Survey on the use of national LCA-based assessment methods for buildings in selected countries

A Contribution to IEA EBC Annex 72

February 2023

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Preface

This publication is an informal background report. It was developed as part of the international research activities within the context of IEA EBC Annex 72. Its contents complement the report "Context-specific assessment methods for life cycle-related environmental impacts caused by buildings" by Lützkendorf, Balouktsi and Frischknecht et al. (2023). The sole responsibility for the content lies with the author(s).

Together with this report, the following background reports have been published on the subject of "Assessing Life Cycle Related Environmental Impacts Caused by Buildings" (by Subtask 1 of IEA EBC Annex 72) and can be found in the official Annex 27 website (https://annex72.iea-ebc.org/):

– Level of knowledge & application of LCA in design practice: results and recommendations based on surveys (Lützkendorf et al. 2023);
– Basics and recommendations on modelling of processes for transport, construction and deconstruction in building LCA (Soust-Verdaguer et al., 2023);
– Basics and recommendations on influence of service life of building components on replacement rates and LCA-based assessment results (Lasvaux et al., 2023);
– Basics and recommendations electricity mix models and their application in buildings LCA (Peuportier et al., 2023);
– Basics and recommendations on influence of future electricity supplies on LCA-based building assessments (Zhang 2023);
– Basics and recommendations on assessment of biomass-based products in building LCAs: the case of biogenic carbon (Saade et al., 2023);
– Basics and recommendations on influence of future climate change on prediction of operational energy consumption (Guarino et al., 2023);
– Basics and recommendations in aggregation and communication of LCA-based building assessment results (Gomes et al., 2023);
– Basics and recommendations on discounting in LCA and consideration of external cost of GHG emissions (Szalay et al. 2023);
– Documentation and analysis of existing LCA-based benchmarks for buildings in selected countries (Rasmussen et al., 2023)
– Rules for assessment and declaration of buildings with net-zero GHG-emissions: an international survey (Satola et al. 2023)

It is important to mention that parts of the analysis of in this report is based on a survey among experts via a questionnaire which was realized during 2020. The authors would like to acknowledge the following survey contributors in addition to the ones already identified in the author list: Laetitia Delem (Belgium), Julie Železná (Czech Republic), Paul Mittermeier & Anna Braune (Germany) Erik Alsema (Netherlands), Ricardo Mateus (Portugal), Groupe AGECO (Canada) and Manish Dixit (USA).

Summary

This background report examines existing mandatory or voluntary national assessment methods for the life cycle related environmental impacts caused by buildings (LCA-based methods for environmental performance assessment) with the aim to provide an overview of their major variations. Part of this overview also explores the type and extent of awareness and application of these methods in each country covered. The descriptions of the methods and the situation in different countries are based on a survey among the A72 experts.

This forms a first basis to develop rules and recommendations for national authorities and private organisations on how to create or improve such methods which was one of the main objectives of Annex 72.

Particularly, this report first provides a concise overview of the situation in 17 participating countries in Annex 72, covering Europe, Oceania, North America and Asia, and addressing the following topics:
– Historical background/ Beginning of the application of LCA in the construction sector
– Situation in the field of LCA application /Application context
– Methodological bases
– Databases
– Number of applications and users
– Integration into the design process
– Acceptance and dissemination

The overviews cover the situation up to early 2021. In a second step, this analysis was also combined with a structured multi-part questionnaire to acquire more details of the methods, especially in relation to their differences in:
– System description
– Modelling aspects
– Environmental indicators
– Assessment standards, data, tools and benchmarks
– Market Conditions and driving forces

With the help of the questionnaire the details of 25 methods from 19 countries were reported and analysed. The analysis showed great variations among the methods in use. Each country has a different starting point and is at a different stage of development in this field. Nevertheless, to enable comparability and usability of lifecycle-based results, the provision of a consistent and transparent basis for a methodology and reporting structure for environmental performance assessment of buildings in line with international and regional standards is needed. The present background report intends to contribute to this.

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Abbreviations

Abbreviations	Meaning
AP	Acidification Potential
ADP	Abiotic Depletion Potential
A72	IEA EBC Annex 72
BIPV	Building-integrated Photovoltaic
EoL	End-of-Life
EP	Eutrophication Potential
EPBD	Energy Performance of Buildings Directive
EPD	Environmental Product Declaration
GFA	Gross Floor Area
GHG	Greenhouse Gas Emissions
GWP	Global Warming Potential
HFA	Heated Floor Area
HVAC	Heating, Ventilation, Air-conditioning
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
KBOB	Koordinationsgremium der Bauorgane des Bundes
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
MEP	Mechanical, Electrical and Plumbing
NFA	Net Floor Area
ODP	Ozone Depletion Potential
PE	Primary Energy
PE,nr	Primary Energy, non-renewable
POCP	Photochemical Ozone Creation Potential
RSP	Reference Study Period
SIA	Schweizerischer ingenieur- und architektenverein
VOC	Volatile Organic Compound

Definitions

Life cycle Assessment (LCA): LCA is a systematic set of procedures for compiling and examining the inputs and outputs of materials and energy, and the associated environmental impacts directly attributable to a building, infrastructure, product or material throughout its lifecycle (ISO, 2006).

Global Warming Potential (GWP): Impact category (or characterization factor for climate change) describing the radiative forcing impact of one mass-based unit of a given greenhouse gas relative to that of carbon dioxide over a given period of time. A time frame of 100 years is currently most commonly used and accepted. [kg-CO2eq] (adapted from ISO 14067:2018)

Indicator: quantitative, qualitative or descriptive measure (ISO 15392:2019).

Life cycle stage: all consecutive and interlinked stages in the life of the object under consideration. The life cycle comprises all stages, from raw material acquisition or generation from natural resources to end-of-life (ISO 21930:2017).

Information module: distinct parts for a building's life cycle for which impacts are to be declared. Each building's life cycle stage is comprised of more than one information modules.

Operational impacts: Impacts associated with energy and water consumed during a building's operation.

Embodied impacts: When an environmental impact of a product is characterized as "embodied" it does not mean that it is really embodied in the product itself. It is used in a metaphorical sense to describe the impacts caused by life cycle stages of a product other than the operation (embodied in a virtual sense).

System boundary: boundary representing what building parts and life cycle stages are included and what not in the building assessment (adapted from EN 15978:2011)

Component: item manufactured as a distinct unit to serve a specific function or functions. A building component is a part of a building, fulfilling specific requirements/functions (e.g. a window or a heating system). The service life of a building component can be shorter than the full service life of the building. Building components are sometimes referred to as "building elements" (ISO 21931-1:2022).

Benchmark: reference point against which comparisons can be made (ISO 21678:2020).

Environmental Product Declaration (EPD): claim which indicates the environmental impacts and aspects of a product, providing quantified environmental data using predetermined parameters and, where relevant, additional environmental information (prEN 15978-1:2021)

Reference unit: Denominator of a characteristic value to which the numerator is related.

1. Introduction

To develop a well-informed guideline for national authorities and private organisations on how to create or improve context-specific methods for the assessment of life cycle-related environmental impacts caused by buildings (A72 report by Lützkendorf et al. (2023)), it is important to examine existing methods and standards first. The aim of this background report is to provide an overview and analysis of existing national methods of/approaches to life cycle assessment of buildings, which in some cases are mandatory (i.e. part of building codes and regulations), in others voluntary (i.e. part of voluntary sustainability certification systems, national standards, funding activities or research activities), and to discuss the major variations in building LCA, and therefore the challenges of harmonising it. Part of this overview is also to explore the type and extent of awareness and application of the methods in the countries.

In order to analyse the possibilities of further development and gradual alignment of the methodological foundations, it is necessary to identify areas of potential alignment and context-specific reasons behind key methodological choices. To this end, this background report presents the results of an international survey among the in Annex 72 involved experts and country representatives on the methodologies applied to assess the environmental impacts of buildings in some of the participating countries.

Regardless of whether an official mandatory or voluntary national method is in place, Section 2 provides a concise overview of the situation in some participating countries in Annex 72 in relation to:

- Historical background/ Beginning of the application of LCA in the construction sector
- Current situation in the field of LCA application /Application context
- Methodological bases
- Databases
- Number of applications and users
- Integration into the design process
- Acceptance and dissemination

This overview covers the situation up to late 2020/early 2021. For the Annex 72 participating countries with a particular method in place, details of the methods were provided by means of a multi-part questionnaire which was filled out by country representatives or national experts. A short analysis of the answers is presented in Section 3. The questionnaire survey intended to reveal the various levels of development of different methods and differences in approaching life cycle environmental assessments of buildings. Topics covered were:

- System description
- Modelling aspects
- Environmental indicators
- Assessment standards, data, tools and benchmarks
- Market conditions and driving forces

2. Short Overview of State-of-the-Art of Environmental Life Cycle Assessment of Buildings as a Method in Selected Countries Around the World

2.1 Situation in Europe

2.1.1 Austria

Historical background/ Beginning of the application of LCA in the construction sector

The use of building certification systems in Austria dates back to late 1990 and follows up initiatives like e.g. IISBE. One of the first systems was developed within several research projects, now launched under the umbrella of ÖGNB. In late 2000 the DGNB system was founded and adapted in Austria by ÖGNI.

Situation in the field of LCA application /Application context (as of early 2021)

The LCA methodology for the assessment of buildings' environmental performance throughout their life cycle is not mandatory in Austria. As an alternative, various building certification schemes exist, that can be applied in order to get an insight into their environmental performance.

As an example, the klimaaktiv framework (Klimaaktiv, 2021) provided by the Austrian government, has the most applications throughout the market. Yet, klimaaktiv does not require a full LCA according to EN 15978. For the embodied impacts in klimaaktiv, the so-called 'OI3-Index' (IBO, 2021), developed by the company IBO Verein und GmbH is applied. The 'OI3-Index' evaluates the ecological quality of the building materials on the basis of the environmental indicators global warming potential, acidification potential and the demand for non-renewable primary energy and represents the performance as a single number. In the calculation, the user can change between different system boundaries. Regarding the operational impacts, klimaaktiv addresses the mandatory energy certificate calculation according to EC (2010). Overall, klimaaktiv is a certification system that rates a building's quality via a scoring system. The criteria in klimaaktiv thereby are heavily focused on energy performance, yet a slight shift is observed towards a more holistic view of the building.

Other voluntary certification frameworks are the ÖGNB-Total Quality Building (TQB) (ÖGNB, 2021) framework or the 'Holistic Building Program' (HBP) (Bundesimmobiliengesellschaft, 2021) by the Austrian governmental real estate company BIG, that in general behave very similar to the klimaaktiv certification framework.

The most advanced framework applied in Austria, that includes a full life cycle LCA, is the certification system by ÖGNI (ÖGNI, 2021), which has adopted the DGNB methodology for Austria. As with DGNB, it requires a full LCA based on EN 15978:2011.

Methodological bases

The methodologies to perform an LCA in Austria are the Austrian national standards based on the EN 15978 and EN 15804. Yet, the beforehand described 'OI3-Index', used by klimaaktiv, TQB and HBP does not state the modularity principle of EN 15978 explicitly. This index includes, depending on the system boundary chosen, the environmental impacts until the refurbishment (Module B4). To the authors' knowledge, the end-of-life emissions (Module C1-C3) and benefits and loads beyond the system boundary (Module D) are not included in the 'OI3-Index'.

As mentioned before, the ÖGNI methodology, based on the DGNB methodology, as it demands a full life cycle LCA, addresses the modularity principle according to EN 15978 and addresses the major modules throughout the life cycle.

Databases

The main database available in Austria is 'Baubook' (baubook, 2021), which is also developed and maintained by the company IBO Verein und GmbH. This database, in the authors' view, gets the most recognition throughout the market, since it is used to calculate the beforehand described 'OI3-Index'. This database is linked with various software applications for the calculation of the mandatory energy certificates for buildings.

Yet, users conducting solely LCA studies as well as environmental product declarations (EPD), also apply the Swiss Ecoinvent database (Wernet et al. 2016) in Austria. Within DGNB / ÖGNI system the ökobaudat database is being used.

