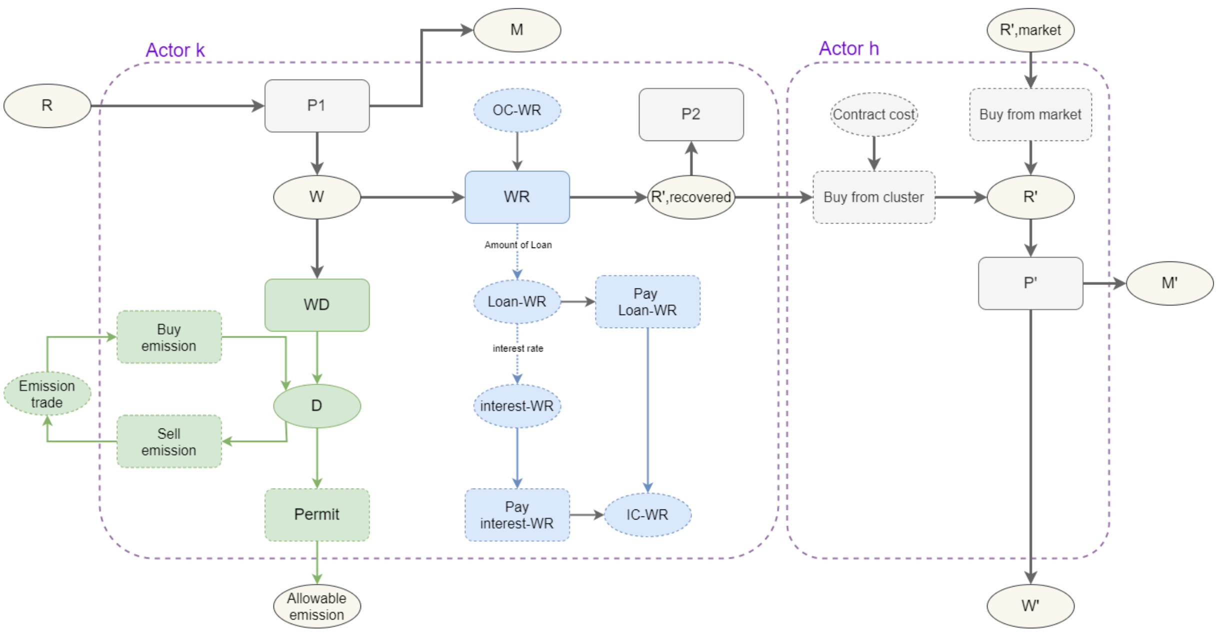

Figure 2 Formation of IS among two actors

All processes and products in Figure 2 are subjected to socio-technical costs and constraints. WD is limited by price-based or quantity-based emission control policies. The figure shows how such limitations are detailed in Linn-R by either assigning an upper bound on allowable disposal or negative price on emission trade. On the other hand, WR exerts new investment cost (IC) and operation cost (OC) on actor *k*. As illustrated in this figure, OC and IC could be deducted from the actor's cash flow using data type products (dotted ones). However, symbiotic exchange will not shape if the two actors are not interested in collaboration with each other. We reflected actors' willingness to collaborate in the upper bound of the "Buy from cluster" process.

Furthermore, exchange costs (e.g., contracting and transportation) are assigned to this process.

Configurations and scenarios

In this paper, we built two configurations of the cluster as listed in Table 3. WR0 represents the cluster without any waste recovery and exchange. In WR+, waste recovery plant P14 was added to the model to recover the high-grade waste heat generated in the power plant as electricity. The generated electricity can be consumed by other companies inside the cluster or sent to Bandar Abbas (BAC) to be used in conventional air conditioners for cooling purposes. Household electricity demand for cooling was obtained from nationally available data for Hormozgan province and considered to increase yearly proportional to population growth. As elaborated in Table 4, three energy price scenarios were examined on each configuration to study cluster operation and IS formation under varying external factors.

Table 3 Waste recovery and exchange possibilities in configurations WR0 and WR+

Configuration	Waste recovery	Possible exchanges
WR0	No waste recovery exists	No symbiotic exchange
WR+	Electricity recovery from WH,P6 (P14)	HPP electricity exchange with SKS, HOS, SAB, AAC, and BAC

Table 4 Energy price scenarios considered in this study

Scenario	Explanation
EN0 (Fixed)	No change in electricity and natural gas prices during the next 20 years
EN+ (Moderate rise)	10% annual rise in electricity and natural gas prices increase over the next 20 years
EN* (Drastic rise)	Electricity and natural gas prices doubled and then increase with the rate of 10% over the next 20 years

Results and Discussion

Integrated cluster block diagram

Integrating block diagrams of all production and utility plants in the form of cluster block diagrams provided knowledge about the material and energy performance of the whole cluster. Yearly, 4.32 million tonnes main product was produced from 8.89 million tonnes input raw material. 4.57 million Tonnes of gaseous or solid by-products were also generated, which means the material productivity of the whole cluster was around 49%. From 1,448 MW energy input to PGSEZ in the form of electricity, natural gas, and coke, around 41% (592 MW) was emitted as high, medium, and low-grade waste heat streams. 160 MW electricity was generated and consumed inside the cluster. 21.89 million m^3 seawater was taken, and 14.91 million m^3 brine was disposed to the gulf yearly, plus 3.68 million m^3 of industrial wastewater.

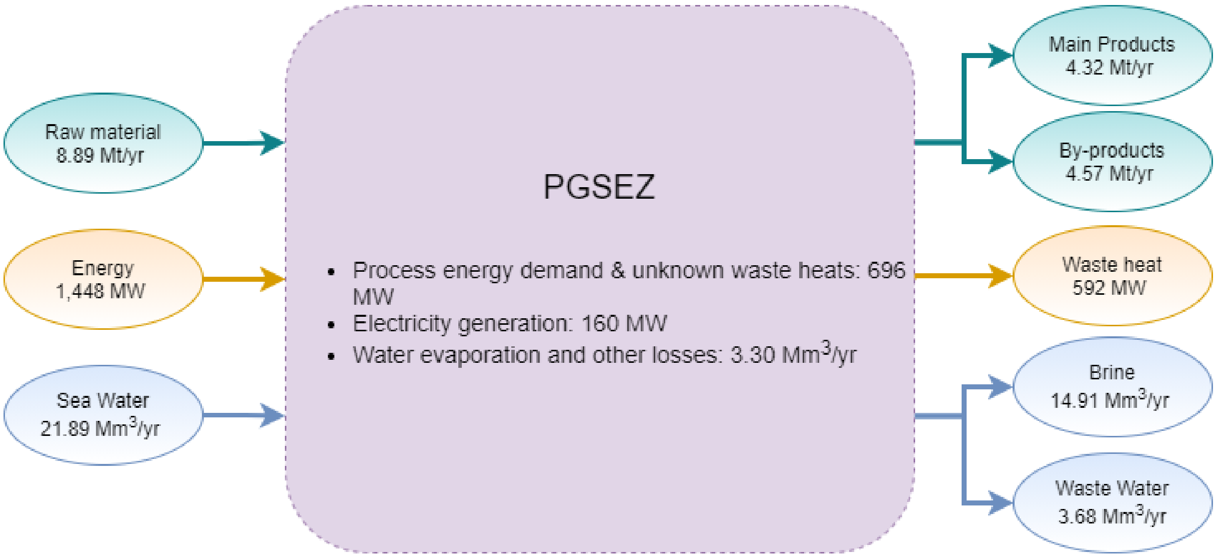

Figure 3 Cluster block diagram incorporating material, energy, and water flows

Multi-level assessment of energy exchange potential

As stated in the previous section, 592 MW waste heat was spotted by studying plant output flows. In plant-level source exploration, process flow diagrams of steelmaking (SMP) and direct reduction (DRP) plants were studied in more detail. SMP investigation revealed that electric arc furnace (EAF) flue gas, which carries theoretically 15 to 35 percent of EAF energy input (Barati, 2010; Kirschen et al., 2011), is mixed with other gases and cooled down before exhaust at 90 °C. Utilizing energy content of this flow for IS before mixing and cooling replaces 40 MW low-grade heat with 85 MW high-grade heat. In DRP, combustion flue gas is diluted with fresh air before disposal because of environmental limitations. High-grade waste heat will be available for IS purposes if the flue gas is utilized before dilution. In multi-level sink exploration, intra-cluster and outside-cluster utilization were examined, and suitable waste recovery technology was selected according to Oluleye et al. (2017). Intra-cluster demand was considered electricity, while outside cluster utilization was chosen based on first ranked technology. The results are summarized in Table 5. It shows that source exploration at the intra-plant level reveals higher qualities and quantities of available waste heat. Besides, waste heat can be recovered in the form of cooling or heating through more efficient technologies if sink exploration is not limited to intra-cluster demands.

Table 5 Multi-level comparison of IS potential in PGSEZ (Noori et al., 2021)

	Available waste heat (MW)	Temperature (°C)	Energy exchange potential (MW)			
			Intra- Cluster		1st ranked technology	
			Amount	Form	Amount	Form
Plant input-output	40	90	4 (1)	electricity	28 (2)	cooling
	75	150	13 (3)	electricity	90 (4)	cooling
	130	300	35 (5)	electricity	104 (7)	heating
	330	500	106 (6)	electricity	264 (7)	heating
Intra-plant level	75	150	13 (3)	electricity	90 (4)	cooling
	130	450	42 (6)	electricity	104 (7)	heating
	330	500	106 (6)	electricity	264 (7)	heating
	85	1100	27 (6)	electricity	68 (7)	heating

(1) ORC efficiency for low-temperature input heat was assumed 10% (Oluleye et al., 2016)
(2) Single-stage absorption chiller COP was assumed 0.7 (Reddy, 2013)
(3) ORC efficiency was assumed 17% (Oluleye et al., 2016)
(4) Double stage absorption chiller COP was assumed 1.2 (Reddy, 2013)
(5) ORC efficiency was assumed 27% (Oluleye et al., 2016)
(6) The efficiency of the HRSG plus steam turbine is assumed 32% (Ahmed et al., 2018).
(7) The average efficiency of heat recovery heat exchangers was considered 80% (Jouhara et al., 2018)

Previous collaborations and the role of cluster management

As illustrated in Figure 4, most pre-emergence collaborations were shaped among three steel production companies or cluster management. The next part of the questionnaire revealed that the cluster management or other governmental organizations were involved in around 75% of successful collaborations in the last five years. Nevertheless, they have provided the required infrastructures for less than 30% of collaborations. In addition, involved industries have initiated activities themselves. Among different IS drivers, the respondents admitted infrastructure readiness, governmental financial stimulations, and resource scarcity as the most encouraging motives to engage in new IS collaborations. On the other hand, workshops and seminars, lowering Greenhouse Gas Emissions, and rising waste disposal costs were less prominent drivers for the respondents.

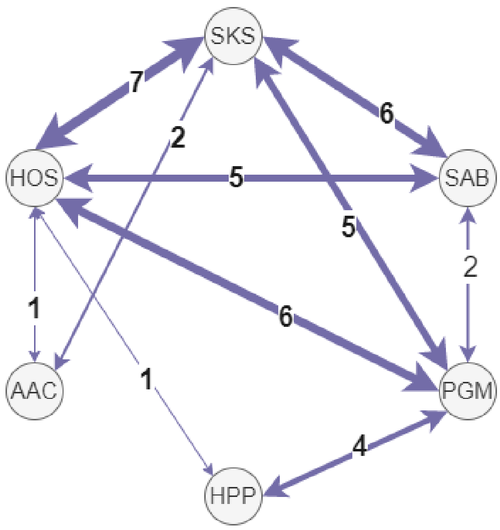

Figure 4 Number of pre-emergence collaborations among different actors during the last five years

Institutional lens upon IS

Figure 5 outlines the results of ADICO analysis. Among 183 institutional statements, only 19 were identified as rules, with an explicit penalty or sanction in case of violation. In addition, the role of cluster management was not elaborated in the legislation, as we found only five statements with cluster management as an attribute. In topic, most statements proposed eco-efficiency improvement, environmental monitoring and assessment, and industrial or cluster development. It could be said that legislation in Iran does not support either facilitated IS or eco-clustering considering only a few statements regarding infrastructure provision, knowledge development, and market brokerage. Self-organization and governmental planning are the most supported dynamics by legislation. This finding was in line with the field study outcomes which showed the despite existence of cluster management team, the most successful previous collaborations have been initiated and facilitated by the industries themselves.

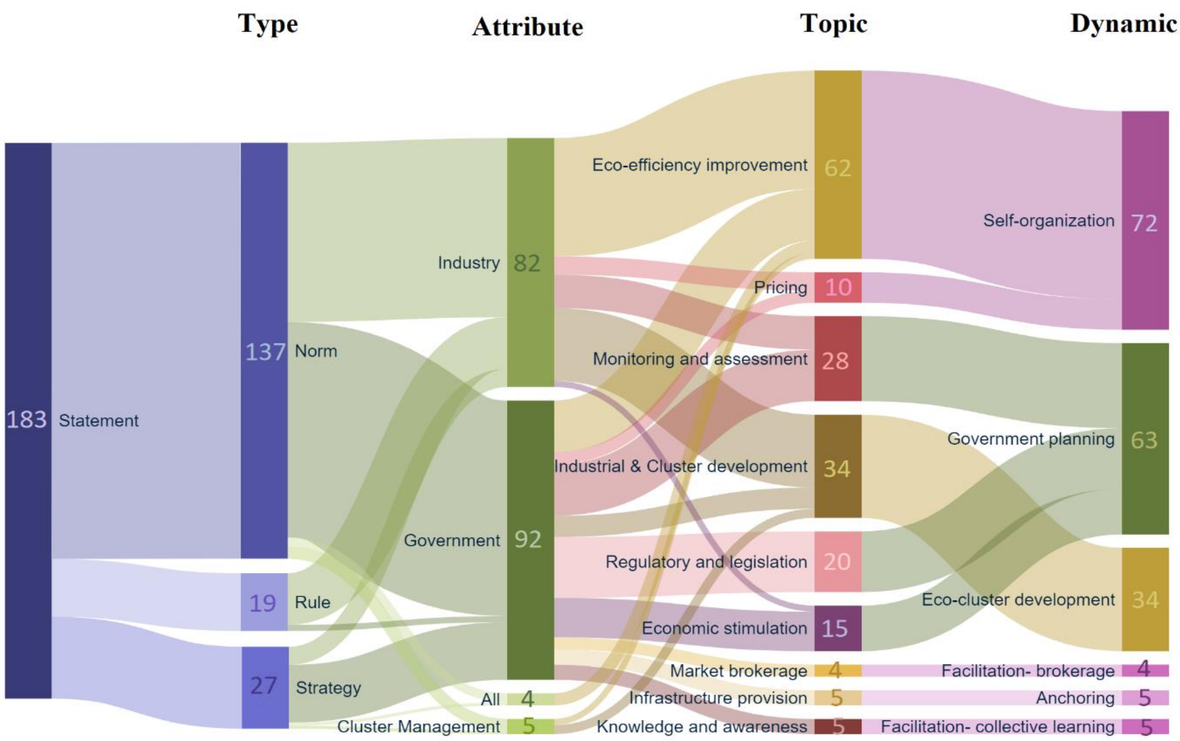

Figure 5 Composition of invetigated institutional statements in terms of type, attribute, aim, and supported IS dynamic (Noori et al., 2020)

Production levels and cash flows

Before investigating the operation of waste recovery units, the production level of nine industrial plants was studied under three energy price scenarios. Under the EN0 scenario, the production level of all plants remained fixed over 20 years. However, by a 10% yearly rise in electricity and natural gas prices, the plants shut down after few years. The aluminum plant, which is the most energy-intensive one, stopped after eight years. Then, plants in HOS, SKS, and SAB stopped operation one after each other (Figure 6). The same pattern was observed in EN* scenario, but with a more severe drop in production levels. Nevertheless, power plant operation was not influenced by the rise in energy price. Comparing cluster operation in WR0 and WR+ configurations revealed that the existence of waste recovery and exchange aided plants' production up to higher energy prices. As energy cost is one of the main expenditures of steel and aluminum industries, all actors' cash flow dropped due to energy price increment. Again, the drop was more drastic in EN* scenario compared to EN+. Only the power plant's cash flow increased, as this plant earned more from electricity generation.

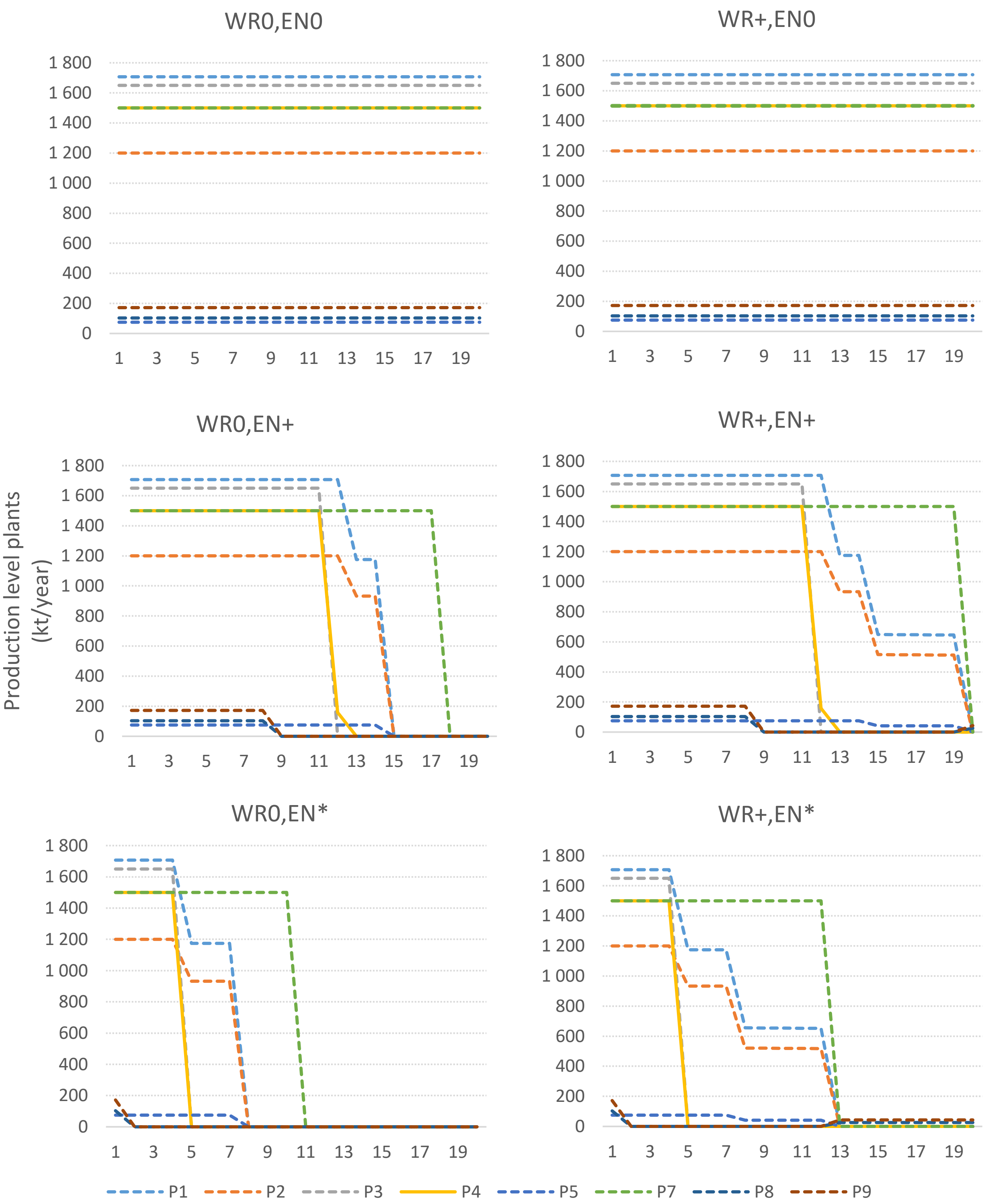

Figure 6 Production level of industrial plants under different scenarios and configurations

Waste recovery and symbiotic exchanges

P14 came into operation in all three scenarios. Recovered electricity in P14 found different destinations under different scenarios. In all scenarios, recovered electricity was cheaper than urban electricity price. Therefore, BAC received all its electricity demand from recovered electricity in the cluster. By increase in energy prices in the EN+ scenario, four aluminium and steel industries inside the cluster also consumed part of recovered electricity. However, the capacity of P14 exceeded cluster internal demand, and excess electricity was sent to the grid. However, electricity supply to the grid is not categorized as IS by definition. Details of exchanged electricity among actors are illustrated in Figure 6. In EN* scenario, all recovered electricity was exchanged with the other actors, and there was no electricity supply to the grid. Recovered electricity consumption by AAC increased significantly in this scenario. As explained in the previous section, AAC stopped production after one year in this scenario. But, the company was able to come into operation again in the last eight years by receiving recovered electricity from HPP. It was not possible to interpret symbiotic exchanges in this figure without understanding the production plant's behaviour under different scenarios. Hence, IS cannot be understood separately from the whole cluster operation.

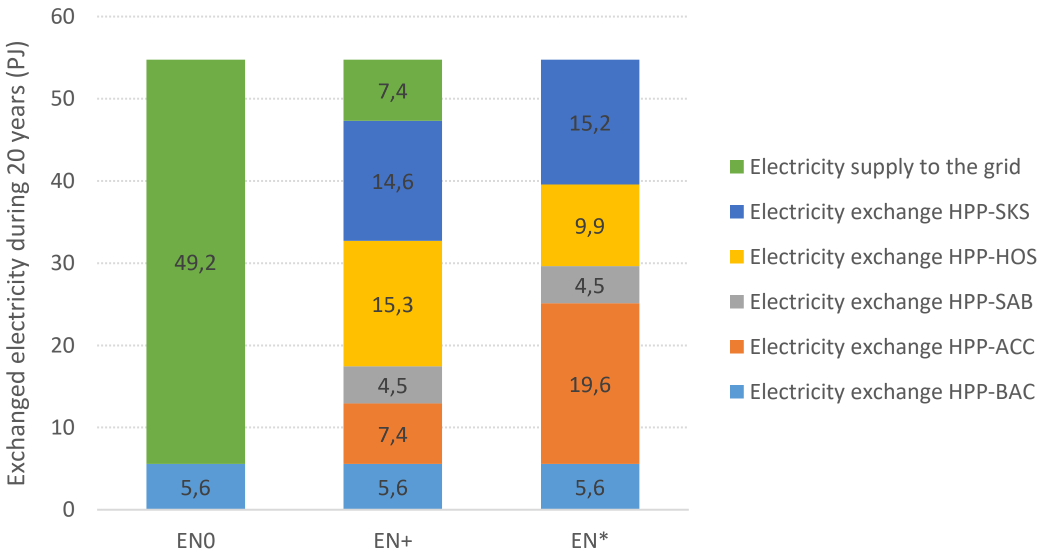

Figure 7 Amount of exchanged electricity between actors over 20 years

Cluster performance improvement

In this study, cluster cash flow and grid electricity consumption were studied as cluster economic and energy performance indicators. As shown in Table 6, both measures improved because of introducing waste recovery and exchange options to the cluster. As explained previously, cluster cash flow and electricity consumption dropped by increasing energy prices. However, cash flow was higher in WR+ compared to WR0 under all scenarios despite all expenses required for IS formation (investment, operation, and contract costs). Negative net grid electricity intake values in Table 6 express supply from the grid. Around 54.8 PJ less grid electricity was consumed in the presence of waste recovery units. It showed that techno-economically feasible IS connections are not in line with actors' willingness to collaborate necessarily. HPP can improve cluster energy performance significantly if engaged in IS collaborations, although the company has not collaborated with the other actors in PGSEZ before.

Table 6 Changes in cluster economic and energy performance in 20 years under different configurations and scenarios

Configuration	WR0			WR+		
Scenario	**EN0**	**EN+**	**EN***	**EN0**	**EN+**	**EN***
Cluster cash flow (M€)	5,062.6	2,226.6	1,026.6	5,092.7	2,606.1	1,441.6
Net grid electricity intake (PJ)	-311.9	-122.4	15.3	-257.2	-80.0	40.4

Conclusions

In this study, frameworks from waste heat utilization, the emergence of collaborations, institutional analysis, and IS dynamics are integrated and utilized to provide a holistic insight into the complex structure of industrial clusters. Then, this complex structure was modelled in Linny-R to investigate the cluster performance, specifically IS formation, under different circumstances.

The multi-level technical potential assessment showed that higher quality or quantity of waste heat might be available for IS purposes if waste flows are examined inside plant boundaries. Furthermore, recovered waste heat can find new destinations if sink exploration covers the nearby urban area or future cluster development possibilities. Although this paper focused on energy exchange assessment, the methodology applies to material networks as well.

In collaboration assessment, we investigated pre-emergence collaborations and their structure to get insight into actors' willingness to start IS. It revealed that, despite presence of a centralized management body in the cluster, pre-emergence collaborations were often self-organized. It was also inquired which IS drivers are more influential in the cluster, which led to infrastructure readiness, financial aid, and resource scarcity.

ADICO grammatical syntax was implemented to investigate legislation about IS implementation in Iran. Our analysis showed that although regulations encourage energy efficiency improvement and environmental monitoring, explicit penalties and sanctions in case of violation are not specified. Moreover, the responsibilities and authorities of cluster management were not elaborated in national-level legislation.

This modelling work shed light on the fact that ISO cannot be investigated as a standalone phenomenon. Changes in cluster internal or external conditions affect the operation of industrial plants and waste recovery plants simultaneously, so the whole cluster must be studied as a system. This method also reveals contradictions between techno-economically feasible IS collaborations and involved actors' willingness to collaborate. This outcome provides more realistic insights into socio-technically favourable collaborations and actors' investment decisions.

We investigate IS collaborations at the system level within the complex structure of the cluster. Under assumed conditions, symbiotic exchanges covered all required investment, operation, and contract costs and brought economic benefit for the cluster in the long term. It should be noticed that these conclusions are valid for conceptual design and system-level analysis. The establishment of suggested collaborations calls for more specific technical and economic considerations. However, IS is not the only sustainable industrial development strategy. At the system level, IS might create industrial decarbonisation synergies in combination with other options such as carbon capture and storage, which calls for further research.

Appendix A: Model input data

Table A1 Material and energy consumption and generation rates in different processes in PGSEZ (Noori et al., 2021)

Actor	Product	Process	flow rate	Unit
SKS	Pellet	P1	1.45	tonne/ tonne product
SKS	DRI,SKS	P1	1.00	tonne/ tonne product
SKS	Sludge,D	P1	0.05	tonne/ tonne product
SKS	Dust,D-SKS	P1	0.06	tonne/ tonne product
SKS	EL,i-SKS	P1	0.47	GJ/tonne product
SKS	NG-FS	P1	0.20	tonne/ tonne product
SKS	NG	P1	1.58	GJ/tonne product
SKS	WH,P1	P1	0.71	GJ/tonne product
SKS	IW	P1	1.00	Nm^3/tonne product
SKS	WW	P1	0.40	Nm^3/tonne product
HOS	Pellet	P3	1.45	tonne/ tonne product

Actor	Product	Process	flow rate	Unit
HOS	DRI,HOS	P3	1.00	tonne/ tonne product
HOS	Sludge,D	P3	0.06	tonne/ tonne product
HOS	Dust,D-HOS	P3	0.03	tonne/ tonne product
HOS	EL,i-HOS	P3	0.42	GJ/tonne product
HOS	NG,FS	P3	0.20	tonne/ tonne product
HOS	NG	P3	1.58	GJ/tonne product
HOS	WH,P3	P3	0.75	GJ/tonne product
HOS	IW	P3	1.02	Nm^3/tonne product
HOS	WW	P3	0.30	Nm^3/tonne product
SAB	Pellet	P7	1.37	tonne/ tonne product
SAB	HBI	P7	1.00	tonne/ tonne product
SAB	Sludge,D	P7	0.02	tonne/ tonne product
SAB	Dust,D	P7	0.02	tonne/ tonne product
SAB	EL,i-SAB	P7	0.50	GJ/tonne product
SAB	NG,FS	P7	0.19	tonne/ tonne product
SAB	NG	P7	1.49	GJ/tonne product
SAB	WH,P7	P7	0.72	GJ/tonne product
SAB	IW	P7	1.72	Nm^3/tonne product
SAB	WW	P7	0.69	Nm^3/tonne product
SKS	Scrap	P2	0.02	tonne/ tonne product
SKS	DRI,SKS	P2	1.26	tonne/ tonne product
SKS	Lime	P2	0.07	tonne/ tonne product
SKS	Ferroalloys	P2	0.03	tonne/ tonne product
SKS	Coke	P2	0.49	GJ/tonne product
SKS	Billet	P2	1.00	tonne/ tonne product
SKS	Slag	P2	0.26	tonne/ tonne product
SKS	Dust,S	P2	0.01	tonne/ tonne product
SKS	Sludge,S	P2	0.05	tonne/ tonne product

Actor	Product	Process	flow rate	Unit
SKS	Loss,CCM	P2	0.02	tonne/ tonne product
SKS	EL,i-SKS	P2	2.70	GJ/tonne product
SKS	NG	P2	0.18	GJ /tonne product
SKS	WH,P2	P2	0.47	GJ/tonne product
SKS	IW	P2	1.12	Nm^3/tonne product
SKS	WW	P2	0.53	Nm^3/tonne product
HOS	Scrap	P4	0.03	tonne/ tonne product
HOS	DRI,HOS	P4	1.23	tonne/ tonne product
HOS	Lime	P4	0.06	tonne/ tonne product
HOS	Ferroalloys	P4	0.05	tonne/ tonne product
HOS	Coke	P4	0.20	GJ /tonne product
HOS	Slab	P4	1.00	tonne/ tonne product
HOS	Slag	P4	0.26	tonne/ tonne product
HOS	Dust,S	P4	0.01	tonne/ tonne product
HOS	Sludge,S	P4	0.08	tonne/ tonne product
HOS	Loss,CCM	P4	0.02	tonne/ tonne product
HOS	EL,i-HOS	P4	2.76	GJ /tonne product
HOS	NG	P4	0.11	GJ /tonne product
HOS	WH,P4	P4	0.34	GJ /tonne product
HOS	IW	P4	0.93	Nm^3/tonne product
HOS	WW	P4	0.53	Nm^3/tonne product
AAC	Calcined Coke (CPC)	P8	0.60	tonne/ tonne product
AAC	Pitch (CTC)	P8	0.15	tonne/ tonne product
AAC	Spent Anode	P8	0.25	tonne/ tonne product
AAC	Anode	P8	1.00	tonne/ tonne product
AAC	NG	P8	2.45	GJ /tonne product
AAC	EL,i-AAC	P8	0.50	GJ /tonne product
AAC	WH,P8	P8	0.56	GJ /tonne product

Actor	Product	Process	flow rate	Unit
AAC	Alumina	P9	1.96	tonne/ tonne product
AAC	Cryolite	P9	0.03	tonne/ tonne product
AAC	Aluminum fluoride	P9	0.04	tonne/ tonne product
AAC	Anode	P9	0.45	tonne/ tonne product
AAC	Aluminum ingot	P9	1.00	tonne/ tonne product
AAC	SPL	P9	0.02	tonne/ tonne product
AAC	EL,i-AAC	P9	56.88	GJ /tonne product
AAC	WH,P9	P9	11.38	GJ /tonne product
HOS	Lime9	P5	0.02	tonne/ tonne product
HOS	Molasses	P5	0.04	tonne/ tonne product
HOS	CBI	P5	1.00	tonne/ tonne product
HOS	EL,i-HOS	P5	0.06	GJ /tonne product
HPP	NG	P6	3.06	GJ /kWh product
HPP	WH,P6	P6	2.06	GJ /kWh product
HPP	EL-HPP	P6	1.00	GJ /kWh product

Table A2 Input prices and costs

Resources	Value	unit	reference
Electricity at EN0	4.45	€/ Gj	(Noori et al., 2020)
Natural Gas at EN0	0.83	€/ Gj	(Noori et al., 2020)
Industrial Water	0.14	€/Nm^3	(Noori et al., 2020)
Pellet	100.0	€/tonne	(Vogl et al., 2018)
DRI	215.0	€/tonne	(Steelonthenet, 2020a)
Lime	120.0	€/tonne	(Steelonthenet, 2020b)
Molasses	100.0	€/tonne	
Coke	231.0	€/tonne	(Moya and Boulamanti, 2016)
scrap	225.0	€/tonne	(LME, 2016)
Ferroalloys	920.0	€/tonne	(Moya and Boulamanti, 2016)

Resources	Value	unit	reference
Alumina	279.5	€/tonne	
Aluminum Fluoride	1025	€/tonne	
Cryolite	900	€/tonne	
Calcined coke	200	€/tonne	
Pitch	200	€/tonne	
slab	410	€/tonne	(“Steel Price (Europe) | Historical Charts, Forecasts, & News,” n.d.)
Aluminum	1440	€/tonne	
CBI	280	€/tonne	(Bhattacharyya et al., 2019)
SMP variable cost	66.5	€/tonne	(Vogl et al., 2018)
DRP variable cost	27.5	€/tonne	(IEAGHG, 2013; Vogl et al., 2018)
ARP variable cost	200	€/tonne	(Rosenberg, 2012)

Table A3 Techno-economic characteristics of added waste recovery unit in configuration (b)

Actor	WR Process	Type	Output	Efficiency (%)	Capacity (GJ)	Investment (k€)	Operation Cost (k€/GJ)
HPP	P14	STP	EL	32	2,730	105,000	0.7

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156 Conflicts in meat consumption: exploring their effects on social norms and consumer behavior

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Abstract

There has been increasing attention to the effects of food production and consumption on the environment and human health, especially regarding meat consumption. Traditionally, meat is one of the most important food items in the human diet: it is part of many societies' dominant dietary habits. On the other hand, recent dietary guidelines recommend consumers reduce meat consumption and substitute them for plant-based or insect-based food as alternatives to environmentally sustainable food. However, questions are raising in health and environmental areas. For example, studies have suggested that eating meat has both positive and negative impacts on health, and the environmental footprint of diets is country-specific. This discussion takes meat to a controversial position in the human diet. It occurs both in the scientific field and in the mass media, exposing consumers to information conflict and ambiguity, which can affect their food consumption behavior. Since eating meat is considered a social norm in most areas of the world, it is expected that consumers face conflicts regarding these norms and meat consumption. Social norms are negotiated rules and patterns that regulate social behaviors. They are communicated and understood by members of a specific group in a way that they can guide or restrict behaviors and conducts. The influence of social norms in food choice and the consumed amount of food is recognized by the literature, as well as its impact on several elements of the sustainable food consumption process. Our study discusses the possible effects of social norms conflicts regarding meat consumption on consumer behavior, resulting from the ambiguities to which consumers are exposed. To achieve this, we did a narrative review of the literature, addressing topics related to sustainable diet and food consumption behavior, meat consumption, social norms, and normative conflicts. As a result, we propose a theoretical framework that focuses on social norm conflicts and meat consumption behavior, integrating academic insights and research findings from different disciplines. Our framework considers three different types of normative conflicts: (a) conflicting norms within the same group; (b) conflicting norms of different

groups that the person identifies with; and (c) conflicting norms of different groups that the person identifies with one group, but not with the other. With that, this study aims to contribute to promoting environmentally sustainable food consumption in the food domain. Our contribution encompasses insights to (i) the advancement of the Focus Theory of Normative Conduct; (ii) the knowledge related to consumer behavior in the food domain; and (iii) the industry, government, and society, by providing information to support decisions, agendas, and public policies. Finally, we also present research questions that could be explored in future studies.

Keywords: Food; Meat; Social Norms; Conflict; Consumer Behavior

Introduction

Solutions to climate change challenges require structural changes in the economic chain, from production to consumption, including individuals' habits and dietary choices. Food is one of the three most critical sectors regarding consumption-based GHG emissions (Ivanova et al., 2020; Lehner et al., 2016). Hence, there is increasing social pressure for changes in diet, especially in meat consumption patterns (Cheah et al., 2020). Intensive meat production has been identified as a leading cause of atmosphere polluting gases, land, water and energy use, and ecosystem degradation, leading to biodiversity loss (The Lancet, 2018).

The necessary shift in meat consumption patterns is challenging due to the complexity of eating behavior (Vermeir et al., 2020). In a multi-perspective view, eating is more complex than an individual decision: habits and social structures, as family, groups, organizations, and culture are determinants (Klöckner, 2017; Sobal et al., 2014). Furthermore, meat consumption plays an essential role in expressing group identity, economic status, and social identities, such as masculinity, strength, wealth, and social status (Bastian and Loughnan, 2017; De Backer et al., 2020; Macdiarmid et al., 2016). Also, it represents community belongingness, gastronomic, cultural, religious, and familiar traditions (Leroy and Praet, 2015; Rosenfeld and Tomiyama, 2019).

Considering this complexity, interventions to reduce meat consumption have been investigated (see Kurz, 2018; Lacroix and Gifford, 2020; Prusaczyk et al., 2021), including norm-based interventions (Amiot et al., 2018; Sparkman et al., 2020; Stea and Pickering, 2019). The effect of social norms on intentions and behavior is well recognized (Eker et al., 2019; Higgs and Thomas, 2016), including on food consumption domain. Sugar-sweetened beverages (Rosas et al., 2017), food selection in restaurants (Jun and Arendt, 2019), snaking (Schüz et al., 2018), portion size (Raghoebar et al., 2019), salt intake (Mork et al., 2019), suboptimal food (Stangherlin et al., 2018), fruits and vegetables (Gonçalves et al., 2021; Nix and Wengreen, 2017), fish (Olsen and Grunert, 2010), healthy and unhealthy (Liu et al., 2019), and environmentally friend food (Hynes and Wilson, 2016) are an example of investigations exploring social norms and food consumption.

Eating meat is the current social norm in most societies (Sparkman and Walton, 2017), representing a barrier to the transition to more plant-based diets (Lacroix and Gifford, 2020). However, there has been crescent pressure from the academy and mass media to dietary shifts related to meat intake due to its unsustainability production system. One example is the international campaign "Meat Free Monday" encourages people to have one day in the week without eat meat and is supported by celebrities (Meat Free Monday, 2021). This scenario results in meat-related ambiguities, exposing consumers to information conflict. As result, people may be exposed to diverging social norms, and it is expected that consumers face norm conflicts regarding meat consumption.

Individuals use cognitive strategies that affect the behavior to solve the conflict situation, including the consumption behavior. However, what remains underexplored is the effect of the normative conflict regarding meat consumption on consumer behavior. Can the conflict of social norms reduce meat consumption? Social norms depend on the focal behavior (Lapinski et al., 2017), and understanding meat consumption context-specific is necessary. To the best of our knowledge, no academic works explored the effect of conflict of social norms on meat consumption behavior, giving room for further exploration.

We carried out an explorative study using a narrative review strategy to propose a theoretical framework that focuses on social norm conflicts and meat consumption behavior. We seek to integrate academic insights and research findings from different disciplines. From our theoretical exploration also emerged research questions that could be explored in future studies.

Methods

To achieve the proposed objective of this article, we carried out a narrative review of the literature, addressing topics related to sustainable diet and food consumption behavior, meat consumption, social norms, and normative conflicts. This type of review aims to summarize prior knowledge using a usually selective search strategy of conceptual and empirical sources (Paré et al., 2015). However, the narrative review does not review the literature systematically or comprehensively. Consequently, it does not necessarily explain the review process (Paré et al., 2015). Therefore, the objective was not to expose all the papers that deal with the addressed theme here but highlight relevant aspects of the main papers that focus on topics addressed for this paper.

In our review, we start defining the research question that guided the search: "*how the social norm conflict affect meat consumer behavior?*". To answer this question, We have tried to deepen our understanding of the topics i) sustainable diets; ii) meat consumption"; iii) influence of social norms on food consumption behavior. We carried out a search on Google Scholar and ISI Web of Science databases articulating four blocks of terms: social norms (*social norm**, *normative*, *injunctive*, descriptive), conflict

(*conflict, misalignment, disparity, discrepan*, divergen*, incompat*, ambiguity, dissonance*), consumer (*consumer behavior*, *consumption behavior*), and food and meat (*food*, *meat*, *beef*). Scopus was selected for being the largest database of abstracts and citations reviewed by peers and its emphasis on social sciences (Bossle et al., 2016; Homrich et al., 2018). ISI Web of Science is widely accepted and frequently used to analyze scientific publications (González-Serrano et al., 2020; Morioka and de Carvalho, 2016).

We select peer-per-reviewed papers published in English in journals from the first and second quartile of the SCImago Journal Rank (SJR). The ranking measures the journal influence by the average number of citations in the last three years weighted by the knowledge area, based on Scopus Database information (SCImago, 2021). We use the snowball technique to identify others publications, including papers, books and chapters cited as references on the selected papers.

As result, we read approximately 180 sources from more than 80 different academic journals of diverse knowledge areas (health, psychology, environment, biology, anthropology, management, sustainability, medicine, nutrition, among others). During the reading, we made annotations of topics and information related to our questions. After all readings, we elaborated the theoretical scheme.

Results and Discussion

This section presents an overview of the main topics that support our theoretical framework proposition.

Sustainable diet and meat consumption

There is growing pressure for healthier and more sustainable diets due to the overall impact of food production and consumption. In terms of environmental impact, sustainable diets support food production chains that reduce gas emissions, freshwater use, biodiversity loss, land-system change, and preserve nitrogen and phosphorus cycles (Willett et al., 2019). Regarding the social dimension, sustainable diets must consider rights, equity, markets, access to resources, food traditions, and equal access of vulnerable groups taking into account gender class and race (Jones et al., 2016; Springmann et al., 2018). Also, should consider socio-cultural outcomes nutrition, health and animal welfare (FAO, 2018).

The consumer can engage in sustainable diets by (i) choosing products with sustainable production and (ii) changing their dietary pattern of food intake (Verain et al., 2015). The first strategy can be considered an efficient behavior strategy because the consumer seeks to maintain their original diet but reduces its impact by selecting organic, fairly traded or free-range animals products raised in agroecological systems (Ivanova et al., 2020; Soule and Sekhon, 2019). The second strategy involves eliminating or curtailing the consumption of food categories, such as stopping or reducing meat consumption (Verain et al., 2015), which can be achieved by substituting plant-based or proteins from other origins such as lab-grown meats (Machovina et al., 2015).

However, eating is a multifaceted activity, encompassing multiple dimensions as physical, biological, psychological, and socio-cultural (Sobal et al., 2014). Thus, changes in eating patterns are challenging and hard to achieve (Vermeir et al., 2020). Additionally, previous research identified an attitude-behavior gap regarding purchasing sustainable food products, which differs from the consumer behavior process described in the consumer behavior theory (Vermeir and Verbeke, 2006).

The complexity of eating behavior takes on another dimension concerning meat consumption. Meat is a high-quality nutritional food because of its nutrient density, highly satiating, and components that cannot be easily substituted and were crucial in human evolution (Leroy and Barnard, 2020; Milton, 1999). Eating meat is also important to social representations of personal and collective identities (Cheah et al., 2020). For example, meat consumption has been linked to the expression of masculinity (De Backer et al., 2020; Timeo and Suitner, 2018) and gender differentiation (Leroy and Praet, 2015). It also has a symbolic role in representing community belongingness, gastronomic, cultural, religious, and familiar traditions (Leroy and Praet, 2015; Rosenfeld and Tomiyama, 2019).

Besides, the omnivorous diet is widely accepted and the current social norm in most western societies (Soule and Sekhon, 2019; Macdiarmid et al., 2016). Deviant meat-eating behaviors cause social reactions, which do not happen with other food items. For example, vegans suffer discrimination for not following standard eating behaviors, including vegaphobia and stigmatization (Markowski and Roxburgh, 2019; Plante et al., 2019; Vandermoere et al., 2019)

From a biological point of view, the human being is an omnivorous animal. However, despite the physiological ability to eat meat, people can make a personal choice whether or not to eat it. The literature describes the dietary patterns related to meat intake into categories that vary between authors. For example, Springmann et al. (2018) analyze four energy-balanced dietary patterns: flexitarian, pescatarian, vegetarian, and vegan, while de Gavelle et al. (2019) explores four dietary types: omnivores, pro-flexitarians, flexitarians, vegetarians. Soule and Sekhon (2019) suggest six categories, according to environmental, health, animal welfare motivations, and diet outcomes: omnivore conventional, meat-eaters concerned about animal welfare, flexitarian/reducitarian, pescatarian, vegetarian, and vegan.

De Backer and Hudders (2015) classified meat diet patterns into three categories: full-time meat-eaters, flexitarians, and vegetarians. Similarly, Apostolidis and McLeay (2019) identified three consumer groups: meat-eaters, meat reducers, and vegetarians. Randers et al. (2020) identify meat consumption patterns as consumption, reduction, or avoidance of meat. These three categories seem to cover the main categories of behavior related to meat consumption.

The first category includes full-time meat-eaters, including consumers that adopt an efficient behavior strategy purchasing more sustainable meat (Apostolidis and McLeay, 2019). The second category comprises people who eat meat with a conscious reduction in the amount eaten. They still eat meat, but in less quantity and frequency, or eat just some kind of meat (e.g., fish or chicken and not red meat) (Apostolidis and McLeay, 2016; Rosenfeld et al., 2019). Finally, the third category is the people who do not eat meat, including different levels of restriction on the consumption of food of animal origin—vegetarians and vegans—(De Backer and Hudders, 2015).

Among the three categories of behavior related to meat consumption described, meat-eaters are the most frequent and current standards. Meat reducers are estimated at around 20-30% of the population in the United States (Rosenfeld et al., 2020) and Europe (Kemper and White, 2021). It is a growing category, with an increasing number of people report their intention to reduce or even stop meat consumption (Apostolidis and McLeay, 2019). People who do not eat meat are around 5-10% of the population (Apostolidis and McLeay, 2019; Bryant, 2019; Rothgerber and Rosenfeld, 2021).

Diets free of or with reduced meat consumption have been linked to four principal motivations in this order of prevalence: animal welfare, health, sustainability and religious arguments (Plante et al., 2019; Soule and Sekhon, 2019). Also, they demand a replacement of the meat proteins, which is done by plant protein (De Boer et al., 2014). The substitution can be made by natural and unprocessed food (e.g., mushrooms, beans) or processed food. Among processed food, there are products not designed to mimic meat (e.g., tofu) and others mimicking meat in flavor, taste, texture and appearance (e.g., meat-like burgers and sausages) (Santo et al., 2020).

On the consumer side, the meat consumption complexity is expressed by cognitive and behavioral manifestations. For example, despite negative attitudes about meat intake (Vandermoere et al., 2019) and a crescent intention to reduce meat consumption (Apostolidis and McLeay, 2019), few attitudes have effectively changed eating patterns. Macdiarmid et al. (2016) affirm that meat-eaters face the meat-paradox: although they have negative attitudes about eating meat, they are unwilling to change their diary habits.

This belief–behavior inconsistency can be explained by the meat-related cognitive dissonance. To naturalize the meat intake, consumers apply perceptual strategies as third part blame, denying the animal mind, and dichotomization (Rothgerber and Rosenfeld, 2021). Another strategy is rationalizing the consumption by the natural, normal, necessary, and nice justification, known as the 4 Ns (Piazza et al., 2015).

Regarding the justification of being “normal”, it refers to “what most people in civilized society do and what most people expect from us” (Piazza et al., 2015, p. 115), and it is linked to dominant social norms in society.

Social Norms and food consumption

Humans are social beings, and the social environment influences shaping them (Hirsh and Kang, 2016). People segment, categorize and classify the social environment through groups, enabling the relative perception of the individual’s position and role in the social system (Abrams and Hogg, 1990). Group affiliation results in following a specific prototype, which guides behavior, beliefs, attitudes, and feelings (Hogg, 2016).

The group prototype is influenced by a single, particular, and shared normative system, group cohesiveness by shared customs, traditions, standards, rules, and values (Cialdini and Trost, 1998; Fritsche et al., 2018). Social norms are negotiated rules and patterns to regulate social behaviors communicated and understood by members of a specific group (Cialdini et al., 1990). They guide or restrict behaviors and conduct, although they are not supported by a formal law system (Cialdini and Trost, 1998).

The strength of social norms is influenced by the salience of the norm and the degree of identification with the group (Goldstein et al., 2008; Hirsh and Kang, 2016). Circumstances and environmental clues can put the norm in focus, resulting in its salience (Cialdini et al., 1990). Perceived similarity (Rimal et al., 2005), group’s meaningfulness to the individual (Goldstein et al., 2008), affinity and desire to connect with a reference group (Lapinski and Rimal, 2005), and the importance of the group for the self-concept (Hirsh and Kang, 2016) influence the group identification strength. Stronger group identification implies greater adherence to group social norms (Hirsh and Kang, 2016) and, consequently, greater engagement with norm-related behaviors (Lapinski and Rimal, 2005).

Two types of social norms emerge from the same socio-cultural context but with different motivation sources (Cialdini et al., 1990; Hamann et al., 2015). Descriptive norms are standard social behaviors, following what other group members do by observation and imitation (Cialdini et al., 1990; Miller and Prentice, 2016). They dictate what behavior is “normal” and commonly done (Thøgersen, 2006). Injunctive norms—also called prescriptive norms—are related to socially valued behaviors resulting from approval or disapproval by the group peers (Hawkins et al., 2019). They determine what should and should not be done, what people typically approve or disapprove (Hamann et al., 2015).

Food choice involves multiple daily decisions, and the context matters (Sobal et al., 2014). It is a social process and plays an essential role in expressing group identity (Rosenfeld and Tomiyama, 2019). As group affiliations and social identity processes are connected to follow group social norms (Hogg, 2016), social norms affect eating behaviors (Olsen and Grunert, 2010; Stok et al., 2018; van Rongen et al., 2020).

Both types of norms influence beliefs and behaviors (Smith and Louis, 2008). However, descriptive and injunctive norms' effects on eating behavior differ. Previous studies found a significant association between descriptive norms and food consumption intention and behavior, including fast food, sugar-sweetened beverage, fruit and vegetable (Pelletier et al., 2014), unprocessed insects (Liu et al., 2019) and meat (Nguyen and Platow, 2021). Descriptive norms indicate what is normal by imitation and observation, explaining the greatest influence of descriptive norms on every type of dietary behavior (Bell and Holder, 2019). Injunctive norms, however, were found influential just to consumption of unhealthy foods (Bell and Holder, 2019), suggesting an influence of the moral judgment on the consumption of this food category.

Toward a theoretical framework for normative conflict applied to meat consumption

The complexity of the social environment can result in situations in which norms are different and misaligned, leading to normative conflicts. There are three possible situations of normative conflict: a) conflicting norms within the same group; (b) conflicting norms of different groups that the person identifies with; and (c) conflicting norms of different groups that the person identifies with one group, but not with the other.

In the first case, a conflict occurs between descriptive and injunctive norms that simultaneously activate and contradict each other (Hamann et al., 2015). The conflicting norms emanate from the same source (a specific group—e.g., family or peers) and usually put the individual in a situation of supportive versus unsupportive norm (Smith et al., 2012). Here, what is relevant is the relationship and the strength of the two types of norms.

In this normative conflict, the group formally approves some behavior, but members did not engage in this behavior indeed. Or, in reverse, people disapprove of some behavior but, in fact, behave like this. For example, a group of peers can approve and stimulate meat consumption reduction, but the real behavior of the members is to maintain the same pattern of meat intake.

The misalignment between the two types of norms has been studied empirically, and most results indicated that conflict could weaken the normative influence on intentions and behavior (Hamann et al., 2015; Jun and Arendt, 2019). It occurs because conflict may: i) undermine conformity to either norm, reducing the intention to engage in the behavior in question (Smith et al., 2012; Staunton et al., 2014); and ii) to reduce perceived social pressure to conform with the norm, discouraging people from engaging in the behavior (Jun and Arendt, 2019). According to Smith et al. (2012), when descriptive and injunctive norms are incongruent, the intentions to engage are equivalent to the intentions of individuals exposed to norms related to disapproval or disengagement in some behavior. On the other hand, an alignment between descriptive and injunctive norms results in an increased norm effect on behavior compared to using a norm alone (Cialdini, 2003; Schultz et al., 2018).

However, Plows et al. (2017) suggest that the misalignment between descriptive and injunctive group norms can mobilize healthy eating behavior. The authors explain that healthy eating impacts primarily at the individual level, and norm misalignment may have a motivator effect on behaviors considered positive, like healthy eating. Meat can be considerer both beneficial and prejudicial to health, presenting positive and negative outcomes (Barnard and Leroy, 2020b, 2020a; Leroy and Barnard, 2020). Thus, we propose the following research question:

RQ.1 – What is the effect of the conflict between descriptive and injunctive ingroup social norms in meat consumption?

The second and third situation of normative conflict occurs when a person is exposed to conflicting norms of different groups, activated at the same time. Group memberships and social identities are defined by many factors, including nationality, peer group, family, friendships, gender, race, culture, sexual orientation, and political preferences (Higgs, 2015; Hirsh and Kang, 2016). Thus, a person is concomitantly affiliated with and influenced by different social groups and is exposed to different normative expectations (Amiot et al., 2020; Hirsh and Kang, 2016). Considering the norm as a group standard (McDonald and Crandall, 2015), it is reasonable to expect that groups have different norms among themselves (McDonald et al., 2013).

Group identification plays an important role in this situation. As a self-categorization and self-concept process, intragroup comparison also reinforces the contrast among groups and, consequently, among group norms (Amiot et al., 2020). In a conflict between norms of a valued group and another group with less importance (the second case), it is expected to reinforce the behavior related to social norms of the group the person identifies with (i.e., relevant group). It occurs to highlight outgroup differentiation and strengthens group cohesiveness, stability and affiliation (Fritsche et al., 2018; Hogg, 2016).

However, when two or more incongruent social norms from different and equally relevant groups are salient simultaneously, the expected effect on behavior is unclear. For example, one individual can be part of a relevant peer group with a supportive norm related to reducing meat consumption. However, at the same time, their family group can have unsupportive norms relate to reduction behavior. In this situation, the individual is aware of the divergence and realizes that this difference can lead to a position that harms their social relationships because of incompatible behavioral expectations (Giguère et al., 2010; Hirsh and Kang, 2016). As a result, there is a feeling of failure to satisfy the role requirements of identities and comply with a group's norms that can put the affiliation at risk (Gibson et al., 2020).

Previously research explored the conflict between social norms of different groups in the pro-environmental domain (McDonald et al., 2013, 2014a, 2014b; Salmivaara and Lankoski, 2019) and alcohol consumption behavior (Cail and LaBrie, 2010). Norms conflict impact in behavior can be mixed, positive, or negative and are influenced by other factors (Fritsche et al., 2018; McDonald et al., 2014a). Considering that, we ask:

RQ.2 – What is the effect of conflicting social norms of different groups on meat consumption behavior?

RQ.2.1 - Will conflict between social norms lead to reduced meat consumption?

