future in process...

EXPLORING SUSTAINABILITY, PARTICIPATION AND THE BUILDING LIFE CYCLE

MASTERTHESIS

Submitted in fulfilment of the
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in the fiels of architectural studies

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Faculty of Architecture

MARTIN RÖCK, BSC

Supervision
Alexander Passer
Ass.Prof. Dipl.-Ing. Dr.techn. MSc
Institute of Technology & Testing of Construction Materials Working Group Sustainability Assessment
Faculty of Civil Engineering

Andreas Lichtblau
Univ.-Prof. Dipl.-Ing. Arch.
Institute of Housing
Faculty of Architecture

Guillaume Habert
Prof. Dr.
Institute of Construction & Infrastructure Management
Department of Civil, Environmental & Geomatic Engineering
ETH Zurich

Graz, October 2016

future in process...

EXPLORING SUSTAINABILITY, PARTICIPATION AND THE BUILDING LIFE CYCLE

STATUTORY DECLARATION

I declare that I have authored this thesis independently, that I have not used other then the declared sources/resources, and that I have explicitly indicated all material which has been quoted either literally or by content from the sources used. The text document uploaded to tu graz online is identical to the present master's thesisi dissertation.

Graz, ...

THERE IS NO EXPLICIT DIFFERENTIATION BETWEEN FEMININE OR MASCULINE FORMULATIONS WITHIN THE TEXTS. GENERALLY, MALES AND FEMALES ARE EQUAL.

content.

EVEN THOUGH IN THE ACTUAL PROCESS OF THIS PROJECT WORK ON THE DIFFERENT ASPECTS DID RUN SIMULTANEOUSLY MOST OF THE TIME, I WILL IN THE FOLLOWING TRY TO SEPARATE THEM INTO CLEAR TOPICS TO GIVE A BETTER OVERVIEW OF THE CONTENT PRESENTED IN THIS THESIS.

abstract.

The architectural thesis presented can be understood as the report of an exploration of sustainability, participation and the building life cycle. Against the background of changing societies and our planet's changing climate, the project presented deals with the various aspects of sustainability, and tries to envision a democratic and sustainable design process ,supported by technology.

To identify the goal and purpose for the project, a participatory design process with a co-housing group in Austria was performed to detect the group's common vision and requirements towards a residential building. Through several workshops these were elaborated and shaped into first conceptual designs. To assess and improve the environmental performance of these concepts and support fact-based design decisions, a variety of scenarios for building materialisation, energy standard and energy supply mix were compared using the method of Life Cycle Assessment (LCA). Working towards the integration of LCA into the architectural design and planning process, a prototypical workflow to combine LCA with the planning method of Building Information Modelling (BIM) was developed. Through the application of visual scripting, essential steps of LCA could be integrated into a BIM workflow and novel methods, of communicating assessment results using the digital building model, could be shown.

I. position & context

LONELY
PLANET EARTH
FLOATING IN
THE DARK
DEPTHS OF
SPACE.

PICTURE
TAKEN BY
NASA'S
APOLLO 8
MISSION ON
DECEMBER
24TH 1968

“One of the great revelations of the age of space exploration is the image of the earth finite and lonely, somehow vulnerable, bearing the entire human species through the oceans of space and time.”

CARL SAGAN

position.

HUMANITY ON PLANET EARTH

As planners and architects, I think it's our collective responsibility to develop high quality spaces and buildings that emphasize construction and technology which enable a bright and healthy future for humanity on our one planet.

I am convinced that the planning processes we choose in the design of our built environment are interdependently connected with our lives together as globally connected society. Transparent and democratic decision-making processes are creating opportunities for participation and stimulate collective awareness and participation.

In the formulation and implementation of these buildings, it is not exclusively an economic question of how much we can afford, it is a social and environmental challenge of our time to find the right balance as well as to develop holistic, sustainable concepts that allow for a peaceful future on a healthy planet earth.

MARTIN RÖCK

BUILT DENSITY

PICTURE
TAKEN BY
ANGELIKA
HINTERBRANDNER
2016

context.

It's hard these days not to be aware of the global problems our species faces. Next to the notion of financial, political and social inequalities and instabilities everywhere, we are facing global challenges unprecedented in human history.

The implications of climate change and the massive loss in biodiversity are deeply questioning the consumerist lifestyles in our capitalist economies as well as the current state of equality and fairness in the societies and on our planet. Not only are many of these problems interdependently linked to each other, they are all caused or supported by human action and may therefore as well be solved by our common effort, one way or another.

On the upcoming pages I will use contemporary media reports and other publically available information to give a bold introduction and insight for the motivation to work on the project and aspects presented in this thesis. After the initial problem statement, I want to take a solution-oriented approach by highlighting recent positive development and the transformational potential inherent in these crises.

I will try to explain why I am convinced architects have a key role in this struggle for improvement, if we take the chance to support the constructive forces of change and use the tools at hand.

“Warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level”

INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, 2016

CLIMATE

“2016 set to be world‘s hottest year on record, says UN“

THE GUARDIAN, 2016

what is...?

TYROLIAN ALPS DURING THE WINTER 2016

AGAIN — NO SNOW

“All three major global surface temperature reconstructions show that earth has warmed since 1880. Most of this warming has occurred since the 1970s, with the 20 warmest years having occurred since 1981 and with all 10 of the warmest years occurring in the past 12 years.

what is...?

Even though the 2000s witnessed a solar output decline resulting in an unusually deep solar minimum in 2007-2009, surface temperatures continue to increase.”

HOW DO WE KNOW? NASA ON CLIMATE CHANGE

„Human activities increasingly influence the Earth's climate and ecosystems. The Earth has entered a new epoch, the Anthropocene, where humans constitute the dominant driver of change to the Earth System."

ROCKSTRÖM ET AL, 2009

what is...?

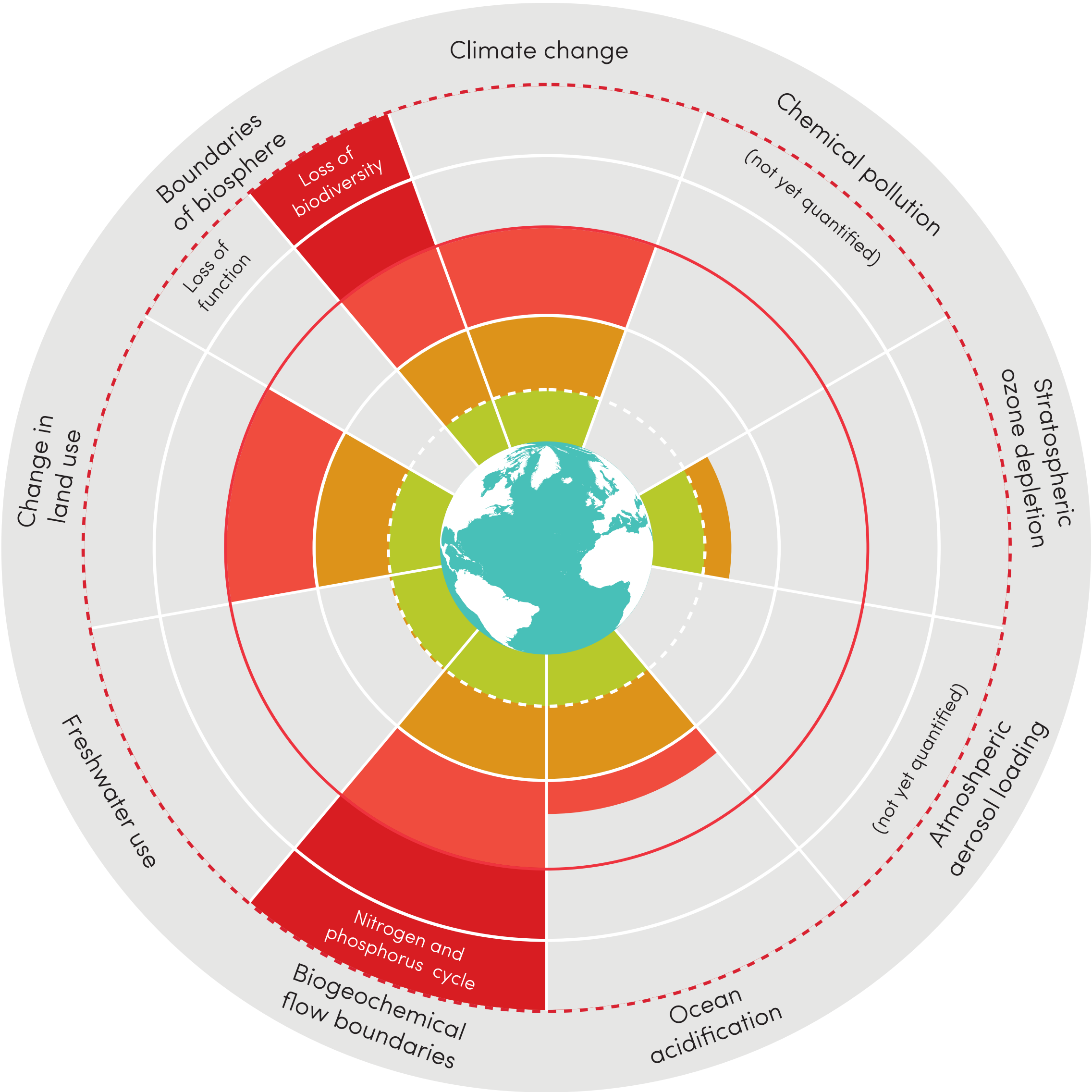


FIGURE ACC. TO ROCKSTRÖM ET AL, 2009

“Five times in the past, the Earth has been struck by these kinds of cataclysmic events, ones so severe and swift (in geological terms) they obliterated most kinds of living things before they ever had a chance to adapt.

WASHINGTON POST, 2015

what is...?

— Now, scientists say, the Earth is on the brink of a sixth such ‘mass extinction event.’ Only this time, the culprit isn’t a massive asteroid impact or volcanic explosions or the inexorable drifting of continents.

It’s us.”

„Earth Overshoot Day, also known as Ecological Debt Day, is the day of the year when human demand for ecological resources exceeds what the planet can replenish annually. Since 1970, it's come earlier and earlier every year – meaning humans are using up natural resources at a faster rate than we used to."

GLOBAL FOOTPRINT NETWORK

what is...?

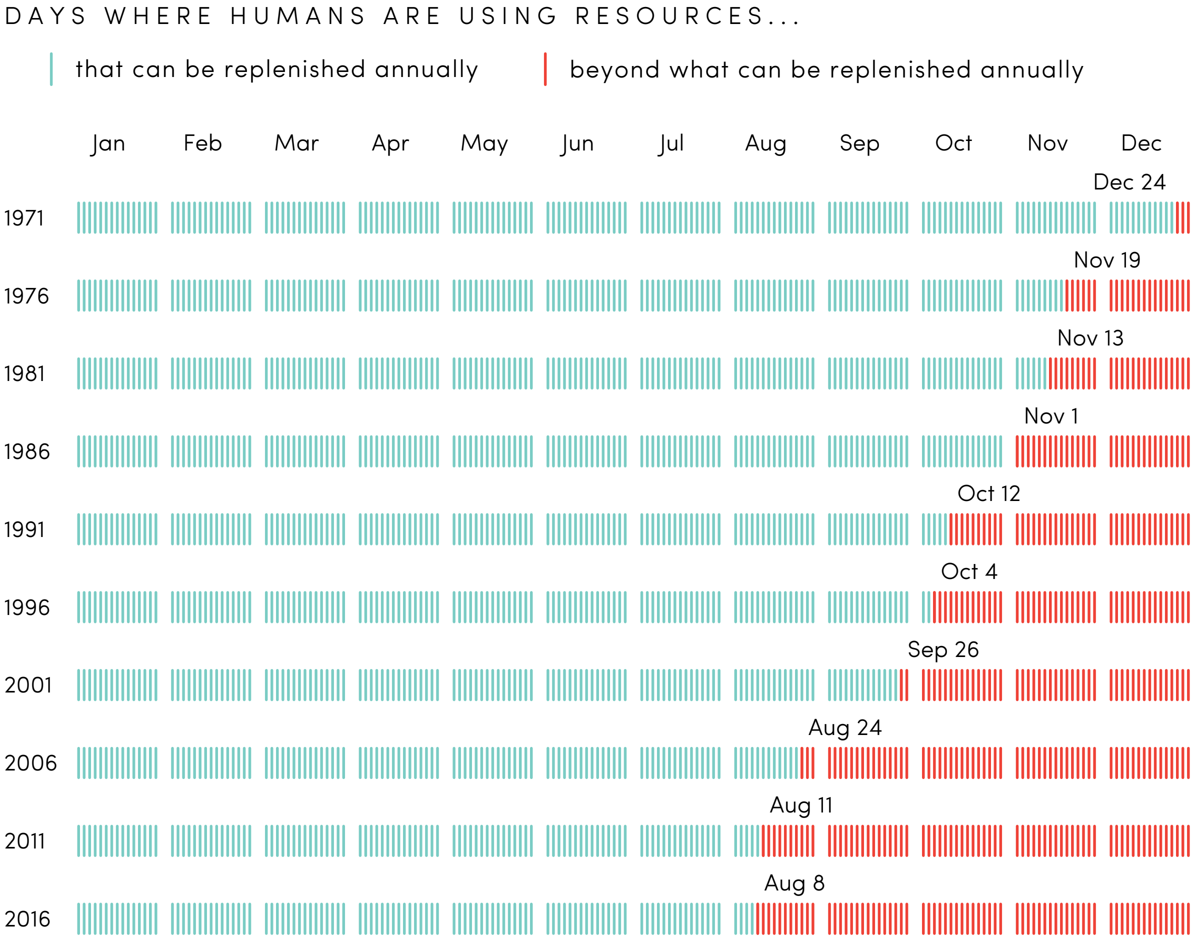
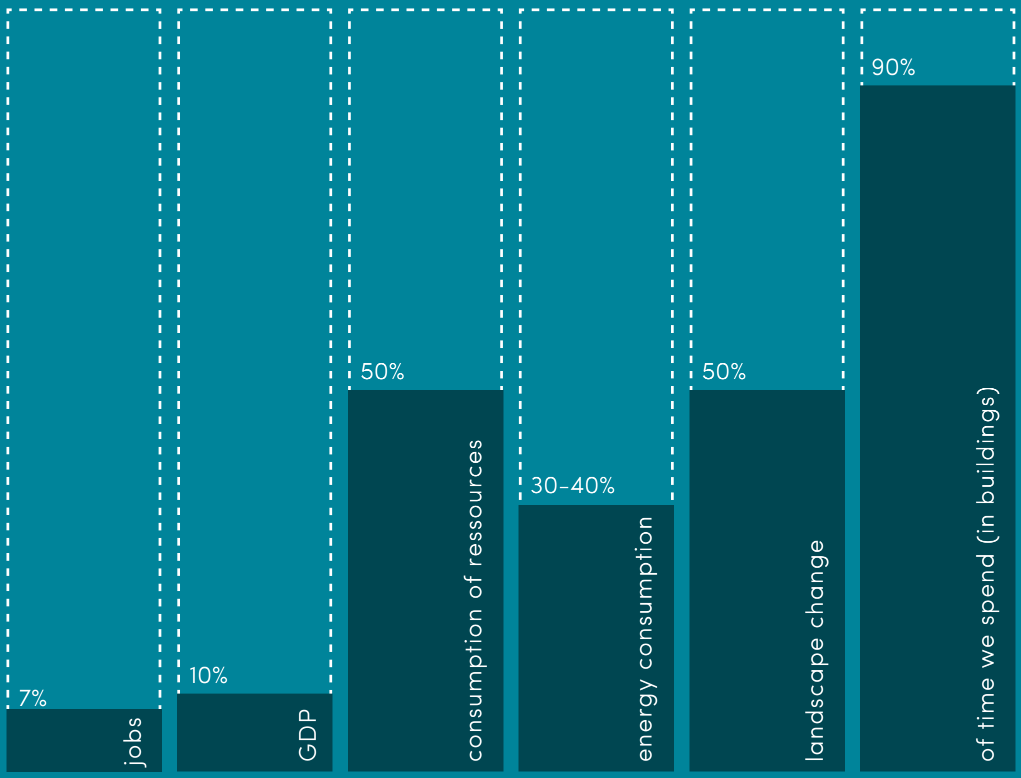


FIGURE ACC. TO WORLD ECONOMIC FORUM, 2016

„It is essential nowadays not only to invest in the design of more energy-efficient buildings but also to pay more attention to the embodied energy of such building concepts. It is necessary to consider the energy required for the manufacture and maintenance of such buildings and, thus, to take into account the full life cycle.“

MARIA BALOUKTSI & THOMAS LÜTZKENDORF, 2016

what is...?



BUILDINGS AND THE CONSTRUCTION SECTOR ARE RELATED TO...

FIGURE ACC. TO UNEP, 2009

“Since 2008, an average of 26.4 million people has been displaced from their homes each year by disasters brought on by natural hazards - equivalent to one person displaced every second.

WHEN
LANDSCAPE
BECOMES
DESERT —

FOREST
FIRES

what is...?

[...] Policy makers are pushing for concerted progress across humanitarian and sustainable development goals, including disaster risk reduction and action on climate change"

IDMC, 2015

"The global inequality crisis is reaching new extremes. The richest 1% now have more wealth than the rest of the world combined. Power and privilege is being used to skew the economic system to increase the gap between the richest and the rest. A global network of tax havens further enables the richest individuals to hide 6.8 trillion euro. The fight against poverty will not be won until the inequality crisis is tackled."

OXFAM, 2016

what is...?

62
Individuals

Have the same wealth as the poorest 3.6 billion people in the world.

$542
Billion

Since 2000, the poorest half of the global population received only 1% of the increase in global wealth.

$1
Trillion

The increase in wealth of the richest 62 individuals since 2010.

1%

The fall in wealth of the poorest 3.6 billion people since 2010.

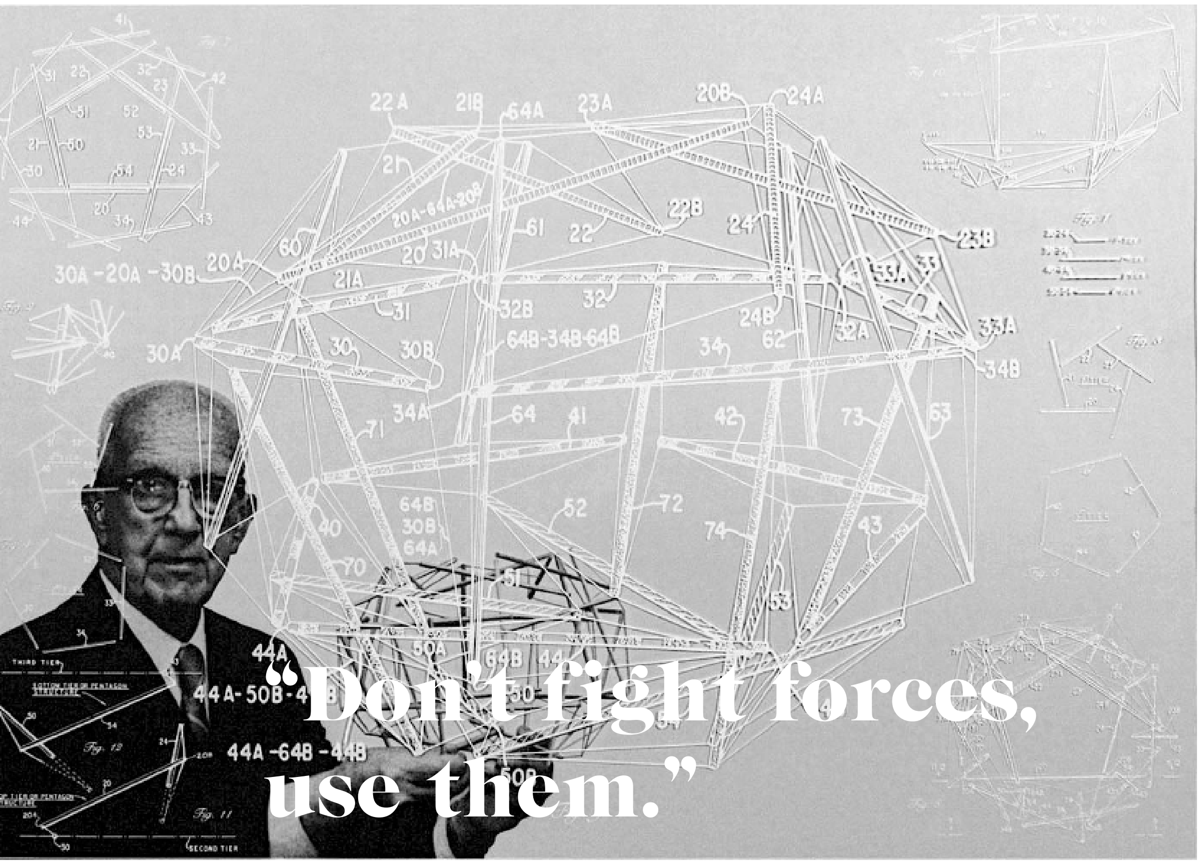
50%

The amount of the global wealth increase since 2000 received by the top 1%.

$3

Rise in the average annual income of the poorest 10% of people on the world.

FIGURE ACC. TO OXFAM, 2016



“Don’t fight forces, use them.”

RICHARD BUCKMINSTER FULLER

architect‘s mind.

ARCHITECT’S MIND

When it comes to tackling the issues and supporting the positive developments mentioned, everyone has its role to play and a chance to contribute to the bigger whole in whatever way they decide. My understanding of the architect mindset, seeking for holistic improvement and aesthetics with the eventual goal of creating livable space and a better society, may therefore not only be applied in a construction context but as a universal paradigm to creatively work towards the better.

Talking about building design and managing space the architect is a key stakeholder and even though himself restricted by numerous requirements of different sorts still in a highly influential position in the process. A lot of the aspects touched on earlier are inherent in the design and planning, the construction and operation processes and can therefore be influenced by the architect. I want to quote Buckminster Fuller to emphasize that it’s us to decide which forces we want to support in our daily practice and we should use the tools at hand to do this the best we can.

#DESIGN #PARTICIPATION #COMMUNITY #SPACE #MATERIAL
#LIGHT #AIR #CONSTRUCTION #HUMANSCALE #ENERGY
#RECYCLING #OPERATION #SOCIETY #EMPOWERMENT
#EQUALITY #FUNCTION #SUSTAINABILITY #TECHNOLOGY
#NATURE #ENVIRONMENT #HUMANITY #SOLIDARITY

II. Chronology & participatory design process

Together in diversity — a participatory design process

project chronology.

On the following pages I set out to explain in brief the chronology of the participatory process that is one of the key aspects and led to the architectural concept and its environmental assessment presented later in this thesis.

CHRONOLOGY

1504

After initially meeting with the group of people interested in creating a co-housing project for the first time in April 2015, we discussed the possibilities of working together on the architectural concept as part of a thesis. I proposed to support a participatory design process - frequently lead by architectural offices specialized in the subject - and started to intensify research on the topic.

1504 — 1507

To increase the understanding for the matter I consulted three different sources representing different stakeholders in a participatory process:

Firstly, I read through a contemporary publication on participation by Susanne Hofmann[1] and the Berlin-based architectural collective Baupiloten[2]. By reviewing her book, I learned about the theory behind their approach towards contemporary creative inclusion of inhabitants and stakeholders in a common participatory design process based on distinguishing the atmospheric qualities of a project and its spaces. I very much liked Hofmann's approach of seeing the users as experienced experts in housing and atmospheres that could contribute their expertise in a face-to-face process with the experts of structure and spaces, the architect.

Secondly, through a friend I got to meet Peter Nageler of nonconform[3], the Vienna based architectural office which is focusing on participation and stakeholder involvement in the initial ideation phase of projects. Nageler gave some interesting insight in their approach of the Ideenwerkstatt, a format of very intense workshops, where in a mediating process they try to involve all interested stakeholders, collect ideas and within only three days try to come up with an intuitive common solution to architectural and spatial challenges of all kinds. We also discussed his experience from accompanying co-housing projects as architects responsible for the building design, having the group independently manage their internal structure.

1 Hofmann, 2014
2 www.baupiloten.com
3 www.nonconform.at

Thirdly, I got in touch with Kumpanei[4], a co-housing community in Graz, who were at the time trying to expand their community for the upcoming planning process for their project in the West of Graz. During our trip to cohousing-project Wohnprojekt Wien[5] in Vienna, we were introduced to their approach of co-housing and got to experience the multiple common spaces and functions which eins:eins architects[6] had managed to include in the project. With the ratio of 20% of common spaces they themselves stated to have reached the reasonable maximum of common spaces in a project like this.

1507

After this initial research I tried to get a better understanding of the co-housing groups intent and goals. We created a list of questions, asking the group members to individually answer simple questions in the context of housing. This helped to form an understanding of individual past experiences, current situations and future requirements.

1508

Summer 2015 came and I started working on the preparation of Wienerberger Sustainable Building Academy[7], a European research project aimed at MSc and PhD students of multiple disciplines, addressing building sustainability on the example of a case study project building 2226 by baumschlager+eberle[8]. The building has no heating or cooling systems and is conditioned by a sophisticated system of automatized natural ventilation controlled by constant indoor air quality measurements. This innovative low-tech approach was also a starting point and exemplary role model in the starting process with the co-housing group.

4 www.cumpane.com
5 www.wohnprojekt.wien
6 www.einszueins.at
7 Further reffered to as WISBA wisba.wienerberger.com
8 www.baumschlager-eberle.com

1509

During the preparation and execution of the WISBA research project my understanding of architecture, buildings and sustainability expanded. Embodied energy in construction materials, energy demand during operation as well as flexibility and adaptability to current and future use scenarios were aspects investigated. Life Cycle Assessment (LCA) and Life Cycle Costing (LCC), Building Energy Simulation and Building Information Modelling (BIM) as well as scenario analysis to check adaptability were the tools which we used to determine the current and future sustainability of the case study project. The life cycle approach applied in the research project proved the same prospective and future-oriented view as stated by the co-housing group.

1509 — GROUP PROCESS

As one of the goals of the project was to create a project that would be commonly owned by the co-housing group or within a cooperative framework, we conducted additional research on alternative ownership models for co-housing projects. The solidary concepts of "new housing communities", as in the existing co-housing community of Wohnprojekt Wien, and also the nationwide cooperation model of Habitat[9] were looked into and discussed in the group. We also got in touch with Gemeinsam-Bauen-Wohnen[10], an Austrian platform for cooperative building and living.