Number of applications and users

We do not have any relevant data for this.

Integration into the design process

As it is not mandatory in Austria to perform a LCA of a building, the integration into the design process is currently still under development in research projects. To the authors' knowledge, currently available software packages are performing like databases and do not allow a smooth design process.

Acceptance and dissemination

With recent developments, we see that the topic of LCA implementation gains more and more acceptance. Cities and governments increasingly set their focus on environmental issues and with that, also financial resources are set free for LCA calculations of buildings.

2.1.2 Belgium

Historical background/ Beginning of the application of LCA in the construction sector

In recent years, various steps have been taken to integrate LCA in the Belgian building practice (Trigaux, et al., 2018). Firstly, since 2010, a national LCA method, called MMG ("Environmental profile of building elements"), was developed to assess the environmental impact of building elements and buildings in a harmonized way (Allacker, et al., 2018). Secondly, a national database was established with specific data for Belgian construction products based on Environmental Product Declarations (EPDs) (Belgische Staatsblad 2014). Thirdly, a web-based calculation tool TOTEM ("Tool to Optimize the Total Environmental impact of Materials") was launched in 2018.

Situation in the field of LCA application /Application context (as of late 2020)

The TOTEM tool can be used by architects and other building stakeholders on a voluntary basis. Furthermore, the use of TOTEM is required in the Flemish sustainability rating tool for public buildings "GRO", more specifically for the fulfillment of the material-related assessment criteria (Flemish Government 2019).

TOTEM currently focuses on residential and office buildings, but the tool will be extended to other building typologies in future.

Methodological bases

The MMG LCA method is in line with current LCA standards and methods in Europe (CEN 2011; CEN 2013; EC 2013; EC-JRC 2011) and specifies the life cycle scenarios for the Belgian context. The whole building life cycle is considered, including the product stage (modules A1-A3), construction process stage (modules A4-A5), use stage (modules B2, B4, B5 and B6) and end-of-life stage (modules C1-C4). Module D is not included as it falls outside the system boundaries and is not compulsory (CEN 2011; CEN 2013).

Databases

In the current version of the TOTEM tool, generic environmental data from the Swiss Ecoinvent database (version 3.3) are used for the Life Cycle Inventory (LCI) (Wernet et al. 2016). Preference is given to Western European transformation processes to ensure the representativeness for the Belgian context. When generic Western European processes are lacking, Swiss data records are adapted by replacing the energy and water flows by European corresponding processes. In future, specific environmental data from the Belgian EPD database will be included in TOTEM.

Number of applications and users

As TOTEM is a relatively recent tool, the implementation in the building practice is still in its early stages. In June 2019 about 2000 users were registered on the TOTEM website.

Integration into the design process

The implementation of TOTEM in the building practice is still in its early stages. The number of architects and building stakeholders using LCA during the design process is currently rather limited.

Acceptance and dissemination

The acceptance and dissemination of LCA among Flemish architects was investigated in a survey in 2014 Meex (2018). The results showed that architects mainly focused on energy-related aspects. Less than half of the participants had heard of the term “LCA” and only a limited number used LCA in their architectural practice. When LCA was used, it was mainly in a passive way, i.e. by consulting LCA databases, rather than in an active way, i.e. by making LCA calculations. As the survey was carried out before the launch of the TOTEM tool (2018), an update would be required.

2.1.3 Czech Republic

Historical background/ Beginning of the application of LCA in the construction sector

Environmental life cycle assessment is being used in Czech Republic for applications in the construction sector since about 2010. At the beginning it was used for scientific use. The motivation was the fact that the legislation on the compulsory Energy Performance Building Declaration for all buildings came into force in the Czech Republic in that time. The environmental quality of buildings has been therefore in scientific projects enriched by other parameters, such as embodied energy of building materials. It was based on the LCA method, number of indicators was limited.

Situation in the field of LCA application /Application context (as of late 2020)

Currently, the only national LCA methodology is embedded in SBToolCZ, the Czech multi-criteria building assessment. This national method is therefore used for all buildings that seek SBToolCZ certification, but there are not many. It is also used in applications where only the environmental impacts of a building need to be evaluated, but for this purpose the method proves to be insufficiently complex and detailed. Therefore, the national LCA method is currently being prepared, which will focus specifically on the assessment of the environmental impact of buildings on the basis of the LCA method.

Methodological bases

The method in its basic outline is based on the standards EN 15987 and EN 15643-2. Only the A1-A3, B4 and B6 modules are included. To calculate B4, the method provides a table with the service lives of building materials and components. The method includes 6 indicators. Some of the other stages of the life cycle (A4, end-of-life phases) are also taken into account by SBToolCZ, but not in line with LCA method. The new method that is now being developed will include more life cycle stages and provide more detailed guidance.

Databases

According to the current method, data from the Czech database called Envimat, based on the Ecoinvent database, should be used. However, in practice, the Ecoinvent or other generic database which is available to the practitioner, is often used. In the methodology, which is now under development, the database recommendation will include the possibility of using EPD in addition to generic databases.

Number of applications and users

We do not have any relevant data for this.

Integration into the design process

The LCA method is not included in any Czech legislation. Thus, it only enters the building design process where the investor is interested in reducing the environmental impact of his building, even in other life cycle phases than the operational (environmental impacts of the operational phase are already partly regulated by EPBD, which is mandatory). In addition, LCA is used in cases where the investor seeks for a building quality certificate SBToolCZ or BREEAM.

Acceptance and dissemination

Designers, architects and investors' awareness of the environmental impact of buildings is in most cases limited to the operational phase of the life cycle. The motivation of investors to be willing to pay extra for environmental assessment and optimization of their home is still low. Designers' knowledge is increasing, but they do not currently have enough tools and data.

2.1.4 Denmark

Historical background/ Beginning of the application of LCA in the construction sector

LCA was introduced to the Danish building sector in the late 1990'ies. A research project elaborated LCIA data on common construction materials and integrated these into a software tool that was freely available, the BEAT model (Building Environmental Assessment Tool). Some 10 years later, the new established Danish Green Building Council chose an adapted version of the DGNB International certification scheme to become their 'official' scheme for operation. In this scheme, the building LCA weighs ~14% of the final score. In 2014, the Danish government put additional emphasis on LCA in the construction sector by financing a collection of research/guidance reports and the development of a new tool, the LCAbyg.

Situation in the field of LCA application /Application context (as of late 2020)

LCA is applied with the different certification schemes in use among building designers. A voluntary sustainability code is under preparation for inclusion in the building regulations and LCA will most likely form part of this.

Methodological bases

The methodological basis for LCA in Denmark is the EN 15978. Via the development of the DGNB method and the LCAbyg, a consistent method for application has been set. The method builds on existing, national research on service life of materials and buildings as well as waste handling of materials. For the operational energy, the Danish implementation of the EPBD sets the basis for calculating the operational energy demands.

Databases

Impact assessment data for construction materials are implemented in LCAbyg based on Ökobau.dat. It is mainly average product data that are integrated although the user can manually integrate product specific data. Impact assessment data for the energy mixes is developed from the politically agreed plans for a more renewable-based future energy mix.

Number of applications and users

In Denmark, as of 2019, more than 230 buildings are DGNB-certified or in the process of becoming certified. Further, more than 650 consultants have been trained in LCA through the courses held by the Danish Green Building Council. Additional LCA courses, hosted by other networks/organisations, further increase the number of stakeholders informed about and able to use LCA. LCA is also an integrated part of several university and vocational courses.

Integration into the planning process

LCA is not mentioned as part of the regulation. An appendix for the description of services by consulting architects and engineers include LCA as a potential topic for inclusion.

Acceptance and dissemination

The organizations behind the consulting architects and engineers have openly lobbied for more ambitious political targets concerning sustainable construction, including LCA targets. From case to case, consultants still see a lack of demand on environmental assessment services from the client's side.

2.1.5 France

Historical background/ Beginning of the application of LCA in the construction sector

Environmental life cycle assessment is being used in France for applications in the construction sector since 1995 (Polster, et al., 1996). Initial applications were performed in research institutions.

Situation in the field of LCA application /Application context (as of late 2020)

Since around 2008, life cycle assessment has been used within the framework of sustainability assessment systems such as BREEAM and later E+C- (2017)[1]. The application of certification schemes, and of LCA within such certification, is voluntary. It may become compulsory in the next regulation planned for end of 2021. Applying LCA is more useful at early design phases, when decisions are made which have the largest impacts on environmental performance, but this approach is still rare. Applications at a neighbourhood level are also performed since 2004 (Popovici & Peuportier, 2004).

Methodological bases

Building life cycle assessment is based upon ISO 14040 and EN 15978. But there are differences among tools, in particular regarding energy use: e.g. EQUER is linked to energy simulation and hourly electricity mix values are used, whereas constant mixes are used in E+C-. Module D is included as avoided impacts either using the 50/50 method (EQUER) or only 33% (E+C-). Furthermore, both systems differ regarding the replacement of building elements: simulation in EQUER (i.e. integer number of replacements), non-integer number of replacements in E+C- (building life span divided by the element life span). A 50 years reference study period is fixed in E+C-, which leads to overestimate the contribution of products and may lead to encourage programmed obsolescence.

Databases

The data to perform LCAs are either derived from "Ecoinvent" by contextualisation (EQUER) or obtained from INIES (E+C-). INIES includes data from industry-specific and manufacturer-specific EPDs, but accounts for a limited number of substances in inventories (e.g. dioxins are mixed with other VOCs) so that health and biodiversity related indicators cannot be precisely evaluated. Indicators of air and water pollution are based upon a critical volumes method. These EPDs are based on EN 15804. Generic data, particularly if they

[1] Référentiel « Energie – Carbone » pour les bâtiments neufs – Méthode d'évaluation de la performance énergétique et environnementale des bâtiments neufs – Juillet 2017

address also health and biodiversity issues, are more appropriate at early design than specific EPDs, which can be used at later phases.

Number of applications and users

The share of floor area of new constructions that apply environmental LCA is not known. The number of LCA experts has increased over the last decade. More and more professionals receive training to prepare for the next regulation. Institutes for sustainable construction have been set up at some universities/schools, also offering lectures on LCA for students of architecture and civil engineering.

Integration into the planning process

In the regulation specifying the fees for architects and engineers, LCA is not explicitly mentioned. If LCA is compulsory in the next regulation, the corresponding work will be accounted for as other regulation related tasks like energy calculation.

Acceptance and dissemination

The use of LCA in design process is low and architects have still little knowledge. LCA will probably be used at the end of the design to check the compliance with the regulation, which is not the most useful application of this method.

2.1.6 Germany

Historical background/ Beginning of the application of LCA in the construction sector

Environmental life cycle assessment is being used in Germany for applications in the construction sector since about the 1970s (Gartner et al. 2018). As early as 1922, however, the quantities of coal required for the manufacturing of building products and the heating of buildings were determined and assessed (Friedrich et al. 1922). Initial applications focused on scientific issues and were reserved for universities and research institutions.

Current situation in the field of LCA application /Application context (as of early 2021)

Since around 2008, life cycle assessment has been used within the framework of sustainability assessment systems such as BNB[2] (Rietz et al., 2019), DGNB[3] (Braune & Duran 2018), BNK[4] (Essig, 2019) and NaWoh[5] (Rietz et al., 2020). The application of BNB is obligatory for federal new buildings. Therefore, LCAs have to be created for all newly built office buildings of the federal government and their results to be compared with benchmarks.

Methodological bases

The requirements for life cycle assessment are based on ISO 21929-1 and EN 15987. Despite this uniform basis, there are differences when it comes to their practical application. This applies in particular to module D. This is either included in the considerations (DGNB) or regarded as additional information and not yet determined (BNB) because of too large data gaps. Furthermore, both systems do not consider all information modules – i.e. A4 and A5. Both systems provide both a simplified short procedure and a detailed procedure for the modelling of the building and its life cycle. Other national systems in which LCA is used are BNK for new one- and two-family houses as well as multi-family houses with up to five residential units and NaWoh for new multi-family houses.