To solve this conflict and ensure stability, individuals use cognitive activities and behavior as strategies (Reed et al., 2012). Each person has a complex psychological system—self-concept—that encompasses a set of identities constructed from the interaction between personal characteristics and the social environment (Amiot et al., 2007). This set of identities organizes previous experience and manifests social roles, determining who a person was, is, and may become. The literature describe strategies related to the self-concept and self-identities. Potential reactions include switching between identities (Giguère et al., 2010), suppressing one of the conflicting identities, enhancing elements of the dominant identity, and denying the conflict (Hirsh and Kang, 2016).

Compensatory consumption of products and/or services to reinforce a specific identity is one possible strategy to enhance a dominant identity (Coleman et al., 2019). If a compensatory consumption behavior is a direct strategy, scholars interpret the act of avoiding consumption also as a manifestation of self-identity and an indirect strategy to reinforce self-concept. Thus, consumption reduction, avoidance, or rejection are practices of anti-consumption and self-expression to take distance from undesired self-identity (García-de-Frutos et al., 2018).

Considering the diversity of possible strategies for conflict resolution, we propound the following research question:

RQ.3 – What strategies do consumers adopt to solve the conflict between social norms of different groups regarding meat consumption?

Table 1 summarizes the discussion and helps organize our understanding of normative conflicts.

Table 1. Type of normative conflicts and main characteristics

Type of conflict	Type of norms involved	What matters	Group identification	Possible effect	Example
Social norms of the same group	Descriptive and injunctive	Relationship between the norms; norm salience	Not applicable	Weaken or strengthen norm influence on behavior	"people are reducing the amount of meat in their diet" *versus* "people should eat meat regularly."
Social norms of different groups	Descriptive or injunctive	Norm salience, affiliation salience, group identification	High identification with one group but not with the other	Strengthen norm influence on behavior	"people should reduce meat intake in their diets" *versus* "people should eat meat regularly in their diets"
			High identification with both groups	Weaken or strengthen norm influence on behavior	

Finally, based on our literature review, we propose a theoretical framework to conflict between social norms regarding meat consumption.

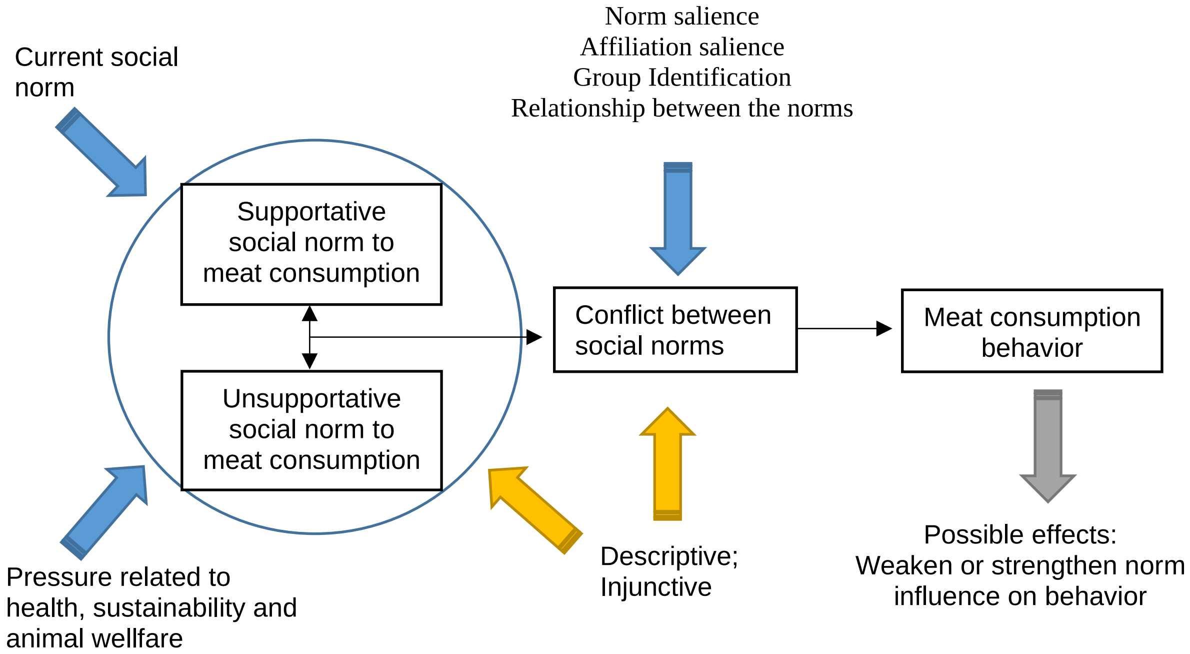

Figure 1. Theoretical framework of normative conflicts.

Conclusions

Our paper explored the possible conflict between social norms and their effects on meat consumption behavior. We proposed a norm conflict categorization that can be applied in multiple consumption areas (Table 1), a theoretical framework focused on meat consumption context (Figure 1) and research questions to guide future investigations. We have identified three different situations of social norm conflict occurrence, separated into two categories: conflict between social norms of the same group and different groups. The categories differ on the type of norm involved, variables that interfere, and behavior's possible effect.

The theoretical framework considers eating meat as the current social norm in western societies and a supportive social norm to this behavior. It takes into account the social pressure to reduce meat consumption (Cheah et al., 2020; Piazza et al., 2015) as an unsupportive social norm based on the paradoxical meat status in actual society. Meat is benign, pleasurable, and economically important, but it entails environmental and health externalities and tradeoffs (Bateman et al., 2019; Leroy, 2019).

Our proposal is based on an extensive literature review, which presents limitations related to this approach. We suggest that future studies and interventions related to meat consumption and social norms verify our findings empirically.

The paper sought to contribute to the academic, managerial and social fields to promoting environmentally sustainable food consumption in the food domain. The main theoretical contribution refers to the advancement of the Focus Theory of Normative Conduct and other influential behavioral theories that use social norm as a component of behavioral change interventions (e.g., Theory of Planned Behavior).

Expanding studies on the domain of eating behavior deepens the understanding of food consumption behavior and dietary choices. Additionally, there has been increasing attention to food production and consumption effects on the environment and human health, especially meat consumption. Considering the growing concern about environmental and climate issues and the increasing intention to reduce or curtail meat consumption (Soule and Sekhon, 2019), it seems to be a flourishing field. Furthermore, social norms and normative conflicts can be drivers or barriers to meat consumption, and understanding their effects on meat eaters' behavior is relevant in this context.

Our work can contribute to business and the economy once changes in meat consumption patterns influence global value chains, which need to adapt to new scenarios. Alternative products to substitute meat are also a growing market that can be impacted by recent trends in meat consumption, including new niches such as products developed for meat-eaters (Curtain and Grafenauer, 2019). The economic and social importance of the livestock chain is relevant in farming, consuming, and exporting countries.

Studies on meat consumption meet society's demand for a more sustainable and healthier lifestyle and habits, providing information to support decisions, agendas, and public policies. In addition, the increasing global warming, rapid environmental degradation, and the loss of biodiversity present complex and multidisciplinary challenges in the last decades and results can contribute to future public interventions and policies to changes in eating patterns to more sustainable diets.

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293 Emergy analysis of Biofactories destined to the production of healthy food in Peasant Agroecological

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Abstract

Humanity has drastically changed its relationship with food in recent years, since the complexity in the search for food, the physical effort that it took for millions of years to obtain it, in general terms, practically disappeared; this was achieved thanks to the evolution of agriculture to the conventional model that has currently been adopted, detaches the farmer from his innate job of producing from his traditional cognition, avoids the appropriation of knowledge of the productive system, typical of the art of agriculture, in most of the actors, it focuses on obtaining high productions, demands high amounts of agrochemicals, offers a low variety of foods and low nutritional values, and has a highly negative impact on nature. But, there are alternatives to conventional agriculture such as agroecological production systems, which pose a complex solution, supported by scientific research and which addresses the problems of current agriculture in a holistic way; within this production system there is a key subsystem that are biofactories, where the production of biopreparations is mediated, made from the farm´s own resources, complementing the balance of the productive system with the immersed environment, allowing the elimination of the use of synthetic agrochemicals, ensuring biodiverse and healthy products. As a methodology, an emergetical analysis of three biofactories located in three agroecological farms in the Valle del Cauca, Colombia was proposed, using the methodology of Odum (1996). I have incorporated the analysis of the emergy flow by Sociocultural Collection, according to the evaluation methodology of Rodriguez et al. (2021). The evaluation of the nutritional quality of its products is under development. Among the preliminary results, high values of renewability and socio-cultural heritage for agroecological farms were found, presenting themselves as the two most representative emergy flows in the studied biofactories, and the hypothesis of higher nutritional values is calculated for agroecological products in comparison with conventional productions. Finally, it is concluded that biofactories, in addition to being renewable and sustainable over time, a great flow of information that allows their maintenance and constant transformation

circulate in them according to the dynamics of agroecosystems; reinforcing the empowerment of communities that develop agroecological production systems, which is proposed as a necessary alternative to continue researching and promoting. These initiatives do not have real support from governments to favor their development, and from academy we must continue to show their benefits.

Keywords: Agroecological systems, Biofactory, Sociocultural heritage, Healthy food, Biopreparation.

Introduction

The man in his historical process of relationship with food has undergone many changes, but none as accelerated as in recent times, after the industrial revolution. Since the Arboreal period, through the Paleolithic and other stages of millions of years, there have always been some characteristics such as the complexity and the demand for a high physical effort to feed, in addition to a high variety of foods (Teaford & Ungar, 2000). Nowadays, the human diet in general is based mainly on cereals such as wheat, rice and corn. There is a false perception of variety, but the reality is that these three foods supply 50% of the energy needs of humanity (UNCSN, 2020) cited by (Altieri & Nicholls, 2020). This style of eating, with so little adaptation time and the great ease we have to acquire food, without any physical effort, has led us to have worrying rates of chronic diseases such as diabetes or hypertension among others (L Cordain, 1999).

But the evolution of the relationship between man and food, not only remains in the very fact of food. This relationship is influenced by the way of producing food and also generates feedback to it, this is how enormous changes have been generated in the way of obtaining food. Conventional agriculture is the most widely adopted production model in the world, it has been polished over time, but with a focus on achieving high quantities of food, this has led us to develop production methodologies with a high dependence. Food production under the current conventional model requires enormous amounts of products such as fertilizers, pesticides, and hormonal products, in addition to dependence on transgenic seeds and other genetically modified organisms (GMO) (Coleto Martínez, 2004). It has also led to the massive production of cereals due to their apparent high yields, generating a low variety of foods in the human diet, contamination of food with traces of synthesis products harmful to health that accumulate over time, a low nutritional quality in the diet and finally, it has a very high energy demand, supplied by non-renewable elements such as oil.

However, in the world there are other less dependent forms of food production such as agroecological production systems (FAO, 2021). Through agroecological production models, high amounts of food and biomass are achieved, food with higher nutritional quality and a high variety of products can be obtained (Raigón, 2008). Also,

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291 Energy Poverty and Health: Transitioning to a Bioeconomy in Romania and the EU

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Abstract

Reducing the energy poverty, while also improving the economic development and health of a country is a priority for institutions such as the World Bank and the European Union. Defining residential energy as a condition where households cannot afford energy to a necessary level, is a good start but does not include other important energy measures such as caloric intake. Eastern Europe is not often considered in this context. However, since the end of socialist dictatorships there have been many energy, housing, economic, and social reforms that have had implications for energy poverty. This study examines the interaction between energy poverty, socioeconomic indicators, health, and economic development for Romania and the European Union. A comparative analysis of Romania with their European counterparts. A panel analysis is used to show the relationship energy poverty and health interaction for the EU-27 countries. A time series ARDL model is used to examine the relationship for Romania. This comparative analysis enables Romania's standing to the rest of Europe, illustrating any disparities that exist between energy poor and non-energy poor societies in Europe, to be shown. The results of the panel analysis show a long-run relationship between self-perceived health, arrears on utility bills, and population unable to keep home adequately warm. There are also short-run connection for the population unable to keep home adequately warm to self-perceived health as bad or very bad for females and current health expenditure with self-perceived health as bad or very bad. The results for Romania suggest that being arrears on utility bills and population unable to keep home adequately warm enhance self-perceived health as bad or very bad for overall population and for females. The results are used to show the bigger political and economic context in which energy policy should be discussed. To effectively introduce bioeconomic policies on a large-scale efforts the energy system in Romania and other energy poor countries in Europe must be improved and modernized.

Keywords: Energy Poverty, Bioeconomy, Health

Introduction

Energy poverty is one of the biggest issues facing the world today and a priority for institutions such as the World Bank and the United Nations. "Eradicating poverty is the greatest global challenge facing the world today and an indispensable requirement for sustainable development, particularly for developing countries … This would include actions at all levels to: … Assist and facilitate …the access of the poor to reliable, affordable, economically viable, socially acceptable and environmentally sound energy services" (United Nations 2002, p. 9, 12). There is an expanding body of literature that energy poverty is problematic in Eastern Europe due to the specific social and physical conditions that exist there, such as cold climates, the liberalization of energy prices, and the reliance on foreign sources for their energy supplies, for example, Russia (Lampietti and Meyer, 2002; Buzar, 2007).

The former socialist countries in Eastern Europe placed an emphasis on energy security and developing new sources to supply excessive energy consumers, heavily reliant on carbon-based fuels; they also had an energy intensity problem - a low value on energy and other natural resources leading to their overconsumption (Gray, 1995). The centrally planned economies treated housing and heating as goods and services accessible for all, so housing, public transportation fees, and energy were heavily subsidized (Duke and Grime, 1997). As a result, consumers had no reality of the true cost of energy.

Making matters worse, the vast majority of urban households in the centrally planned Eastern European countries had direct heating. According to Buzar (2007) the centrally located combined heat and power or heat only boiler plants typically burn coal or fuel oil in order to produce hot water usually for space heating and direct household use. The hot water was transported through pipelines to substations where it was distributed to collective or individual buildings. The direct heating pipes and apartment buildings were vertical requiring radiators in rooms that were on top of each other to be supplied by the same pipe. Therefore, measuring energy consumption at the household level was very difficult, especially since meters are often not used. As a result, room temperatures were frequently too low or too high, causing windows to be open to cool over heated rooms leading to losses of heat.

With the end of the centrally planned system, the subsidies that existed for energy costs were put under pressure to be removed. As a result, the privatization or partial privatization of the energy industry in these countries slowly occurred. The idea was that consumers would pay the full economic cost of production, distribution and supply of electricity they consume (Stern and Davis, 1998). However, direct heating systems remained largely because there were insufficient financial resources available to operate, maintain, rehabilitate, and modernize heating systems (European Commission, 2016).

In contrast, Western European countries largely rely on decentralized heating systems. These countries created more stringent building and efficiency standards in the late 1960s and early 1970s to counter high energy prices (Berkland, 2014). As a result, many countries in Western Europe, such as the United Kingdom, Spain, Germany, Italy, and France, have residential natural gas and oil boilers or direct electric heating systems as their main unit. In Nordic countries, such as Finland, biomass stoves and furnaces are typical for residential purposes (European Commission, 2016). Additionally, Western European nations have progressed more in shifting to renewable energy, such as solar thermal energy.

Regardless of the two vastly different approaches that Eastern and Western European countries take for their heating needs, energy poverty persists impacting those most vulnerable. The vulnerable populations include those with little marketable skills and less mobility, such as children, the elderly, women, the disabled, some minority groups, and single parents (Torrey et al., 1999; Cornia et al., 1996). However, there are other groups that are just as much at risk. For example, young adults who may have just graduated and are looking for employment, the long-term unemployed, and those that live pay check to pay check. This last group, considered the working poor, do not necessarily fit the definition of the economic poor. These people could have well-paying jobs but may not have the ability to pay for their energy needs.

Unlike income poverty, which can be defined as having a lack of financial resources, energy poverty is much more intricate. Energy poverty can be related to poverty, but does not have to be. Energy poverty can be related to domestic energy efficiency but does not have to be. Energy poverty can be related to political circumstances but does not have to be. As a result, energy poverty is very difficult to define due to its complexity. In developing countries, the search for energy is a continuous battle (Sovacool, 2014). However, those in developed countries are not immune to the problem of energy poverty either.

This paper examines the issue of energy poverty in Europe, providing a comparative analysis of the European Union and Romania. Energy poverty persists in both the EU and Romania and these reasons will be investigated. The rest of the paper is structured as follows. The next section provides a description of the data and research methodology used to analyse the data, followed by a section which provides a discussion of the results. The last section concludes the paper.

Methods

Two different analytical methods are used in this paper: panel data models for the EU-27 countries (2003-2020) and time series models for Romania (2007-2020). Missing data forces us to consider a shorter period for Romania. Under the hypotheses of heterogeneity, cross-dependence and non-integration, panel Autoregressive Distributed Lag models (panel ARDL) will be considered. Given the low volume sample, a Bayesian nonparametric approach is proposed to estimate ridge regression for Romania. The dependent variable is represented by self-perceived health as bad or very bad (total and for females). The explanatory variables are: current health expenditure (% of GDP), arrears on utility bills for (total and females) (arrears), population unable to keep home adequately warm (population).

The basic ARDL model:

$$\log(self\ perceived\ health_{it}) = \alpha_i + \sum_{l=1}^{p} \beta_0 (self\ perceived\ health_{it-l}) + \sum_{l=0}^{q} \beta_1 \log(arrears)_{it-l} + \sum_{l=0}^{q} \beta_2 \log(population)_{it-l} + e_{it} \quad (1)$$

Where i is the index for country and t is the index for time.

After parameterization, equation (1) becomes:

$$\Delta\log(self\ perceived\ health_{it}) = \alpha_i + \Phi_i\big(self\ perceived\ health_{it-l} - \theta_1 \log\ \_arrears_{it-l} - \theta_2 \log_{(}\ population_{it-l}\big) + \sum_{l=1}^{p-1} \lambda_{il}\, \Delta\log(self\ perceived\ health_{it-l}) + \sum_{l=0}^{q-1} \lambda'_{il} \Delta\log(\mathrm{arrears}_{it-l}) + \sum_{l=0}^{q-1} \lambda''_{il} \Delta\log(population)_{it-l} + e_{it} \quad (2)$$

where λ, λ′, λ″ are short-run coefficients corresponding to lagged endogenous variable, arrears on utility bills and population unable to keep home adequately warm respectively. θ_1 and θ_2 are the long-run parameters for arrears on utility bills and population unable to keep home adequately warm. The speed of adjustment is denoted by Φ_i.

The pooled mean group (PMG) estimator is based on the homogenous long-run equilibrium across countries and heterogeneous short-run connection. The heterogeneity specific to countries is caused by different responses to external shocks. The main advantage of the PMG estimator is the ability to reduce endogeneity.

Table 1 provides the descriptive statistics of the variables used in the analysis in this paper.

Unlike the least squares estimator in the linear regression model, the linear ridge regression model constructs estimates by a reduction being used to explain self-perceived health in Romania. Estimates and the posterior probability are calculated for the standardized parameter to fall within a standard deviation of 0. Beta represents the standardized coefficients (a posterior mean), based on the centred mean and the normalized explanatory variables of mean 0 and variance 1. The coefficients are between - 1 and 1 when all explanatory variables are uncorrelated (there is no multicollinearity). PP1SD represents the posterior probability that a standardized coefficient is at maximum a standard deviation of zero. An explanatory variable significantly influences the dependent variable if PP1SD is less than 0.5.

Table 1. Descriptive statistics

Variable	Mean	Standard deviation	Minimum value	Maximum value
Arrears on utility bills; total population (%)	10.44	8.36	1.1	42.2
Arrears on utility bills for single; females (%)	7.65	7.49	0.3	38.8
% Population unable to keep home adequately warm	11.39	11.98	0.3	69.5
Self-perceived health as bad or very bad; total population (%)	10.58	4.75	2.5	26.8
Self-perceived health as bad or very bad; females (%)	11.85	5.39	2.7	27.5
Current health expenditure (% of GDP)	8.13	1.72	4.70	11.58

Source: own calculations in Stata 15

Results and Discussion

The assumption of heterogeneity is checked since the sample is composed by developed and developing countries in the EU with different patterns of economic and social development.

Table 2. The results of CD Pesaran's test.

Variable	Calculated statistics*
Arrears on utility bills; total population (%)	21.76
Arrears on utility bills; females (%)	8.41
% Population unable to keep home adequately warm	10.73
Self-perceived health as bad or very bad; total population (%)	4.55
Self-perceived health as bad or very bad; females (%)	9.33
Current health expenditure (% of GDP)	20.63

*Note: * shows that all the p-values are less than 0.05*

Source: own calculations in Stata 15

CD Pesaran's test is applied to check for cross-sectional dependence for the basic variables. Since p-values are lower than 0.05, the hypothesis of cross-section independence is rejected at 5% level of significance (see Table 2). The cross-sectional dependence is explained by the fact that all the EU countries are the subject of common regulations.

The logarithmic forms for all the data series are considered to allow the interpretation in terms of elasticities. The Im-Pesaran-Shin test is used to check for a unit root since it assumes non-balanced panels and heterogeneity. The null hypothesis states that all panels contain unit roots. The results after the test application are presented in Table 3.

Table 3. The results of Im-Pesaran-Shin test for unit roots in panel data

Variable (in logarithm)	Calculated statistics	p-values
Arrears on utility bills; total population (%)	-0.2600	0.3974
Arrears on utility bills; females (%)	-4.4385	0.0000
% Population unable to keep home adequately warm	-0.0732	0.4708
Self-perceived health as bad or very bad; total population (%)	0.1196	0.5476
Self-perceived health as bad or very bad; females (%)	0.4496	0.6735
Current health expenditure (% of GDP)	-1.1948	0.1161

Source: own calculations in Stata 15

The data series are stationary (integrated of order 0: I(0)) for the arrears on utility bills for females (see Table 3). The rest of the variables are non-stationary. The data in the first difference were stationary. Therefore, we can state that the panel data for the rest of the variables are integrated of order 1 (I(1)). The Westerlund test for cointegration was applied, but the results suggest no cointegration between arrears on utility bills, population unable to keep home adequately warm and the rest of the dependent variables. Starting from these results, for non-stationary and non-cointegrated panel data series, the long-run and short-run relationships might be represented using a panel autoregressive distributed lag model (panel ARDL model). A particular case of panel ARDL model is used, PMG. This estimator assumes homogenous long-run equilibrium across countries and heterogeneous short-run connection and it reduces the endogeneity.

Self-perceived health is explained using PMG estimators (Table 4). The results of estimations indicate a significant overall long-run relationship between self-perceived health, arrears on utility bills, and population unable to keep home adequately warm. Only in the short-run, population unable to keep home adequately warm is the cause for self-perceived health as bad or very bad. In the long-run, arrears on utility bills explains the self-perceived health as bad or very bad. There is a short-run connection for the population unable to keep home adequately warm to self-perceived health as bad or very bad for females. As expected, there is a positive correlation between arrears on utility bills and population unable to keep home adequately warm.

Considering the deviation from the long-run, the speed of adjustment to the equilibrium is measured by the error correction term in absolute value. The rate of correction in the bivariate model explaining self-perceived health as bad or very bad (total) is 31.05% according to the PMG approach. In the case of self-perceived health as bad or very bad for females, the speed of adjustment is lower (28.3%).

Table 4. PMG estimators to explain the self-perceived health in the EU-27 countries (2003-2020)

	Variables (in log)	Dependent variable	Variables (in log)	Dependent variable
		self-perceived health as bad or very bad (total)		self-perceived health as bad or very bad for females
Long-run relationship	arrears on utility bills	0.125 (0.000)	arrears on utility bills for females	0.011 (0.728)
	population unable to keep home adequately warm	0.006 (0.713)	population unable to keep home adequately warm	0.026 (0.144)
Error correction term		-0.3105 (0.000)		-0.283 (0.000)
Short-run relationship	arrears on utility bills	0.037 (0.264)	arrears on utility bills for females	0.015 (0.511)
	population unable to keep home adequately warm	0.071 (0.007)	population unable to keep home adequately warm	0.093 (0.02)
	Constant	0.571 (0.000)	Constant	0.580 (0.000)
Residuals	I(0)	I(0)	Residuals	I(0)

Note: p-values in brackets

Robustness check- additional variable (current health expenditure (% of GDP))

Table 5 shows current health expenditure is a short-run cause for self-perceived health as bad or very bad (total).

Table 5. PMG estimators to explain the self-perceived health in the EU-27 countries (2003-2020)

	Variables (in log)	Dependent variable	Variables (in log)	Dependent variable
		self-perceived health as bad or very bad (total)		self-perceived health as bad or very bad for females
Long-run relationship	arrears on utility bills	0.149 (0.000)	arrears on utility bills for females	-0.433 (0.000)
	population unable to keep home adequately warm	0.121 (0.000)	population unable to keep home adequately warm	0.196 (0.000)
	current health expenditure	1.729 (0.000)		-117.303 (0.000)
Error correction term		-0.219 (0.000)		-0.046 (0.046)
Short-run relationship	arrears on utility bills	0.021 (0.625)	arrears on utility bills for females	0.022 (0.421)
	population unable to keep home adequately warm	0.043 (0.150)	population unable to keep home adequately warm	0.018 (0.585)
	current health expenditure	-0.315 (0.023)		50.749 (0.000)
	Constant	-0.469 (0.000)	Constant	0.998 (0.007)
Residuals	I(0)	I(0)	Residuals	I(0)

Note: p-values in brackets

In the short-run, the increase in health expenditure reduces the negative perception on health, but in the long-run the pessimistic perception on health increases when health expenditure grows. This result indicates that health expenditure in the EU-27 countries is not sustainable and further policies should focus more on individual needs of these individuals with arrears on utility bills and unable to keep their home warm.

When health expenditure is considered, there is a long-run relationship between all the self-perceived health as bad or very bad (total) explanatory variables and self-perceived health as bad or very bad (total). The rate of correction is lower for overall case (21.9%) and for females (4.6%).

A separate case is represented by Romania for which the models are run in a Bayesian framework. The results of Elliott-Rothenberg-Stock point-optimal test (Table 6) indicate that only the series for current health expenditure is stationary in the first difference, while for the rest of the variables the data series are stationary in level. The critical values for equation with intercept, respectively for equation with intercept and trend are 2.97, respectively 5.72 at 5% level of significance.

Table 6. The results of Elliott-Rothenberg-Stock point-optimal test for Romania

Variable (in logarithmic values)	Include in the equation:	p-statistic
arrears on utility bills	Intercept	13.37501
	intercept and trend	137.9013
arrears on utility bills for females	Intercept	18.24017
	intercept and trend	264.3925
population unable to keep home adequately warm	Intercept	382.0152
	intercept and trend	53.87204
current health expenditure	Intercept	1.592448
	intercept and trend	3.282076
self-perceived health as bad or very bad (total)	Intercept	15.94518
	intercept and trend	6.083708
self-perceived health as bad or very bad for females	Intercept	12.13633
	intercept and trend	16.13844

Source: own calculations in EViews 9

A covariate is a "significant" predictor when the posterior probability that the standardized coefficient is within 1 standard deviation of 0 is less than 0.5.

The results for Romania in Table 7 suggest that arrears on utility bills and population unable to keep home adequately warm increase the percentage of people with self-perceived health as bad or very bad for overall population and for females.

More current health expenditure reduces the bad or very bad perception on health only for total population.

More public expenditure for health does not have a significant impact of females perception on their health.

Table 7. The results of ridge regression for Romania

Variables (in log)	Dependent variable: self-perceived health as bad or very bad (total)		Variables (in log)	Dependent variable: self-perceived health as bad or very bad for females	
	Unstandardized Coefficients	Posterior probability that the standardized coefficient is within 1 standard deviation of 0		Unstandardized Coefficients	Posterior probability that the standardized coefficient is within 1 standard deviation of 0
arrears on utility bills	0.123	0.183	arrears on utility bills for females	0.077	0.471
population unable to keep home adequately warm	0.201	0.021	population unable to keep home adequately warm	0.176	0.063
current health expenditure in the first difference	-0.355	0.455	current health expenditure	-0.243	0.568
constant	1.827	1	constant	2.030	1

Source: own calculations in MatLab

Conclusions

There is little literature that explores the relationship between energy poverty and health. However, this relationship is important, one that requires much further research and discussion. Those individuals experiencing energy poverty are more susceptible to poorer health because they will not have adequate heat during the winter months, sufficient cooling in the summer months, or other necessities that require energy. On the other hand, individuals with poor health will have higher out-of-pocket medical expenses that may preclude them from having the ability to purchase the amount of energy services necessary to maintain a good health. Therefore, energy poverty/health is a dual causal relationship that has not been sufficiently examined. The objective of this paper is to fill the gap in the literature by analysing EU-27 countries and Romania. The results show a relationship between energy poverty and poor health.

The results for the EU-27 show a long-run relationship between self-perceived health, arrears on utility bills, and population unable to keep home adequately warm. In the short-run, population unable to keep home adequately warm is the cause for self-perceived health as bad or very bad, while in the long-run, arrears on utility bills explains the self-perceived health as bad or very bad. There is a short-run connection for the population unable to keep home adequately warm to self-perceived health as bad or very bad for females. Furthermore, there is a positive correlation between arrears on utility bills and population unable to keep home adequately warm.

Current health expenditure is a short-run cause for self-perceived health as bad or very bad. In the short-run, increases in health expenditure reduces the negative perception on health, but in the long-run a negative perception on health increases when health expenditure grows, indicating that health expenditure in EU-27 countries is not sustainable. Additionally, there is a long-run relationship between self-perceived health as bad or very bad for the total population with health expenditure.

The results for Romania suggest that being arrears on utility bills and population unable to keep home adequately warm enhance self-perceived health as bad or very bad for overall population and for females. An increase in current health expenditure reduces the bad or very bad perception on health only for total population. More public expenditure for health does not have a significant impact of females perception on their health.

Further research will investigate the complex relationship between energy poverty and health. Exploring the EU-27 is necessary to determine the magnitude of the problem within Europe. This analysis of Europe is particularly important given the reliance on energy imports until an adequate level of sustainable, renewable energy can be developed. An analysis of Romania is necessary to determine if there are public policies that one or the either uses to address the interconnected issues. Given the number of pensioners and the relatively low-income, in comparison to the rest of

Europe, the energy poverty/health dynamic is especially crucial as those individuals are among the most vulnerable.

This particular study is important because the results indicate both long-run and short-run causal relationships between energy poverty and health. Energy poverty is a multifaceted issue that both impacts health and can be caused by bad personal health. As a result, public policies must be examined at the European, national, and local levels. However, only with rigorous analysis will policy-makers take this dynamic seriously enough to address the issue. Not developing public policy that will help alleviate the energy poverty/health relationship will likely cost countries more, in terms of additional healthcare costs, lost productivity, and reduced GDP, than if they were to properly correct the issue. Therefore, the results of this study provide meaningful insight that could be used to support governmental action against energy poverty.

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174 Fashion Stores as potential educators of conscious consumers. 2 case studies: H&M Group and Inditex

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Abstract

The fashion industry is considered one of the most polluting, due in part to the huge use of raw materials and water in their processes, and the GHG emissions. Fashion brands are aware, and they are working to transform the industry towards a more sustainable one. In recent years, this industry has launched some initiatives to commit themselves (with other international organizations), to mitigate climate change (UN Fashion Charter for Climate Action) or positively contribute to preserve biodiversity, oceans, and climate (The Fashion Pact). In terms of product, brands are also launching so-called sustainable collections and giving information to their consumers about the materials, processes, and manufacturers, in an effort to reach and show full traceability. Although the progress is far from the objectives, the sustainability strategy is clear in most of them, and accessible for the consumers, both in terms of information and goals. But fashion brands are also retailers, with a specific weight in the built environment through their stores. The building sector is also one of the key seven product value chains identified by the New Circular Economy Action Plan as relevant, with a high potential for increasing material efficiency and reducing climate impacts. The brands have included their stores in their strategy to reduce GHG emissions and have plans to improve their energy efficiency. The retail store, the space where fashion and architecture meet, could be a good showroom of the sustainable and circular practices of the brands, both in terms of products and buildings, but this potential seems to be ignored by now. In a moment of rethinking the physical stores because of the Covid 19 pandemic and the growth of online markets, we wonder if the fashion stores could play an important role in educating consumers towards a more sustainable behaviour. This study addresses the issue through the analysis of the two biggest mass-market European fashion players: Inditex and H&M. Inditex had 7,469 stores in 2019, while H&M had 5,076. Inditex's strategy is based on circularity and digitalization; H&M strategy is based on three pillars: leading the change, circular and climate positive, and fair and equal. Both groups are committed to the UN Sustainable

Development Goals, have circularity as an essential axis, and have special collections (Join Life and Conscious) of more sustainable materials. Based on the information disclosed by the brands on their Annual Reports and their websites, we have analysed the actions they are doing in their stores to commit to sustainability and circularity, and we have compared the results for the two groups. The results show that these brands do not use all the potential of their stores as a channel to communicate their commitment to sustainability.

Keywords: fashion stores, sustainable fashion, conscious consumer, Green Deal, Fashion Pact

Introduction

Sustainability is one of the main issues in the fashion agenda, as it is considered one of the most polluting industries: due in part to the huge use of raw materials and water in their processes (this sector occupies the fourth position in materials pressure), and it is the fifth in Greenhouse gas (GHG) emissions (EEA, 19). Fashion brands are aware, and they are working to transform the industry towards a more sustainable one. In recent years, this industry has launched some initiatives to commit themselves (with other international organizations), to mitigate climate change (UN Fashion Charter for Climate Action) or positively contribute to preserve biodiversity, oceans, and climate (The Fashion Pact).

In terms of product, brands are also launching so-called sustainable collections and giving information to their consumers about the materials, processes, and manufacturers, in an effort to reach and show full traceability. Although the progress is far from the objectives, the sustainability strategy is clear in most of them, and accessible for the consumers, both in terms of information and goals.

But fashion brands are also retailers, with a specific weight in the built environment through their stores. The building sector is also one of the key seven product value chains identified by the New Circular Economy Action Plan (European Commission, 2020) as relevant, with a high potential for increasing material efficiency and reducing climate impacts. Some brands have included their stores in their strategy to reduce GHG emissions and have plans to improve their energy efficiency or even to commit to circular design practices. The retail store, the space where fashion and architecture meet, could be a good showroom of the sustainable and circular practices of the brands, both in terms of products and buildings.

In a moment of rethinking the physical stores because of the Covid 19 pandemic and the growth of online markets, we wonder if the fashion stores could serve as a means to educate fashion consumers towards a more sustainable behaviour.

A lot of research has been done about fashion sustainability, fashion retail, stores, but it is scarce the academic literature addressing the sustainability aspects of the fashion store design, and even more in terms of the potential of the stores to communicate this commitment to their customers. The research question was: “Can the fashion stores play an important role in educating consumers towards a more sustainable consumption pattern?”

This study tends to fill this gap, through the analysis of the information displayed by the two biggest mass-market European fashion players: Inditex and H&M, both with thousands of physical stores all over the world.

The paper is organised as follows: after the Introduction, there is a section with the Theoretical background of sustainability in fashion, architecture and sustainability, and the fashion retail store; it is followed by the Methodology where the case studies are presented; the Results and discussion; and the final section with the Conclusions, limitations and further research.

Theoretical background

Sustainability and fashion

Sustainability might be a buzzword, but is a really serious concept if we go back to this definition in 1987, by the Brundtland Commission, as the “development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs” (WCED and Brundtland, 1987). Even more, if we consider the triple bottom line of Elkington (1998), that considers furthermore, equally economic and social aspects.

The concern about sustainability emerged even before this definition, as the first United Nations Conference on the Human Environment in Stockholm, Sweden, in 1972 tackled the environmental issue in the context of both, the human wellbeing and the human responsibilities: “Man is both. creature and moulder of his environment, which gives him physical sustenance and affords him the opportunity for intellectual, moral, social and spiritual growth. (…) A point has been reached in history when we must shape our actions throughout the world with a more prudent care for their environmental policies” (1973)

Sustainable fashion, in words of Wei and Jung (2017), refers to fashion products that contribute to creating a sustainable future without sacrificing or at least harming the environment and society in the process of production and consumption.

The fashion industry has been first reacting to social and environmental campaigns devoted by NGO and organisations demanding better practices (Fashion Revolution, Greenpeace, ZDHC, etc.), and it is currently driving the change in big coalitions involving all the agents: industry (fashion brands, textile companies, logistics and transport companies, retailers, other providers), educators, organisations, etc. The most recent significant milestones are The Fashion Industry Charter for Climate Action, signed in Katowice in December 2018, during the UN Climate Change Conference (COP24); the UN Alliance for Sustainable Fashion, created in March 2019 within the context of the UN Environment Assembly in Nairobi; and the Fashion Pact, presented in August 2019 within the context of the G7 Summit in Biarritz.

While the two first are driven by the United Nations, the third was born as a mission from the French President Emmanuel Macron to the Chairman and CEO of the luxury group Kering, François-Henri Pinault, to lead the change of the industry from inside the industry. As of April 2021, 71 fashion groups, representing one third of the turnover of that industry, have signed the Pact, that is focused on biodiversity, climate change and oceans.

The Fashion Industry Charter for Climate Action's main objective is to drive the fashion industry to net zero GHG emissions by no later to 2050, through a commitment on sixteen actions. To cite only a few: to reduce 30 percent aggregate GHG emissions in scope 1, 2 and 3 by 2030 against a baseline of no earlier than 2015; to prioritize materials with low-climate impact without affecting negatively other sustainability aspects; to pursue energy efficiency and renewable energy in the value chain; and to establish a closer dialogue with consumers to increase awareness about the GHG emissions caused in the use and end-of-life phases of products.

Scope 1 are all direct GHG emissions from sources owned and controlled by a company; Scope 2, indirect GHG emissions from the generation of electricity, heat and steam purchased by a company; and Scope 3, other indirect emissions (outside the direct control of the entity, such as from a company's value chain activities).

Its first Progress Report released in June 2021 highlights the achieving: it has been signed by 125 companies and 41 supporting organizations, representing $450 billion in revenue. In the first year, 60% of the signatories achieved a reduction in GHG emissions (annual saving of 3.48 million tonnes of CO_2 equivalent and $117.14 million savings from emission reduction), and 72% are publicly reporting to the CDP (Carbon Disclosure Project) platform to track and report the progress of climate commitments. They are organized in seven Working Groups. The Working Group Decarbonization Pathway has settled the frame to report and control these emissions. Regarding to raw materials, they have a first commitment to increase from 14 to 45% the global percentage of recycled polyester used by 2025. The Working Group of Brand, Retailer Owned or Operated Emissions has agreed on focusing primarily on switching to renewable energy under Scopes 1 and 2, mapping out existing energy efficiency initiatives; developing a collection of best practices from leading brands and retailers; and providing guiding for renewable energy sourcing practices, among others (in this first year, only an average of 33% of total power purchased comes from renewable sources; and only 7% responding signatories' total consumption is sourced from renewable energy) (UNFCCA, 2021).

If we go to the Fashion Pact, its first progress report was published in October 2020. The signatories have set 7 tangible targets for climate, biodiversity and oceans (the three pillars of the pact). Related to climate, the first is the implementation of the principles of the UN Fashion Charter, followed by achieving 25% low-impact materials sourcing by 2025, and 50% renewable energy by 2025 and 100% by 2030% in their operations. The results show reductions of 350,000-450,000 tonnes of CO2 equivalent (only 10% of the global number recorded by the UN Fashion Charter, but it was recorded nine months before, and the signatories are not exactly the same). If we go to the energy from renewable sources, signatories of the Fashion Pact source 40-45% from renewable energy. Regarding to biodiversity and oceans we highlight supporting zero deforestation by 2025, and the elimination of unnecessary packaging in B2C by 2025 and B2B by 2030.

Apart from these big institutional frameworks, researchers have devoted attention to sustainability in the fashion industry. Some have tackled the social aspects, focusing on the reporting and the corporate social responsibility (Ferri, 2017, García-Huguet, 2021, Joy et al., 2012; Köksal et al., 2018; Marques et al., 2020; Perry, 2012). Others have analysed the impacts of the raw materials and innovative processes (Mihaleva, 2020; Rex et al., 2019;), or the role that designers play currently in sustainability (Karell and Niinimäki, 2020; Regadera et al., 2020).

It is also reported the gap between intentions and sustainable purchasing of consumers (Blázquez et al., 2020; Friedrich, 2021; Ozdamar and Atik, 2015). Some state that the fast fashion model cannot be sustainable by the model itself (Arrigo, 2017; Henninger et al., 2016; Kim and Oh, 2020). On the contrary, the big main retailer groups of fast fashion are triggering the shift towards a more sustainable value chain. And this sentence, that Arrigo, E. (2017) applies to luxury brands, would be suitable either for fast fashion: when a brand is marked by social and environmental responsibility, this contributes to enhancing the customer relationship, since customers are proud of buying products from a sustainable company.

Architecture and sustainability

The building sector is one of the critical industries to fight against climate change. In ten years, buildings have passed to be responsible for 40% to 50% of energy consumption in Europe, according to the European Parliament (2010), and the European Commission (2019b). Moreover, they are responsible for 50% of extracted materials, 33% of water consumption and 33% of waste generation.

This directive settled the objective of by 2020 all the new buildings in Europe were Nearly Zero Energy Building. It has not been achieved. However, those buildings built after 2000, consume (in average), half of those of 80s (European Parliament, 2010).

In 2019, two milestones drafted the panorama about architecture and sustainability in Europe: the European Green Deal and Level(s).

The European Green Deal (European Commission, 2019a) is a roadmap for making the EU's economy sustainable, with actions to boost the efficient use of resources by moving to a clean, circular economy and stop climate change. Although it covers all sectors of the economy, seven key value chains have been identified as critical, including building and textiles.

Level(s) is the European framework for sustainable buildings. It provides a common language for assessing and reporting on the sustainability performance of buildings (European Commission, 2019b). It is based on six macro-objectives that address key sustainability aspects over the building life cycle: GHG emissions; resource efficiency and circular material life cycles; efficient use of water resources; healthy and comfortable spaces; adaption and resilience to climate change; and optimized life cycle cost and value.

Although it seems to be very useful as it is open access, well-structured and complete, it is not applied by practitioners and architects, nor there is published academic research yet. To have a common framework to measure sustainability in buildings would be paramount, as there is no tool now, except some private certifications like LEED and BREEAM.

The fashion retail store.

The fashion retail spaces are the point when architecture and fashion meet, and where might be transmitted the sustainable values of the brands. They are usually located in streets with high patronage and reach directly many people. Some academics have assimilated the store as a marketing communication tool (Clow and Baack, 2010; Kent, 2003), while Arrigo (2017) has researched on how flagship stores of luxury fashion brands disseminate externally their corporate sustainability.

"Buildings [...] habitually frequented by the city's inhabitants, such as those in retail spaces [...] are capable of raising awareness of environmentally friendly consumption and practices. ...] should be encouraged to disseminate information on energy efficiency to the public by prominently displaying energy performance certificates, particularly in buildings of a certain size [...] that are frequently visited by the public, such as stores and shopping centers "(European Parliament, 2010).

This message has been, unfortunately, ignored both for the retailers and the brands, although some of them display the LEED for Retail or BREEAM certificates on their facades, showing their efficiency.

Apart from the energy efficiency, other possible sustainable actions related to the stores have been forgotten, despite the number of responses to a circular value system that have emerged in established fashion firms. These commitments are not often shown in the environmental management of their physical stores, the final link with the consumer. According to the Report Pulse of the Fashion Industry (Global Fashion

Agenda, 2018), there were major advances for sustainability in most of the value chains comprising the textile industry -notably in product design and development, and in the management of its end of use- except in the retail sector, which has barely experienced improvements compared to 2017 activity. However, the retail space makes up, together with packaging and transport, only 15%; which justifies firms and organizations to focus their efforts on the other fields that generate greater negative impacts (GFA, 2018).

This does not imply that the sustainability potential of retail spaces might be forgotten. In fact, the big retailers (as the ones of our study, Inditex and H&M), have special plans for their stores, as they are the definitive environment for the product and brand message, in addition to the link and connection with the consumer, an important agent for the transition towards the Circular Economy.

The lack of circularity-oriented tools for the physical spaces makes difficult to compare performance or criteria of the stores. However, they are strongly relevant in terms of reduction of GHG emissions (Scopes 1 and 2) and energy renewable sourced, some of the goals of the aforementioned commitments, both UN Fashion Industry for Climate Action and the Fashion Pact.

To help brands to commit to circularity, we developed a guide for circularity in stores, taking in consideration the one proposed by Jaca et al, (2019) for small and medium enterprises. Then, we have compared the information disclosed by the two groups, H&M and Inditex, with our guide, in order to identify the items that they have developed yet and the potential areas of improvement.

Methodology

This paper builds on qualitative data, based on secondary material: existing literature and documents disclosed by the groups of our case studies.

There are three steps: the review of the existing literature, the case studies H&M and Inditex, based of the information disclosed by them, and the comparison of their information with our previously developed guide for circularity in stores (Valerio, 2020), following the five fields of action of circular economy (take, make, distribute, use, and recover / enrich) and the guide proposed by Jaca et al. (2019) for small and medium businesses.

Our guide aims to be a support for both big and small retail shops, and ca be applied to other fields of architecture.

To review the literature, we have selected the documents in Scopus, with two keywords: “fashion” and “store”. The search until July 2021 shows 124 documents. If we refine the search using the keywords “retail store” and “fashion”, the documents reduce by a half, as they are 55. When we have tried to add a more architectural vision with the third keyword “design”, there are 4 documents. If we add the sustainability dimension with other keywords, like “circular design”, the result is 0 documents, or 1 document if the third keyword is “circular economy”, or 2 if the keyword is “sustainability”. If we refine the search incorporating the “conscious consumer” as the third keyword after “fashion” and “retail store”, the result is again 0.

As the academic literature is scarce and there is not a solid theoretical frame, we have decided to use case studies, Case study methodology is recommended for compensating the lack of established theory or when the research builds mainly on secondary data.

The fashion groups selected for the study are Inditex, a Spanish group, and H&M, Group a Swedish one. Both of them are owners of several fast fashion brands. Inditex has in its portfolio Zara, the most well-known, Pull&Bear, Bershka, Zara Home, Stradivarius, Massimo Dutti, Oysho, Uterqüe. H&M has H&M, COS, &Other Stories, H&M Home, ARKET, Weekday, Afound, Monki, and Sellpy.

Our brands operate using one type of store format: “single-brand specialty store”. Although each group has several brands, they do not use the format of “multi-brand store”. We use single brand according to the sense given by Miao (2019): “single-brand specialty store” as a fashion retail store which carries a single brand and operates with the intention of building the single brand.

The company chosen are well recognized by their influence in the fashion world and by their commitment to sustainability: both were founding signatories of the UN Fashion for Climate Action and the Fashion Pact, and many others. We have summarised some in Table 1.

Table 1. Some data about our groups in terms of volume and sustainability

	Inditex	**H&M**
Number of employees*	176,611	126,376
Revenue (USD), 2019*	31.3 billion	24.3 billion
Activity	textiles & clothing manufacturing	retail
Number of stores 2019	7,469	5,076
Headquarters	Arteixo (Spain)	Stockholm (Sweden)
Number of brands	8	8**
Sustainabel Apparel Coalition	Yes	Yes
Dow Jones Sustainability Index (S&P Yearbook 2020)	Gold (67)	Gold (68)
Carbon Disclosure Project	Yes	Yes
Make Fashion Circular (Ellen MacArthur Foundation)	YES Core partner	YES Core partner
CEO Water Mandate	YES (s. 2011)	YES (s. 2008)

Corporate Knigts' Annual Ranking Most Sustainable Corporations 2020	94th	27th

*Data from Orbis Database, 2019

**In this case, we do not consider Sellpy as a brand, but a way of delivery.

The data collected was based on secondary sources. Regarding to the groups, we have specifically used public information available on internet: Annual Report 2019 (Inditex, 2020), H&M Annual Report 2019 (H&M 2020a), H&M Group Sustainability Performance Report 2019 (H&M 2020b), and on their webpages.

Case study: Inditex

Their Sustainability Roadmap is founded on two cornerstones (Inditex, 2020:76):

-A commitment to the circular economy and decarbonisation

-Fully adhering to the Sustainable Development Goals and aligning their strategy with the United Nations 2030 Agenda and ultimately, to the promotion and respect of human rights.

They have core policies and strategies steering their sustainability actions, that include "Inditex's Environmental Sustainability Policy, Global Management Strategy, Global Energy Strategy, not to mention their manual for the design, construction, management and evaluation of Ecoefficient stores.

The circular economy approach has resulted in three initiatives: Closing the Loop, Zero Waste, and Green to Pack.

Closing the Loop is the plan to extend the useful life of textile products by collecting, recusing and recycling them. In 2019, the program was already implemented at 1,206 Zara stores in 46 markets (Inditex, 2020:179). The main uses of these garments are donation, upcycling in new textiles (not much developed); downcycling to non-textiles industry (mostly building sector); sale at second-hand stores, and energy recovery (we understand that by incineration) without exceeding 5% of the total garments).

Related to Zero Waste, their commitment is that none of the waste generated by their activities in their offices, logistics, and stores ends up in a landfill (Inditex, 2020:180). It is directly tackled by logistics, packaging, packing, the "single hanger" initiative, and training to the employees to recover the waste.

Green to Pack is their programme to improve their packaging using recycled materials and eliminating plastic bags in stores.

Going to the buildings, their plan for decarbonisation and circularity is focused on energy and water, through five actions: global energy consumption, major commitment to renewable energies, reduction of GHG emissions, energy management, and water management (Inditex, 2020:160).

Their commitment is to achieve 80% of consumption form renewable sources in their facilities by 2025, and in 2019 they had achieved 63% of electricity. The reduction of GHG emissions of Scopes 1 and 2 was of 35% per m2 emissions (Inditex, 2020:164-165).

They have an efficient plan of energy management at logistics centres, own factories and store, through which have reduced 2% the consumption of electric energy per m2 in comparison with 2018 (Inditex, 2019: 166); and 6% per m2 in stores (Inditex, 2019: 170). In 2019 they had 5,891 eco-efficient stores (92.7% of the group), and in 2020 they have reached 100%.

In 2019 they had 40 owned stores certified under the sustainable construction standards: 29 LEED Gold, 10 LEED Platinum and 1 Breeam. They have nearly all the brands (except Stradivarius), and in 17 countries: 21 Zara stores, 3 Pull&Bear, 4 Massimo Dutti, 2 Bershka, 5 Oysho, 4 Zara Home, and 1 Uterqüe (Inditex, 2020:171).

Case study: H&M

Their strategy on sustainability is based on three pillars: Circular & Climate Positive, Leading the Change, and Fair and Equal (website).

In 2019, they have monitored 10.1% reduction in electricity since 2012, 96% renewable energy in their own operations, 13% of water recycled, 67% of facilities in own operations with water efficient equipment, 29,005 Tonnes of garments collected through garment collecting initiative in 2019, and 62% of stores with recycling systems for main types of store waste. (H&M, 2020b:26).

According to their Priority 1 related to circular & climate positive: energy efficiency, they want to be leaders in energy efficiency and use as little energy as possible across their entire value chain. The majority of H&M Group’s own electricity consumption happens in their stores, and they are working to reduce store electricity intensity, including improving heating, ventilation, air conditioning, HVAC, and lighting systems (H&M, 2020b:31).

On their webpage, they have published in 2021 some stories about sustainability, being one of them about circularity in architecture: Built with circularity -form storefronts to office floors, that perfectly explains what we pretend with this article, to show how the sustainable practices that a brand is carrying out can be shown at the retail space.

H&M Group’s Circular Innovation Lab is working in new more sustainable materials and processes. They created interior panels made from textile fibres and dust, that have been used as interior in H&M stores, as well as in a pop-up concept for COS, saving 3,198 kg of fabric waste. They are also testing biocement as a floor in one office in Sweden, made of waste aggregate and microorganism mixed with water. They are also working with the Ellen MacArthur Foundation and with Arup to address circular business not only in their core business but also in their built environments. They want to optimise resources used in the group's stores and offices, by reusing interior and construction materials.

At the stores' level, there are two examples: & Other Stories prolonged the life of their mannequins, and Monki used recycled yoghurt pots in their window interiors.

Results and Discussion

We have analysed the 124 documents indexed in Scopus with the keywords "fashion" and "retail".

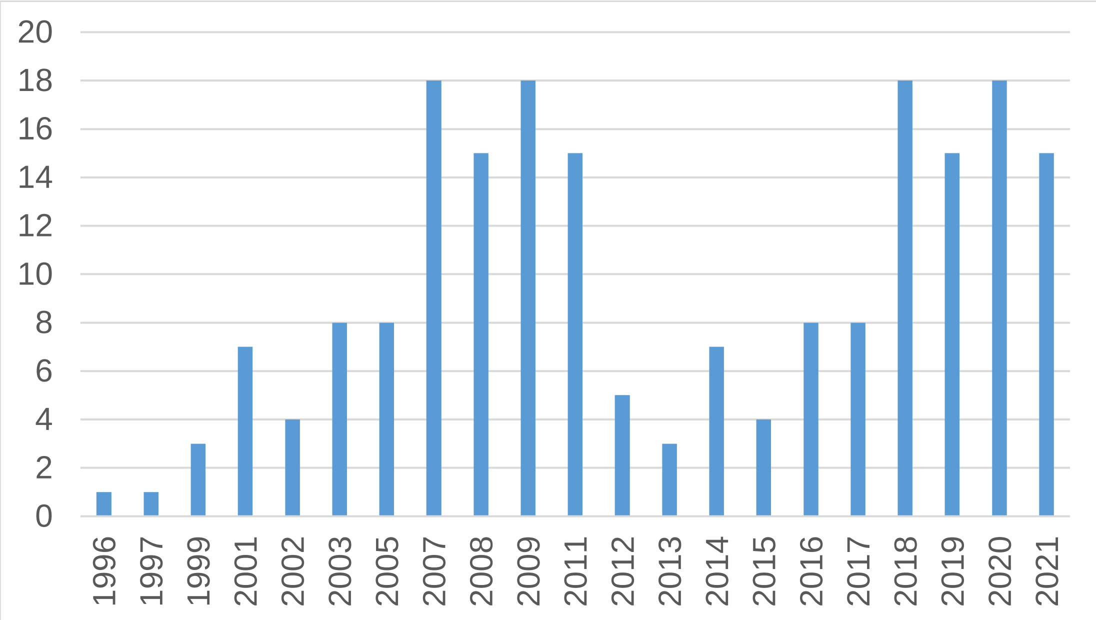

Figure 1: Number of indexed documents per year

We observe in Table 1, as there have been some peaks in the production around 2007-2011, and from 2018 on, coincident with the major economic crisis. It might be because of the need of rethinking how to improve the retail activities in those moments.

If we go to the areas covered by these documents, we observe in Table 2, that the majority of studies come from business, management. Although there are some from engineering, almost all refer to technologies such as RFID or other systems to improve stockage. One studies the energy efficiency of the stores, analysing the Inditex stores and how the managers well informed can improve the performance of HVAC system by reducing the gap of indoor and outdoor temperature (Loureiro and Labandeira, 2019).