9 habitat.servus.at
10 www.gemeinsam-bauen-wohnen.org

project chronology.

GROUP PROCESS

In order to continue the co-housing group's process, get broader acknowledgement and eventually more people interested in the project we formulated the common vision for the project and advertised in local newspapers and specific co-housing newsletters. Based on the results of previous discussions with the co-housing group and the insights gained through the work on the WISBA research project we established the projects key points: Community and solidarity, conscious living, environment and sustainability, independence and simplicity, pioneer spirit and vision.

PROJEKTGRUPPE

Wohnen etwas anders

VÖCKLABRUCK. Immer mehr Menschen wünschen sich eine Wohnsituation, die mehr Gemeinsamkeit ermöglicht, mit Menschen, die das auch leben wollen. Es gibt in Österreich bereits umgesetzte Wohnprojekte unterschiedlichster Größe und Organisation. Grundidee ist, dass es neben der eigenen Wohnung Gemeinschaftsbereiche gibt (beispielsweise Werkstatt, Garten, Atrium, Fernseh- und Feierraum, Sauna), die alle nutzen können. Gemeinschaftliche Wohnprojekte haben ein großes Potenzial für die Umsetzung hoher Wohnqualität. Mehrere Generationen finden sich in solch einem Wohnprojekt – behindertengerecht, integrativ, gemeinschaftlich. Verschiedene berufliche Hintergründe und Weltanschauungen begegnen einander, es kommt zu einem voneinander und miteinander Lernen. Im Bezirk gibt es eine Gruppe von Menschen, die ein gemeinschaftliches Wohnprojekt für etwa zehn Wohnparteien verwirklichen wollen. Diese Baugruppe befindet sich in der Gründungsphase, es werden weitere Interessenten gesucht. Wer Näheres wissen möchte und sich für gemeinschaftliches Wohnen interessiert, hat am Donnerstag, 17. September, um 19.30 Uhr im Otelo (ehemalige LMS) die Gelegenheit, sich zu informieren. Infos auch unter baugruppe.vb@gmail.com

Gemeinsam bauen und wohnen

ATMOSPHERIC IMPRESSION OF THE SITE.

THE EXISTING FARM BUILDINGS ON THE RIGHT, THE VILLAGE CENTRE & CHURCH IN THE BACKGROUND

project chronology.

1510

After unsuccessfully trying to get LEADER[11] funding for a professional participatory process, the co-housing group's search for a suitable site and potential partners continued just as did the research at WISBA.

1511 — THE SITE

A potential building site in Regau came to be of interest and we contacted the owner. While not being interested in selling the plot, he was interested in the community approach and the environmental aspects and eventually agreed to have the site being used as the basis for the architectural concept of the co-housing project within the thesis. Talks with local housing cooperatives were interesting but did not prove successful due to a limited possibility for involvement of the co-housing group during the initial design stages of their project.

1512

Around New Year's Eve, early in January 2016 after finishing the WISBA research project, I presented our findings to the co-housing group. The comprehensive environmental assessment of the innovative building concept as well as the differentiation of embodied and operational energy were of high interest to the group. We discussed potential future steps for both the group and their co-housing efforts and me for further research on building sustainability within the thesis and how to possibly combine the two. We decided to continue our collaboration and to arrange for two workshops in which to determine the group's common idea and requirements for a co-housing project and develop a prototypical building concept that could then be used for the environmental assessment.

In the sense of Hofmann, the individual members of the co-housing group would be the experts for living, stating their preferences within our workshops, and I would be the expert for spatial design and sustainability developing the project.

1601

After some more literature review on participatory processes I developed the concept for two workshops with the co-housing group. In the first workshop we would collaboratively

11 Leaderregion VöcklaAger, further information via www.vrva.at

work in a creative process to determine people's individual expectations and the common vision of the group as well as the requirements in terms of function and spatial program. In the second workshop we planned to focus on the actual building concept, the distribution of building mass, spatial qualities between and within, on the distribution of functions, zoning of common and private spaces and on possible individual flat layouts.

1601 — WORKSHOP 01

In this first workshop we worked on the group's vision and requirements for the co-housing project. To express the individual vision people created atmospheric collages, while for the common requirements group discussions were held. After presenting a number of architectural case studies and typologies the group created a mood-board from samples provided, to express the common vision. We ended the workshop with hands-on model studies on building massing and zoning for the architectural concept.

1602

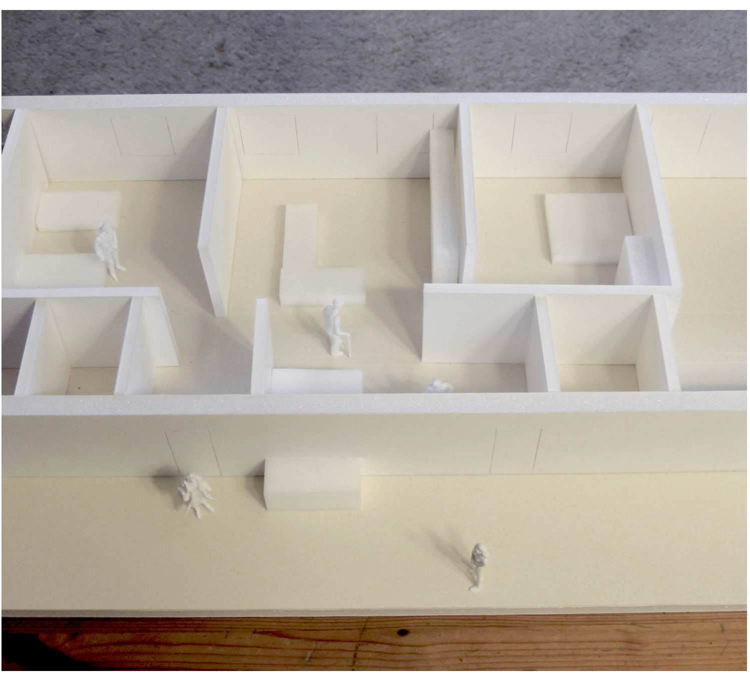
Equipped with a lot of individual ideas and a common vision on atmosphere as well as with the spatial requirements and the program agreed on, I continued to do more research on building typologies. With the requirement of spatial simplicity and adaptability, to account for probable changes of spatial needs of the inhabitants during the life cycle of the building, I reviewed a broad variety of flat layouts and developed a concept on zoning the different building areas in a layer-like structure.

ATMOSPHERIC COLLAGES OF THE DIFFERENT VISIONS OF THE GROUP

WORKSHOP 01

1602 — WORKSHOP 02

Building on the common vision and requirements established in the first workshop, we used the second one to focus the actual architectural concept. The main parts of the workshop therefore were the presentation and discussion of conceptual design options, the developed zoning concept and the functional distribution in the building. In addition, the group worked with models based on the developed zoning concept to create and discuss individual flat layouts.



STUDY MODEL
1:50

WORKSHOP 02

1603 — 07

Motivated and again equipped with a lot of thoughts and input I approached the next steps. Invited by the Chair of Sustainable Construction I got the opportunity to spend time at ETH Zurich[12]. There I dug into the various aspects and approaches to sustainability, the environmental assessment of buildings and established a prototypical workflow of BIM and LCA to be used for the assessment of the architectural concept developed through the participatory process. During this highly constructive time at ETH I also did research on the possibilities of using BIM for visualisation and communication of LCA results within the design process.

1607

Coming back from Zurich I was highly enthusiastic about the opportunities I recognized in applying LCA during the architectural design of buildings to improve their environmental performance. I again met the co-housing group and presented my research, the development of the building concept and results of the environmental assessment.

12 www.sc.ibi.ethz.ch

As some months had passed since our last meeting, the group was very interested in the work and we had lively discussion on the environmental impacts of building, operational and embodied energy as well as on the building concept and the current state of the co-housing group.

For some people in the group the situation had changed quite a bit as they inherited property further away and their motivation and endurance to continue working on the co-housing project declined. The remaining members, while still enthusiastic about continuing the co-housing project, were still looking for a suitable building site they could agree on.

1608 —

YOU CAN'T FORCE IT

After some weeks — in August 2016 — the group met again and as individual circumstances of some group members had changed, they agreed that for the moment the required strength and effort to continue the project were not given, no suitable site seemed available and next steps were unclear. After more than a year of collective effort the group decided to postpone their quest of establishing a co-housing project and people are for now individually re-evaluating their current and future living situations. It's still in process. And you can't force it.

project chronology.

(STILL) DISCUSSING
NEEDS & DREAMS

FROM WORKSHOP 01

MISSION STATEMENT

Ahead of the participatory process a statement on the vision and goals of the co-housing project was written by the first core group, which was then also used to advertise the vision and address interested parties. This mission statement served as a constant reminder of the initial idea and guidance throughout the process.

mission statement.

COMMUNITY AND SOLIDARITY

The project will be owned by the co-housing community, formed by the residents of the buildings. Residents therefore not only buy their individual flat but a share of the whole building. The distribution of financial burden should be based on the individual situation of residents and where needed shared in solidarity across the group. This is to put the project on solid ground and retain the built living spaces from real estate speculation. Common areas and spaces in and around the building are for use of the whole community and offer generous spaces for all residents.

CONSCIOUS LIVING

Mindfulness in handling natural resources and energy are important aspects to the project. The future users are already engaged in the initial building design process and invited to reflect on their demand for individual space, resources and energy. During the process we also question which spaces have to be individual and private and where functions and spaces may be shared with the housing community.

ENVIRONMENT AND SUSTAINABILITY

Reduction in technical systems will be tested to improve the environmental performance and shall as well lead to reduction in cost of living during the building life cycle. The building concept aims for a low-tech energy concept through passive and active use of solar power, the building's mass and seasonal reduction and extension of living spaces. Elaborated heating and cooling concepts will be developed to provide environmentally friendly living in a sustainable building.

INDEPENDENCE AND SIMPLICITY

The reduction of technical services and equipment not only reduces cost for construction and operation, but shall also support independence and resilience. Complex simplicity in function and construction thereby enable and ask for autonomous, conscious living.

PIONEER SPIRIT AND VISION

The building concept will be developed in cooperation with future residents, this is to support consciousness and responsibility for sustainable living. The building concept will be developed within an architectural master thesis in cooperation with Technical University Graz and ETH Zurich. Already during the planning process, the environmental performance of the concept will be assessed to improve the life cycle performance of the final building concept.

WORKSHOP 01 - VISION & REQUIREMENTS

ATMOSPHERE & VISION

Still in the process of getting to know each other the workshop participants were asked to share their individual vision through the visual presentation in the shape of atmospheric collages made from pictures and elements provided. Each person individually created his/her piece and explained to the group what he or she wanted to express and which requirements should be fulfilled by the common project. This very sensual process of approaching a common vision through the creation of atmospheric collages was especially pleasing to observe as it revealed the individual needs as well as the similarities in people's visions for a common housing project.

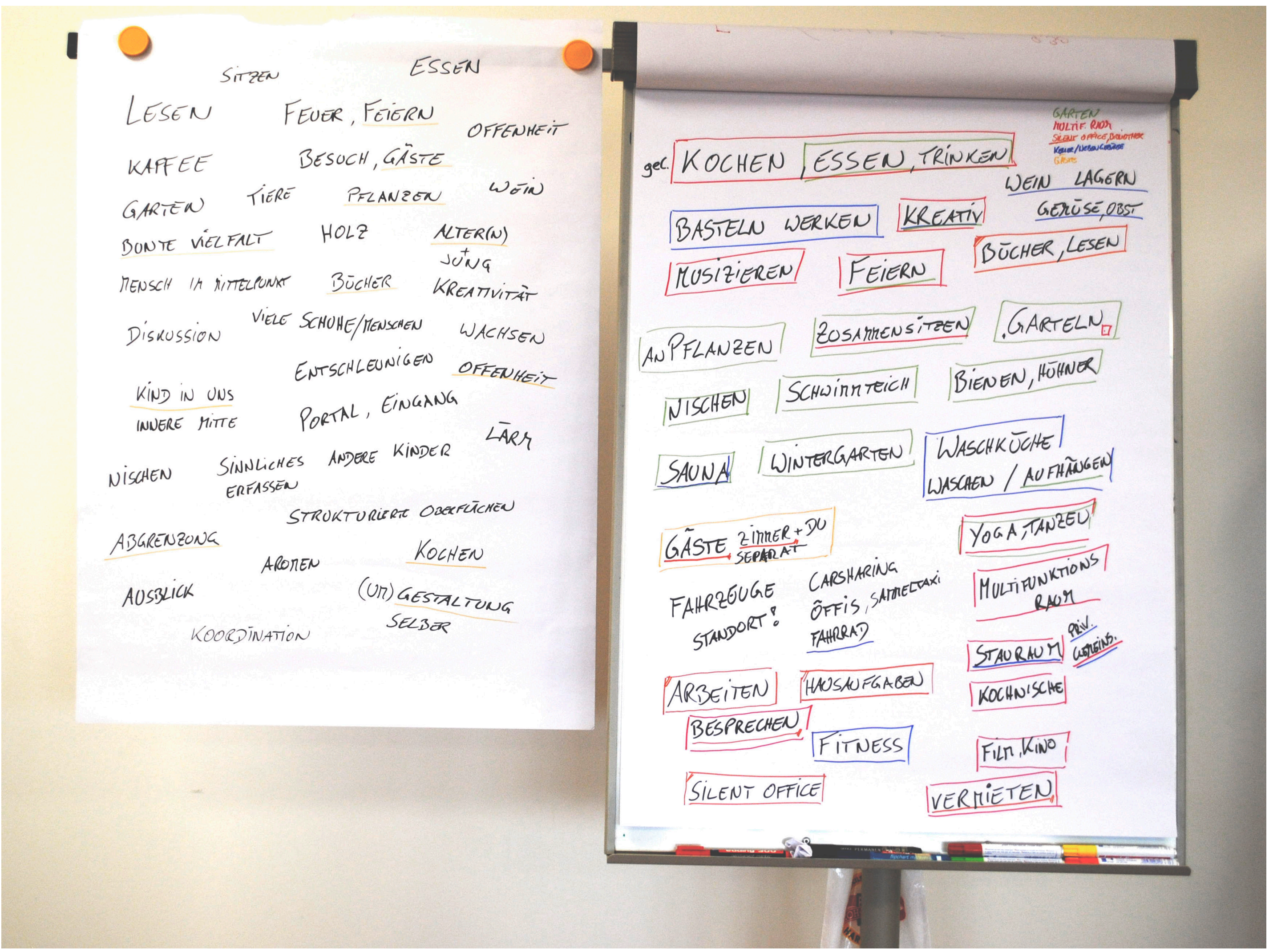
REQUIREMENTS & PROGRAM

ATMOSPHERE & VISION

In an open discussion we now formally established functional requirements on the program and spaces that should be provided in a co-housing project. After an initial brainstorming session on desired activities for the common spaces we took a step back to cluster the activities and assign them to spaces in a future building. This clustering showed the need for five types of common spaces:

- garden and outdoor spaces for sports
- recreation and common enjoyment
- a multifunctional community room easily accessible to the visitors
- space for retreat, a silent room that might also hold a library; a shared guest room to temporarily accommodate friends and family visiting
- and finally a workshop and individual storage spaces which we had agreed on at an earlier stage would be placed in separate buildings.

participatory design process.



ACTIVITY &
FUNCTION
FLIPCHART

WORKING AS A GROUP — THE PROCESS

WORKSHOP 01

MOODBOARD DEVELOPED DURING THE GROUP PROCESS

MOOD BOARD

After the individual atmospheric collages we aimed at establishing a common understanding of what a built co-housing project could look like. Therefore, a mood board was created as group activity from provided pictures of materialization, interspaces, views in and out, as well as other material and spatial qualities.

BUILDING TYPOLOGIES & MODEL STUDY

To give an introduction to building typologies and the aspects of interspace, common spaces and circulation we presented a number of projects of different kinds. A number of different co-housing projects and other interesting spatial examples were presented and discussed. After this presentation of references and some more practical and fun exercises on circulation and spatial relationship in buildings we approached the sample building site and people grouped to come up with a number of intuitive proposals for mass distribution on site.

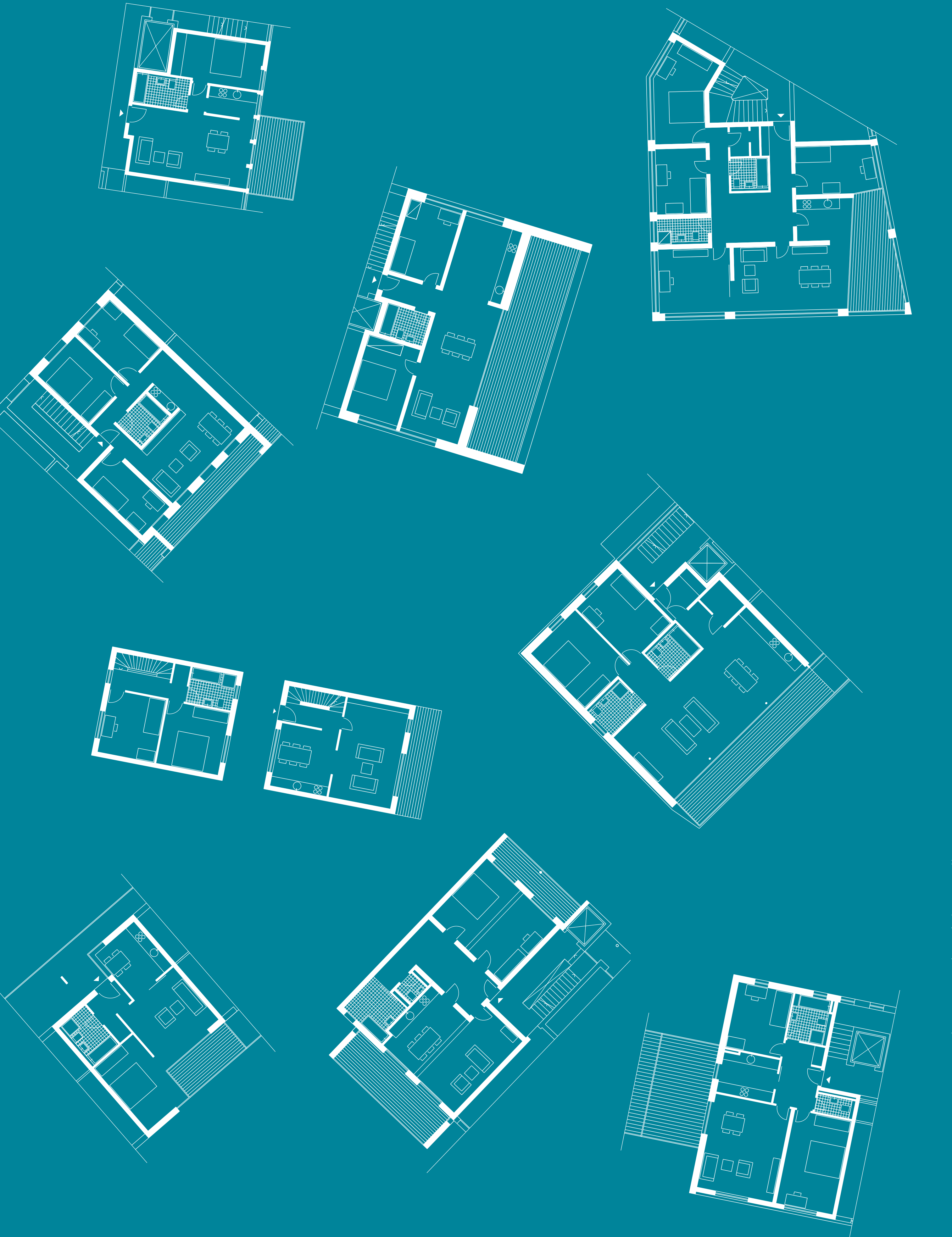
We ended this initial workshop after presenting and discussing the different options and determining different ideas and qualities contained in the modelled proposals.

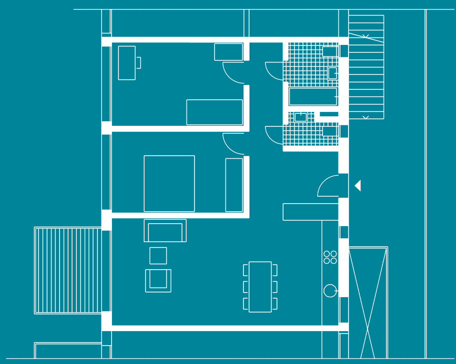
SPACIAL LAYOUT — RESEARCH

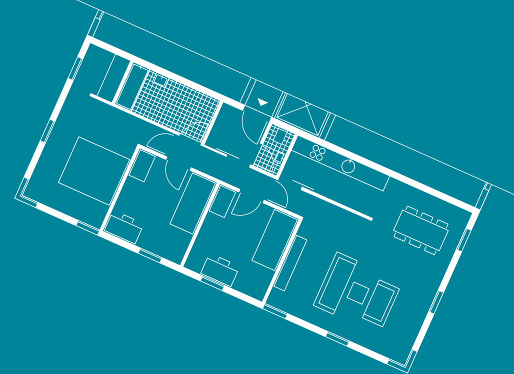
Equipped with a lot of individual ideas and a common vision on atmosphere as well as with the spatial requirements and the program agreed on, I continued to do some more research on floor plans and flat layouts[13]. With the requirement of spatial simplicity and adaptability, to account for probable changes of spatial needs of the inhabitants (size of flat, number of rooms) during the life cycle of the building and during the life span of the inhabitants, I reviewed a number of flat layouts and developed a concept on zoning the building areas in a layer-like structure.

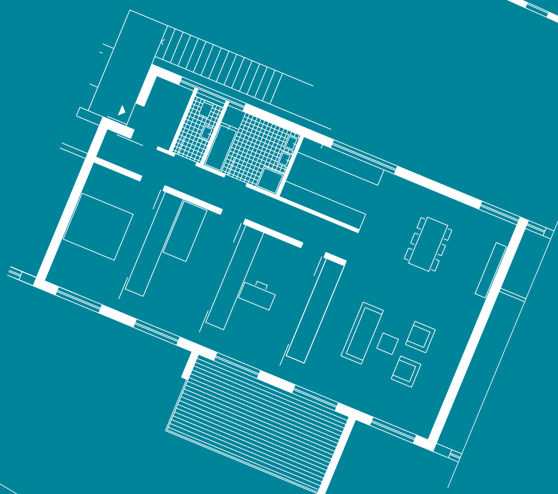
Based on this zoning concept and the other requirements and proposals received from the group I developed a number of conceptual design variants to be presented and discussed in the second workshop. Furthermore, we prepared sections of 1:50 scale models to be used by the group during the workshop for testing and discussing options in flat layouts.

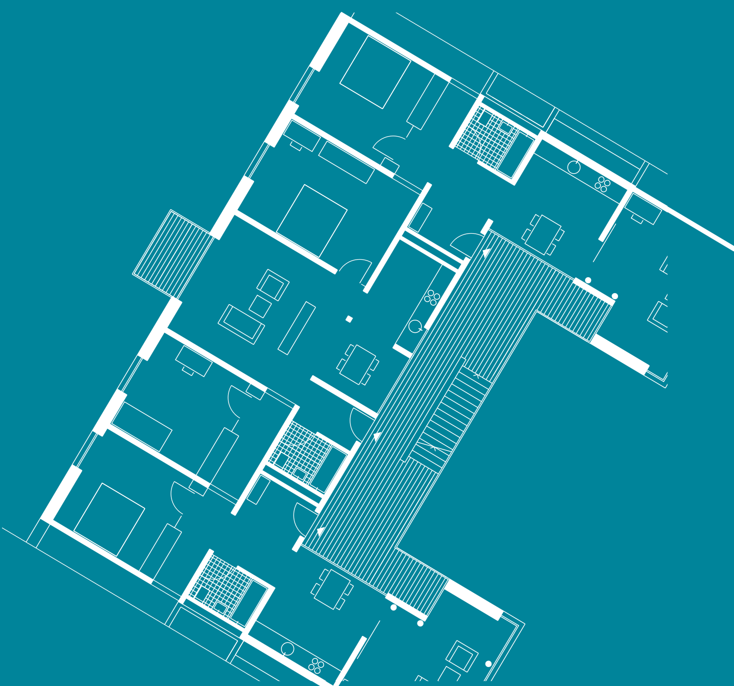
13 Jocher et al., 2010







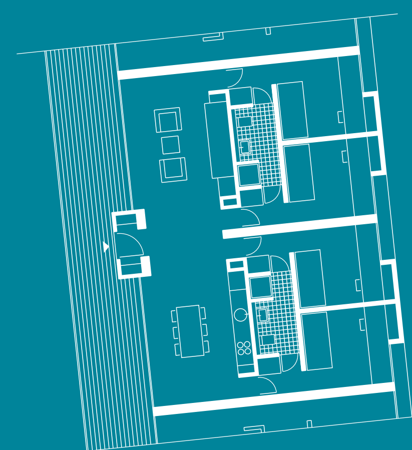


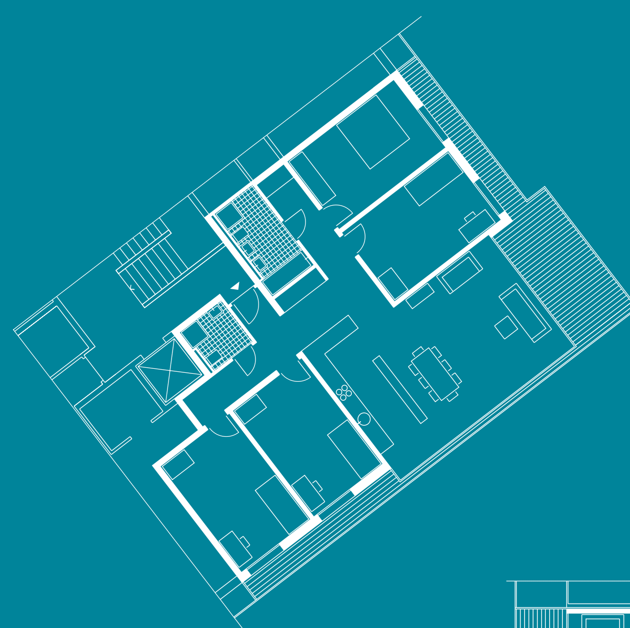


WHAT DOES
A GOOD
FLOORPLAN
LAYOUT LOOK
LIKE?