Databases

The data to perform LCAs are usually obtained from a publicly and freely available database for LCA data on construction products - ÖKOBAU.DAT, see details in the A72 report by Chae and Kim (2023). It includes

[2] https://www.bnb-nachhaltigesbauen.de/en/assessment-system/
[3] https://www.dgnb-system.de/en/system/index.php
[4] https://www.bau-irn.com/bnk-system/was-ist-das-bnk-system
[5] https://www.nawoh.de/

data from both industry-specific and manufacturer-specific EPDs. These EPDs are based on ISO 21930 and EN 15804 (currently under revision). Once the EN 15804 revision is finished, the DGNB and BNB systems are likely to be updated following the new requirements.

Number of applications and users

The total DGNB-certified floor area is reported to be 57,5 million m^2 (unknown during which period), while for BNB gross floor area of about 211.000 m^2 for office buildings. This makes up a share of approximately 10% m^2 of floor area of new constructions during the last decade that apply environmental LCA (considering that about 45 million m^2 are added to the stock annually in Germany). The number of LCA experts has also increased over the last decade. The first reason for this is that more and more professionals receive training to become sustainability assessment auditors - often through the further education of engineers, architects and real estate experts. In addition, institutes for sustainable construction have been set up at many universities, which also offer lectures on LCA for students of architecture and civil engineering.

Integration into the planning process

In the regulation specifying the fees for architects and engineers, LCA is not explicitly mentioned. However, sub-aspects of an environmental life-cycle assessment can be agreed as a "special service" – for example see Official Scale of Fees for Services by Architects and Engineers (HOAI)[6].

Acceptance and dissemination

Early surveys on the use of LCA by architects are available from 2004 (Klingele et al., 2007). It must be assumed that, with some exceptions, the use of LCA in design process is low and architects have still strong reservations. This is confirmed by the results of the recent A72 survey from 2019 which show that less than one fifth of architects is currently using LCA (Lützkendorf & Balouktsi, 2020).

2.1.7 Hungary

Historical background/ Beginning of the application of LCA in the construction sector

Work on building LCA started in 2003 in the framework of a national research project (Tiderenczl et al., 2006). In this project, international methods, standards and databases were compiled and the first database and the first simple LCA tool was developed for scientific purposes. A large scale life cycle assessment study of new buildings was conducted (Szalay, 2008) and research on natural materials started[7].

Current situation in the field of LCA application /Application context (as of late 2020)

Two Excel-based LCA tools have been developed at the Budapest University of Technology and Economics. These are coupled with energy performance calculation according to the Hungarian regulations (KESZ_LCC_LCA and Belső Udvar-E-P-LCA-LCC). The tools are mostly used for education and research projects and for some commercial projects. The use of LCA is not mandatory. LCA is increasingly applied in projects aiming at a sustainability certification (BREEAM and LEED), however these use not the national tools but international tools and databases (e.g. OneClickLCA). A new international project, IS-SUSCON is developing a new web application based on OneClickLCA including Hungarian cases. The app will target non-expert users to spread life cycle thinking.

Methodological bases

The university tools are in accordance with the EN 15804 and EN 15978 standards. The whole life cycle of the building is assessed from product stage (modules A1-A3), construction process stage (modules A4-A5), use stage (modules B2, B4 and B6) and end-of-life stage (modules C1-C4). Module D is not included in the assessment.

[6] https://www.nachhaltigesbauen.de/fileadmin/pdf/Leitfaden_2011/LFNB2011-Anlage.pdf

[7] Medgyasszay Péter: A FÖLDÉPÍTÉS OPTIMALIZÁLT ALKALMAZÁSI LEHETŐSÉGEI MAGYARORSZÁGON - különös tekintettel az építésökológia és az energiatudatos épülettervezés szempontjaira, PhD dissertation, 2008, Budapest University of Technology and Economics

Databases

In the KESZ_LCC_LCA and in university research projects the Swiss ecoinvent v3.6 database (Wernet et al. 2016) is applied but with adaptations to the Hungarian context. The electricity mix and natural gas have been exchanged for Hungarian datasets in case of products that are predominantly produced in Hungary. Typical transport distances are also added based on the number and location of manufacturing plants. In Hungary, the number of national EPD-s is still very low so these are not applied yet.

Number of applications and users

The number of designers using LCA is still very low, only a few designers specialised in ecological constructions apply it. The numbers are slowly increasing with the increase of high end green certified projects in the recent years. Universities offer some lectures on LCA for architectural and civil engineering students but only in specialised courses.

Integration into the planning process

In the usual architectural practice LCA is not applied. However, the few architects specialising in ecological architecture apply LCA as an integral part of their design process. Projects targeting a green certification scheme usually order the LCA study from an external specialist and LCA does not have a real influence on design decisions.

Acceptance and dissemination

There has been no survey on the use of LCA before. Architects have a general knowledge on sustainability issues and many have heard about environmental assessments but have no deeper knowledge on LCA.

2.1.8 Italy

Historical background/ Beginning of the application of LCA in the construction sector

In 2006, the Italian LCA network was created. It became the Italian LCA network Association in 2012. The goal of this Association is the diffusion of the LCA methodology in Italy and the exchange of experiences. The Association has different working groups that focus on the application of LCA to different products and services. Among them, two are of interest for buildings: the working group “Building” and the working group “Energy and sustainable technologies”.

Current situation in the field of LCA application /Application context (as of late 2020)

Focusing on buildings, mainly the operation step is taken into account at this moment by legislation and practices. LCA is used for research purposes.

LCA is applied to building materials for developing EPD. There is an Italian Program Operator called EPDItaly. In 2017, it published the PCR for building products. Currently, 54 EPDs of building products are available in the EPDItaly website.

With the law 221/2015 (art.18) and the following law D.lgs. 50/2016 “Code of procurements” (art. 34 on criteria of energy and environmental sustainability) (modified by the law D.lgs 56/2017), the Italian Governments introduced the Minimum environmental criteria of buildings in the context of the public procurements. One way to demonstrate the existence of the required Minimum environmental criteria is to have an EPD for building products.

Methodological bases

The LCA developed for research purposes is based on the international standards ISO 14040 and ISO 14044 and on the EN 15987.

Databases

The data to perform LCAs can be obtained from EPDs or from environmental databases like Ecoinvent. Until now, no Italian environmental databases except EPDs are available.

Number of applications and users
Information not available

Integration into the planning process
LCA is not mentioned in the regulations that specify the fees for architects and engineers. LCA is not integrated in the design process.

Acceptance and dissemination
Information not available

2.1.9 Slovenia

Historical background/ Beginning of the application of LCA in the construction sector
The first studies in the field of LCA have been carried out in the last decade. The initial applications of the LCA of the studies were mainly in the research sector. The first studies focused on building materials and components since producers of building materials expressed their interest for Environmental Product Declarations (EPDs) very early.

Current situation in the field of LCA application /Application context (as of)
The LCA is mostly applied in the construction research sector for assessing building materials and components. There are only a few cases of whole building assessment. Currently, some incentives are being prepared, that should increase the use of LCA in the construction sector (e.g. subsidies for EPDs, workshops about LCA, etc.)

Methodological bases
The studies are following the rules of ISO 14040, EN 15804 and EN 15978 standards (ISO, 2006; CEN, 2011). There are no national recommendations or requirements for the methodology or the data that should be used for the study. For determining the scope of the study (the reference study period, the reference service life, end-of-life scenarios, etc.) the authors are mostly referring to published literature.

Databases
The studies rely on the data published in literature or use commercial or public databases. In the research commercial databases are used (e.g. Ecoinvent, Gabi). Some studies also rely on public databases (e.g. Ökobaudat). A local database of EPDs is available (ZAG EPD[8]).

Number of applications and users
Until now 14 EPDs have been published and some are still in progress. LCA is used in most of the research project connected to buildings and building materials, but it is seldom applied practice. The number of sustainable building certifications requiring an LCA analysis is also low.

Integration into the planning process
The integration of the LCA in the design and planning process is low. The practitioners are generally not familiar with LCA. However, LCA is being increasingly included in the curriculum of the universities and therefore it is assumed that the use of the LCA will increase in the future.

Acceptance and dissemination

[8] https://www.zag.si/en/certificates-and-approvals/service-for-technical-assessment-and-approvals/

The LCA methodology is not well-known in the building sector and therefore in is also not used in practice. The government is also developing national indicators for assessing the sustainability of building where some initiatives to use LCA are included, which may contribute to a wider use of LCA in future.

2.1.10 Spain

Historical background/ Beginning of the application of LCA in the construction sector

Environmental life cycle assessment is being used in Spain for applications in the construction sector since about 2004. Initial experiences were considering the environmental impacts in constructions products (e.g. BEDEC ITEC Instituto de Tecnología de la Construcción). Initial applications of LCA in the field of Building construction were mainly carried out by Universities and Research institutions.

Current situation in the field of LCA application /Application context

Since around 2004, life cycle assessment has been included in construction databases and, since 2010 in environmental declaration programs (e.g. DAPC) and within the framework of sustainability assessment systems such as VERDE. The application of VERDE is not obligatory in any case. Some Universities and research institutions have developed their own Buildings LCA Tools (eg. LCA-US Tool).

Methodological bases

The requirements for life cycle assessment are generally based on ISO 21929-1 and EN 15987. Despite this uniform basis, there are differences when it comes to their practical application -e.g. VERDE is focused in B6 and B7, US-LCA Tool consider A, B –except B1-,C stages and the D is took into account considering the service life of the building product in relation with the service life of the building.

Databases

BEDEC database has been commonly used by professionals and researchers. In the research field GaBi and, overall, ECOINVENT are the most usually used.

Number of applications and users

More than 50 buildings have been VERDE certified until now. This includes residential, commercial, educational, administrative, hotels, among other uses. The knowledge about sustainability certifications is increasing in the last years. This is because, among other reasons, many curricula in architecture and engineering are increasingly including the description of these methods and tools. Some Architecture Schools also includes lessons on the LCA methodology applied to buildings.

Integration into the planning process

The integration of LCA in the design and planning process in Spain is still low. Very few of architects and engineers obtain LCA results from their buildings in order to optimize them. Maybe this is because the lack of regulation in this respect.

Acceptance and dissemination

The LCA methodology is not very well-known in the building sector. The use of LCA in design process is still very low.

2.1.11 Sweden

Historical background

In the end of the 1990s and the coming decade, the basis for development of LCA methods for buildings targeting practice in Sweden was formed, with primarily the EcoEffect tool (Assefa et al., 2007) and the Environmental Load Profile (ELP) (Forsberg, 2003; Brick, 2008). Parts of the EcoEffect tool were used in practice to some extent at the time, but primarily this development was important for more simplified approaches developed after that. The ELP also had a wide scope and was used by Stockholm municipality partly in evaluating the project development of the large spearhead neigbhourhood development Hammarby Sjöstad which started in 1996[9]. However, this was done by a consultant and not by the developers in the area. In 2006, the first more commercially oriented LCA tool for buildings was developed, Anavitor[10]. It has since then been used primarily by the large contractor and developer Skanska to build internal knowledge and develop their work with LCA.

Implementation of LCA has since then been an on-going discussion in the fore-running companies in Sweden, who in various projects have cooperated with academia in successive competence-building. However, it has up to recently still not existed any clear drivers for the implementation. Apart from absence of drivers, the main barriers have been (and to some extent still are) no freely available software managing digital calculations and a lack of "consensus" data-sets to use.

Five years ago, the interest for LCA for buildings, however started to change. One important reason was the report launched and communicated by the Royal Swedish Academy of Engineering Sciences and the Swedish Construction Federation in 2014[11]. It received a lot of attention within industry and among national policymakers, and the main message was proclaiming that half of the GHG emissions of new Swedish multifamily buildings (in an LCA perspective) are associated with the product and construction stages, building on a new LCA-study performed by KTH in collaboration with the research institute IVL (Liljenström et al., 2015).