Table 2: Subject area of the documents indexed

Subject Area	%
Business, Management and Accounting	33.8
Engineering	14.3
Computer Science	9.1
Social Sciences	9.1

Economics, Econometrics and Finance	8.2
Materials Science	6.1
Decision Science	5.6
Arts and Humanities	3.9
Mathematics	2.6
Environmental Science	2.2
Other	5.2

We have observed that there are no documents (using those keywords), addressing the challenges due to Covid or closed stores during 2020. There is only directly related to architecture, but in terms of regeneration of malls or commercial buildings (Dunham-Jones and Williamson, 2017). It might be because some architecture journals are not indexed in Scopus. Chan et al., (2012), Haug and Münster (2015), Khoa et al. (2020) and Miao (2019), refer to some aspects of design (atmosphere, formats, variables, attributes) that more influence the purchase. Arrigo (2017, 2018) explore the sustainability issues that could be communicated by the luxury brands in their stores, applying one to the Kering case.

Chan (2012) states that It is not enough for fashion companies to manufacture fashion clothing in an ethical production system and develop and design fashion clothing with sustainable and recyclable materials: They must also improve store-related attributes of eco-fashion to better satisfy fashion consumer needs, and should be cautious in the direct and moderating effect of price premium level of eco-fashion when determining the price. This study, however, takes into consideration store design and store's environmental practices, always form the point of view of purchasing decision.

After the revision of the literature, we have applied our guide for circular design to the information given by the groups of our case studies in their disclosed documents. We observe in Table 3, that both of them comply with most of the items that should be taken in consideration when trying to apply circular design criteria to the buildings.

So, the guidelines and priorities established by the groups regarding to circularity, have good expressions in their stores. However, when we go to the brands webpages, only COS (from H&M group) has some information about the circularity of their stores, in their magazine.

COS is the acronym for Collection of Style. Its objective is to deliver quality design at a reasonable price. Its General Manager, Marie Honda, states that the brand "is strongly influenced by architecture and design". The guiding principles of the brand are: timeless, modern, functional and tactile. Everything is designed until the minimum detail: garments, interiors, graphics, packaging, to achieve high quality of performance.

Since its launching in 2007, COS has currently retail-stores in 47 countries, in extremely selected locations. Although each space is unique, all of them follow three main concepts in design, from the Pentagram Partner Emeriti, architect William Russell: first, to obtain an open space, like “rooms inside a room”, without fixed walls, using metal rails or runners; second, the space is like a white paper so as to the product can speak on its own, but when it is needed, it is possible to use some materials (like concrete, metal or warm wood to create a more agreeable atmosphere) to enhance the product; in third place, to preserve as much as possible the original features of the building and to take advantage of the maximum natural lighting, while creating a modern and friendly space.

Table 3: Circular design guide applied to the strategies of the groups

Circular design guide for retail stores				INDITEX	H&M
Value	TAKE	1	Materials origin	1	1
		2	Environmentally friendly extraction processes	1	1
		3	Ease and abundance of materials selected	1	1
		4	Toxic-free use	1	0
		5	Material life cycle (resistance, long life performance)	1	1
Effectiveness	MAKE	6	Design according to the characteristics of the material	0	1
		7	Optimization of the material	1	1
		8	Minimum transformation processes	1	0
		9	Reduction of unnecessary variety of materials	1	1
		10	Avoidance of hazardous or harmful chemicals	1	0
		11	Minimize waste when avoidance is not possible	1	1
		12	Modularity and standardization	0	0
		13	Inter-company organization of production tools (sharing machinery and equipment)	1	1
Optimization	DISTRIBUTE	14	Work with local materials (Km 0 when possible)	1	1
		15	Transport by the most sustainable means and routes	0	1
		16	Elimination of unnecessary packaging, or use it recyclable, biodegradable or reusable	1	1
		17	Easy transportation of the products (dissasembled to occupy less space)	0	0
Efficiency	USE / CONSUME	18	Maximum life cycle	1	1
		19	Ease and economic use/maintenance/cleaning guidelines	1	1
		20	Universal design, adaptability	1	0
		21	Easy of repair	1	1
		22	Easy disassemby of parts	0	0
		23	Minimise the need for external energy, in the pursuit of energy self-efficiency	1	1
		24	Minimal waste generation during use	1	1
		25	Alternatives to ownership of the products /retail space: rentals, pop-up, services.	0	1
Resilience	RECOVER / ENRICH	26	Adaptability and flexibility (direct re-use)	0	1
		27	Repair and restoration for re-use	1	0
		28	Use of its components as components of new products	0	1
		29	Easy separation of its components without damaging	1	0
		30	Recycling of its components through low environmental impact processes	1	1

COS applies the same sustainable principles both to its garments and its physical stores. The interior design department usually works with innovative materials and processes to reduce waste and minimize environmental impact.

COS is a good example of best practices in circularity of the stores.

COS Cloche D'OR Luxembourg: Designed by the COS architecture team in London, in 2019. Located: Centre commercial Cloche D'Or, in the centre. It is the heart of a new district in town. The interior façade is made of Stone Cycling bricks, form mushrooms waste. It means a total of 8,960 kg of waste recovered

COS Banhofstrasse, Zurich (Switzerland): Designed by the COS architectural team. Located: Ancient bank in a building of 1920, 3 stories, 812 m2. Rehabilitation project: integral preservation of the characteristics of the existing elements: exterior façade, marble floor, terracotta facing of the pillars, etc.

COS Gwanggyo Gallery, Suwon (South Korea): Designed by architect Woojai Lee in 2020. Material. Bricks made out of recycled newspapers with glue, with an appearance similar to marble surface, paper texture and stone structure.

COS Tallinn (Estonia) Designed by the COS architectural team, led by head of interior Delphine Gautier in 2021. Located: A part-demolished industrial building of 19th Century: a former bread making factory in Rotermann Quarter. Working with the local historic committee in Tallinn, the architects preserved the materiality and highlighted the spaces within the building, designing a store to bridge the gap between the old structures, existing layout and its original purpose. Material: Existing limestone walls of the building, and an entire shopfitting reused from a previous COS store: to the concrete to the rail systems and cash desks. By refurbishing and reinstalling in Tallinn, COS saved 10,358 kg of waste from going to landfill.

This is a decisive step to circularity of the brand. As COS say in their Magazine, "The reuse test was an immense success for us. It allowed us to verify a process of repurposing materials on a global scale and identify the challenges in doing so. Going forward, we are now confident we can make our next store openings even more sustainable to help us achieve our goal of 100% circularity" (2021a).

But even if COS does so many things in the field of architecture, exploring its webpage, there is no reference to it in its Sustainability section: there is a lot about materials, about reduction of packaging, and about social issues. COS (2021b).

Conclusions

In this analysis, we have seen that the groups Inditex and H&M are coherent in their strategies addressed to the stores with the principles of the circular economy, as stated in our guide. In the case of COS, moreover, the stores are showing excellent practices in circular design, and the group communicates them as a corporative asset. We miss this information on the website of the brand, that is more oriented to consumers and purchasing.

From this research, we observe that the planned actions about the sustainability of the store are more focused on corporative level than on consumers. There is no public information in the stores about the main issues, or the materials or the policies implemented; nor information disclosed on the brands' websites (that are the most used by consumers).

The answer to the research hypothesis "can the fashion stores play an important role in educating consumers towards a more sustainable consumption pattern?" would be yes, but not now. The stores have values of sustainability, but they are not currently used by the brands as a mean of communication with their consumers. The information about these practices has to be found on the corporative documents, or in architecture forums (both of them not usually consulted by consumers).

This exploratory paper would serve to these two groups to engage with their consumers through the sustainable values of their stores, improve the conversation with them and help creating a more sustainable behaviour on them

Limitations

This is an exploratory research based on secondary material. It would be necessary to test the findings with the consumers in an experimental study.

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294 How to accelerate positive impact innovation to address climate change?

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Abstract: How to accelerate positive impact innovation to address climate change?

EIT Climate-KIC is Europe's largest public-private climate innovation initiative focused on cities, industry, land use and finance. EIT Climate-KIC has been successfully engaging with startups over the past decade. Several thousand business proposals and startup applications to accelerators and within them at certain selection stages have been evaluated, selected, and supported. Therefore, EIT Climate-KIC has comprehensive and deep experience on how to select and support start-ups for the highest possible impact. The ultimate objective is to trigger seed and venture capital investments in those startups and young businesses with the highest climate impact and business growth potential.

This paper focuses on answering the following questions. - How can climate impact forecasts (CIF) be useful for startups, organizers of startup support programmes, jury members and startup investors? - How to choose and support the right startups to get to climate impact? - How can we leverage the opportunity of impact investment? - How to ask innovators for impact?

The paper describes the Climate Impact Framework developed and used by EIT Climate-KIC and one of its key tools, the Climate Impact Forecast (CIF) Tool. Both, the Climate Impact Framework and its support mechanisms as well as the CIF Tool are described and illustrated. The climate impact of three startups is described in detail to provide examples. In terms of results the paper describes what start-ups, organisers of start-up programmes, jury members and startup investors get out of working with the Climate Impact Framework and CIF. Following a discussion of the questions from above, the paper concludes with three key recommendations. These emphasize the importance of a clear process and standard for climate impact assessment at multiple startup support selection stages, the need to make investment contingent on substantiated, data-driven and transparent impact claims and the value of a tool and dataset to support startups to substantiate their climate impact claims in a scientific, transparent, data-driven and comparable way.

Keywords: Climate Impact, Mitigation, Entrepreneurship, Avoided Emission Potential, Innovation

How does EIT Climate-KIC support startups?

The EIT Climate-KIC community has worked to identify, support and scale climate impact startups for the benefit of society for nearly a decade. The ultimate objective is to trigger seed and venture capital investments in those startups and young businesses with the highest climate impact and business growth potential. Several thousand business proposals and accelerator startups have been evaluated, selected, and supported as part of the Climate Launchpad and the ClimAccelerator Programme (Figure 1). Across all programmes the focus has continuously been on maximizing climate impact with scalable commercial solutions resulting in a very comprehensive and deep experience on how to select and support startups for the highest possible impact.

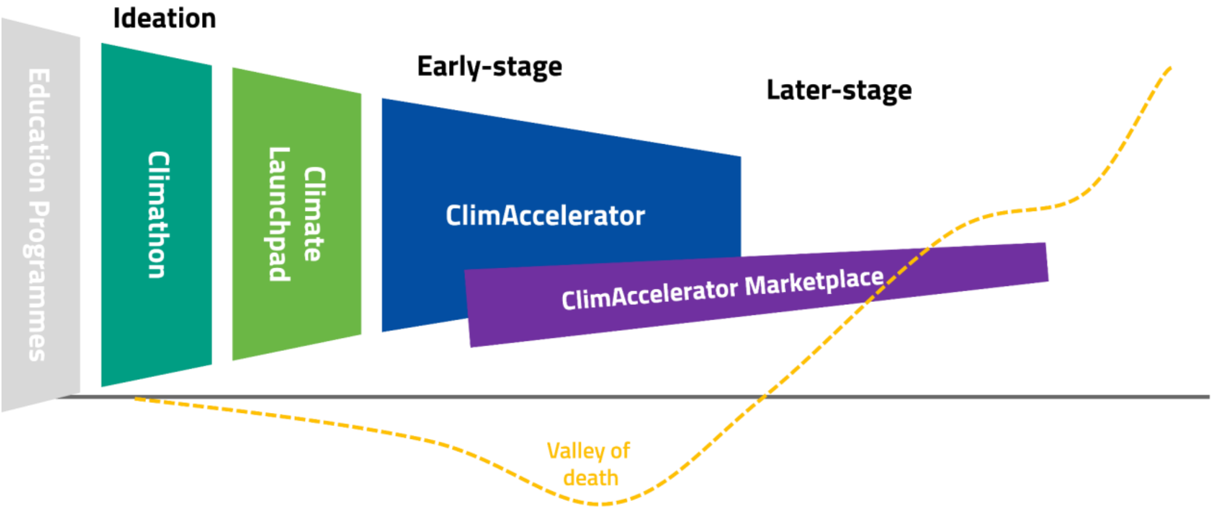

Figure 1. Startup support programmes of EIT Climate-KIC

The most relevant programmes and services provided by EIT Climate-KIC includes the (1) **Climathon**, a city-based programme, that offers a clear pathway to action and interaction - an opportunity for cities and citizens to co-create local ideas to share climate challenges. At the core of the programme is an ideathon organised by passionate local organisers - the people who know their cities and climate challenges the best (Climathon, 2021).

The Climathon gives the opportunity to innovators to explore ideas and decide to pursue them in the form of start-up companies. Teams that decide to do so can then apply to the (2) **Climatelaunchpad**, a competition that creates a stage for new ideas and operates in more than 50 countries worldwide to support hundreds of new climate startups each year. In many parts of the world, particularly in developing countries, it is the only platform supporting such businesses. It is therefore particularly active in Africa, Asia and Latin America. The competition creates a stage for climate business ideas, has a 6-year track record, and has supported approximately 900 entrepreneurs every year (ClimateLaunchpad, 2021), hence a total of about 5400 climate impact entrepreneurs over the past six years.

After the ClimateLaunchpad some of the startups enter the (3) **ClimAccelerator**, a global programme that gives startups access to innovate, catalyse, and scale the potential of their climate solutions. In a global community of organisers, Climate-KIC runs both theme-based and place-based acceleration programmes. It goes beyond European borders, building a bridge between world's industry experts and systems to break new ground in carbon reduction (ClimAccelerator, 2021).

Parallel to the ClimAccelerator the (4) **ClimAccelerator Marketplace** offers a comprehensive overview of the investment opportunities into early-stage startups. The dealflow stems from EIT Climate-KIC's ClimAccelerator programme and is therefore, also linked to the Climate Impact Framework (EIT Climate-KIC, 2021).

During all the programmes the **Climate Impact Forecast** (CIF) tool is used to measure the environmental impact of the startups. The CIF tool was developed by EIT Climate-KIC in collaboration with Impact Forecast (www.impact-forecast.com) to allow early-stage innovations to calculate and gain views of the emissions reduction potential of innovations easily and in an interactive manner. It is based on a modified model of the Life Cycle Assessment (LCA) to meet the particular needs of innovations at very early-stages. This tool is embedded in the Climate Impact Framework EIT Climate-KIC applies in its entrepreneurship programming to help forecast the positive or negative climate impact of the ventures it supports.

Most recently EIT Climate-KIC has been awarded funding from the European Innovation Council for the Project "Rapid Acceleration of Climate Entrepreneurs", which aims at aligning and improving innovation portfolios towards the European Green Deal goals. One area of work is supporting the European Innovation Council and 60-80 of its beneficiaries to test EIT Climate-KIC's climate impact framework to forecast the climate impact of early stage innovations and integrate a methodology for measuring systems transformation potential at a portfolio level, supporting a 1,5° scenario.

Methods: The Climate Impact Framework

While many different impact methodologies and tools have been applied over the years, the field of impact measurement has developed a lot within and outside the EIT Climate-KIC community. The Climate Impact Framework is bringing these different experiences together in a joint approach on how to set common impact targets for the individual startups, how to monitor progression and how to do programme evaluation.

Figure 2. Climate Impact Framework

The Climate Impact Framework (Figure 2) offers to build narratives which the participating startups and partners can use for gaining a solid understanding of their expected climate impacts from their specific innovations. It will help them build a stronger narrative around climate impact outcomes. This will also support the programme in general. The tool is based on the benchmark Life Cycle Assessment (LCA) method, used by design engineers, but with a narrower scope - only modelling differences between the innovation and baseline.

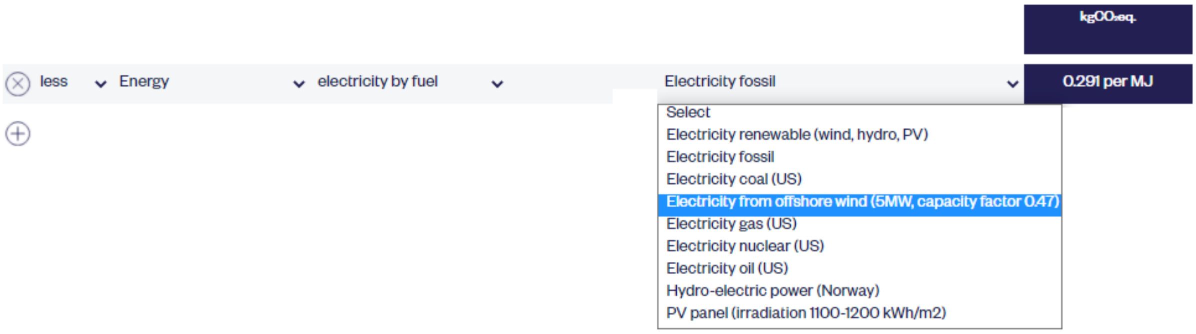

Figure 3. Impact bars dropdown

Impact bars make it easy to see which of the modeled resources and activities reduce or add to climate change (Figure 3). The database behind the tool provides the opportunity to explore options with the drop-down lists of materials, fuels, foods, etc. Users can discover new options that can be added easily, to make a big contribution towards a positive impact.

Climate impact, in tons or kilograms of CO_2 equivalent, is the key metric of the tool. Climate is not the only kind of impact, the tool also includes human health, eco-toxicity and resource depletion. Depending on the innovation it may be important and relevant to look at other data and indicators such as, e.g water footprints, DALY or ReCiPe scores, marine life effects, biodiversity, and many more LCA indicators.

The tool has been designed to be a fast-track LCA that allows the startups to measure their impact in one day, decreasing the time frame and need of resources drastically in comparison to a complete LCA. Furthermore, the tool is designed to be used iteratively by the startups, allowing them to keep developing their innovation and updating their climate impact at the same time.

Table 1. Support mechanisms within the Climate Impact Framework

Step 1: Workshop	Step 2: Coaching	Step 3: Validations	Step 4: Reporting
Full-day workshop, which consists of a climate impact quiz, an introduction to the science of impact assessment, examples of impactful companies and their best practices, a CIF demo and a 2-hours guided workshop on using the tool. By the end of the day the startups will know how to forecast their impact and have a preliminary climate impact in kgCO2 eq.	One hour support from an impact expert, to improve how to calculate and communicate impact with the CIF tool. The impact experts are experienced impact assessment specialists, ready to support the startups to do their impact forecasts, unearth relevant LCA data and find potential for improvement of their calculations.	The validation is a structured check of a climate impact forecast by a third party LCA expert, who provides feedback and time for a revision before determining if the impact forecast is positive, significant, and valid.	Consist of production of an executive summary & impact story, and a validated climate impact forecast file, impact projection and a future scenario. The report can be shared with investors or showcased online.

Sample climate impact of three startups

Three startups were selected based on an open call sent to startups that had already got an external validation of their climate impact forecast.

Brill Power provides BrillMS EV Battery Management System with zero battery replacements per vehicle lifetime instead of one battery replacement per vehicle lifetime. The difference in impact is calculated per year for 353775 times the electric vehicle battery is not replaced (52 KWh, 356Kg).

Rebel Meat provides burgers with 50% beef and 50% plant based ingredients instead of 100% beef. The difference in impact is calculated per year for 60,000 pieces of 135g burgers.

Soil Steam international provides steaming machines with steam technology instead of using pesticides. The difference in impact is calculated per 5 years for 80 machines produced.

After applying the Climate Impact Framework the validation results where showcased like this:

Table 2. Climate Impact Forecast for selected startups.

Company	Sector	Unit	No. Units per year	Kg CO_2 per Unit	Tonnes CO_2 per company/year
Brill Power	Transport	52KWh battery	363,775	-12566	-4445505
Rebel Meat	Food	135g patty	60,000	-0.198	-11.88
Soil Steam	Agriculture	1 machine produced	80	-81543	-6521

The following image (Figure 3) showcases how the Rebel Meat validation results are shown on the Impact Forecast Platform:

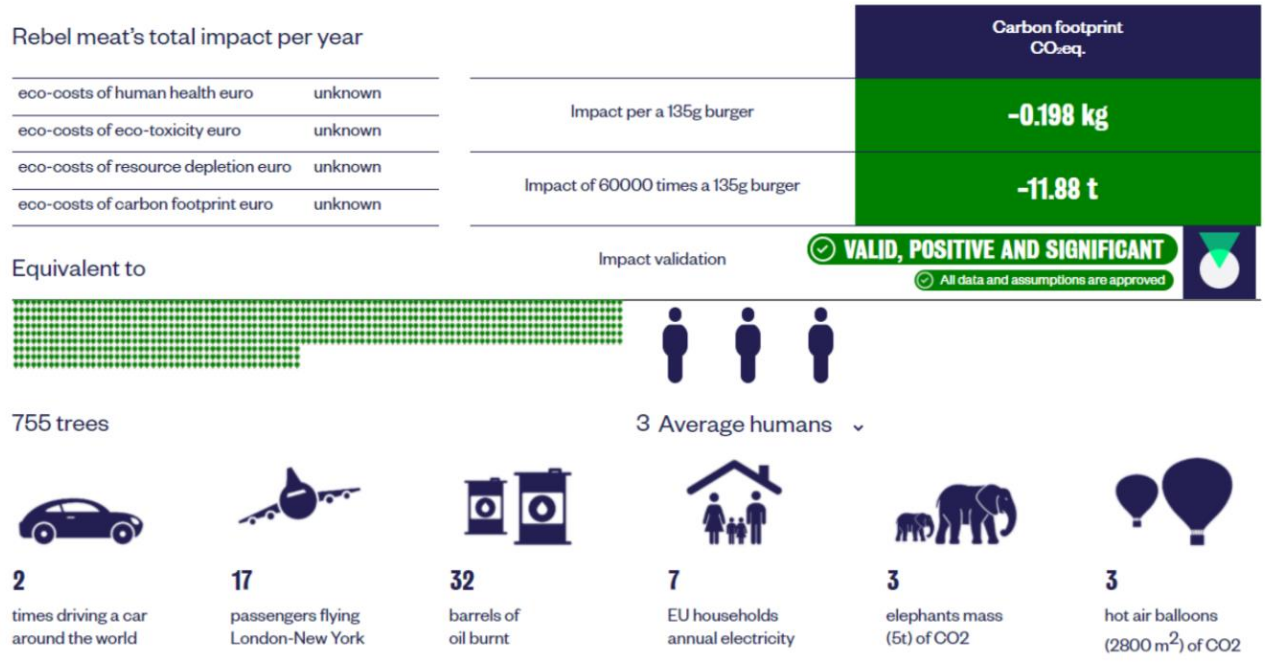

Figure 3. Rebel Meat Validation result 2021.

Results

How can climate impact forecasts be useful for startups?

The Climate Impact Framework helps **startups** to understand their climate impact potential in an early stage of their development. This can then have a positive influence in terms of integration of climate mitigation thinking on the further development of their products and services. In addition, having their own climate impact narrative gives them more trust from potential funders.

Organisers of startup support programmes are reporting in a similar way; “Two years ago we held the first impact forecast workshop for accelerator startups, and have since then also tried other impact assessment tools from different LCA consultancies and impact organisations. I find the Climate impact forecast to be the best fit for the needs of our startups, not only providing a forecast of the impact in a short time, but also for delivering a very pedagogic exercise bringing the startups an important understanding around their impact assumptions and how to improve their value proposition.” – Mikkel Trym, former Startup Accelerator manager in Denmark, Sweden and Norway.

Jury members of programme selection committees have reported: "The Impact Framework allows us to to gain new insights and helps us to take science-based decisions on innovations where the potential positive or negative climate impact is not always obvious" – Beñat Egaña, Entrepreneurship Co-lead Europe of EIT Climate-KIC.

Startup Investors want to be sure that they will have a return on their investment. When they sit on juries, they are looking for impact metrics and credible impact pathways. They want to see how the product or service of a startup is expected to achieve its impact and whether the logic behind it is credible. They will also check the assumptions and whether they are realistic and spelled out clearly. Startups are often over-optimistic when it comes to the assumed scale of the market their product or service is going to reach. This again is an aspect an investor or a jury would like to check to see whether the assumptions that were made seem to be realistic. The perceived impact equals the calculated impact multiplied by its credibility. This means that it is much better to have a few credible assumptions rather than something more complex that is harder to believe.

Investors appreciate the climate impact forecast tool and its results. They tend to say that it is cost-effective, in particular compared to consultancy (which is prohibitively expensive pre-funding). They find it great to have the climate impact forecast on a one-pager. This makes it easier to digest as they have to look at many key performance indicators with climate impact being just one of them.

“I have tested the Climate Impact Forecast and agree that it is a great tool both for startups themselves and venture capitalists / incubators / governments choosing who to fund." – Jeremy Faludi, LCA specialist and educator at TU Delft, VentureWell, Autodesk

How to choose and support the right startups to get to climate impact?

Initially there was no standard for impact information, at interviews (application and selection stages 1 and 2). Selection relied on knowledge available with the local managers and investors, but this was not reliable information. So later, when we used life cycle assessment (LCA) to know the climate impact, sometimes we found out that it wasn't there.

Several scaled down versions of LCA consultancy were tried in parallel and each showed the benefit of LCA data and that a standardised and simplified method to assess impact would be very helpful.

Now there is a series of online tools that can be used to measure the environmental impact of companies. In the article "How to measure the climate performance potential of startups" by Višević, D. and Valenzuela, D. (2021), nine tools were described, from which only three are public, LCA based and have a bottom-up approach, these tools are Climate impact Forecast (Cif), Crane and One Click LCA. The fact that Cif was under that description in combination with the fact that Cif is a key component of EIT Climate-KIC's climate impact framework facilitated its implementation.

Discussion

The Climate Impact Framework aims to strengthen and cascade the climate impact outcome with the following impact innovation best practices:

- setting clear impact targets helps source and select the best startups;
- improving the selection and support of the most impactful startups throughout the different development stages of Climate Launchpade and the ClimAccelerator;
- defining a clear process and a tested and trusted methodology for climate impact measurement, from pre-revenue Climate Launchpad to Acceleration and growth;
- building climate impact competences across the startups and the partner community.
- Having a clear narrative centred around climate impact to promote programme startups, partners and the community, including building a strong value proposition around climate impact measurement for future funders.

What we have seen from an accelerator manager and programme design perspective, is that these impact innovation best practices do change the results we are seeing with the teams. Before entering the programme and getting in touch with tools from the Climate Impact Framework, startups often describe their potential impact in a very broad and unspecific way. Especially the first exercise of the Framework, which is to define the Key Differences and Functional Units to compare the innovative solution with a baseline solution, is challenging to most startups. But in the end, it always helps the startups not only to describe the climate impact potential, but also the value proposition and the target groups as impact and usage are clearly connected. So startups profit in terms of better understanding their impact and business and being able to create synergies out of the work with the tools of the Climate Impact Framework.

The Climate Impact Framework adapts to a progression model where the impact methodology advances according to the Technology Readiness Level (TRL) of the startup and adaptation of the product or services in the market. A reason for this is that the need for validated impact measurement becomes more critical as the venture grows, whereas also the probability of success and the calculation estimates becomes more certain.

We take caution interpreting the numbers. Large deviations in the results should be expected from assumptions on market size, and choice of baseline and functional unit. The solution is to focus not too much on the actual number but on how well the number can be trusted. With these uncertainties, choosing the highest impact startups is not the best approach, as these startups might also be the ones most prone to optimism bias. Instead, the value of an impact assessment in at early stage is in removing those solutions which cannot show a clear and credible impact pathway, or who even show with reasonable certainty, to create more emissions than their solution avoids. The emphasis must be put on the certainty with which a startup can realise significant CO_{2eq} reductions.

How can we leverage the opportunity of impact investment?

Impact funding is available from many sources such as e.g., the large-scale European Commission Horizon 2020 Programme as well as specific mission driven venture capital. However, to get funding from these organisations, a claim in a defined impact standard is not always needed. The application for such funding asks startups to define their impact, often without reference to a standard, tool, or dataset to be used. As a result, the definitions of impact given by applicants, are difficult to compare and base a decision on.

It is possible, even easy in some cases, to overlook “the possible adverse effects of the solution [Pedrós Cayo, L. 2021]. It may for instance go unnoticed that the recycling of a material uses so much energy, that the climate impact of the recycled material is higher than that of the virgin material it is aimed to replace. When the energy use is known, we can find a break-even point and determine whether it is realistic to keep energy use well below this point.

In enabling technologies, the impact depends on the behavior of the enabled users. For instance. the impact of a ride sharing app depends on people sharing rides. And the impact of a hybrid car depends on how people fuel or charge it. The startup usually has to emit greenhouse gases to produce a solution, and the GHG reductions come from its intended use. When the degree of behavior change is known, we can find the required levels of adoption and engagement, and make it a priority to test if the market responds well above these levels.

Science based impact standards (LCA based CO_2 footprints in the case of climate impact) address the potential impact costs and benefits of a solution and help to prevent the omission of adverse effects. Without a data-driven approach to impact claims, there is a risk of funding startups that have the opposite impact of what they themselves and those funding them were aiming to achieve.

Impact data and standards are available which can be used to distinguish proposals on their ability to make the impact that the funding is dedicated to. When startups are asked to substantiate their impact claims, we have seen them increase their awareness and knowledge of their impact and gain the know-how to improve it. Therefore, making impact funding contingent on impact claims has a multiplying effect on the overall impact of the funding.

How to ask innovators for impact?

Firstly, simply asking for impact data, and defining precisely what you want to know, is creating value on its own. It lets the startups know you are basing decisions on substantiated, data-driven and transparent impact claims. In the case of climate impact innovations we ask for ‘the GHG reduction potential in tCO_2eq per year, for years 1 through 5, in the beachhead market’ to be substantiated with a CIF. This is better than asking for the ‘GHG reduction potential’ without further specification, which returns answers that differ in geographical scope, timeframe, tool, dataset, calculation method and impact metric. The problem is defining is asking for enough detail, while keeping the amount of work manageable for the startup and the selection committee.

A highly detailed assessment of the innovation is neither useful nor feasible; a full life cycle assessment (LCA) in the case of climate impact -or more broadly a full impact report of corporate social responsibility (CSR), Global Reporting Initiative (GRI), Green House Gas (GHG) emissions or Sustainable Development Goals (SDG) contribution-contains too much information to be legible in a selection procedure. These full assessments are also too time-consuming for the startups to create and costly to outsource to specialists. The solution in the Climate Impact Forecast is to simplify the procedure of LCA with an accessible tool, containing climate impact data, and focused on key differences between an innovation and business as usual. In simple terms, CIF asks what you use, produce and reduce, and calculates the corresponding climate impact. As such CIF is asking information which any credible startup will have, and translate it into the climate impact forecast needed for decision making.

So, to ask innovators for impact we leverage existing standards, ask for key information, offer consistent impact data, and require startups to quantify their resource use. Across the Impact Framework, we require increasing levels of accuracy and transparency, and have to offer increasing levels of specialist support, as the startups progress.

Conclusions

How to choose and support the right startups to get to climate impact?

It is important to set out a clear process and standard for climate impact assessment at multiple selection stages and reject teams which cannot show or describe a clear impact. The understanding of the own impact case also helps the startup but also the programme organisers to find the right coaches or mentors to further improve the impact case.

How can we leverage the opportunity of impact investment?

Making investment contingent on substantiated, data-driven and transparent impact claims drives startups to understand and improve their impact, which in turn improves and multiplies the overall impact of the funding.

How to ask innovators for impact?

It is important to ask for a standardized impact claim, and offer a tool and dataset to support startups to substantiate their climate impact claim in a scientific, transparent, data-driven and comparable way. By using one methodology and a certain set of tools, also the language gets more comparable.

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125 Indirect 3D Printing of recycled glass fibres from end-of-life products: towards a design engineering approach to circular design

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Abstract

Sustainability is increasingly becoming a key aspect for the design of new products and services. Within this context, digital technologies represent a reliable way for the development of new circular economy models. Basically, Additive Manufacturing (or 3D printing) allows to implement not only distributed production strategies but also the reuse and recycle of products at their end of life. In the last years, the development of new recycled materials for additive manufacturing has received much attention from both industry and academia, especially considering the most common materials (i.e. thermoplastics). Only few studies are actually focused on the recycling of less conventional products and wastes, as in the case of glass fibre composite materials. Since recycled fibres shall often fulfil specific requirements for the development of a new 3D printable material, coarse recycled fibres are not generally considered for the design of new products with additive manufacturing. Furthermore, designers are not fully aware of the existence of these new recycled materials, and their potential use for new applications may not be completely figured out during the design process. Especially for recycled composites, new materials are usually developed considering quantifiable physical properties as a priority at the expense of expressive-sensorial qualities related to human perception.

How could the use of these circular materials be encouraged for the design of new products? Is it possible to develop new recycled materials for real applications by considering a different approach to additive manufacturing? The aim of this work is to define a strategy for the design and production of new products from recycled composites through low cost and accessible 3D printing technologies.

Firstly, a new thermally-curable epoxy-based material filled with coarse shredded end-of-life wind blades was characterised taking in consideration both physical and expressive-sensorial qualities. At this purpose, a preliminary mechanical characterisation was performed, as well as different samples were created and compared according to the main visual and tactile properties. Contemporarily, a suitable process for the production of customizable pieces was defined through an indirect approach, which means by pouring the material in moulds made from a Fused Filament Fabrication 3D printer (Indirect 3D Printing).

Afterwards, the whole experimentation was validated thanks to the design and prototyping of a product for temporary exhibitions and stands, which can be reused as urban furniture or interior design element after its life cycle. To conclude, this strategy allows to design and produce customized long-lasting products from a waste-based material with an accessible technology, giving to the designer more flexibility for the development of new sustainable solutions. Further efforts should be done in order to better define an integrated approach for the development of new circular materials merging product design and material engineering expertise. In addition, other end-of-life products and materials could be potentially considered, as well as the use of biobased matrixes. Finally, the use of low-cost additive manufacturing technologies may lead to new bottom-up circular economy models for real applications from end-of-life products and common wastes.

Keywords: Product Design, Additive Manufacturing, Circular Economy, Glass Fiber Reinforced Polymers, 3D Printed Molds

Introduction

According to the main policymakers and stakeholders, sustainability has become a central aspect to reach responsible models of production and consumption (United Nations, 2015). In particular, Circular Economy is able to keep products and materials in use by preserving resources through the generation of closed loops (Ellen MacArthur Foundation, 2013). Different strategies, namely the “R-imperatives”, are fostering the transition toward circular economy models such as recycle, reuse, and repair (Reike et al., 2018). Consequently, designers have a crucial role in this practical transition through the design of new sustainable products and services (Camocho et al., 2018; Stegall, 2006).

Similarly, digital technologies actively support the implementation of new circular economy strategies. In particular, Additive Manufacturing (also known as 3D printing) shows the potential to implement distributed production strategies and allows the reuse and recycle of products and materials at their end of life (EoL) (Colorado et al., 2020; Despeisse et al., 2017; Sauerwein et al., 2019). Furthermore, new recycled materials from EoL products or waste have been progressively developed for additive manufacturing, especially considering Fused Filament Fabrication processes (FFF, also called Fused Deposition Modelling, FDM). In this emerging context, the most common waste materials (i.e. thermoplastics) have been receiving much attention from both industry and academic research (Cruz Sanchez et al., 2020). However, only few studies are dealing with the recycling of less conventional products and wastes, such as composites. In particular, Glass Fibre Reinforced Polymers (GFRPs) represent a good opportunity for new circular economy strategies based on Additive Manufacturing considering the future amount of products made with GFRPs at their EoL (Deeney et al., 2021; Witten and Mathes, 2019). Recently, some works focused on the development of new products from EoL wind turbine blades (Bank et al., 2018; Jensen and Skelton, 2018; Joustra et al., 2021), or 3D printable materials after the mechanical recycling of these composite waste (Romani et al., 2020). In this case, recycled fibres from mechanical processes have to fulfil some specific requirements to develop a new 3D printable material, for example a maximum size of the fibres related to the nozzle diameter. As a consequence, coarse recyclate powders with significant variations in particle dimensions are less considered for the development of new materials for additive manufacturing and, consequently, for new products.

Currently, the knowledge of these recycled 3D printable materials for new applications is not well-established amongst designers and practitioners, even though their role is crucial to enlarge the range of application of those kinds of materials (Romani et al., 2021). In addition, the development of new recycled composite materials mainly considers the quantifiable physical and technical properties due to the predominant use of composites for high-performing products. The expressive-sensorial qualities of these kinds of materials are scarcely considered through the whole development process despite their significant contribution in the perception of new products from waste (Sauerwein et al., 2017; Veelaert et al., 2020).

This work aims at defining a preliminary strategy for the design of new products starting from the development of new recycled composites. For this reason, the characterization of a rGFRP from shredded EoL wind turbine blades was performed by taking into consideration the mechanical properties and expressive-sensorial qualities. At a later stage, the goal of this work is to show a possible way to use accessible FFF technologies for the development of new products from EoL wastes that allows to use coarse recyclate powders.

In this work, a preliminary mechanical characterization was carried out on two different material formulations based on an epoxy resin matrix filled with coarse shredded powders from EoL GFRPs. Visive and visuo-tactile qualities were characterized through the comparison of different samples obtained from 3D printed casting moulds. As a preliminary validation, a plausible application field was then detected for this indirect approach to 3D printing considering the results from the characterization. The life cycle of a temporary customizable element for stands and exhibitions was then defined by considering the recycle and reuse R-imperatives to generate possible closed loops in urban furniture and interior design fields. Afterwards, the scaled model of a possible configuration was designed and prototyped as a proof-of-concept of the strategy. Despite the preliminary nature of this work, this strategy fosters the development of new customized and long-lasting products with materials from composite waste considering both technical properties and expressive-sensorial qualities through design prototyping. Designers and practitioners can therefore directly experience with these new materials to understand how to best use the experiential knowledge for the design of new value-added products. Moreover, this work sets the stage for the development of a new integrated approach for circular materials merging product design and materials engineering expertise, as well as bottom-up projects for new application fields from EoL products and materials.

Methods

Material (rGFRPs)

In this study, mechanically recycled GFs from EoL wind turbine blades were used as reinforcement for the new rGFRP samples and prototypes. EoL blades were provided by Siemens Gamesa Renewable Energy S.A. whereas the mechanical recycling was carried out by STIIMA-CNR (Istituto di Tecnologie Industriali e Automazione – Consiglio Nazionale delle Ricerche). EoL wind turbine blades were composed by an epoxy resin matrix reinforced with continuous GFs. A coarse powder (hereinafter called recyclate) was obtained by shredding these EoL parts through grid holes of 1 mm. As a consequence, the recyclate powder was composed by the shredded epoxy matrix and GFs with a variable dimension of around 1 mm.

The new matrix was composed by an epoxy-based resin (Araldite BY158, Huntsman International LCC, USA). A curing agent (Aradur 21, Huntsman International LCC, USA) was added to Araldite BY158 with a weight ratio of 100/28 for the crosslinking, reaching a gel time of approximately 80 minutes. The recyclate powder was added to the matrix with a nominal percentage from 15% to 45% wt. and mixed for 10 minutes with a mechanical stirrer at 50 rpm. The mixture was then poured into 3D printed moulds and the samples were demoulded after 24h at room temperature. Finally, a thermal post-curing was carried out at 100°C for 1h to complete the crosslinking.

3D Modeling and Indirect 3D Printing

Different samples were designed and produced for the preliminary experimentation of this work: the tensile specimens for the mechanical characterization, six 3D models with complex curved surfaces for the experiential characterization of the expressive-sensorial qualities (“3D Tiles”), and three open, closed and full parts for the proof-of-concept of the product application (“Bricks”). “Fusion 360” (Autodesk, USA) and

“Rhinoceros” (Robert McNeel & Associates, USA) CAD software were used to produce the 3D models of the samples and the moulds.

A Prusa i3 MK3S FFF 3D printer equipped with a nozzle diameter of 0.4 mm was used to 3D print the moulds (Prusa Research, Czech Republic). The Gcode files for the production were obtained with the open source software “Prusa Slicer” (Prusa Research, Czech Republic). In this case, a water-solvable filament was used for the 3D printed moulds, which is a BVOH (Butenediol Vinyl Alcohol Co-polymer) filament from Verbatim Italia S.p.A., Italy. This material is generally used as support material for FFF multimaterial 3D printing. A minimum 20/1 water dilution ratio is required for the disposal of this material with the household effluent for a maximum of 2 kg of dissolved BVOH per day (Verbatim, 2018). Considering other water-solvable materials (i.e. PVA, Polyvinyl Alcohol), lower temperatures and times are required for the dissolution of the 3D printed parts. Moreover, it absorbs less humidity during the storage, therefore it causes less clogging issues during the material extrusion.

The 3D tiles had a nominal length of 40 mm, a height of 40 mm and a width of 6, 8, 10 or 16 mm according to the specific sample for the experiential characterization. Considering the proof-of-concept, 1:10 prototypes were made, and the bricks had an overall dimension of 58x25x30 mm. A layer height of 0.10 mm was chosen for all the specimen moulds, which were 3D printed with the vase mode to reduce the overall amount of BVOH to dissolve.

The rGFRP samples were made by pouring the liquid mixture into the moulds made with the BVOH filament. In other words, 3D printing was used to create the tooling parts rather than the final pieces. Complex shapes with a wide range of materials can be obtained thanks to this approach, also known as “Indirect 3D Printing”. As a matter of fact, thermosettings and composites that cannot be directly 3D printed can be processed by using 3D printed moulds. Among those materials, silicones represent the most spread materials for moulds and countermoulds, especially in electronics and medicine (He et al., 2020). Other applications have been recently explored in different fields (i.e. architectural design), including the use of sacrificial water-solvable moulds for complex parts with overhangs or multimaterial pieces (Burger et al., 2020; Leschok and Dillenburger, 2020; Montero et al., 2020; Naboni and Breseghello, 2018; Rossing et al., 2020).

As previously mentioned, the rGFRP samples were obtained starting from an epoxy-based thermosetting resin filled with the shredded recyclate. After the first curing phase of 24h at room temperature, the moulds were dissolved by immersion in a beaker filled with cold water for 3h. The parts were manually washed every about 1h to remove the residues of BVOH, and then re-immersed in fresh water following the above-mentioned water dilution ratio. At the end, the thermal post-curing was performed to complete the crosslinking reactions of the final samples. The mould of a 3D tile with the corresponding casted shape are shown in Figure 1a, whereas the mould and the casted shape of an open brick are visible in Figure 1b.

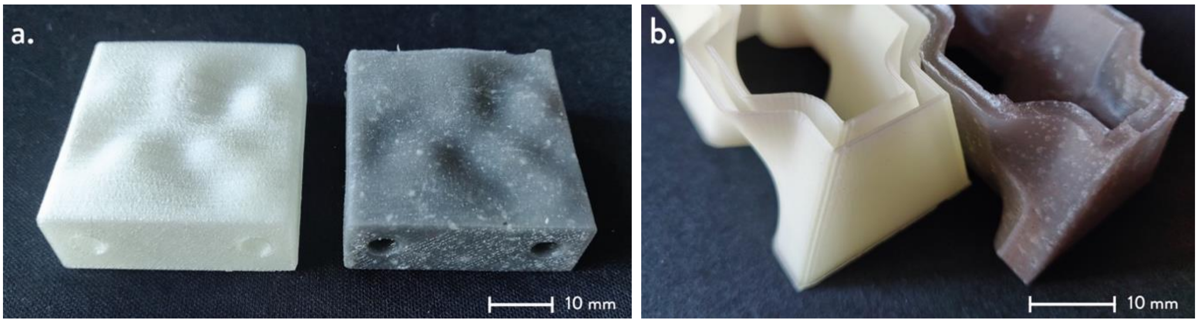

Figure 1. Samples of the 3D printed solvable mould and final shape of the (a) 3D Tiles for the preliminary experiential characterization and of the (b) Bricks.

Mechanical properties and expressive-sensorial qualities

A preliminary mechanical and experiential characterization was performed in order to consider both the technical properties and expressive-sensorial qualities of the new rGFRPs for the definition of a suitable application field. As a result, both aspects can be considered during the design phase of new products from EoL GFRPs although this holistic approach should be further developed for a practical implementation.

Figure 2. Tensile test specimens with 35% wt. of GF recyclate after the removal of the 3D printed mould according to the ASTM ISO 3039 standard.

Tensile tests were carried out by means of Zwick Roell Z010 equipped with a 10 kN cell load (ZwickRoell GmbH & Co, Germany) to evaluate the Elastic modulus, tensile strength and elongation at break of the rGFRPs. The tests were performed according to the ASTM D3039/D3039M-17 standard (ASTM International, 2017) at a speed of 1 mm/min. In particular, the elastic moduli were assessed in the starting slope of the linear elastic region. Experimental data were used to calculate a mean value and a standard deviation for each mechanical property. Two batches of at least five specimens each were prepared with a recyclate percentage of 35% wt. and 45% wt., respectively. Each specimen had an overall length of 100 mm, a width of 10 mm, a thickness of 2.5 mm and a nominal gauge length of 40 mm. A manual polishing was then performed to remove the asperities related to the fibers, reaching a constant cross-section. The tensile specimens with 35% wt of recyclate are visible in Figure 2.

Two batches of 3D tiles were produced for the experiential characterization. In detail, the first batch aimed at showing the variation of the visive qualities of the recycled material through 18 3D tiles according to the thickness of the sample (6, 8 and 10 mm), the recyclate percentage (15% wt., 20% wt., 25% wt., 30% wt., and 35% wt) and the different light exposition (direct or indirect light). The second batch focused on the investigation of the visuo-tactile qualities by modifying the recyclate percentage (25% wt., 30% wt., and 35% wt.) and the surface details (curved surfaces, engraves and embosses). The samples were then placed to create two different matrixes of comparison that can be useful for designers and practitioners to evaluate the different perception of the recycled material according to the selected variables.

Results and Discussion

Mechanical properties and expressive-sensorial qualities

Tensile tests were performed to evaluate the experimental elastic moduli, tensile strength and elongation at break for two batches of specimens with different rGFRP percentages. This evaluation step was useful to choose a possible field of application for these rGFRPs. In detail, two material formulations with 35% wt. and 45% wt. of recyclate powder were used for Batch 1 and 2, respectively. The main results are shown in Table 1.

Table 1. Elastic Modulus, Tensile Strength and Elongation at Break for two different batches of tensile specimens (35% wt. and 45% wt. of recyclate)

Batch	Recyclate percentage (% wt.)	Elastic Modulus (GPa)	Tensile Strength (MPa)	Elongation at Break (%)
1	35	4,5 ± 0,6	42,6 ± 6,2	1,2 ± 0,2
2	45	5,0 ± 1,1	36,7 ± 12,4	0,9 ± 0,2

Comparable values of elastic moduli, tensile strength and elongation at break are exhibited from the two material formulations. This can be due to the standard deviation values linked to the variability of recyclate powders. In general, the properties of composites filled with mechanically recycled reinforcements may significantly change from one batch to another, since the particle dimensions and distribution of the recyclate are influenced not only by the specific material waste but also by the conditions of the recycling setup. Moreover, further experimentation should be done to test other batches with different recyclate percentages, as well as to predict the effect of this misaligned short GF reinforcement on the mechanical properties of the composite (Fu and Lauke, 1998).

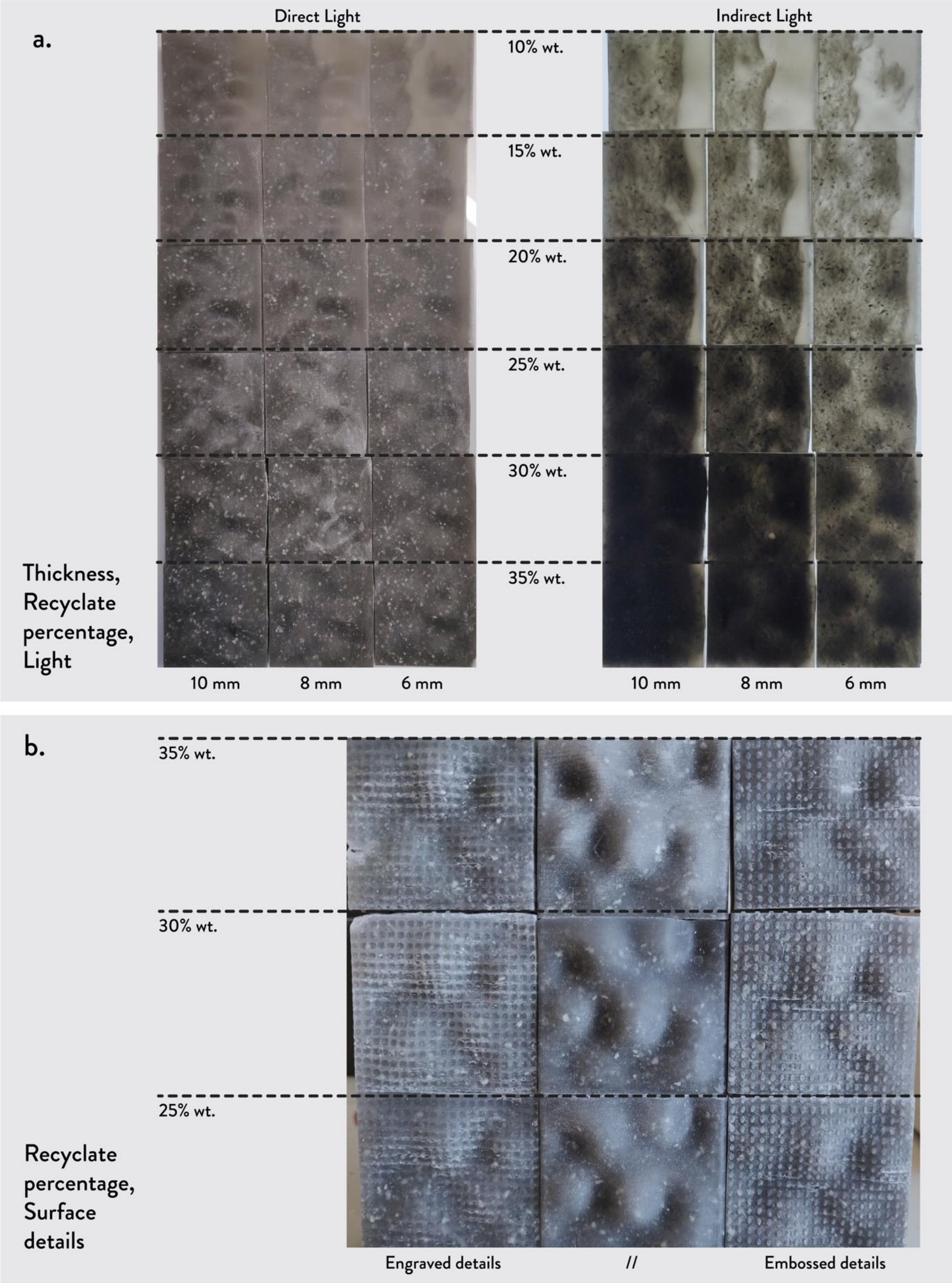

Figure 3. Samples for the preliminary experiential characterization: expressive-sensorial qualities related to (a) the thickness, the recyclate percentage and the light variation; and (b) to the recyclate percentage and different surface details.

Since expressive-sensorial qualities play a key role in the perception of a product (Karlsson and Velasco, 2007; Whitaker et al., 2008), a preliminary experiential characterization was set through two batches of samples from 3D printed moulds. According to Material Driven Design, an experience-oriented perspective should be considered to design new experiences starting from a material (Karana et al., 2015).

To this purpose, the 3D tiles were useful to tinker with the material and to directly experience with the variation of different parameters. The first batch (Figure 3a) was useful to assess the qualitative variation according to the different thickness of the samples, the recyclate percentage and the effect of the light exposition. A variation of 2 mm was designed for the 3D tiles thickness (from 6 to 10 mm), and an increase of 5% wt. was chosen for the recyclate percentage (from 15% wt. to 35% wt.). A matrix was then created for the qualitative comparison, and two different light setup were used. As shown in the matrix of Figure 3b, the second batch is linked to the variation of the visuo-tactile qualities according to the different recyclate percentage and the surface details. Also in this case, an increase of 5% wt. was chosen for the recyclate content (from 25% wt. to 35% wt.), and the superficial texture was modified by adding engraved or embossed details.

As a result, different translucencies and visive effects can be reached, as well as different textures could be added to the surface. A random pattern was visible in both cases, mainly related to the variability of the recyclate particle size. The creation of physical samples can be considered a powerful tool for the designers in order to fully exploit the potentials of new materials from wastes from an experiential point of view. Future works should be focused on the investigation of different expressive-sensorial qualities, also involving the users to assess their perception for the design of new value-added products (Veelaert et al., 2020).

Indirect 3D printing process

As previously mentioned, FFF 3D printing process was used for the creation of water-solvable moulds made in BVOH. Since this material is biodegradable and non-toxic, it could be considered one of the most suitable alternatives for sacrificial moulds. Moreover, BVOH could be recycled by collecting the material during the demoulding phase, that can be dried and shredded for the production of new moulds with pellet-based FFF 3D printers (Leschok and Dillenburger, 2020).

The use of 3D printed moulds may allow to select the most suitable shredding process or to avoid some steps for the mechanical recycling of EoL composites, i.e. fine shredding and sieving, reducing the overall impact of this process. As a matter of fact, the development of new extrudable reinforced materials for a direct approach to 3D printing shows some constraints related to the dimensions of the reinforcing particles. In particular, the nozzle diameter plays a crucial role in determining the maximum dimensions of the particles that can be successfully extruded. As an example, the maximum fibre length value for a nozzle with a diameter of 1 mm corresponds to 160 µm, and different steps or processes could be required to reach this dimension (Romani et al., 2020). Furthermore, the variability of different recyclate batches could significantly affect the printability of a composite material from EoL waste, while a lower effect might be noticed using a coarse recyclate as a reinforcement for poured rGFRPs.

Finally, indirect 3D printing for new rGFRPs could be a suitable way to produce large-format parts with complex shapes, especially considering that further work is needed to reach a scale up of new 3D printable materials from EoL GFRPs (Burger et al., 2020; Naboni and Breseghello, 2018; Nieto and Molina, 2019; Romani et al., 2020). However, some limitations may be related to possible entrapped air bubbles in the material during the casting or to deformations of the BVOH moulds for the exothermic reaction during the resin crosslinking.

Application Proof-of-concept

After the preliminary characterization of the rGFRP presented in this work, a suitable application field was chosen considering the material properties and the possibilities enhanced through 3D printing. From a technological point of view, 3D printed moulds allow to produce complex and customizable parts with a good control of the overall shape thanks to the digitalization of the mould construction. This aspect is particularly noticeable in large format applications such as building and furniture sectors, where the use of 3D printed moulds (or formworks) is increasingly gaining attention (Burger et al., 2020; Leschok and Dillenburger, 2020; Naboni and Breseghello, 2018). Moreover, furniture making represents one of the most sustainable solutions to recycle waste from wind turbine blades according to the Sustainable Development Goals (Deeney et al., 2021; United Nations, 2015).