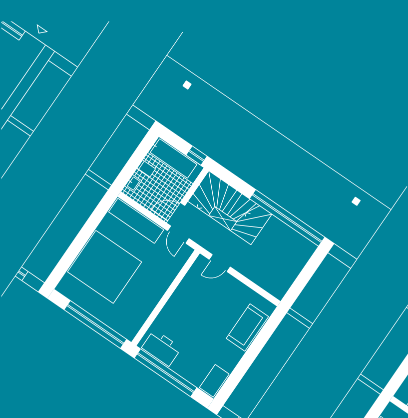
SPATIAL
LAYOUT
RESEARCH

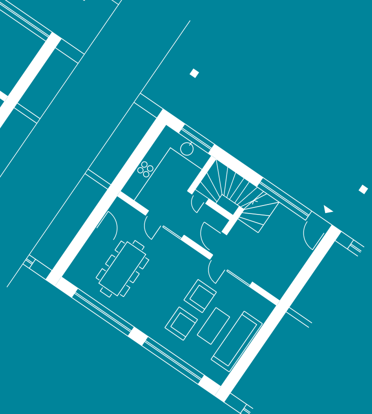
#1602

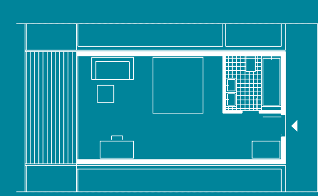


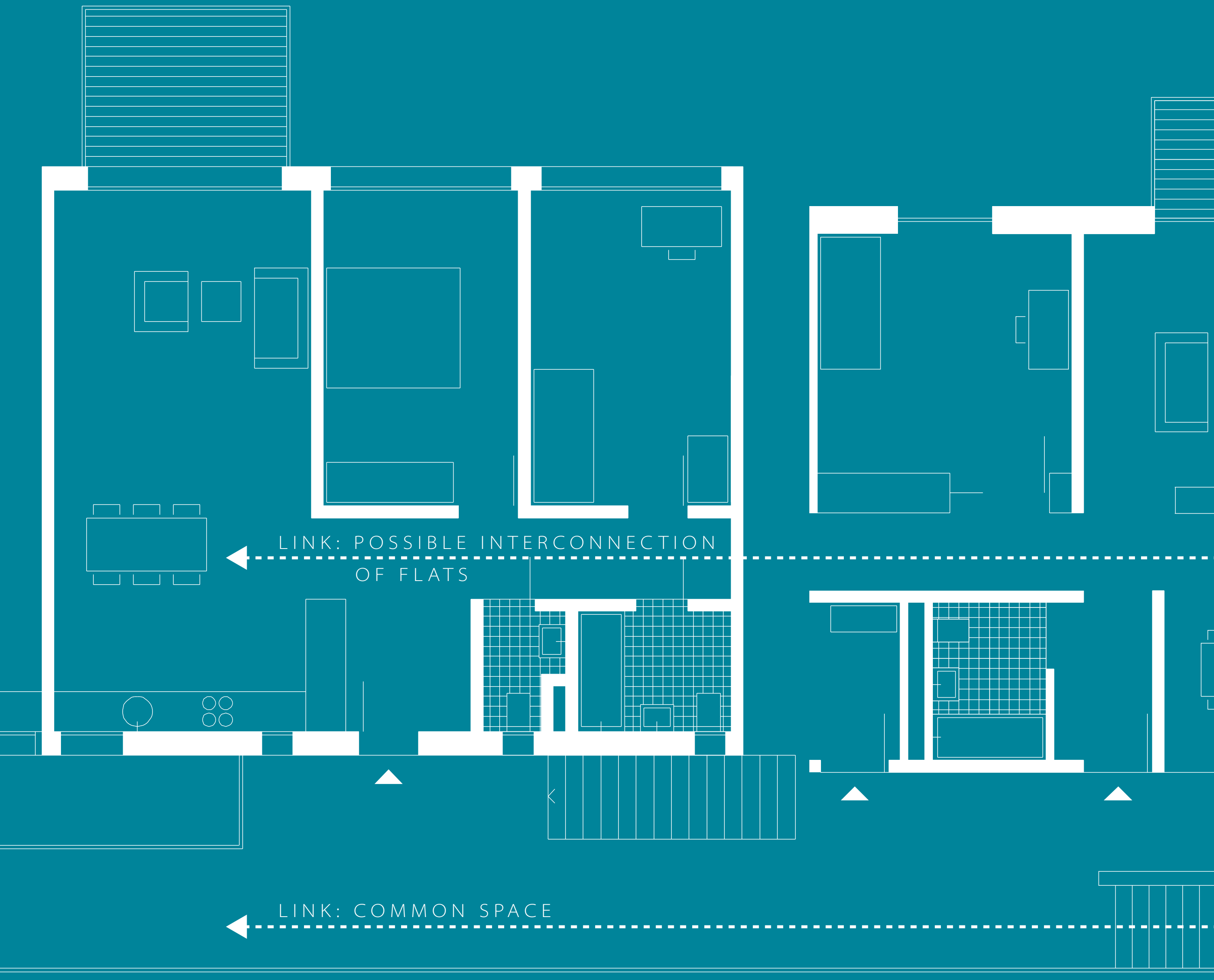


ALL FLOORPLANS
ARE ORIENTED NORTH





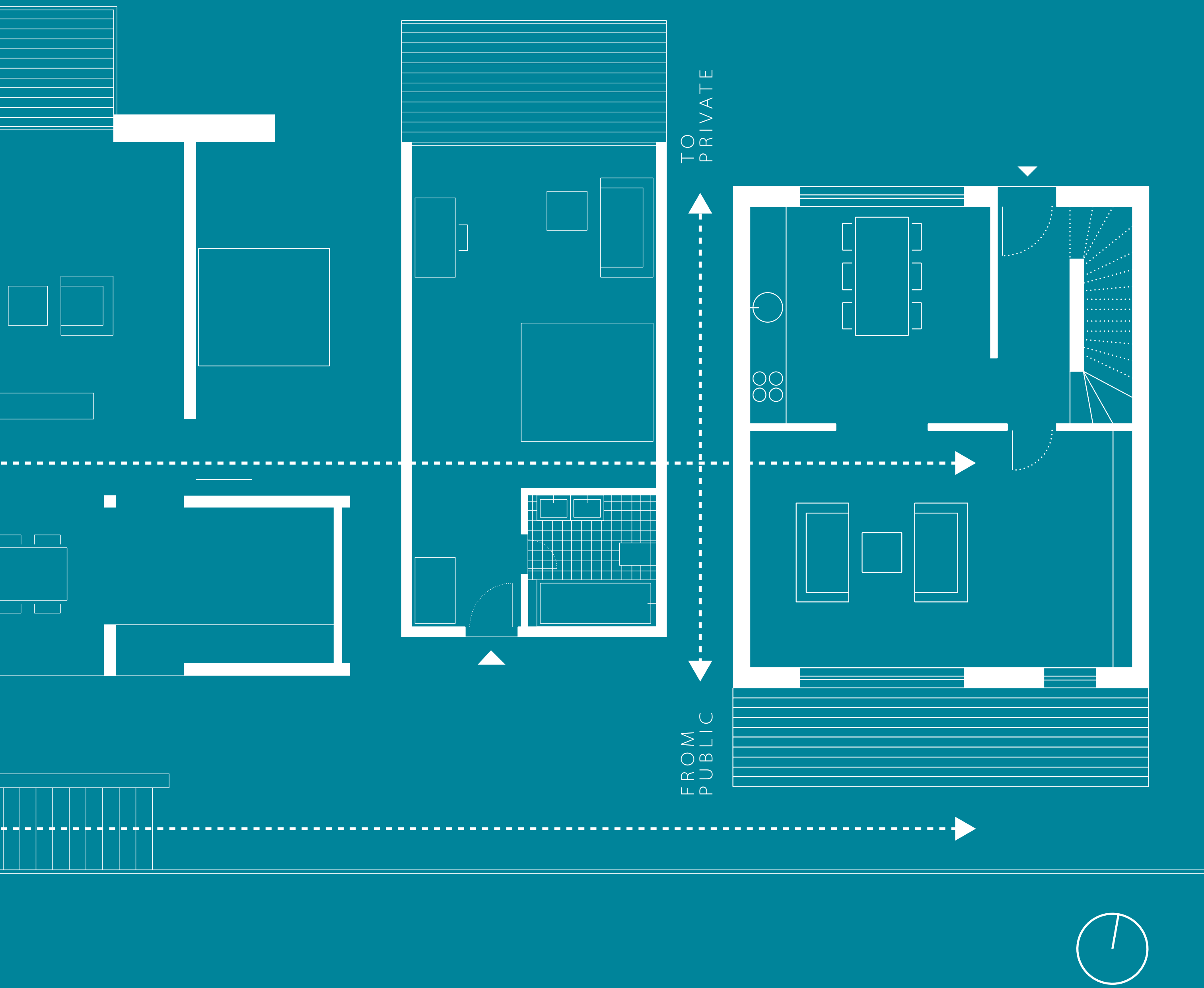



LINK: POSSIBLE INTERCONNECTION
OF FLATS
LINK: COMMON SPACE

ZONING
CONCEPT

CONNECTIVITY
& ADAPTABILITY

#1602



WORKSHOP 02 - ELABORATION AND SPACES

CONCEPTUAL MASSING

Based on the premise of a simple yet adaptable building, the aim for a low tech energy concept and environmental optimization as well as for cost effectiveness we chose a linear building typology with attached external circulation on the south side of the building. This was to open towards the garden at the south side and make use of incoming sunlight as part of a passive energy concept. We established this southern circulation area to be expanded in depth to create a generous terrace that provides common and also more intimate external spaces as well as access to individual flats.

FUNCTIONAL DISTRIBUTION

The general public and common functions as well as the more private and intimate individual flat areas were arranged according to a functional distribution diagram based on the requirements from the participatory process.

With a general tendency to structure from open, common spaces towards private and individual ones the most accessible and common functions of garden in the inner yard and the multifunctional common space were located in the ground floor. Further into the building one approaches the common terrace and individual flat entrances on the different levels of the building. Located on the third floor the more intimate spaces for retreat, the library, as well as the room for guests are placed.

ZONING CONCEPT

Based on the research on flat layouts and examples of external circulation I developed a layer-like zoning concept. From south to north the vertical layers of the building should provide spaces for circulation and common terrace space; a more private terrace and flat entrance area; inside the flats the more open individual functions like cooking and living spaces; an axis that connects the building and its units from east to west and provides additional adaptability of the flat layout; and at the northern back of the building, the intimate and private spaces of individual rooms for sleeping, learning and other activities. See an exemplary case study at the previous page.[14]

14 Jocher et al., 2010

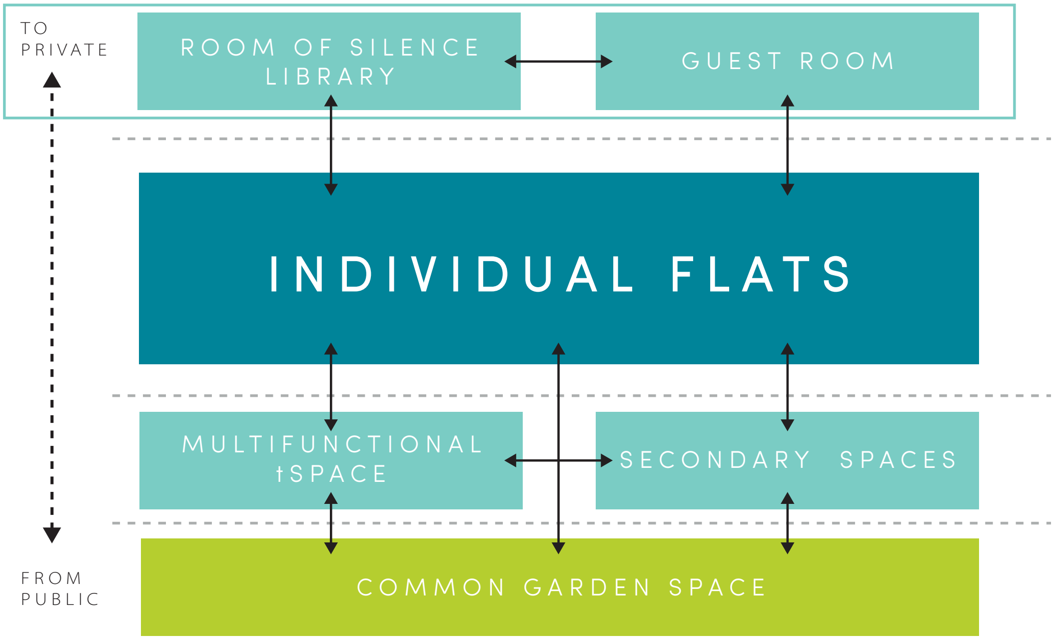
participatory design process.

BUILDING SCENARIOS

Three architectural concepts were presented and discussed with the group. A focus was put on the entrance situation and the distribution of community space across the building. For the common areas in the ground floor we aimed at an inviting visual connection while keeping a clear demarcation of the community's space. This was finally achieved by placing the main and side buildings to leave a gap that creates the constriction leading visitors and inhabitants onto the project area.

FLAT LAYOUT MODEL STUDIES

After arranging the members of the group according to the type and size of flat they were opting for we used the prepared 1:50 flat models to test and discuss possible flat layouts based on the earlier presented zoning concept. The group thereby created flat layouts of small (45-55m²), medium (55-80m²) and large (+80m²) flats with a different number of rooms. The individual proposals were then documented and incorporated into the further development of the architectural concept.





participatory design process.

WORK IN PROGRESS

DIFFERENT CONCEPTUAL MASSING SCENARIOS

EXCURSUS: DECISION-MAKING USING SYSTEMIC CONSENSING[15]

During this workshop we also included a short digression into alternative decision-making processes. To support a discussion on pros and cons of a number of building sites under investigation, we applied "systemic consensing", a decision-making model developed to find a common solution with least resistance.

PRESENTATION

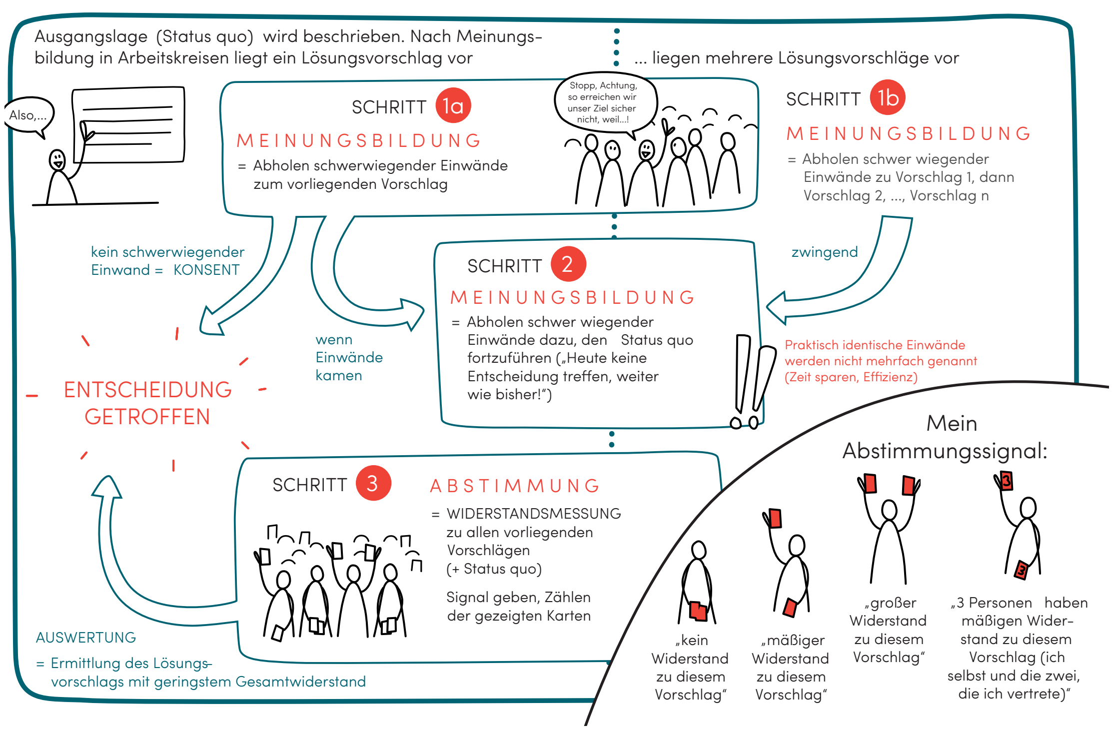
With the outcomes of this participatory process, and the conceptual design that evolved from it, I went to Zurich to work on the environmental assessment. At the Chair of Sustainable Construction of ETHZ I deepened my understanding of the building life cycle and Life Cycle Assessment[16] of buildings.

At some point of my research I learned about the Swiss concept of the 2000 Watt society, which establishes benchmarks of environmental performance based on the sustainable amount of energy consumption per capita – an interesting concept that was also pursued for the environmental assessment. In addition to the research on existing approaches of LCA, I worked on concepts to potentially use Building Information Modelling[17], a planning and building management method I had been working with for many years, to support the building assessment during the design stage.

15 find more info via http://www.ic.org/wiki/systemic-consensus-principle/

16 Further referred to as LCA

17 Further referred to as BIM

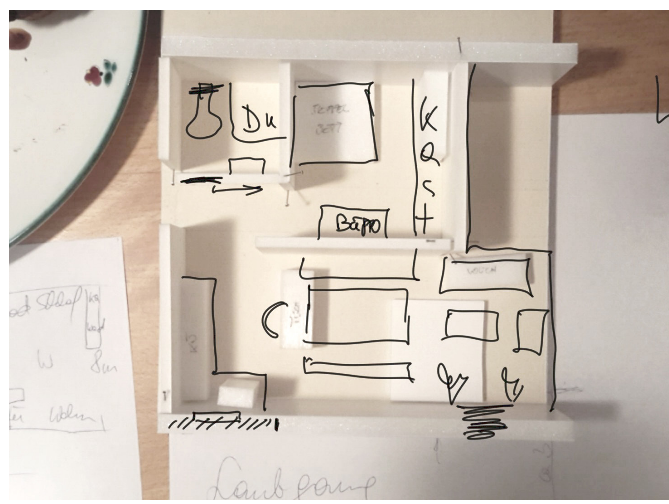


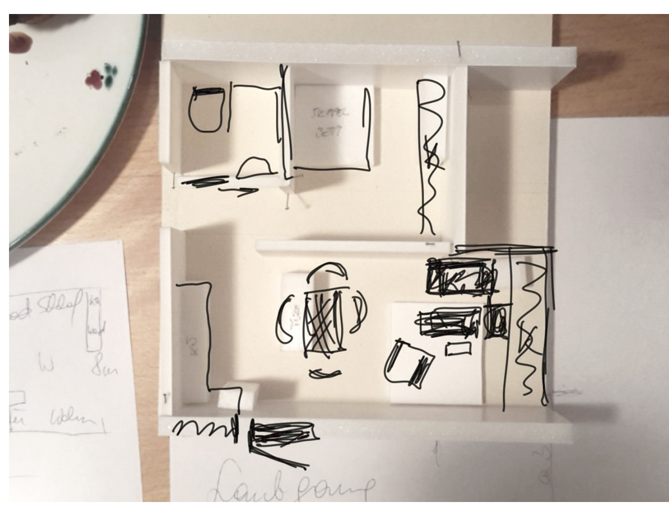
participatory design process.

Based on the conceptual design established in the participatory process, different materialisation and construction scenarios were established and an initial environmental assessment was carried out. After evolving to a developed design, which then was also modelled as a digital building model, a refined assessment with detailed results could be executed.

Based on these interim results a final building design was established and again assessed. The results of which can now also be presented using the digital building model, through a prototypical method I developed at ETH Zürich.

In summer 2016 the architectural concept as well as the results of the environmental assessment were presented and discussed with the co-housing group. The final building design for the co-housing project is presented in detail in the following chapter. A specific description of the assessment process and results as well as the technologies and methods used, are explained in chapter III: Building life cycle and environmental assessment.





MODEL
STUDIES |
FLAT LAYOUT

“Global climate march 2015: hundreds of thousands march around the world – as it happened”

THE GUARDIAN, 2015

what it also is...!

#PEOPLE'S
CLIMATE MARCH
#PEOPLESCLIMATE
#ACTONCLIMATE

“The United Nations just announced their boldest goal ever: To eradicate extreme poverty for all people everywhere, already by 2030.“

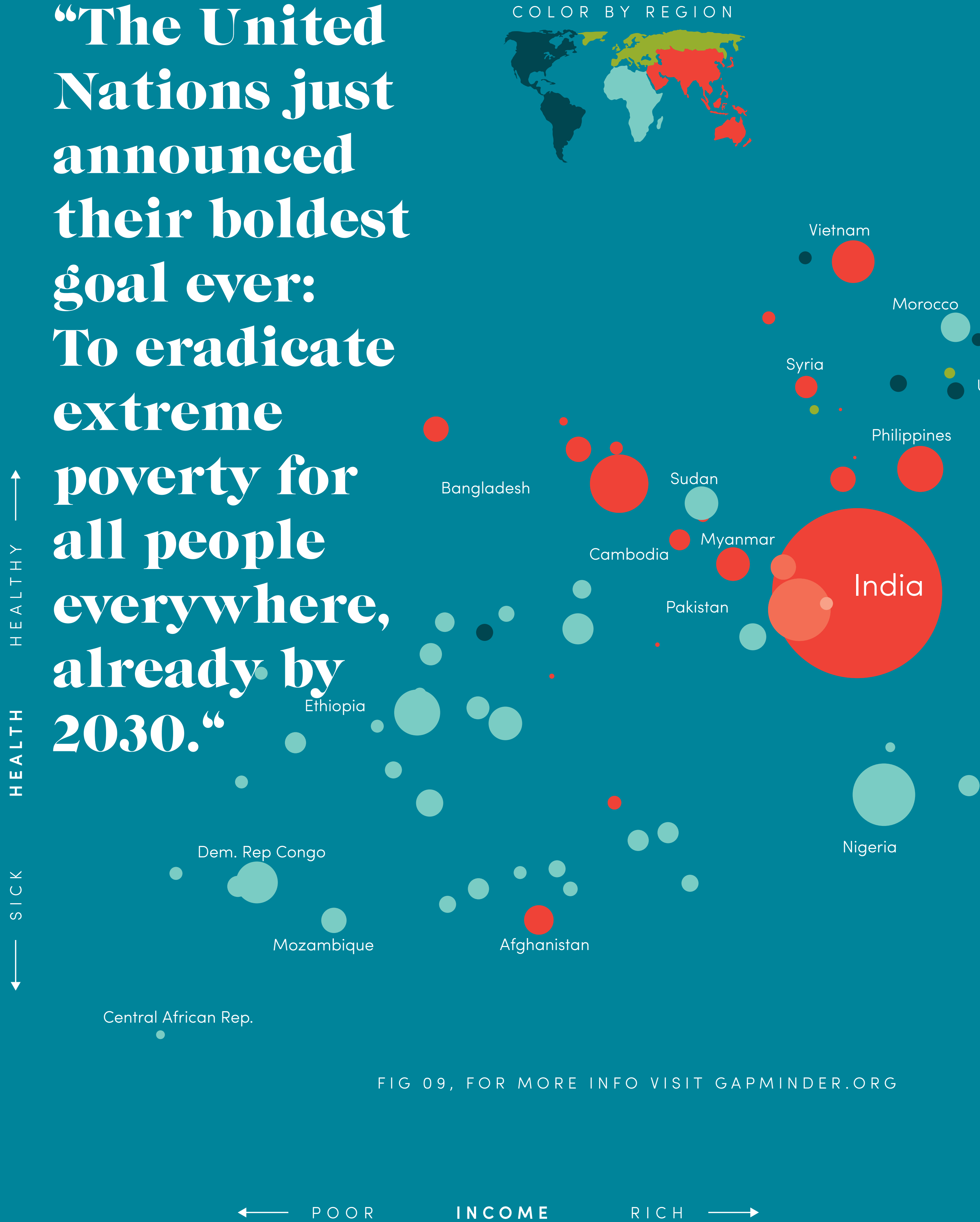
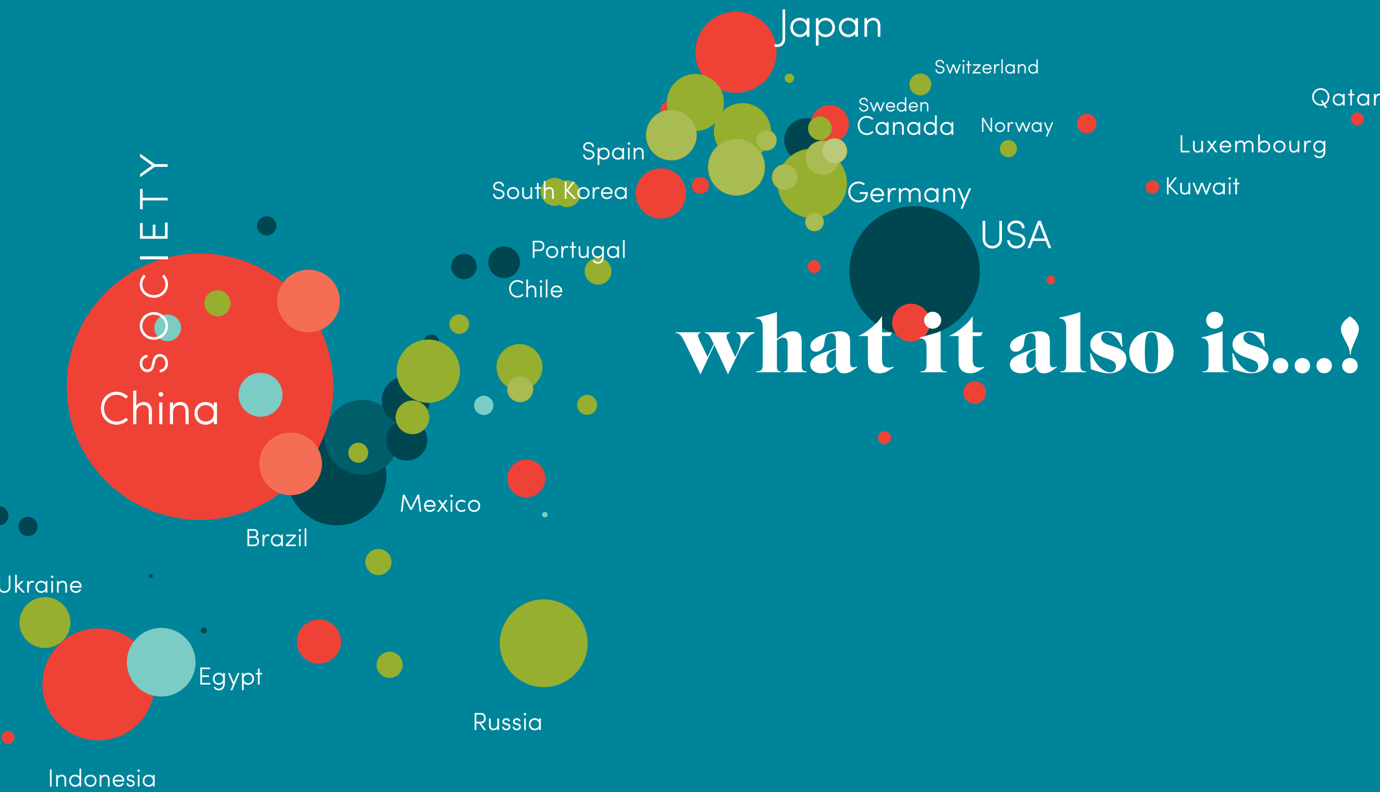


FIG 09, FOR MORE INFO VISIT GAPMINDER.ORG



what it also is...!