During the mid-2000s the national environmental certification tool for buildings was developed, called Miljöbyggnad (Malmqvist et al, 2009) by two joint research groups in cooperation with approx. 30 industry partners, insurance companies and authorities. To include an indicator demanding LCA calculation was discussed, but was at that time considered a too demanding choice. Embodied emissions were therefore not considered at all by this tool, but an explanation for that was that the tool from the beginning was primarily targeting certification of existing buildings rather than new. At the time when the tool was completed, there was much debate about "which" tool to go for. At that time, more stakeholders had an increasing interest for BREEAM and LEED, and the powerful contractors Skanska and NCC with international activities, each argued for LEED and BREEAM respectively. The future of Miljöbyggnad was therefore first unsecure, but after the founding of the Sweden Green Building Council (SGBC) in 2009, all three systems are now operated by SGBC in parallel, with Miljöbyggnad being the leading certification scheme in Sweden.

Situation in the field of LCA application (as of early 2021)

As said above, a broader interest for LCA application emerged in Sweden around five years ago. The government (both the political majority before and after the election in 2014) and the national authority for housing, building and planning (Boverket) have since then initiated a series of missions, resulting primarily in a proposal for a new regulation, a mandatory climate declaration for all new buildings in Sweden from 2022 (Boverket, 2018)[12], and a guideline on LCA for buildings for practitioners[13]. Already the knowledge of this forthcoming regulation has led to numerous initiatives now taken in the building industry to build up competence and capacity in the area. Boverket has also proposed a road-map for expanding this regulation later on with limit values, as well as inclusion of additional life cycle modules (Boverket, 2020). Here follows a number of important examples on initiatives during the last five years which both increase application of LCA and improve the opportunities for LCA application in the coming years:

– A new indicator requiring a calculation of embodied GHG emissions was added in the certification tool Miljöbyggnad, in 2017.

[9] A broad aim stated that the environmental performance of buildings in a life cycle perspective should be twice as good as the present-day state of the art
[10] www.anavitor.se
[11] https://www.iva.se/publicerat/climate-impact-of-construction-processes/
[12] Law proposal in English: https://ec.europa.eu/growth/tools-databases/tris/en/index.cfm/search/?trisaction=search.detail&year=2020&num=439&mLang=en&CFID=995299&CFTOKEN=e0e52b5820b0e82e-F0A573AB-F2C2-EC14-02289396E7B15E26
[13] https://www.boverket.se/sv/byggande/hallbart-byggande-och-forvaltning/livscykelanalys/

- The Swedish Transport administration (STA) have developed their own open tool, Klimatkalkyl[14], which is used for large infrastructure projects. STA require climate calculations as part of their procurement of large infrastructure projects since 2015
- Large strategic innovation programme, Smart Built environment has/is currently increasing the opportunities to establish digital LCA´s
- Stockholm municipality require climate calculations of all their own new building projects from 2019
- A Road-map for a fossil-free building and construction sector[15] was launched last year and is currently signed by 120 companies/organisations. One important component is to promote calculation and consideration of embodied emissions in construction projects.
- As a result of a R&D project the research institute IVL (in collaboration with KTH) launched an open, free tool (BM-tool) with open data, to promote climate calculations by practitioners.
- Sweden Green Building Council have launched a new certification system called Noll CO_2 (Zero CO_2)[16] as well as a new certification system for sustainable urban areas- post construction, Citylab (Lind et al, 2019; Lind, 2020; SGBC, 2019)[17], which include requirements on calculating GHG emissions in a life cycle perspective and linked limit values.

Methodological bases

As described above, the current situation in Sweden means that there is still (as of early 2020) not ONE national method. The methods used are however similar and follow EN 15978 (and indirectly EN 15804). The STA tool for infrastructure works is however not following the modular thinking of these standards in the same way. Regarding buildings, if the Climate declaration regulation comes into place this will essentially become the official national method. The following methodological description therefore concerns this method (Boverket, 2018). Like the name says, it only concerns assessment of GHG emissions and in the initial step only covers the modules A1-A5. The reasons for this is to reduce complexity since it is still a considerable knowledge leap that needs to be taken for involved stakeholders, that it is the part of the life cycle that can actually be verified, and that it puts focus on the most important part of the life cycle that is not already regulated (module B6 is regulated through the Energy performance directive). By including the entire A stage in the declaration, all key stakeholders in the value-chain for new construction, so to speak, also need to engage.

Databases

There is not yet a publicly and freely available database for construction products in Sweden, which up to recently has been an important barrier for practitioners who were interested in performing building LCA´s. However, with the STA tool, some country specific data are now openly available. Also, the BM-tool is including around 100 country-relevant datasets from the most up-to-date database that the research institute IVL owns. This data builds on Gabi data and quality checked EPD´s for products used in Sweden. The Swedish concrete federation is now also offering an EPD-tool for concrete producers. The national authority Boverket will launch an open, and freely available database on generic data for construction products, which is to be used when making the mandatory climate declarations according to the coming regulation. The database is developed together with the Finnish ministry and is planned to be launched in early 2021.

Number of applications and users

This is very difficult to tell. So far, LCA assessments are limited but a number of fore-running companies are now increasingly making at least climate calculations for their buildings, as a result of the new requirements in Miljöbyggnad, in light of the proposed climate declaration regulation and/or to meet procurement requirements by for example Stockholm municipality.

Acceptance and dissemination

[14] https://www.trafikverket.se/klimatkalkyl
[15] https://fossilfrittsverige.se/fardplaner/
[16] https://www.sgbc.se/utveckling/utveckling-av-nollco2/
[17] https://www.sgbc.se/certifiering/citylab/anvandarstod-citylab/citylab-guide-och-manual/

Primarily, more and more practitioners are now learning to make and understand LCA´s. During the last year also on a much broader basis than earlier. Consultancies in the building and construction sector are building up their capacity to offer LCA´s. So far, the acceptance for the proposed climate declaration regulation is considered as high, both among policy makers and within the building and construction industry. With the proposed regulation, in the last years, a tremendous increase in a much broader competence-building concerning similar climate calculations can be observed.

2.1.12 Switzerland

Historical background/ Beginning of the application of LCA in the construction sector

Environmental life cycle assessment is being used for applications in the construction sector since the late eighties (Ems et al. 1989; Hofstetter et al. 1992; SIA 1995, 1997).

Situation in the field of LCA application /Application context (as of late 2020)

Environmental life cycle assessments of buildings are used in certification schemes Minergy-eco[18], NNBS (network of sustainable buildings Switzerland)[19] and when assessing buildings against the benchmarks defined according to the 2000-Watt-Society (SIA 2017, 2020). The assessments are performed with certified planning tools. The SIA energy efficiency path, SIA 2040 offers a free tool to assess buildings in the early design stage[20]. In late 2011 the platform Life cycle assessment data in the construction sector was founded. The platform maintains the KBOB recommendation 2009/1 "life cycle assessment data in the construction sector" (KBOB et al. 2016, 2017), a comprehensive LCA database, which was published the first time in 2006. These data form the universal basis for all certification schemes and environmental assessments in the construction sector and in 2000-Watt-society assessments.

Methodological bases

Building life cycle assessment is based on ISO 14040 and 14044 (International Organization for Standardization (ISO) 2006a, b) and SIA 2032 (SIA 2020). Building material life cycle assessment is based on the ecoinvent v2 methodology and the complementary KBOB guidelines (KBOB et al. 2017). These rules are applied uniformly on all building LCAs requested by privately run certification schemes and those commissioned by public authorities. Since decades, Swiss LCA follow the recycled content approach and potential Module D impacts are disregarded. Similarly, allocation in multifunctional processes is done based on physical or other relationships avoiding system expansion approaches. The reference study period is 60 years.

Databases

Buildings LCAs are performed using the LCA data published in the KBOB recommendation 2009/1 (KBOB et al. 2016), which provides LCA data (greenhouse gas emissions (IPCC 2013), cumulative energy demand non renewable and renewable (Frischknecht et al. 2015) and overall environmental impacts according to the ecological scarcity method (Frischknecht & Büsser Knöpfel 2013) on construction materials and building elements (doors, window frames), building technology (heating systems, ventilation systems, solar collectors and panels, sanitary and electrical equipment), transport services (goods and people), energy supply (heat, district heat and electricity) as well as waste management services. These data are updated regularly.

Number of applications and users

The share of floor area of new constructions that apply environmental LCA is not known. Until 2017 about 1'500 buildings were certified against Minergy-eco (an estimated 1.5 mio m^2 energy reference area, Faktor 2018) and the energy reference area of buildings assessed according to SIA 2040 is estimated at about 100'000 m^2 energy reference area[21].

[18] https://www.minergie.ch/de/zertifizieren/eco/, accessed 12.11.2020
[19] https://www.nnbs.ch/standard-snbs-hochbau, accessed 12.11.2020
[20] http://www.energytools.ch/index.php/de/, accessed 12.11.2020
[21] personal communication, Katrin Pfäffli, Pfäffli Architects, 24.5.2019

Integration into the planning process

In the regulation specifying the fees for architects and engineers, LCA is not explicitly mentioned. It is part of the planning process in view of buildings that shall comply with Minergy-eco, SNBS or SIA 2040.

Acceptance and dissemination

The use of LCA in design process is low and architects have little knowledge. LCA embedded in planning tools is being used (if commissioned, see above) by companies specialised in energy modelling and calculations (building physicists) and architects dedicated to environmental issues.

2.2 Situation in Oceania

2.2.1 Australia

Historical background/ Beginning of the application of LCA in the construction sector

Environmental life cycle assessment has been used in Australia for applications in the construction sector since the early 1990s (Frith et al., 1993; Fay, 1996; Alcorn and Baird, 1996; McArdle et al.,1993; Pullen, 1995; Treloar, 1994), but LCA at this time mainly focused on research on energy limited to life cycle energy or embodied energy. Most of the research was mainly conducted by universities (Frith et al., 1993; Fay, 1996; Mackley, 1998; Treloar, 1996, 1999) and national research institute (Tucker et al., 1993; Tucker et al., 1996), and practical application to construction industry was insignificant.

Situation in the field of LCA application /Application context (as of late 2020)

In the beginning of the 21st century, research on LCA and its applications to the construction industry gradually increased. Of note was the development of life cycle assessment tools such as LCAid (Eldridge, 2002) and LCADesign (Seo et al., 2008; Tucker, 2003; Tucker, 2004). The latter integrated an LCI database with 3D building models based on the early version of Building Information Model (BIM), one of the first efforts to do so. From 2014, the Green Building Council Australia (GBCA) began to give additional points to projects that apply environmental LCA in their building certification process. However, the application of LCA has been limited to the materials used, not the entire building.

Methodological bases

There is no typical building LCA methodology in Australia. Most LCA research for building or construction industry generally follow international standards, such as ISO 14044 and EN 15978. Current commercial LCA tool (e.g., eTool[22]) is also based on these two guidelines.

Databases

The Building Products Innovation Council (BPIC) developed a LCA database for key building materials in 2011 based on an Ecoinvent shadow database (ecoinvent version 2.2). Currently this database is included in the national LCI database called AusLCI[23]. The national LCI database is regularly updated by the Australian LCA Society (ALCAS[24]). In addition, EPD data of some Australian building and construction products began to be developed and are now being used. Currently, 63 Australian EPD for building products are available[25].

Separately, the EPiC (Environmental Performance in Construction) database, in development for many years using the hybrid approach (Crawford et al., 2019), was published in 2019. The database provides environmental impacts (embodied energy, carbon and water) for 250 construction materials.

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[22] See: https://etoolglobal.com/about-etoollcd/
[23] See: https://www.alcas.asn.au/auslci
[24] See: https://www.alcas.asn.au/
[25] See: https://epd-australasia.com/epd-category/construction-products/

Number of applications and users
The application of LCA for buildings is on the rise, and the use of LCA has increased significantly as GBCA introduced LCA credits into the Green Star Rating Tool since 2014. Also, the Australian LCA Society (ALCAS) is now conducting LCA CP test to train qualified LCA practitioners as the number of LCA users increases.