For these reasons, exhibition and furniture sectors were chosen as a case study to define the life cycle of new customizable products for new closed loops based on recycle and reuse. A conceptual scheme for the design of customizable and reusable exhibition – furniture structures from rGFs is shown in Figure 4a. Starting from the mechanically rGFRPs coarse powders (1), new composite materials can be developed and characterized from a technical and an experiential point of view to fully exploit the potentials for new products (2). New customizable products can be designed and produced through indirect 3D printing based on FFF processes (3). After their first life cycle, these products can be reused multiple times for similar applications (A) or in different contexts and sectors (B), generating new closed loops. This strategy could be also useful to foster a behavioural change in local communities using these products as a tangible medium to involve users and citizens in the transition toward circular economy practices (Camocho et al., 2018). Within this context, designers and practitioners can actively contribute to this change, adding value to recycled composite materials through design (Romani et al., 2021).

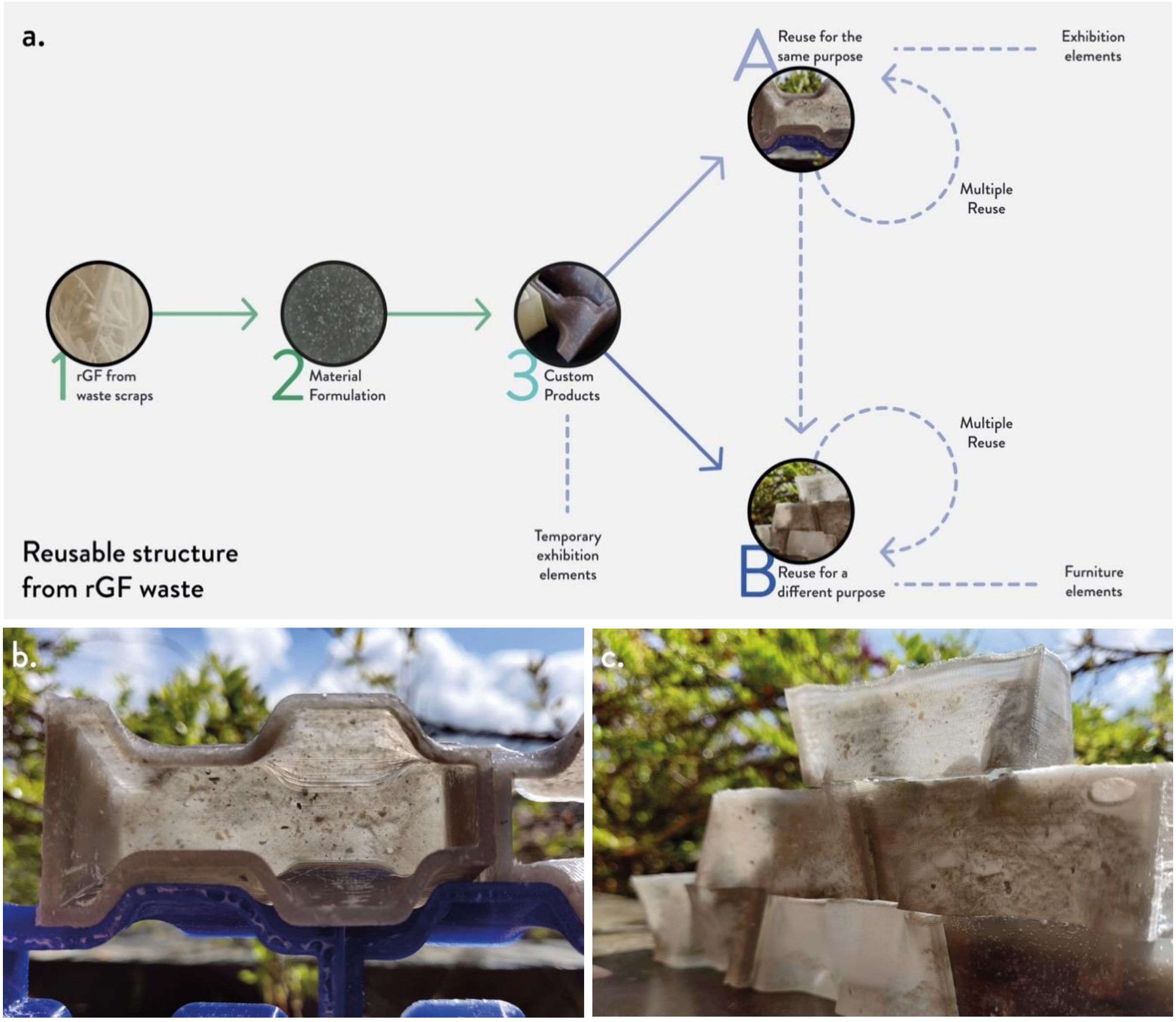

Figure 4. Concept of the reusable custom exhibition – furniture structure from rGFs: (a) concept of the life cycle; (b) detail of the "Brick" single element (1:10 prototype); and (c) possible configuration of the exhibition elements (1:10 prototype).

As a proof-of-concept, a temporary customizable element for stands and exhibition was designed. Following the scheme in Figure 4a, the exhibition element can be produced with 3D printed moulds by pouring the rGFRPs from EoL turbine wind blades. After its first life cycle, the product can be reused for other exhibitions and/or in local community public spaces as urban furniture or interior design elements. The 1:10 prototypes of three different configurations of the "Brick" sample (open shape, closed shape and full shape) were created to validate the overall strategy. Through this preliminary prototype shown in Figure 4b and 4c, some possible stand configurations using the exhibition elements were created, also considering the preliminary experiential characterization. This design prototype demonstrates that this strategy is able to foster the generation of new closed loops following an experiential and practical approach to new circular materials from EoL waste. Furthermore, FFF 3D printing technology allows designers to develop new customized and sustainable solutions.

Considering the preliminary stage of this work, further investigations should be done to assess other intrinsic features of the material or to develop other sustainable alternatives based on bio-based matrixes or different EoL composites. Additional work could be linked to evaluate the safety issues of these rGFRPs for real products. Finally, an integrated and holistic approach for new circular materials could be developed by merging product design and materials engineering expertise including a wider range of technical properties, expressive-sensorial qualities and a well-structured workflow.

Conclusions

To sum up, this work presented a possible approach to design new products starting from the development of new circular materials from EoL waste. A preliminary characterization of the mechanical properties and of some visive and visuo-tactile qualities was performed on rGFRPs filled with coarse recyclate powders from mechanically recycled GFs. An indirect approach to FFF 3D printing was adopted for the production of the samples that were poured in 3D printed water-solvable moulds made with a BVOH filament. In this way, designers and practitioners can directly tinker with new circular materials to better exploit their potentials for new products.

Afterwards, a conceptual scheme for new closed loops was designed considering the recycling of EoL composites and the reuse of the new developed products (Recycle and Reuse R-imperatives). Starting from the developed rGFRPs and the FFF technology, a proof-of-concept was designed and prototyped to validate the whole strategy. Exhibition and furniture sectors were chosen as suitable fields for new customizable elements for multiple reuse that aim to foster the behavioural change towards more sustainable models of production and consumption. Therefore, the designer has the opportunity to enhance this transition through the design of new products from EoL waste considering this behavioural change as an intrinsic added value. Even though this approach should be further developed, this work paves the way to a new holistic approach that considers design and engineering for new products starting from EoL waste. At a later stage, new bottom-up initiatives and applications may be detected and investigated with this approach to foster the transition towards circular economy models and a paradigm-shift in the behaviours of users and local communities.

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122 Circular Conference Toolkit. Case study ERSCP 2019 conference.

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Abstract

Conference and fair events are fully integrated into the cities' economic activity. They are highly valued as place marketers, promoting tourism and talent-attraction. Considering sustainability, they can make critical choices to have a positive influence not only on the local environment but also to avoid embodied impacts in the form of CO2 emissions, land, and water use.

The increase of this kind of activity and not taking into consideration the COVID-19 crisis, motivates this article to describe the process to design the "Circular Conference Toolkit" which aims to provide tips for organizing more sustainable conferences. The Circular Conference Toolkit lowers carbon emissions contributing to achieve carbon neutrality, reduces and recirculates waste towards zero waste, and increases sustainability awareness amongst the attendees promoting sustainable consumption to conference and fair events.

Following the Action-Research methodology, the toolkit was piloted in the 19th ERSCP Conference as a case study. Under the research paradigm of pragmatism, the design process was divided into three cycles; the first one implied analysing the state of the art; the second cycle consisted firstly in designing the tools through stakeholders and location analysis, brainstorming, co-creation and co-decision matrix. Secondly, piloting the toolkit in the case study and thirdly involving the post-conference evaluation that presented an assessment of the sustainable initiatives implemented during the ERSCP 19 Conference including a checklist, an environmental impact assessment, surveys and social media analysis. The environmental impact assessment was carried out through the comparison of two material flow analyses represented with Sankey diagrams of the estimation of the conference streams, with and without the implementation of the Circular Conference Toolkit. This analysis showed savings of

GHG emissions due to the use of renewable energies, and the CO2 offset program, which compensated 19% of the attendees' travel emissions (49000kg of 252426,38kg of CO2 eq/kg). Regarding materials, the strategy adopted considered a degrowth and an ecological perspective in the conference purchasing. The use of paper was reduced from around 400kg to 20kg thanks to digitalization. Plastic use also showed a significant reduction, from approximately 500kg to 4kg as a result of the zero plastic approach during the conference. Refusing plastic packaging at the catering in favor of compostable and biodegradable materials and avoiding other plastics by eliminating merchandising gifts to the attendees contributed to reducing the amount of plastic used. After strongly reducing waste streams, ensuring the treatment of the remaining waste through a conscious-chosen circular approach contributed to enhancing the sustainability of the event.

The result of the whole process was the Circular Conference Toolkit, a set of 37 guidelines divided by areas of action consisting of carbon neutrality, towards zero waste and sustainable consumption. The toolkit encompasses an open process of collaboration and reflection where the conference attendees, organisers and service providers are all included.

Keywords: Circular Economy, Sustainable development, Research action, Sustainable conference.

Introduction

A sustainable event is one designed, organized, and implemented in a way that minimizes potential negative impacts and leaves a beneficial legacy for the host community and everyone involved. Event greening or Sustainable event management (SEM) is the merging of event management with sustainability principles and practices, where sustainability awareness, design, and decision making are fully integrated into its management logistics, operations, and production (Katzel, 2007).

This paper describes the design of the Circular Conference Toolkit, which was applied and tested at ERSCP 19 Conference in October 2019 at the Universitat Politècnica de Catalunya (UPC-Barcelona Tech). As sustainability is a cross-cutting discipline that involves environmental, social, and economic spheres, the Circular Conference Toolkit's emphasizes three areas of action defined by the own ERSCP19 organizers: Carbon neutrality (energy usage and transport), Towards Zero Waste (resource use and waste management) and the principles of Sustainable Consumption.

The conference participants were engaged to take part in all the phases of the design process; from asking them ideas and conference expectations, to testing the Circular Conference Toolkit during the conference and making a post-event evaluation. The ultimate goal was being able to develop a toolkit exportable to further conferences, not only at UPC but also abroad.

Methods

This paper follows the Action-Research (AR) methodology. AR is traditionally described as a research approach based on a collaborative problem-solving relationship between researcher and client aimed at solving a problem and generating new knowledge (Zeichner, 2001). This aspect of problem-solving accurately introduces the research paradigm, which in this case would be pragmatism. This research paradigm is concerned with knowledge of action and change (Goldkuhl, 2011). The purpose of knowledge here is to improve existence through action (Dewey, 1931) and in this specific case study, by the design of a service and its implementation. The similarities between AR methodology and the design process are also noted. According to Cal Swann in his theory about *Action Research and the Practice of Design* (Swann, 2002), AR provides a tried and tested model for immediate translation to design practice where the implicit process becomes explicit. It lets you learn consciously from the project and thus growing empowered through the process.

As mentioned before, AR is a sequence of events or iterative cycles. Following the Cal Swann theory, the design process is described as iterative because it can only be effective if it is a constant process of revisiting the problem, reanalyzing it, and synthesizing a revised solution. This relation between AR and the design process is remarkable since both are integrated into this thesis, structured through the three cycles that allow designing a system as a result; the Circular Conference Toolkit in this case. Figure 1 shows the action research process, it's phases and tools used in this case study.

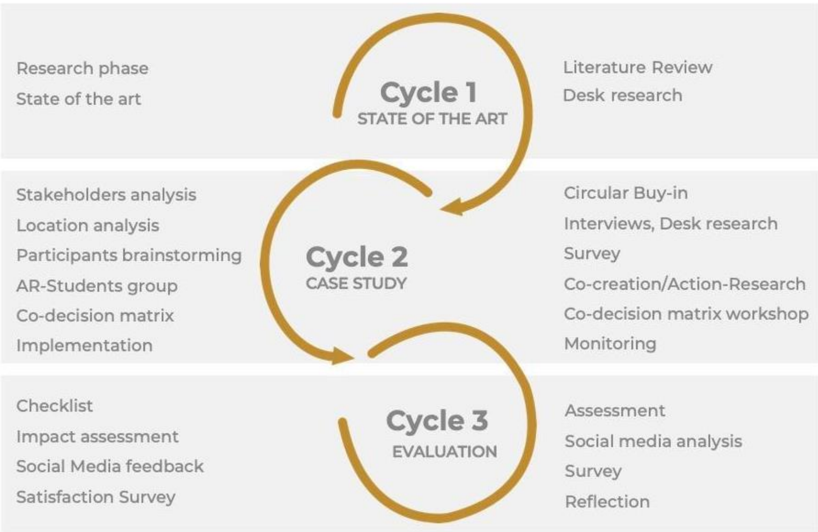

Figure 1. Action Research cycles, phases (left column) and tools (right column).

Cycle 1: State of the art

Even if researching and literature reviewing is inherent to the whole process, the First Cycle (C1) is the research phase. It explores the state of the art of sustainable and "circular" events. This research focuses transversely on the three areas of action of

ERSCP 2019: Carbon neutrality, Towards Zero Waste and Sustainable Consumption. The main methodology to be applied is a literature review and desk research.

Cycle 2: Case study

The Second Cycle (C2) consists in developing the case study, ERSCP 19. It is composed by different sections and it includes a variety of methodologies depending on each approach:

- **UPC location Analysis:** It is an overview of UPC's current status about the three areas and conference celebration and it highlights the UPC policies that could promote sustainability in conferences among the UPC campuses. The methodology applied is desk research to analyze the UPC's current status and interviews to complement the information obtained.
- **Participants brainstorming:** Six months before the conference, 19 participants of the ERSCP answered a survey aimed at gathering ideas regarding the three areas of action. The survey allowed knowing their expectations and sustainable awareness. The methodologies applied were brainstorming, survey and their corresponding analyses
- **Action Research. Co-creation with students´ group:** This section consisted in a co-creation session with the master student's group from the course "Research-Action Workshop on Sustainability Science and Technologies" of the Master’s Degree in Sustainability Science and Technologies. This collaboration provides new ideas for the conference and engages master students in its organization. The methodologies applied are Action-Research and co-creation.
- **Co-Decision Matrix Workshop:** This matrix is formed by the conclusions from the different sections along C1 and C2. The objective is evaluating and deciding which initiatives are going to compose the Circular Conference Toolkit according to an experts committee criteria. The methodology applied is decision matrix, and the evaluation criteria is: impact, viability, and desirability.

Cycle 3: Evaluation

The third Cycle (C3) is the post-conference evaluation. It presents an assessment of the sustainable initiatives applied during the ERSCP 19 Conference. The objective is to know which of the initiatives worked properly and which did not. Firstly, we will do a checklist and secondly a brief impact assessment. To know the conference' participants feedback, we will do a social media analysis based on twitter and a feedback survey:

- **Checklist:** The checklist is designed to check which initiatives were implemented and succeeded, which ones were implemented but did not succeed, and which ones could not be implemented. This enables us to do a reflection of the implemented initiatives and investigate ways of improving.

- **Environmental Impact assessment:** This is a qualitative analysis that shows the environmental impacts that could not be avoided at the ERSCP 19 Conference.
- **Satisfaction Survey:** This survey is intended to be sent after the conference to know the satisfaction of the participants and their opinion about the Circular Conference Toolkit test. It enables us to identify gaps and opportunities to improve in future ERSCP Conferences.

Results

Results of Cycle 1: State of the art

The development of the state of the art revealed that ISO1400, ISO20121 and EMAS (Environmental Management Auditing Scheme) are three standards related to sustainable events. The first one is related to environmental management, the second one is applied explicitly to sustainable event management, which makes it a feasible option to be applied in this industry and the third one belongs to the European system and works towards the continuous improvement cycle and an increase in environmental performance.

In relation to the 3 areas of action of the ERSCP 2019, Carbon neutrality in conferences and events have shown to be directly related to mobility, energy consumption, location and infrastructure and indirectly related to product consumption, food and waste. Zero waste applied to events has shown to be related to waste management, merchandising and products purchasing and catering. Research showed how sustainable consumption in conferences and events is related to water consumption, products consumption, food and employment.

In terms of general impacts in conferences and events, literature points out that those have a significant global ecological impact. Attracting a large number of people into a limited geographic space for a relatively short period of time inevitably comes with undesirable impacts (Nguyen, 2018). The most significant impacts that have been identified are: visitor travel (carbon pollution), food and drink consumption, and waste (Dickson & Arcodia, 2010). In contrast to negative impacts, significant events can stimulate the development of infrastructure for waste management and long-term conservation of natural areas to protect against influxes of large crowds (Musgrave & Raj, 2009). Thus, they can serve as a platform to raise awareness of local environmental issues (Porter & Kaufman, 2012), but this is not always the general trend. While financial gains may allow for many benefits, events that do not pay sufficient attention to the local social and environmental concerns may ultimately result in long term costs for the hosting community (Cashman, 2003). Table 1 synthetases the impacts of events by the three pillars of sustainability.

Table 1. Impacts of events by the three pillars of sustainability based on literature: Dwyer et al. (2000), Fredline & Faulkner (2000), Cashman (2003), Gursoy and Kendall (2006), Bowdin et al, (2006), Da´vid (2006), Wait (2008), Musgrave and Raj (2009), Pernecky & Lucky (2015).

Impacts	Economic	Social	Environmental
Positive	Direct / Indirect expenditure. Additional trade and business development. Event product extensions. Impacts related to tourism (destination promotion, commercial activity and job creation).	Induced development. Job creation. Revitalizing traditions. Expanding cultural perspectives. International prestige. Development of administrative skills. Talent attraction.	Providing models for best practice. Raising awareness of environmental issues. Urban transformation renewal. Improved public transport. Development of wasteland.
Negative	Cost of event failure to the local economy and financial loss. Inflated price of products, services and housing (Gentrification). Unequal distribution of wealth. Community resistance to tourism. Loss of local identity. Exploitation.	Exploitation of local human resources. Unequal distribution of wealth. Disruption of local lifestyle and normal business. Community manipulation. Social dislocation. Increased risk of security issues. Future use of new events infrastructure not maximized. Community apathy and rejection.	Location damage in the short and long term. Waste pollution. Noise pollution. Traffic disruption and congestion. Increase in energy demands and other natural resources. Destruction of heritage. Carbon emission from travel. Food waste.

To facilitate the design of the Circular Conference Toolkit, specific potential impacts of the ERSCP 19 Conference were detected and divided in the three areas (carbon neutrality, towards zero waste and sustainable consumption). Figure 2 presents the prevention of potential impacts of the ERSCP 19, considering the context of location, time, and own organization resources. These impacts were considered during the design of the Circular Conference Toolkit to avoid or reduce them.

3 AREAS	ACTIVITY	IMPACTS
CO_2	TRANSPORT	· Emissions: enhanced greenhouse effect, acidification, health problems
	ENERGY Electricity use and gas consumption	· Energy use from natural resources: depletion of natural resources, · Carbon emissions
	CATERING	· Food production and transport: air pollution and carbon emissions, greenhouse effect
	CATERING	· Food waste: food shortages, water consumption, agricultural land use · Plastic packaging: plastic pollution
	WASTE GENERATION	· GHG emissions · Overfilling of landfills · Pollution of air, soil and water · Harm towards animal and marine life · Wasting of resources
	WATER CONSUMPTION	· Waste loss from food waste: fresh water scarcity · Water pollution from waste and toilet use
	CONSUMPTION	· Packaging and one-use products waste · Unequal income distribution · Manufacturing effects: pollution and GHG emissions
	TOURISM	· Gentrification · Local entity loss · Addition environmetal effects: GHG, waste, waster consumption · Temporal and low-paid working conditions

Figure 2. Impacts prevention of the ERSCP 19 Conference.

Results of Cycle 2: Case study

Results of the UPC location analysis:

ERSCP 19 takes place at Vertex Building (Campus Nord) at the Universitat Politècnica de Catalunya - BarcelonaTech. Since the location is part of the university infrastructure, the ERSCP 19 conference is conditioned by UPC resources. Figure 3 shows the UPC and ERSCP 19 contributions to the three areas of action (carbon neutrality, towards zero waste and sustainable consumption, in order of appearance in the figure).

3 AREAS	UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH (UPC)	ERSCP 20 19 BARCELONA
CO_2	· 100 % renewable energy at Vertex Building · Energy cerfication level "B" at Vertex Building · Comunnication about 100 % renewable energy during the ERSCP 19	· Carbon emissions offset project to compensate mobility and catering
	· UPC Recircula Points: selective collective of waste · Information about the water fountains location	· Catering waste management · Donation of catering leftovers · To add more water fountains · Durable and reusable indications and signase · To add more water fountains
	· Inclusive infraestructure facilities at Vertex Building · Ecological and toxicity free toilet and cleaning products	· Local providers · Catering with local food · Information about sustainable mobility · Information about local sustainable hotels and businesses

Figure 3. UPC and ERSCP 19 contribution to the three areas of action.

Results of the participants brainstorming:

The survey was answered by 126 people, from 35 different countries, most of them from Europe. The professional status of the contestants was essentially related to the academic field (researcher, academic, Ph.D. or master student) while there was a little proportion, 5.6%, with a different background such as policymaker, business, manager and previous students from the Master in Sustainability Science and Technology. 70 suggestions were gathered in relation to the Zero Waste area of action, 65 for Sustainable consumption, 54 for Carbon neutrality and 23 as additional ideas or comments. Answers were filtered, eliminating those which were not considered valid, i.e., "no" or "nothing". Repeated answers were classified as "popular suggestions" and "expectations of the participants". Suggestions that were interesting according to the authors criteria were used as a source of ideas. Table 2 gathers the most popular suggestions to achieve carbon neutrality, zero waste and to promote sustainable consumption during the conference.

Table 2. Results of the survey brainstorming. Popular suggestions to achieve carbon neutrality, zero waste and promoting sustainable consumption at ERSCP 2019.

Areas of action	Ideas	Popularity (times of appearance)
Carbon neutrality	Compensation project of carbon emissions	12
	Encourage sustainable mobility	7
	Vegan or vegetarian menu	4
	Calculate carbon footprint	4
Towards zero waste	Do not offer single-use articles	16
	Reusable bottles and cutlery	15
	Digitalization and APP	13
	Avoid printed materials	13
	To bring own mugs, bottles and bags	7
	Zero waste catering service	7
Sustainable consumption	To provide local and organic food	12
	Vegan or vegetarian menu	12
	No plastic and single-use articles, paper-free	12
	Offer tap water	5
	Reusable mugs and bottles	4
	Zero waste catering service	7
	Share information about best practice businesses	4

Results of the Action Research. Co-creation with student's group:

This section shows the results of co-creation with a master student's group from the course "Research-Action Workshop on Sustainability Science and Technology". Main results involved a carbon footprint estimation of the event, a CO2 compensation program and an estimation of a Material flow analysis.

The calculation of the Carbon Footprint Estimation is based on the practical guide to calculate greenhouse gas emissions of the *Oficina Catalana del Canvi Climàtic* (2019). The carbon footprint of the conference is divided in two parts; Fixed and variable and it is calculated considering 250 assistants.

Fixed part includes Energy supply (electricity and gas), water consumption, Food consumption and catering transport and waste carbon footprint. The Variable part includes an estimation of the mobility (travel mode) of each participant.

Figure 4 shows the carbon emission percentages with the different proportions of the ERSCP 19 carbon footprint estimation. Most of the carbon footprint comes from air travel (98,16 %). The Fixed part only represents less than 2% thanks to the ERSCP 19 organization committee in developing the conference as sustainable as possible.

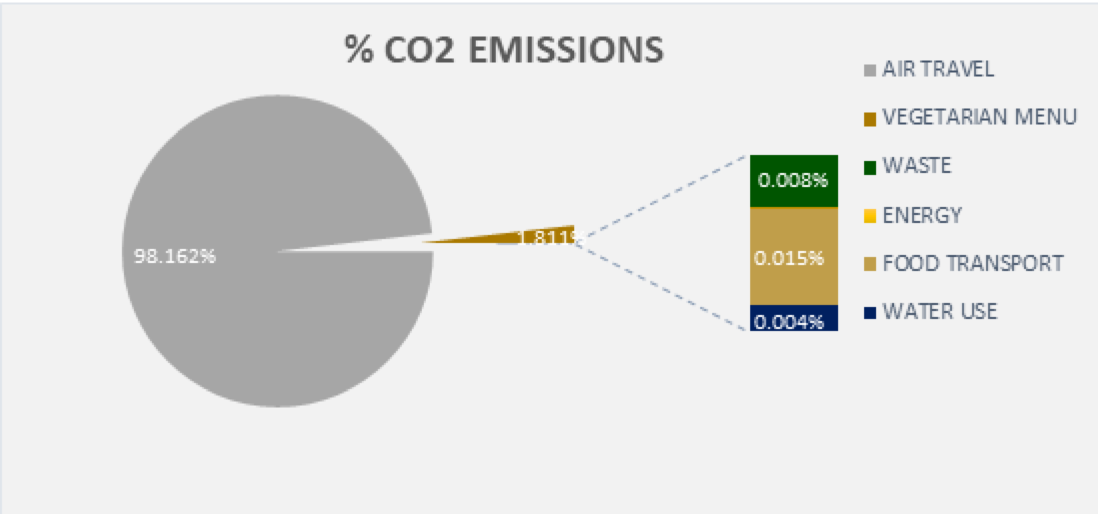

Figure 4. Carbon footprint percentages by categories.

To tackle the issue of the carbon footprint from air travel, we have designed a carbon CO_2 compensation program. There are some existing companies that offer as a service the calculation and the compensation of the event's carbon footprint. From the point of view of the ERSCP 19 organization committee, these mentioned companies are not transparent at all, and people are getting used to paying and forget about the impacts they are generating. For this reason, we have created a program where the participants take action during the process. During the online registration, there was the option to participate in the CO_2 compensation program. Participating was voluntary because there were some identities/universities that already had their own compensation programmes. Also, some people choose alternative travel modes like the train instead of the plane to reduce their carbon footprint. To get involved in the CO_2 Compensation Program, during the online registration the participants had to choose their option depending on the country they came from. Regarding the CO_2 Compensation projects, we explored some options such as reforestation projects in Spain, research projects at the UPC and UB (Universitat de Barcelona) and funding students projects. Finally, we selected two projects to be voted on by the participants during the ERSCP 19 Conference. The project UPC, Biodiversity Conservation at Torre Girona and the project ADENC, Biodiversity Conservation Parc Gripia Ribatallada at Sabadell-Terrassa. A further idea for the Carbon Compensation program was adding a CO_2 icon in the badges. The number of icons depended on each participant's performance about their mobility, as Figure 5 illustrates.

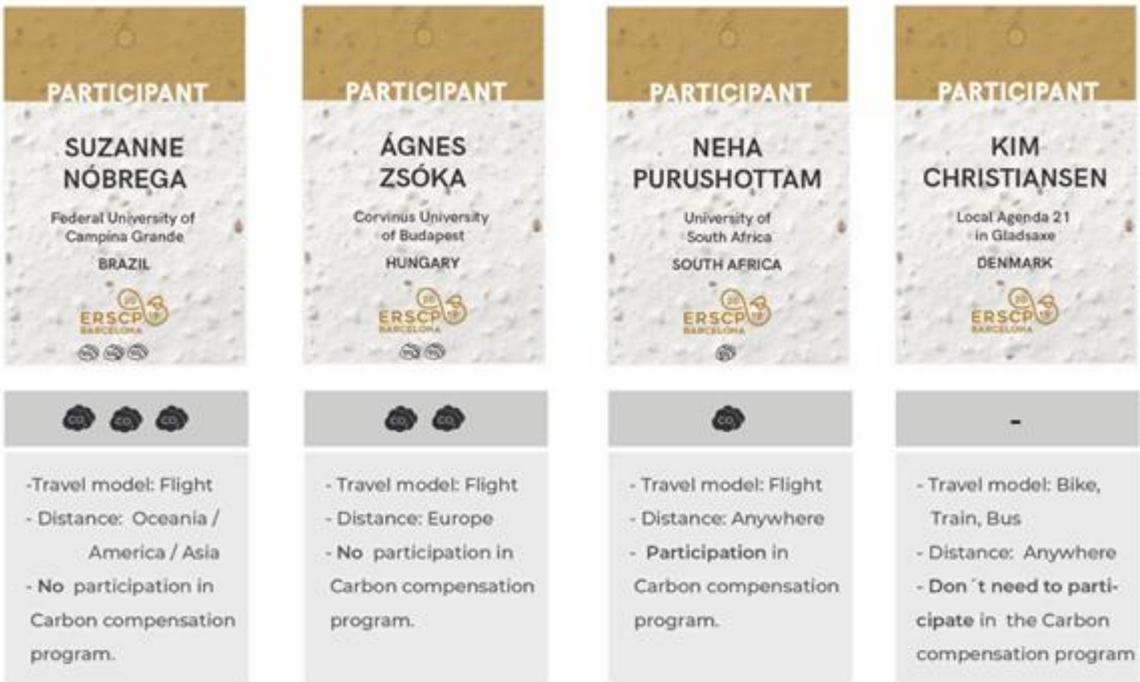

Figure 5. Participants badges showing their Carbon footprint performance through icons.

Figure 6 shows an estimation of a general conference material flow, which does not consider sustainability. The graph maps all the potential wastes and impacts. The Material Flow Analysis of DGTL Festival 2018 by Metabolic (Cycle 1) has been taken as a reference.

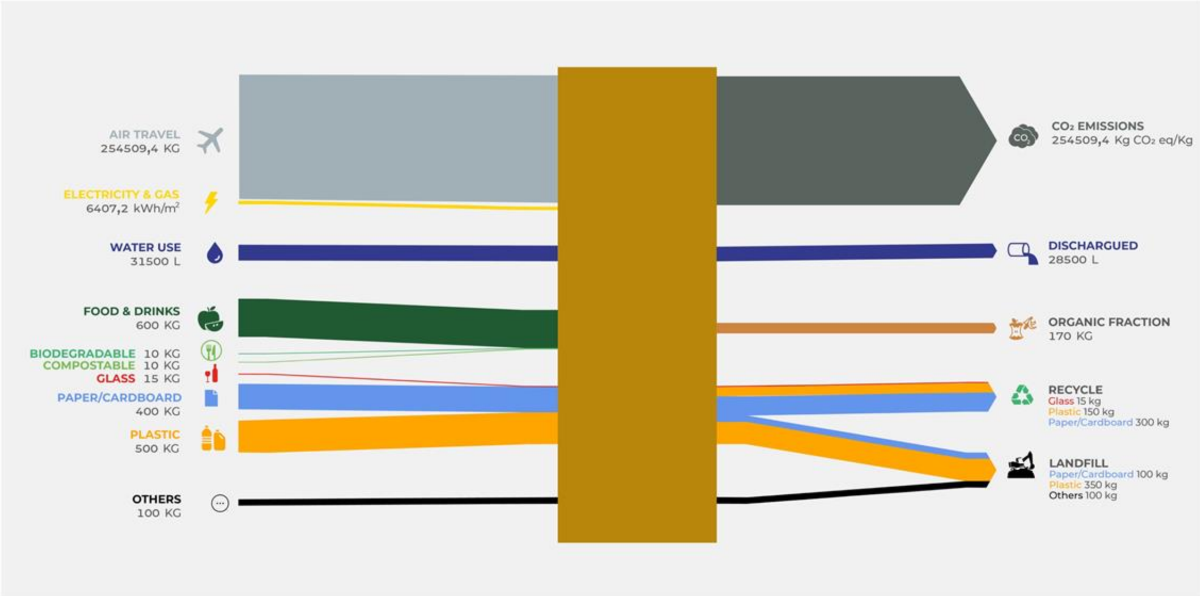

Figure 6. Material flow analysis of the ERSCP 19 without the Circular Conference Toolkit.

Co-decision matrix workshop

A co-decision matrix workshop was conducted with an expert committee. The objective consisted on choosing adequate existing ideas and actions to reach Carbon neutrality, Towards zero waste and Sustainable consumption at the ERSCP 19. As an outcome, we created a list that contained selected actions related to the three areas of action to implement during the ERSCP 19. This list is the Circular Conference Toolkit applied at the conference of this case study.

Table 3. Circular Conference Toolkit applied at ERSCP 19.

The Circular Conference Toolkit	
Areas of action	**Actions to be implemented**
Carbon neutrality	Location: accomplishment with sustainability standards
	To calculate the carbon footprint
	An adequate use of air conditioning
	Compensation program of Carbon footprint
	To incorporate renewable energy in the supply contract
	To maximize the use of natural lighting

	To provide reusable infrastructures (In case of use)
	Lowering fees for people who travels by train instead of aviation
Towards zero waste	Promote a selective collection of waste
	To scale the purchasing based on the conference needs (event typology, location, number of assistants, schedule, duration…)
	To eliminate or reduce printed materials. To prioritize recycled paper.
	Digitalization: to provide information by mail, website, apps...
	Avoiding the use of single-use plastic plates, glasses and cutlery.
	To choose a provider which ensures the correct waste management
	To inform participants to bring their own mugs, bottles and bags and badges lanyards.
	Zero waste catering service
	Avoiding Conference merchandising gifts
	To ensure an adequate Waste management system
	To avoid and reduce the source waste generations: product packaging.
	The possibility to give away the food leftovers
	To scale the need of food to minimize food waste
	Material Flow Analysis: qualitative (previous) and quantitative (after).
	To establish a local system of composting
Sustainable consumption	To provide water refill stations
	To promote social inclusion through the conference services and providers
	To promote and inform about sustainable and ethical accommodation, restaurant, and other activities for the assistant’s

	free time.
	Vegan or vegetarian (at least) menu
	To establish green purchasing policies and criteria
	To prioritize green / local food and drinks
	To ensure positive impact on local community
	Joint collaboration project among participants. To facilitate networking and meeting spaces.
	Swap corner (Rent corner: charge cables, pen drives…)
	To allow virtual participation to limit travel

Results of Cycle 3: Evaluation

Results of the Checklist

Figure 7 shows the checklist of tasks divided by the three areas of action of the ERSCP 2019. In general terms, most of the tasks that were implemented did succeed. Specifically the plantable badge had a good reception by the participants; the development of an app contributed to save a very high amount of paper; informing participants about bringing their own reusable bottles allowed to reduce drastically the use of plastic bottles during the sessions; merchandising gifts were not missed by the participants and the vegetarian and "Zero km" menu showed a good acceptance.

In relation to those tasks that were implemented but did not succeed, the Zero Waste catering turned out to be a "Zero Plastic" catering. The use of compostable and biodegradable plates and cutlery was prioritized over the option of reusing. For future conferences, a clear and consistent communication with providers is essential to avoid misunderstandings about different views of sustainability. The CO_2 Compensation program counted with the economical contribution of 34% of the participants (85 of 250). Even so, participation during the voting session gathered only 3 members of the 85 contributors. This low participation could be caused by various reasons:

- Misunderstanding or lack of communication of the second phase of the CO2 compensation program
- Voting was not a priority, parallel sessions were being held at the same time.
- The voting session took place on the last day of the conference and a significant part of the participants had already left the conference.

- Lack of interest or information. CO_2 compensation programs usually consist of paying and do not require more implication afterwards. The ERSCP 19 compensation program was innovative and symbolic. People did not expect the voting phase. Even if it was explained during the opening session and at the webpage, it probably failed to be understandable or motivational enough.

ERSCP 20 19 BARCELONA	CHECKLIST	Status
CO_2	To ask for the mobility option at the registration form	Succeeded
	To inform about sustainable transport options	Succeeded
	To provide the energy from clean sources and communicate it	Succeeded
	To calculate an estimation of the total carbon footprint	Succeeded
	Carbon compensation program: To choose local projects	Succeeded
	Carbon compensation program: Votation at the conference	Implemented but not fully succeeded
	Waste prevention: To map potential waste streams	Succeeded
	To provide an adequate waste collection system	Implemented but not fully succeeded
	To translate the UPC Recircula Points	Implemented but not fully succeeded
	To inform about the location of the water fountains and the UPC Recircula Points	Succeeded
	To encourage to bring reusable bottle and badges' lanyards	Implemented but not fully succeeded
	Catering: Zero Plastic, Do not use any plastic bottles, glasses, plates, and cutlery	Succeeded
	Catering: To prioritizice reusable rather than compostable or biodegradable	Implemented but not fully succeeded
	Catering: To avoid food waste, to donate the leftovers	Implemented but not fully succeeded
	Digitalization: App use rather than paper	Succeeded
	To avoid printer paper for signage and to the sessions, workshops...	Not implemented
	In case of printing, to use recycled paper	Succeeded
	Do not give corporate gifts	Succeeded
	To inform about sustainable businesses and activities in the city for the free time	Not implemented
	Catering: Menu with organic and "Zero Kilometer" food	Succeeded
	Catering: Vegetarian menu and vegan options	Succeeded
	Providers: Local enterprises, that ensure fair working conditions. Prioritize social inclusion	Succeeded
	Providers: Sustainability criteria ensuring the use of suitable materials to be recovered or recycled at the end of their use life. Ex: Plantable badges	Implemented but not fully succeeded
	Engage local community into the conference. To share knowledge	Not implemented

Succeeded
Implemented but not fully succeeded
Not implemented

Figure 7. Checklist of tasks divided by the three areas.

Results of the Environmental Impact assessment

Figure 8 shows the environmental impact that could not be avoided at the ERSCP 19 Conference. The analysis is separated by the three areas and shows how the "Sustainable Consumption" area is missing due to the lack of significant environmental impacts in this area.

	ACTIVITY			IMPACTS
CO_2	TRANSPORT	Flights Train Car	CO_2 emissions	· Enhanced greenhouse effect · Acidification · Health problems
	CATERING	Food waste from leftovers Biodegradable and compostable waste from cutlery and plates	Organic Waste	· Food shortages, water consumption, agricultural land use · Methane emissions
	SIGNAGE & WORKSHOPS	Printed paper waste Big papers non-recycled and post-its waste	Paper Waste	· Harm towards animal and marine life · Wasting of natural resources (forest) · Pollution

Figure 8. Environmental impacts that could not be avoided at the ERSCP 19 Conference separated by areas of action.

The major environmental impact is related to the emissions caused by mobility, specially air travelling. The variability of this impact depends on the location and the participants' traveling options. The ERSCP 19 organization promoted sustainable alternatives and developed the CO_2 Compensation Program. As expected, these measures are not enough to mitigate this impact since they do not address the root of the problem. To truly end the mobility environmental impact it is necessary to celebrate the conference remotely or conduct a significant change in the mobility system, which means a transition in the energy and transport technology system, that is far from the scope of the Circular Conference Toolkit.

"Towards Zero Waste" environmental impacts are caused by waste generation. It comes specially from the catering and some paper used during the sessions. The waste from the catering is organic since the cutlery and plates were biodegradable and compostable. The glass from the wine and water bottles is recyclable, the same as the paper used during the sessions. As a result, impacts are not very high but they could be improved by changing compostable and biodegradable materials to reusable ones in the catering service.

Figure 9 shows a Sankey diagram about the Material's Flow Analysis of the ERSCP 19 Conference with the implementation of the Circular Conference Toolkit. The figure shows an estimation of the material's flow of the ERSCP 19 Conference. The major impact is mobility by aircraft, and the CO_2 Compensation Program approaches to compensate the 19% of the total mobility emissions. Another source of emissions is the energy used during the conference, but it is not appreciated since it comes from renewable sources. The big majority of materials are recirculated since they are composted, recovered by *UPC Recircula*, recycled, and reused. The use of water has not been clarified so the diagram indicates that it ends up discharged. The higher quantity of the ERSCP 19 materials fraction is organic. It is composed of all the food of the conference and the plates and cutlery made from biodegradable and compostable materials. Their treatment consists of composting by the catering provider, so it can be considered circular. Glass fraction comes from wine and water bottles. It is recycled by the local waste management system. Paper and plastic are almost absent and recovered and recycled by the *UPC Recircula* waste system. Plastic comes from packaging of office materials that we could not avoid (pens, markers…) and paper comes from post-it's, printed signage and paper resources used during workshops at the sessions. All paper used was recycled to reduce its impact, and a part of the used paper is being reused as draft paper. The fraction "others" represents the materials that are not identified and are components of objects used during the conference. It embraces elements that are out of the focus but the amount is an indicative figure.

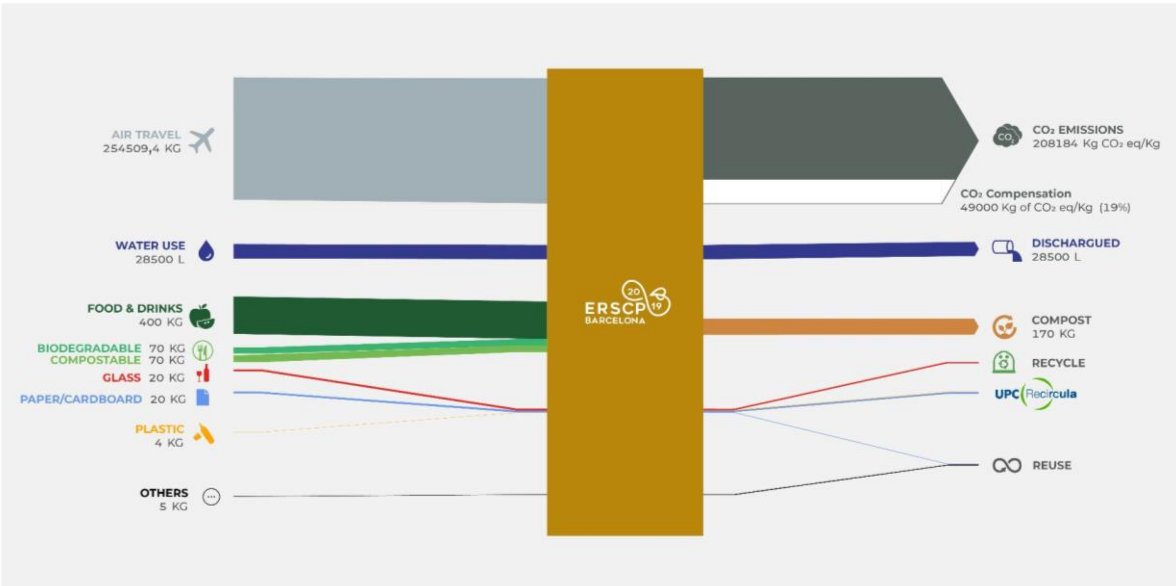

Figure 9. Sankey diagram showing the Materials Flow Analysis of the ERSCP 19 Conference with the implementation of the Circular Conference Toolkit.

Figure 10 shows a comparison of the materials flow when the Circular Conference Toolkit is implemented or not by overlapping Figures 6 and 9. Lighter colors are overlapped to appreciate the differences of the materials flow. The main differences are the following:

- The energy only affects without the Circular Conference Toolkit because during the conference, it came from renewable sources.

- The CO_2 compensation program allows to compensate the 19% of the Kg eq. of CO_2 emissions, that represents 49000 kg of CO_2 eq/kg.
- The water use has decreased from 31500 L to 28500 L thanks to the choice of the vegetarian menu and the sustainable behavior of participants.
- The amount of food (from 600 to 400 kg) has decreased too to avoid food waste but the use of biodegradable and compostable materials is new. So the compost made is much more than before.
- The compost was born as an alternative to avoid plastic and paper waste. In fact, it can be seen the great reductions of these two materials.
- In the case of paper from around 400 kg to 20 kg thanks to the digitalization (app and web page use) and the reduction in purchasing and packaging.
- Regarding plastic, there is a significant reduction, from 500 kg to 4 kg thanks to the zero plastic approach during the conference. The typical plastic packaging at the catering has been refused in favor of compostable and biodegradable materials, and we avoided other plastic from not giving merchandising gifts to using a degrowth and ecological perspective in the conference purchasing.
- Another significant difference that makes the conference circular is the waste treatment. Since in Figure 22 (Section C2.4), some materials end up at landfill or leave the responsibility to the local waste management system and its inefficiencies, the Circular Conference Toolkit approaches circularity.

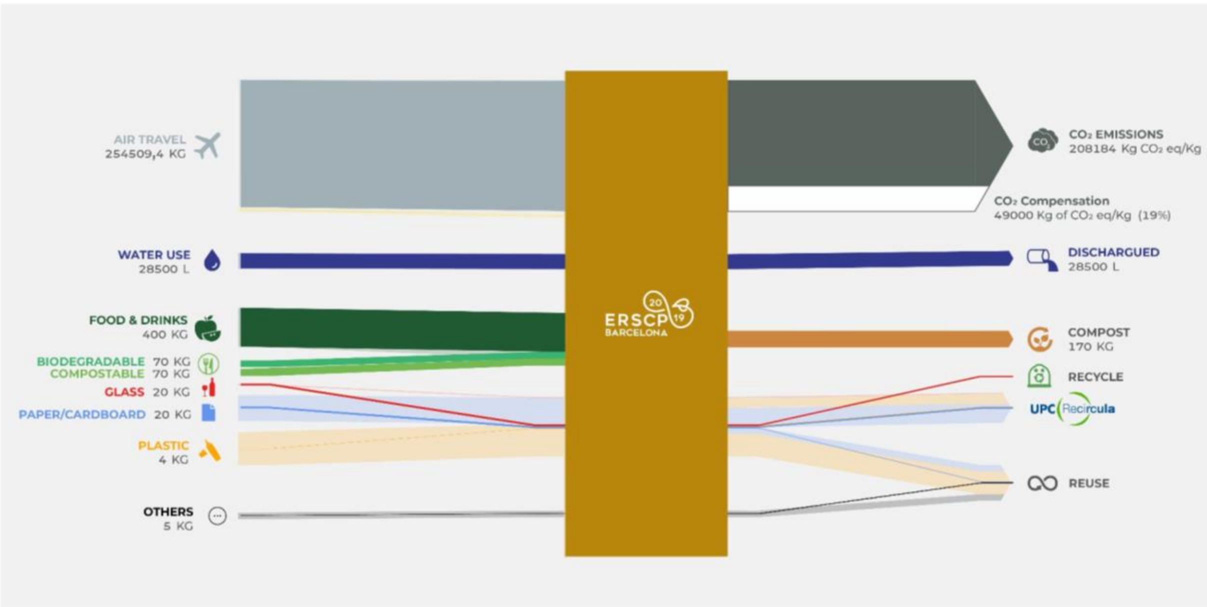

Figure 10. Sankey diagram about the Material's Flow Analysis of the ERSCP 19 Conference with the implementation of the Circular Conference Toolkit.

Results of the Satisfaction survey:

The survey was sent to 250 participants and it was answered by 16%, 40 participants. Even considering the low participation in this survey, it is significant that 30% of the participants were not sure if they paid the CO_2 Compensation Program or not. In relation to the selection of CO_2 compensation projects, the participation was extremely low since only 3 participants of the 85 who paid the CO_2 Compensation Program participated. Only one of the participants answered that he or she participated in the selection of the CO_2 Compensation Program. The poor participation in the selection of the CO_2 Compensation Program may be caused by various reasons:

- Misunderstood or lack of clear communication. The process of this CO_2 compensation program is new. It is an option that most of the contributors did not expect to vote for the project and misunderstood the process even though it was communicated in the welcome session, the website and the schedule.
- Lack of interest: As people are already used to the traditional offset programs where you pay and forget about it, following our process may require a new effort. Also, in the cases that the registration has been paid by their work identities, the money spent used to has less consideration.
- Parallel sessions: While the session of the Project's selection, there were other sessions that also were interesting to the participants.
- Current Context: Some participants left the conference before that they had planned because of the socio-political situation during that week.

The initiatives implemented were also rated through the survey. Participants had to rate from 1 (very poor) to 5 (excellent). Table X shows the average scoring of the initiatives.

Table 2. Results of the survey brainstorming. Popular suggestions to achieve carbon neutrality, zero waste and promoting sustainable consumption at ERSCP 2019.

Initiative	Score
CO_2 Pre-Estimation	3.9
CO_2 Compensation Program	3.9
Ease of Conference accessibility by public transport	3.5
Vegetarian menu	3.9
Local and organic food choices	3.9
Zero waste catering service, mainly focused on zero plastic	3.9
The decision of not giving merchandising gifts	4.5

UPC Recircula Waste System	4.1
To encourage to bring reusable bottles and badges lanyards	4.3
Ease to access to drinking water fountains	3.9
The use of the ERSCP-19 App instead of paper	4.6
“Plantable” badges and recycled cotton lanyard	4.5

To conclude, when participants were asked about the sustainable achievement of the 19th ERSCP Conference, almost all rates were between an interval from 3,9 to 4,3. Thus, we could say that the sustainability initiatives succeeded enough according to the participants' opinion.

Conclusions

As a general point, the testing of the Circular Conference Toolkit during the organization of the ERSCP 19 have succeeded. The aspects that did not work as expected have been evaluated, analyzed and justified along the Cycle 3. It should also be pointed that the ERSCP 19’s budget ended with a significant economic gain, which demonstrates that the Circular Conference Toolkit is not only environmentally and socially sustainable but also economically, in compliance with the three pillars of sustainability paradigm. The lessons obtained by the ERSCP 19 Conference experience are:

Less is more: The simplest ideas were the ones that worked the best. To make a circular conference comes down to minimizing waste as much as possible. “Reducing” and “reusing” were the Circular Conference Toolkit mantra since it allowed to avoid a high amount of waste and reduce greenhouse gasses emissions, as well as to result in cost saving.

Communication: The importance of communication is crucial, both with the conference participants and the service providers. The aspects that did not work as expected were - in part – a symptom of a lack of communication: translated in misunderstanding or not emphasizing enough. And on the contrary, the communication with the conference participants during the process of design of the Circular Conference Toolkit have resulted very grateful.

Location, location, location: To celebrate the ERSCP 19 in the UPC campus and specially, at the Vertex building facilitated the aim of the Circular Conference Toolkit, since there are some UPC’ policies that foster sustainability. However, the extended location analysis made in the Cycle 2 has been crucial, because the location conditions represent the basis to make a circular conference and its own success.

Some conclusions regarding the three areas:

Carbon neutrality: Even the advantage of the renewable energy consumption provided by the location, and other efforts made by the conference organization. The carbon neutrality area has been the most difficult to accomplish because of the carbon footprint of the participants' mobility (flights). The palliative solution presented is the CO2 Compensation program, but this is not enough because it is inexact and takes a long time to work.

Towards zero waste: It has been implemented a lot of efforts to make the conference zero waste and circular, and the results are rewarding. The only critical aspect is a misunderstanding with the catering service, who understood zero waste by the use of compostable and biodegradable materials, when from the conference organization we were demanding a step forward (reusable materials). Nevertheless, they adapted good enough to our demand. This experience demonstrates one of the lessons mentioned above: The importance of communication.

Sustainable consumption: The sustainable consumption was practically the rationale of the conference (SDG 12). In the context of the ERSCP 19, this area has been transversal and have accompanied the others two. The sustainable consumption has been specially reflected by the great reduction on purchasing (it could be considered degrowth), and the choosing of providers that accomplished our sustainable criteria.

Once the Circular Conference Toolkit have been tested and evaluated, it is time to promote it in other contexts in order to take a step forward and challenge it in more conferences. The Circular Conference Toolkit can be considered as an iterative process of improving though its implementation in future conferences and events.

Another next step is to transform the Circular Conference Toolkit into a circular business model, since the great quantity of events celebrated around the world, it can be very useful and profitable.

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198 A Path towards Climate neutral Production of Cement in Austria via a new Circular Economy

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Abstract

Mineral resources are a fundamental part of the circular economy. Concrete, for example, can be recycled 100 percent. Along the value chain of cement and concrete, there are several routes for re-use and recycling processes. Concrete mainly consists of natural materials: up to 80 percent of aggregates, like sand, gravel or crushed stone, and water. Cement acts as the binding agent and makes up 10 to 15 percent by volume. Cement itself consists of natural materials as well, mainly limestone and clay. These components are burnt at a temperature of 1,450 °C, thus transform into a substance called clinker. This process is mainly responsible for the CO_2 footprint of concrete: about two thirds of direct CO_2 emissions arise from the chemical process of the decarbonisation of limestone, another third from heating of the rotary kiln. Thanks to improvements in kiln and abatement technologies, emissions have been continuously reduced since 1990. The European cement industry aims at being climate neutral by 2050. The European Cement Association set out this ambition of net zero emissions in its Carbon Neutrality Roadmap, to be reached by measures at each stage along the value chain: clinker, cement, concrete, construction and (re)carbonation. While some of the measures have already been put in place, others are still in the research, development and demonstration phase. The Austrian Cement Industry is currently working on its national roadmap to climate neutrality along the value chain. In Austria, cement clinker is produced in rotary kilns with preheater. This state-of-the-art technology enables the use of waste heat for preheating fuels and raw materials, thus reducing the overall energy consumption for the production of cement. Moreover, several cement companies in Austria supply waste heat for district heating. In addition to energy efficiency, resource efficiency is an important pillar of cement production in Austria: for each tonne of cement produced in Austria, 441 kg of secondary materials are reused. Three main categories for the use of alternative resources in cement production have been identified: first, alternative raw materials provide the chemical

elements required for the formation of clinker minerals. Second, alternative fuels are used at a rate of about 80 percent in Austria, substituting conventional fuels like coal and oil. Via co-processing, the combination of simultaneous material recycling and energy recovery from these alternative fuels, natural raw materials and fossil fuels are replaced. And finally, alternative additives to clinker, like slag or fly ash, contribute to the required properties of the cement types produced. With an emission intensity of 0.54 tonnes CO_2 per tonne of cement produced, the Austrian cement industry is considered a global front runner in terms of CO_2 reduction measures. Compared to the world-wide average, almost 6 million tonnes of CO_2 have been avoided since 2005 in Austria. Already in the near future, breakthrough technologies will make it possible to capture CO_2 and recycle it to hydrocarbons as new raw materials. Details and projects will be shown in the Climate Neutrality Roadmap of the Austrian Cement Industry.