Up-to-date statistics show that recent global progress is ‘the greatest story of our time’ – possibly the greatest story in all of human history. The goal seems unrealistic to many highly educated people because their worldview is lagging 60 years behind reality.”

HANS ROSLING — HOW TO END POVERTY IN 15 YEARS, 2015

"Good lives for everyone in harmony with nature."

D. MEADOWS, 1998

what it also is...!

FIGURE 11,
UN SUSTAINABLE
DEVELOPMENT GOALS

“In December 2015, the 21st Session of the Conference of the Parties (COP21/CMP1) convened in Paris, France, and adopted the Paris Agreement, a universal agreement whose aim is to keep a global temperature rise for this century well below 2 degrees Celsius and to drive efforts to limit the temperature increase even further to 1.5 degrees Celsius above pre-industrial levels.“

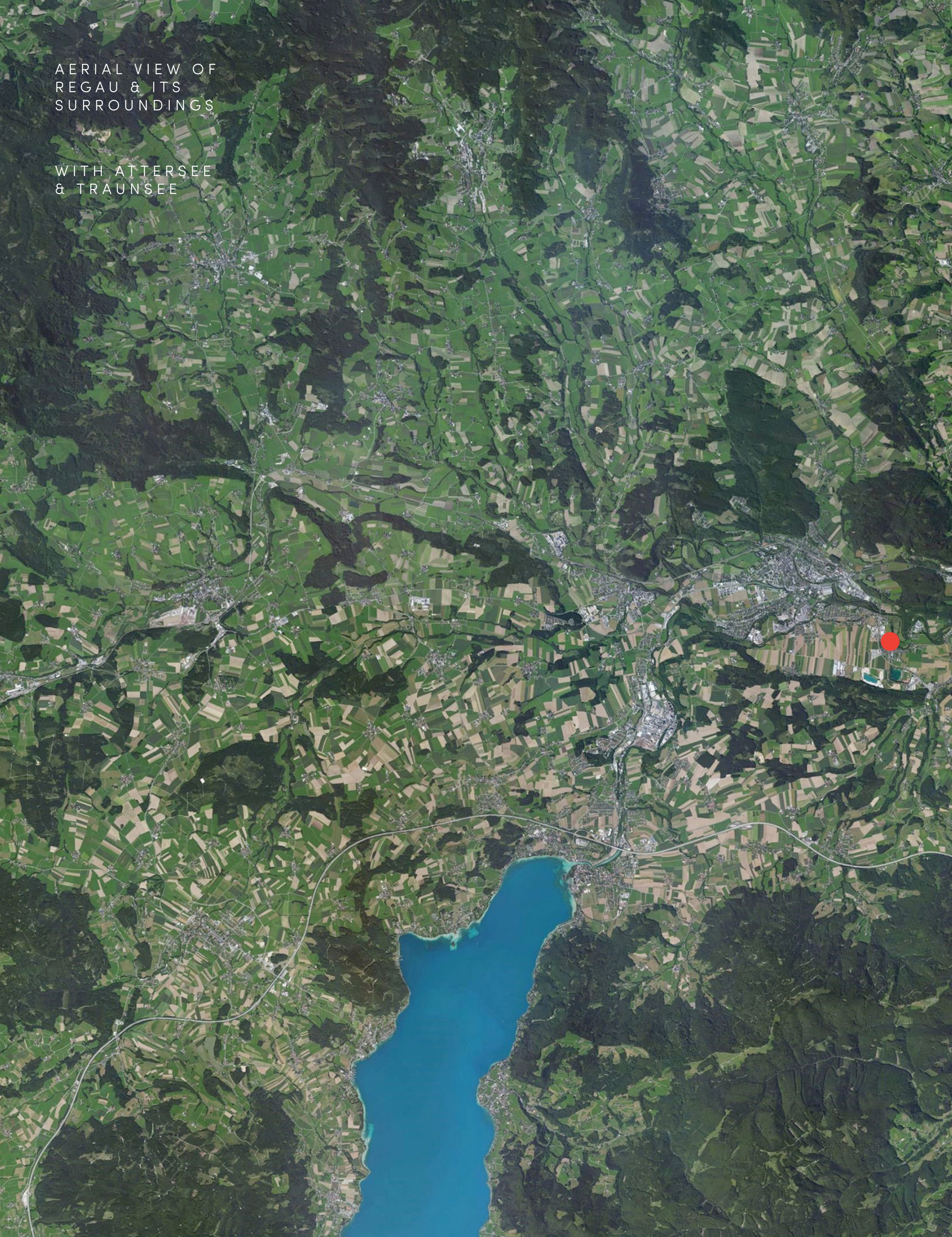
THE UN SUSTAINABILITY PLATFORM, 2015

what it also is...!

China & the U.S. sign the Paris Agreement as well 73 other parties. The Paris Agreement will enter into force on 4th of November 2016.

PRESIDENTS BARACK OBAMA & XI JINPING SIGNING THE PARIS AGREEMENT

III. architectural concept.


AERIAL VIEW OF
REGAU & ITS
SURROUNDINGS
WITH ATTERSEE
& TRAUNSEE

region & site.

FIGURE GROUND
PLAN
M 1:5000

region & site.

REGION

Regau is a village in the rural area of Upper Austria. The market village was first mentioned in 800 AD under the name of Repagove, referring to the winegrowing culture in the area at that time. It has around 6.500 inhabitants on the total area of 34 km^2, with only a few hundred people living in the village centre, that at its borders quickly dissolves into business parks and loose single-family house developments.[18] The village is surrounded by a federal highway, bypassing it in the West and North, cultivated grasslands and crop growing areas in the South as well as the Ager river meadowlands in the North-East.

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18 www.regau.at

AERIAL VIEW
OF THE
BUILDING SITE

region & site.

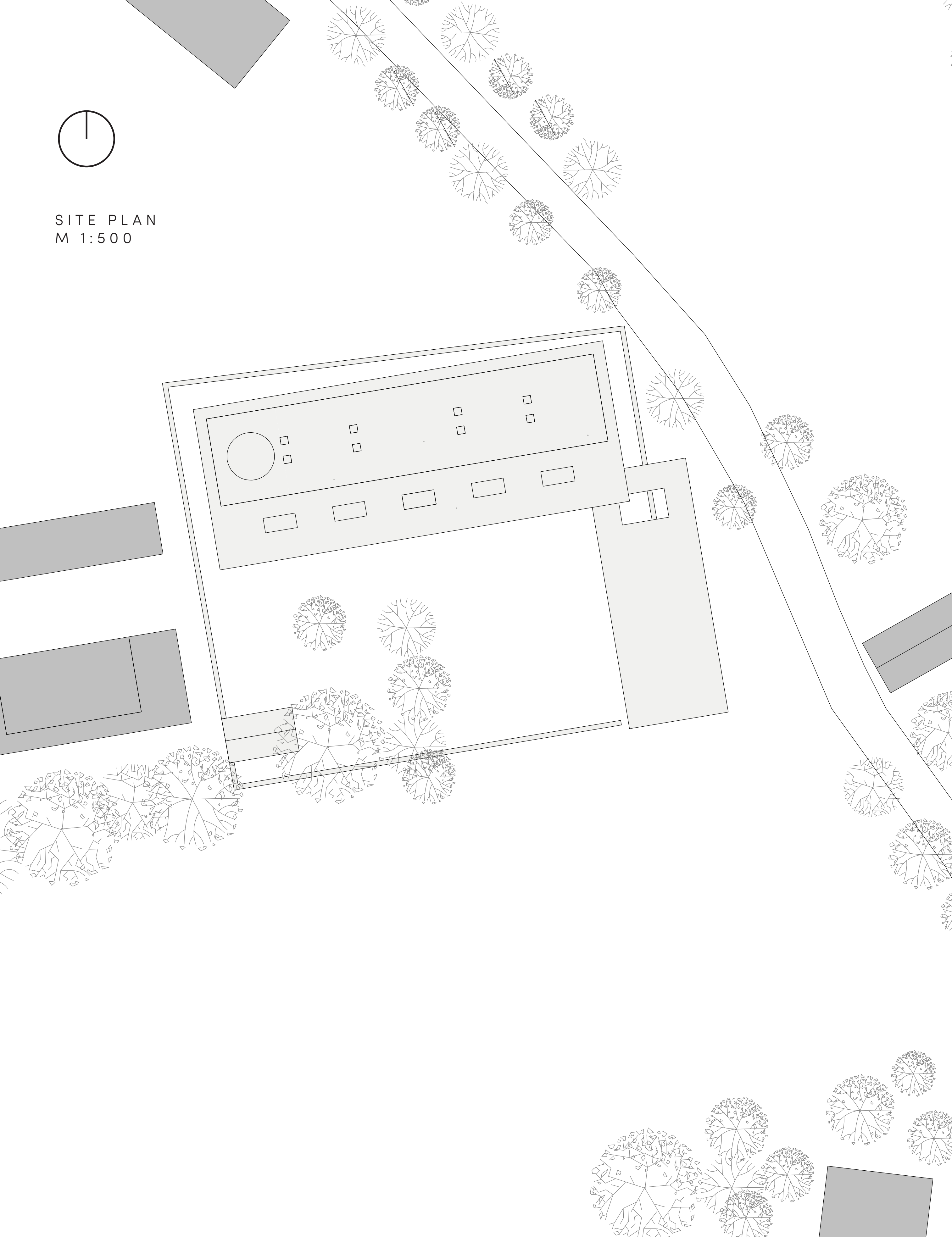
Regau is connected through federal highway B145 leading from the near national motorway A1 exit towards the district's capital Vöcklabruck which is less than five kilometres away, making Regau a high potential residential location with good links to the close-by trans-regional private and public transit networks as well as to the trans-regional education centre of Vöcklabruck, which provides a number of public and private schools of different types.

Regau very much benefits from the well-linked position and it has developed the sites adjacent to the federal highway. When passing by Regau, one faces a number of shopping centres, car dealers and other business areas as well as a big cinema and entertainment complex, all dominating the first row of appearance. After leaving the federal highway, passing by one and two floor private house developments, one enters the smaller central road towards the village's centre that is the main square, the old marketplace in front of the 15th century Catholic church.

This central point of the village is only two-hundred meters from the building site, making the reference to this place an important connection in the further design of the building concept.

Even though this central marketplace is of a certain quality, which is regularly proven by people gathering at social events taking place all year round, the village of Regau has a growing problem of vacancy in their central buildings. This is partly due to shops and businesses leaving the village centre to move towards the aforementioned federal highway for better accessibility for motorized private transport. Even though the school centre of Regau provides a certain number of pupils as potential customers, it is also caused by a decreasing number of people living in the centre of the village, that would be regular customers appreciating the shopping opportunities in walking distance.

This rather short sighted development once noticed by local authorities and the municipalities planning department could be shifted towards a prospective view, supporting local in-village businesses and companies as well as fostering the creation of high quality residential spaces accompanied by a sophisticated densification of the areas immediately surrounding the village centre. The co-housing project therefore also aims to connect with the local community to emphasize existing qualities of the village and support the local economy.



SITE PLAN
M 1:500

region & site.

SITE

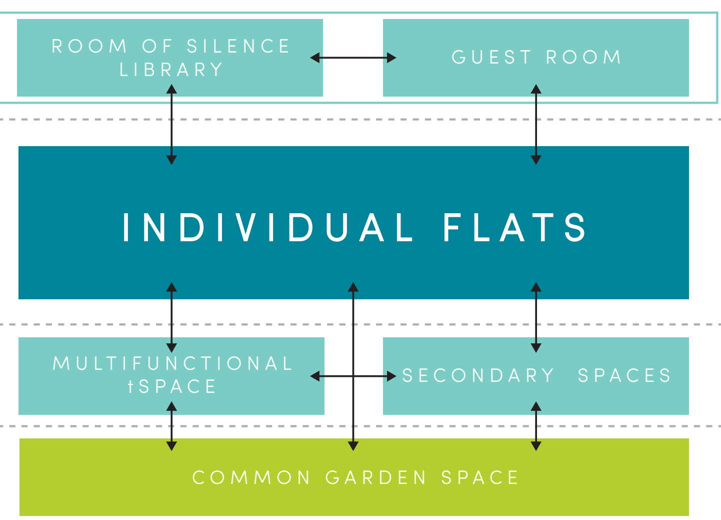
The site chosen to develop the building concept is located slightly north of the central marketplace of Regau, on the axis of the churches bell tower and the local cemetery. The somewhat significant address of the site, Friedensweg 1 – which translates to peace way / path of peace - indicates the traditional function of the pathway connecting the church and the cemetery in the north of the plot and therefore being people's "last walk" at funerals. It is immediately surrounded by grassland in the East and South, with a business park starting 300 meters north, and the village's central marketplace 200 m south of the plot. Adjacent in the West are a new, three-storey residential building and some other existing single family houses. Further west a number of multi-storey housing blocks are situated, partly shielding the site from the federal highway passing by in the West. On the east side, the plot is neighboured by a single family house with attached side building, a soft meadow and the cemetery North-East. Behind these the topography slopes down merging woods into grasslands and the Ager river meadowlands.

The site chosen in accordance with the co-housing community due to their serious interest in the location was not in their possession. The current owner is interested in the approach of co-housing community, which is why even though he stated to have no intention of selling the plot, he agreed to have the site taken as a basis for the development of the presented co-housing communities building concept.

The plot currently holds an old farm with a main building made of bricks and stones and accompanying timber-constructed side buildings - an attached old barn and a detached tool shed. Due to the bad condition of these existing structures the whole arrangement is already authorized for demolition. Therefore, existing structures cannot be maintained but will be recycled and could be embedded in the new design in parts.

PLAN OF SITE

After evaluating several massing options during the first participatory workshop a line typology with external circulation on the south side was favoured for the main building. After testing configurations with several volumes the decision was made to go for one big building facing South with spacious external terraces on the south side, providing space for circulation and common spaces leading towards the individual flats entries. Following height of the existing old farm house and the surrounding structure, the main structure is a three-storey building. This main structure is accompanied by a single-storey side building holding secondary uses, storage and parking spaces. These two masses confine the inner yard space towards North and East, with the gap between them providing a covered transition from the outside to the inside, an access to the complex, the common spaces, the yard and eventually the private flats. A third, smaller mass is situated on the plot - a small vernacular garden shed that might hold a henhouse - completing the composition by providing a symbolic reference to the local context and the site's historic farm buildings while also defining the spatial endpoint in the South-West corner. These three masses are framed by a wall of brickwork made from the bricks and stones of the original farm building. This perimeter not only references the history of the site but, with its low height, provides visual relations and enables interaction across it while clearly defining the borders of the plot and creating a sense of spatial demarcation.



FUNCTIONS AND PROGRAM

The new co-housing project is designed to provide individual and common spaces for six to ten parties. Depending on the size of parties and their respective flats we decided to design common spaces with the area of about one extra flat for a viable ratio of individual and common spaces.

Focusing on the common areas we used the workshops to define the functional requirements, the required areas for the program as well as desirable relations of common spaces. After an initial brainstorming session on future activities for the common spaces we took a step back to cluster these activities and assign them to common spaces.

This clustering showed the need for five types of spaces:

- Individual space for six to ten flats
- A multifunctional community room, easily accessible for visitors;
- Space for retreat, a silent room that might also hold a library; a shared guest room to temporarily accommodate visiting friends and family; and finally
- Workshop and individual storage space we had agreed on at an earlier stage would be placed in separate buildings.
- Common garden and outdoor space for sports, recreation and gardening;

function & program.

Based on the spatial requirements and the zoning concept established with the co-housing group, a building structure was developed, which provides an open floorplan and the flexibility to customize and change internal separation and flat layouts throughout the building's life cycle according to the inhabitants' requirements.

DISTRIBUTION OF COMMON SPACES

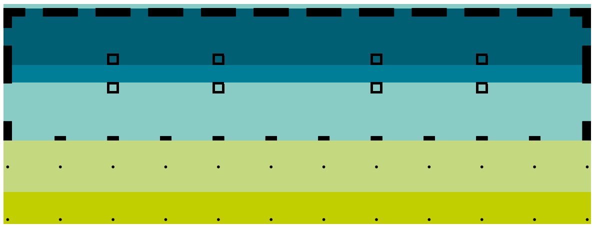
During the work on the program and the functions required, through the survey and in the first workshop, the quality and placement of common spaces were discussed. A distribution of common spaces across the building should provide a diversity of qualities, in addition to spatial qualities provided in the individual flats.

We decided to place the main common multi-purpose room right next to the entrance of the site. A central location with access and visual connection to the courtyard, where inhabitants pass by incidentally and which also provides easy access for visitors. The space provides room for a shared kitchen and common dining space, and may as well be separated in two and used for sportive indoor exercise, yoga lessons or regular plena of the inhabitants. In this area also the common laundry room is situated, a utility space that is frequently visited and it also provides an informal opportunity to get in touch with the others. Closely connected with the big terrace in front of the multi-purpose room, this is also a place where the housing community can gather to celebrate, for big dinners, music and dances or other common events.

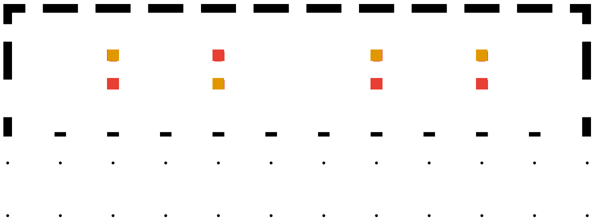
A second accumulation of rooms and spaces is provided in the opposite corner of the building, spanning a symbolical axis of common spaces across the building. The roof terrace on the second floor is part of a quieter, more intimate common space in the upper part of the building. A generous roof terrace creates secluded outdoor space and the entrance to the guest room and the library.

Guests are welcomed and integrated in the community, as temporary residents they control their own spaces with close connection to their hosts and other permanent residents. The small common library serves as a room to draw back and focus on reading, doing homework, or just having a nice private chat with a friend. If needed this "room of silence" can be turned into a temporary guestroom as well, doubling the capacity to host guests in separated guestrooms.

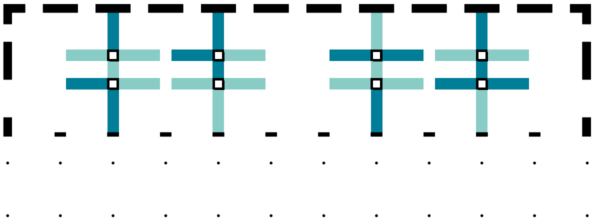
ICONOGRAPHIC
EXPLANATION OF
THE CONCEPT



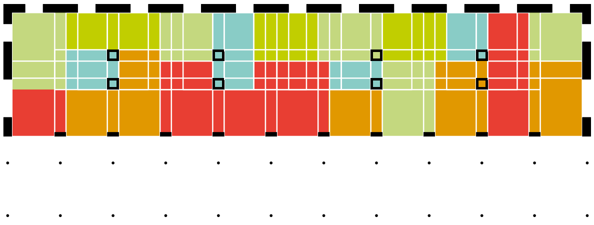
01 |
FROM COMON TO
PRIVATE



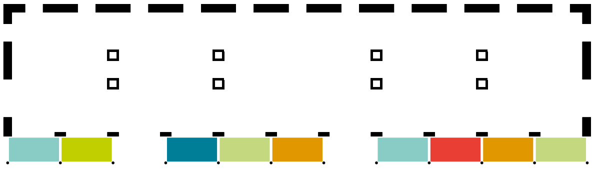
02 |
INFRASTRUCTURE
PILARS



03 |
POSSIBLE
SANITATION
POSITION



04 |
PARTITION
POSSIBILITIES



05 |
SEASONAL
EXTENSION OF
LIVING SPACE

statics, services & spatial concept.

STATICS, SERVICES AND SPATIAL CONCEPT

With spatial adaptability and functional flexibility being major requirements, an adaptable concept for spatial separation and infrastructural services was developed. The main static structure provides freely spanned inner space, with floor slabs spanning north to south from the massive back wall to the dissolved skeleton structure facing the arcadia.

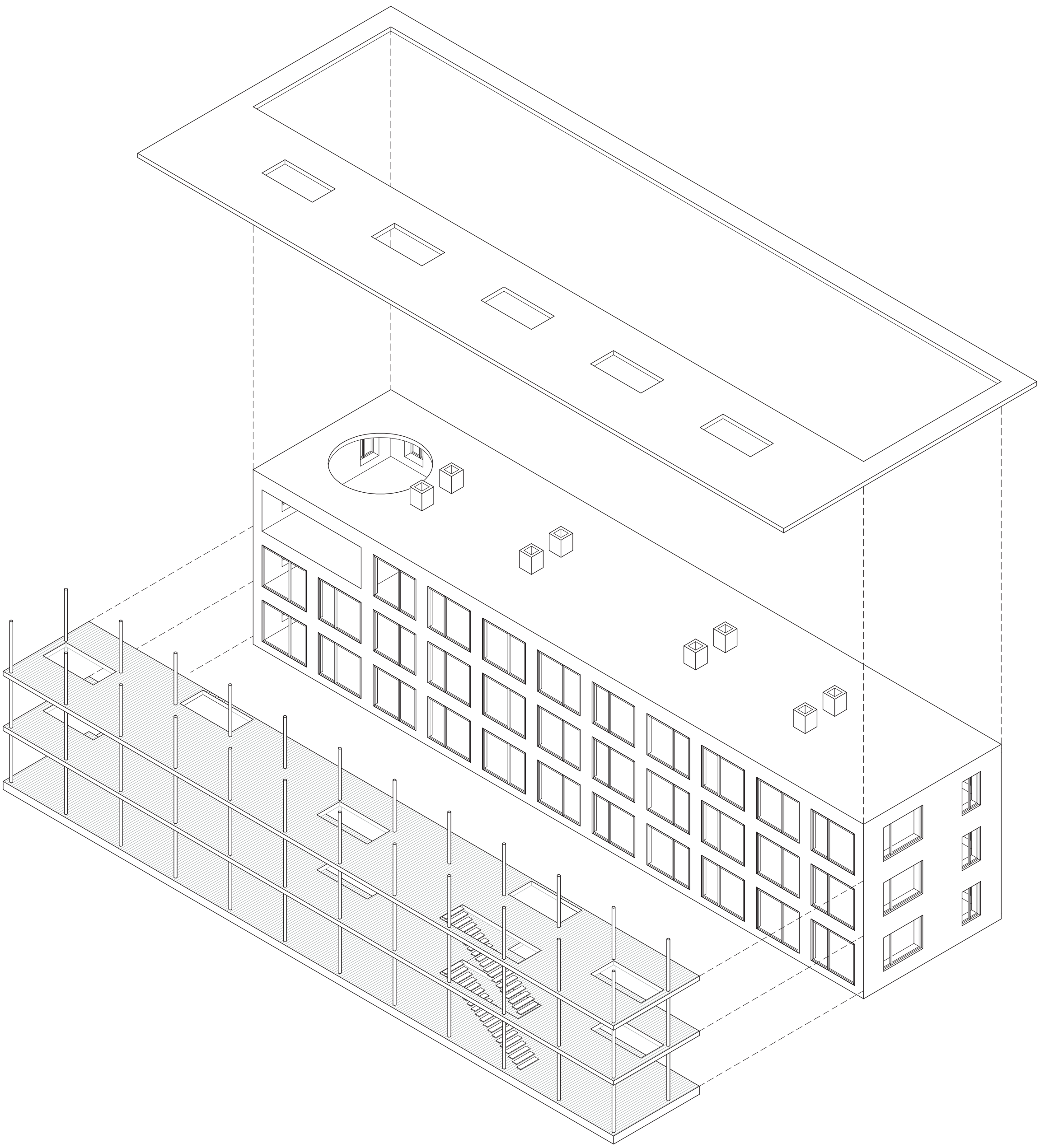
Vertical infrastructure pillars offer points of connectivity for sanitation and other infrastructural systems. Sanitary equipment and kitchens can be connected in different places and allow for a diversity of flat layouts and typologies ranging from open spaces with sanitation core to flats with multiple separately enclosed rooms.

The depth and width of the building volume as well as the window layout have been fine-tuned through testing various flat layouts and separation possibilities to meet the internal requirements.

This flexibility in spatial separation provides adaptability of the floor plans and allows for individual layouts that can be changed with little effort. By placing non-structural walls as required, the building can also host alternative functions.

Towards the terrace in the south, a layer of additional enclosed space provides protected entrance areas and can be used to seasonally extend living space. Working like a winter garden this layer also provides a thermal buffer from outdoor conditions and enables the passive use of solar power

AXONOMETRIC
VIEW



plan material & visualisation.

TECTONICS

The main building's structure is comprised of a massive cube type volume, confining the flats and common spaces of the main building. Attached to this cube the arcadia is a skeleton structure that provides the building circulation and common terrace spaces. These two components are covered by a common roof slab, condensing the parts into one building structure.