Integration into the planning process
Currently, LCA is not required for building code or regulatory compliance. LCA is used on a voluntary basis in the design and planning stages of construction projects. LCA is included in voluntary sustainable rating tools for building (e.g., Green Star) and civil infrastructure works (e.g., ISCA Rating).

Acceptance and dissemination
LCA is slowly being accepted by architects and some segments of the industry since it is included in voluntary sustainable rating tools (Green Star and ISCA). But more efforts are needed to improve the awareness of its benefits and value amongst the public and the broader industry.

2.2.2 New Zealand

Historical background/Beginning of the application of LCA in the construction sector
Historically, some bespoke LCAs have been carried out for specific construction materials, for example, laminated veneer lumber (Love, 2010), up to whole buildings (for example, the Waitakere NOW Home® (Drysdale & Nebel, 2009)). Not all this work has necessarily ended up in the public domain. An evaluation was also undertaken for the Ministry of Agriculture and Forestry (now the Ministry for Primary Industries) of the potential for adapting LCA data for building materials in New Zealand (Nebel et al., 2011). Alcorn (2010) additionally published embodied carbon and energy figures for a range of construction materials, as well as assessing house designs, based on a hybrid analysis method.

In 2013, the Building Research Association of New Zealand (BRANZ) published a plan for the development of environmental product declarations (EPDs) and building level LCA in New Zealand (Dowdell, 2013). This was consulted on with the New Zealand construction sector and was well supported. Research then commenced on development of the New Zealand whole-building, whole-of-life framework ('framework') which contains a growing database of generic and specific data on environmental impacts of construction materials, as well as generic activity data for other life cycle stages (for example, material wastage rates at construction sites with end-of-life routes and materials service life information for different building elements). Framework resources are freely available at www.branz.co.nz/buildinglca (and select "Data").

An EPD programme, called EPD Australasia[26] was launched in 2014, providing a platform for manufacturers to declare the environmental impacts of their materials/products.

Situation in the field of LCA application / Application context (as of late 2020)
There is currently (December 2020) no regulatory driver for developing EPDs or undertaking building LCAs in New Zealand. However, the current situation appears likely to change.

In late 2019 the Climate Change Response (Zero Carbon) Amendment Act became law in New Zealand[27]. It provides a framework for New Zealand to develop and implement policies to contribute to the global effort under the Paris Agreement to limit global average temperature rise to no more than 1.5°C above pre-industrial temperatures. The Act's four key aims are to:

– set a new domestic greenhouse gas emissions reduction target for New Zealand to:
    a. reduce net emissions of all greenhouse gases (except biogenic methane) to zero by 2050
    b. reduce emissions of biogenic methane to 24-47 per cent below 2017 levels by 2050, including to 10 per cent below 2017 levels by 2030

[26] See: https://epd-australasia.com/epd-category/construction-products/
[27] See: https://environment.govt.nz/acts-and-regulations/acts/climate-change-response-amendment-act-2019/

– establish a system of emissions budgets to act as stepping stones towards the long-term target
– require the Government to develop and implement policies for climate change adaptation and mitigation
– establish a new, independent Climate Change Commission to provide expert advice and monitoring to help keep successive governments on track to meeting long-term goals.

In response, the Ministry of Business, Innovation & Employment (MBIE) established a Building for Climate Change Programme (www.mbie.govt.nz/building-and-energy/building/building-for-climate-change/) during 2020. The Programme recognises the part that the building and construction sector needs to play for New Zealand to achieve its climate change goals, including net zero carbon by 2050, as well as improve New Zealand's resilience to climate change. It anticipates getting New Zealand "building in a completely different way", with changes anticipated to current building laws – the Building Act and the Building Code.
The Programme is divided into two frameworks on which MBIE began a consultation in August 2020:
– Transforming operational efficiency – emissions directly and indirectly attributable to building operations, including energy and water use, and occupant health and wellbeing.
– Whole-of-life embodied carbon emissions reduction – emissions across the full supply chain of construction materials and products, construction processes, repair and maintenance, and processes at end-of-life of a building.

At the time of writing, the outcome of this consultation is awaited.

In the absence of a current regulatory driver, the main voluntary driver is the New Zealand Green Building Council's Green Star building environmental rating tool. This also recognizes selection of products with an EPD.

Methodological bases

The BRANZ-developed framework is based on EN 15978 (CEN, 2011) and EPD Australasia, which is affiliated to The International EPD System, requires that construction-related EPDs are based on EN 15804 (CEN, 2012 + A1).

Currently, resources available in the BRANZ framework facilitate calculation of environmental impacts for the Product stage (modules A1 – A3), Construction Process stage (modules A4 – A5), maintenance (module B2), replacement (module B4), operational energy use (module B6), operational water use (module B7), the End-of-Life stage (modules C1 – C4) and Benefits and loads beyond the building life cycle (module D). Office and residential buildings are evaluated for a 60 year and 90 year service life respectively using the framework. A method for constructing and testing Building Information Models (BIM) to provide material quantities suitable for building LCA has been developed by Berg (2014) and used as the basis for the framework (Berg et al., 2016).

Massey University and BRANZ research has resulted in the development of New Zealand-specific carbon budgets for residential and office buildings, using a top-down, absolute sustainability approach, and consistent with the 1.5oC warming threshold (Chandrakumar et al, 2020; McLaren et al., 2020). These carbon budgets are embedded in the LCAQuick tool (see "Databases").

Databases

BRANZ publishes an embodied carbon (modules A1–A3) dataset called BRANZ CO2NSTRUCT[28] which is largely derived from EPD data. BRANZ has a larger database of materials embedded in its free, building LCA tool called LCAQuick[29]. The database features a mix of data derived from product-specific and industry-average EPDs, as well as generic data based on modelling using EcoInvent, so varies in quality. A database also exists within E-Tool LCD, a building LCA tool developed in Australia, which is also finding application in New Zealand.

[28] See: https://www.branz.co.nz/environment-zero-carbon-research/framework/branz-co2nstruct/
[29] See: www.branz.co.nz/lcaquick

Number of applications and users

Lack of current regulatory drivers or incentives continues to provide a barrier to uptake of building LCA. Building clients rarely require it, and design teams rarely offer it. No firm data exists on the use of building LCA in New Zealand. Some case study examples are available on the BRANZ website[30].

Integration into the planning process

Building LCA is not currently required or incentivised by the planning process. However, the MBIE whole-of-life embodied carbon emissions reduction framework consultation document featured a proposal that reporting on whole-of-life embodied carbon will become mandatory as part of the building consent process, with subsequent and progressively tightening mandatory caps being set thereafter.

Similarly, the MBIE transforming operational efficiency framework consultation document proposed the setting of a mandatory operational emissions cap and a mandatory water use cap, both of which will tighten to a final level by 2035. There will additionally be defined indoor environmental quality parameters for all new buildings.

Acceptance and dissemination

The use of building LCA by architects and designers is currently low, with a few exceptions which tend to be one-off exercises primarily driven by recognition in building environmental rating tools. BRANZ launched a "Transition to Zero Carbon Built Environment" research programme in 2020[31]. As part of this, BRANZ is engaged in an active process to help inform, educate, train and support design teams and their clients. In this capacity, BRANZ has run seminars, webinars and training events, using LCAQuick as an education tool to help the sector better understand what building LCA is, how it can be used, and its value.

2.3 Situation in North America

2.3.1 Canada

Historical background/ Beginning of the application of LCA in the construction sector

Environmental life cycle assessment is being used in Canada for applications in the construction sector since the early 1990s. Initial applications of building LCA were carried out by an academics' consortium named Athena Project (Athena Sustainable Material Institute, 2020). Professionals started doing LCA more regularly around 2010. Athena project is now known as Athena sustainable material institute and has a widely known tool among practitioners named Athena impact estimator.

Situation in the field of LCA application /Application context (as of late 2020)

Life cycle assessment is slowly getting mainstream among construction professionals (outside of architects). Despite the long history of LCA in Canada, most of the incentive until recently came from LEED standards (Singh 2017). Since it's still a voluntary process for the most part, clients and their counterparts need to be aware of the environmental problematic caused by building, and, most importantly, be willing to certify their building. Some cities and regions regulate for public owned buildings, but, thus far, LEED has been mostly used by a handful of developers, mostly for marketing purposes.

Methodological bases

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[30] See: https://www.branz.co.nz/pubs/case-studies/lcaquick/

[31] See: https://www.branz.co.nz/environment-zero-carbon-research/

The requirements for life cycle assessment within the LEED standards and the Athena impact estimator are based on EN 15 978. Despite both using the same standard, there are differences when it comes to the application. Indeed, there is no singular methodology for Canada, resulting in disparities in the scope of analysis. As an example, surveyed practitioners include detailed module calculation for most of the life cycle beside the end of life and Module D. In comparison, Athena impact estimator includes only generic modules of A1-A5, B4, C1-C4 and D.

Databases

Outside the Athena impact estimator tool, there is no specific national database. Most practitioners use the ecoinvent database with a generic software such as SimaPro.

Number of applications and users

More and more professionals are receiving training on this matter, but there is no official data. LEED has certified over 4350 certified buildings in Canada (but that does not mean that every building had completed the LCA to get their points) (CAGBC, 2020).

Integration into the planning process

The integration of LCA in the design and planning process in Canada is still very low. Most of the analysis come in the latter stages in order to obtain LEED certification.

Acceptance and dissemination

The methodology and use of LCA is widely accepted among architects working in the industry. Legal requirements and public sectors need to push the large-scale application of LCA in the construction industry.

2.4 Situation in Asia

2.4.1 China

Historical background/ Beginning of the application of LCA in the construction sector

Environmental life cycle assessment is being used in China for applications in the construction sector since 1998 (Yang, 2009). Initial experiences were considering the environmental impacts in constructions products based on the National "Ninth Five-Year" High-tech Research Program (863 Program) - Research on Environmental Coordination Evaluation of Materials, which was hosted by Beijing University of Technology.

Situation in the field of LCA application /Application context (as of late 2021)

Life cycle assessment has not been used within the framework of sustainability assessment system - Green Building Evaluation Standard (GB/T 50378-2019). Some Universities and research institutions have developed their own Buildings LCA Models/Tools, such as the BEPAS Model (Tsinghua University) (Zhang et al. 2006), BELES Program (Tsinghua University) (Gu, 2009), BESLCI Tool (TongJi University) (Xing et al., 2008) and eFootprint (IKE)[32]. To make it easier to calculate carbon emissions, tools have been developed over last two years according to Standard for Building Carbon Emission Calculation (GB/T 51366-2019), including PKPM-CES, T20-CE, AIARCH, etc. It seems that the most mature one is PKPM-CES, which can use CAD model and read the quantity data automatically while LCA data can only be assigned manually if detailed calculation is required. At early design stage, rough default data, which are sourced from a similar case in the built-in case database, can be used. The energy simulation core is IBE, which was developed in 2017 by China Academy of Building Research. Because General Specification for Building Energy Efficiency and Renewable Energy Utilization (GB55015-2021) will take effect on 1 April 2022, which requires that operational carbon emissions of all the residential and public buildings must be reduced by 7kgCO^2/m^2/a

[32] See: https://www.efootprint.net/login#/home

compared with the emission intensity[33] of buildings that followed standards in 2006. However, the tools are still being improved to adapt to early and late design stage. It is foreseeable that carbon emission calculations will be more and more widely used, both in practice and in research.

Methodological bases

Standard for Building Carbon Emission Calculation (GB/T 51366-2019) is based upon ISO 14040 and ISO 14044. But there are differences. Firstly, only carbon emission is calculated. Secondly, fewer stages are involved compared with EN 15978, including production (A1-A3), construction (A4-A5), replacement[34] (B4), operational energy[35] (B6), and demolition (C1). Thirdly, the reference service life of buildings is 50 years.

Databases

The EPD data for Chinese building material and products are rare and not open access. CLCD (Chinese Core Life Cycle Database) [8] provides generic data for major materials and energy products. Data for specific building products (such as window frames), service system, and end of life stages are mostly not available.