Keywords: Circular Economy, Recycling, Climate Neutrality, Carbon Capture and Use, Carbon Cycle

Introduction

Cement is a mineral-based hydraulic binder. Applied as a binder in concrete, it is the building material with the greatest economic importance worldwide: Currently, 4.1 billion tonnes of cement and 33 billion tonnes of concrete are produced annually worldwide (IEA, 2021; Bhardwaj et al., 2021). In Austria, 5.2 million tonnes of cement were produced in 2020 (Mauschitz, 2021) and approximately 40 million tonnes of concrete (öbv, 2021). Concrete is the most widely used building material in the world because of its strength and durability, among other benefits. Concrete is used in nearly every type of construction, including residential, commercial and public buildings, roads, bridges, airports and subways. The production of cement naturally involves the generation of carbon dioxide (CO_2). In a cement plant, CO_2 is produced directly during the production of the main component of cement, the cement clinker. Around two thirds of the CO_2 is released during the decarbonisation of limestone. Another third results from the combustion of fuels. According to the latest figures from the Netherlands Environmental Assessment Agency, global greenhouse gas emissions amounted to 57.4 billion tonnes CO_{2eq} in 2019, made up by the sum of 74% CO_2, 17% CH_4, 5% N_2O, 3% F-gases, (PBL, 2020). The global cement industry emitted 2.4 billion tonnes CO_{2eq} in the reference year 2019 (IEA, 2021), thus had a share of less than 4.5% of greenhouse gas emissions worldwide. Related to the climate gas CO_2 only the share of the cement industry's emissions was 5.6%, if land use, land-use change and forestry, short LULUCF, are included. Figure 1 shows the global greenhouse gas emissions by sector in 2010, a total amount of 49 Gt CO_{2eq} (IPPC, 2014). The largest sector is electricity and heat production with 25%, followed by deforestation and agriculture with 24%. Cement, with a contribution of less than 4,5%, is part of the sector industry that comprises 21% in total, followed by the sector transportation with 14%.

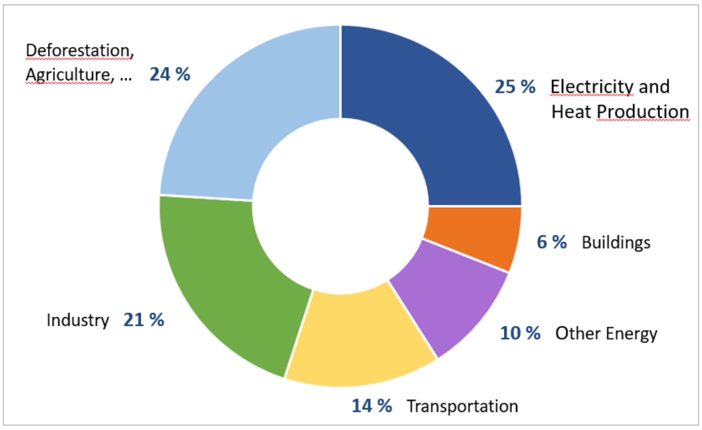

Figure 1. Global Greenhouse gas emission by sector in 2010, the emissions of approx. 4,5% of cement industry are included in the sector industry (IPPC, 2014).

The share of cement industry seems high, but have to be set in relation with the fact that concrete is a ubiquitous material and the second most used material in the world, after water. In fact, the embodied energy [MJ/kg] and the embodied carbon per kg of concrete [CO_2/kg] are rather low compared to other building materials, shown in table 1.

Table 1. Embodied energy and embodied carbon [per kg] of different building materials (Hammond & Jones, 2008a; Hammond & Jones, 2008b; Scrivener, 2019).

Material	MJ/kg	kg CO_2/kg
Cement	4.6	0.83
Concrete	0.95	0.13
Masonry	3.0	0.22
Wood	8.5	0.46
Wood: multilayer	15	0.81
Steel: virgin	35	2.8
Steel: recycled	9.5	0.43
Aluminium: virgin	218	11.46
Aluminium: recycled	28.8	1.69
Glass fibre composites	100	8.1
Glass	15.7	0.85

Figure 2 displays the data of table 1 on a chart, which shows at first glance the specific impact of the different building materials.

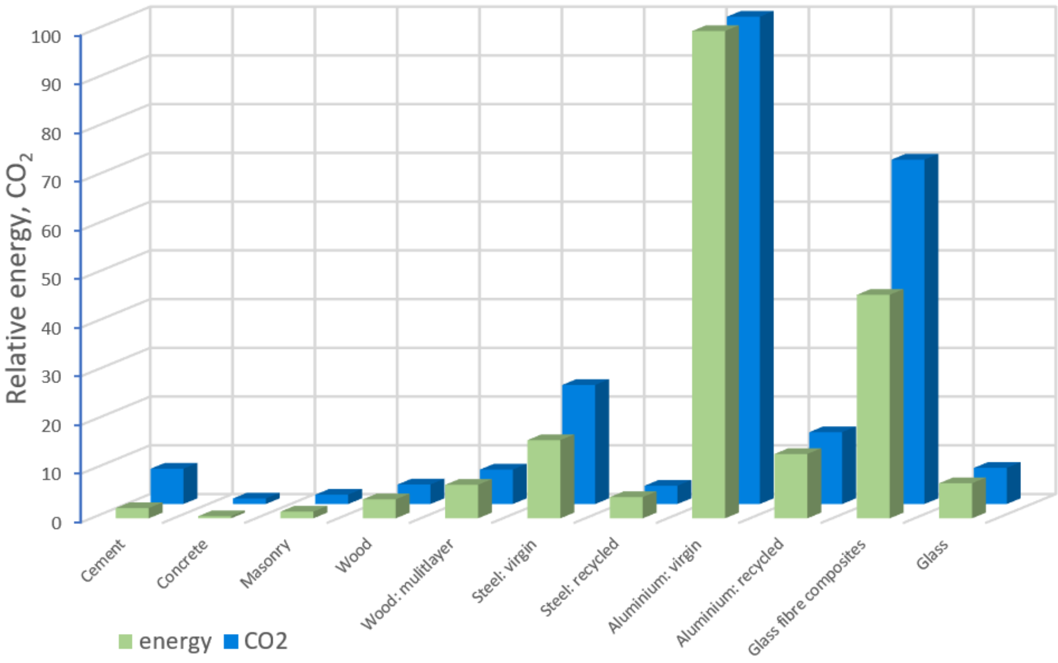

Figure 2. Embodied energy [MJ/kg] and embodied carbon [kg CO_2/kg] of different building materials (Scrivener, 2019)

Although being the binder in concrete Portland cement is displayed at the very left, next to concrete. CO_2 emissions and the often-stressed climate impact of concrete and cement are due to the fact that the use of concrete amounts to approximately 33 billion tonnes or 14.5 billion m³ per year worldwide. A comparison with the global yearly sawn wood production of 0,45 billion m³ and the wood panel production with 0,41 billion m³ makes clear that concrete cannot be replaced by alternative building materials (FAO, 2019). These are reasons why we need to decarbonize cement and concrete.

The cement production process offers excellent opportunities to make use of alternative materials and provides the potential to contribute considerably to a circular economy. During the production process of cement there are several steps where alternative resources are used. Concrete itself is an artificial stone and is 100% recyclable. The production of cement leads to considerable CO_2 emissions, in Austria of about 2.7 Million tonnes per year. Consequently, strategies for the decarbonization of cement are crucial. The European Cement Association has published its way to carbon neutrality till 2050 (CEMBUREAU, 2019). This European Roadmap highlights how CO_2 emissions can be reduced by acting at all different stages of the value chain – clinker, cement, concrete, construction and (re)carbonation (5C approach). Goal is to achieve zero net emissions by 2050. The roadmap quantifies different technologies in reaching CO_2 emission savings, by technical and political recommendations to support this objective (CEMBUREAU, 2019). The Austrian Cement Industry will publish its roadmap towards a climate neutral production of cement in autumn 2021.

Methods

The Austrian cement industry has attained many years of extensive experience in the use of alternative fuels, raw materials and additives. Alternative resources in cement production require high level know-how, inputs in quality management systems and significant investments. In addition, several environmental protection technologies were used for the first time in Austrian plants. These include the world's first regenerative thermal post-combustion, the development of catalyst technology to reduce nitrogen oxide emissions, and the testing of mercury separation technologies. (Spaun and Papsch, 2016). The following sections give an overview of methods that have already been implemented in the Austrian cement industry since the 1980s, of methods that will be part of the 5C concept of the roadmap in the upcoming years, comprising clinker, cement, concrete, construction and (re-)carbonation, and of breakthrough technologies in the cement industry.

Current Measures

In Austria, 100% of cement is produced by advanced five-stage preheater kilns which is the state-of-the-art technology. The waste heat generated at all production steps is recovered and used to preheat raw materials and to dry the fuels. Energy is used and reused the most efficient way. In addition, waste heat for district heating is being decoupled at several cement plants. Furthermore, resource efficiency is an additional important pillar of cement production in Austria: for each tonne of cement produced in Austria 2020, 441 kg of secondary materials have been reused (Mauschitz, 2021; VÖZ 2021). Three main categories for the use of alternative resources in cement production have been identified:

- First, the use of alternative raw materials provides chemical elements required for the formation of clinker minerals. In cement production, 15% of the raw materials is already delivered by alternative raw materials. Today, 798,000 tonnes mostly residual demolition and construction waste are recycled (Mauschitz, 2021).
- Second, alternative fuels substitute conventional fuels like coal, oil and gas. Alternative fuels are used at a rate of about 80 percent in Austria, the highest share worldwide, as shown in Figure 3. Alternative fuels provide the necessary thermal energy for clinker production, and moreover some of them, e.g. paper fibre residues, used tyres or sewage sludge, also contribute main elements which are required for the formation of clinker minerals, such as calcium or iron (Spaun and Papsch, 2016). This combination of simultaneous material recycling and energy recovery is called “co-processing”, it is listed as good practice in the “European Circular Economy Stakeholder Platform” (2014):

Figure 3. Use of alternative fuels in cement Industry. Diagram by VÖZ based on GCCA data (GCCA, 2020).

- Third, alternative additives to clinker, e.g. industrial by-products such as slag or fly ash, contribute to the required properties of the cement types produced. The increased use of supplementary cementitious materials, e.g. blast furnace slag, has reduced the average clinker content in cement to about 69%. As a result, less clinker has to be produced for the same quantity of cement, while maintaining the high quality of the product. Total CO_2 emissions are significantly reduced.

5C Measures Road Map 2050 and Current Research Projects

Clinker / cement: The Association of the Austrian Cement Industry is working together with the research partner Smart Minerals on a family of climate-friendly cements. With the publication of the new Cement Standard EN 197-5 (CEN/TC 51, 2021) new cement types, namely CEM II/C and CEM VI, are being developed and will enter the market soon. These new cement types will enable higher amounts of supplementary cementitious materials while reducing the clinker content. The aim is to produce “new cements” on a large scale without compromising usage quality, like workability, performance, durability etc. Traditional additives are slag and fly ash, their availability will be limited in the future. Therefore, in addition to reducing the clinker content in new cements, the suitability of other additives such as calcined clays is under investigation. Clays are available in Austria in sufficient quantities and, after calcination, they can replace a significant proportion of clinker in cement. Figure 4 shows the availability of different additives according to a study on eco-efficient cement (Scrivener et al., 2018).

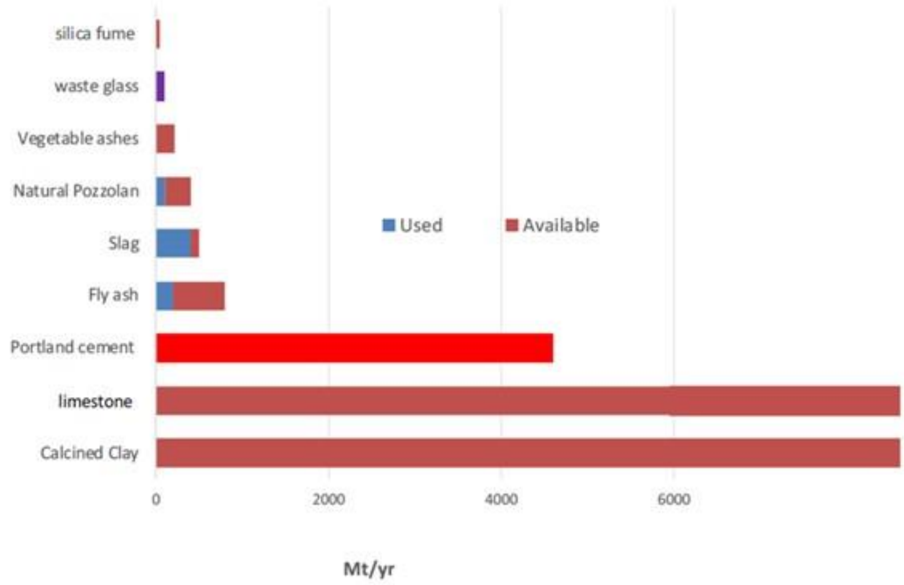

Figure 4. Use and availability of possible cement additives (Scrivener 2019)

Calcination of clays is reached by heating to a certain temperature. This process is not as energy-intensive as burning clinker since temperatures are significantly lower. The first step of the ongoing research project is to identify available domestic clay pits with adequate chemical and mineralogical composition. Furthermore, the calcination process will be optimised to achieve maximum properties like reactivity and strength contribution. Based on these findings, high performing cement mixtures will be developed. In the end, this new cement composition will be tested in concrete with a special focus on performance and durability.

Concrete / construction: Applied as a construction material, concrete allows for savings of CO_2 emissions. An example is the infrastructure for renewable energy: wind power plants or hydropower plants could not be built without using concrete. Concrete is also the material of choice for the public mass transit transport or the construction of railways and subways. Bridges or tunnels shorten road stretches and thus help reducing emissions. The European Concrete Paving Association EU PAVE analyses environmental, economic and societal aspects of concrete pavements. An infographic with the title “Concrete pavements make roads more sustainable” gives an overview of different benefits, like 100% recyclability, less global warming potential because of reduced fuel consumption especially of heavy trucks and a higher albedo, higher resilience to climate change and to extreme meteorological events and a contribution to sustainable water management, e.g. by the means of possible infiltration (EU PAVE 2020). Such savings are usually not taken in account when talking about the CO_2 balance of concrete. About one third of the concrete in Austria is used in civil engineering, approximately two thirds for structural engineering (öbv, 2021). Considerable savings are being achieved during the use phase of concrete buildings thanks to their thermal mass. Thermal mass refers to the ability of heavyweight materials to store energy, which is later released. Thanks to its high material density and good thermal conductivity, concrete can be turned into an energy storage by means of thermal component activation: Pipes are laid in solid building components through which water flows as a heating or cooling medium, resulting in a surface heating or cooling system, a schematic view is shown in figure 5. The activated building components emit heat over their entire surface or absorb it again – depending on whether heating or cooling is needed.

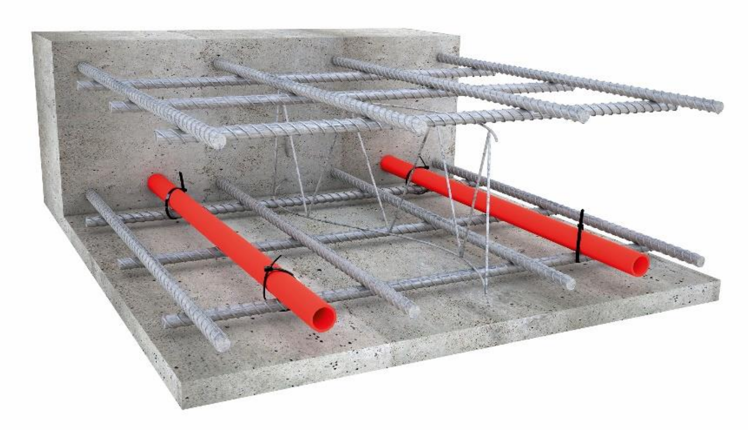

Figure 5. Functional schematic design of thermal component activation: the water-carrying pipes in concrete slabs, walls or floors turn concrete into an energy storage.

Due to the large surface, system temperatures can be kept very low, with a temperature difference between surface and room air of approx. 1 to 6 °K. The high efficiency reduces the overall energy consumption and facilitates the use of renewable energy instead of fossil energy. In regard to a 100% supply with renewable energy, storage capacity has become increasingly important (Klima- und Energiefonds, 2020). The vast amount of concrete structures provides large reserves that can be used for energy storage. Thus, thermal component activation can contribute considerably to achieving climate goals. The roadmap of the Austrian Cement Industry will focus on reducing emissions from its own sector. Nevertheless, with regard to life cycle calculation, the offsetting of emissions versus savings, especially for societal benefits, need to be considered in some way as well.

Carbonation is a process that occurs naturally per se in the cement paste. During cement production, CO_2 is released from limestone in the calcination process; carbonation is the reversal of this process, i.e. the cement stone absorbs CO_2 again from the ambient air. This CO_2, in combination with the calcium hydroxide and water present in the cement paste, becomes limestone. The durability of the concrete is improved by this process, it turns denser and stronger. Steel reinforcement has to be protected from corrosion by an appropriate concrete cover. Carbonation is a relevant parameter for the global CO_2 cycle. The Global Carbon Project (2020), an international scientific network, compiles and updates the global CO_2 balance annually. The CO_2 balance 2020 addresses "cement carbonation" for the first time: between 1840 and

2019, cement paste is assumed to have absorbed approximately 40% of the geogenic CO_2 process emissions back from the atmosphere, also shown in figure 6.

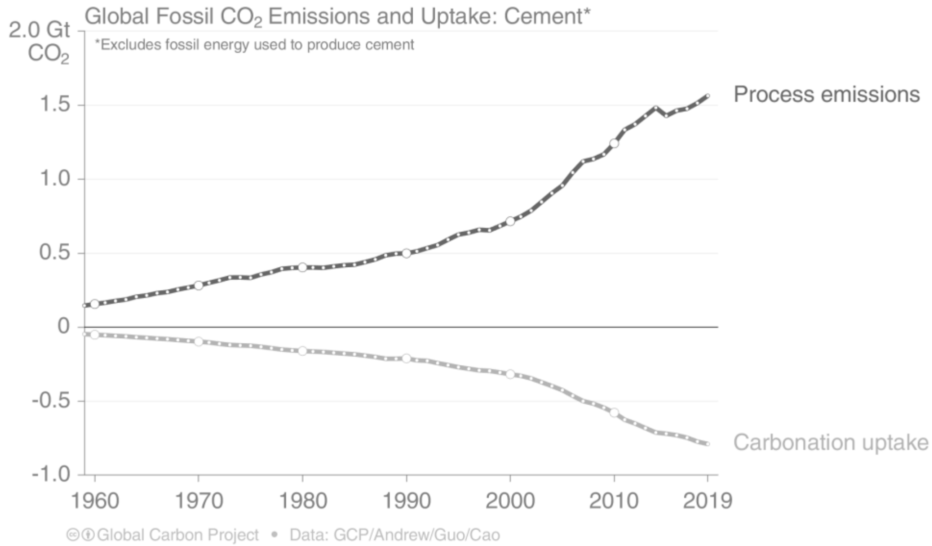

Figure 6. The production of cement results in process emissions of CO_2 from the chemical reaction. During its lifetime, cement slowly absorbs CO_2 from the atmosphere. (Global Carbon Project 2020, p. 39)

This effect also needs to be taken in account in future life cycle assessment of cement and concrete, e.g. concerning environmental product declarations. The IPCC, the Intergovernmental Panel on Climate Change, has to decide, if this sink effect can be considered in national climate balances. In a specific report, the Swedish Environmental Research Institute IVL proposed that a 23% reduction in CO_2 emissions from the raw material should be recognised in the annual greenhouse gas balance for cement production (Stripple H. et al., 2018). These percentages refer to the CO_2 process emissions, i.e. the geogenic emissions released from the limestone during the cement burning process. The potential for the absorption of CO_2 could be higher if special treatment was provided in recycling, e.g. when concrete is broken up and cement stone is exposed to CO_2.

Breakthrough technologies: Carbon Capture and Utilisation

In the near future, breakthrough technologies will make it possible to capture CO_2 and recycle it to hydrocarbons, which can be used as new raw materials. Carbon Capture and Utilisation, CCU, will be a key technology to reduce CO_2 emissions from cement plants. In recent years, significant research has been initiated at a pilot scale level to optimise reagent and membrane capture techniques. Trials are ongoing to find ways of concentrating the CO_2 in the gas stream as to make the carbon capture more efficient and cost-effective. Captured CO_2 can also be transported to geological formations such as empty gas fields, where it is permanently stored, Carbon Capture and Storage, CCS. An example is the Brevik plant in Norway, operated by Heidelberg Cement (CEMBUREAU, 2019). The storage of CO_2 is prohibited today in Austria, therefore an Austrian project with the focus on CCU is planned by a consortium of four companies (Lafarge, OMV, Verbund, Borealis, 2020). The project “Carbon2ProductAustria” or short C2PAT aims at building a plant for capturing around 700,000 tonnes of CO_2 per year by 2030 at the Mannersdorf cement plant, located about 30 kilometres southeast of the OMV refinery in Schwechat. Mannersdorf is the largest cement plant in Austria with an annual capacity of around 1.1 million tonnes. The objective of C2PAT is to build an infrastructure and a fully operating system for producing renewable based hydrocarbons and using this compound to produce a broad range of renewable based olefins, plastics and fuels. The partners aim to put the full-scale plant into operation by 2030. A first step towards this goal will be further investigations on current technological and economical obstacles by jointly conducted research and development activities regarding the envisaged Carbon Value Chain. The key innovation is the utilisation of CO_2 from cement production as a valuable raw material for the manufacture of petrochemical products: This cross-sectoral approach is a big step forward and has not been realised before. C2PAT will also demonstrate the circular economy in the cement industry and the chemical industry by recycling and reusing the renewably produced plastics in different ways. C2PAT will explore the market potential for renewable products and advance models for managing and optimising the entire value chain (Kitzweger, 2020).

Results and Discussion

With regard to the climate footprint, the Austrian cement and concrete industry have already taken a lot of measures to reduce the footprint of cement and concrete (VÖZ, 2019). In this respect, both industries hold a top international position concerning the comparatively low climate impact. Compared to the European average, almost 10 million tonnes of CO_2 could be saved between 1990 and 2020. The Global Cement and Concrete Association GCCA gathers and publishes key data recording the industry’s sustainability commitments. The GNR (“Getting the Numbers Right” or “GCCA in NumbeRs”) is monitoring and reporting tool for sustainability progress. Data of 2019 show that the Austrian Cement Industry produces cement with the least specific CO_2 emissions per ton of cement. Figure 7 gives an overview.

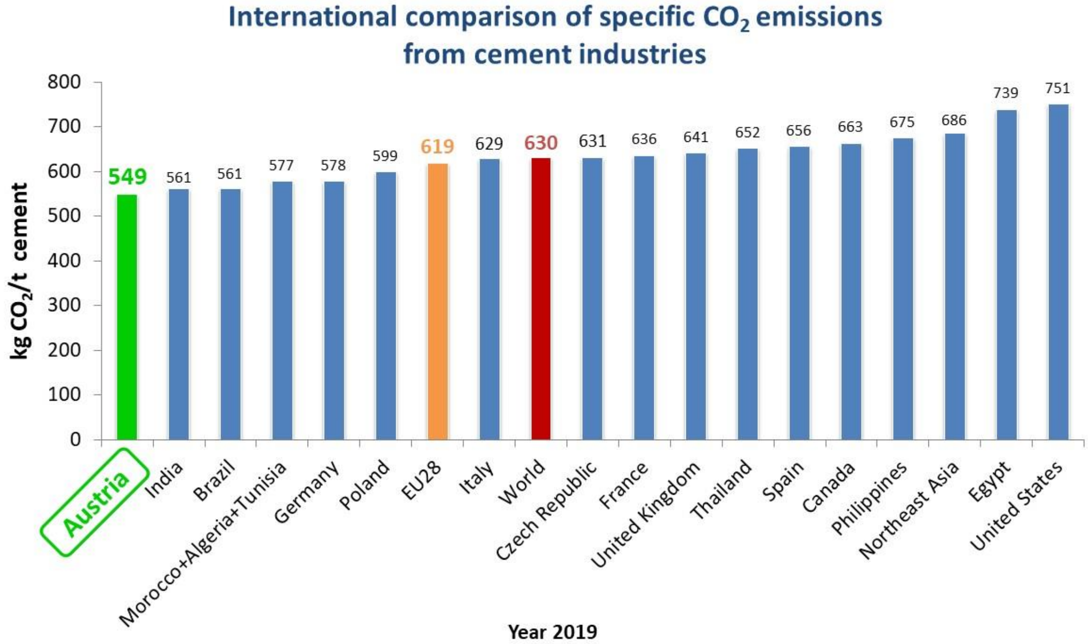

Figure 7. Specific CO_2 emissions from cement industries [kg CO_2/t cement] – international comparison (chart by VÖZ, 2021, based on GCCA, 2021).

Technical possibilities for a more climate friendly production of cement, like minimising energy consumption or substituting fossil fuels, are already widely in use in Austria and CO_2 as well as other emissions are very low in comparison to the rest of the world. In terms of building materials, the binding agent "cement" has also been continuously improved concerning its climate foot-print and the CO_2 intensive Portland cement clinker has been replaced by additives such as granulated blast furnace slag or fly ash. However, due to economic and technical changes in the steel industry and the decrease of fossil fuels such as coal, a shortage of these raw materials is taking place. Therefore, alternative strategies must be pursued to reduce the climate impact. From the point of view of building materials, various optimisation strategies are being pursued, whereby a further reduction of the clinker content is currently the most advanced and seems the most promising. This comprises the production of so-called composite cements or binders with an increasing proportion of climate-friendly additives (pozzolana, limestone, etc.).

Another strategy for minimizing CO_2 emissions is the capture and storage of CO_2 (CCS), where ideally the CO_2 is further processed (carbon capture and utilisation CCU).

Conclusions

In its roadmap 2050, CEMBUREAU (2019) concludes that the objective of climate neutrality for the cement sector is ambitious but feasible. A concerted effort, by the European cement industry and its value chain with the support of governments at the European, Member State and local levels can move climate neutrality in the cement and concrete sector from vision to reality. The most effective scenario on the way to decarbonisation and climate neutrality is the cooperation of all actors along the entire value chain of concrete, namely through the following measures:

- CO_2 reduction in clinker production including the development and upscaling of carbon capture, storage and utilisation.
- the use of composite cements with low clinker content (CEM II/B, future CEM II/C, CEM VI etc.)
- the targeted selection of concrete types with low CO_2 emissions already in the planning stage, the CO_2 optimisation of concrete types through combinations of cements and additives
- material-efficient or CO_2-efficient constructions by optimising the shape of components and structures;
- durability of concrete structures and life time (esp. for infrastructures) have to be guaranteed and
- consideration of the CO_2 absorption of concrete over its lifetime and recycling.

The optimisation of climate compatibility with accompanying CO_2 savings requires investments in terms of research and demonstration, the training of employees, additional infrastructure and deep investments. At the end of the day, however, these expenditures must be cost-covering for the companies in order to ensure a level playing field. Policies have to guarantee a certain planning security, e.g. predictable CO_2 prices, to create a stable economic environment. The Austrian Cement Industry is ready to meet these challenges; strong political support and a supportive framework have to follow.

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103 Exploring direct and indirect investment schemes for installing small and medium size energy systems in remote local communities: Cases of clean energy systems in Japan

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Abstract

There is a strong focus on the diffusion of clean energy technologies under Paris Agreement. As part of its endeavours to achieve the goals under the agreement, each country is accelerating its efforts by setting their own targets for removing fossil fuel-based systems and introducing clean energy systems. In parallel, the scale of ESG finance including both equity and debt investments is growing recently in the financial community. Many central and local governments as well as financial institutions have issued green or sustainability bonds partly targeting toward investment into clean energy systems.

The research illustrated in this article addresses various funding mechanisms such as government subsidy, direct investment (equity) and indirect (debt) investment for installing clean energy systems in local communities in Japan. The target of the research is small and medium size systems in remote local communities, as they tend to bring more direct and positive social, economic, and environmental benefits to them. The remote local communities struggle to attract investors into such systems, as they face declining population causing various social issues. The introduction of the systems could support them to utilize their local resources such as biomass and solar, provide more opportunities for younger generations to reside in a nature surrounding local area, and become energy independent, especially among rural areas and remote islands that tend to be dependent on energy sources from other locations.

The target systems for analysis are small size photovoltaics, wind, biomass, geothermal, and mini-hydro projects in Japan. The focus on financial schemes for the size of the systems is a uniqueness of this research. It is expected that the lessons learned from the cases in Japan contributes to explore other cases on another country or region.

Keywords: Clean energy system, Renewable energy, Financial mechanism, Investment, SDGs

Introduction

In 2015, there were two key global agreements on sustainability. Sustainable Development Goals (SDGs) were adopted at the United Nations as 2030 Agenda for Sustainable Development Goals setting goals on global economic, social, and environmental issues. The Paris Agreement was adopted in the same year to cope with global climate change and reduce greenhouse gas emission reductions on the global scale. At the same time, in the finance community, there are stronger interests for investing into sustainability under ESG (Environmental, Social, and Corporate Governance) investing schemes. The movement toward ESG investing has accelerated as a growing number of investors started to recognize the investment into fossil fuel-based industries could become stranded assets in the near future and investment into clean or renewable energy could provide better investment opportunities in the time of decarbonization. Many central and local governments as well as financial institutions have issued green or sustainability bonds partly targeting toward investment into clean energy systems.

Under the Paris Agreement, there is a strong focus on the diffusion of clean energy technologies. As part of its endeavours to achieve the greenhouse gas emission reduction goals under the agreement, each country is accelerating its efforts by setting their own targets for removing fossil fuel-based systems and introducing clean energy systems. On the other hand, there is growing research interests as well as the needs from policymakers under SDGs to understand the interlinkages among the goals (Nilsson, M. et al., 2016, Nilsson, M. et al., 2018). The interlinkages could be synergies, trade-offs, or cancelations of each effort. There are also research focusing on the interactions between climate change mitigation issues and other issues related to SDGs (Shawoo, Z. et al., 2000, Bertheau, P., 2020). McCollum (2018) provides thorough review on various research specifically examining the interlinkages between energy and SDGs. Santika (2019) analysis the interlinkages quantitatively.

This article has twofold objectives. The first objective is to examine how and what types of financial arrangements are being made to implement clean energy systems in local communities in Japan. The article investigates funding mechanisms such as government subsidy, direct investment (equity) and indirect (debt) investment for installing clean energy systems in 14 local communities in the country. The research targets are small and medium size systems in remote local communities, as they tend to bring more direct and positive social, economic, and environmental benefits to them. The remote local communities struggle to attract investors into such systems, as they face declining population causing various social issues.

The second objective of this article is to explore the interlinkages of the introduction of a clean energy system and social and economic agenda in Japan. The introduction of the systems could support local communities to utilize their local resources such as biomass and solar, provide more opportunities for younger generations to reside in a nature surrounding local area, and become energy independent, especially among rural areas and remote islands that tend to be dependent on energy sources from other locations.

Literature review: Finance and SDGs interlinkages

There have been numerous research initiatives and programs exploring financial opportunities in clean energy systems. Frankfurt School - UNEP Collaborating Centre for Climate & Sustainable Energy Finance publishes a report on global trends in renewable energy every year (Frankfurt School - UNEP Collaborating Centre for Climate & Sustainable Energy Finance, 2020). United Nations Environmental Program (2009) and Sustainable Energy for All and the Climate Policy Initiative. (2019) analyzes a variety of financial mechanisms such as government subsidy, venture capitals, development assistance, equity investment, debt investment, mezzanine finance, and risk guarantee. Josh Carmody and Duncan Ritchie (2007) summarizes roles and financial expectations of different investors in clean energy systems in different stages of technological development. The analysis of financial returns from the investment into clean energy systems as well as the risk assessment of such systems have been conducted among several studies (Hürlimann, 2019, Masini, A., & Menichetti, E., 2013, United Nations Environmental Program, 2009). Among international institutions, there have been a particular focus on the analysis of the trends in finance among developing economies (The World Bank 2017, United Nations Economic and Social Council 2019).

As for the SDGs interlinkages, there have been research initiatives empirically analyzing social, economic, and environmental impacts of the introduction of clean energy systems in emerging economies. For example, Bertheau (2020) analyzes how the implementation of solar power and batteries is linked to various SDGs in rural parts of the Philippines. Burney et al. (2017) examines the impacts of solar electrification on women's empowerment in the local community. Khellaf (2018) investigates economic and social impacts of renewable energy projects in Africa. In Europe, there have been a number of studies that attempt to investigate the acceptance of various clean energy systems in society based on the social acceptance research framework (Scherhaufer, P. et al., 2018, Fytili, D., & Zabaniotou, A., 2017). While there have been such research initiatives in Japan, many of research results have not been addressed in English.

Research targets: 14 local communities in Japan

As described above, there has been a variety of research examining social, economic, environmental impacts of the introduction of clean energy systems. Some research results suggest that there are positive impacts on improving current situations in education, health, workplace, employment in the rural area. In the case of emerging economies where electrification has not reached the rural area, small simple renewable energy devices could improve the quality of life among people in the rural community by providing electricity at night at home, workplace, or public and private facilities.

The situations in Japan are different with respect to electrification, as it has reached almost 100% rate of electrification. On the other hand, the declining population as well as the aging population have addressed serious social and economic issues particularly in the rural area in the country. According to Statistics Bureau of Japan (2021), the current number of populations of the country is 125 million in 2021, while according to Cabinet Office (2012), the number could decline to 99 million in 2048 and 86 million in 2060. Besides this country-wide trend in declining population, the economic gap between cities and rural farming, fishing, forestry communities have been widening. There are high expectations among people in the rural communities in Japan that the introduction of clean local energy systems could provide new economic opportunities by saving energy costs and using the resources for other activities, attracting younger generations inside and outside of the country to reside, and enhancing resilience to natural disaster by establishing independent off-grid systems.

The Japanese government announced that the country is going to reduce greenhouse gas emissions by 46% before 2030. This target is line with other targets among developed countries, for example, compared to 55% reduction targets in the EU. In its efforts to reduce the emissions to the level, the government started to support strongly the diffusion of clean energy systems in the country. According to the Institute for Sustainable Energy Policies (2020), the rate of electricity from renewable energy sources in Japan was 20.8% in 2020 and it is expected to increase in coming years.

This article examines financial arrangements such as government subsidy, direct investment (equity) and indirect (debt) investment to implement clean energy systems in 14 local communities in Japan. It could provide help us to understand what types of arrangements are being made and could be possible for different types of systems in rural communities where obtaining financial resources could be a major barrier for installing a clean energy system. The article also attempts to explore what social and economic benefits, so-called SDGs interlinkages, could be brought or envisioned through the introduction of such systems.

Appendix to this article summarizes the information on the 14 projects including renewable energy types, locations, electricity capacity, investment size, project title, project description, financial arrangements, and impacts to local community. 14 projects are selected from various sources with a particular attention to unique features of the projects with respect to the financial arrangements as the impacts to local communities. The list contains biogas, biomass, gas-cogeneration, mega-solar, photovoltaics, small hydro, solar heat, and wind projects.

Results and Discussions

The results of the review of the 14 projects among local communities indicate that small or medium size local banks have started to participate in debt finance actively. Their participations were observed in most of the cases in the attached list. In the case of the combined biomass, biogas, and solar project in Aichi, a local bank, Hyakugo Bank provided debt finance equivalent to $47,77 million. The bank acted as the arranger and agent and another local bank participated in debt finance as well. In the case of the biomass project in Okayama (Project 7), a local bank, Chugoku Bank acted as the lead arranger and agent for the syndicated loan totalling $19.5 million. These cases may suggest that even though some part of the risk being involved in clean energy projects are still uncertain, local banks have gradually accumulated knowledge and know-how in financing such projects.

Another observable trend is that some projects have received a subsidy from different parts and levels of the governments such as Project 5, 7, 11, and 12. In the case of the small hydro project (Project 12), 75% of the initial investment costs are subsidized by the prefecture and the city. In the case of the other small hydro project (Project 8), it is being co-financed by a local bank and Development Bank of Japan. On the other hand, two large projects on the list are financed directly by private companies including Project 3 and 14. In the case of the large biomass project (Project 3), one of the largest trading companies in Japan, Sumitomo Cooperation is the main equity investor of the project.

There are two other points to note in the review of the projects. The geothermal project in Fukushima (Project 11) have received 80% of a guarantee of debt finance. If debt guarantee becomes more available for clean energy projects, it may encourage local banks to participate in debt finance and promote clean energy systems among local communities. The other interesting point is that the private company involved in the wind project in Nagasaki (Project 14) are collecting finance through the issuance of a green bond. Green or sustainability bonds could be a promising financial vehicle to secure finance necessary for clean energy projects.

As for the interlinkages with social and economic agenda through of the introduction of a clean energy system in Japan, the review results suggest that designing a scheme where both production and the consumption of electricity could take place in the same community is the key for circulating financial resources in the community. This point is emphasized among Project 1, 6, and 10. For example, the mega-solar project in Hokkaido (Project 1) indicates that “the finance is mainly raised by local or regional financial institutions for electricity to be consumed in the local community. This may help to encourage the local economy.” (Daiwa Energy Infrastructure Corporation, Hokkaido Electric Power Company, & Hokuyo Bank, Ltd., 2020).

Several projects (Project 6, 10, 11, and 13) further indicate that this helps to lower the costs for the local community. The biomass/biogas/solar project in Aichi (Project 6) states that “the city is able to reduce its financial burden by about $120 million over 20 years.” (New Energy Foundation, n.d.). The geothermal project in Fukushima (Project 11) states “after the end of the Feed-in-Tariff Program, the company aims to contribute to the community by providing electricity at a price in the range of 10 cent per kWh.” (Ishida, 2018).

Apart from financial contributions to the local communities, several projects (Project 7, 12, 13, and 14) address that the introduction of clean energy systems has positive impacts on hiring local employment, encouraging resettlement in the rural community, and increasing the number of visitors to the area. This is an important contribution of clean energy systems, especially in Japan, as the declining population as well as the aging population have addressed serious social and economic issues particularly in the rural area in the country. In addition, Project 2 points out that the project could provide learning opportunities for the students in the community. In fact, several projects on the list provide opportunities for those who are interested in learning about clean energy facilities. This could be in line with the concept of eco-tourism or learning tourism on sustainability.

There are two other points to note about the impacts to local communities. The biomass projects (Project 3, 7, 13) suggest that the use of local biomass resources “encourages appropriate thinning and removal of leftover wood from the forest to keep the forest in a healthy condition” (Ishida, 2017) (Project 7). As majority of the land in Japan is covered with forest, biomass electricity generation projects would be helpful for forest management as well. The other point is that Project 9 and 10 demonstrate that the introduction of clean energy systems would help to increase resilience against natural disaster. Project 10 illustrates that when there was “a power outage in 2019 due to the damage on the central grid electricity distribution, the plant provided electricity, hot water, and bathroom facilities to local residents" (CHIBA Mutsuzawa Energy Co., Ltd., 2019). Building an off-grid independent system would be particularly important for remote islands such as Project 9 where the islands could be vulnerable to the shortage of energy supply in the event of irregular weather patterns or disaster.

Conclusion

This article examined different financial arrangements being made to implement clean energy systems in local communities among 14 local communities in Japan. It turned out that small or medium size local banks have actively started to participate in debt finance in such systems. A guarantee of debt finance as well as issuance of bond investment are observed in two projects. These mechanisms could be instrumental in promoting clean energy systems in Japan. The possibility of the use of the mechanisms could be explored outside of Japan as well.

The article also explored the interlinkages of the introduction of a clean energy system and social and economic agenda in Japan. The review results indicated that designing a scheme where both production and the consumption of electricity could take place in the same community is the key for circulating financial resources in the community. It appears that the circulation of financial resource in the same community helps to lower the energy costs for the local community. The saved resources could be used for other economic or social activities in the community. Further research including interviews with stakeholders such as citizens, project developers, and financial managers as well as field observations are necessary to explore possibilities of financial arrangements as well as social and economic impacts through the introduction of clean energy systems in rural communities.

Notes

Japanese currency is converted into US dollar at the exchange rate of US $1 for 100 Japanese yen. The titles of the articles, names of the projects, and others in Japanese are translated in English by the authors. Some of the draft texts in Japanese used in the Appendix are translated into English using the free version of the Deep L translator.

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Appendix

Appendix summarizes the information on the 14 projects including renewable energy types, locations, electricity capacity, investment size, project title, project description, financial arrangements, and impacts to local community. The list of references to generate this list is attached at the end of the Appendix. The titles of the articles are translated from Japanese to English.

Number	Renewable energy types	Location	Electricity capacity	Investment size	Project title	Project description	Financial arrangemen
1	Mega solar	Hokkaido	9MW 2MW 1MW (3 locations)	$50 million	Hokkaido Renewable Energy Promotion Platform	A special purpose company (SPC), Hokkaido Renewable Energy Promotion Platform, starts operation in March 2020. The investment targets are three power plants in Hokkaido. The fund targets "local production for local consumption of energy and finance." Hokkaido Electric Power Company and North Pacific Bank (Hokuyo Bank) are participating in the fund through debt and private equity investment. The portfolio is unique in that it is limited to a specific region.	A local bank, the North participated as an asse (ABL) lender in this fur Daiwa Energy Infrastru manager is Daiwa Rea Management and othe receives a subsidy by t Environment. $1.9 mill provided through North under its "green loan" s project has received a Japan Credit Rating Ag environmental perform
2	Biogas	Aomori	660kW	$22 million	Biogas Energy Towada (B-GET)	The plant starts operation in August, 2020. It is the first biogas powerplant being launched in Aomori prefecture. It processes up to 120 tons of organic sludge and garbage per day collected from households and companies. According to the website, It is a locally produced, locally consumed energy system that maximizes the use of local resources.	A local bank, Aomori B in debt finance. Japan Corporation and a loca participate in finance.
3	Biomass	Yamagata	50MW	$250 million	Sakata Biomass Power Plant	The plant started operation in August 2018. It is one of the largest biomass power plants in Japan. It is operated by Summit Sakata Power being financed by Sumitomo Cooperation. 40% of fuel are wood chips that are unused wood and forest residues, mainly from forests in the region. The rest of fuel include wood pellets from North America and Palm Kernel Shell (PKS) from Indonesia and Malaysia. As for PKS, the plant attempts to collect certified sources of PKS such as Roundtable for Sustainable Palm Oil (RSPO).	One of the largest trad Japan, Sumitomo Coo main equity investor of bank, Yamagata Bank finance. In addition, Ya Prefecture's systematic used other local loanin including Yamagata Pr Commerce and Industr Fund's Industrial Locat Fund.

4	Wind	Hokkaido	4MW	$16 million	Atsuta Citizen's Wind Power Generation	Operated by Atsuta Shimin Wind Power Co. Two wind turbines (2MW each) were installed on a hillside in Ishikari City in Hokkaido. The turbines have been operating since December 2014 and there is a power purchase agreement under the Feed-in-Tariff Program until December 2034.	This is a syndicated lo local banks, Hokkaido Bank, with a total loan million. In addition, the Promotion Organizatio million and the Citizen' Fund 2014 Ishikari Ats $0.99 million. This proj non-recourse loan that repayment source to o sales income generate generation project.
5	Solar	Iwate	1,607kW 2,367kW (2 locations)	N.A.	Miyako Solar Power Project	The project started in September 2015 being operated by Miyako Power Generation Company. This project was implemented in Miyako City, Iwate Prefecture, as part of the Miyako City Smart Community Project. The power plants are located in two locations, both of which are within the disaster risk zone caused by the earthquake in 2011. The objectives of the project are to create a decentralized power source in the community, to improve the efficiency of the energy supply-demand balance with a focus on the Community Energy Management System (CEMS) , to restore the affected area through land use, and to improve disaster resistance.	The loan was co-financ bank (Iwate Bank) and Bank of Japan (DBJ). company (SPC) was fo equity investment by J According to the websi has provided various t the Miyako Smart Com
6	Biomass/Biogas/Solar	Aichi	1,000kW (biogas)1, 995kW (solar)	$137.2 million	Toyohashi Biomass Resource Utilization Center	The plant is operated by Toyohashi Biowill since October, 2017. Sewage sludge, manure, septic tank sludge, and food waste, which used to be treated separately , are integrated into a methane fermentation process. Biogas produced is used as fuel to generate electricity. In addition, the residue generated by the methane fermentation is also carbonized and converted into fuel. There is also solar power generation in the same location.	A local bank, Hyak provided debt fina to $47,77 million i The bank acted as and agent and and bank, Toyohashi S participated in the Hyakugo Bank act participate in the P Initiative (PFI) Acc website, PFI is a m outsourcing a seri from design, cons operation, and ma facilities to the priv

							actively utilizing pr funds, manageme and technical know public projects imp the national and lo governments. Acc website, this proje largest PFI project has involved until
7	Bioma ss	Okayam a	10MW	$41-43 millio n	Maniwa Biomass Power Generatio n	The plant started its operations in April, 2015. It is operated by Maniwa Biomass Power Generation. The power generation system uses wood chips generated from thinning, forest residues, and lumber mills in Maniwa City in Okayama Prefecture as fuel. It uses 10,000 tons of chips every month. The boiler is a stoker system and can burn bark, branches and leaves with high moisture content. The collection and supply of fuel involves forestry cooperatives, forestry business entities, lumber manufacturers, and chip manufacturers. With a power generation scale of 10 MW, the plant can generate electricity for 22,000 households, which is more than 17,000 households in Maniwa City.	A local bank, Chug acted as lead arra agent for the synd totaling $19.5 milli 2014. National ban Mizuho Bank and acted as joint arra Bank of China, Mi Aozora Bank, San and Tomato Bank participating financ institutions. The pr received a subsidy from the Ministry o Forestry and Fishe Acceleration of Fo Development and Revitalization, and subsidy from Mani equity investment by a local construc as well as Maniwa

8	Small hydropower	Kagoshima	995kW	$15 million	Funama Small Hydro Power Plant	The plant is operated by Kyushu Power Generation company since August, 2014. It is the largest small hydropower project in Japan.	The loan was co-f local bank, the Ba Kagoshima and th Development Ban Generally speakin hydropower projec longer payback pe other renewable e The experience ar of implementing a small hydropower lacking compared renewables. On th the Bank of Kagos following reasons loan: the commerc small-scale hydroe generation leads t development, con reducing environm and build a cooper with the local com companies related
9	Solar	Okinawa	N.A.(The capacity can increase as the application for the installation of roof-top PV under way.)	N.A.	Roof-top PV for individual houses, apartments, business facilities	The project takes place on a remote island, Miyako Island in Okinawa region. A local energy company, Miyakojima Energy. was established in April 2018 and promotes renewable energy including roof-top PV for individual houses, apartments, business facilities on the island. The company procures and owns solar power generation equipment, storage batteries, hot water heaters, and other equipment in bulk to reduce the installation cost. The equipment are installed free of charge at	The Okinawa Dev Finance Corporati invested $0.56 mil company (Miyakoj Energy Company) renewable energy in September, 202

						the locations The generated electricity is sold to the property owners or occupants for their own consumption, while surplus electricity is sold to a electricity company. An affiliate company remotely controls the equipment at all times to optimize the supply-demand balance, thereby reducing the impact on the power system and enabling the diffusion of solar power generation equipment.	
10	Gas co-generation/Solar/Solar heat	Chiba	80kW (Co-generation) 20kW (Solar PV) 37kW (solar heat)	N.A.	CHIBA Mutsuzawa Energy: CHIBA Mutsuzawa Smart Wellness Town	The project is operated by CHIBA Mutsuzawa Energy, which was established by Mutsuzawa Town and local companies. In Mutsuzawa Smart Wellness Town, which opened in September 2019, electricity and heat generated by gas cogeneration, solar power, and solar heat are supplied in an integrated manner. The project also features a hot bath facility using waste heat, disaster countermeasures and curtailment of consignment fees through self-owned lines, and undergrounding of self-owned lines to improve the landscape and disaster prevention.	A local bank, Chib announced in 201 invested $4,500 in Mutsuzawa Energ and the Organizat Promotion of Priva Initiative also prov financing to Mutsu Wellness Town Co amount is unknow participates as a n Mutsuzawa Town Creation of Town, Work (Mutsusawa general strategy p organization) and Service Managem Feasibility Study C addition, he is also the local productio consumption of el addition, to promo production and loc consumption of el

							bank's neighborin purchase electricit Mutsuzawa Energ to the information bank also made in neighboring busin support their comr
11	Geothermal	Fukushima	400kW	$7.06 million	Geothermal power generation in Tsuchiyu Onsen, Fukushima Prefecture : Tsuchiyu Onsen Energy	Operated by Tsuchiyu Onsen Energy; started operation in November 2015. The business was launched to promote recovery from the reputational damage caused by the nuclear accident as well as the damage caused by the earthquake. Profits are used for the redevelopment of the hot spring resort. The plant uses a binary system, with a maximum output of 400 kW.	A local, bank, Fuk Shinkin Bank prov $5.57 million. Japa and Metals Nation (JOGMEC) guarar the debt. In additic has received a loa million yen from Ja Corporation and a $0.65 million from Economy, Trade a
12	Small hydropower	Gifu	100kW	$2.4 million	Small-scale hydroelectric power generation in Ishitetsuhaku	The electricity plant is operated by a NPO, Yasuragi-no-Sato Itoshiro. It started operation in March 2011. Water is drawn from a nearly river and a water turbine of about 100kW is installed and operated using a 110 m gap in the altitude. There	In June 2016, the was constructed a $2.4 million. $1.8 r subsidized by Gifu (55%) and Gujo C the cooperative pa million. $0.2 millior million yen was pr

					Village, Gifu Prefecture : Yasuragi no Sato Itoshiro	are four hydroelectric generators. The annual income from electricity sales is about $0.195 million.	residents, and the $0.4 million was fi Japan Finance Co
13	Bioma ss	Hokkaid o	550kW x 2 (boilers) 15kW (solar PV) Several other boilers in the area	N.A.	Biomass Use for District Heating System in Shimokaw a Town in Hokkaido	The community in Shimokawa Town has developed a district heating system using wood chips obtained from local forest.	N.A.
14	Wind	Nagasa ki	2MW	N.A.	Offshore floating wind power generatio n in Goto Islands in Nagasaki	The area is recognized as ideal for installing a offshore floating wind power generation facility with annual average wind speed 7.5 m/s. Toda Construction Company has chosen this location, conducted a research project since 2007,and installed a 2MW power generation facility for the operation in 2016. It has a plan to expand the facility including up to 10 wind turbines.	Goto City has prov power generation Floating Wind Pow 100% subsidiary c Construction Com are additional cost the installed seabe other facilities ons According to the ir source, the actual investment is not u is estimated arour

							The project plans power generation Company announ November 2017 th going to collect $1 through the issuar bond.

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195 Facilitating Industrial Symbiosis

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Abstract

The industrial processes and product use (IPPU) sector accounts for 8% of the European Greenhouse gas emissions. The Energy Transitions Commission believes that, by developing a Circular Economy strategy, there is a potential to reduce CO_2 emissions in the sector by 40% (EEA, 2021).

Industrial Symbiosis (IS) has been highlighted as a strong pathway to implement a circular economy, by developing waste-as-resource business models aiming at reducing waste and promoting cross-sector and cross-cycle collaborations through the creation of markets for secondary raw materials (EEA, 2016).

Despite this evidence, the deployment of IS solutions through industrial and territorial management systems is still in a minimal stage. This problem will become even more critical in the recovery phase of production systems post-covid, when a peak in pollution is expected (Brunekreef Bert, 2021)

According to existing literature, the barriers refer to the lack of clear regulations in impeding a smooth IS development, the overly-rigid spectrum of environmental regulations and missing enabling conditions for the actors taking part of IS. The second type of barriers definitely refer to missing information and knowledge regarding the way by-products, energy and waste exchange and use can be made possible and contribute to the economic viability of the participating actors.

This second type of barrier relating to rigid environmental regulations mainly affects SMEs, which have a lack of in-house expertise in IS operations. The research methodology has been divided in two phases: the first phase is focused on understanding recent literature and training programs related to IS, exploring the needs and gaps regarding IS and providing analysis on skills, competences and knowledge necessary to frame the emerging profile of an IS facilitator. The second phase explores the framework conditions for enabling or, on the contrary, hindering the implementation of IS. In order to foster IS, two approaches are considered: (1) supporting the industrial

park's administration and other stakeholders in acquiring and developing the necessary knowledge, skills and competences to accelerate the implementation of IS strategies; (2) creating enabling conditions for companies and industrial parks to develop sound business cases and participate in IS initiatives.

The main objective of INSIGHT, a Strategic Partnership Erasmus Plus project, is to foster the implementation of Industrial Symbiosis (IS), a CE business model (waste-as-resource) through the development of a training material whose direct impact will result in innovation and excellence of entirely new industry opportunities as well as the transformation of the existing industrial base in Europe. Therefore, by supporting lifelong learning and fostering a new educational initiative that offers learners the possibility of enhancing their skills and acquiring new knowledge, the pool of suitable candidates will broaden and allow factories to be better equipped to fabricate future CE business strategies. INSIGHT will attempt to develop a new professional profile for the Industrial Symbiosis Facilitator to cooperate with companies, industrial parks and others stakeholders through defining and promoting synergies, capitalising on the benefits of the circular economy for them, etc.

Keywords: industrial symbiosis, knowledge, facilitator, policy, training

Introduction

The linear economy model "take-make-consume-dispose" reflects a time when resources and energy were believed to be unlimited and easy to obtain and there was no awareness regarding the serious environmental consequences of this model (Steffen et al., 2015) .

In the last years, Circular Economy (CE) is proposed as a logical and viable alternative, with the aim to address the main challenges of this linear scheme. CE refers to a production and consumption system that creates as little economic loss as possible, and where the majority of the products and resources used in production processes can be reused and recycled. This alternative approach to address product design and production processes is expected to help minimise waste and increase the potential of unused resources, and, thereby, have a positive environmental impact (Johnsen et al., 2015) (COM 98 final, 2020). The European Commission (EC) stresses that "transition to a more circular economy requires changes throughout value chains, from product design to new business and market models, from new ways of turning waste into resource to new models of consumer behaviour"(COM 0398 final, 2014).

Sustainability will make the business cluster more competitive in international markets in the long term, and to achieve this, it is necessary to use all the elements available to them. For this great transformation challenge, the cooperation of all possible economic and social agents will be necessary in order to mobilize sustainable investment and develop new technological solutions. This cooperation will make the creation of value for all stakeholders, new business models and solutions adapted to the new environment and the values of each organization possible (COM 98 final, 2020).

This industrial transition requires a shift from current manufacturing industries to future-oriented activities (even in traditional sectors), which can lead to above-average unemployment rates due to locally concentrated deindustrialization and the existing skills based in declining sectors. Therefore, it is key to ensure that training and adequate provision through appropriate retraining and upskilling of workers, including through access to lifelong learning, is combined with policies that stimulate investment in new sources of employment and productivity growth (OECD, 2019).

Under this framework, it is important to mention the existence of new business models as Industrial Symbiosis (IS), which is an enabling factor that could achieve green growth and the implementation of CE. This model is focused on retaining the added value of products for as long as possible and eliminate waste at the same time. IS is an innovative way to increase resource productivity because it involves the physical exchange of materials, energy, water, by-products, etc. aside from integrating digitalization to achieve proper management of all these flows. IS is a waste-as-resource business model which provides new opportunities for innovation across fields of circular economy and digitalization (European Environment Agency, 2016).