CUBE

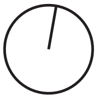
The main building shape is reduced to a simple cubic volume. Shielding the private spaces towards North, East and West, the cube is opening towards South where the massive walls are starting to dissolve into columns, merging with the arcadia. This is in part also to achieve compact geometry and mass for a passive thermal concept and keep a good wall to window ratio.

To shield the building towards the highway in the north and still provide good daylight quality in the interior spaces as well as a visual connection, big windows with low parapet heights are placed regularly in the north façade. The window layout has been developed through testing of multiple scenarios for internal separations, to allow for various room sizes and flat layouts while keeping a calm and simple window layout and façade design. The cubic shape opens south with big level openings that support the connection of semi-public kitchen and living spaces with the common terrace and entrance areas on the arcadia.

ARCADIA

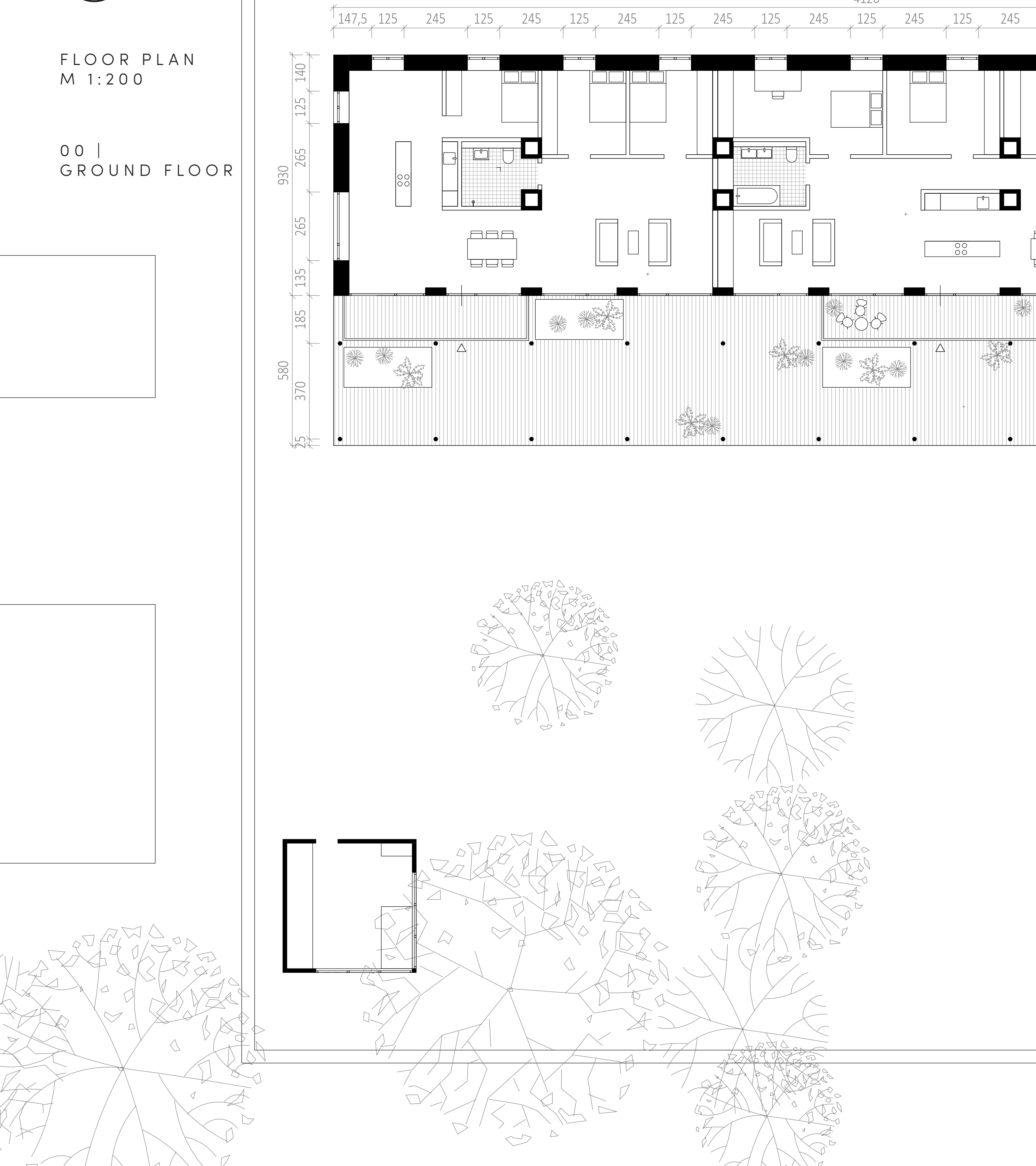
A skeleton like structure opens the building towards the common terrace and exterior spaces, the green space in the garden and the surrounding landscape. The arcadia creates an open space, it provides common and semi-private terrace spaces as well as access to the flats.

Its slabs act as big brise soleil, providing shade and weather protection for circulation and protected common outdoor spaces all year. A number of vertical cuts form openings that connect the multiple levels, arrange the space and help distinguish common and circulation spaces from the semi-private entrance and terrace spaces in front of the flats.

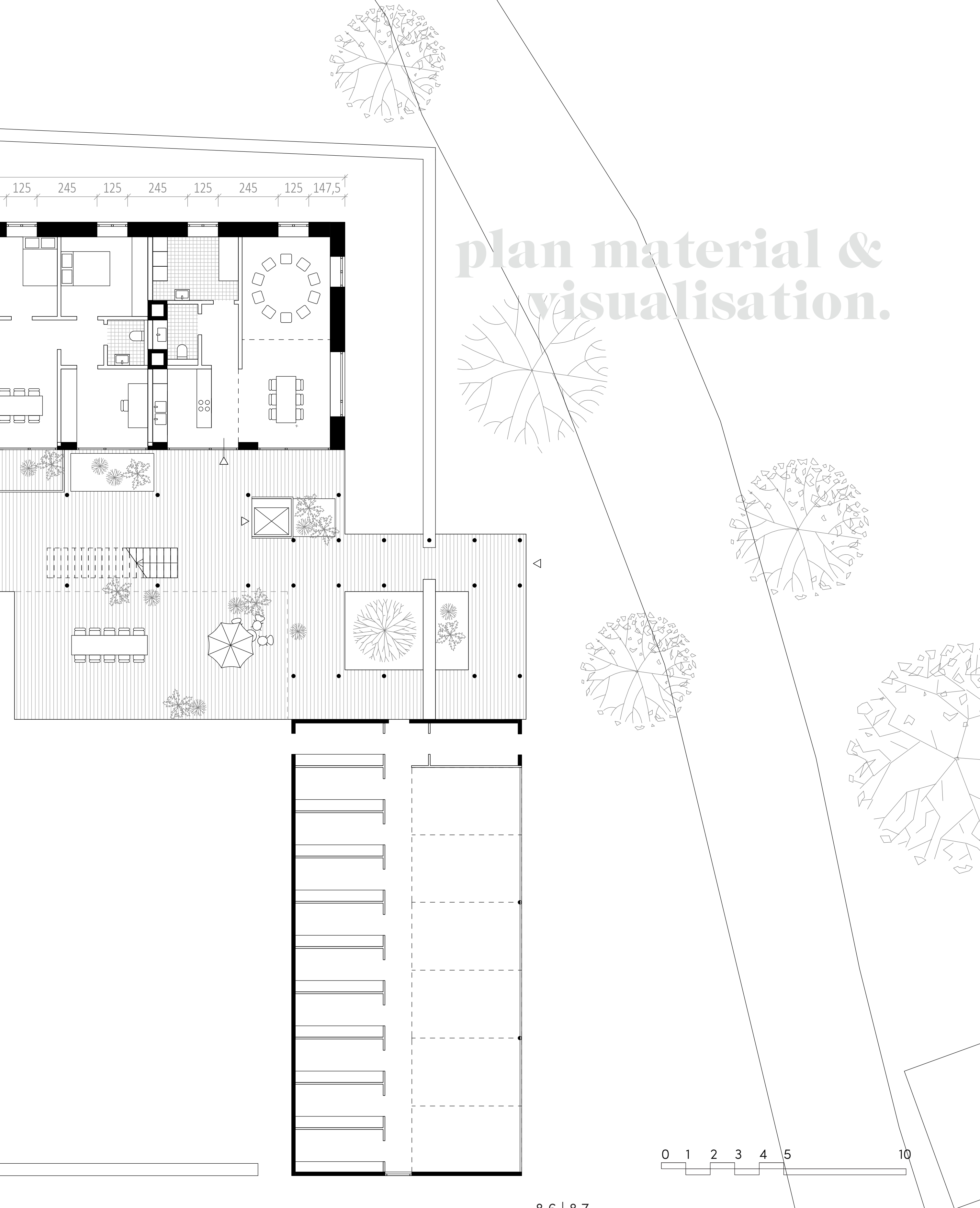


FLOOR PLAN
M 1:200

00 |
GROUND FLOOR

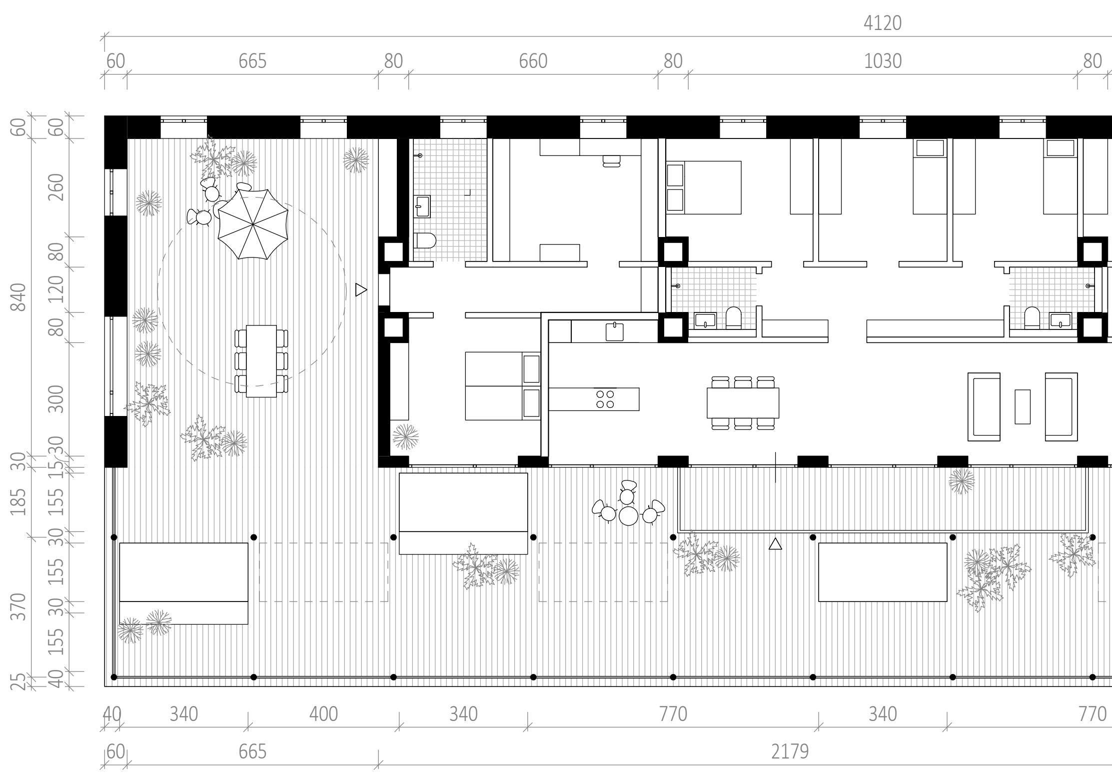


plan material & visualisation.



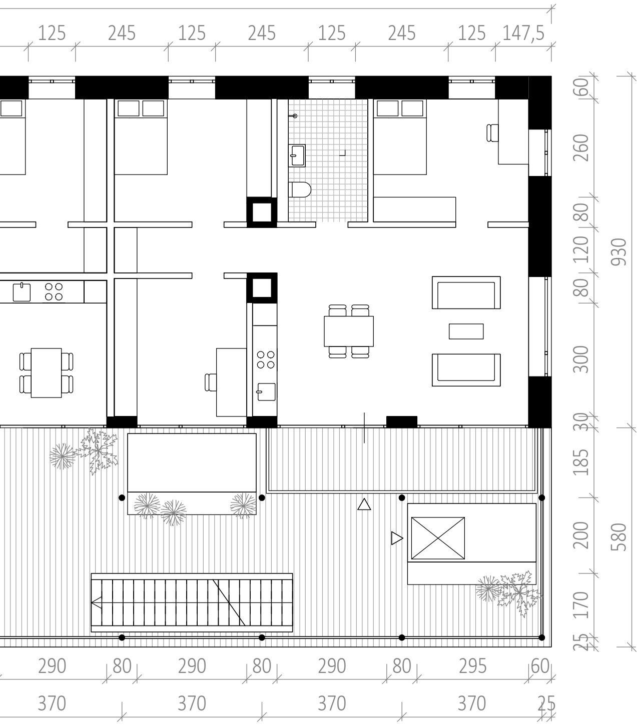
FLOOR PLANS
M 1:200

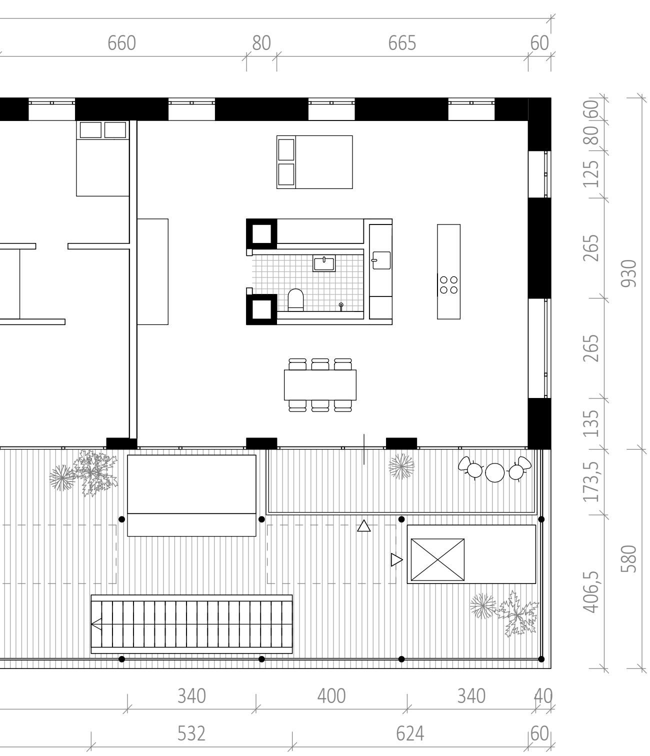
01 |
FIRST FLOOR

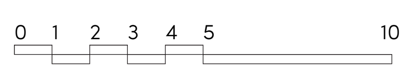


02 |
SECOND FLOOR

plan material & visualisation.







SECTIONS
M 1:200

A |
FACING SOUTH

B |
FACING WEST

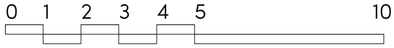
plan material & visualisation.

ELEVATIONS
M 1:200

01 |
EAST

02 |
SOUTH

plan material & visualisation.

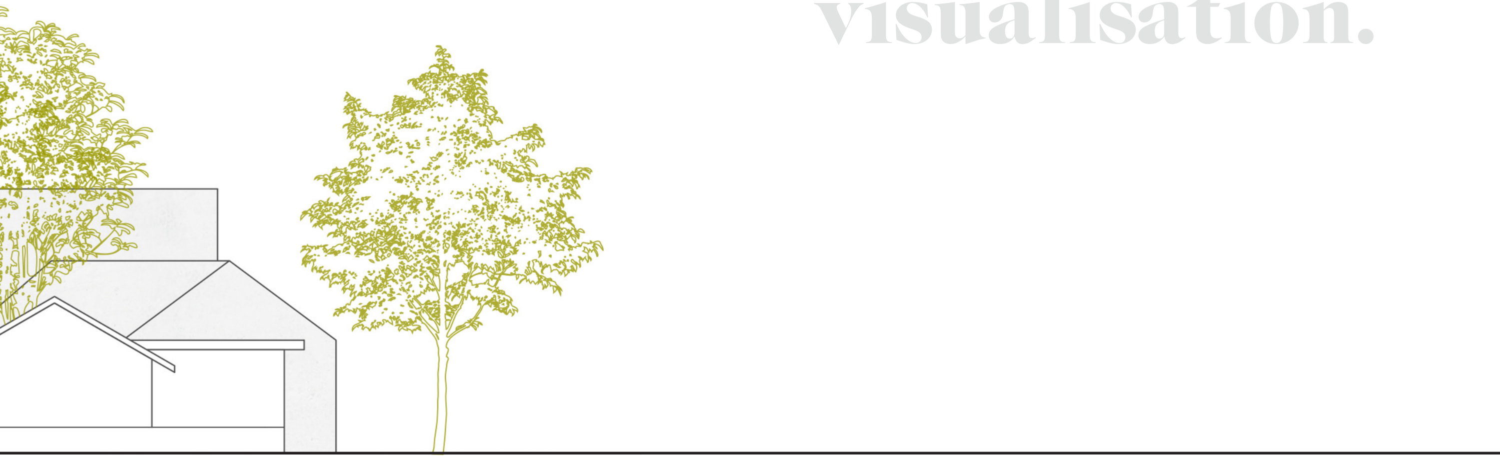


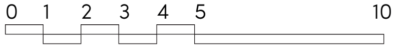
ELEVATIONS
M 1:200

01 |
WEST

02 |
NORTH

plan material & visualisation.





PERSPECTIVE VIEW OUTSIDE

01 | APPROACH - ENTERING THE CO-HOUSING PROJECT

plan material & visualisation.

PERSPECTIVE
VIEWS INSIDE

02 |
GARDEN &
COMMON
SPACE

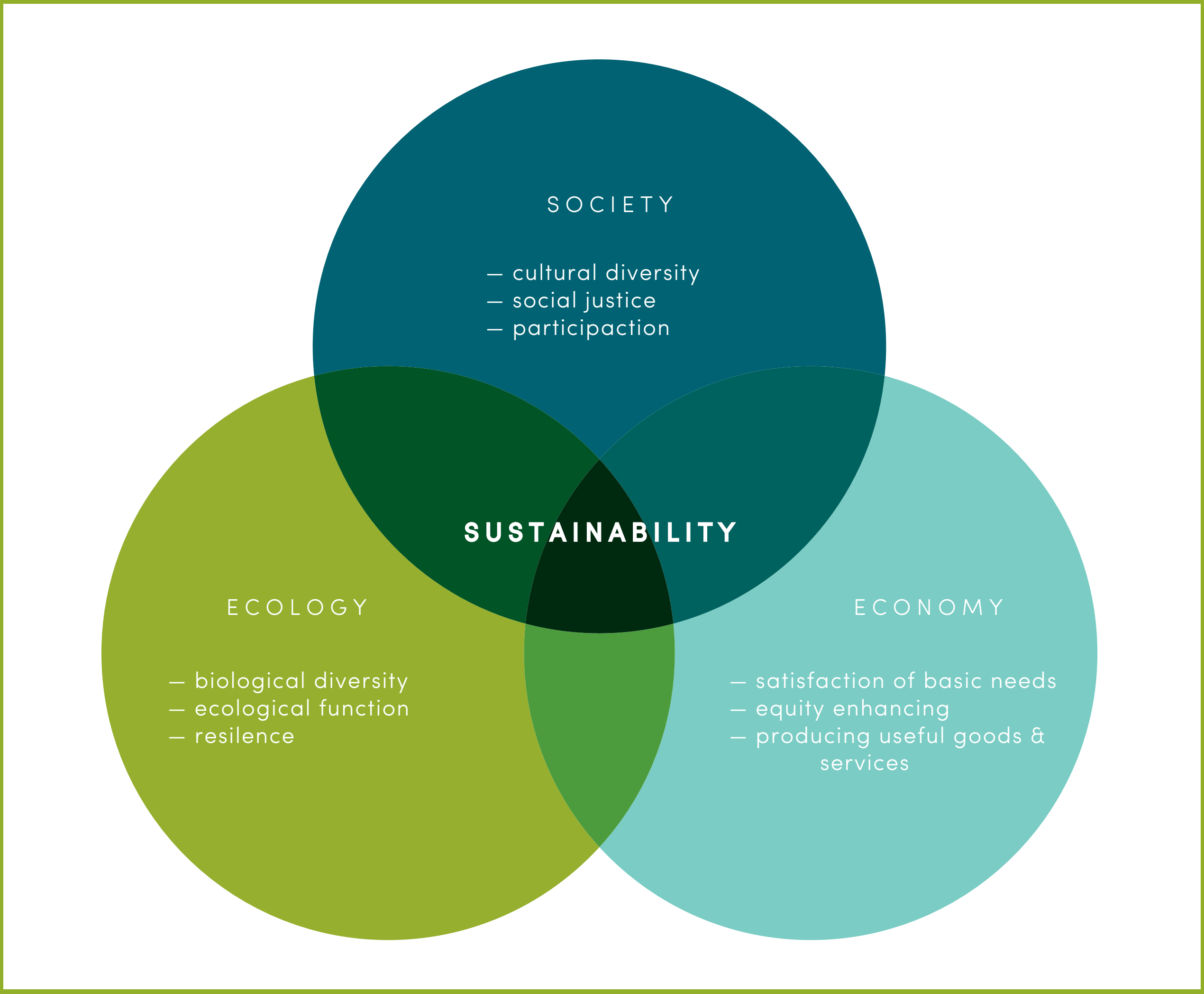
plan material & visualisation.

03 |
COMMON
TERRACE &
CIRCULATION

"A development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

D. MEADOWS, 1998

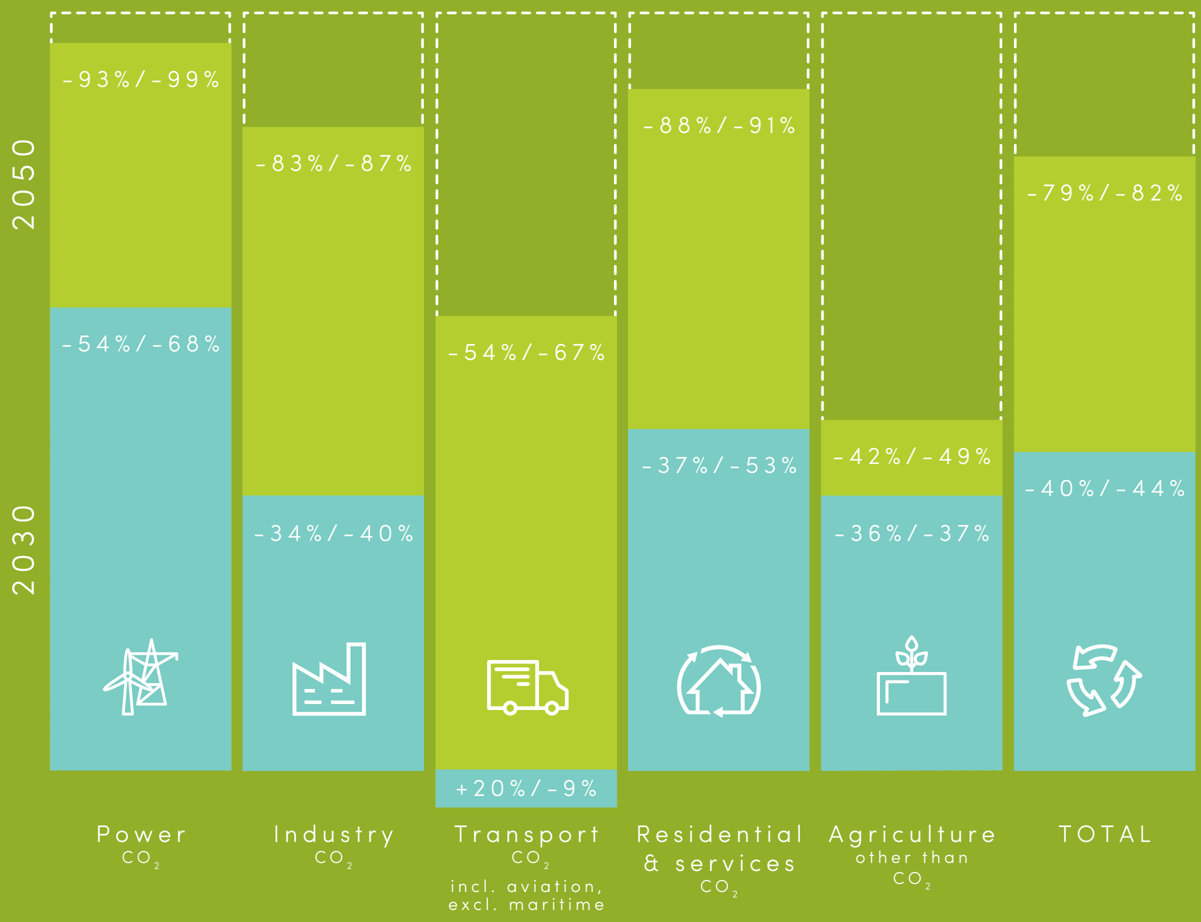
what it could be:



ASPECTS OF SUSTAINABILITY

The EU low-carbon economy roadmap suggests that:

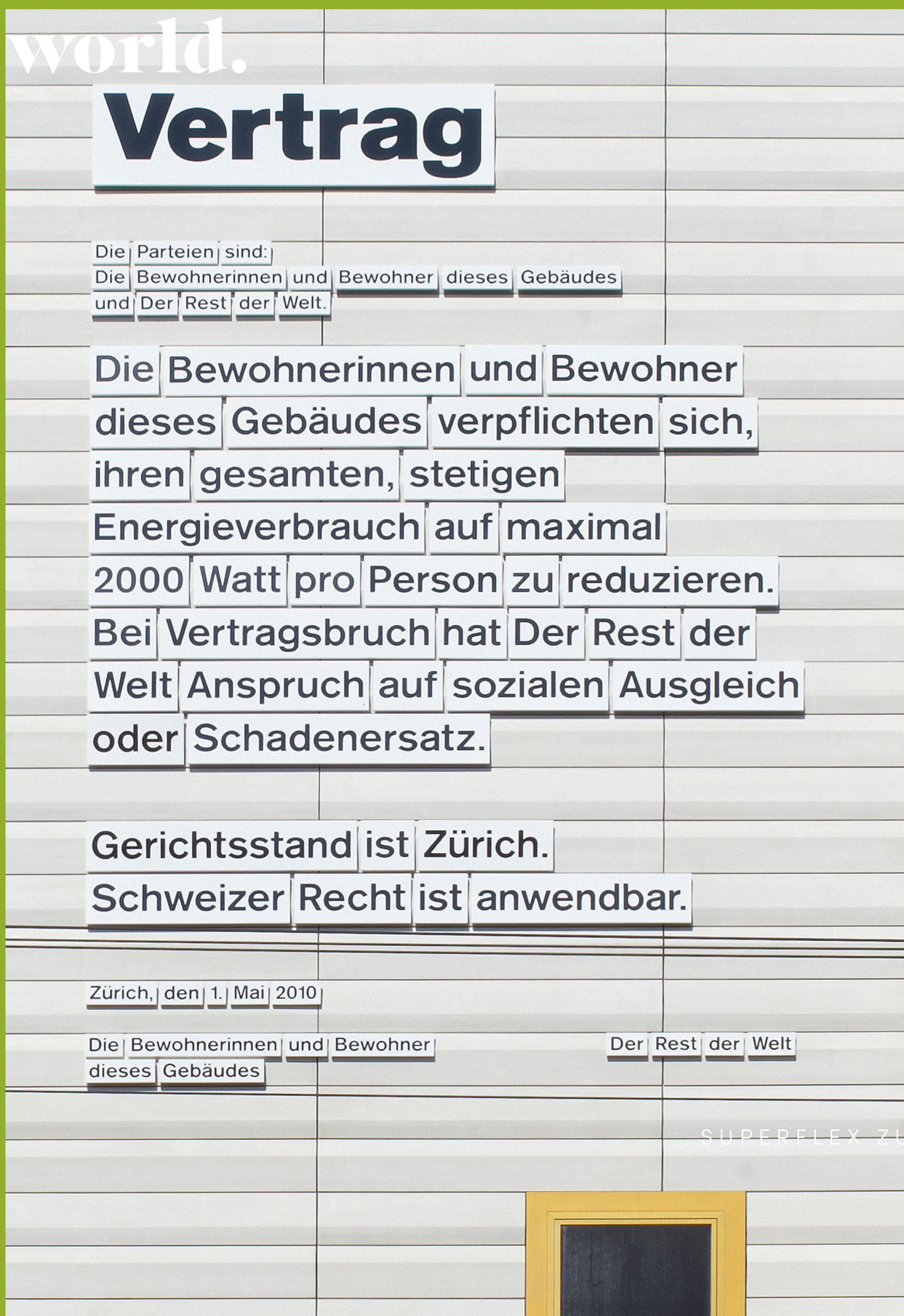
EUROPEAN COMISSION, 2016



what it could be:

- By 2050, the EU should cut emissions to 80% below 1990 levels
- Milestones to achieve this are 40% emissions cuts by 2030 and 60% by 2040
- All sectors need to contribute
- The low-carbon transition is feasible & affordable.