Number of applications and users

Application in new construction is rare, although research on LCA is increasing. The number of LCA experts has increased over the last decade. Some universities/schools are also offering lectures on LCA for students of architecture and civil engineering.

Integration into the planning process

The integration of LCA in the design and planning process in China is still low. Very few of architects and engineers obtain LCA results from their buildings in order to optimize them. Maybe this is because the lack of regulation in this respect.

Acceptance and dissemination

The use of LCA in design process is low and architects have still little knowledge. LCA will probably be used at the end of the design for retrospective research.

2.4.2 Hong Kong

Historical background/ Beginning of the application of LCA in the construction sector

The initial applications of the LCA of the studies were mainly in the academic research sector, which focused on building materials and components. In 2006, there were initiatives from the government and the public housing sector to commission consultancy studies to develop protocols and databases to study the LCA for office and residential buildings in Hong Kong. A local LCI database comprising building materials and building services components had been developed by localizing the overseas databases. The original intention of the government was to develop an application software for facilitating building designers and contractors to apply LCA in their design and construction. However, it has never been put out to the industry practice.

Current situation in the field of LCA application /Application context (as of late 2020)

The LCA has mostly been applied in the construction research sector for assessing building materials and components, and a limited number of studies extended the LCA assessment to cover building services system components. There are only a few cases of whole building assessment. Currently, there is a credit provision within the Building Environment Assessment Method (BEAM-Plus) relating to LCA in building design. 1 credit will be awarded for demonstrating the embodied energy in the major elements of the building structure of the building has been studied and optimized through a Life Cycle Assessment (LCA). However,

[33] There is only an experience data, about 37kg/m^2, provided by Tsinghua Energy Efficiency Center.
[34] Only the GHG emitted by refrigerant is included. The replacement of components and equipment is not considered.
[35] GHG emissions caused by HVAC, DHW, lighting and elevators, renewable energy, carbon sink on the site are included.

it is noteworthy pointing out that BEAM-Plus is only voluntary in nature and designers have an option whether to earn the specific LCA credit in their building certification.

Methodological bases

The studies generally followed the rules of ISO 14040 or other EN standards. There are no local recommendations or requirements for the methodology or the data that should be used for the study. For determining the scope of the study (the reference study period, the reference service life, end-of-life scenarios, etc.) the authors have been mostly referring to published literature.

Databases

A majority of local LCA studies has been relying on the data published in overseas literature or public databases. There was a local database being developed some years ago but unfortunately never came to full application.

Number of applications and users

LCA is used in most of the research project connected to buildings and building materials but it has seldom been applied to industry practice.

Integration into the planning process

The integration of the LCA in the design and planning process is low. The practitioners are generally not familiar with LCA. However, LCA has been increasingly included in some curricula of the universities and therefore it is assumed that the use of the LCA will increase in the future.

3. Short Overview of Method Variations

In the following, an overview of the variations in methodological choices behind 25 method approaches (as of late 2020) from 19 countries – some countries reporting more than one methodology (i.e. France, Denmark, Germany, United Kingdom and Canada) – is provided (see Table A.0 in Appendix). Particularly, similarities and differences are shown with respect to: (a) selected reference study periods (RSPs), as well as life cycle and physical system boundaries; (b) modelling of the different life cycle stages; (c) type and scope of environmental indicators; (d) Assessment standards, databases, tools and benchmarks used; (e) market conditions and driving forces.

Of course, more methods than the reported ones, sometimes also company-specific methods, may exist in a country. However, it is assumed that the reported methods set a standard for a large amounts of building LCAs performed in each considered country.

To have a better overview of the differences in methodological developments among different countries especially in Europe, the results of this survey can be combined with other literature sources, such as the comparisons of methods prevalent in the Nordic countries by the Swedish Life Cycle Centre[36], the recent report by Röck et al. (2022)[37], as well as the recent report by OneClick LCA[38] which review European methods and best practices.

It should be noted that there is a dynamic development of methods around the world, therefore, some of the responses may already be outdated at the date of publication. However, the conclusion that there is still a high variation in choices remains. This conclusion constitutes the starting point for the A72 report "Context-specific assessment methods for life cycle-related environmental impacts caused by buildings" by Lützkendorf et al. (2023), among others.

3.1 System Boundaries

3.1.1 Typically considered reference study period per building type

The survey showed that the most common reference study period (RSP) indicated by the various national methods is 50 years irrespective of the type of building. What changes is the range of the RSPs considered. A detailed overview of the considered RSPs per building type in the different methods is given in Table A.1 (Appendix).

Figures 3.1a-b show that for new residential buildings (single-family and multi-family) 50 years is also the minimum RSP applied, while the max values can reach 90-120 years and have been seen in methods applied in Denmark and New Zealand, i.e. the Danish LCAbyg tool[39] and NZ LCAQuick tool. The assumption of 90 years' service life for New Zealand houses is based on research carried out by Johnstone (1994)[40]. Only

[36] See: https://www.lifecyclecenter.se/nordic-building-lca-comparison/ (accessed January 2023)
[37] See: https://fs.hubspotusercontent00.net/hubfs/7520151/RMC/Content/EU-ECB-1-Facing-the-data-challenge.pdf
[38] See: https://www.oneclicklca.com/construction-carbon-regulations-in-europe/
[39] Currently LCAbyg has switched to a 50-year RSP to adapt to the upcoming requirements regarding the climate impact of buildings in Denmark.
[40] In his paper, Johnstone states: "About 50% of dwellings have been lost from each dwelling cohort by the age of 90 years and the distribution of losses follows that of a bell shape skewed to the left." (Johnstone, 1994, p. 181).

about 50% of methods go beyond a focus on residential and office buildings and consider other types of buildings such as industrial and educational buildings. Figure 3.1d shows that industrial buildings appear to have the lowest min value for RSP (i.e. 20 years) as well as the lowest max value (i.e. 60 years).

Methods usually are in place for assessing new buildings, but in cases they do consider the renovation of existing buildings, the recommended RSP is either the same as the new building or no specific RSP is recommended. Therefore, no clear method differentiations are found between new and existing buildings.

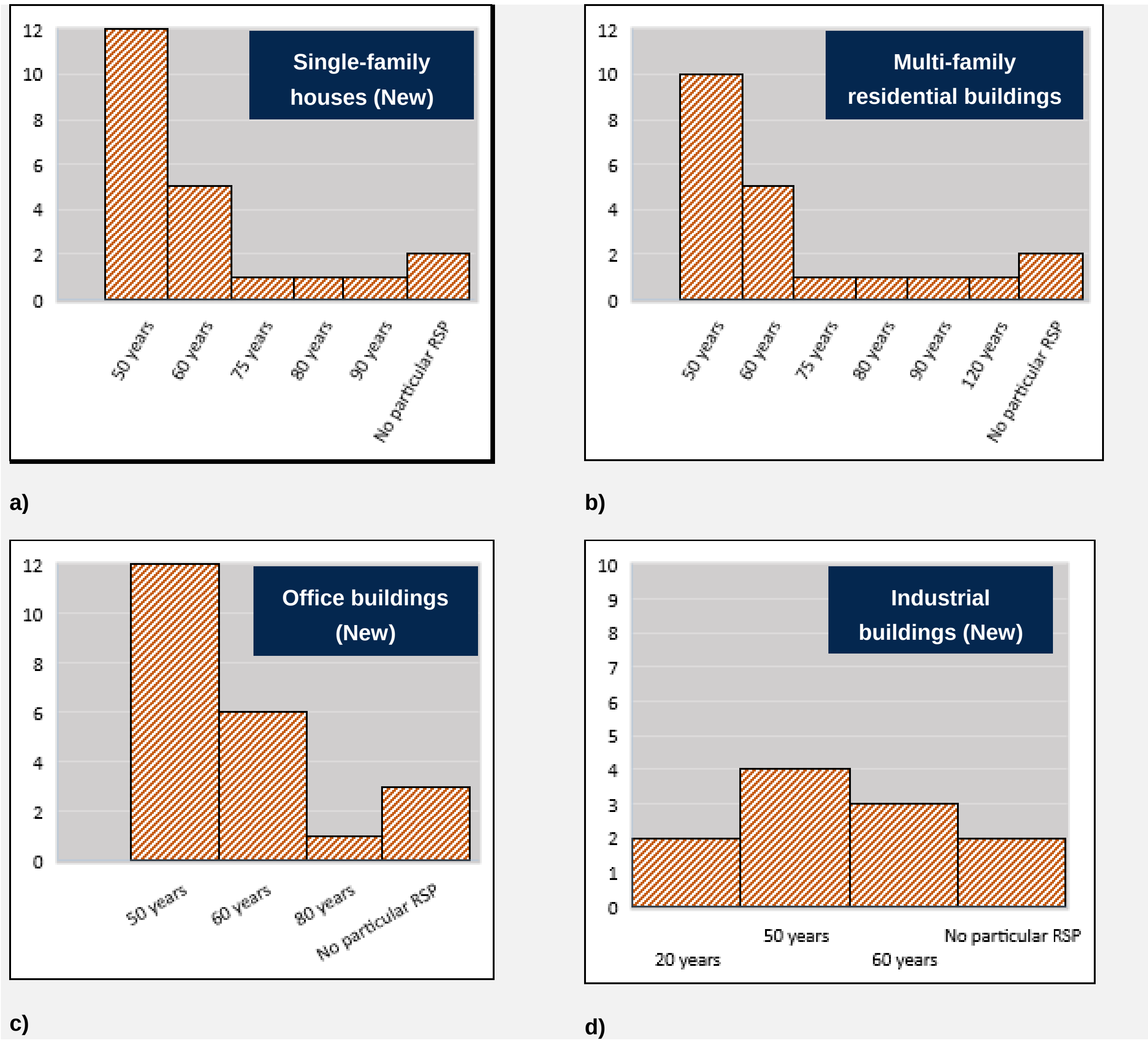

Figure 3.1: Distribution of RSPs considered for: a) single-family residential buildings; b) multi-family residential buildings; c) office buildings; d) industrial buildings. Details are given in Table A.1 (Appendix).

3.1.2 Typically considered life cycle stages and modules

Together with RSPs, a detailed overview of the considered life cycle information modules in the different methods is given in Table A.1 (Appendix). As expected, all methods consider modules A1-3 (product stage) (see Figure 3.2). Furthermore, all countries consider operational energy use in their assessments; for the ones who declared they do not, it is not that operational impacts are not accounted for in their country, but they have dedicated methods for embodied impacts, and these were the ones reported as part of the survey, such as the Dutch GWW method[41], the Swedish coming law[42] and the BRE method[43].