Nowadays, the industry in general is aware that it is immersed in profound changes driven by digital and green principles, and for this reason a decision to carry out a complete evolution of its business model has been made, a decision which will enable business owners to improve their competitiveness in an increasingly internationalized sector, where competition is at its maximum capacity and where the improvement of manufacturing processes is the key for survival.

Some companies have already started this change (World Economic Forum, 2017), while others are keeping a passive attitude towards change. The way this transformation is affecting and impacting companies will be analyzed in this research together with the skills, knowledge and competences required to undergo this transition.

Research objective and methodologies

General information

Under this context, the INSIGHT project[1] (*Fostering Industrial Symbiosis through the development of a novel and innovative training approach)* was developed under the framework of the EU program Erasmus+ with the aim of developing a new professional profile, that of the Industrial Symbiosis Facilitator, and the e-training curriculum leading to this profile.

The IS facilitator is responsible of different tasks: to conduct an analysis in its area of influence, to define and promote synergies between companies from different sectors, to capitalize on the benefits of the Circular Economy for the industry they account for, etc.

At this stage, the following research questions (RQs) were formulated:

RQ1: Which barriers and enabling factors influence the success of Industrial Symbiosis processes, with a focus on solutions implemented by SMEs?

RQ2: Which critical knowledge, attitudes and skills affect the Industrial Symbiosis process, from the design to the operative functions for the sustainability of this new Industrial Symbiosis facilitator profile?

RQ3: What is the most suitable Joint Curriculum for Industrial Symbiosis Facilitator?

RQ4: How is it possible to integrate Industrial Symbiosis through INSIGHT project in a blueprint?

To answer these questions and bridge the gaps in the literature on this topic, the following study will provide an analysis of all the research done under INSIGHT project.

Desk analysis

On one side, a blended methodologies structure has been implemented including desk analysis and on-field research actions, as synthetised in the Figure 1.

[1] https://www.insight-erasmus.eu/

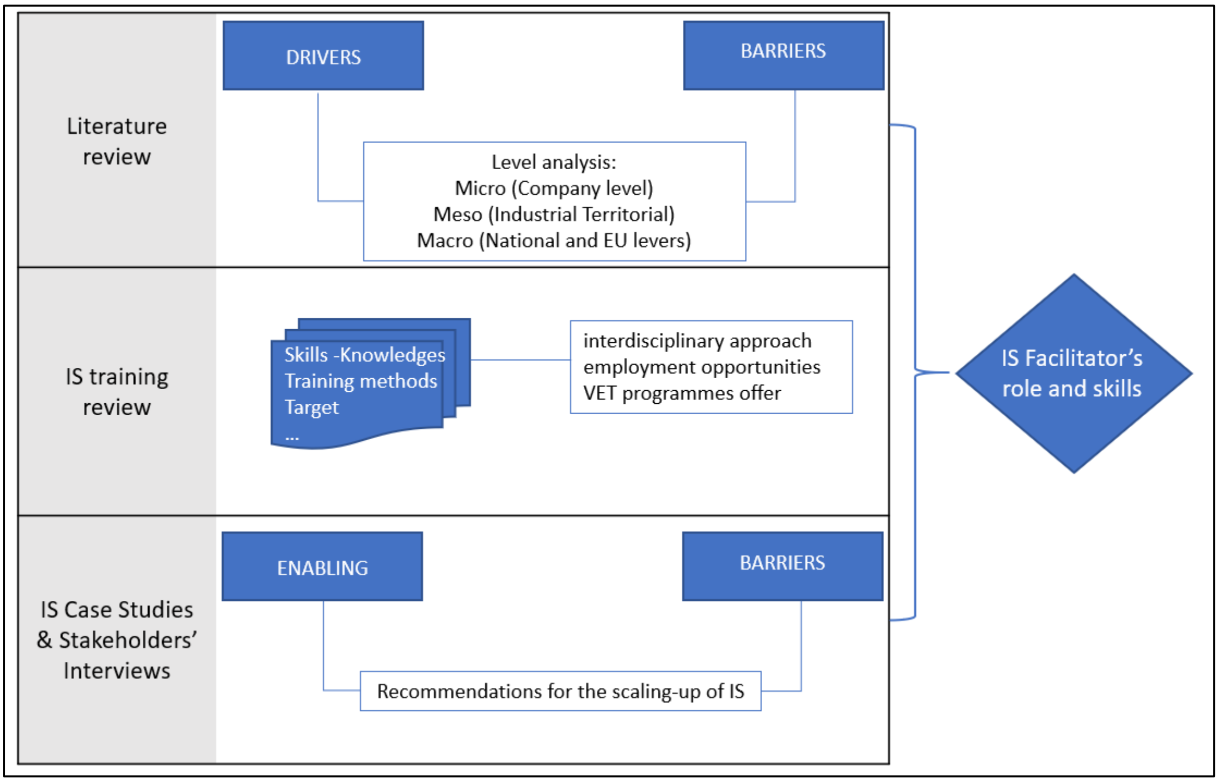

Figure 1. INSIGHT Research Design.

The first research action responds to the objective of updating the analysis of Industrial Symbiosis cases by articulating a framework of enabling factors and barriers referring to different levels of implementation. The three-level considered are:

- The micro-level focuses on the internal management of firms.
- The meso-level focuses on the connection between firms (industrial park level) and involves other actors at a higher level of intervention such as intermediaries and regional authorities.
- At the macro-level, national instruments and legislative framework are considered.

This multi-level framework does not assume that each aspect of IS is found exclusively at one level; the boundaries are porous, and one aspect could be tracked at a different level depending on the characteristics observed.

An extensive analysis of IS training pathways was carried out at international level, investigating methodologies, learning outcomes and the structure of the IS training offer.

Finally, the on-field research actions collected evidence on the IS skills gap conducting two types of interviews:

- **The analysis of more than 30 IS case studies**, carried out in Europe (from Spain, Slovenia, Italy, Romania, Luxembourg, Belgium, France), highlighting different IS deployment fields (material valorisation, shared resources, shared services, energy valorisation, energy exchanges), as well as IS implementation levels (including the national level cases, to mark out the IS policies and strategies way forward, IS supportive services and applied solutions cases meeting the territories and enterprises clusters needs).In order to get an exhaustive picture, the case studies selection gathers micro enterprises (30%) and big companies (14%), while the rest are SMEs. Furthermore, the company's maturity is well represented: a third of companies are older than 20 years, another third between 10 and 20 years and the last one younger than 10 years. The representation of public/private is balanced, too.

- **The dialogue with more than 60 stakeholders** representing the different fields required to interact for fostering the Industrial Symbiosis. The stakeholders are representatives of the following sectors: Research and Universities (17%), Business Associations and IS Consultants (33%), Public Authorities (18%), Educational Institutions and Trainers (11%), Enterprises (11%), Industrial Park and Support Organisation (10%).

The INSIGHT Stakeholders Engagement process is a founding methodology of the INSIGHT project. 94 stakeholders contributed to comment and enrich the orientation of the Industrial Symbiosis Facilitator profile.

It should also be mentioned that the project reflects the complexity and integration of interests and decision-making processes that drive IS from its partnership composition. In fact, both IS research centres (EcoRes, Symbiosis) and organisations representing IS management (Styrian Industrial Park), organisations representing sectorial enterprises (CETEM), VET Providers (SFC), consumers association (Centrul National pentru Productie si Consum Durabile), and network of cities and regions (ACR+ as associated partner) are involved.

The multi-actor nature of the industrial symbiosis decision-making process is reflected in the identification of emerging competences for the role of IS facilitator, confirming an interdisciplinary nature of the training course (INSIGHT news, 2020a).

The training offer of INSIGHT project

Learning is dependent on the pedagogical approaches that teachers use in classrooms or in e-learning. A variety of pedagogical approaches are common, but some strategies are more effective and appropriate than others, special for e-learning as in the INSIGHT case.

In good online education, it is the course rather than the education that provides an appropriate learning environment for students. Rather than simply referring to a set of materials, the course represents the structure of learning that is designed into the course materials.

INSIGHT project has defined 5 training modules taking into account the learning pre-requisites (defined through skills, knowledge and experiences of potential target users and related stakeholders).

Evaluation of the Joint Curriculum

On the other side, a Joint Curriculum has been defined by INSIGHT Consortium and later on, in terms of validation and in order to identify potential weaknesses and opportunities for improvement, each partner was requested to identify at least 73 stakeholders, who were in charge of reviewing the INSIGHT Joint Curriculum and to provide feedback in terms of relevance, consistency with the objectives defined in the project and impact. This Joint Curriculum has been developed and integrated in the e-learning platform of INSIGHT project (INSIGHT news, 2020b).

In order to carry out the evaluation and validation of the Joint Curriculum, the partners identified a series of questions, which evaluate general and specific aspects, related to each individual module and training unit. The tool used to carry out this activity is Google Forms.

The partners disseminated the questionnaire to a large number of stakeholders. They represent different kinds of organizations and institutions, ranging from universities, regional development agencies, enterprises, business support organizations, etc.

Each stakeholder was provided with a copy of the INSIGHT Joint Curriculum Overview and was requested to answer different kind of questions:

- The first part of the questionnaire was dedicated to general information regarding the respondent (name of organization, position, country).
- Two short questions were defined for assessing general aspects.
- Two short questions were defined for asking an opinion on specific matters.
- The rest of the questions (8) were focused on ranking the necessity of Modules and Training Units.

INSIGHT Blueprint Policy

In order to ensure the project's focus on sustainability, raising awareness about the importance of IS facilitation and building capacity, the development of a Blueprint policy is proposed.

A Blueprint Policy is a policy recommendation, a framework for strategic cooperation between key stakeholders in a given economic sector, that can stimulate investment and encourage the uptake of proven concepts and methods. According to Oxford researchers, "blueprint policies consist of the range of constitutional provisions, legislation, plans, reports, and policy machineries that governments use to establish general principles" for a specific state of the action at national and sub-national levels. (Mazur, 2003). The INSIGHT Blueprint will provide a roadmap of how the organisations' activities are expected to deliver the desired IS principles by making use of certain inputs and resources. All relevant EU and national qualitative evidence and quantitative data produced under the Blueprint will contribute to the Skills Panorama and the new Europass Framework, as well as generating recognition towards the facilitation and of the importance of building up capacity and creating awareness towards upscaling the industrial symbiosis.

In order to develop the INSIGHT Blueprint, the partners have firstly defined the scope of the policy, taking the objectives of the project and the existing limitations into account. The next steps are to analyse the existing policies in the five European countries, and other relevant policies, discuss the range and timing of policies found and define the criteria for selecting the policy cases that should be covered by the Blueprint.

Based on a specific set of criteria the policies are analysed in order to determine five priorities, as the baseline for developing the action plan, mapping key factors for a collective impact strategy aimed at improving facilitation, capacity building and creating awareness for an IS plan. The validation of the proposed policy is a key step in developing the recognition of the Insight Blueprint by the stakeholders and is planned to be performed in the six partner countries, through interviews and face to face consultations.

The main steps of developing the INSIGHT Blueprint are presented in Figure 2:

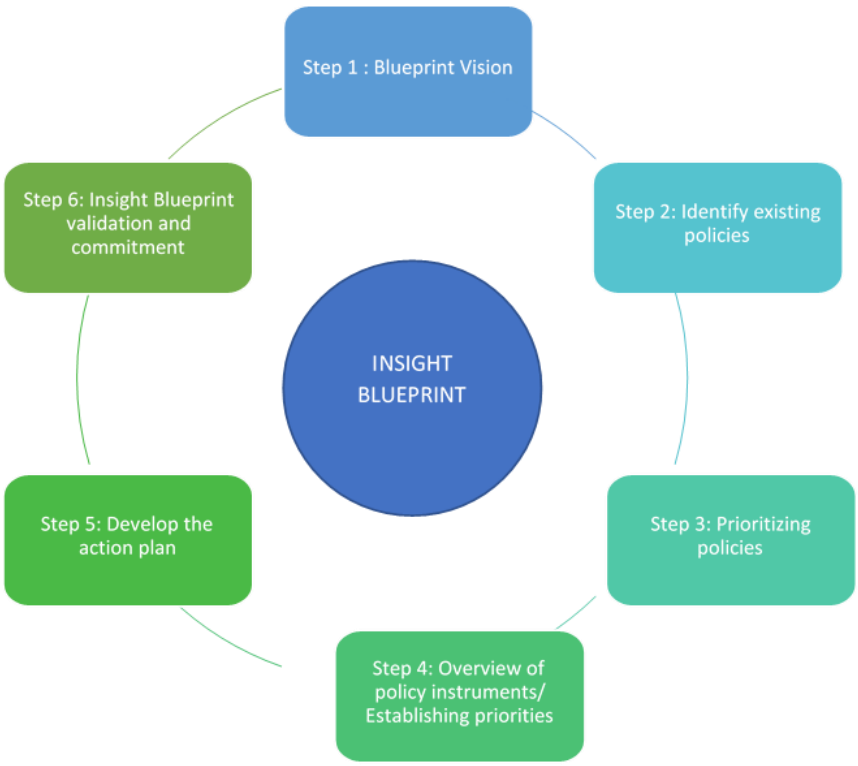

Figure 2. Steps for developing the INSIGHT blueprint.

Results and Discussion

Drivers and Barriers for the implementation of Industrial Symbiosis

INSIGHT research on IS case studies confirms the interlaced of several **drivers** determining the IS initiatives, defined as external and internal impulse.

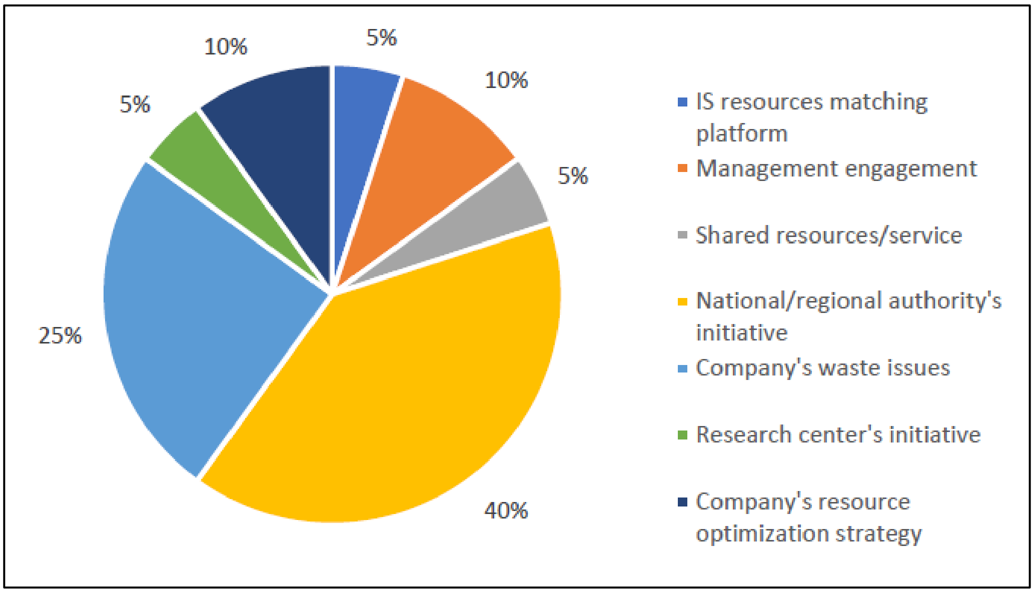

Figure 3. *"How did the Industrial Symbiosis initiative start?"*.

Although the company's waste issues are a prominent driver to implement IS plans (25%) defining concrete company needs in terms of cost savings, IS initiatives seem to be driven by an authority-led initiative at national and regional level (40%). Chamber of Commerce initiatives, CE programs represent the investment opportunity and the consultant supportive framework to launch the IS programs. The company's strategy in pursuing the business model innovation is one of the key drivers for IS. The management engagement (10%) as well as the company's resource optimisation strategy (10%) ensure the maintenance of IS processes over time. Both those elements combine the two management factors of the IS initiative motivation and the optimisation of the material flows.

Among the lesser-mentioned drivers, but whose results are crucial for the enhancement of industrial symbiosis, are:

- The IS resource matching platform (5%), that is an emerging tool addressing the SMEs' needs to be constantly informed about possible collaborations between companies, at territorial and sectoral level.

- The shared resources/services (5%), allowing companies renting out the same building/common facilities in order to lower related costs. Following in this direction, the collaborative platforms developed facilitate communication and transcend the companies' existing customer/supplier network.

Among the main **barriers** in the implementation of IS are:

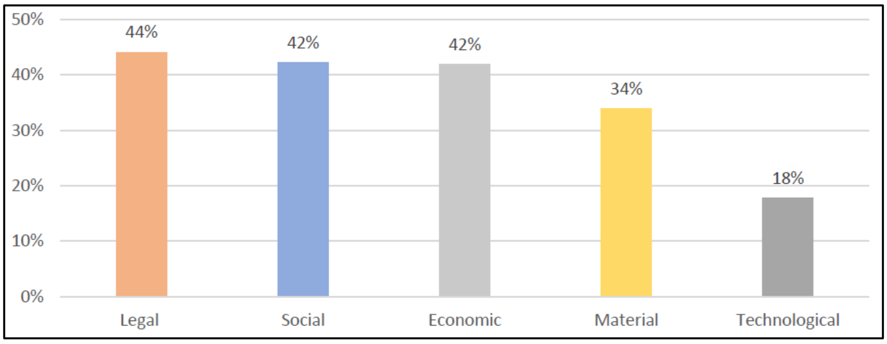

Figure 4. "Challenges/Barriers in the implementation and scaling-up of Industrial Symbiosis initiatives".

Legal issues, which mainly concern the overly rigid 'waste' status in the EU, preventing the reuse of a side-stream in another industry. In this way, the 'waste' classification of a product often buries the IS initiative. The recent regulatory review that is taking place in some EU countries moves in the way to create the pre-requisites to achieve the Green Deal objectives, and it acts to open up the definition of waste.

The **social aspects** are identified as the second most cited challenge by the interviewees. This has an impact both on the openness to consider waste as a new resource, effectively curbing the use of IS solutions, and on the development of specific knowledge about IS by a wide range of stakeholders. There is a need to integrate eco-design at the start of the production line, so the 'waste'/side stream can be of quality and reusable (using a systemic approach). Moreover, the lack of collaboration between actors is one of the key difficulties: "some companies don't want to share production data with their industrial ecosystem for confidentiality reasons, while other companies are not used to share knowledge and data with outside parties geographically close-by".

The initial investment extent, as well as the return time on investment, are **economic barriers,** as they imply an uncertain long-term relationship with the industrial ecosystem involved. The durability of the market for products developed by IS plans is also a determining factor. In managing the uncertainty of the initial investment, as well as the stability of trade between material flows, the profile of the IS facilitator would play a prominent role, together with the availability of enabling incentives.

The uncertainty about the constant supply of sufficient incoming material, of the right quality and with a predictable flow rate is a **material-related barrier** that the IS plan must be able to handle. A solution to overcome this barrier is to involve multiple stakeholders from the side-stream/waste producers and users of those streams. The whole industrial ecosystem needs to be put in place with a 'market'-based approach.

Finally, **technological barriers** are indicated as the least constraining difficulties, due to the available technology providers.

The training offer of INSIGHT project

Learning is dependent on the pedagogical approaches that teachers use in classrooms or in e-learning teaching. A variety of pedagogical approaches are common, but some strategies are more effective and appropriate than others, special for e-learning as in the case of INSIGHT.

In good online education, it is the course rather than the education that provides an appropriate learning environment for students. Rather than simply referring to a set of materials, however, the course is the structure of learning that is designed into the materials.

The INSIGHT project has defined 5 training modules taking the learning pre-requisites into account (defined through skills, knowledge and experiences of potential target users and related stakeholders).

Table 1. INSIGHT training modules.

INSIGHT Modules	Training Units
M1. IS theory, concepts and context	1.1. Introduction to Circular Economy 1.2. Introduction to Industrial Symbiosis 1.3. Circular Economy and Industrial Symbiosis at EU level
M2. Resource management	2.1. Source Circularity 2.2. Resources Management: focus on waste 2.3. Resources Management: focus on water resources 2.4. Resources Management: focus on energy
M3. IS management	3.1. System-thinking approach to Industrial Symbiosis 3.2. Data Collection and Resources flow analysis 3.3. Existing Circular Economy and Industrial Symbiosis platforms 3.4. Financial opportunities for Industrial Symbiosis 3.5. IS Business Model
M4. Soft skills for IS	4.1. Pitching IS 4.2. Entrepreneurship, design thinking strategies and co-creation methods 4.3. Models of collaboration and inter-companies teamwork
M5. IS case studies	5.1. IS Case Studies: Territorial approach 5.2. IS Case Studies: Industrial Park approach 5.3. IS Case Studies: Company approach

Furtherly, an appropriate standard pattern and being well-structured for all didactic materials has been defined. All the units were developed by using the following didactic materials:

1. Course book.
2. Power Point Presentation.

Both materials are integrated into the e-learning platform, together with different dynamic resources that will enhance student's learning by engaging and motivating them.

Finally, the INSIGHT course has integrated a learning assessment. The objective of the learning assessment is to evaluate the extent of knowledge, skills and competences acquired, which are proposed by the educational program. Students are evaluated throughout the course in the context of demonstrating their ability to meet the expected learning outcomes. The course is evaluated to determine if the content was sufficiently developed and delivered to provide the students with the necessary tools and skills to meet the learning objective.

Both quizzes and assignments are provided to assess student performance throughout the course (Figure 5). If the student does not sufficiently answer the questions or assignments, then they will be directed back to prior sections of the unit for further assistance. The correct answers for assignments are provided to the student to further clarify the questions.

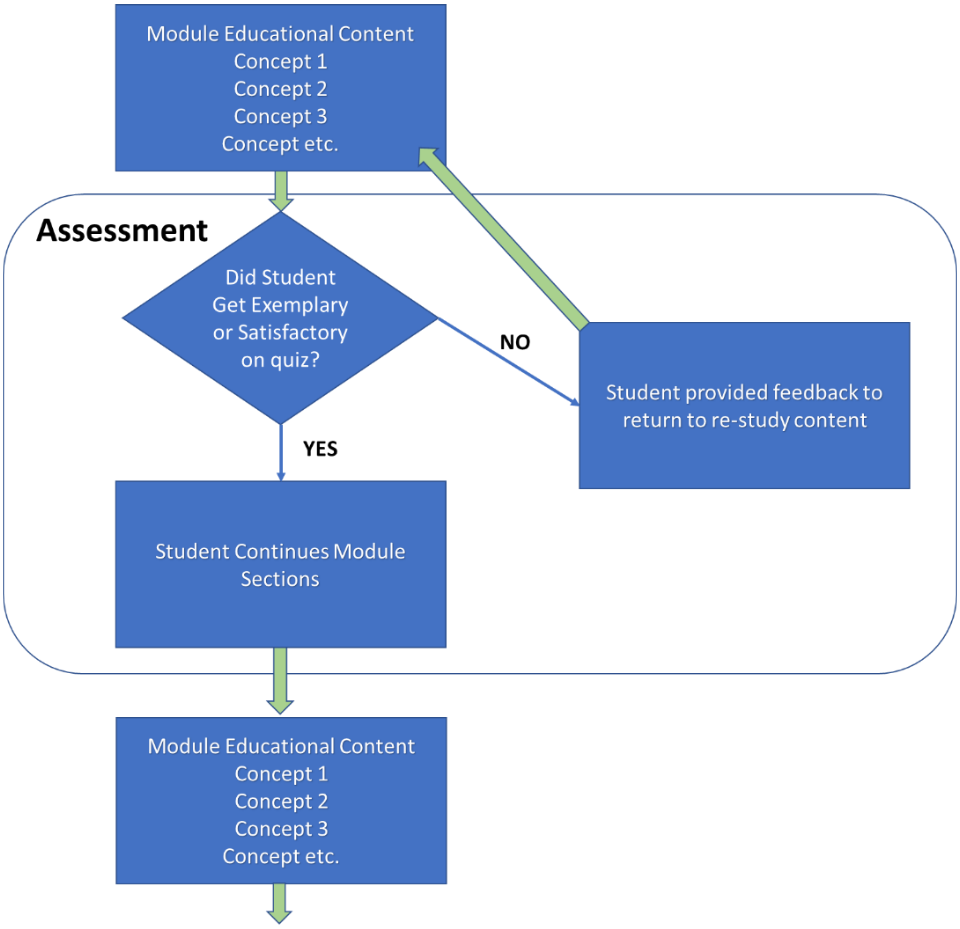

Figure 5. Example flow of learning outcome assessment and performance.

Finally, in order to deploy all the training materials prepared during the project, a Massive Open Online Course (MOOC) has been created. Figure 6 shows the global architecture of INSIGHT e-learning platform, based on the Opigno software. This software was selected because it is open source a nd makes the creation of interactive content possible.

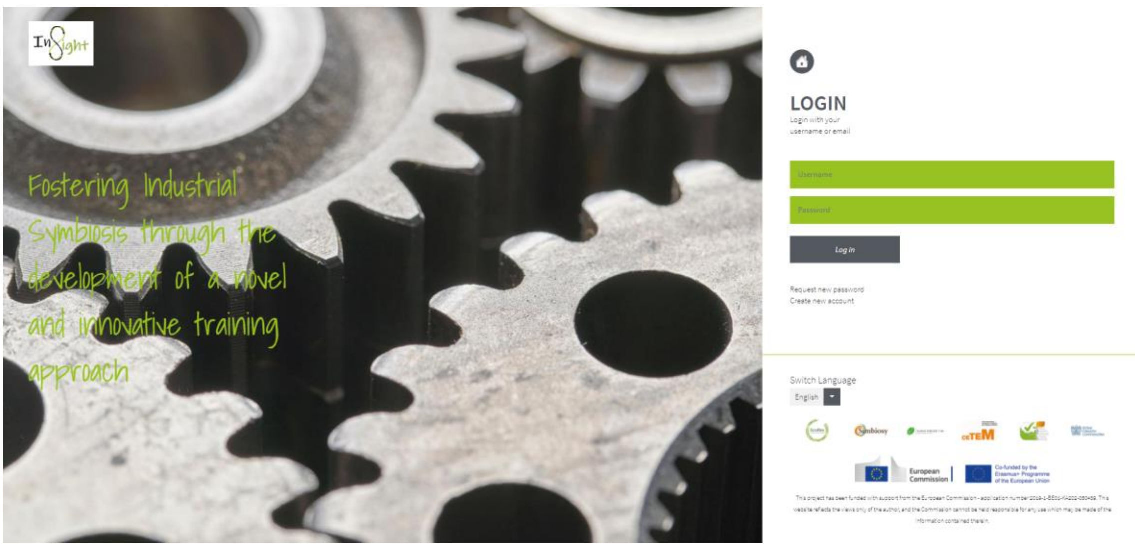

Figure 6. INSIGHT e-learning platform.

Evaluation of the Joint Curriculum

The defined INSIGHT Joint Curriculum – with its five Modules and related Units – is considered by stakeholders, who participated to the evaluation and validation, as generally very positive.

There is a general harmony between Modules and Units. Due to the fact that the topic of IS is relatively wide, the comments received are beneficial for the INSIGHT partners to understand which topics require more attention and if there are aspects that should be furtherly strengthened. The obtained feedback will be useful not just to the revision of the Joint Curriculum, but also to the development of the related training materials.

Generally, there is no significant weakness in the Joint Curriculum. Some aspects are more recurrent, while in general the feedback is mostly positive. Nevertheless, each received feedback is going to be taken into consideration by the partners when improving the Joint Curriculum and transitioning towards the training and development activities.

The following table summarizes the most important comments received by the stakeholders throughout the questionnaire. It attempts to identify the main aspects, which partners will most likely follow-up on in the Joint Curriculum, as well as in the training content.

Table 2. Follow-up actions for the Joint Curriculum and O2 development.

No.	Comment	Follow-up
1	**It may be necessary to provide students with a feedback**	Quizzes might be enough, but partners will consider implementing peer reviewing in order to get qualitative feedback and generate discussion about the content.
2	**Objective and outcomes may be abstract**	Partners will review the objectives and the learning outcomes in the Joint Curriculum to make sure they are even more concrete.
3	**The course may be long and complex.**	Partners will make sure that each unit keeps an appropriate length of the course.
4	**Individual modules may be too theoretical and not practical enough.**	Partners will avoid to develop content, which is too theoretical and complex. Rather it should be in line with the needs of the target group, with more focus on practical exercises.
5	**The scope of IS may not be clear enough (in enterprises, inter-enterprises, etc.)**	Partners agree that, although the scope was already defined in the project application, it will be further developed and explained in Module 1 and practically explained in Module 5.

5	**Soft skills and pitching should be assigned more time to cover the topics properly.**	Partners will make sure that the right amount of content and learning time related to soft skills and pitching is assigned when developing the training content.
6	**A tool to make industrial symbiosis more attractive may be useful**	Partners agree to identify an easy-to-use platform / online tool, which helps IS to be more attractive and more of use for the students.
7	**The kind of professionals addressed by the project may not be clear**	Partners agree that no specific fields of work are needed to participate to the INSIGHT training course, except for the entry-level requirements defined in the Joint Curriculum. In general, the target group of the project is defined as businesses, public institutions, etc.
8	**Financial aspects around governance and risks may need more focus**	Partners will discuss these aspects shortly in the training unit dedicated to IS Business Model.
9	**The role of R&D in the development of new products obtained from wastes may be missing**	Though partners agree that this topic is out of the project scope, they also believe it is good to mention the role of R&D in the IS Business Model.

Research of existing IS policies in Industrial Symbiosis and Circular Economy in the partners countries

The literature has extensively reviewed success factors and barriers to IS development. A commonly reported cause of failure of technical and economically viable synergies is the inability of organisations to reach a mutually beneficial agreement. This relates to both organisational and communicational barriers. Problems of communication between companies and disparity of business culture may also pose risks to the process of realisation of synergies. The lack of technological knowledge, the precarious understanding of the waste fluxes and the inability of firms to adapt to structural changes, new technologies or new organisational concepts complete the picture (Teresa Domenech, 2018). Facilitation approaches help to overcome some of the barriers to IS by increasing the knowledge of resource flow and potential synergies, reducing transaction costs, risk and uncertainty of IS transactions and promoting collaborative structures for scalability. (Ashton, 2008).

According to the authors of the European Commission Report (Teresa Domenech, 2018), three key policy approaches have been demonstrated to be effective in promoting IS: (1) promoting the emergence and development of self-organised activity, when synergies are the results of spontaneous interactions between companies; (2) planning initiatives to promote the development of Eco-Industrial Parks or re-structuring the existing ones and (3) the “middle-out approach”, which proposes a combination between facilitation and curated interaction, requiring a third party to help stimulate emergence and development of the network and to work on overcoming barriers linked to information deficits and lack of technical capability (Costa, 2010).

The starting point was to identify the existing national strategic framework and whether there are any policies linked to IS application, eco-industrial park development and IS facilitation & capacity building. During the research, partners identified various policies for promoting IS, from legal acts to strategies, from policy mechanisms to financial instruments, generally any available national legal and financing mechanisms that could support industrial parks and companies when implementing IS approaches. The most representative policies, enclosing clear components referring to industrial symbiosis facilitation, awareness creation and capacity building are presented in Table 3.

Table 3. Policies promoting IS and key related content.

Country	Name of the policy	Key content related to the scope of the blueprint
Belgium	Circular Valonia (https://content.digitalwallonia.be)	The program establishes a platform through which the profession of facilitator can be officially recognized, supported and sponsored. In a word, the facilitator will act as a bridge between technical and institutional aspects of the project and will be able to guarantee the necessary endorsement of banks and financiers. In addition, several measures are planned to prepare and inform all the financial actors involved.
	I.D.E.A. Strategic Plan 2021 – 2022	The plan is articulated through 5 "transitions", concerning in order: economy, energy, environment, digitization and management. Each field has different objectives and some among them envisage a new role for certain IDEA agents, who will become facilitators in industrial symbiosis.
	PREC – (Circular Economy Program of Brussels Region)	Measures 5 and 6 of the programme are focused on the Employment in sector of the circular economy / Making Training and Teaching as levers for tomorrow. The institutions in collaboration with training and anti-unemployment agencies introduce the circular economy in all its facets within the program of educational and professionalizing offer. In addition, institutions are working to introduce the circular economy within the more traditional training circuit such as high education. Training for the professional adaptation of staff in key sectors of the local economy.
Spain	Circular Economy Interplatform	The activities of the Interplatforms Group are aimed at boosting initiatives and actions for public-private collaboration in the field of research and innovation, as well as launching projects within the framework of national and international R&D&I programmes. Interplatforms Group has developed activities aimed at raising awareness of the concept of circular

		economy, publicise the financing of R&D&I in the circular economy, show success stories, facilitate the search for partners from different sectors
	Circular Economy Action Plan	The Circular Economy Action Plan is based on the objectives of the Spanish Circular Economy Strategy and includes 116 measures that the General State Administration will implement over the three-year period 2021-2023 to consolidate a circular and decarbonised economic model. The measures are articulated around 8 lines of action: production, consumption, waste management, secondary raw materials and water reuse, awareness and participation, research, innovation and competitiveness, and employment and training. In the production line of action, the impulse to industrial symbiosis is specified.
Italy	Law 28 December 2015, no. 221 - "Provisions to promote green economy measures and for the containment of the excessive use of natural resources"	The national law introduces resource-efficiency issues, such as the IS Facilitation (Article 23. Programme agreements and provision of incentives for enterprises that produce, market, purchase goods from recycled materials from waste, disassembly of complex products) and incentives to be granted in accordance with the minimis rule of the EU Regulation (EU) No 1407/2013.
	"Policy framework document and strategic positioning " of the Ministry of Environment & Ministry of Economic Development	The strategic document provides a general overview of the circular economy and IS for business, and defines the strategic positioning of the country, encourage the development of new business models that can make the most of Italian excellence, arise the Symbiosis as a tool for system eco-innovation for the efficient use of resources, through the creation of resource sharing networks and carrying out evaluations and in-depth analysis of the symbiotic opportunities.
Romania	POCU - Operational Programme Human Capital	The specific objective of the investment priority 3, is to improve the level of knowledge / skills / skills related to the competitive economic sectors / areas. The participation in vocational training programs in accordance with the requirements from competitive economic and from the fields of intelligent specialization. Assessment / validation, certification and recognition of skills related to job requirements in competitive economic sectors.
	Romanian Strategy for Circular Economy 2030 (draft)	Priorities related to the scope of the project: 1/ Waste hierarchy: Effective application of the principle of waste hierarchy, preventing their generation, promoting readiness for reuse, consolidation of recycling, the energy recovery of those wastes that cannot be recycled, thus favoring its traceability and reducing the abandonment of waste in the environment and its arrival at sea.

		2. Production efficiency: Introducing guidelines that increase innovation and efficiency of production processes, through the use of digital infrastructures and services, as well as by adopting measures such as the implementation of management systems thus promoting competitiveness and sustainable economic growth. 3. Employment and education / training: education, retraining, development of new skills that respond to the opportunities that open up, training for employment labor force as a result of the transition to a circular economy, and job creation. The improvement of existing jobs will have to be based on special policies that will play a role in the future circular economy. The development of a standard for the occupation of expert circular economy is an important step in qualifying the workforce for new profession.
Slovenia	Roadmap towards the Circular Economy in Slovenia	The Roadmap towards the Circular Economy in Slovenia sets the path for Slovenia to become a circular economy front runner in the region. Designed through an inclusive, multi-stakeholder approach, it identifies four priority sectors, give recommendations to the government and identifies best practices. The Roadmap introduces the Circular Triangle, a model which unites three inseparable elements – Circular Economy (business models), Circular Change (government policies) and Circular Culture (citizens), three interdependent aspects that are at the core of systemic change from a linear to a circular economy in Slovenia.
	Strategy for the Transition to Circular Economy in the Municipality of Maribor	The underlying idea of the Strategy for the Transition to the Circular Economy in the Municipality of Maribor, is to have an own innovative model as a system for managing all the resources available in the Municipality of Maribor and the wider urban area. The model is based on the operation of enterprises that are predominantly publicly-owned and already provide public services for residents. They are thus the city's bottlenecks that until now have not functioned as a connecting link, which is a fundamental principle in the transition from linear to circular economy.

Policies assessment and selection of priorities

The prioritization of policy interventions was inspired by the UNIDO policy support tool (Dick van Beers, 2017) and includes a detailed template for a multi-criteria analysis, in which the identified policy intervention options are assessed according to prioritization criteria:

(1) Political viability: high-level and long-term commitment from relevant government institutions; support from the private sector, inclusion of a multi-

stakeholder approach and collaboration between government, educational institutions and industrial parks/SMEs;

(2) Policy intervention areas: prioritization of interventions for capacity building in industrial symbiosis, prioritization of interventions for industrial symbiosis facilitation, fidelity with best practices and recommendations of the EU for advancing industrial symbiosis;

(3) Policy domains and instruments: suitability to the country's level of industrialization, environmental and socio-economic needs, coherence with other strategies, opportunities and challenges associated with industrial parks, country's ability to monitor and enforce compliance where necessary;

(4) Policy pathways and integration: addressability of the economic, environmental, and social risks and benefits of industrial parks, instruments and their pathways assessed for any potential negative impacts over the short, medium and long-term

(5) Policy implementation: addressability of the enforcement activities, implementation of related policies supported by regular monitoring through performance indicators, periodic reviews and a system for corrective actions by relevant stakeholders, concrete action planning-including responsibilities, timeline, and financial/human resourcing.

A weighting system allows the prioritisation of the policies with the final purpose of selecting five best ones, which is an ongoing process, following the project sequences and timeline.

The next steps will concentrate on the selection of five most relevant priorities, stakeholder's engagement, and finally the elaboration and validation of the action plan.

Priorities will be defined based on the performed prioritisation, keeping the main scope of the INSIGHT Blueprint in mind and selecting the best identified policies, based on the listed criteria.

Stakeholders can assist in the establishment of a national plan for adoption of industrial symbiosis and the development of the eco-industrial parks. It is therefore important to identify and establish interest among high-impact industry sectors, park operators, local and regional authorities as park developers who may have a stake in decision-making, as well as in developing and implementing industrial symbiosis programs at national level (UNIDO&World Bank Group , 2018). They are going to be identified and categorised based on their interest, potential adoption of industrial symbiosis and their influencing abilities. The main objective is to assess stakeholders on their suitability for participating in the policy process, with a core focus on policy related stakeholders relevant to IS interventions.

The development of the Blueprint draft involv an extensive research and process of stakeholder consultation, to ensure that the future direction reflects local needs and that it is targeted to achieve tangible outcomes in the dissemination of training and practices for Industrial Symbiosis.

Conclusions

Acquiring knowledge and acknowledging potentials instead of challenges and risks can lead to raising awareness and generating interest in the initiation of new businesses or improvement of a business' own processes. The literature review of 90 articles regarding critical factors influencing IS, concludes that awareness and interest in IS can be created through technical and social infrastructure promoting the IS consideration and facilitating the good IS examples. Policy is a very important factor when it comes to generating awareness of IS possibilities and interest in gaining its benefits (Lucia Mortensen, 2019).

The Erasmus Plus INSIGHT project consortium cooperated during two years for the development of the key intellectual outputs of the project: the IS Facilitator job role, course curricula, training platform and, in the near future, the blueprint paper promoting facilitation and capacity building in industrial symbiosis. The intellectual outputs have been developed by considering the existing context in the partners countries, barriers and enabling factors influencing the success of Industrial Symbiosis processes, and by investigating, the stakeholder's position and asking for their validation at all stages. The extensive educational programme proposed is designed to build knowledge, skills and competences for the IS Facilitator, setting up the ground for the creation of a new job role, demonstrated to be highly important for the deployment, scaling up and replication of industrial symbiosis and the development of eco-industrial parks.

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193 Sustainability in engineering education: practical examples

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Abstract

Recently, education about sustainability in engineering has faced several challenges. Firstly, many educational institutions had to transition from face-to-face to online teaching in 2020. Secondly, sustainable development requires additional expertise to be included in the scripts and discussions. Giving priority to the topics of sustainability, the global supply of raw materials and raw materials policy, the Austrian branch of the International Competence Centre for Mining-Engineering Education under the auspices of UNESCO has promoted awareness of these topics to engineering students, researchers and wider public, consisting of several practical examples including an online lecture series, the joint master's degree programme "Engineering Geoecology," and international partnerships in education with a focus on sustainability. Conceptualised and coordinated by the Austrian branch, the online research and education lecture series "Sustainable Development Approaches in Engineering Research and Education" was held for the first time in the winter semester of 2020/2021. Within the International Competence Centre's network, eight international experts including five professors held lectures on the specific topics of their expertise in mining, the sustainable supply of raw materials, materials science, recycling, and engineering education. Being freely accessible without any restrictions, on average, 70 participants from more than 20 different countries attended each lecture. The new joint master's degree programme "Engineering Geoecology" includes sustainable development-related courses in the curriculum, allowing the young generation of engineers to acquire this specific knowledge during their studies. Synergies of the recent widespread use of the online format in education and international collaboration

have allowed the creation of new successful opportunities to raise awareness about sustainability in engineering education.

Keywords: sustainability, engineering education

Introduction

We can assert that the sustainable development of any society is determined by the provision of its economic structures with qualified personnel. The hubs for the educations of such qualified personnel often are located at universities and higher education institutions (HEIs) in general.

The training of personnel is becoming not only the most important factor in the development of the country but also a condition for its survival. The data of experts, as well as the requirements of the labour market, confirm that it is the training of modern skilled workers and specialists that will largely determine the rates of economic growth and the quality of life.

Therefore, the reform and modernisation of vocational education in the 21st century should become the most important task of society and the state. The transition to an information society, the volatility of market structures, and the recent developments and disruptions under a global pandemic, dictate and accelerate the use of information and communication technologies. This included the introduction of distance learning in vocational and additional education.

The main goal of modern education is the formation of competencies that meet the requirements of the modern stage of society, the trend of which is the concept of "education throughout life", lifelong education or continuous education.

Today, the most demanded skills by employers are the so-called supra-professional competencies, in other words, the ability to work in a multidisciplinary environment.

Therefore, a modern engineer should be able to handle a multitude of different situations. This includes, firstly, “setting tasks” in the framework of complex design and production curtailment activities, which includes market analysis, analysis of opportunities created by new technologies, search for credit or investment resources, product development and related production processes, building sales networks, analysing the entire system and improving individual links or links between these systems.

Further, communication, management, interdisciplinary skills are becoming more and more important in engineering. Therefore, we must understand that today engineering science, industry, education is not a separate subject, it is a complex system that cannot be built only on the development of one direction.

In addition to the above mentioned, and in the context of supporting the Sustainable Development Goals (SDGs) of the United Nations, focusing on SDG 4 Quality Education, the International Competence Centre for Mining Engineering Education under the auspices of UNESCO was established in 2019. Its vast network of global partners is, among other things, devoted to the vocational training and professional development of (mining) engineers.

With its mission “Educating today’s engineers for a sustainable tomorrow” the Austrian branch of the Centre at Montanuniversität Leoben, Austria, is giving priority to the topics of sustainability, the global supply of raw materials and raw materials policy.

Aiming to raise awareness of these issues to engineering students, researchers and the wider public, a new learning and knowledge transfer concept with interactive elements was implemented:

The online research and education lecture series “Sustainable Development Approaches in Engineering Research and Education” was held for the first time in winter semester of 2020/2021 and successfully continued in summer semester 2021.

Being freely accessible and using a variety of online tools, on average 70 participants in the first semester and 110 participants in the second semester from more than 20 different countries attended each lecture.

Bringing together eight international institutions, the lectures were weekly showcasing renowned experts who shared their expertise using selected examples in the fields of raw materials, mining, materials sciences, recycling, engineering education and digitalisation.

The online tools and platforms used included: Moodle, Eventbrite, Padlet, Zoom & Zoom Polls, Chat functions, Webex, Wordcloud, Mentimeter, and Youtube.

At the respective text passages, the online lecture series serves as an underpinning and living example of how modern knowledge transfer can function across borders.

Vocational training, continuous education and MOOCs

In general terms, it is important to understand that continuous education is a holistic process that ensures the progressive development of the creative potential of the individual and the all-around enrichment of its intellectual world (Bebnev, 2013).

In order to define lifelong education, it is necessary to quantify three main characteristics: 1) lifelong learning 2) continuing education as adult education; 3) continuing education as a continuing professional education.

At present, when professional activities are increasingly organised in an electronic environment, it is an urgent task finding and introducing online tools into the educational process for coordinating the joint activities of learners, students, researchers, enterprise specialists, and managers at various levels. In the process of joint activities, learners cooperate and unite their efforts, which ultimately leads to the acceleration and facilitation of learning, or the implementation of research, projects or events.

One of the qualitatively new phenomena in the world of education, resulting from the realities of the information society, is the widespread use of massive open online courses (MOOCs). Education experts have ranked the MOOCs among the 30 most promising trends of its development up to 2028.

MOOCs are open and free online courses (José, A., 2021). To get access to them, it is enough to have an Internet connection and speak English at a proper level.

Considering the wide variety of MOOC types, it allows us to say that this direction in e-learning is of interest to society, but at the same time it needs theoretical research to develop a single standardised apparatus. To date, there is also no agreed definition of how to interpret the concept of MOOC components, which are mass, openness, online.

To address the application of the above considerations of MOOCs, the following interpretation could be offered:

1. Availability:

Previously, for learning to take place, both learners and teachers had to be physically present in the same location. With internet technology allowing instant and convenient communication over long distances at the touch of a button, this is no longer the case. How has technology changed learning? In higher education, this has led to the possibility of online education. Some higher education institutions offer only some of their courses online, while others operate entirely online, where the participants in the educational process never meet face to face. In primary and secondary schools, this same technology enables cyberlearning where children can do their jobs from the comfort of their assignments from homes. Online learning has helped overcome geographic barriers that have long prevented many learners from entering specific educational institutions. For example, imagine someone who wants to study a highly specialised programme that is only available at one institution across the country, but cannot attend due to family obligations. Thanks to online education that person has the opportunity to pursue their studies.

Taking a look at our example, the online lecture series was available and accessible to anyone signing up for free on the ticketing website “Eventbrite”. As a result, there was participation from students, industry professionals, researchers and lecturers from

South America (Columbia, Brazil), Africa (Somalia, Ghana), Australia, Asia (Iran, Kirgizstan, Mongolia, Indonesia), Russia and Europe (Spain, Germany, Austria, Albania, Finland, etc.)

2. Flexibility:

The idea of being flexible with the Internet goes hand in hand with accessibility. Online classes have freed students from having to attend school at specific times, which is often impossible due to work or family responsibilities. Instead, course materials are available online, and students are free to study and complete study assignments when their schedule permits. Technology has opened the doors to education for many who would otherwise not be able to attend traditional educational institutions. For example, anyone who works full time will now be able to combine their work with an education. Parents with young children can also find the opportunity to attend school. Children who take sports very seriously and train for hours during the day are now free to adjust their learning to their busy schedules.

As for the online lecture series, those students who signed up within the system of their home university (Montanuniversität Leoben) had access to the recordings of each lecture until the deadline of the submission of the respective homework after the session. Further, the audience was provided with relevant pre-readings to prepare for each session in order get an even deeper understand of the respective topic during the lecture.

3. The variety of types of interaction between students and teachers:

With the development of online educational programmes, the interaction between learners and teachers has undergone a fundamental shift. There are advocate on both sides of this issue: some say that this is a change for the better, while others, for the worse. Perhaps the most useful position is that this change is neither completely negative nor completely positive, but instead has both pros and cons. For instance, since interaction takes place online classroom time is no longer the only opportunity for learners to ask teachers questions and receive information. Instead, they can use e-mail, instant messaging and text messaging to ask their professors questions anytime, rather than waiting for the next lesson when the question is no longer fresh in their minds.

4. The emergence of online testing:

Along with online education comes online testing, which is of immense benefit for a variety of reasons. Among these, one main reason is the fact that online testing is impartial and completely fair. If the machine evaluates the test and automatically corrects the incorrect answers, it is impossible to show any signs of bias. In addition, online testing can be a great solution for those who suffer from anxiety disorder and are stressed by taking tests in a room with a group of other people. Further, it is better for those on a busy schedule who may find it difficult to get to the testing centre at certain times.

However, online testing is not without its drawbacks. In particular, it is only effective for multiple-choice tests and not for essays or short answer questions. Students can still take the online essay-based tests, but they will have to be assessed by a human examiner.

Taking our example of the online lecture series, the organisers decided that the weekly homework had to be submitted online, but had to be assessed by one of the employees of the centre. This makes the evaluation process time consuming, since it is equal to paper-based testing.
Nevertheless, for the next online lectures, starting in October 2021, it is planned to offer one final exam based on multiple-choice questions.

5. Meeting the needs of students with disabilities:

In the past, the rigorous structure of the classroom defined the academic world. Each learner had the same experience, regardless of their different needs or abilities. While some students were able to function well in this environment, others had unmet needs. Technology is increasing the ability of educational institutions to meet the needs of all types of learners. Now students with hearing, speech or vision impairments, or those who are mostly home-bound, can still receive a quality education. Regardless of what it might be, technological advances can also meet the needs of learners with intellectual, social or developmental disabilities. Technology affects education for the better, improving our ability to create learning environments that work for everyone.

6. Online availability of training materials:

Previously, training took place exclusively in the classroom. The educational tools were either textbooks or officially released videos. One of the ways the Internet has also changed education, is the opportunity to share their knowledge with the world by publishing an educational blog, an e-book or a video on YouTube. This is a huge advantage, making it easier for anyone to learn. Imagine you are planning a trip to Spain and want to get basic knowledge of spoken Spanish. You no longer need to sign up for classes at your local university or even visit your local library to check out a stack of overflowing textbooks. Now all you have to do is open your laptop or phone and find a free app to teach you.

7. Interactivity:

Traditional educational models are based on the idea of passivity, where learners are passive listeners to teachers. However, this concept leaves little room for interactivity and student engagement. In contrast, modern online learning settings have the advantage of being more interactive. Students can connect directly with interactive models, videos and games, navigate through websites, search for information on the internet, etc.

For example, imagine the difference between trying to memorise a list of all the countries in the world from a book and an interactive tool that asked you to click on each country, when offered a name. Interactive tools help to create a broader interest in the subjects studied, which leads to interest and the desire to continue learning new material.

Taking our case from the online lecture series, interactivity was between the audience and the speakers, but also between the participants themselves was created with different tools:

One example is the "Padlet" world map where each participant was able to pin their location, share their field of studies/expertise and contact details and also after each session on learning they took away. Then, other participants could come back to the world map and get inspired by the perspectives of the others and also contact to develop joint activities.

Other interactivity tools, among the audience and the speaker, are Zoom polls, Mentimeter and WordCloud. Whereas the first ones are used for opening questions or to check the general understanding of a topic; the latter one allows to depict colourfully the perception of or the associations created about a topic. For instance: "Name 3 issues that you consider sustainability priorities for mining". While the audience types in their replies (eg. Energy consumption, water user, emissions, biodiversity, recovery of metals, etc.) a real time world cloud grow on the screen.

On the one hand, this allows the speaker to directly elaborate on the answers. On the other hand, the audience feels included in the process and therefore paying attention and retaining information is done with ease.

8. Increased ability to keep up with current events:

The most commonly teaching tools a teacher has are textbooks, most of which contain information released at least a year ago due to a lengthy publishing process. This may not have been a problem in the past, but today the world is moving faster than ever thanks to technology. If the only information you have to share with students is several years old, you may also be decades behind. Technology allows educators to keep learners informed not only of current events but also of the latest research and cutting-edge discoveries. By leveraging PowerPoint, YouTube, blogging technology, and the power of a good search engine, educators can help their students better understand the modern world they live in and learn about its secrets.

Considering this aspect in the online lecture series, the audience is provided with the most current information and state of the art discoveries. The speakers were experts in their respective fields being involved in the development of the latest solutions. That said, the information received during the lecture allows to stay up to date, include it in one’s own work or directly create synergies and cooperation. Otherwise it would take months or years until those insights are shared in publicly accessible papers or textbooks and then already be outdated.

9. Adaptability and personalisation:

Educational institutions are increasingly aware of the fact that what helps one student learn may be practically useless to another, and that what makes no sense to one student may be the only thing that makes sense to another. Everyone's brain works differently and everyone has their learning style, but over the years, all of these students have learned from the same textbook. How does technology affect education? They solve problems while leaving room for personalisation. Using modern technologies, students find the right source for themselves to gain new knowledge.

10. Changing the dynamics of learning in the classroom:

With the advent and popularisation of internet technologies the dynamics in classrooms, especially in universities, is changing. If once a professor could be the only source of knowledge, the internet has changed that. All information in the world is available on the internet, and students have the opportunity to obtain information on their own. Because of this, the forms of conducting classes are changing: students are more engaged in independent cognitive activities, studying new concepts and ideas. In the classroom, together with the teacher, they discuss, direct knowledge in the right direction and conclude. In such classes, the teacher is not a lecturer, he acts as a moderator and mentor. The same model applies to online schools, where students learn new material on their own, then share their conclusions on discussion boards and forums, and professors act as moderators. Students can connect with their professors via text or online messages, or they can spend their opening hours in local public places such as libraries and cafes.

11. Advantages of online education:

In addition to the above-mentioned positive aspects of online learning, the following should be added:

Firstly, online learning and online education offers have a low barrier to entry. This means that everyone can be trained in any direction and discipline.

Secondly, it is also the scalability of training, which manifests itself in the ability to conduct classes for a large number of students at low costs.

Thirdly, with online education a wide potential audience can be reached. This means that along with professionals, students and learners who are not yet specialised in a particular field can attend online courses.

Fourthly, the availability of data and tools for the analysis of learning activities is another advantage of online training.

12. Disadvantages of online education:

As with every new development, also the downsides should be considered.

Since books and face-to-face lectures have dominated the intellectual and academic space for so long, many people have felt a little shocked by the sudden inclusion of webinars, video conferencing, video presentations, video lectures, e-books, and podcasts into these spaces.

Limited technical capabilities and slow modems lead to delays in the transmission of sound, video and graphics, although the corresponding technologies are constantly improving.

Due to the lack of confidence in electronic means of communication and training, listeners often want to see the teacher and communicate with him/her "live".

The success of the training depends in part on technical skills in computer management, internet navigation and the ability to cope with technical difficulties.

It is also important to note, that a number of practical skills can only be obtained when performing real (and not virtual) practical and laboratory work.

Additionally, in some cases, for example in rural areas, access to the Internet is still difficult.

It should be borne in mind that the organisation of online training is also associated with challenges. For example, the difficulty of authenticating students, since at the moment it is technically difficult to provide personal access of the course for each student.

In addition, a large amount of development costs is needed at the start, because all the material is created by the course developers themselves, and it is necessary to provide technical equipment for conducting video lessons, etc.

For courses using peer learning technology and collaborative working technology, a certain level of "digital literacy" is required from the learners.

There is also the problem of the heterogeneity of the quality of online courses since different teams of developers work on the creation of training material, which may have different ideas about the learning outcomes.

Discussion

Based on the possibilities of using online courses in additional vocational education (primarily for advanced training), several main aspects of using online courses have been identified.