Contract. The parties are: The residents of this building and The rest of the world.



SUPERFLEX ZURICH, 2010

what it could be:

The residents of this building undertake to reduce their total, constant energy consumption to a maximum of 2000 Watts per person. In breach of contract, The rest of the world is entitled to social compensation or damages. Jurisdiction is Zurich, Swiss law is applicable.

IV. building life cycle & environmental assessment

introduction.

INTRO

As the proven effects of human behaviour on our planetary ecosystems and climate, and the resulting effects on human societies become increasingly clear, agreement to mitigate greenhouse gas[19] emissions and adopt to climate change effects within the coming centuries is being established and integrated on national, international and global levels.[20] Also in the national context of Austria, the need to significantly decrease, even halve, energy consumption to mitigate future climate change effects and a "a swift and serious transformation to a carbon-neutral economic system [which] requires a cross-sectoral closely coordinated approach with new types of institutional cooperation in an inclusive climate policy"[21] are required.

Buildings and infrastructure are an essential aspect of human life and a major contributor to the anthropogenic effects on our ecosystem. The built environment and the construction industry are linked to 50% of consumption of resources, up to 40 % of our global energy consumption and hold a 30% share in annual greenhouse gas emissions. Buildings therefor play a major role in our everyday lives, as far as the impact on the environment is concerned and as 90% of our personal time is spent inside of them. [22] In a rapidly evolving and energy demanding present, sustainability is therefore gaining ever more relevance in designing new buildings and infrastructure as well as retrofitting the existing building stock. The sheer number of stakeholders involved in the highly interrelated aspects of the building design and planning process emphasizes the need for clear communication among all parties involved on how to improve the environmental performance of the built environment.[23]

19 Further referred to as GHG
20 (European Commission, 2010; EC, 2011; France et al., 2013; Schnitzer et al., 2014; IDMC, 2015; Savaresi, 2016
21 Schnitzer et al., 2014, p. 53.

Looking at the numbers we see the explicit need to establish a common framework for international target values to improve the environmental performance of buildings as well as to improve the quality and environmental performance of buildings to tackle climate change effects while improving our economies and enhancing living conditions.[24]

To evaluate the environmental performance of buildings over their life cycle, the method of Life Cycle Assessment[25] has

22 UNEP SBCI, 2009, p. 9.
23 Balouktsi, 2016
24 (Zimmermann, Althaus and Haas, 2005; European Commission, 2010; Kellenberger et al., 2012; Schnitzer et al., 2014; Wyss et al., 2014
25 Further referred to as LCA

been widely accepted, standardized and is increasingly applied to assess the built environment LCA provides "an objective process to evaluate the environmental burdens associated with a product, process, or activity by identifying energy and materials used and wastes released to the environment, and [can be applied] to evaluate and implement opportunities to affect environmental improvements"[26].[27]

While the LCA method is commonly used to assess and improve upstream processes, like material sourcing and production of construction products through Environmental Product Declarations[28], comprehensive LCA of buildings is mainly applied to evaluate and document existing buildings but is hardly implemented in the building design process.[29] The lacking or cumbersome integration within the building design process hinders the initial environmental optimization of building designs with a life cycle perspective under consideration of interdepencies between embodied and operational environmental impacts (SEE FIGURE 25).

With already many years of efforts to enhance energy efficiency and reduce operational energy[30] of buildings, embodied energy[31] increasingly dominates the life cycle as can be seen in FIGURE 26.[32] This domination in share is accompanied by an absolute increase of the embodied impact, mainly due to high mass construction, additional insulation and increasingly complex technical systems.[33] Emphasizing the urgency to address this trend is that embodied energy "gains significant importance considering the swift release of emissions, or a 'carbon spike', associated with construction phase emissions [that] can dominate life cycle emissions in the time horizon relevant to adopted climate mitigation goals."[34]

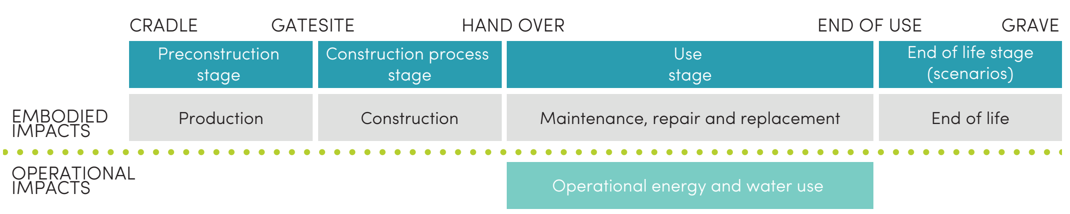


FIGURE 25 | EMBODIED AND OPERATIONAL IMPACTS IN THE BUILDING LIFE CYCLE (TU GRAZ 2016)

26 Zabalza, Scarpellini and Aranda, no date, p. 2
27 CEN, 2006, 2006, 2012; Gschösser, Passer and Marchtrenker, 2013; Frischknecht et al., 2015
28 Further referred to as EPDs
29 Hollberg and Ruth, 2016
30 Further referred to as OE
31 Further referred to as EE
32 Dixit et al., 2012; Ibn-Mohammed et al., 2013; Seo et al., 2016
33 Anderson and Thornback, 2012; Klöpffer, 2014; Wyss et al., 2014
34 Giesekam, Barrett and Taylor, 2015

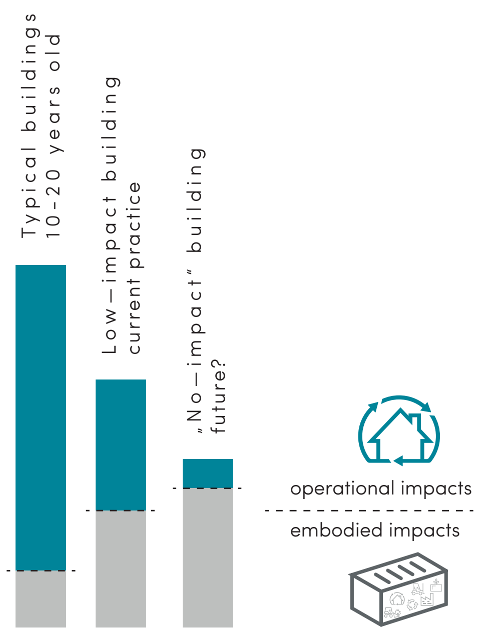


FIGURE 26 | DISTRIBUTION OF EMBODIED AND OPERATIONAL IMPACTS FOR PAST, CURRENT AND FUTURE BUILDINGS. EMBODIED IMPACTS INCREASINGLY DOMINATE THE BUILDING LIFE CYCLE RESULTING IN A "CARBON SPIKE". EVEN FOR HIGHLY ENERGY EFFICIENT AND SELF-SUSTAINING BUILDINGS IN THE FUTURE, A CERTAIN AMOUNT OF OPERATIONAL (EXTERNAL) IMPACTS IS TO BE EXPECTED. (ACC. TO ANNEX 57, TU GRAZ 2016)

Even though a number of LCA tools recently established links to CAD and BIM planning tools they can only in part be used to compare variants but are currently not suitable to indicate a building's embodied impacts in relation to set target values.[35] The existing variety of methods and tools applied, as well as the lack of a harmonized structure of the Life Cycle Inventory[36] furthermore impedes a detailed comparison of assessment results.[37] Regarding future benchmarks on embodied impacts for buildings, this inconsistency of the LCI hinders the comprehensible verification of the fulfilment of set target values during the building design.

At the same time, state-of-the-art planning and building management methods like Building Information Modelling, follow an object-oriented modelling approach and provide potential to integrate life cycle information and LCA during the design process. The increasing application of BIM for building cost calculation or life cycle costing – at times referred to as the "fifth dimension" of BIM – provides valuable knowledge and a potential structure to be applied for process-integrated LCA of buildings. The increasing standardization of BIM in terms of building element structure, Levels of Detail in modelling[38], and intended purpose of the building model in different planning stages furthermore supports a transparent and

35 Takano and Kuittinen, 2013; Hollberg and Ruth, 2016
36 Further referred to as LCI
37 Lasvaux et al., 2014, 2016
38 Further referred to as LOD

comprehensible application of BIM for LCA.[39] Comprehensibility is important to create verifiable and comparable LCA results from BIM-based assessment workflows. Automated assessment processes, visual scripting and building simulation show further potential to include the evaluation and optimization of OE and EE in future design processes.[40]

In order to tackle the outlined challenges and support the integration of comprehensible LCA during the building design process, we build on the advances mentioned and integrate information on embodied impacts into BIM. This enables us to use the model to evaluate the sum of embodied impacts using predefined construction profiles to test different materialization options by linking the process with an existing assessment tool. Furthermore, we present a prototypical method to visualize the embodied impacts using the BIM model, to support intuitive optimization and the communication of assessment results throughout the planning process.

METHODOLOGY

The environmental design process presented (SEE FIGURE 27 ON THE FOLLOWING PAGE) is based on requirements and a building design developed throughout a participatory design process[41] with future inhabitants of a residential co-housing project in Austria.

To assess the environmental performance of the architectural concept in various stages, we perform a simplified LCA through application of the district evaluation spreadsheet tool (DEST) of the Swiss 2000 Watt society, comparing the results to the underlying benchmarks of the 2000 Watt society model.[42] A first assessment comparing different materialization options is based on the program and requirements of the participatory process and serves as an estimate result to further develop the conceptual building design.

For the prototypical method presented, the Swiss tool and values are applied as there are no comprehensive benchmarks for the environmental performance of buildings specifically for Austria. The similarities of Switzerland and Austria in terms of climate and technology level are considered to provide different, yet comparable results. The method presented is expected to also be applicable to specifically Austrian values and benchmarks, if provided with the appropriate structure.

The developed design is then assessed using actual element quantities of the BIM model to refine the LCI. Within the DEST the LCI is structured according to Swiss building element structure eBKP-H which was designed to evaluate building element cost.[43] This element structure is also applied to structure the building elements of the BIM model to serve as a common structure and support data exchange between the DEST and the BIM model.[44] This is used for the

39 NATSPEC, 2013; ASI, 2015; BIMForum, 2015; CEN, 2016
40 Kensek, 2015; Norouzian-Maleki et al., 2015; Hollberg and Ruth, 2016
41 Further referred to as PDP
42 Kellenberger et al., 2012
43 SIA, 2009
44 Autodesk Revit, www.autodesk.de

tools & methods.

extraction and transfer of quantities as well as for the integration of life cycle information in the BIM model, which is automated through the application of visual scripting.[45]

The method presented aims to explore potentials of using BIM for a process-integrated assessment to improve environmental impacts considering the building life cycle. Focusing on embodied impacts the goal of this workflow is to use the BIM model to provide element quantities for LCA with different materialization options as well as to present the results to the design team and other stakeholders throughout the process.

TOOLS

PARTICIPATORY DESIGN PROCESS - PDP

It is vital to get people involved in processes and decisions made on their behalf. Even more so with a topic as intimate as housing, deeply related to the inherently human aspects of community and privacy. Creating shelter and housing is the archetypical task of people acquiring space for their safety and comfort. In contemporary times this task is mostly performed by architects and planners, who through their thorough knowledge are expected to be able to design and build high quality, comfortable and liveable spaces and buildings. In the few cases, where the involvement of future inhabitants seems possible it is often considered to unnecessarily complicate the process and is therefore avoided. However, a common process of the architect, as an expert for spatial design and building requirements and also the future inhabitants, as experienced experts of everyday life in buildings can lead to high quality results, identification with the building and the community established and has potential to be an instructive and enlightening experience for all parties involved in the process.[46]

The starting point of the project presented in this thesis was the discussion with a private group of people in Upper Austria about their vision of creating a community housing project. The participatory process of developing a common vision, the requirements and spatial program for a common housing project performed with this group where the basis for the architectural concept presented as a case study in this work.

45 Autodesk Dynamo, www.autodesk.de

46 Hofmann, 2014

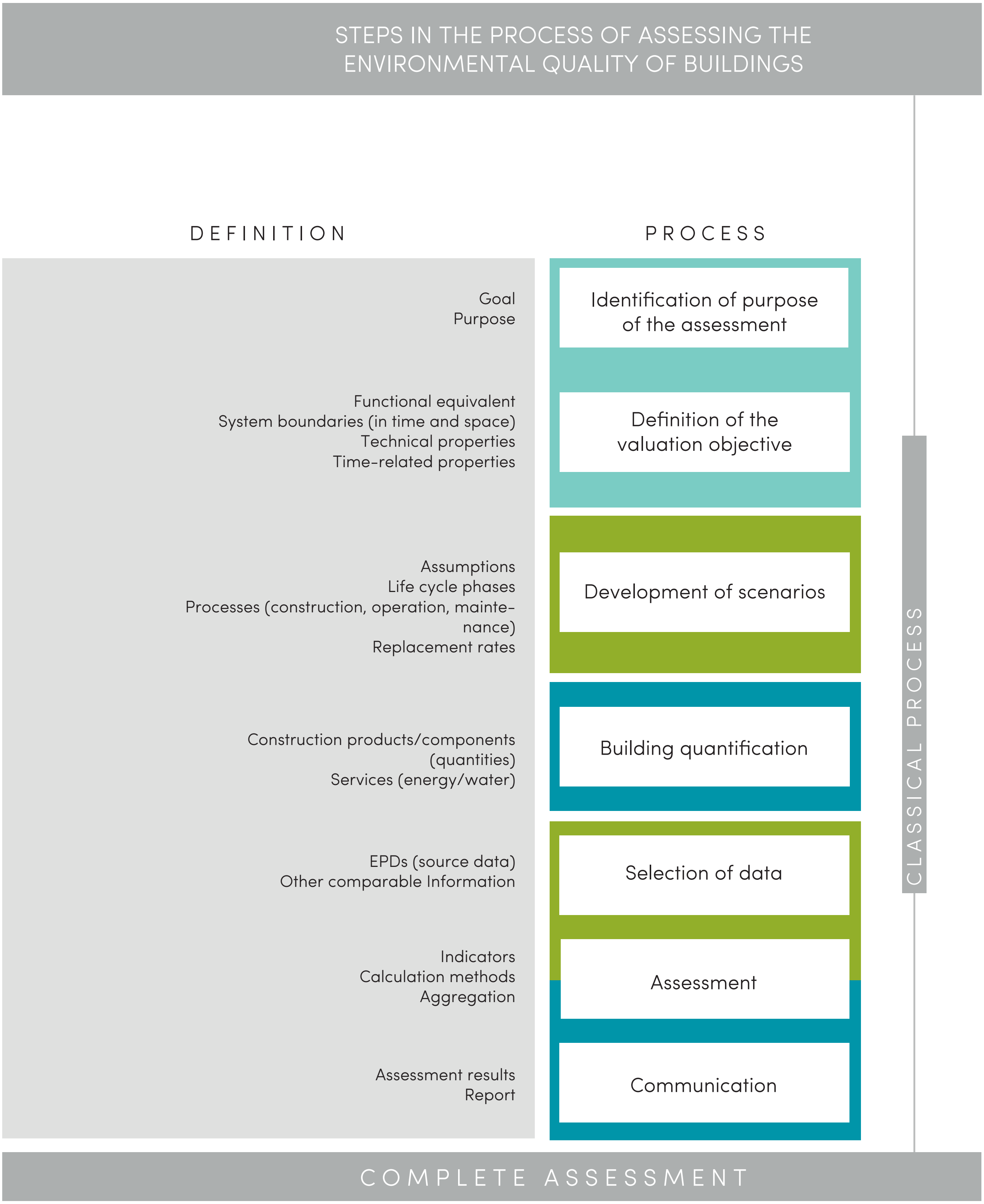
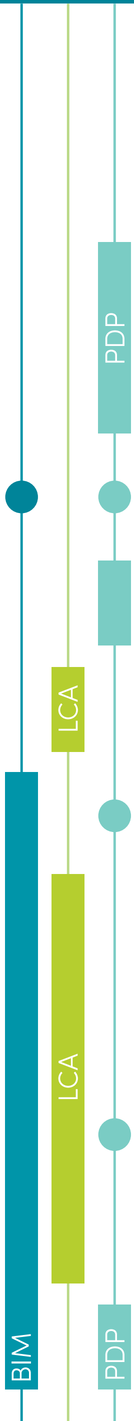


FIGURE 27 | CONVENTIONAL STEPS OF THE ENVIRONMENTAL ASSESSMENT OF BUILDINGS (ACC. EN 15978) COMPARED TO THE STEPS OF THE ENVIRONMENTAL DESIGN PROCESS PRESENTED.

STEPS OF PARTICIPATORY DESIGN PROCESS & ENVIRONMENTAL ASSESSMENT INTEGRATING BUILDING INFORMATION MODELLING

tools & methods.



PROCESS	DEFINITION
Ideation	Vision, purpose and goal
Requirements	Common vision Functional requirements Spatial program
Conceptual design	Building massing Distribution of functions
Concept elaboration	Feedback on conceptual design Elaboration on spatial concept and layouts
Scenarios and estimation	Scenarios for construction, energy standard and supply mix Generic estimation of environmental performance
Developed design	Concept for building structure, spatial seperation and services Creation of BIM model for developed design
Building quantification	Quantitification from BIM model of developed design Building elements structured to match with assessment tool
Refinement	Scenario refinement (construction and energy mix data) Refinement of assessment with quantitites from BIM model
Final building design	Development of final building design, refinement BIM model
Visualisation	Transfer of assessment results and integration in BIM model Visualisation workflow for comprehensive presentation of assessment results on the BIM model
Communication	Visualisation and presentation of design and LCA results

ENVIRONMENTAL DESIGN PROCESS

BUILDING INFORMATION MODELLING - BIM

Building Information Modelling is a contemporary digital planning and building management method. A building information model (BIM model) is a component-specific building database that can be used to hold, update and document information related to the building life cycle. It is mainly represented through a digital 3D building model of which elements' information can be extracted in various ways like plans, schedules and lists, visualizations as well as other geometric and alphanumeric information. The idea behind BIM is to support collaboration amongst all stakeholders involved and provide consistent information throughout the building life cycle. This means BIM is not only applied during the design and planning stages of a building, but is supposed to be used for documentation, operation and maintenance as well as disposal, therefor covering the whole life cycle of a building. The object-based BIM model is increasingly used for cost management and life cycle analysis (SEE FIGURE 04). In the present thesis BIM is used to extract building quantities for LCA as well as to host life cycle information on the environmental performance of the building elements. The 3D model can also be used as a communication tool to other professionals as well as clients and other stakeholders. In this way the BIM model was also used in communicating the design and different aspects of the concept to the housing community.

As a BIM database is able to hold about any desired number of alphanumerical information it is very well suited to also incorporate life cycle information for the environmental assessment of buildings. A prototypical example of integrating life cycle data in a structured way to use the BIM model for the assessment and the visualization of results was developed and applied for communication within the participatory design process. The method presented was developed using the popular BIM authoring software Revit. [47]

LIFE CYCLE ASSESSMENT - LCA

Looking at the aforementioned problems and targeted goals one might wonder how we will know if we are doing well in achieving environmental goals, e.g. how to evaluate the effectiveness of our efforts. Life Cycle Assessment is scientifically accepted and the only standardized method developed against this background.[48] LCA is a method to evaluate the various environmental effects of a process, product or whole building over its whole life cycle. For buildings this means looking into the impact of sourcing and production of the materials and construction products used, the environmental impact and energy consumption generated through the construction and maintenance of a building, the operational energy demand and its environmental impact as well as the impact of recycling, reuse and eventually the disposal of building components. To structure these life cycle phases LCA established standardized life cycle

47 Autodesk Revit, http://www.autodesk.de/products/revit-family/overview, Access 04/09/2016

48 CEN, 2006, 2014; Seo et al., 2016

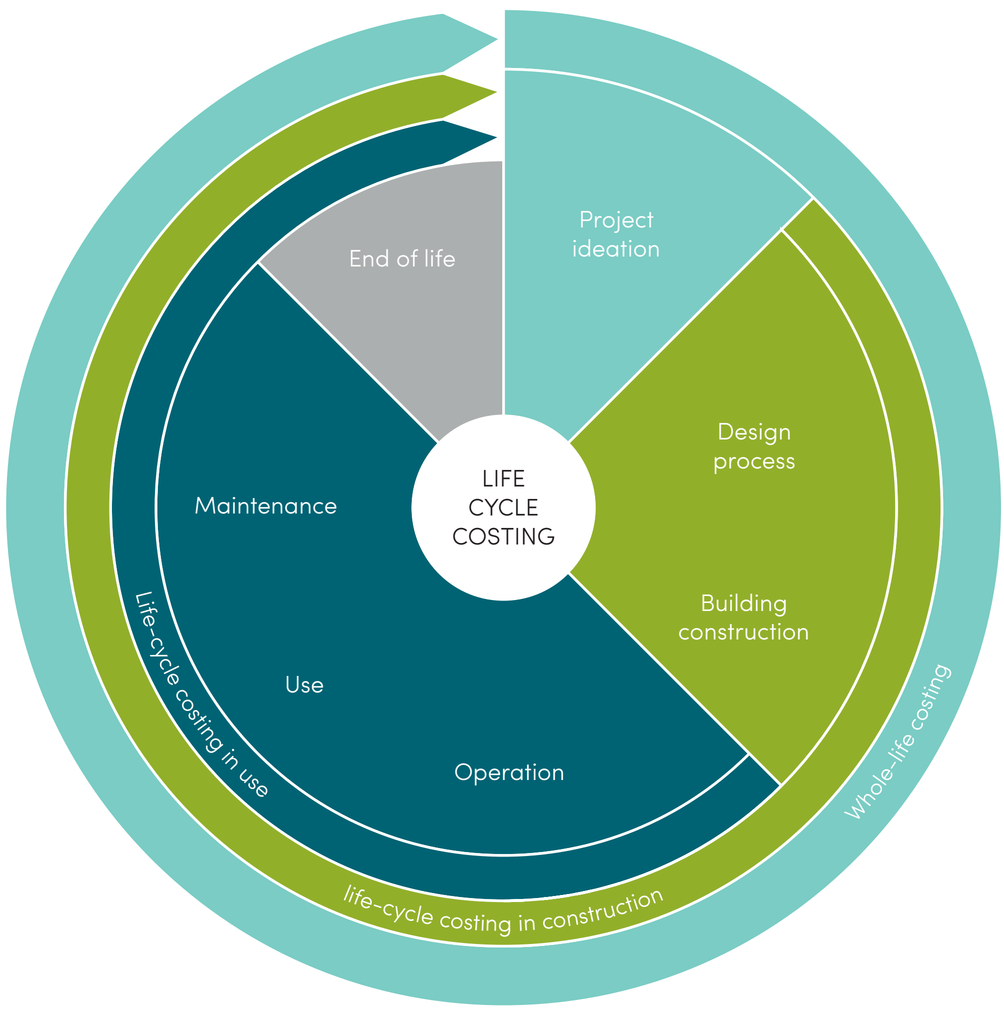


FIGURE 28 | THE BUILDING LIFE CYCLE BASED ON THE LIFE CYCLE COSTING APPROACH (ACC. TO ISO 15686-5:2008, TU GRAZ 2016 modules (SEE FIGURE 29). A detailed assessment of a building's life cycle proves the importance of the often neglected embodied impacts, which mean the environmental impacts embedded in construction, product and materials. In the assessment of the case study presented embodied impacts are brought into focus as materialization is one of the main aspects in architectural design and therefore highly influenced by architects' decisions.