[41] See: https://milieudatabase.nl/wp-content/uploads/2019/05/SBK_Assessment_method_version_2_0_TIC_versie.pdf
[42] See: https://www.boverket.se/en/start/building-in-sweden/contractor/tendering-process/climate-declaration/
[43] See: https://bregroup.com/products/impact/

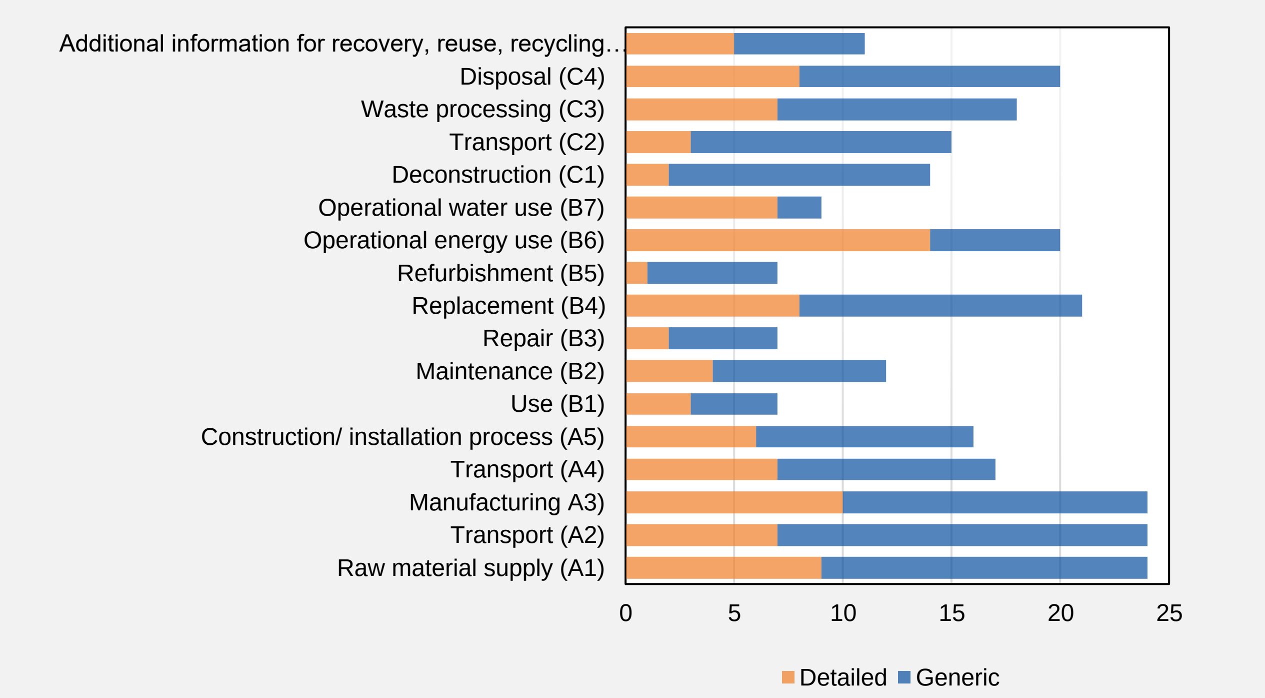

Figure 3.2: Consideration of life cycle modules in the minimum assessment scope based on generic/detailed input (based on 25 methods). Details are given in Table A.1 (Appendix).

Modules A4-5 (construction process stage) are considered by more than 2/3 of the methods. It can be observed that it is considered in (a) countries where transport distances seem to be non-negligible, such as Spain and New Zealand e.g. see Frischknecht et al. (2019; 2020); (b) countries where the methods reported are or will be part of building regulations, such as the Danish voluntary sustainability standard[44], the French E+C- method[45] and the Swedish coming law[46]. Slightly less methods consider modules C1-C2 (deconstruction and transport) than A4-5 assumingly due to their higher uncertainty.

Although replacements typically constitute the most important embodied share after product stage impacts, especially in the case of buildings with a significant share of technical equipment, some methods do not consider replacement (B4), i.e. Portugal, Sweden and Canada. In the case of the Swedish coming regulation, the intention of this omission is to put focus on:

- emissions that happen today
- emissions that can be verified at the time when the declaration is handed in
- the most impacting life cycle modules that are currently not targeted by any other regulation (which is the case for module B6)

Modules such as B1, B2, B3 and B5 are the least considered, because:

- they are still unclear to method developers, and/or
- are considered unimportant.

Figure 3.3 decomposes module B6 in more detail, following the structure of ISO carbon metric use stage ISO 16745-1 (ISO, 2017). Broadly speaking, regulated operational energy is the energy included in building regulations of a country. Typically, this is the operational energy use which a client has direct influence over, such as the energy used for space heating and cooling, domestic hot water supply and ventilation. For office buildings parts of the regulated energy use, normally, is also fixed lighting (e.g. in Austria and Germany). All other energy used in a building is referred to as unregulated energy, and can be building-related or user-related.

[44] See: https://im.dk/Media/637602217765946554/National_Strategy_for_Sustainable_Construktion.pdf
[45] See: https://www.ecologie.gouv.fr/batiment-energie-positive-et-reduction-carbone
[46] See: https://www.boverket.se/en/start/building-in-sweden/contractor/tendering-process/climate-declaration/

It is evident that the overwhelming majority of methods focus on regulated building-related energy use. This is called B6.1 in the context of Annex 72 and recent standard updates, while the unregulated parts of energy use are called B6.2 (building-related) and B6.3 (user-related) (see Lützkendorf et al. (2023) and EN 15643:2021). Up to late 2020, only three methods included indoor transportation (B6.2) – i.e. the Austrian DGNB/ÖGNI Certification[47], the NZ whole-building whole-of-life framework/LCAQuick[48] and the method used by Groupe AGEGO in Canada (which is based on LEED standards). However, this type of energy consumption can account for 5-10% of the total operational energy consumption (Karlis 2014; De Almeida 2012). An extended scope of operational energy use including user-related energy consumption was considered in only three countries (four methods) (i.e. France, Spain and New Zealand) as shown in Figure 3.3. However, in recent developments of methods the importance of the unregulated part of operational energy use has been started being acknowledged and therefore considered in the calculation scope and benchmarks. Some examples are (a) the UK Future Homes Standard / Future Buildings Standard (2025) which provides an overall design target of 35-40 kWh/m2/yr for all energy use of new buildings from 2025; (b) the German quality label QNG[49]. One of the reasons is to deal with questions of PV systems dimensioning and the determination of the degree of self-use of solar-generated electricity in a more comprehensive way.

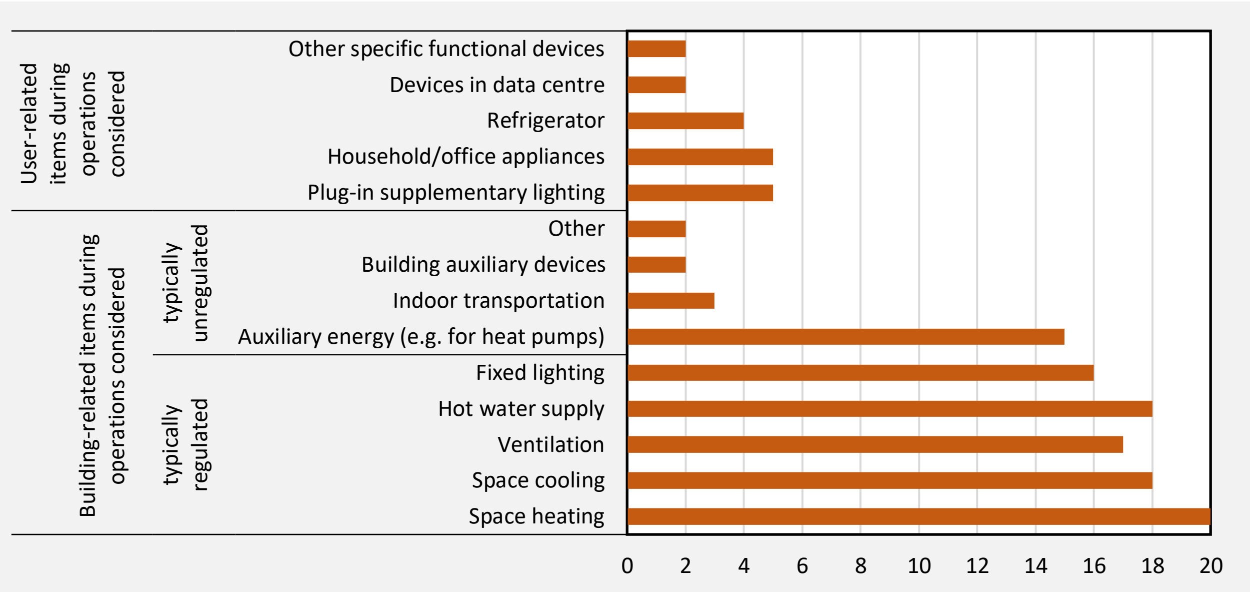

Figure 3.3 Energy uses included by the different methods. Details are given in Table C.2 (Appendix) Note than building-related items are Carbon Metric 1 (CM1) and both building-related and user-related items are Carbon Metric 2 (CM2) acc. to ISO 16745-1.

3.1.3 Typically considered building elements

The physical system boundaries of the different methods show great variance, especially when it comes to the inclusion of building services (see Table A.2 in the Appendix for a detailed overview). As seen in Figure 3.3, about 80% of the methods show completeness in the consideration of substructure, superstructure and finishes. The inclusion/exclusion of elements that cause variance are:

- **with respect to substructure**: foundations (e.g. piling), which are excluded in three methods (i.e. Belgian MMG method, Portuguese SBToolPT-H method and British BRE Global IMPACT Building LCA method) despite their importance for the embodied impacts when it comes to high-rise buildings or buildings built on harsh ground conditions.
- **with respect to superstructure**: stairs and ramps, which are excluded in four methods as well as internal doors, perhaps due to the use of simple building geometric models by some methods.

[47] See: https://www.ogni.at/leistungen/zertifizierung/
[48] See: https://www.branz.co.nz/environment-zero-carbon-research/framework/lcaquick/
[49] See the manuals (in German): https://www.nachhaltigesbauen.de/austausch/beg/

– **with respect to finishes**: In general finishes are not easy to define during early design stages. three out of 24 methods exclude all types of finishes, while two only internal finishes.

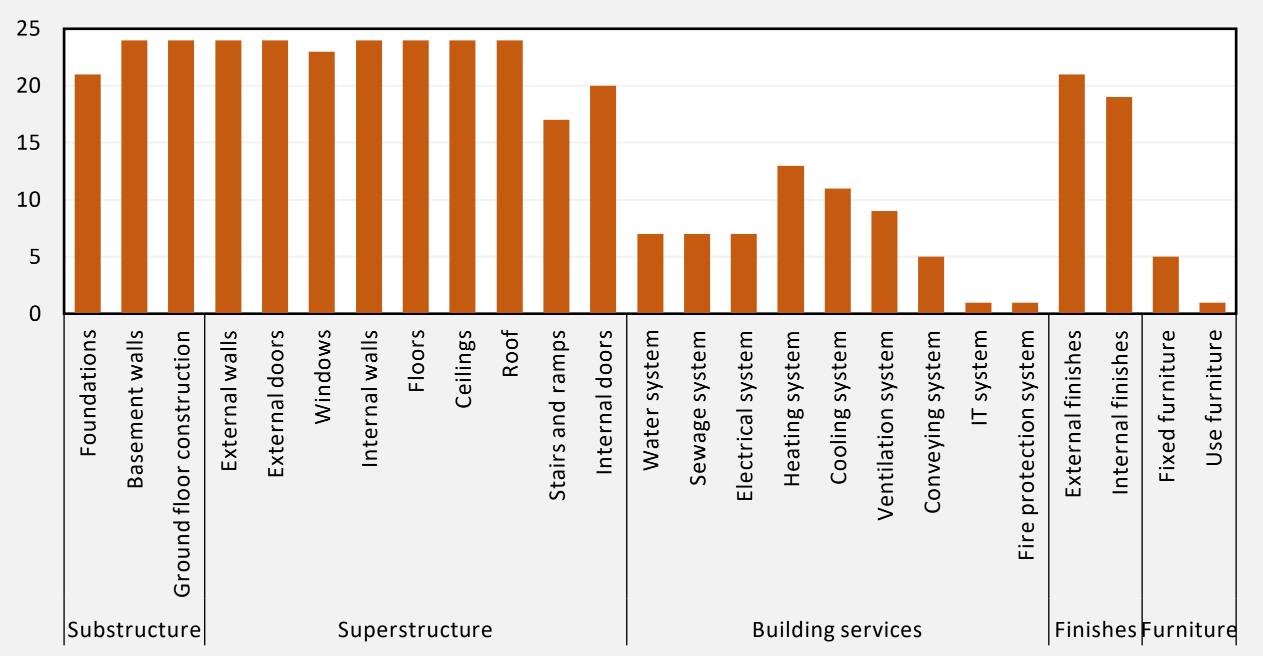

Figure 3.3: Variance of completeness of building description (i.e. physical boundaries) based on the typically considered building elements of 24 methods from 18 countries. Details are given in Table A.2 (Appendix)

Regarding **building systems**, if included, most methods tend to focus on heating, cooling and ventilation systems, which are also the systems responsible for regulated operational energy consumption in most countries. Less than 1/3 of the methods include water, sewage and electrical systems. The reason for omission of building services is, in most countries, the lack of data. Regarding furniture, about 20% of the methods include fixed furniture (e.g. sinks and basins), while only the Spanish method additionally includes user furniture. The latter is hard to predict not only during a building's design, but also at the handover, since it depends on the tenant's choices.