Firstly, online courses are currently in high demand, and the audience is expanding. In this regard, for online education, it becomes possible to form a new direction for the training of scientific personnel and use of open courses (Sofronova, 2018).

Secondly, the implementation of MOOCs involves the development of all materials for the course by qualified personnel, content taught from specialists in their field, the development of a clear schedule of the educational process and the inclusion of course assignments and an assessment procedure. Further, anyone can enroll and take the course.

Thirdly, it should be noted that online learning is not a complete substitute for or competitor to traditional training and education. After all, online learning complements the traditional model and makes learning more informative and effective.

Fourthly, the compilation of high-quality content and a well-organised teaching-learning scenario, a properly chosen combination of lectures and practical exercises are able to provide a certain level of knowledge. However, the quality of the acquisition of the material is not only influenced by the content, but also by how it is communicated when solving educational practical problems and situations.
Thus, such courses should be considered within the framework of higher education institutions in the implementation of basic professional educational programmes as a complement and expansion of opportunities for teaching listeners and students.

Fifthly, for higher education institutions, short online courses (16-48 hours) such as the online lecture series “Sustainable Development Approaches in Engineering Research and Education” may be attractive. This is due to the fact that they do not require large expenditures for the development of educational content and the time-consuming work of the specialists (Resta, 2015).

Also the control of quality of courses should be considered. We offer the main criteria for evaluating an online course (requirements): 1) a charismatic lecturer, passionate about the material; 2) high-quality visual design; 3) consistency and self-sufficiency of the course; 4) the ability of the course to engage and retain learners (gamification); 5) scalability; 6) licensed purity (materials were developed by the authors of the course or the authors have given their consent to the use of these materials).

Conclusion

The concept and features of the use of online courses in additional professional and vocational education, as well as the main types and principles of their organisation were examined. The finding found that online courses are mainly used for additional education because these courses have several advantages that allow not spending a lot of time and resources on training. In traditional teaching, online courses are used as a tool to relieve the burden of face-to-face classes in those disciplines where the focus is on practice. In addition to the advantages, disadvantages were also identified that make online courses challenging to deliver and organize.

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247 - Low cost method of industrial symbiotic network on large amounts of residual materials

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Abstract

Industrial symbiotic networks for the exchange of residual materials within a regional economic community have been set up. High-perceived costs of organizations that coordinate industrial symbiotic networks could be a barrier for funding by e.g. governments. Therefore, a low cost method of an industrial symbiotic network was tested and compared to three programs that coordinate an industrial symbiotic network (NPSI, SILVER and FISCH). The low cost network was tested by inviting companies to meetings, find matches between companies to exchange a residual material, and interview the attendees. This method was compared to the three programs by interviewing the managers and/or project leaders. The low cost method was compared to the three programs. In the two years the method was tested the personnel input was a 0,07 to 0,11 full-time-employee equivalent (fte), compared to other programs which took at least 2 fte. The low cost method had reached 55 companies. Attending companies found barriers in exchanging residual materials in strict governmental regulation on waste and involvement of waste firms. This corresponds with the findings in the three programs and literature. The method tested in this research shows the absolute minimum to start a group of companies exchanging residual materials three aspects are required: a trusted coordinating body, recruitment of attendees, and basic knowledge on materials in order to match these. Governments can support such a coordinating body by flexible regulation in waste management and by services that map material flows in industrial areas.

Keywords: Industrial Symbiosis, Network Coordination, Waste Exchange Platform

Introduction

The exchange of materials in a regional economic community can be stimulated or facilitated between normally unrelated companies. An example of a facilitation brokerage program of industrial symbiosis opportunities is the National Industrial

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179 Monitoring Sustainable Public Procurement Behaviour – Demand-side Analysis of public tenders in Switzerland

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Abstract

Sustainable procurement requires organizations to align their purchasing behaviour with regard to broader goals linked to resource efficiency, climate change mitigation, social responsibility and other sustainability criteria. As for public procurement activities this means to detect sustainability criteria covered in the awarding stage of a public tender. The main reasons that hinder the inclusion of sustainability in awarding criteria vary from inflexible procedures and attitudes as barriers for innovative approaches, to missing market intelligence about sustainable products. To overcome such obstacles an in-depth-analysis is performed that assesses all procurement sector activities and further monitors sustainable procurement practices within a sector. In a next step, a performance reporting on the level of public authorities is proposed, e.g. to reach targeted ambition level for own procurement strategies or report progress of national sustainable development through public procurement. Doing so, hot-spot supply chain analysis is used to evaluate ecological and social sustainability criteria within a procurement sector as well as to identify corresponding hot spots. For this study the overall sustainability performance is monitored for Swiss public procurement actives in ICT, Construction, Road Transport, Food and Catering as well as for the procurement of Textiles. To this end, more than 102’000 tender data sets are retrieved from the Swiss national procurement platform simap.ch and screened for sustainability criteria using the Common Procurement Vocabulary (CPV) nomenclature to identify relevant procurement projects within a sector. The results reveal to which extent such public tenders include sustainability criteria. Thus, it is possible to monitor procurement behaviour, by identifying market-available sustainability standards and labels, best-practice as well as innovative procurement approaches. This is done by screening tender criteria such as selection criteria (SC), technical specifications (TS) and award criteria (AC). Moreover, it becomes possible to measure sustainability using the MEAT approach, a framework that provides substantial inputs to incorporate sustainability issues for decision-making based on the best price-quality ratio principle. The examination of sustainability performance for public agencies on federal, cantonal or municipal level shows huge differences. This is because as federal agencies usually

procure large volumes managed by professional procurement teams. In contrast, municipal procurement offices tend to issue tenders with fewer employees with less know-how regarding sustainability. So, most ambitious and innovative approaches are found by federal and cantonal agencies. In addition, most ecologically comprehensive approaches were found in the German-speaking part while most comprehensive social approaches were found in the French-speaking part. With these results at hand, best-practice approaches help to overcome the gap on sustainable product knowledge, as the mentioned sustainability measurements provide support with regard to inflexible procedures. Thus, this study provides novel insights on how public agencies from 2010 till June 2021 take sustainability into account when procuring goods or services. As governments spend 12% global GDP to purchase goods and services from the private sector, in Europe even more than 14% GDP, comprehensive sustainable decision-making in public procurement can leapfrog to the urgently needed contributions towards local, regional, national and international sustainability goals.

Keywords: Sustainable Public Procurement, Hot-spot Supply Chain Analysis, EU GPP framework, Most Economically Advantageous Tender (MEAT), Common Procurement Vocabulary (CPV)

Introduction

Promoting more progressive sustainable decision-making in public procurement (UN Environment, 2017) means to identify sustainability challenges throughout all product categories as well as to incorporate those as specifications in day-to-day procurement, such that the sustainability level of procurement activities of public agencies can be monitored (ARE, 2018). As for the purpose of this article, decision-making advice is provided to procurement professionals by an analysis of five of the most important sectors in public procurement (ICT, Construction, Road transport, Food and Catering, and Textiles) (Clement et al., 2016) to investigate to what extent environmental and social sustainability aspects are integrated into public tenders. In addition, also economical concepts and innovative procurement approaches are considered to provide advice for strategic procurement as well as for procurement practice.

International agreements like the UN 2030 Agenda for Sustainable Development encompasses 17 sustainable development goals (SDG) (United Nations General Assembly, 2015a) of which two directly address sustainable procurement. SDG 12 (Ensure sustainable consumption and production patterns) as well as SDG 8 (Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all) explicitly mention the relevance of sustainable procurement activities by the public sector. The need for progress towards Goal 12 was emphasized by data in the report of the Secretary General of the UN (United Nations Economic and Social Council, 2019): worldwide material consumption had reached 92.1 billion tons in 2017, up from 87 billion in 2015 when the goal was formulated, with the rate of extraction accelerating every year since 2000. Without urgent and concerted political action, as e.g. setting up sustainable public procurement strategies, global resource extraction could grow to 190 billion tons by 2060.

Building upon the above intended political actions UN Environment initiated a 10 Year Framework of Programmes on Sustainable Consumption and Production Patterns (10 YFP) in 2015 (United Nations General Assembly, 2015) explicitly addressing sustainable procurement. One of the major goals of 10 YFP aims to foster national action plans. As of today it is recognized that especially European countries are working to embed sustainable procurement within environmental, social, and innovative policies providing some of the best examples of good sustainable public procurement (SPP) practices (UN Environment, 2017). As governments spend 12% global GDP to purchase goods and services from private sector (World Bank, 2020), in Europe even more than 14% GDP (European Commission, 2016a), it becomes obvious that sustainable decision-making in public procurement is key to fulfil local, regional, national and international sustainability goals (United Nations Economic and Social Council, 2019).

State of the Art

Enacting in line with the purpose of 10 YFP, most member states of the European Union (EU) have approved national sustainable public procurement action plans that follow policy recommendations from the European Commission as stated in the global review of SPP by UN Environment (UN Environment, 2017). Mostly those national action plans were built upon the 7th Environment Action Programme (EAP) in 2013 (European Parliament and Council, 2013), further stated in the corresponding EU public procurement directives. Those three new directives 2014/23, 2014/24, and 2014/25 intend to ensure the inclusion of environmental protection, social responsibility, innovation, combating climate change, employment, public health and other social and environmental considerations. Analysing current obstacles, needs and trends implementing the above postulated political actions, scientific literature as also SPP key actors' statements are studied.

Therefore, the scientific works of Sönnichsen and Clement (Sönnichsen and Clement, 2020), Marrucci, Daddi and Iraldo (Marrucci et al., 2019), as well as Cheng, Appolloni, D'Amato and Zhu (Cheng et al., 2018) were examined as well as the statements by UN Environment (UN Environment, 2017), EU Green Public Procurement (European Commission, 2016a), and ICLEI – Local Governments for Sustainability (Clement et al., 2016). In conclusion, it appears that public agencies lack the capabilities to embrace exemplarity and responsibility to enact change towards SPP, despite increased flexibility allowed by national action plans. This results in a reluctant integration of social and environmental criteria of product functionalities in procurement projects, evident on the strategic procurement as well as the procurement practice level.

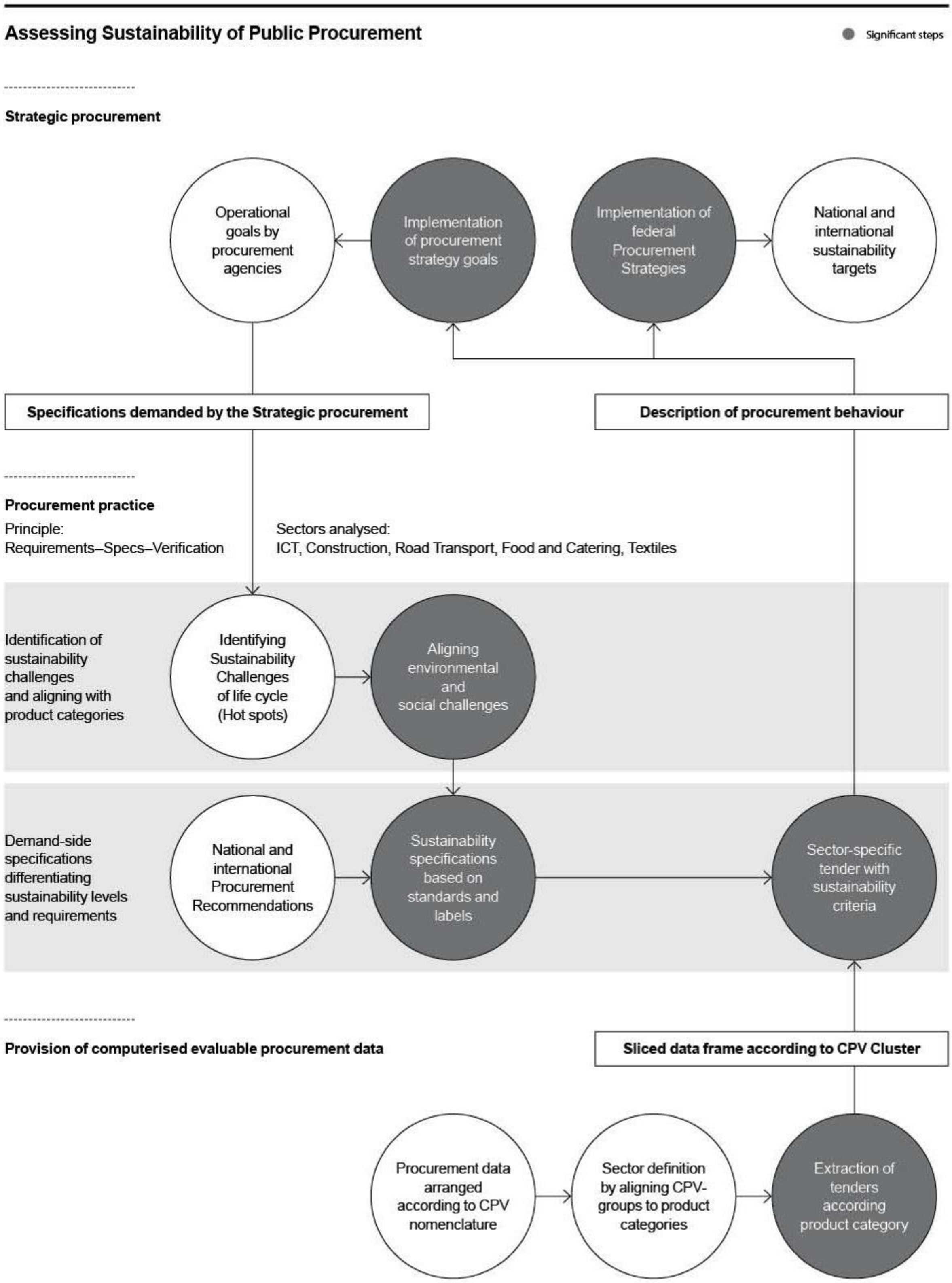

Figure 1. Structure to monitor sustainable public procurement activities.

To enact change that serves pledged national actions plans, like federal procurement strategies or sub-federal procurement strategy goals, it is crucial to recognize the entire product life-cycle and look deeper into the supply chain to consider environmental, ethical and fair business practices. Preconditions to enable SPP are political mandates, a professional procurement team as well as knowledge of the financial efficiency of sustainable alternatives. To encompass the above stated challenges in SPP in the following analysis, Figure 1 presents an analytical approach that enables monitoring sustainable procurement activities at federal, cantonal and municipal level. As such, the approach consists of four steps: provision of computerised evaluable procurement data according to the Common Procurement Vocabulary (CPV), extraction of sector-specific tenders, description of sustainability criteria focussing on ecological and social hot spots, concluding in a sustainability analysis of identified tenders that hold sustainability criteria to determine the sustainable procurement behaviour in the context of sector-specific standards. To ensure the implication of sustainability criteria in procurement activities, the principle: requirements – specifications – verification, is fundamental.

Actions towards Implementation

As the implementation of political action depends on national actions plans, the following analysis is conducted for the conditions in Switzerland, on federal legislative level. Doing so, the Swiss federal administration has adopted the Agenda 2030, which led to the commitment of different roles taken by central and decentralized federal agencies with regard to responsible entrepreneurial behaviour as employer, investor, and procurer (ARE, 2018). Thus the federal administration has accepted the duty of exemplarity and is perceived in this role by cantons and municipalities. The revision of the federal public procurement law in 2019 explicitly requires the integration of sustainability criteria in public procurement. In addition, in 2020 the so-called “Beschaffungsstrategie der Bundesverwaltung 2021-2030” which can be considered as Swiss national action plan on SPP was published. This directive contains specific federal and sub-federal procurement strategies that are fundamental for the policy requirements outlined above. With regard to the implementation of sustainability criteria into day-to-day procurement a guide for procurers (FOEN, 2019) containing 19 procurement sectors for goods and services has been published.

Based on Figure 1, that covers the overall structure monitoring sustainable procurement activities, Figure 2 describes in detail the strategic procurement level and the political actions like federal procurement strategies and sub-federal procurement strategies to foster sustainable procurement activities. Thus, it is essential that the strategic procurement level expresses the particularly demanded requirements to be executed on the procurement practice level. In detail those specifications are designation of sustainable ambition levels, definition of sourcing scenarios, approval of procurement approaches, as well as applicable economic valuation tools.

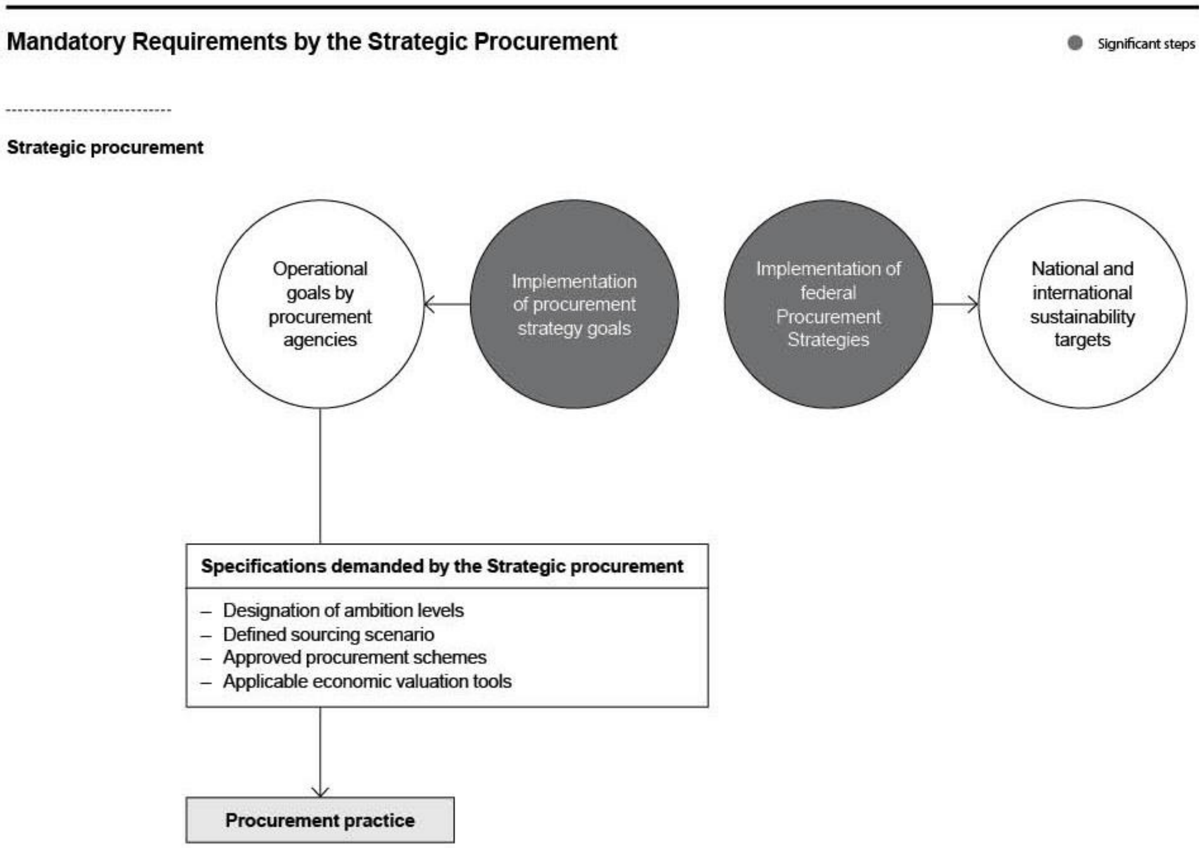

Figure 2. Requirements to be set by the strategic procurement.

Methods

Much research in the field of SPP has been devoted to understand the motivation and determinants driving the adoption of SPP practices, with some research additionally attempting to measure the efficacy of this adoption. Upon closer inspection, this field is dominated by two approaches categorized as "holistic" and "sectoral". In the former case, researchers seek to understand how SPP is generally implemented across public procurement sectors (Fet et al., 2020; Lintukangas, 2016; Rosell, 2021; Zhu, 2013). In the latter case, researchers focus on individual public procurement sectors to better understand specific SPP implementation processes (Ahsan, 2017; Cerutti et al., 2016). In a systematic review of GPP-related research literature published between 2000 and 2016, Cheng et al. seek to identify conceptual gaps in a research field which, according to the authors, has focused mainly on the implementation of GPP as an environmental policy tool without considering in more detail its efficacy and innovativeness in comparison to other such tools. Of the many gaps identified by Cheng et al., one is of special interest with respect to the sustainability analysis developed in this paper. In their discussion, Cheng et al. conclude that the "effectiveness of GPP […] lacks a comprehensive analysis in terms of environmental performance tracking and measurement. This identifies one of the scientific and policy challenges to GPP related research, as the evaluation of the actual performance of green public purchases is crucial to achieve a better understanding of GPP potential in the context of the environmental policies toolbox." (p. 782, emphasis added). In a recently published article, Jolien Grandia and Peter Kruyen (Grandia and Kruyen, 2020) assess the implementation of SPP by using text-mining techniques to analyse over 140'000 Belgian public procurement notices between 2011 and 2016. This approach is "holistic" because it seeks to address how SPP practices are implemented across the entire spectrum of public procurement sectors rather than in specific sectors. It is also innovative in that it employs text-mining techniques rather than self-report measures (e.g. interviews and questionnaires).

Based on the before-hand noted challenges in SPP, and alongside the structure monitoring SPP activities in Figure 1, the focus lies on the procurement practice level where all demand-side recommendations are communicated as specifications to the supply-side or in other words to the market. Text-mining techniques are also used in this analysis with a more comprehensive and structured approach to detect tender with sustainability criteria on sectoral level. This is done by identification of sustainability challenges as well as extraction of demand-side specifications in the tender invitation and the tender award notice. Figure 2 shows the additionally required steps like the specifications demanded by the strategic procurement as well as a prepared data set holding all relevant procurement projects to monitor sustainable procurement activities on sectoral level.

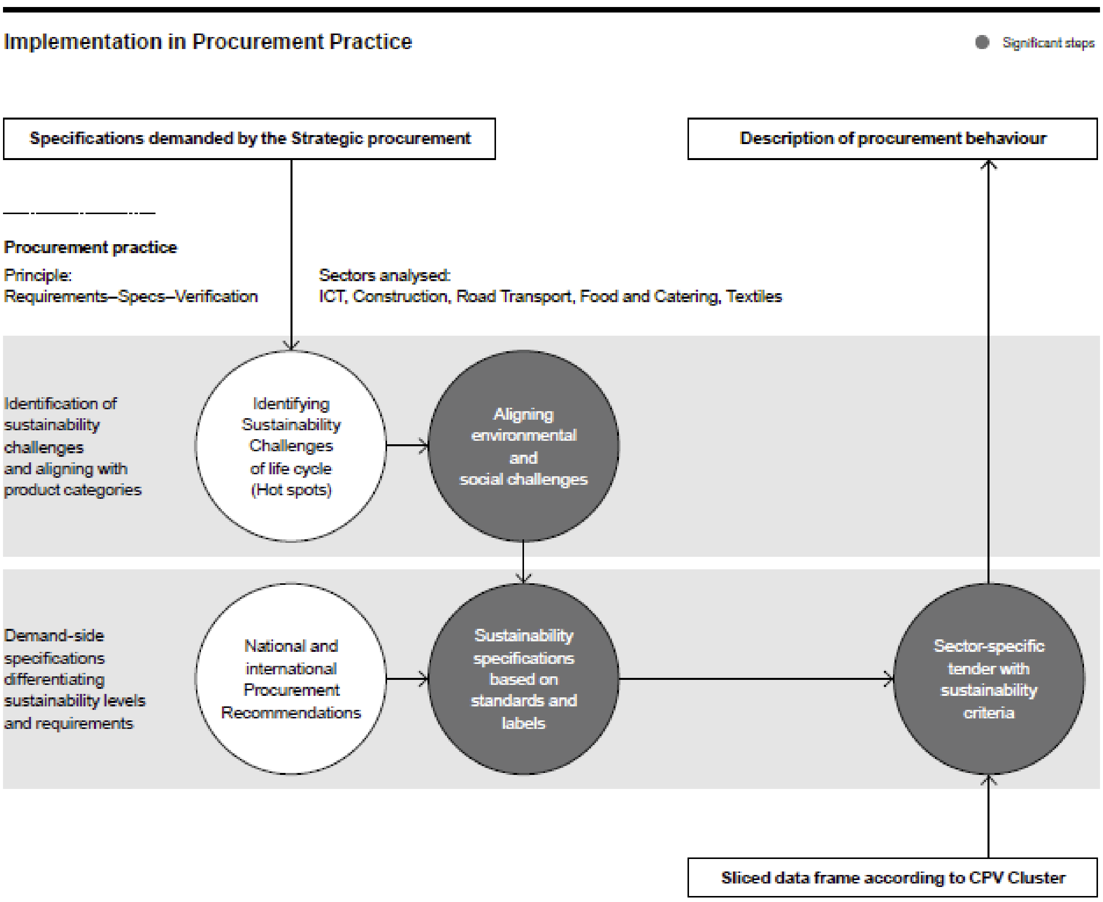

Figure 3. Implementation of sustainability specifications in procurement practice.

From Theory to Procurement Practice

In our research, the lack of performance evaluation is addressed by monitoring sustainability in public procurement adopting the concept of life cycle thinking as formulated in (Stucki et al., 2021). The general idea of this approach relies on the fact that public agencies use the concept of Common Procurement Vocabulary (CPV) (European Commission, 2007) to comprise all kinds of goods and services to describe the subjects of any procurement project. It is therefore essential to incorporate sustainability issues to this given concept using qualitative and quantitative Life Cycle Management methods (Jensen and Remmen, 2006). Thus, it is key to derive ecological and social hot spots using sustainable Hotspot Analysis (FOEN, 2019) along the supply chain on sector level (qualitative approach). Further, these hot spots must be converted into quantitative approaches like the concept of the Most Economically Advantageous Tender (MEAT) (European Commission, 2015) or Life Cycle Costing (LCC) (Estevan and Schaefer, 2017), to be accounted for in public procurement activities. Both steps reveal to which extent sustainability criteria are included in public tenders. This allows to monitor the penetration of sustainability and the applied level of sustainability over time in public agencies on federal, cantonal and municipal level.

In order to assess sustainability at all, it is necessary to describe at first the procurement sector as such. This means to list all processes that rely on the respective product categories to cover the procurement sector as such. For example, starting with the extraction of raw materials and ending with the disposal of materials after usage. For this purpose, the concept of Life Cycle Management (Jensen and Remmen, 2006) (p. 90) is used to clearly define specific product or service life cycles. Such a life cycle includes all processes form cradle to grave, subdivided into three phases of manufacture, use, and disposal, as outlined in Figure 4. This analysis allows to locate environmental and social sustainability challenges within each life cycle phase of a procurement sector. To ensure all such challenges have been identified, the consultation of sector-specific Supply Chain Sustainability Analyses is recommended where available. In the context of Switzerland, sector-specific Supply Chain Sustainability Analyses are carried out and published by the Swiss Federal Office for the Environment (FOEN) in the form of so-called “Relevanzmatrix” (FOEN, 2019). To measure the extent of particular harm it is customary to assess ecological challenges using midpoint impact assessment methods as used in Life Cycle Assessment (LCA), e.g. Global Warming Potential (GWP). Whenever possible the environmental hot spots are assigned to the corresponding midpoint impact category by the ReCiPe2016 assessment method (Huijbregts et al., 2017). Social challenges have to adhere to the core conventions of the International Labour Organization (ILO) and can thus be considered very reliable.

Measuring sustainable consumption behaviour

This section describes a six-step procedure, Figure 4, converting the structure as shown in Figure 3 to assess a procurement sector. In order to foster sustainable decision-making in public procurement (UN Environment, 2017), it is crucial to both identify the sustainability challenges related to each specific product category and to monitor the sustainability performance of public agencies such as contracting authorities or contracting entities.

Discussing explicitly the ability to measure the extent of specific sustainability challenges, is viable to consider the overall market-available sustainable solutions. Thereby it is crucial to identify the most relevant sustainability challenges (Step 1 – alignment of sustainability challenges with life cycle). To do so, the so-called hot spots are introduced to explicitly extricate the urgency to act within a demand type or product category. Sustainability hot spots are those challenges with the most potential for improvement to lever sustainability. Known supply chain sustainability analyses only take into account the life cycle as such, while the concept of EU green public procurement (GPP) distinguishes sustainability challenges on product category level.

Sustainability Assessment of Public Procurement Sectors

Alignment of Sustainability Challenges with Life Cycle (Hot Spots)		
Manufacture	**Use**	**Disposal**

Procurement Guidance and Sustainability Standards		
Description of sector scope	Compulsory directives	Eligible standards

Market-available Sustainability Standards	
Ecological label schemes	Social label schemes

Product Category Identification by CPV-Code
Enumeration of CPV-groups per product category

Sustainability Keywords		
General	Technic-specific	Verification-general
Sector-specific	Product category-specific	Verification-specific

Results	**2010–2013**			**2014–2017**			**2018–2021**		
	federal	cantonal	municipal	federal	cantonal	municipal	federal	cantonal	municipal
Technical Specifications									
Selection Criteria									
MEAT									

Figure 4. Procedure to implement sustainability specifications.

Step 2 – procurement guidance and sustainability standards, describes the overall procurement sector as well as the compulsory sustainability directives binding for a procurement agency and further eligible standards, means guidance schemes, that provide additional criteria to formulate sustainability requirements for a certain procurement project.

As to verify market-available sustainability criteria, step 3 represent relevant ecological and social label. As by now sustainability requirements are clearly defined by public authorities describing the demand-side. Vice versa the supply-side needs to communicate their offered work, goods and services according to these requirements in a transparent and comparable manner. For this purpose, label schemes are well suited. In the context of public procurement, a certain label has to meet at least the stated requirements as defined by the respective procurement agency. Label schemes can even overachieve certain requirements. This can happen on the one hand because public authorities have low expectations on sustainability or the requirements are somewhat outdated.

Product category identification by CPV-Code is performed in step 4. This is done for two reasons, first to use procurement practice terminology and second to gather all product categories that represent a procurement sector. This is an important step, as from now on all call for tender are allocated in a consistent classification system and to gather sufficient information with regard to the demanded sustainability specifications.

In step 5 sustainability keywords are used to extend the work of Grandia and Kruyen by the retrieval of sustainability criteria on sector level or more differentiated “general”, “technique-specific”, “sector-specific”, and “product-specific” criteria. Understanding current sustainability challenges in a sector is key to further describe potential sustainability levels, the basis to define the demand of sustainability obliged by public authorities. As done before, public procurement terminology is used to incorporate sustainability challenges into tender criteria, namely award criteria (AC), selection criteria (SC) as well as technical specifications (TS). Doing so, sustainability is accounted for in tender criteria in the award stage of a call for tender.

Finally, step 6 holds a comprehensive representation of sustainable procurement activities on ecological, social and economic level considering tender criteria and in addition use the so-called MEAT concept (Most Economically Advantageous Tender) (European Commission, 2015) to represent the included aspects such as quality, technical merits and functional characteristics, as well as criteria relating to environmental and/or social issues and operating costs (Parikka-Alhola et al., n.d.). This makes it possible to analyse public tender, as done here, for three different time periods, on federal, cantonal, and municipal procurement level.

Technical Realisation

In Switzerland public procurement tenders are usually published on the Swiss electronic tendering platform simap.ch, established in 2009. In addition, our research centre has developed a unique data platform, IntelliProcure, based on simap.ch for consulting large-scale public procurement notices from 2009 as well as tender documents from 2017 on enabling market intelligence for Swiss public procurement for these time spans. As of July 2021, the data platform IntelliProcure provides access to more than 129'000 tenders, 680'000 documents (2.2 TB), 4'000 public procurement agencies, and 15'000 suppliers. To access the simap.ch data in the sense of this study, all data sets are indexed and transferred to an SQL database. As by this step not all necessary information re retrievable, an additional date conversion is done to identify the tender criteria (AC/TS/SC) for the invitation as well as the award notice. Both of these data sets are further merged to create one data set that provides all information with regard to the invitation notices and an additional data set that holds all award notices. So the fundamental data is provided to do further preliminary preparations.

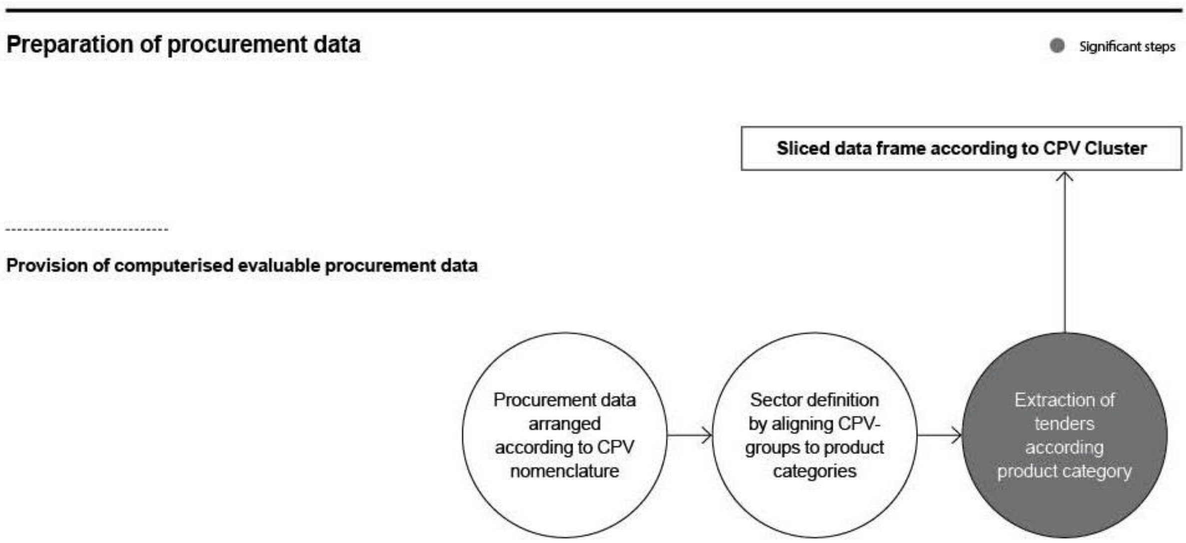

Figure 5. Provision of evaluable procurement data sets.

In order to comprise all kinds of goods and services all tenders are assigned to appropriate product categories. For this classification the Common Procurement Vocabulary (CPV) in its latest version of 2008 (European Commission, 2007) is used. The purpose of CPV is to standardize the terms used by contracting authorities to describe the subjects of contracts. These standard codes promote transparency and also set up an information system for public procurement. The CPV code is structured as an 8-digit number representing a hierarchy of categories. For the purpose of the present analysis the level of CPV-Class (e.g. 30210000 - Data-processing machines and CPV-Category (e.g. 30213000 - Personal computers) is examined. A computerised evaluable procurement data set thus available, to be used for the purpose of examining sustainable public procurement practice as shown in Figure 3.

Results and Discussion

In this chapter five procurement sectors, ICT, Construction, Road Transport, Food and Catering, and Textile are analysed regarding their specific sustainable procurement behaviour. For this purpose, Swiss public procurement data from the period of 2010 till June 2021 is examined. Around 102'000 tender notices are available, of which more than 83'500 are suited for this analysis. As mentioned above, text-mining techniques are used to handle this vast amount of data in order to create a reliable and reproducible result deducted by an automated code analysis. This is done in comparison to an earlier analysis by Welz and Stuermer (Welz and Stuermer, 2020), where only the ICT sector was examined manually for a period of two years, 116 tenders examined. According to the general principle: requirements – specifications – verification, to imply sustainable criteria in public procurement, the strategic procurement level has to specify the preliminary requirements on how sustainability has to be adopted on procurement practice level. It is the challenge for the procurement practice to define certain requirements per product-category respectively procurement sector asking for verification provided by the supply-side. One of the most comprehensive schemes (UN Environment, 2017) that holds sustainability criteria is the EU GPP (European Commission, 2016a) chosen for this study. Complemented by national guidance frameworks form the Netherlands and Austria which turn out to be the most innovative while also providing the latest sustainability knowledge. These three schemes hold the baseline on sustainability criteria retrieved form the following web platforms (European Commission, 2021a), (Pianoo, 2021), (BBG, 2021). To address identified hot spots, valid label schemes as for example for ICT and Textiles that are globally-sourced or Construction and Food and Catering that underlie mostly national directives have to be chosen. The time periods for investigating public tender have been selected based on the following criteria. In 2010 simap.ch was established, in 2014 WTO GPA became effective in Switzerland providing some regulatory options to demand sustainability criteria and EU GPP directives became effective providing first procurement guidance documents. From 2018 on for almost all procurement sectors guidance documents are available by EU GPP. The sustainability level of tender criteria (AC/ SC/ TS) is assessed using ecological and social keywords of unspecific nature (“general” and “technique-specific” keywords) as well as of more specific nature using “sector-specific” and “product-specific” keywords. Overall 415 keywords are identified, the unspecified group holds 90 general keywords and 36 keywords for verification. Considering AC using the MEAT concept to assess tender based on the best price-quality ratio (BPQR) rather than price alone does address a wider range of sustainability issues as performed in the following sector observations. To distinguish substantial sustainability challenges among product categories within a procurement sector the LCA-based approach of the Functional Unit (FU) is used to identify and to treat each of the challenges appropriately.

ICT Sector

In this chapter the ICT sector is monitored regarding its specific sustainable procurement behaviour. First the most relevant sustainability challenges are identified, followed by a general sustainability assessment is performed.

Most relevant Sustainability Challenges per Product Category

Hot spots in a Life Cycle: Manufacture Use

Product Category	Sustainability Scope	Key Sustainability Challenges	
		Ecological	Social
Product lifetime extension (FU 1)			
– Computers – Notebooks – Tablets – Peripheral equipment – Monitors – Smartphones – Fixe line devices	– Extending a product's life at the end of its service life (recircle) – Extended services and warranty – Design for durability, upgradability and reparability – Maximisethe recovery of resources	Fossil resources Global warming Particulate matter Mineral resources	Occupational safety Child labour
Optimisation of energyconsumption (FU 2)			
– Server	– Purchase of energy-efficient models – reduced potential for hazardous emissions upon disposal	Global warming Particulate matter	Occupational safety Child labour

Sources: EU GPP Criteria – Personal Computer, Server, Printer (European Commission 2021, 2020a, 2020b)/ BAFU Relevanzmatrix (FOEN 2019)/ Make ICT Fair (Watt et. al.,2020)

(FU) Functional Unit – Subject matter that defines the overall sustainability aim

Figure 6. Key sustainability challenges – ICT sector.

For the ICT sector two FU have to be served, namely product lifetime extension (FU 1) and optimisation of energy consumption (FU 2), differentiated according to the sustainability scope in Figure 6. The key sustainability challenges in form of ecological hot spots for (FU 1) are located in the manufacture-phase and for (FU 2) in the use-phase. Overall, the social hot spots occur to be the same for all product categories.

As all product categories in the ICT sector are sourced globally, any guidance scheme covering the above mentioned hot spots is eligible to serve the Swiss conditions. For ICT several Swiss directives are effective on the federal level. Investigating keywords that represent sustainability criteria was done by considering the following procurement schemes: EU GPP – Personal Computer (European Commission, 2021b), EU GPP – Server (European Commission, 2020a), EU GPP – Printer (European Commission, 2020b), and Make ICT Fair (Watt et al., 2020). Based on this guidance documents 17 specific keywords and 10 keywords for verification were identified. In result, Figure 7, 95 tenders are identified for the ICT sector. The amount of ecological and social keywords found in TS turns out to be low. The same holds for sustainability in SC. Looking for the composition of the MEAT, it was found that only a few entries on this category are available.

Alignment of Sustainability Challenges with Life Cycle (Hot spots)		
Manufacture		**Use**
Fossil resources (eco) FU 1 Global warming (eco) FU 1 Particulate matter (eco) FU 1	Occupational safety (soc) FU 1+2 Child labour (soc) FU 1+2 Mineral resources (eco) FU 1	Global warming (eco) FU 1 Particulate matter (eco) FU 2

Procurement Guidance and Sustainability Standards		
Description of sector scope	Compulsory directives	Eligible standards
Utilise hardware efficiently/ Analyse and monitor total energy consumption Considered criteria schemes: EU GPP, Pianoo(NL), NaBe(AT)	AGB Bund (soc) EC P025, P026 (eco) TS/AC	EU GPP (eco) TS/AC Make ICT fair (soc) TS/AC

Market-available Sustainability Standards	
Ecological label schemes	Social label schemes
TCO Certified, Blue Angel, Energy Star, Nordic Ecolabel, EPEAT, EU Ecolabel	Responsible Business Alliance, BSCI, Electronics Watch, SA 8000, Fair Labour Association, Responsible Minerals Iniative

Product Category Identification by CPV-Code (Selection)		
Computers, Notebooks, Tablets	Monitors	Smartphone
30212000 Minicomputer hardware 30213000 Personal computers	30231000 Computer screens 38652000 Cinematographic projectors	32252000 GSM telephones 64212000 Mobile-telephone services
Server	Fixed line device	Peripheral equipment
30211000 Mainframe computer 48820000 Servers	32552000 Electrical apparatus 64215000 IP telephone services	30232000 Peripheral equipment

Sustainability Keywords		
General	Technic-specific	Verification-general
environnem*, durable*, sociale*, Nachhaltig*, ecologie*,	Umweltmanagement, Energieeffizienz, Contri- bution de l'entreprise au développement durable	No Hot-Spot: ISO 14001, Eco-entreprise Hot-Spot: --
Sector-specific	Product category-specific	Verification-specific
Total Costs of Ownership, Lifecycle Costing, Green IT	Energy star, power usage effectivenss	No Hot-Spot: ILO Convention Hot Spot: Energy Star

Results	**2010–2013**		**(22 Tender)**	**2014–2017**		**(33 Tender)**	**2018–2021**		**(40 Tender)**
	federal	cantonal	municipal	federal	cantonal	municipal	federal	cantonal	municipal
Technical Specifications									
Ecological	0	0	0	0	3	0	0	2	0
Social	1	0	2	1	0	0	0	0	0
Ecological + social	3	0	0	0	0	0	1	0	0
Hot Spot %	25	0	0	0	0	0	100	0	0
Selection Criteria									
Sustainability – general	0	1	1	1	6	0	6	5	0
Sustainability – specific	0	0	0	0	0	0	4	0	0
MEAT									
Price %	nan	90-100	50-50	nan	50-85	60-60	50-60	25-60	60-70
Sustainability – general %	nan	10-10	nan	35-35	nan	nan	5-5	6-6	nan
Sustainability – specific %	nan	nan	nan	nan	nan	nan	6-6	nan	nan

Figure 7. Sustainability assessment – ICT sector.

Construction Sector

In this chapter the Construction sector is monitored regarding its specific sustainable procurement behaviour. First the most relevant sustainability challenges are identified, followed by a general sustainability assessment.

Most relevant Sustainability Challenges per Product Category

Hot spots in a Life Cycle: Manufacture Use

Product Category	Sustainability Scope	Key Sustainability Challenges	
		Ecological	Social
Minimum energy performance (FU 1)			
– election of the design team and contractors – Detailed design and performance requirements – Completion and handover – Facilities management	– Low or zero carbon energy sources – Building energy management system – Incorporation of the recycled content – Quality of the office environment	Fossil resources Global warming Mineral resources	
Resource efficient construction (FU 2)			
– Strip-out, demolition and site preparation works – Construction of the building/ Major renovation works – Installation of energy systems/ Supply of energy services	– Installation and commissioning of building energy systems – Site waste management plan	Land use/ transformation Terrestrial Acidification Terrestrial ecotoxicity Freshwater eutrophication Human toxicity Water use	

Source: EU GPP Criteria – Office buildings (European Commission 2016b)

(FU) Functional Unit – Subject matter that defines the overall sustainability aim

Figure 8. Key sustainability challenges – Construction sector.

For the Construction sector two FU have to be served, namely minimum energy performance (FU 1) and resource efficient construction (FU 2), differentiated according to the sustainability scope in Figure 8. The key sustainability challenges in form of ecological hot spots for (FU 1) are located in the use-phase as (FU 2) in the manufacture-phase. Overall, no social hot spots are recognized for this sector.

As all product categories in the Construction sector are sourced based on national directives, suited guidance schemes for Swiss conditions have to be identified beside the general guidance for the sector based on EU GPP – Office buildings (European Commission, 2016b). In this case SNBS (CH) (NNBS, 2021) is chosen for national guidance, as this framework represents all essential building label. Based on this guidance documents 12 specific keywords and 34 keywords for verification were identified. In result, Figure 9, 1'020 tenders are identified for the Construction sector. The amount of ecological and social keywords found in TS turns out to be low. The same holds for sustainability in SC. Looking for the composition of the MEAT it was found that only a few entries on this category are available.

Alignment of Sustainability Challenges with Life Cycle (Hot spots)		
Manufacture		**Use**
Land use/ transformation (eco) FU 2 Terrestrial acidification (eco) FU 2 Terrestrial ecotoxicity (eco) FU 2	Freshwater eutrophication (eco) FU 2 Human toxicity (eco) FU 2 Water use (eco) FU 2	Fossil resources (eco) FU 1 Global warming (eco) FU 1 Mineral resources (eco) FU 1

Procurement Guidance and Sustainability Standards		
Description of sector scope	Compulsory directives	Eligible standards
Specifics of adaptive capacity/ Ask tenderer on env. measures (BEMS) Considered criteria schemes: EU GPP, Pianoo(NL), NaBe(AT), SNBS(CH)	AGB Bund (soc) EC	EU GPP (eco) TS/AC KBOB Guide (eco) TS/AC

Market-available Sustainability Standards	
Ecological label schemes	Social label schemes
SNBS, MINERGIE, SIA 112/1, LEED, GEAK, SGNI, BREAM, Gebäudestandard Energiestadt, Natur im Siedlungsraum	Gutes Innenraumklima, WELL, SméO

Product Category Identification by CPV-Code (Selection)		
Selection of the design team and contractors	Construction of the building	Detailed design/performance requirements
71210000 Advisory architectural services 71220000 Architectural design services	45210000 Building construction work 45262690 Refurbishment of run-down	71240000 Engineering services 71311100 Civil engineering support
Facilities management	Completion and handover	Installation of energy systems
71631300 Technical building-inspection 71730000 Industrial inspection services	71247000 Supervision of building work 71315400 Building-inspection services	39715000 Water heaters and heating 65200000 Gas distribution

Sustainability Keywords		
General	Technic-specific	Verification-general
durable*, environnem*, sociale*, Nachhaltig*, ökologi*, oekologi*, Equité sociale	Contribution de l'entreprise au développement	No Hot-Spot: -- Hot-Spot: --
Sector-specific	Product category-specific	Verification-specific
--	--	No Hot-Spot: FSC Hot Spot: Minergie

Results	2010–2013 (459 Tender)			2014–2017 (561 Tender)			2018–2021 (635 Tender)		
	federal	cantonal	municipal	federal	cantonal	municipal	federal	cantonal	municipal
Technical Specifications									
Ecological	2	1	0	2	4	0	0	0	0
Social	7	1	10	5	3	4	3	1	1
Ecological + social	14	0	2	4	0	0	14	0	10
Hot Spot %	0	50	0	0	29	0	6	0	0
Selection Criteria									
Sustainability – general	17	5	4	4	11	27	5	48	33
Sustainability – specific	1	1	0	0	0	1	0	2	2
MEAT									
Price %	30-60	10-100	10-80	30-70	20-100	25-100	10-100	20-100	20-85
Sustainability – general %	5-10	5-10	10-15	10-10	15-15	5-35	7-10	5-30	5-20
Sustainability – specific %	nan	nan	15-15	nan	nan	10-10	nan	30-30	5-5

Figure 9. Sustainability assessment – Construction Sector.

Road Transport Sector

In this chapter the Road transport sector is monitored regarding its specific sustainable procurement behaviour. First the most relevant sustainability challenges are identified, followed by a general sustainability assessment.

Most relevant Sustainability Challenges per Product Category

Hot spots in a Life Cycle: ● Manufacture ● Use

Product Category	Sustainability Scope	Key Sustainability Challenges	
		Ecological	Social
Using vehicles with low environmental impact (FU 1)			
– Passenger cars – Delivery trucks – Lorries – Buses – Coaches – Sweepers – Specialist vehicles – Motorcycles – Bicycles	– Greenhouse gas and air pollutant emissions produced by energy consumption during the use phase – Environmental impacts of batteries of electric vehicles – Noise emissions produced by the vehicle and tyres	Fossil resources Global warming Particulate matter Noise	Occupational safety Freedom of association

Sources: BAFU Relevanzmatrix (FOEN 2019)/ EU GPP Criteria – Road Transport (European Commission, 2019a)

(FU) Functional Unit – Subject matter that defines the overall sustainability aim

Figure 10. Key sustainability challenges – Road Transport sector.

For the Road transport sector one FU has to be served, namely using vehicles with low environmental impact (FU 1) differentiated according to the sustainability scope in Figure 10. The key sustainability challenges in form of ecological hot spots relate to the use-phase, while all social hot spots occur in the manufacture-phase.

As all product categories in the Road transport sector are sourced globally, any guidance scheme covering the above mentioned hot spots is eligible to serve the Swiss conditions. Investigating keywords that represent sustainability criteria was done by considering the following procurement schemes: EU GPP – Road Transport (European Commission, 2019a) as well as the national guidance documents by VCS (CH) (VCS, 2021) as this framework lists the market-available sustainable solutions for several product categories. Based on this guidance documents 43 specific keywords and 16 keywords for verification were identified.

In result, Figure 11, 351 tenders are identified for the Road Transport sector. The amount of ecological and social keywords found in TS turns out to be low. The same holds for sustainability in SC. Looking for the composition of the MEAT it was found that only a few entries on this category are available.

Sustainability Assessment of Public Procurement Sector

Alignment of Sustainability Challenges with Life Cycle (Hot spots)			
Manufacture	**Use**		
Occupational safety (soc) FU 1 Freedom of association (soc) FU 1	Fossil resources (eco) FU 1 Global warming (eco) FU 1	Particulate matter (eco) FU 1 Noise (eco) FU 1	

Procurement Guidance and Sustainability Standards		
Description of sector scope	Compulsory directives	Eligible standards
Consider alternatives/ Select the right cars/ Sustainability as consideration Considered criteria schemes: EU GPP, Pianoo(NL), NaBe(AT), VCS(CH)	AGB Bund (soc) EC VBS Directive (eco) --	EU GPP (eco) TS/AC

Market-available Sustainability Standards	
Ecological label schemes	Social label schemes
Clean Vehicles Directive, Eco-Drive, ECOSTARS, EURO-6	INOBAT, Global Battery Alliance

Product Category Identification by CPV-Code (Selection)		
Passenger cars	Buses	Specialist vehicles
34111000 Estate and saloon cars 34113000 4-wheel-drive vehicles	34121100 Public-service buses 34622300 Trolleybuses	34114100 Emergency vehicles 34144500 Vehicles for refuse and sewage
Delivery trucks	Lorries	Sweepers
34131000 Pick-ups 34136000 Vans	34134000 Flatbed and Tipper trucks 34138000 Road tractor units	34144430 Road-sweeping vehicles 34921100 Road sweepers

Sustainability Keywords		
General	Technic-specific	Verification-general
environnem*, durable*, sociale *, Umweltverträglichkeit, ökologi *, lifecycle	Contribution de l'entreprise au développement durable	No Hot-Spot: -- Hot-Spot: --
Sector-specific	Product category-specific	Verification-specific
--	--	No Hot-Spot: -- Hot Spot: --

Results	2010–2013 (72 Tender)			2014–2017 (114 Tender)			2018–2021 (165 Tender)		
	federal	cantonal	municipal	federal	cantonal	municipal	federal	cantonal	municipal
Technical Specifications									
Ecological	0	7	0	0	0	0	0	6	0
Social	1	0	2	0	0	1	0	0	3
Ecological + social	0	0	0	2	0	0	1	0	0
Hot Spot %	100	0	0	0	0	0	0	0	0
Selection Criteria									
Sustainability – general	0	22	2	0	0	3	0	21	4
Sustainability – specific	0	2	0	0	0	0	0	0	0
MEAT									
Price %	nan	10-100	20-40	50-50	nan	30-80	50-70	25-100	35-70
Sustainability – general %	nan	5-10	35-35	nan	nan	5-15	nan	5-10	5-15
Sustainability – specific %	nan	nan	nan	nan	nan	nan	nan	nan	nan

Figure 11. Sustainability assessment - Road Transport sector.

Food and Catering Sector

In this chapter the Food and Catering sector is monitored regarding its specific sustainable procurement behaviour. First the most relevant sustainability challenges are identified, followed by a general sustainability assessment.

Most relevant Sustainability Challenges per Product Category

Hot spots in a Life Cycle: ● Manufacture ● Use

Product Category	Sustainability Scope	Key Sustainability Challenges	
		Ecological	Social
Consumption of food products with low environmental impact (FU 1)			
– Fish and seafood – Meat, Milk and Cheese, Eggs – Fruit and vegetables, Bread and cereals – Oils and fats – Hot drinks – Cold drinks – Transportation	– Increase offer of plant-based menus – Select organic food products – Prevention of food waste – Select responsible-sourced vegetable fats	Global warming Water use Terrestrial acidification Land use/ transformation Freshwater eutrophication Human toxicity	Occupational safety Freedom of association Gender inequality
Optimisation of energy and resource consumption (FU 2)			
– Operational support – Food storage and preparation – Processing of products – Transportation	– Prevention of food waste and other waste – Reduction of energy and water consumption in kitchen – Use of products and consumables with lower environmental impact	Fossil resources	

Source: BAFU Relevanzmatrix (FOEN 2019)/ EU GPP Criteria – Food and Catering (European Commission, 2019b)

(FU) Functional Unit – Subject matter that defines the overall sustainability aim

Figure 12. Key sustainability challenges – Food and Catering sector.

For the Food and Catering sector two FU have to be served, namely consumption of food products with low environmental impact (FU 1) and optimisation of energy and resource consumption (FU 2), differentiated according to the sustainability scope in Figure 12. The key sustainability challenges in form of ecological hot spots for (FU 1) are located in the manufacture-phase and for (FU 2) in the use-phase. All social hot spots occur in the manufacture-phase.

As all product categories in the Food and Catering sector are sourced based on national directives, suited guidance schemes for Swiss conditions have to be identified beside the general guidance for the sector based on EU GPP – Food and catering (European Commission, 2019b). For this purpose the labelinfo.ch scheme (PUSCH, 2021) is chosen for national guidance, as this framework represents all essential food label. Based on this guidance documents 17 specific keywords and 34 keywords for verification were identified. In result, Figure 13, 60 tenders are identified for the Food and Catering. The amount of ecological and social keywords found in TS turns out to be low. The same holds for sustainability in SC. Looking for the composition of the MEAT it was found that only a few entries on this category are available.