The environmental impacts originating from the processes grouped within these modules are specified through a number of indicators describing the different effects caused by these processes. The environmental indicators describe impacts like Global Warming Potential, Primary Energy Demand of non-renewable resources (PEDnr), which are the two impact categories used to evaluate the environmental performance in this work, next to many others indicating environmental effects at a local, regional and global level.

The method of LCA is used for the assessment of the building concept, through the application of the 2000 Watt society district evaluation spreadsheet tool (DEST). The methodology and requirements for the calculation of the presented LCA are defined in SIA Merkblatt 2040.[49] The database used is EcoInvent version 2.2 with calculations based on a building Reference Service Period of 60 years.

49 Pfäffli and Preisig, 2010

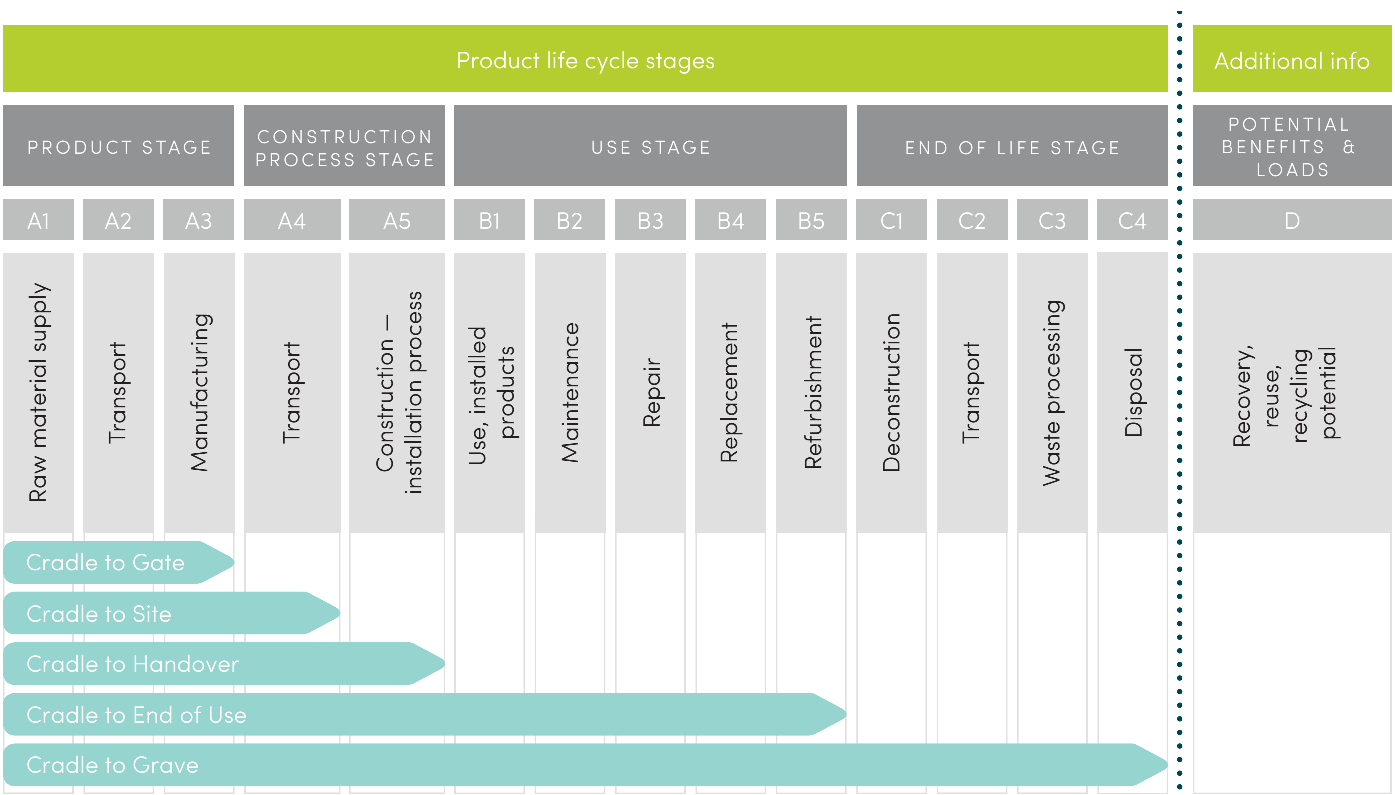


FIGURE 29 | LIFE CYCLE STAGES & SYSTEM BOUNDARIES (ACC. CEN TC 350 (EN 15804:2012), TU GRAZ 2016)

2000 WATT SOCIETY

The simple calculation of how much energy and resources each and every person could consume on our limited planet theoretically, the so-called personalized "environmental budget", is the basic idea behind the Swiss 2000 Watt society.[50] Dividing the environmentally bearable consumption by the number of people on the planet brought about the ambitious goal and opened the opportunity to create benchmarks to evaluate and rate lifestyles in general and the performance of the built environment in particular. A decade ago, ETH Zurich calculated the constant energy consumption per capita must not exceed 1000 Watt as a global average, while at the same time IPCC calculated that greenhouse gas emission per capita should not exceed one ton per year.[51] The 2000 Watt society therefore provides environmental benchmarks for the development of districts and buildings in impact categories of Global Warming Potential and Primary Energy Demand (PEDnr and PEDtotal). Swiss government and citizens thereafter agreed on target values to limit the constant energy consumption per capita from currently around 5.000 Watt to 2.000 Watt until the year 2100 to support sustainable future development with a global perspective. These ambitious goals mean for Swiss people to aim for three times less primary energy consumption and eight times less CO2eq emissions. The foundation for the integration of the 2000 Watt society model has been put forth by the Swiss Society of Engineers and Architects (SIA) within the SIA-efficiency path energy.[52]

CRB EBKP-H

The eBKP-H building component structure, is designed for cost estimation as well as to comprehensibly structure building components for tendering and detailed building cost calculation.[53] It structures the building components into main groups, element groups and specific elements. The structure is prepared to be used for early stage cost estimation but also intended to assess and re-cycle actual cost data of later planning stages to refine the initial estimate values. This process of early stage estimation and constant refinement of values is exemplary for how to also integrate incremental LCA in the design process. It is applied in a slightly adopted way

50 2000 Watt society, http://www.2000watt.ch/die-2000-watt-gesellschaft/ Access 04/09/2016

51 Kellenberger et al., 2012

52 SIA-Effizienzpfad Energie. Comprises the SIA Merkblatt 2040 and associated documentation SIA D 0236.

53 SIA, 2009

in the assessment within the 2000 Watt society DEST. As the eBKP-H component structure was also developed considering the application in a BIM environment it very well fits the element structure processed within a BIM model. To support data exchange between the model and the DEST, this common structure was therefore used to also structure the elements within the BIM model of the case study using custom parameters in Revit.

VISUAL SCRIPTING

Visual scripting provides a graphical scripting interface to manipulate parametrised geometry and alphanumerical data. In our case Dynamo[54] was used to access the BIM model geometry and alphanumeric information within Revit as well as to exchange data with the DEST using spreadsheet software Excel.[55] A number of processes and data transfers were automated through a custom script in Dynamo that connects the BIM model and the 2000 Watt DEST by using the common element structure of eBKP-H to correctly identify building elements and assign information.

The processes to be automated to support the integrated LCA and communication of results are:

a. Extraction of element quantities from the BIM model
b. Transfer of quantities to 2000 Watt DEST
c. Assessment within 2000 Watt DEST based on BIM quantities and scenario settings.
d. Extraction of overall results on building performance in relation to established benchmarks.
e. Extraction of detailed assessment data and results (component-specific embodied impacts)
f. Integration of component-specific impacts into building elements in the BIM model
g. Visualization of component-specific impacts using the BIM model

CASE STUDY AND SCENARIOS

Basis of the environmental assessment was a building design developed through a participatory process. The three-storey residential building is comprised of a compact cubic volume (no basement) hosting the flats as well as an attached skeleton structure, which functions as circulation and external common space. The cubic main building therefore is the functional equivalent throughout all scenarios assessed. The LCA results and level of fulfilment of set benchmarks are based on the main building's components, for which quantities have been extracted from the building model to calculate embodied impacts.

To identify well suited solutions for the further building design process, different scenarios were developed, combining options for materialisation (construction profiles, CP), envelope quality and technical services (energy standard, ES), as well as multiple options for the energy mix used to supply the operational energy demand (energy mix, EM) (SEE FIGURE 30).

54 Autodesk Dynamo, http://www.autodesk.com/products/dynamo-studio/overview, Access 06/10/2016
55 Microsoft Excel, https://products.office.com/en-us/excel, Access 06/10/2016

case study & scenarios.

CONSTRUCTION PROFILE		Overview materialisation
CP1	Massive, concrete	Concrete walls, concrete ceiling and roof construction, wood/aluminum windows, lightweight stud partition
CP2	Lightweight, timber	Wood frame construction walls, wood-concrete composite floor and roof construction, wood/aluminum windows, lightweight stud partition
CP3	Brick-timber (custom)	Perforated brick walls, coffered wooden ceiling and roof construction, wood/aluminum windows, plasterboard partition

ENERGY STANDARD		Description
ES1	muken2008	Operational energy demand and technical systems based on requirements of SIA 380/1 and depending on building type. In our case assumed heating demand is 65 MJ/m^2 (=18,1 kWh/m^2a), which corresponds to OIB class A (25 kWh/m^2a).
ES2	Minergie	Simplified calculation within 2000 Watt DEST using 80% of requirements of SIA 380/1. Heating demand (52 MJ/m^2a=14,4 kWh/m^2a) therefor corresponds to OIB class A+ (15 kWh/m^2a).
ES3	Minergie-P	Simplified calculation using 60% of requirements of SIA 380/1. Heating demand (39 MJ/m^2a=10,8 kWh/m^2a) therefor almost fulfills OIB class A++ (10 kWh/m^2a).

ENERGY MIX		Heating	Domestic Hot Water	Electricity
EM1	Reference: Oil and gas, electricity EU	50% Oil 50% Gas	50% Oil 50% Gas	UCTE-Mix
EM2	Renewable 1: Biomass and electricity AT	50% Biogas DHCP 50% Wood DHCP	50% Biogas DHCP 50% Wood DHCP	AT electricity, medium volt., at grid (custom)
EM3	Renewable 2: Solar, heat pump (HP) and PV own/grid	50% HP (air/water) 50% firewood	50% solar 50%% HP (air/water)	50% PV own 50% PV grid

FIGURE 30 | DESCRIPTION OF OPTIONS FOR MATERIALISATION (CP), ENVELOPE QUALITY AND TECHNICAL SERVICES (ES), AND ENERGY MIX USED TO SUPPLY OPERATIONAL ENERGY DEMAND (EM)

Following the strategy of improving the building's environmental performance through efficiency, consistency and sufficiency a total of 27 scenarios was tested (SEE FIGURE 31).

- EFFICIENCY

Testing different energy standards (ES) for the building follows the attempt to increase building efficiency with the goal of lowering operational energy demand. The parameter ES is also linked to the impacts embodied in building products and technical systems. An improvement in terms of insulation and building efficiency therefore, generally speaking, leads to higher embodied impacts while expectedly lowering the operational energy demand and its impacts in the future.

- CONSISTENCY

While keeping the cubature of the building design as developed in the participatory process, a number of materialisation options were tested. This way the influence of the construction profile (CP) on the overall performance could be assessed while keeping consistency in the functional equivalent, the building design. Also the testing of different options for the energy mix (EM) used to provide the operational energy demand follows a consistency approach.

- SUFFICIENCY

In the context of this case study the aspect of sufficiency was specifically addressed throughout the participatory design process, involving future residents in the definition of their required spaces. By questioning and decreasing the amount of individual flat area while increasing common spaces, sufficiency in terms of building area, which has major influence on both embodied and operational impacts, was addressed in the design process.

RESULTS

In the following, results are first of all presented for the overall performance of the individual building scenarios assessed. Based on these results a group of well-performing scenarios could be identified and investigated in more detail. A best scenario in terms of embodied impacts was identified and the detailed, component-specific, results are presented and discussed in the following. For the refined LCI of this assessment, quantities have been extracted from the BIM model. Detailed LCA results are then presented using conventional diagrams as well as a novel method of visualizing embodied impacts using the BIM model. The three construction profiles are also visually compared to test the visualisation workflow and show its potential for communication of design variants and assessment results to clients and other stakeholders.

SCENARIO RESULTS

The LCA results of the scenario assessments were evaluated in terms of their total environmental impacts regarding the impact categories of Global Warming Potential (GWP) and Primary Energy Demand of non-renewable sources (PEDnr). Results are structured into embodied impacts (construction and demolition + replacement), operational (operational energy demand) and

Scenario	INFLUENCE ON EMBODIED AND OPERATIONAL IMPACTS: Constr. Profile (CP) 1	2	3	Energy Standard (ES) 1	2	3	Energy Mix (EM) 1	2	3
1	x			x			x		
2		x		x			x		
3			x	x			x		
4	x				x		x		
5		x			x		x		
6			x		x		x		
7	x					x	x		
8		x				x	x		
9			x			x	x		
10	x			x				x	
11		x		x				x	
12			x	x				x	
13	x				x			x	
14		x			x			x	
15			x		x			x	
16	x					x		x	
17		x				x		x	
18			x			x		x	
19	x			x					x
20		x		x					x
21			x	x					x
22	x				x				x
23		x			x				x
24			x		x				x
25	x					x			x
26		x				x			x
27			x			x			x

FIGURE 31 | OVERVIEW OF ASSESSMENT SCENARIOS WITH DIFFERENT OPTIONS FOR CONSTRUCTION PROFILE (CP), ENERGY STANDARD (ES) AND OPERATIONAL ENERGY MIX (EM) building induced mobility. Building induced mobility is a parameter set forth by the 2000 Watt society model, which includes the environmental impacts caused by transfer from or to the building, based on the location of the building and the quality of the connection to the public transit networks. As the site location of the project is fixed, the focus was on identifying suitable building scenario based on the improvement of the variable parameters of embodied and operational impacts in both impact categories.

In a first step, all 27 scenarios were assessed and the sum of embodied and operational impacts (total impacts) analysed regarding the fulfilment of the target values for PEDnr and GWP (SEE FIGURE 32).

Scenarios	PEDnr Total	PEDnr Construction and demolition	PEDnr Operation	GWP Total	GWP Construction and demolition	GWP Operation
1	165%	78%	213%	289%	81%	997%
2	167%	83%	213%	280%	69%	997%
3	164%	75%	213%	279%	69%	997%
4	144%	84%	177%	252%	86%	818%
5	146%	89%	177%	243%	73%	818%
6	143%	81%	177%	242%	73%	818%
7	129%	92%	150%	226%	94%	676%
8	130%	94%	150%	214%	79%	676%
9	128%	88%	150%	216%	80%	676%
10	54%	78%	41%	131%	81%	299%
11	56%	83%	41%	121%	69%	299%
12	53%	75%	41%	121%	69%	299%
13	56%	84%	40%	130%	86%	280%
14	57%	89%	40%	120%	73%	280%
15	55%	81%	40%	120%	73%	280%
16	58%	92%	40%	133%	94%	264%
17	59%	94%	40%	121%	79%	264%
18	57%	88%	40%	122%	80%	264%
19	36%	84%	10%	80%	86%	59%
20	38%	89%	10%	70%	74%	59%
21	35%	81%	10%	70%	73%	59%
22	37%	90%	8%	81%	91%	49%
23	39%	95%	8%	72%	78%	49%
24	36%	87%	8%	71%	78%	49%
25	39%	98%	7%	86%	99%	41%
26	40%	100%	7%	74%	83%	41%
27	38%	93%	7%	75%	85%	41%

FIGURE 32 | RESULTS OF SCENARIOS FOR EMBODIED (CONSTRUCTION AND DEMOLITION) AND OPERATIONAL IMPACTS. PERCENTAGE VALUES REPRESENT THE FULFILMENT OF TARGET VALUES.

Arranging the data (SEE FIGURE 33) shows three clusters (green, orange, red), which result from the energy mix chosen for the scenarios.

· Red cluster: Scenarios 1-9, applying EM1 where not able to meet either GWP nor PEDnr target values, due to the high impacts caused by building operation.
· Orange cluster: Scenarios 10-18, applying EM2 are able to meet requirements of PEDnr, however fail to fulfil GWP benchmarks.
· Green cluster: Only the scenarios 19-27, which apply energy mix EM3 manage to fulfil the target values in both impact categories, PEDnr and GWP.

Scenario results showed the green cluster of scenarios 19-27 should be further investigated. As these scenarios were already able to fulfil the target values for both impact categories in general, focus was laid on improving embodied and operational impacts using impact category GWP only. This is supported by the fact that GWP still shows a certain variety of the results, while PEDnr only showed slight percentage changes. As can be seen in FIGURE 08, GWP still shows a spread of 26% for embodied and 18% for operational impacts, while PEDnr is within 16% for embodied and 3% for operational impacts. Closer examination of these results now shows trends according to chosen construction profile (CP) and energy standard (ES), with the latter influencing both

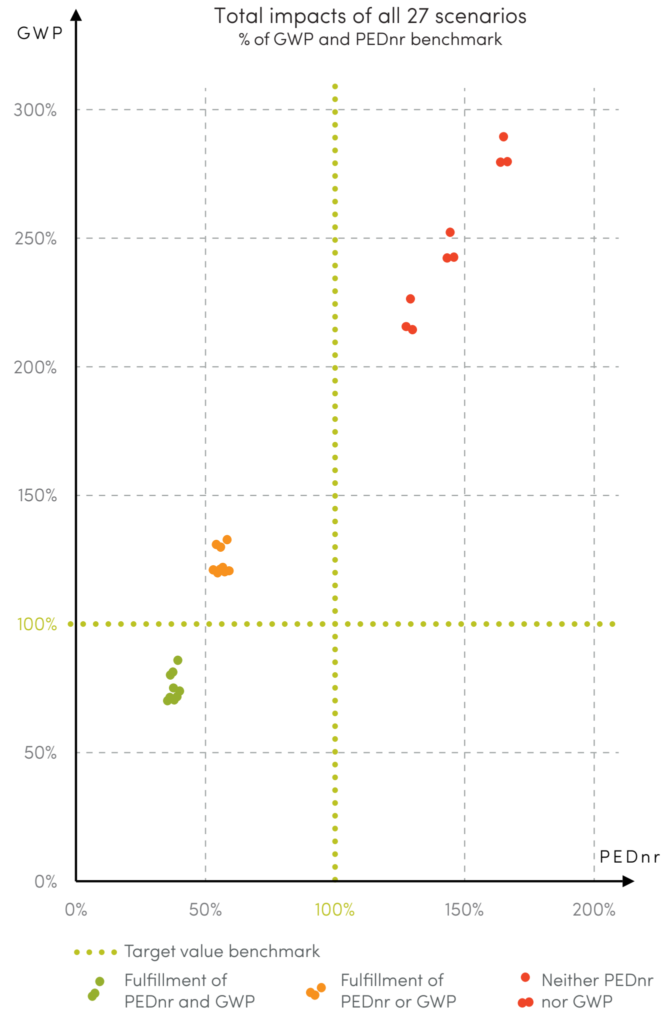


FIGURE 33 | GRAPH SHOWING THE FULFILMENT OF TARGET VALUES FOR THE TOTAL IMPACTS OF EACH SCENARIO IN IMPACT CATEGORIES PEDNR AND GWP. CLUSTERS OF THE SCENARIOS RESULTING FROM CHOSEN ENERGY MIX (EM) CAN BE CLEARLY IDENTIFIED.

embodied and operational impacts, which is indicated by a clear tilt of the CP trend (SEE FIGURE 34). While the E1 scenarios cause the highest operational impacts (of scenario 19-27), they are still performing well within the benchmarks and are the scenarios with the least embodied impacts due to reductions in insulation material and technical systems. A further reduction of operational impacts (OI) by choosing ES2 or ES3, leads to an increase in embodied impacts (EI) for all construction profiles as insulation and technical systems are added.

Based on the premise of reducing embodied impacts - and as scenarios 19-27 are all applying EM3, which is the best performing, renewable energy mix scenario - scenarios 20 and 21 (CP2 and CP3, each with ES1 and EM3) can be considered suitable construction profiles for the further design process.

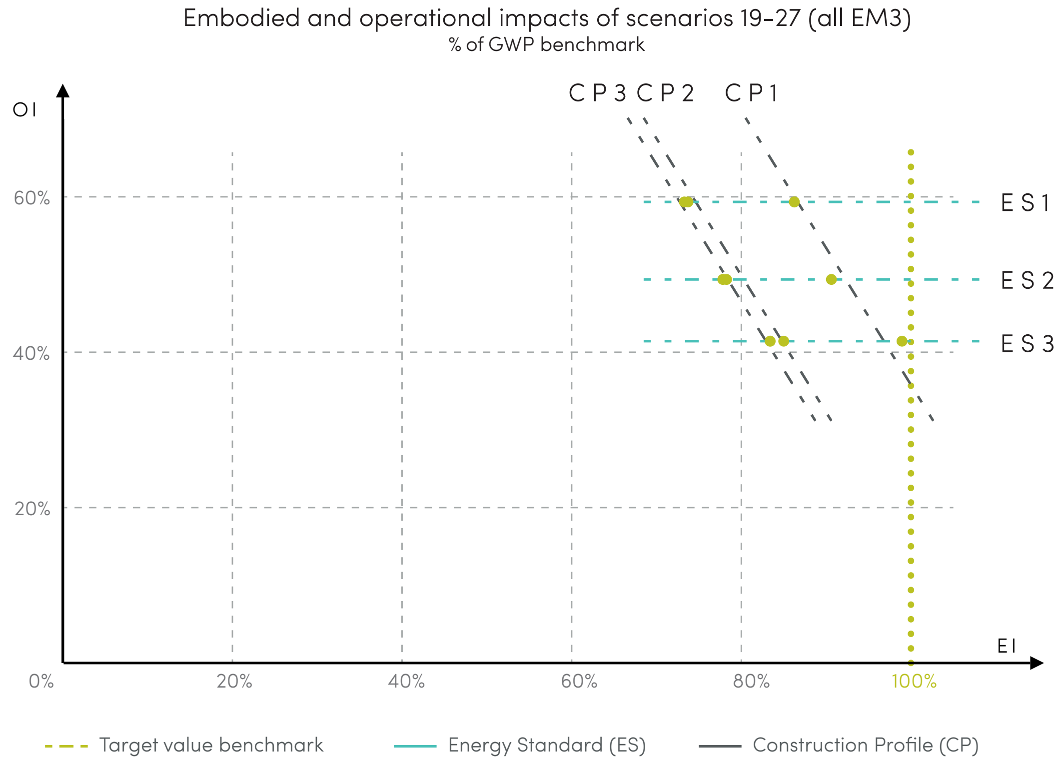


FIGURE 34 | EMBODIED AND OPERATIONAL IMPACTS (EI AND OI) OF SCENARIOS 19-27 (ALL EM3). TRENDS RESULTING FROM CHOSEN CONSTRUCTION PROFILE (CP) AND ENERGY STANDARD (ES) CAN BE IDENTIFIED. DEPENDING ON ES, OI CAN BE REDUCED WHILE EI ARE INCREASING.

DETAILED RESULTS

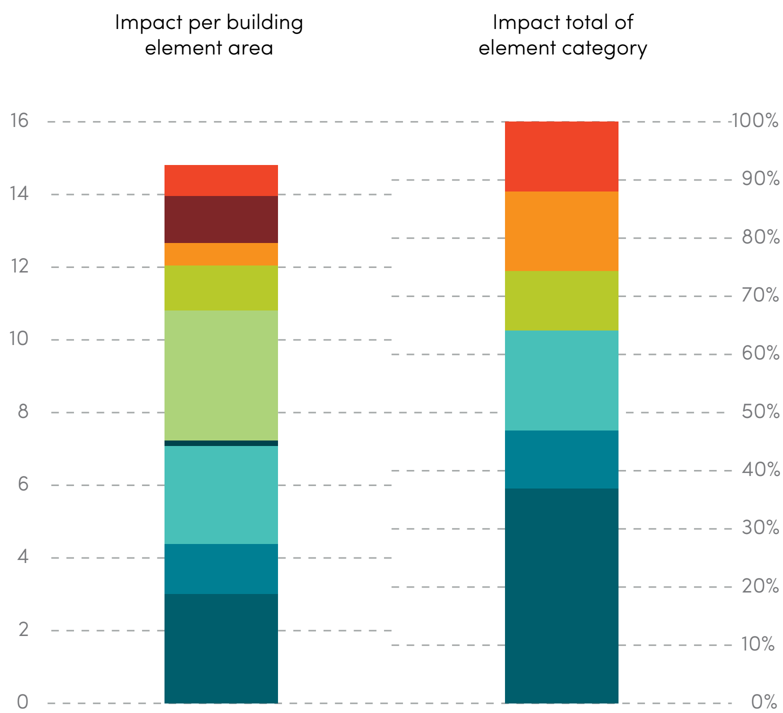
The best performing scenario (SEE FIGURE 32) for both total and embodied impacts, scenario 21 (SEE FIGURE 35), is chosen for further examination of the detailed results.