Alignment of Sustainability Challenges with Life Cycle (Hot spots)				
Manufacture			Use	
Global warming (eco) FU 1 Wateruse (eco) FU 1 Terrestrial acidification (eco) FU 1	Land use/transformation (eco) FU 1 Freshwater eutrophication (eco) FU 1 Human toxicity (eco) FU 1	Occupational safety (soc) FU 1 Freedom of association (soc) FU 1 Gender inequality (soc) FU 1	Fossil resources (eco) FU 2	

Procurement Guidance and Sustainability Standards		
Description of sector scope	Compulsory directives	Eligible standards
Survey actual food use/ Fewer animal and more vegetable proteins Considered criteria schemes: EU GPP, Pianoo(NL), NaBe(AT)	AGB Bund (soc) EC	EU GPP (eco) TS/AC FOEN Guide (eco) EC/TS/AC

Market-available Sustainability Standards	
Ecological label schemes	Social label schemes
Knospe Bio Suisse, Natura Beef, fidelio, KAGfreiland, Delinat, EU Bio La-bel, Demeter, Naturland, Bioland, MSC, ASC, Rainforest Aliance Certified	Claro, Fairtrade Max Havelaar, UTZ

Product Category Identification by CPV-Code (Selection)		
Food procurement		
03142500 Eggs 03200000 Cereals, potatoes, vegetables	03300000 Farming, hunting, fishing products 15100000 Animal products and meat	15300000 Fruit, vegetables 15500000 Dairy products
Catering services (CPV-Code alignment not possible)		
– Operational support – Food storage and preparation	– Processing of products – Transportation	

Sustainability Keywords		
General	Technic-specific	Verification-general
ökologi*, Nachhaltig*, environnem *, Equité sociale, sociale *	--	No Hot-Spot: -- Hot-Spot: --
Sector-specific	Product category-specific	Verification-specific
--	--	No Hot-Spot: -- Hot Spot: --

Results	2010–2013		(19 Tender)	2014–2017		(17 Tender)	2018–2021		(24 Tender)
	federal	cantonal	municipal	federal	cantonal	municipal	federal	cantonal	municipal
Technical Specifications									
Ecological	0	0	0	0	0	0	0	0	0
Social	0	0	0	8	0	0	0	0	0
Ecological + social	0	0	0	0	0	0	0	0	0
Hot Spot %	0	0	0	0	0	0	0	0	0
Selection Criteria									
Sustainability – general	2	0	1	0	0	2	16	1	2
Sustainability – specific	0	0	0	0	0	0	0	0	0
MEAT									
Price %	nan	nan	nan	nan	60-60	70-80	nan	40-40	35-35
Sustainability – general %	nan	nan	nan	nan	nan	nan	30-30	30-30	5-5
Sustainability – specific %	nan	nan	nan	nan	nan	nan	nan	nan	nan

Figure 13. Sustainability assessment – Food and Catering sector.

Textile sector

In this chapter the Textile sector is monitored regarding its specific sustainable procurement behaviour. First the most relevant sustainability challenges are identified, followed by a general sustainability assessment.

Most relevant Sustainability Challenges per Product Category

Hot spots in a Life Cycle: ● Manufacture ● Use

Product Category	Sustainability Scope	Key Sustainability Challenges	
		Ecological	Social
Product lifetime extension (FU 1)			
– Uniforms and presentational workwear – Heavy duty workwear and personal protective equipment – Functional outerwear – Towels and bed linen	– Purchase fibres produced using fewer fertilisers, hazardous pesticides and production chemicals – Purchase textiles that contain recycled materials and fibres – Contract services that maintain textiles in order to extend their lifetime – Contract services that minimise the energy used to wash, dry and iron textiles	Fossil resources Global warming Water use Freshwater ecotoxicity Land use/ transformation Freshwater eutrophication	Child abour Forced labour Occupational safety Gender inequality

Sources: BAFU Relevanzmatrix (FOEN 2019), EU GPP Criteria – Textiles (European Commission, 2017)

(FU) Functional Unit – Subject matter that defines the overall sustainability aim

Figure 14. Key sustainability challenges – Textile sector.

For the Textile sector one FU has to be served, namely product lifetime extension (FU 1) differentiated according to the sustainability scope in Figure 14. The key sustainability challenges in form of ecological hot spots for (FU 1) are located in the manufacture-phase with exception of one hot spot that occurs in the use-phase. All social hot spots occur in the manufacture-phase.

As all product categories in the Textile sector are sourced globally, any guidance scheme covering the above mentioned hot spots is eligible to serve the Swiss conditions. Investigating keywords that represent sustainability criteria was done by considering the following procurement schemes: EU GPP – Textiles (European Commission, 2017). Based on this guidance documents 42 specific keywords and 64 keywords for verification were identified.

In result, Figure 15, 62 tenders are identified for the Textile sector. The amount of ecological and social keywords found in TS turns out to be low. The same holds for sustainability in SC. Looking for the composition of the MEAT it was found that only a few entries on this category are available.

Sustainability Assessment of Public Procurement Sector

Alignment of Sustainability Challenges with Life Cycle (Hot spots)				
Manufacture			**Use**	
Fossil resources (eco) FU 1 Global warming (eco) FU 1 Water use (eco) FU 1	Land use/transformation (eco) FU 1 Freshwater eutrophication (eco) FU 1 Child labour (soc) FU 1	Occupational safety (soc) FU 1 Forced labour (soc) FU 1 Gender inequality (soc) FU 1	Freshwater eutrophication(eco) FU 1	

Procurement Guidance and Sustainability Standards		
Description of sector scope	Compulsory directives	Eligible standards
Avoid unnecessary purchasing/ Sustainable design Considered criteria schemes: EU GPP, Pianoo(NL), NaBe(AT)	AGB Bund (soc) EC	EU GPP (eco) TS/AC

Market-available Sustainability Standards	
Ecological label schemes	Social label schemes
GOTS, bioRe, Öko-Tex 100, bluesign, STeP, Blue Angel, ecocert, Cotton made in Africa, demeter	Fair Wear Foundation, Claro, Naturtextil IVN BEST, Maya, Fair Trade, fair for Life, Fairtrade Max Havlaar, SA 8000

Product Category Identification by CPV-Code (Selection)		
Uniforms and presentational workwear	Heavy duty workwearand personal protective equipment	
18110000 Occupational clothing 18400000 Special clothing and accessories	18130000 Special workwear 18143000 Protective gear	18141000 Work gloves 18830000 Protective footwear
Towels and bed linen		Functional outerwear
39512000 Bed linen 39514000 Toilet and kitchen linen	39518000 Hospital linen 39511000 Blankets and travelling rugs	18200000 Outerwear

Sustainability Keywords		
General	Technic-specific	Verification-general
Nachhaltig*, environnem*, sociale*, durable*, ökologi*, Umweltschutz	composante environnementale au développe-ment durable	No Hot-Spot: -- Hot-Spot: --
Sector-specific	Product category-specific	Verification-specific
--	--	No Hot-Spot: -- Hot Spot: --

Results	2010–2013 (10 Tender)			2014–2017 (25 Tender)			2018–2021 (27 Tender)		
	federal	cantonal	municipal	federal	cantonal	municipal	federal	cantonal	municipal
Technical specifications									
Ecological	0	1	0	0	2	0	0	1	0
Social	1	0	0	2	0	1	2	0	0
Ecological + social	1	0	0	5	0	0	4	1	0
Hot Spot %	100	0	0	100	0	0	100	0	0
Selection criteria									
Sustainability – general	0	0	0	0	4	0	1	3	0
Sustainability – specific	0	0	0	0	0	0	0	0	0
MEAT									
Price %	nan	50-50	nan	nan	30-40	45-45	30-80	30-70	50-50
Sustainability – general %	nan	nan	nan	nan	nan	nan	10-10	15-30	nan
Sustainability – specific %	nan	nan	nan	nan	nan	nan	nan	nan	nan

Figure 15. Sustainability assessment – Textile sector.

Discussion on Sustainable Procurement Behaviour

For the purpose of monitoring sustainable procurement activities on sectoral level an assessment approach is defined as shown in Figure 4. This approach includes a sophisticated description on how public tender are structured, for example the CPV structure and tendering criteria (AC/ TS/ SC). Based on the 415 identified sustainability keywords that are used to address un-specific and specific sustainability criteria, the response rate of found tender is astonishingly lower than expected. With the obtained results monitoring a procurement sector using an automated coding procedure is yet not possible. So far, it is at least possible to report a certain increase of found tender for all observed procurement sectors over time. As this analysis was performed by a code-generated procedure, the fundamentally different results will further be compared to the manually performed study by Welz and Stuermer in 2020. A reasonable explanation for the current results is the structure of the data set, as the simap.ch data convention allows a more or less unstructured notice submission. The structure of how invitation and award notices are completed varies substantially. Additional problems occur with regard on how CPV codes are applied by practitioners. Obviously, the identification of more sustainability keywords or characteristic phrases could deliver better results.

Discussion on automated versus manual Analysis

To further evaluate the not yet representative results of the analysis of five procurement sectors the results of the manually performed analysis by Welz and Stuermer 2020 are consulted. As stated in this study the assumption by Welz and Stuermer, that “it should be possible to use the procedure for the sectoral sustainability analysis as defined […] to assess the level of sustainability for other sectors, like buildings, transport and agriculture” cannot be confirmed. As the manually performed analysis retrieves reliable and reproducible results monitoring sustainable procurement activities, these results represent the benchmark for all forthcoming code-based approaches. In total 116 ICT tenders were identified for the period of 2018-2019 for three product categories, of which 17 contain sustainability criteria corresponding to a quota of 15%. Looking at the product groups individually 5 of 61 tenders (8%) for Personal Computers, 10 of 43 (23%) for Server, and 2 of 12 (17%) for Smartphones. Analysing the behaviour of procurement agencies, cantonal authorities used sustainability criteria in 9 of 66 (14%) projects while municipal authorities did so in 6 of 43 (14%). Agencies on central and decentralized federal level appear quantitatively negligible due to the small number of tenders found. So it is mandatory that for all future automated coding procedures at least the results by the manually performed analysis have to be met. If this is the case, monitoring a procurement sector using an automated coding procedure is justified.

Discussion on Procurement Practice

To create a comprehensive excerpt of the sustainability performance of any procurement project, Figure 16 presents an example on how such a summary could look like. Based on the procurement of server in the ICT sector (simap, 2021) it is shown, which parts of the tender notices have to be screened, namely “specific sustainability criteria”, “contracted sustainability”, “economic sustainability criteria” and MEAT. Thus this summary contains at least all necessary categories as suggested in our approach in Figure 4.

Sustainability Assessment of a Public Procurement Tender - ICT

General Characteristics	
Procurement agency:	Bundesamt für Informatik
Project-ID:	203535
Product Category:	ICT - Server
Value:	280.5 Mio. CHF
Sustainable award criteria:	AC / TS / EC
Sustainability level:	comprehensive

MEAT		
	(Sum of award criteria)	100%
Price:		70.0%
Quality:		12.6%
Service:		9.1%
General sustainability:		4.0%
Specific sustainability:		4.3%

Procurement Concept	
Linear:	Product-specific criteria
Make-solution:	Minimum hardware requirement
Specific Sustainability Criteria	
Ecological:	P_{idle} ERF
Social:	…
Contracted Sustainability	
Label:	Energy Star
Characteristics:	P_{idle} E_{FF}active (PUE alternative)
Economic Sustainability Criteria	
Cost structure:	Price / ~~TCO~~ / ~~LCC~~
Contract performance:	~~CPC~~ / ~~LCC~~ / …

Figure 16. Example of procurement tender assessment.

The manually performed analysis of the ICT sector shows that for the Swiss context, most retrieved tenders satisfy many unspecific sustainability criteria but perform low on specific criteria. Most ecologically comprehensive approaches were found in the German-speaking part of Switzerland while most comprehensive social approaches were found in the French-speaking part. Neither comprehensive nor basic sustainability approaches were found in the Italian-speaking part. With regard to the level of know-how of professional procurement teams, federal agencies perform best and municipal agencies worst. Closing this particular pre-procurement performance gap is important in order to achieve substantial progress meeting operational sustainability goals. Apparently some agencies are pioneers with regard to sustainable procurement leading to high numbers of sustainability criteria being satisfied.

Discussion on Strategic Procurement

Based on the findings of the key actors mentioned in the state of the art section, it appears unfortunately not so easy for public agencies to embrace their duties of exemplarity and responsibility to enact change, even despite the existence of national public procurement action plans. The procurement data found by Welz and Stuermer in 2020 confirm this impression. Especially in this case it is crucial to report feedback on the strategic procurement level. The MEAT approach as well as the award criteria and the technical specifications reflect the existence of sustainability criteria in a specific tender. With this insight it becomes possible to enact as promised, as it is possible to report considered environmental and social hot spots, fulfilment of operational and strategic target and the awareness of market-available sustainable solutions, see Figure 17. Further this knowledge allows a profound re-evaluation of procurement strategies with regard to enacting real change.

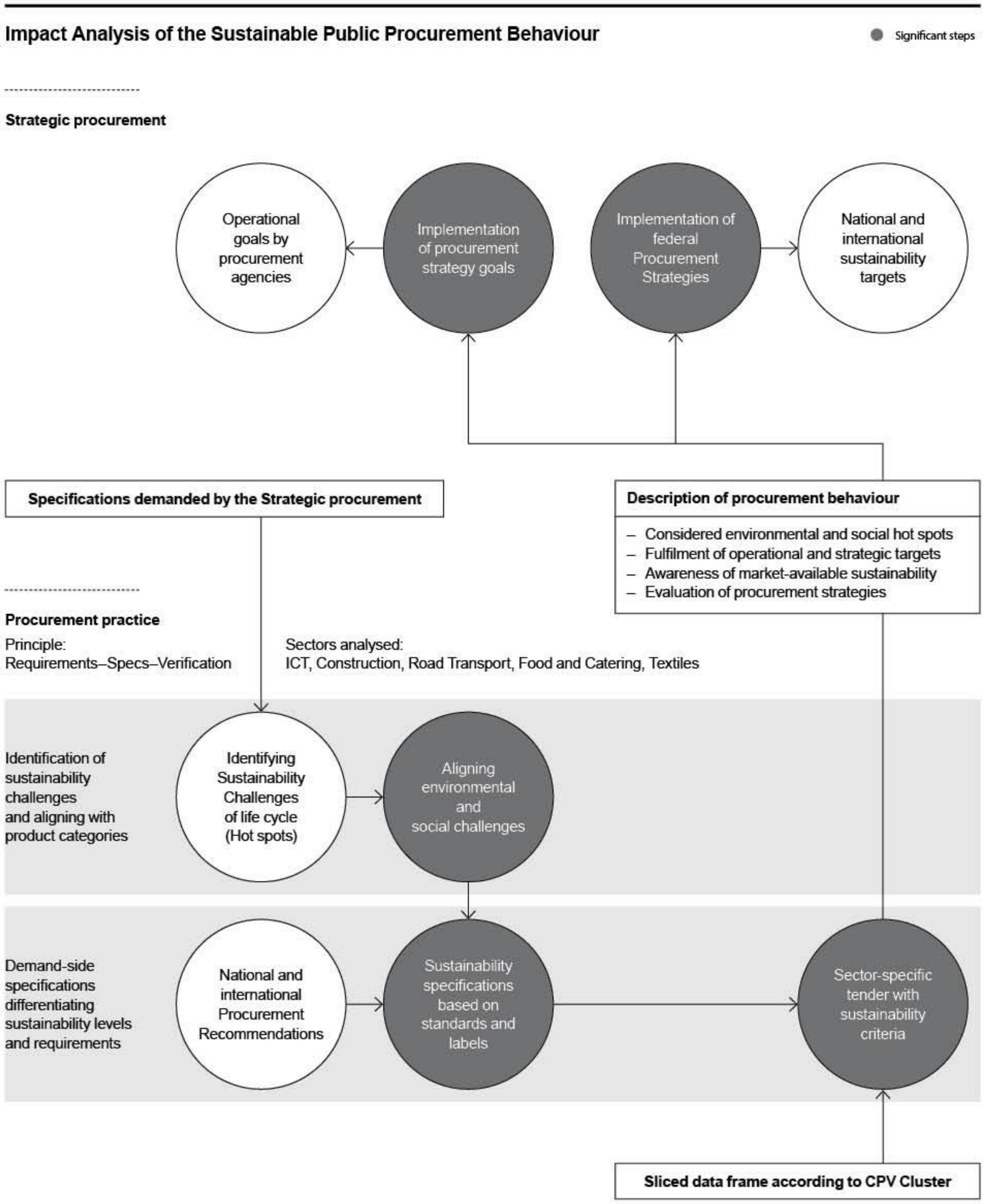

Figure 17. Impact of procurement behaviour.

Conclusions

The particular study-design used to monitor sustainable public procurement behaviour allows retrieving sector-specific tenders from the Swiss national data set for a specified amount of procurement sectors and several types of public procurement authorities. It is thus possible to retrieve tenders with distinguishable “general” and “technic-specific”, “sector-specific”, and “product-specific” properties as well as sustainability criteria (ecological and social). Furthermore, in agreement with national and international sustainability standards a list of keywords is obtained defining sustainability with respect to ICT, construction, road transport, food and catering, and textile tenders encountered in day-to-day procurement. These keywords allow assessing sustainability criteria at the overall sector level, resulting in the level of demanded sustainability in public procurement activities. With the approach at hand, additional classifications such as distinguishing ecological and social challenges and hot spots per product category are possible. Furthermore, additional insights are gained by performing such an analysis as a three step process of firstly describing a sector, secondly crystallising a provisional result as a starting point and thirdly analysing a procurement sector. The results of the intended analysis for the mentioned five procurement sectors show that the used automated coding procedure is not yet reliable enough to monitor sustainable procurement activities for the given data set. Due to this fact, the results of an earlier performed manual analysis are proposed as a minimal benchmark to be achieved by an approved coding procedure in order to be classified as reliable. The assessment approach used in this study shows that technical specifications, award criteria and the MEAT approach are most crucial regarding the overall sustainable tender performance. As observed in the manual performed analysis, most retrieved tenders fulfil general sustainability criteria but perform poorly on specific criteria, in particular meeting international standards. With regard to the level of know-how of professional procurement teams’ federal agencies perform best and municipal agencies worst. This low performance may be explained partly by the need for incorporation of such concepts in the organisations’ sustainable procurement strategy which is usually a rather complex undertaking. Apparently some agencies are pioneers with regard to sustainable procurement leading to high numbers of sustainability criteria being satisfied. The study highlights the need to further overcome several previously identified gaps. Most obviously, a reliable development of the automated code procedure is necessary. This should be accompanied by a newly performed assessment with the data set at hand to monitor the sustainable sector procurement activities reliably. More generally, the need for a holistic sustainability framework is formulated, that explicitly discusses all necessary assessment steps. In addition, this would help to get in the positon to further perform an impact analysis on national level to illustrate how to better imbed SPP on the strategic procurement level. This particular further research is intended to foster the adoption of SPP in day-to-day procurement as well as to consult decision-makers with regard to future calls for tender.

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244 Sharing in a social housing area: a case study in Sweden

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Abstract

In this paper we will explore the potential for sharing between residents, facilitated by a housing company as well as present a guide and stepwise approach for housing companies to start up sharing projects. We have performed a two-year project from 2019-2020 in a residential area in Stockholm, Sweden, called Gröna Solberga, which is an established social housing area with new built areas being produced. The results show that there is a certain interest from residents for sharing which should be analysed in close collaboration with all actors, in order to understand the specific interests from both residents and select and support those in dialogue. A seven step approach has been developed, tailored to the needs of the housing company for implementing and anchoring sharing in the organisation, which can be used to set up projects in new areas or by other housing companies. The findings are useful for housing companies in existing areas as well as new construction, and present suggestions on how housing companies can facilitate sharing via existing groups and channels. Sharing has the potential to facilitate new and old areas to merge, and for different community groups to meet and be a way to strengthen social cohesion in a district. The project also contributes to new models of collaboration between actors in a neighbourhood and how sharing initiatives can be designed and developed, as well as getting a better understanding of what role the social drivers play when businesses share with each other and suggestions on how it can be facilitated and done in interaction with the local community.

Keywords: Sharing cities, reuse, co-ownership, community building, social drivers

Introduction

In previous studies and in the testbeds in Sharing Cities Sweden, we have seen that the social driving forces for sharing are strong both for initiators and for users of sharing initiatives (eg. Bradley 2015, McLaren, D. and Agyeman, J. 2015, Bootsman and Rogers, 2011). Sharing is an ongoing relationship rather than a purchase that is an agreement at one specific moment affects both the driving forces for wanting to share and the conditions for creating sharing opportunities. We have seen that the interest in having access to rather than owning is increasing, however potential rebound effects are also apparent (Skjelvik et al, 2017, Börjesson Riviera, 2014).

Our understanding is that this trend is a result of several factors such as convenience and less responsibility, lack of storage space or the desire for participation and community. We have also observed how sharing can lead to dissolving boundaries between public, private and commercial areas (Heinrich, 2013). We wanted to understand more about how, when and the obstacles and opportunities for sharing. This could mean potential for increased resource sharing and for increased participation and community engagement. Sharing has the potential to go from consumption to the use of shared resources. At the same time, there are several obstacles such as agreements, insurance, laws and practices that are not adapted for sharing but for a change of ownership (Belk, 2014).

The Sharing Communities strategic project is focused on developing sustainability solutions within a housing company located in Stockholm in Sweden. Here, we want to gain a deeper understanding of the social communities around sharing in a relatively small, but representative living area in Stockholm and to develop a model for how housing companies can use the potential for sharing in existing communities to strengthen the connection between existing and new areas. The project studied the following questions:

• What opportunities do existing communities (for example neighbourhoods) provide to enhance sharing?

• How can housing companies facilitate sharing among tenants and offer tools and space for sharing?

Methods

The housing area was built in the 1950’s with 3-storey flats in neighbourhood blocks. There are two local squares, with several empty premises and a larger centre with service by the commuting train station. The housing company’s stock in Solberga are about 1500 households and is close to the average in Stockholm when it comes to demographics. New houses are built as the area is densified and there is an ongoing generational shift. In Solberga in total there are about 12,000 residents which also include villas and complexes from the 1960’s million program. The district is a more exposed area, with lower income, worse health and where crime impact the local community. There is a nature recreation area with a public playground, with organized activities, shared equipment and gardening, an active sports club and an active tenant organisation. Since 2018 there has been a research and demonstration facility, where small businesses and organizations have been testing sustainable solutions to various challenges for the entire housing sector together with tenants.

The project was built up around three phases and involved a variety of actors from the housing company as well as local citizens, that were invited based on their interest which we actively sought in locally organized meetings and gatherings.

Phase 1: Research and prepare

An inventory was made of existing sharing initiatives in the neighborhood, and a dialogue was started up with residents and other actors to prioritize the initiatives.

- Identifying and mapping of what is already being shared, tenants and actors’ needs and interest, possible geographical places for sharing initiatives, possible collaborations, earlier experience in the housing company, other sharing pilots, possible digital tools.

- Previous studies were analyzed concerning customer satisfaction, demographics, impact assessments, urban planning. Dialogue with tenants through a survey, open houses, mailing list, prototyping, events in the area and meetings with existing community groups.

Phase 2: Do and develop

Four sharing areas were explored and developed: share what you have, workshop facility, cultivation and business/organizational space sharing, see Figure 1.

- Possible collaboration with local tenant groups, cultivation group, civil society, companies and the city were explored.

- Prioritizing and prototyping of what could be shared and how at a first stage.

Phase 3: Analysis and guidance

The sharing options were evaluated and a model for how to drive sharing forward was developed for the housing company.

- Analyses of sharing experiences.

- Evaluation of the process.

- Development of sharing model for housing company.

- Embedding results in the housing company.

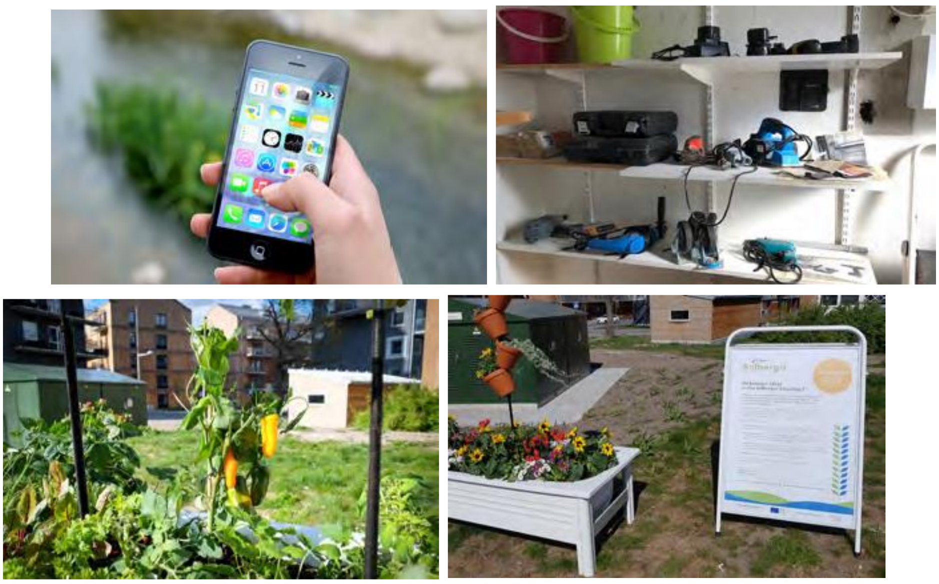

Figure 1. Four areas for sharing were explored: Sharing stuff via an app, sharing a tool workshop, sharing cultivation, sharing spaces.

Results and Discussion

Sharing between residents

In dialogue with the residents and the actors involved, four types of sharing were explored: sharing things you have at home, sharing a workshop facility, sharing cultivation, and sharing spaces.

1. Sharing things you have at home

Facilitate sharing through a platform to share what one has at home.

• For this purpose, a collaboration with an sharing platform provider was started, through an app-based service for sharing locally between private people in a closed group based on area zip codes.

• Dialogue with residents in the Solberga area was sought at various occasions for gaining interest and sharing knowledge into the sharing platform.

• Over 50 users with about 300 items were registered on the platform during the year 2020.

2. Sharing a workshop facility

Facilitate sharing by offering equipment and knowledge.

• The tenants association had a workshop with tools and accompanying space available for wood, textile and metal work which is now more frequently used by members in the association.

• A digital lock system was deemed necessary for smooth exchanges, which was installed by the tenants organization for diminishing the administration around access to the workshop.

• The workshop is now also used for several course moments into crafting, including knowledge sharing and social events.

3. Sharing cultivation

• Both farming in separate small growing boxes, open land farming, and initially indoor cultivation, was sought after by the cultivation group and was established in dialogue with the housing company.

• The interest and commitment have grown during the period, restarted along the way and been supported by the housing company with resources such as pallet collars, soil, seeds, sounding board for organization and support for communication and dissemination.

• An educational series was carried out during the spring and summer within the open land group. It was led by residents and supported by the housing company and the park administration with inspiration, knowledge and skills.

• A seed & cuttings exchange installation is offered through a student project which is aimed for the spring and will start with an announcement board traveling around in entrances of the residential buildings.

• Social events, such as a harvest party, contributed to attracting residents broadly and introducing forms of sharing.

4. Sharing spaces

Facilitate sharing by offering possibilities to share space to organisations whose role is central in the Solberga area.

• Mapping premises – an inventory was made both of all the housing company's premises and also of existing businesses in them to identify who could be interested in shared space or functions. Outdoor spaces and actors present in the area through other property owners of high interest was also identified.

• Prioritised areas/premises/actors where identified through analyzes and a workshop with the project partners.

• Dialogue with potential tenants and civil society where initiated.

• Some collaborations where postponed, investigated for other residential areas or were in the end not realized e.g. collaboration with the Stockholm municipality about a local recycling station including a makerspace, co-working area and bicycle pool, collaboration around laundry tailoring shared furniture's and shared children's outdore leisure equipment. The learnings and insights from the discussions were an important step in the process and where included in the guide for tenants.

• An internal project within the housing company was initiated within the premises department to investigate the possibilities for shared premises, forms of contract and possible development paths and benefits in the long term.

• Within the Tenants' Association, a group has actively conducted a dialogue with the city and the housing company about making a living square. Opportunities have also been investigated here for joint use of premises around the square. The housing company has also had dialogue with two key departments in the municipality around development in the area. During the summer, various pop-up activities were tried out, such as a theatre, studios, indoor gardens and a café on the square. The dialogue about the continued development continues.

Sharing guide for housing companies

Upscaling internally and sharing of insights were sought after at the housing company. In the process of the project and together with the reference group seven steps presented below were identified as well as four levels e of collaboration within those: collaboration with people living in the area, with actors (groups, organisations and business in the area), internally in the housing company and with the city district. The guide is open to all housing companies on how to facilitate sharing of things, mobility, space, knowledge and time among tenants, communities, actors in the area and the city to enhance sustainable lifestyles.

The implementation of the guide is an ongoing process with key functions as area managers, departments of premises and communications and the management looking into how sharing can develop in other residential areas.

Seven steps for sharing in housing companies:

1. Starting an inventory. Residential areas differ in terms of type of residents, type of lay-out, facilities, collaborations, as well as infrastructures. Investigating what already exists and what is needed in an area is important both for sharing solutions to be used and for residents to feel involved and wanting to pursue these further.

2. Setting up sustainability goals. Identifying which sustainability goals the sharing initiatives should contribute to is a way of driving the project in the right direction and asking the right questions all the way. This can be both about set sustainability goals in the company and the municipality to which sharing can contribute and the areas identified in the inventory.

3. Creating dialogue. Creating conditions for dialogue, for example through attendance on site, questionnaires, open house, meetings, workshops or local events and using both formal and informal communication channels. This can be done by building on existing channels, dialogues and organization.

4. Designing for sharing. Based on the inventory and the dialogue there are good conditions for being able to design initiatives and find forms of sharing that respond to real needs. The housing company can facilitate sharing in a number of ways: a digital arena, to share things you have at home, space and function for things you take care of and use together.

5. Supporting engagement and growth. Pay attention to interest and initiatives from residents and local groups, start from commitment and provide the opportunity to grow and organize dynamically.

6. Developing support systems. Identify which key factors would make sharing work in the specific area and see how systems and organization around sharing can be facilitated for example access to areas, equipment or coordination of gardening.

7. Furthering development and independence. For the sharing initiatives to continue to exist, continued growth and independence are needed so that residents and actors in collaboration manage and feel ownership over them. Initiatives that have initially focused on long-term sustainable organizational and business models have been able to become independent.

Conclusions

In this project, the starting point from the beginning has been to develop methods internally and to build relationships in the area that can be ongoing. In the case of Gröna Solberga delar, there has not been an end date for the activities in the area, but merely for the project’s follow-up and conclusions. Earlier initiatives at the housing company, have been project-financed and run by the housing company itself rather than by residents, which is a reason why it was hard to maintain them over time. In one case, Bagarmossen Smartup, it was also run as a project, but from the beginning with the focus on those who wanted to take it further after the project ended and on developing sustainable business models, which proved more successful. Some further important lessons learned were:

Start from community engagement and interests

To base the initiatives on local needs and engagement (in inventory and dialogue, forms of sharing, support systems) helps to build on and scale up existing commitment, create ownership of the initiatives and reduce the risk that initiatives do not meet needs, such as demanding too high IT-maturity in an area with a very high average age, or compete with existing local initiatives with centrally organized ones.

It is important to find the balance between bottom-up and top-down initiatives and to embrace the dynamics between a structured and engagement-driven organization. To pay attention to engagement where it arises and support growth and independence has been a success factor. To build community engagement, a local digital platform could be essential, when compared to a solution at city level. Also, from an environmental perspective a local solution for sharing will limit long transports which has a potential large effect. For the housing company it could be an advantage to gather all communication of the housing company and on local sharing in one solution. For residents it might be seen more as a function between the inhabitants in the area, that they feel co-ownership and responsibility for. An exclusive app for the housing company might also jeopardize collaboration with other housing companies and the gains of strengthening the area.

Offer support for practical challenges and scaling up

Identify which small efforts can provide a large outcome, such as support with code locks, printouts, distribution of information to residents. Agreement- and contract forms as well as insurance solutions are essential for offering and supporting sharing facilities such as spaces, or to gain trust in digital sharing platforms. To have solutions ready can contribute to clearer understandings of responsibility, ownership and financial commitments and make the step to start sharing easier.

Work proactively with gaining trust, to clarify expectations and possible handling of conflicts. If there is a potential conflict of goals among actors, this is important when facilitating the collaboration. Find ways to support groups with different types of organization and access to resources to support a variety of initiatives. Simplify the possibility of stepping in and out of commitment, without requiring long-term responsibility, without taking over responsibility, for example support to complete a cultivation course during a period, or to organize gardens.

Look at different scales

There are several potential benefits to planning and designing sharing capabilities based on different scales of the area:

• Property scale, for example where a smaller project can contribute to the large scale in the form of more efficient use of infrastructure.

• Neighborhood scale, for example by the fact that sharing solutions between more houses / actors can lead to new buildings landing faster on the site.

• District scale, for example by sharing collaboration creates greater opportunities to connect to existing local needs and demand, to involve local actors and create greater conditions for initiatives to be run and taken further locally.

• Urban and regional scale, for example by collaborating on urban development to achieve goals for sustainable development.

Working on several scales is particularly relevant if you want to increase the interaction between areas, for example based on safety. It can also be a way to use spaces more efficiently. It is also relevant to review which scale one works with if the residents' sense of area does not match the administrative divisions. When looking for the right scale for what you want to share to be well used, you may need to change the scale to find sufficient critical mass, for example a bike pool.

Use a system perspective

Have a system perspective when choosing and designing solutions. Can the need be solved in another system? For example, for shared mobility, it is easy to immediately look at the solutions for carpools and bicycle pools you want. Where perhaps increased public transport or joint delivery solutions is an important part of the answer.

Combine multiple forms to create a culture of sharing

Combining forms of sharing, such as sharing things one has at home, sharing common equipment in a makerspace and sharing cultivation, has a greater opportunity to create a habit and culture of sharing, then just one form. Use sharing to create social cohesion Use sharing to create social cohesion between existing and new buildings in a district. Collaboration between property owners, tenant-owner associations and the district on forecasts of what will be needed here in the future and common solutions can strengthen the area. Build on existing collaboration in the district. Address the needs of tenants for the district and include them in the dialogue process.

Be aware of possible social rebound effects

Sharing is a tool for achieving other sustainability goals, such as, resource efficiency, more sustainable lifestyles, reduced carbon footprint, security, community, participation, increased equality, and new business models. However, it is not a given that it is sustainable to share things. Depending on how it is taking place, there is a risk of environmental rebound effects like increased consumption, and increased transports. In the project possible social rebound effects have also been discussed in connection to design of initiatives namely the risk of increased segregation and inequality, that the experience of community is reduced or absent, and reduced responsibility for and maintenance of the common.

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112 What makes smart charging of EV's desirable for the driver?

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At this moment, charging your electric vehicle is common good, however smart charging is still a novelty in the developing phase with many unknowns. A smart charging system monitors, manages and restricts the charging process to optimize energy consumption. The need for, and advantages of smart charging electric vehicles are clear cut from the perspective of the government, energy suppliers and sustainability goals. But what about the advantages and disadvantages for the people who drive electric cars? What opportunities are there to support the goals of the user to make smart charging desirable for them? By means of qualitative Co-design methods the underlying motives of early adaptors for joining a smart charging service were uncovered. This was done by first sensitizing the user about their current and past encounters with smart charging to make them more aware of their everyday experiences. This was followed by another generative method, journey mapping and in-depth interviews to uncover the core values that drove them to participate in a smart charging system. Finally, during two co-design sessions, the participants formed groups in which they were challenged to design the future of smart charging guided by their core values. The three main findings are as follows. Firstly, participants are looking for ways to make their sustainable behaviour visible and measurable for themselves. For example, the money they saved by using the smart charging system was often used as a scoreboard, more than it was about the actual money. Secondly, they were more willing to participate in smart charging and discharging (sending energy from their vehicle back to the grid) if it had a direct positive effect on someone close to them. For example, a retiree stated that he was more than willing to share the energy of his car with a neighbouring family in which both young parents work, making them unable to charge their vehicles at times when renewable energy is available in abundance. The third and last finding is interrelated with this, it is about setting the right example. The early adopters want to show

people close to them that they are making an effort to do the right thing. This is known as the law of proximity and is well illustrated by a participant that bought a second-hand, first-generation Nissan Leaf with a range of just 80km in the summer and even less in winter. It isn't about buying the best or most convenient car but about showing the children that sometimes it takes effort to do the right thing. These results suggest that there are clear opportunities for suppliers of smart EV charging services to make it more desirable for users, with other incentives than the now commonly used method of saving money. The main takeaway is that early adopters have a desire for their sustainable behaviour to be more visible and tangible for themselves and their social environment. The results have been translated into preliminary design proposals in which the law of proximity is applied.

Keywords: Co-Design, Electric Vehicles, Mobility, Smart Charging, User Needs

Project: Smart Solar Charging

Within the project the aim is, using smart charging systems to make the best use of the potential of solar panels and electric cars to capture and distribute energy. Through this innovation, it is possible to store energy in the car and take it out later when needed. This relieves the energy grid, and at the same time develops a smart grid of cars, energy storage and distribution.

In the municipality of Utrecht, there are five experimental areas where the innovation and knowledge in the field of smart solar charging are valorized and further developed. The knowledge concerns the balancing at the area level of energy demand and supply with solar, demand-driven, and bi-directional charging.

This unique 'vehicle2grid' fast charging systems stores a surplus of solar energy in the cars during the day to be able to use it when energy prices are high. This involves innovative technology that enables a sustainable energy system at the neighbourhood level.

Case study: Bi-directional charging

This will be the first time that we as owners of cars, will take energy out of our cars to benefit from it in other ways.
One of the partners within the project developed an app for smart charging towards private-owned e-cars. Through this app, private e-car owners use optimized charging to benefit the most of cost-reduction while charging. As a result, the e-car owners can get a financial payment based on their charging behaviour.

The charging possibility at this moment is one-directional, this means only charging the car. Bi-directional charging is within the application still in development. To explore the obstacles and possibilities of bi-directional charging towards drivers, a co-design process was engaged. How to create a concept to support drivers within the app to apply bi-directional charging.

Methods & Tools

Co-Design & Co-creation

Often projects within smart sustainable mobility have feasibility of viability as an approach. The focus of this research is from the human perspective also known as the desirability principle (IDEO, 2015). The values and incentives for e-car owners are explored through different tools and methods within a co-design process. Co-Design can be used as a tool, mindset or method (Sanders & Stappers, 2008)
Co-creation is a generative tool that can help researchers and designers towards getting better insights. The persons/users who we are designing for, are the "experts of their experience". Thus, we should make use of their knowledge. By supporting the users and use generative tools to help the users express themselves and generate ideas and concepts. Co-design within this project is the whole of the design process in which we used several co-creation methods to create insights. The co-design process is composed of two co-creation sessions, working with the target group on their experiences related to smart charging and electric driving. Before this co-creation session, the participants will receive homework in a form of small assignments related to electric driving and smart charging. During the co-creation session itself, the sensitizers will be involved in the process, using value artefacts, making journey maps, and developing future perspectives and prototypes.
After the co-creation sessions, the data is analyzed, and consists mainly of transcribed video footage, assignments made and notes taken during the sessions. Then this information is processed on a large canvas so that clear insights emerge. Subsequently, these insights are interpreted to visualize initial concept directions. The focus of this paper is on the co-design process, the methods used, the results regarding smart charging and the desires of ev-drivers and the insights.

Sensitizing

To prepare people and get them more involved during the co-creation session, the participants are given tasks before the session. This can be workbooks, assignments, and diaries. It, therefore, supports them to self-document these experiences in their daily lives. The goal of a sensitizer isn't necessarily to gain direct insights for the project but is more focused on preparing the participant for the Co-design session. The intended result is that during the Co-design workshop they are more attentive and remember more of the details and feelings regarding their experiences (van Dam et al., 2020).

Co-creation Session

In co-creation sessions, persons are invited to design their future vision in a visual presentation together. These results can be used as input for researchers and designers to further develop these ideas into concepts or prototypes.

Through various exercises during the co-creation session, individuals are guided to look at the present and the past. Then together they look and create a future. Herein a person can experience his or her dreams.

The Path of Expression is a process in which present, past, and future experiences are explored.

The present and past have already been explored by the sensitizers that were performed before the co-creation session. Through the sensitizers, the person already reflects on their own experiences that have relations to the subject.

During the co-creation session, each person's individual experiences and thoughts are explored in more depth. In addition, each person in the co-creation session will share his or her experiences and thoughts with the rest of the participants. Whereby there is an open and familiar environment in which people can talk to each other about their experiences and their thoughts.

By sharing, one creates an opening to the values and motivations. These values and drives are the first step to thinking and exploring what they experience as a future vision. (Sanders & Stappers, 2012)

"What if…" during a co-creation session.

Visualizing during idea generation promotes creativity and helps to come to a mutual understanding of what different team members mean (van der Lugt, 2002).

To realize a future vision, materials are offered during the session, in the form of craft materials, to let the participants build their vision of the issue in an accessible way. By building it and talking about it with each other, a joint image is created, which can be in the form of a poster but more often in the form of a prototype of a product, service, or system.

The next step is to be able to explain to the other participants and the researchers the rationals of the prototype that is developed. The explanation is often performed through a scenario in which the vision of the prototype is showcased.

Value artefact

One of the challenges during a co-creation session is to make sure everyone's values will be taken into account during the whole session. Participants can lose their core values in the process of co-creation. It is easy to get carried away by a process, an enthusiastic idea, or a more dominant participant. The value artefact helped to ground them and protect the things important to them.

In this case, we developed value cards in the form of a credit card and are meant to be visual and physical reminders of the most important value the individual participants want to guard during the co-creation session. The value cards are personalized and the participants can write their value on them.

Customer Journey map

When creating a product or service it is always part of a bigger picture, a system (Sevaldson & Jones, 2019). A customer journey helps to walk in the user's shoes and see how the solution you're creating fits in their lives. Within the co-design session, we used journey mapping as a sensitizer. To gain more insights into their daily activities regarding driving their e-car and as input during the session to create more in-depth information.

Analysis

The analysis is divided into two parts, the first part focuses on the effects of using Co-design methods with contextually designed facilitation tools in a sustainability project. In the second part we look at the actual insights we gathered for the project by using these methods.

Contextually designed facilitation tools in sustainability projects

The tools and methods used for the Co-design workshop were tailor-made activities catered specifically to the session and its participants (Aguirre et al., 2017). By doing this we can pay careful attention to the situation and mindset of the participants. The goal of this is to gain deeper insights into their experiences and motivation than readymade or templated tools would achieve (Sevaldson, 2010).

Sensitizer

Our observations show three interesting effects. First is the expected; due to the users actively thinking about the subject in the week beforehand they are highly aware of their experiences, down to the small details. This is well demonstrated by the following quote: "And the most important argument that I experienced, and that is often underestimated, is that a traditional car gives an incredible amount of other pollution. The stinking exhaust fumes, the noise, the amount of waste that is created. The spilling of fuel, the leaking of oil. Apart from the CO2, it's just plain dirty."

The second finding is that we noticed a high level of commitment from the participants that we think is related to the reciprocity principle (Chen et al., 2009). Because they received a personalized package, with handmade items that are laser-engraved with their name, the participants realize that we spent time and effort to get good input from them. They sense that their opinion is valued and feel a need to give back to us.

The third effect is that talking about their sensitizers changed the conversation. The participants are all innovators and early adopters of smart charging systems since 3.16% of Dutch passenger vehicles are currently electric (Netherlands Enterprise Agency, 2021). They are often very keen on the technical aspect of their whole electric car system. So, the conversations between them were often about kWh, range, the effect of temperature on the battery, charging speeds, and installing 3-phase charging stations at home. But the positive and negative experiences of the week they recorded on the sensitizer were not about this at all. Suddenly we are talking about gas cars parking on EV charging spots. A young child who is finally able to sleep in the car due to the smooth and silent driving. And conversations at the Tesla Supercharger with a German man who lives in his car. With the sensitizer, we were able to quickly change the mindset of the participants from technological talk to share their actual experiences.

Customer Journey

Our observation is that it is especially useful for finding small details that otherwise go unnoticed, for example, the distance of a charging station from one's location can have a big impact on the way they use it, just like the presence of a neighbour who also uses the same station. The context of the user is important to understand the way they use a system.

Next to that, the customer journey is also a great setup for the upcoming value cards. By digging deeper into their EV journey, the actions, locations, and feelings that go with it, the participants are forced to evaluate habits and practices that they might not otherwise.

Value Cards

We've observed two effects that the value cards had, one on the side of the participant and one for the facilitators. For the participants, it was a reminder of what is most important for them throughout the design process.

From our perspective as facilitators, it helped to promote equal input. When designing in a group there is often a dynamic where a person, idea, or voice has the upper hand. By asking a group to incorporate everyone's value card in the design, the process starts on a more equal foot. And as a facilitator, you can intervene when someone's values are in danger of being undermined, by simply asking; “wherein the design can we find this-and-this value?” This proves especially valuable with the technology-minded participants that tend to think of very technical solutions instead of solutions related to their values.

“What if…”

We provide the teams with a plethora of tools like whiteboards, markers, stickers, kinetic sand, Lego, scrap material, etcetera so they can build their ideas. And by giving the participants a fictional scenario we create an environment where they can think freely without restrictions or feeling hindered by prerequisites of their current situation.

The most important yield here for us is that everything comes together at this point. The participants must take into consideration the context, needs, wants, and problems of all team members which requires them to emphasize with each other and create solutions that work for a broader group of people.

These ideas are not finalized concepts that we can just take and apply in practice. It is about the stories they tell. And where the needs and wishes for the future can be identified and translated into user insights. These insights can then be used as guiding principles in the next phase of the design process.

Results regarding Smart Charging

Starting with their values, for a lot of participants the most important about driving an electric car is related to our future. Four out of eight people in group two mention this on their value card; “To plant a seed (for those around me)…”, “To be part of an innovative future”, “Setting an example for the future” and “Setting the right example”.

If we dive a bit deeper into what future they are talking about and for whom they are setting an example, we see that it is often focussed on those in close social proximity; “We have to do it together (being more sustainable). I try to propagate it in my surroundings as well.”, “And on the other side of the story are the children. I want to still be able to look them straight in the eyes in the future. In any case, I did as much as I could within my means. And I refrained from doing other things. To keep it liveable for you.”, “We want to be able to hand this earth over to our grandchildren. In a normal way without terrible weather conditions, the extremes I’m starting to see.”, “(My child said) daddy, when I grow up, I also want a Tesla. And I liked that. Those children young and old see that car and realize, it is the future, it is good for the environment. I think that's really nice to see."

These underlying motivations and values of the innovators and early adopters are important to be aware of and can be used to guide the design but are not very concrete regarding the day-to-day use of an EV and smart charging system. A notable insight that might offer more direct guidance is that the participants often refer to the optimal use of their electric vehicle as a game or puzzle; "I think the energy transition is also the most beautiful thing, the most beautiful thing to solve, it is a fantastic puzzle.", "Yes, the whole puzzle, I find that fascinating...", "That is a puzzle that you can solve." Next to that, there is a lot of appreciation for the silent and smooth nature of driving electric; "And then when you drive through the beautiful nature, being the only one not emitting anything. I find that fantastic, about the driving.", "What I also find very important is the environmental aspect, but also, of course, very comfortable travelling. Um, and I think the peace and quiet are also very important." Another noteworthy observation is that for several participants the electric car also feels like compensation for other behaviour like, for example, flying; "To compensate a bit for the frequent flying I do for my job."

Figure 1. A participant talking about the beauty of solving the EV puzzle can be seen in the upper left corner of the customer journey.

The ‘What if…” tool where the participants explore possible future scenarios, helps us see what kind of solutions the participants would come up with. The first scenario is “What if the costs for charging your vehicle at the times you currently charge becoming five times as high?” This scenario is related to the need for peak shaving (Reihani et al., 2016). Here we see smart neighbourhood-based solutions with two main facets. First is a smart aspect that looks at the needs, desires, and agenda of the users and distributes energy from sustainable sources accordingly. There is also talk about offering alternative ways to travel if there is less sustainable energy available than the users want. Perhaps the system can suggest carpooling solutions or offer discounts for someone taking public transport, maybe compensate someone for choosing not to travel and work from home.

The neighbourhood part is based upon an understanding of the needs of those around us and a goodwill factor that is lacking among strangers. By not making energy a larger-than-life thing where your individual choices don’t seem to have a direct effect. Make the power grid small and tangible. A retiree for example stated that he was “more than willing to share the energy of his car with a neighbouring family in which both young parents work, making them unable to charge their vehicles at times when renewable energy is available in abundance.” This insight ties in well with the earlier observation that for a lot of people driving electric and participating in a smart charging system directly relates to setting a good example for those close to them.

Figure 2. Showcase: A smart neighbourhood based solution designed by the participants with a central bank collecting and distributing sustainable energy fairly.

Discussion

Experimental tools

The research group Co-Design, which we are part of, explores generative tools that contribute to the design capability of professionals (University of Applied Sciences Utrecht, n.d.). This means that some of the tools used in this research are experimental and have been tested with a small sample size and haven't been peer-reviewed. The Value cards are an example of this. We see great potential in providing participants with a physical object containing their previously stated core values, which carries over through various phases of a workshop or design process. The intended working mechanism here was mainly the physical aspect which serves as a constant reminder that makes the participants more aware of what their goals are. According to our observation, it also helped to create equality in a group process. But these are still preliminary findings and additional research is needed if we want to solidify the reliability of the results and use this tool for future projects.

Priming of the participants

Our previous experience while working with innovators and early adopters of emerging technologies are that this group is very technology-focused in their conversation. The novelty, innovation, and numbers related to the tech are primary topics among themselves. To find underlying motivations and steer the conversation in that direction we started the Co-design session with an icebreaker asking the participants what their ingredients are for a relaxed Sunday. While this had the intended effect and participants were suddenly talking about family, nature, and leisure, there is a potential issue regarding priming. By having the participants talk about a subject that of course brings up family and nature, we might have increased the perceived importance of these subjects regarding EV's and sustainability. In follow-up research, it would be important to see if the results stay the same when we start with a different icebreaker.

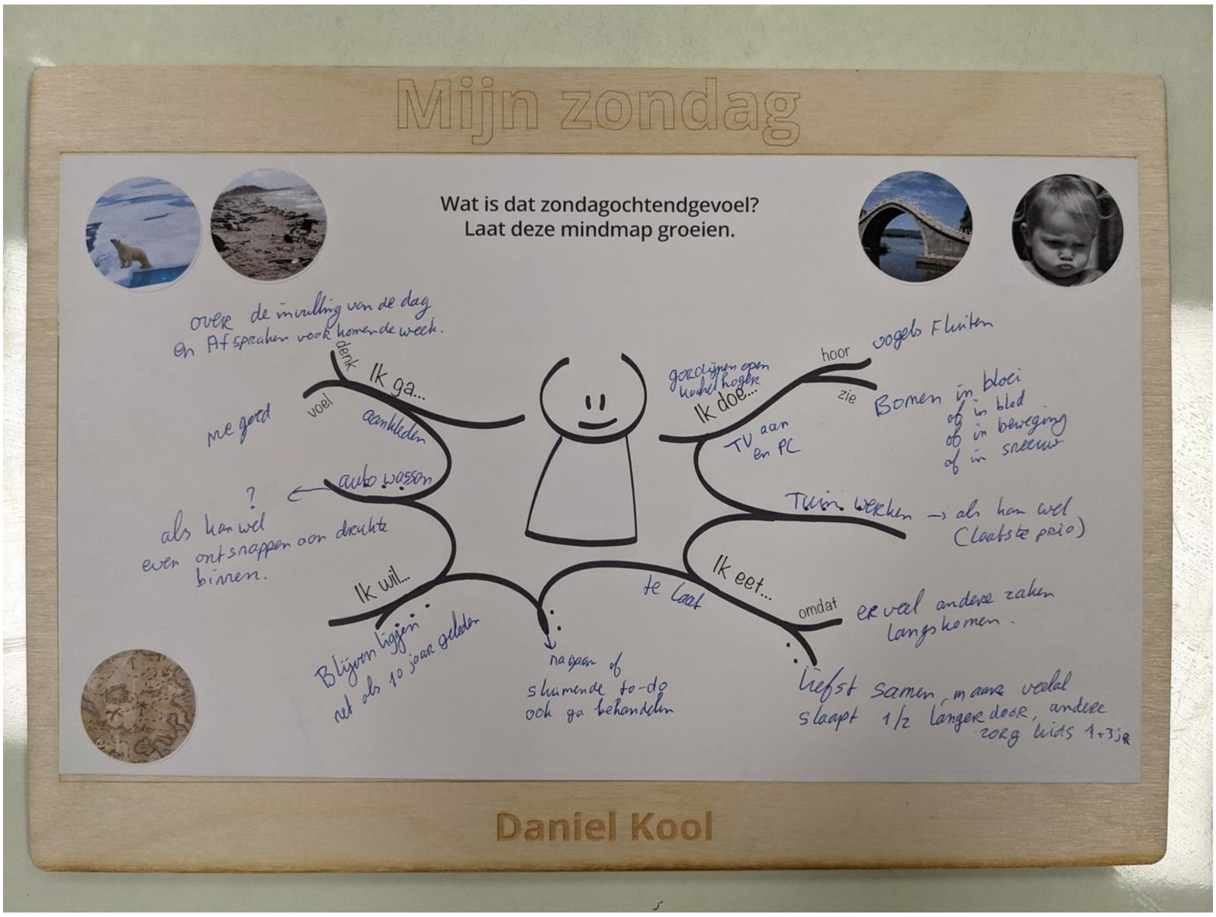

Figure 3. An example of a completed 'Sunday morning feeling' icebreaker.

Innovators and early adopters

This research was conducted in 2019 and the participants are still part of innovators and early adopters of EV vehicles and smart charging. This means that the results of this research don't necessarily carry over to the early and late majority, let alone the laggards. Innovators are eager to try new products and services, to the point where their venturesomeness can become a goal in and of itself. This also means they are willing to take larger risks and aren't deterred by the occasional setback. Due to their high interest they also often have complex technical knowledge. Eventually, when the adaptation of smart charging and EV's outgrows the early adopters and reaches the early majority it becomes important to cross-validate which of the findings carry over to this new demographic.

Conclusions

We have come away with three main findings. First is that the participants are more willing to participate in smart charging and discharging (sending energy from their vehicle back to the grid) if it has a direct positive effect on someone close to them. This offers great possibilities for the design of smart charging systems. Make the energy grid and the effect they have on it tangible for the user.

The second finding is about setting the right example. The early adopters want to show people close to them that they are making an effort to do the right thing. If someone does good, they'd like others to see it. This provides an opportunity for EV car-sharing services, parking places, and charging stations to put sustainability at the forefront and making it highly visible.

Last is that the money users save by adopting a smart charging application is often used as a scoreboard, more than it is about the actual money (the average amount saved monthly by the users of the smart charging app was below €10,-). It's part of a sustainable puzzle the users want to solve for themselves. And scoring better than they did before or better than others do is a great motivator. Designers of smart charging software can focus on this aspect to find new ways of motivating users next to or instead of money.

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