Scenario 21		Description: Heating	Description: Domestic Hot Water	Description: Electricity
CP3	Brick-timber (custom)	Perforated brick walls, coffered wooden ceiling and roof construction, wood/aluminum windows, plasterboard partition		
ES1	muken2008	Operational energy demand and technical systems based on requirements of SIA 380/1 and depending on building type. In our case assumed heating demand is 65 MJ/m² (=18,1 kWh/m²a), which corresponds to OIB class A (25 kWh/m²a).		
EM3	Renewable 2: Solar, heat pump (HP) and PV own/grid	50% HP (air/water) 50% firewood	50% solar 50%% HP (air/water)	50% PV own 50% PV grid

FIGURE 35 | OVERVIEW OF OPTIONS COMPRISING SCENARIO 21, WHICH WAS CHOSEN TO INVESTIGATE IN DETAIL

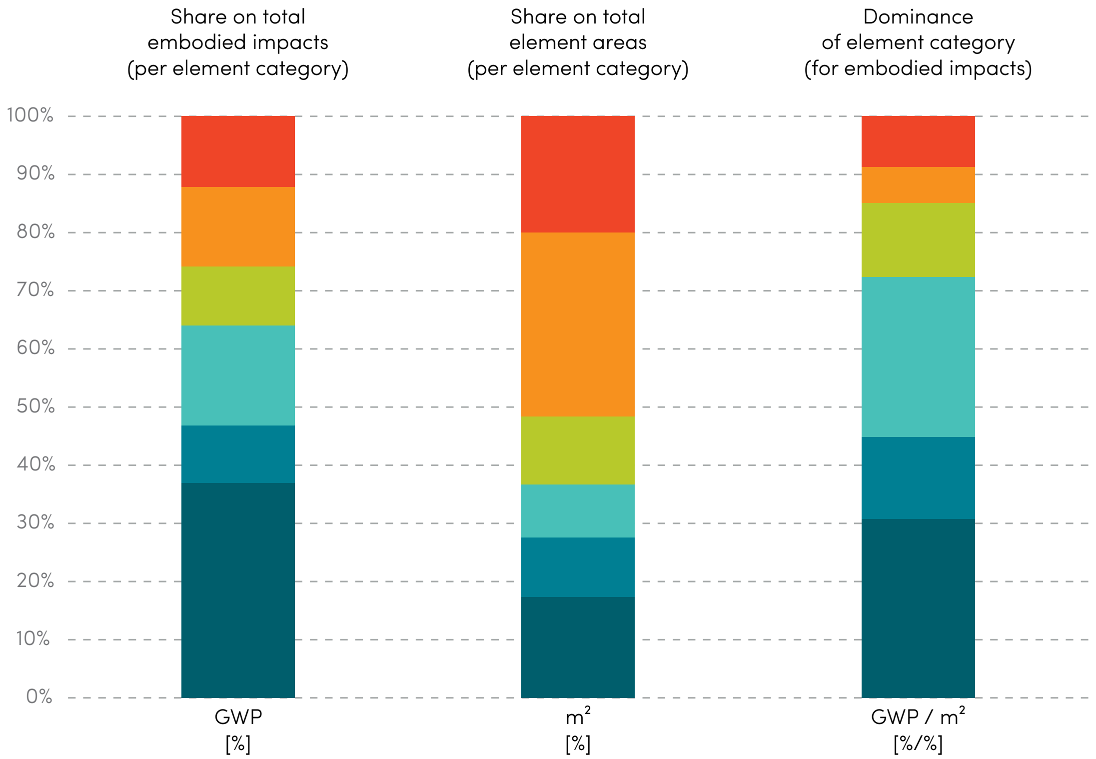
Based on a specific construction profile and energy standard, the impacts per building element and the contribution of different component categories (eBKP-H) to the sum of embodied impacts can be identified (SEE FIGURE 36 ON THE FOLLOWING PAGE). In the current example the component-specific impacts (structured by eBKP-H element structure) for all element categories used in the 2000 Watt DEST are presented. However, some categories don't add to the total result for embodied impacts, as for instance, the case study design does not have a basement and therefore, no external walls below terrain (C 2.1A) are required.

These extensive results given it is necessary to identify specific elements and their potential for improvement, which is in the following exercised by taking element categories C 4.1, C 2.2, C 1, E 3, C 4.4 and C 2.1B. Using quantities of the actual building



	GWP [$kgCO_2eq/m^2$]	GWP [$kgCO_2eq$]
C 4.1	0,85	560,1
C 3	1,29	–
C 2.2	0,61	641,0
C 1	1,24	476,3
C 2.1A	3,60	–
B 6	0,14	–
E 3	2,69	806,3
C 4.4	1,38	469,1
C 2.1B	3,01	1729,2

FIGURE 36 | IMPACTS PER BUILDING ELEMENT AREA AND TOTAL AMOUNT AND SHARE OF IMPACTS PER ELEMENT CATEGORY.



	GWP [%]	m^2 [%]	GWP / m^2 [%/%]
C 4.1	12,0	19,9	0,60
C 2.2	13,7	31,7	0,43
C 1	10,2	11,6	0,87
E 3	17,2	9,1	1,90
C 4.4	10,0	10,3	0,98
C 2.1B	36,9	17,4	2,13

FIGURE 37 | DOMINANCE ANALYSIS OF ELEMENT CATEGORIES. CALCULATED BY COMPARING AN ELEMENT CATEGORY'S SHARE ON TOTAL EMBODIED IMPACTS TO ITS SHARE ON THE TOTAL ELEMENT AREAS ASSESSED.

design, e.g. when directly extracted from the BIM model as in our case, the share of an element category on the total embodied impacts can be put in relation to the share on the total quantities assessed to identify the dominance of a certain element category (SEE FIGURE 37 ON THE PREVIOUSE PAGE). High dominance indicates that certain element categories, or individual building elements for that matter, have higher contribution to embodied impacts than to the sum of areas quantified. Focusing on elements with high dominance therefore provides high potential for an effective improvement of embodied impacts for an existing building design. Especially element categories C 2.1B (external walls above terrain) and E 3 (windows and doors) show high dominance and thus potential for improvement in the further design process.

VISUALIZATION OF IMPACTS

In order to present results and support further development of the design, component-specific embodied impacts can be visualized in different ways. Using the 3D BIM model to present results in a comprehensible way helps to inform designers during the process and to communicate design decisions to clients and other stakeholders. Possible applications of this visualization workflow to present information (FIGURE 38) on embodied impacts are to show – amongst others - the:

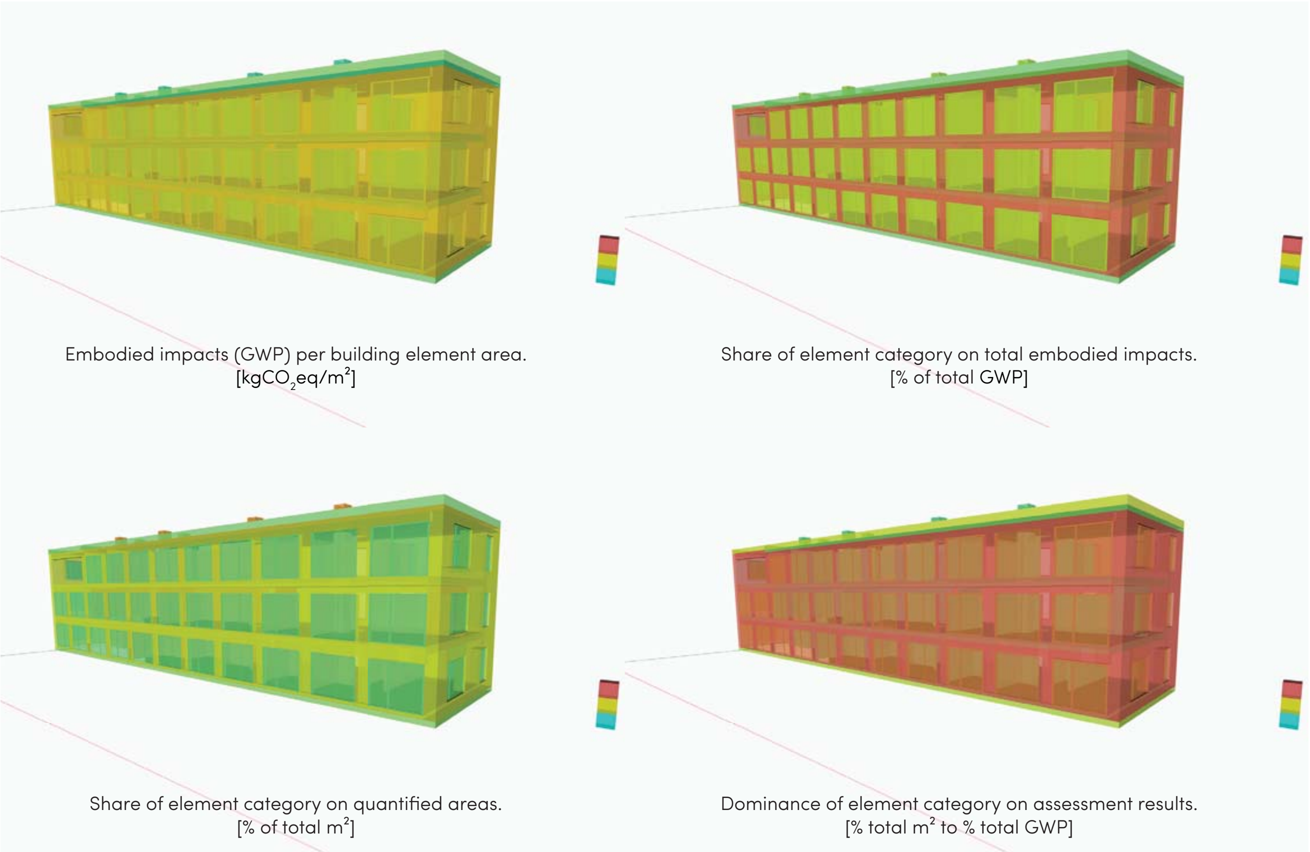
- embodied impact per unit (m^2, m^3 or per piece) of components,
- share of the element category on the total of embodied impacts,
- share of an element category on the totally assessed element quantities, as well as,

dominance of a certain element category on the total embodied impacts, highlighting areas and elements suitable for effective improvement of embodied impacts.

Furthermore, a visual comparison of different construction profiles can help identify strength and weaknesses as well as potential for improvement in the building design (FIGURE 39).

For a detailed visualization, component-specific results were integrated in the BIM model as explained earlier. This workflow of including values on embodied impacts into the BIM model supports the comprehensive communication of detailed results and their potential effects on the building design. It may as well support the future development of BIM integrated LCA processes.

result.



Embodied impacts (GWP) per building element area.
[$kgCO_2eq/m^2$]

Share of element category on total embodied impacts.
[% of total GWP]

Share of element category on quantified areas.
[% of total m^2]

Dominance of element category on assessment results.
[% total m^2 to % total GWP]

FIGURE 38 | VISUALISATION OF DIFFERENT ASPECTS AND RESULTS OF LCA FOR SCENARIO 21. EMBODIED IMPACTS (GWP) PER ELEMENT AREA, THE SHARE OF AN ELEMENT CATEGORY ON THE TOTAL IMPACTS AS WELL AS ON THE AREAS QUANTIFIED FOR THE LCI. COMBINING THESE SHARES ONE CAN IDENTIFY THE DOMINANCE OF A CERTAIN ELEMENT CATEGORY, TO HIGHLIGHT ELEMENTS WITH IMPROVEMENT POTENTIAL.

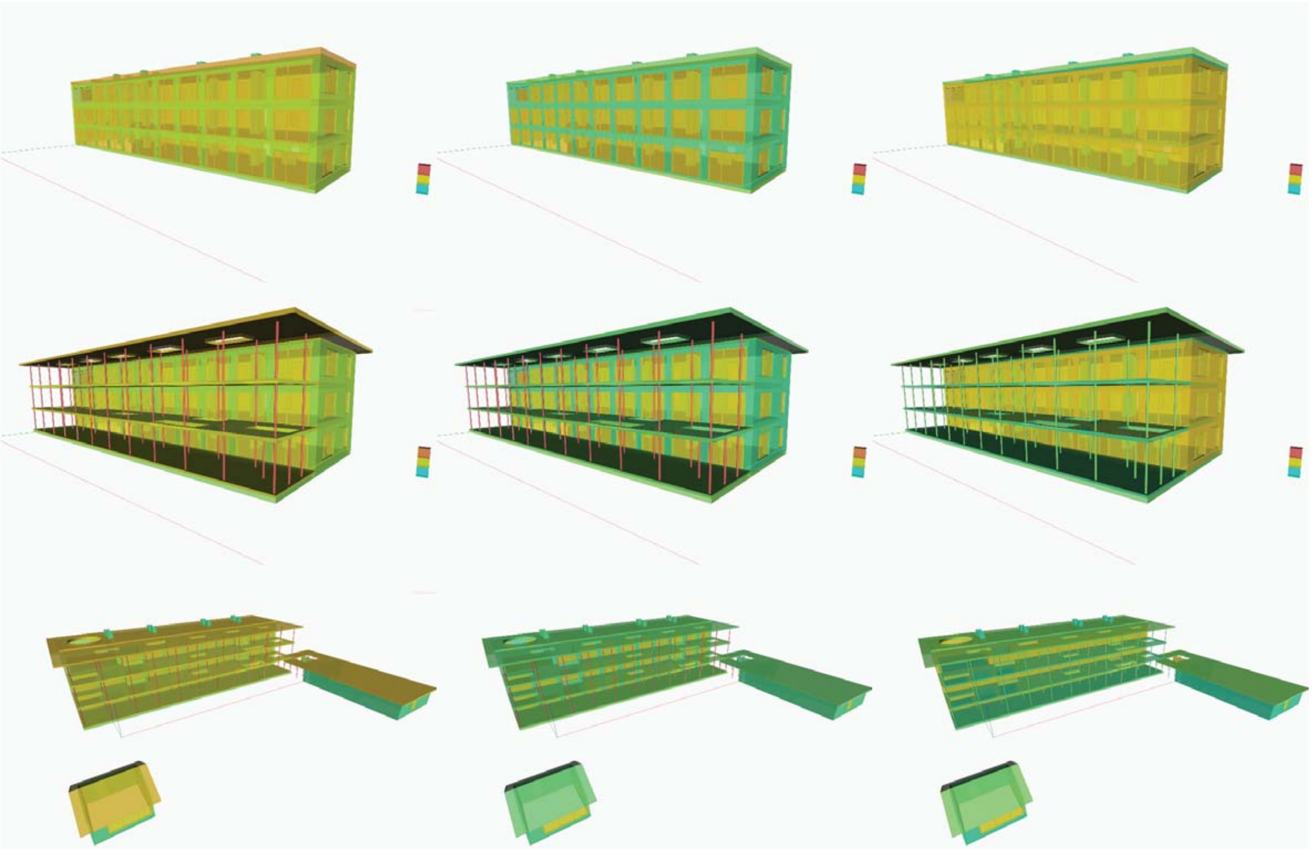


FIGURE 39 | VISUAL COMPARISON OF CONSTRUCTION PROFILES, HIGHLIGHTING THE VARIABILITY IN DISTRIBUTION OF IMPACTS PER BUILDING ELEMENT FOR THE DIFFERENT CPS. EXAMPLE OF SCENARIOS 19,20 AND 21 (CP1, CP2 AND CP3, WITH EM3 AND ES1). DIFFERENT SCALES OF THE PROJECT, TO SHOWCASE APPLICATION POSSIBILITIES ON ONE OR MORE BUILDING STRUCTURES. UNIT USED FOR THE VISUALISATION IS THE GWP PER BUILDING ELEMENT AREA.

SENSITIVITY ANALYSIS

QUANTIFICATION

Quantification for LCA was done by extracting quantities from the BIM model. The validity of this process is verified by comparing the generic element areas assumed by the 2000 Watt DEST when entering only the basic building properties (net floor area, number of floors, cubature compactness, et cetera) with LCA results of an assumed additional basement, different building compactness (3) and results based on quantities extracted from the BIM model.

It can be shown that LCA results are sensitive to building element areas and results based on BIM quantities are in general 5-7% below the generic results, with extremes of up to 24% for GWP of operation phase. The impact of element quantities on the operational energy demand could not be fully clarified, as well as the high variation of the mobility aspect, as there seems to be no transparent connection between an additional basement and a reduction in building induced mobility. These unexpected effects and the overall validity of a BIM integrated LCA will have to be subject of further research.

REFERENCE SERVICE PERIOD - RSP

Changing the RSP of the presented LCA, would be expected to influence results in favour of ES1 for a shorter RSP (less embodied energy), respectively ES3 for an extended RSP (less operational energy demand). The actual service period of the building, however will be defined in practice anyway and is considered to greatly depend on market conditions rather than the construction profile chosen.

DISCUSSION AND OUTLOOK

In the analysis of the scenarios the high dominance of the energy mix could be shown, as in EM3 all construction profiles and energy standards were able to meet the benchmarks. This highlights the importance of choosing a clever energy mix for buildings, which should be based on renewable energy sources wherever possible. The renewable energy mix scenario EM2 (biomass and grid electricity) performed slightly worse than EM3 (heat pump, biomass, solar and PV), and was not able to meet the required benchmarks. This further underlines the importance of grid electricity increasingly including renewable energy, favourably solar powered. However, the influence of designers on the parameter of energy mix, while by far dominating the final results, is restricted or in many cases not deemed as crucial. Changing this perception towards a conscious and optimised selection of energy sources for building operation can greatly increase the overall environmental impacts of buildings.

For construction profiles (CP) and energy standards (ES) tested, the ES chosen for high energy efficiency during operation also showed higher embodied impacts, due to more insulation and technical systems. This led to the "worst" ES (ES1) being the one favoured to achieve minimum embodied impacts, while still meeting the operational impacts benchmarks (due to energy mix EM3). This again highlights the possible advantages of reducing embodied as well as total impacts, through low impact construction materials and a clever energy mix. The conducted scenario analysis and identification of suitable options can improve design decisions throughout the process and support sustainable building design based on a process-integrated assessment.

For the BIM based quantification, plausible values and results could be shown, supporting the applicability of BIM quantity extraction for LCI in future LCAs. Some unclear effects and interdepencies of the result categories of the applied evaluation tool (2000W DEST) remained unclear but are

discussion.

internal calculation issues of the tool and not affected by the BIM quantification as could be shown through the quantities validation.

The application of the common element structure of eBKP-H allowed for an improved data exchange in a comprehensible compilation of the LCI, through automated extraction of element quantities from the BIM model. The integration of impact data into the BIM model using the same element structure, furthermore allowed for a component-specific visualization of impacts, independent of the assessment results. For future application of this workflow a refined and more complete assessment of building elements is desirable. The validity and completeness of an assessment performed on the basis of "per element area" impacts should be subject to further research through the comparison with complete conventional LCAs on a considerably large number of case studies.

The presented visualization of embodied impacts could promote understanding of the embodied impact concept amongst designers as well as the communication of LCA with clients and other stakeholders. In the future, integration of embodied impacts into BIM combined with building energy simulation towards a process-integrated LCA could enable real-time assessment and a constant visual feedback of the building performance in terms of embodied and operational impacts. The application of visual scripting for that matter is to be further investigated and can support the development of such processes.

To compare LCA results of different types of buildings and locations amongst each other and against environmental benchmarks, an international harmonisation of the assessment methodology as well as of the LCI structure is required. Future benchmarks should enable an assessment during the early design stages as well as a constant refinement throughout the design process and may therefore follow defined steps in the design and planning process. The units and scale applied for such benchmarks will have to be discussed as not only benchmarks on the building level should be established, but also the potential for improvement of certain building elements could be shown when compared to element specific benchmarks and guide values.

Current developments of BIM towards the integration of EPDs through the link to external property and product databases may provide potential to include building and element specific environmental benchmarks to be used during a BIM supported building design process.

These developments should be closely monitored and influenced where feasible, to improve the integration of LCA and BIM to support sustainable building design processes of the future.

V. closing words.

Reflecting on the project in general and the participatory process in particular I can conclude that it was and is a great journey:

Starting more than a year ago with the interest in sustainability and participation I got to learn a lot and gained invaluable experience on a variety of aspects of the planning process. Initial talks and discussions with fellow architects and experts in the field as well as with the co-housing group built up trust and understanding and we decided to work together on this project. From the beginning it was a challenge to distinguish between the tasks of mine as an architect and mediator, leading the participatory process and eventually being responsible for the building design on one side, and the group's internal responsibilities of organizing their internal communication and decision-making processes as well as searching a suitable site on the other side. This separation was not always distinct and we kindly supported each other with feedback and inputs, which really made the whole process a common effort and learning experience for all people involved. However, at various points in the process it became important to distinguish these responsibilities to be able to identify tasks to be done on either side in order to progress with the project.

THERE IS NO REAL ENDING, IT'S JUST THE PLACE WHERE YOU STOP THE STORY.

reflection.

We came to a crossroads at our meeting in early January 2016. There was no site, no funding, no design and we could have stopped our collaboration at that point. After talking to the owner of a highly suitable site who, while not promising to sell the plot, was interested in the project and agreed to have us take his site as the basis for our process, the group and I agreed to take this assumption and start a participatory process. Our goal was to support the group in determining their common vision towards a co-housing project and in the process create an architectural concept, that could then also be assessed and evaluated on its environmental performance. At that point I guess we were in a way all hoping to finally convince the owner with a good concept and purchase the site at some time in the future. Looking back only this naivety enabled us to start a process that proved to be highly valuable for all of us.

The participatory process was a great experience as it in many ways questioned the usual authoritarian architectural design processes I was used to. Even though we agreed on many things in terms of the quality of spaces and the requirements for a building, I acquired a more differentiated view on materialization, interspaces and the fragile balance of community and privacy. Even more I learned and experienced the importance of unmaterialized aspects of building; communication and organization during a design process, ownership in terms of finance as well as for identification, and the complex interdependencies of environmental effects influenced by our design decisions.

From the very beginning I tried to approach the project in a structured way. A little hand-drawn schedule proved to be of great help. I had created it in a very early phase to define the project's milestones and main aspects and how they would build upon each other. Even although some dates were shifted and aspects were added, gained more or less importance, it very much helped to navigate through the process.

In the end my personal findings of this process are notions of positivity and humbleness. Positivity, for going through the great experience of the participatory process and the valuable time I got to spend in Zurich. It also triggered my involvement in research which I am now committed to. And humbleness, that in a building context, we as architects can try hard to make it work, but as there are numerous stakeholders involved, it requires a big common effort with many hurdles to overcome to eventually realize a participatory building project.

LET'S ENABLE OURSELVES,
KEEP WORKING TO IMPROVE
AND ENJOY THE PROCESS.

“Coming generations will question – what seems now to be unchangeable and absolute. They will invent new and more valid concepts which will belong to the age in which they live. They will invent things which will be born out of their thoughts, their hopes and their imagination; and they will attempt to refine or to cultivate the use of those things.”

FRITZ HALLER, IN: INTEGRAL URBAN – A MODEL, 1868

to be continued...

TO WALTRAUD, ANDREAS &
TOBIAS.

THANK YOU FOR SHARING THE
WAY AND THE FULL SUPPORT
THROUGHOUT THE YEARS.

I AM MORE THAN GLAD YOU
ARE AROUND.

LOVE YOU GUYS,
MARTIN

thanks.

A BIG THANKS TO THE STAKEHOLDERS & ADVISORS IN THIS PROJECT

CO-HOUSING COMMUNITY, BAUGRUPPE VÖCKLABRUCK

for their motivation to collaboratively work on this project. I highly value the experiences made throughout the process and want to thank everyone of the group for sharing their visions and the contributions during the workshops. I wish all of you the very best and hope for your wishes on living and housing to come true in the near future.

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for generously sharing knowledge, curiosity and creativity in the search for holistic improvements of our built environment. Thank you for kindly hosting and including me in your great group during my time in Zurich. Cheers guys!

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THE MENTORS AND STUDENTS OF WISBA 2015

Thank you for sharing your knowledge and motivation for research and scientific work. It was great working with a motivated team on a project that opened many new aspects of architecture and the built environment for me.

MARKUS PERNTHALER AND THE TEAM OF ARCHITECTURAL OFFICE MARKUS PERNTHALER

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Figure 25: Embodied and operational impacts in the building life cycle (TU Graz 2016)

Figure 26: Distribution of embodied and operational impacts for past, current and future buildings. Embodied impacts increasingly dominate the building life cycle resulting in a "carbon spike". Even for highly energy efficient and self-sustaining buildings in the future, a certain amount of operational (external) impacts is to be expected. (Acc. to Annex 57, TU Graz 2016)

Figure 27: Conventional steps of the environmental assessment of buildings (acc. EN 15978) compared to the steps of the environmental design process presented.

Figure 28: The building life cycle based on the life cycle costing approach (acc. to ISO 15686-5:2008, TU Graz 2016)

Figure 29: Life cycle stages and system boundaries (acc. CEN TC 350 (EN 15804:2012), TU Graz 2016)

Figure 30: Description of options for materialisation (CP), envelope quality and technical services (ES), and energy mix used to supply operational energy demand (EM)

Figure 31: Overview of assessment scenarios with different options for construction profile (CP), energy standard (ES) and operational energy mix (EM).

Figure 32: Results of scenarios for embodied (construction and demolition) and operational impacts. Percentage values represent the fulfilment of target values.

Figure 33: Graph showing the fulfilment of target values for the total impacts of each scenario in impact categories PEDnr and GWP. Clusters of the scenarios resulting from chosen energy mix (EM) can be clearly identified.

Figure 34: Embodied and operational impacts (EI and OI) of scenarios 19-27 (all EM3). Trends resulting from chosen construction profile (CP) and energy standard (ES) can be identified. Depending on ES, OI can be reduced while EI are increasing.

Figure 35: Overview of options comprising scenario 21, which was chosen to investigate in detail.

Figure 36: Impacts per building element area and total amount and share of impacts per element category.

Figure 37: Dominance analysis of element categories. Calculated by comparing an element category's share on total embodied impacts to its share on the total element areas assessed.

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abbreviations.

BIM	Building Information Modelling, the method
BIM model	Building Information Model, the building database and 3D model
CAD	Computer Aided Design
CP	Construction Profile (LCA scenario option)
DEST	District Evaluation Tool (of 2000Watt society)
DHCP	District Heat Cogeneration Plant
EI	Embodied Impacts
EM	Energy Mix (LCA scenario option)
ES	Energy Standard (LCA scenario option)
GHG	Greenhouse Gas
GWP	Global Warming Potential
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
LOD	Level of Detail
NFA	Net Floor Area
OI	Operational Impacts
PDP	Participatory Design Process
PEDnr	Primary Energy Demand of non-renewable resources
PEDtotal	Primary Energy Demand total (renewable and non-renewable)
QTO	Quantity Take-Off
RSP	Reference Service Period

contact.

ADDITIONAL INFORMATION AND DETAILED RESULTS, AS WELL AS THE FILES USED FOR THE ENVIRONMENTAL ASSESSMENT AND THE AUTOMATION WORKFLOW WILL BE GLADLY SHARED.

PLEASE CONTACT THE AUTHOR FOR FURTHER INFORMATION.

MARTIN RÖCK
+43 660 7324764
MARTINROECK@PROTONMAIL.COM
FACEBOOK | LINKEDIN | RESEARCHGATE