Methods also vary regarding the calculation of material quantities (Figure 3.4). Most methods exclusively follow an element-based approach, while some of them allow/provide multiple possibilities. For the latter, one example is DGNB, which proposes a list of tools that can be used for LCA calculations. Some methods vary the quantity take-off method dependent on the design stage (e.g. LCAbyg in Denmark). The consequence is that when several tools are proposed/allowed by a method, these must be checked and approved - based on a reference calculation so that to ensure that they do not lead to different results even if the boundary conditions and databases applied are the same.

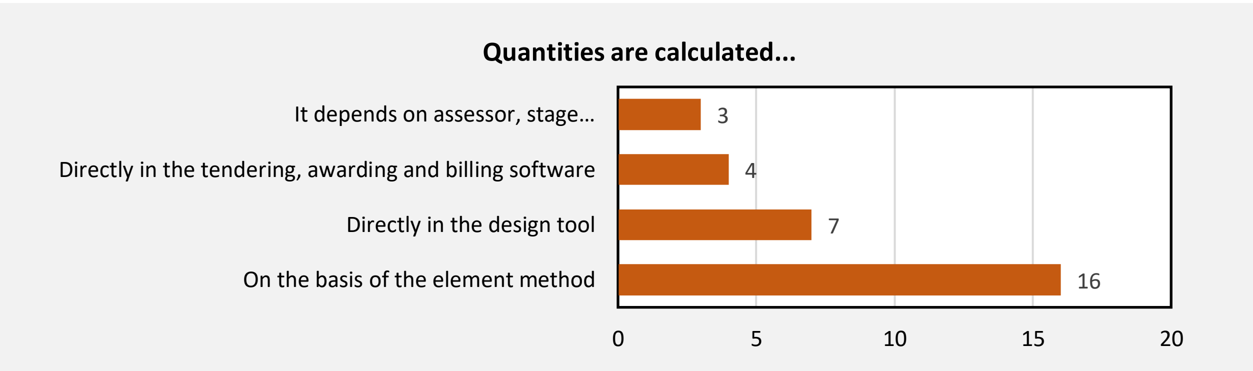

Figure 3.4. Overview of methods used to calculate material quantities based on 24 methods by 18 countries (multiple answers were possible). Details are given in Table A.2 (Appendix).

3.2 Modelling Aspects

During the questionnaire survey, the respondents were also asked to shortly mention essential modelling aspects per life cycle module considered in their national methods. The raw answers are presented in Tables B.1-3. These methods led to investigate some of these aspects in more in-depth surveys and present the analyses in special reports. There reports are:

– Basics and recommendations on **modelling of processes for transport, construction and deconstruction** in building LCA (Soust-Verdaguer et al., 2023)
– Basics and recommendations on **influence of service life of building components on replacement rates** and LCA-based assessment results (Lasvaux et al., 2023)
– Basics and recommendations on **electricity mix models** and their application in buildings LCA (Peuportier et al., 2023)
– Basics and recommendations on **influence of future electricity supplies** on LCA-based building assessments (Zhang 2023)
– Basics and recommendations on **assessment of biomass-based products** in building LCAs: the case of biogenic carbon (Saade et al., 2023)
– Basics and recommendations on **influence of future climate change on prediction of operational energy** consumption (Guarino et al., 2023)
– Basics and recommendations in **aggregation and communication** of LCA-based building assessment results (Gomes et al., 2023).
– Basics and recommendations on **discounting in LCA** and consideration of external cost of GHG emissions (Szalay et al. 2023)

3.3 Environmental Indicators

Figure 3.5 shows that all methods include the indicator GWP, with 3/24 of them (13%) focusing exclusively on this one, i.e. the Danish Sustainability code LCA, the Swedish Act on climate declarations for buildings and the British RICS method. The next most popular indicators are Photochemical Ozone Creation Potential (POCP), Acidification potential (AC), Ozone Depletion Potential (ODP) and non-renewable primary energy demand/use. Surprisingly, despite most methods reported are from Europe, only 6/24 (25%) of the methods fully include the minimum list of indicators recommended by the European standard EN15978 as well as ISO 21929-1:2011 standards. A lower acceptance/consideration of the indicators ADP_{fossil} and $ADP_{elements}$ can be especially observed.

An additional observation is that the methods with the broadest list of indicators exceeding standards expectations are choosing to present their final results in a partially or even fully aggregated form, e.g. the Belgian method MMG, the Dutch method GWW and the British method BRE. More details are given in Table C1 (Appendix). The topic of indicators aggregation is further discussed in the A72 background report by Gomes et al. (2023).

Methods do not differ only in terms of which indicators are considered but also with respect to the scope of each individual indicator. For example, looking at the scope of the indicator(s) used for quantifying embodied energy consumption different types and uses of energy resources can be quantified and considered in the indicator(s). A differentiation between the various types and uses of primary energy resources is provided in Balouktsi et at. (2016) and Annex 57[50] and shown in Figure 3.6.

[50] See: http://www.annex57.org/wp/wp-content/uploads/2017/05/ST1-Report.pdf

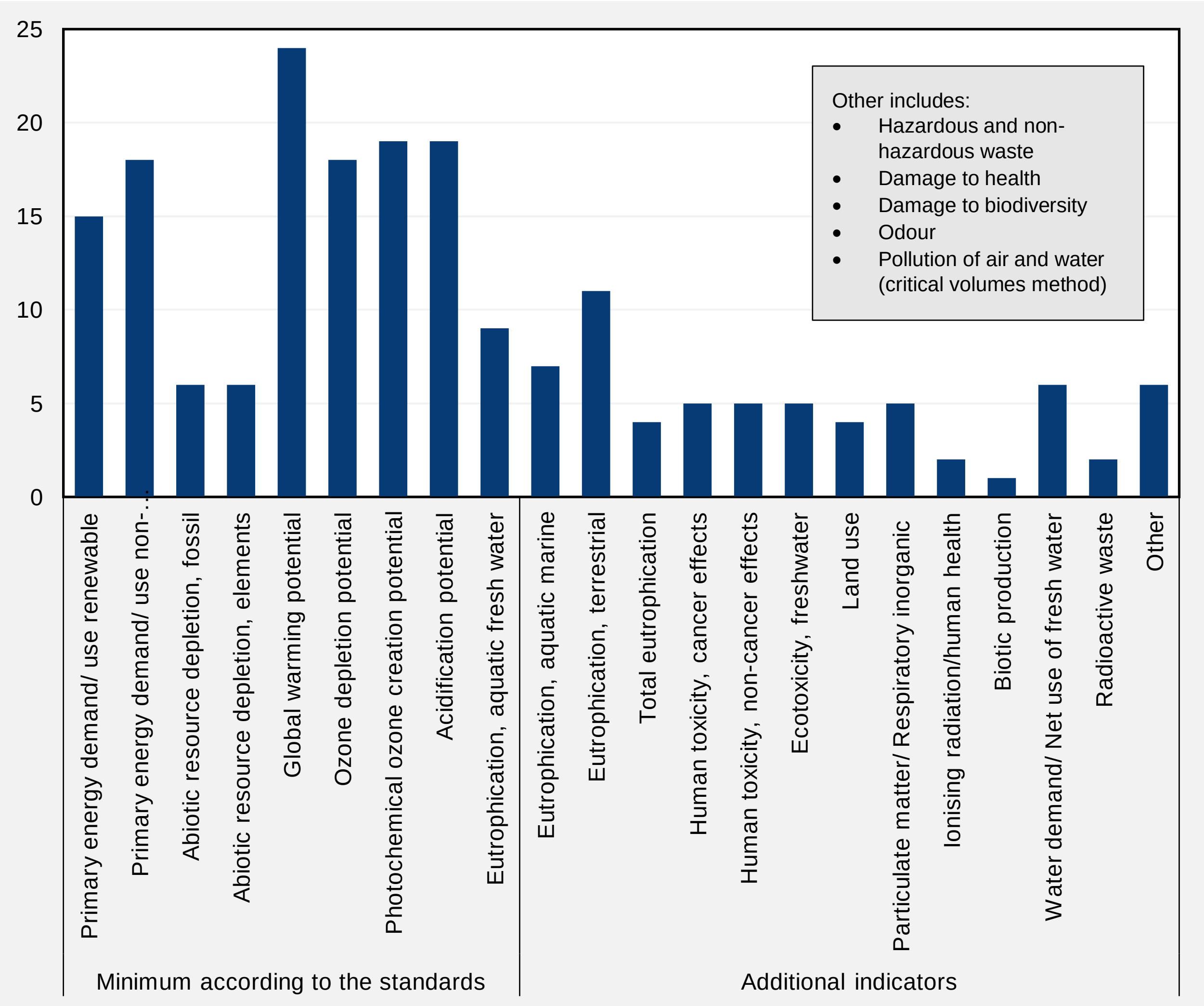

Figure 3.5: Overview of considered indicators in selected national methods. Details are given in Table C1 (Appendix)

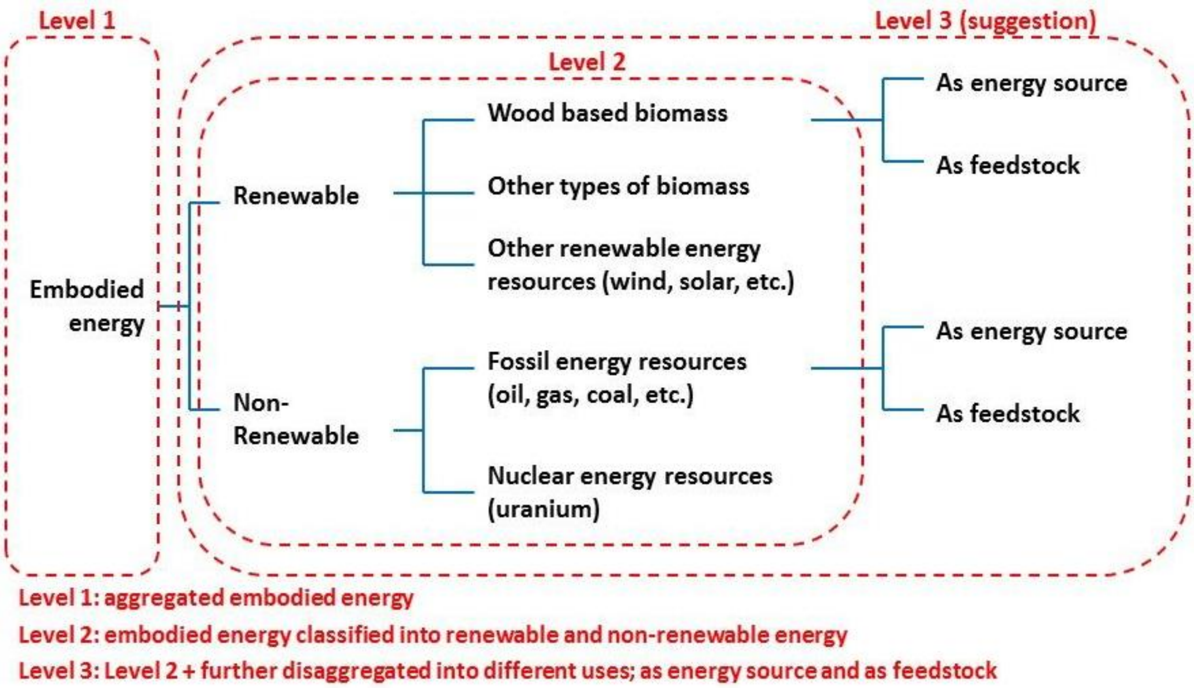

Figure 3.6: Aggregation levels in embodied energy indicator based on the types and uses of resources (adapted from Balouktsi et al. 2016)

Among the methods reported, the biggest variation is seen is the inclusion/exclusion of feedstock energy (Figure 3.7). ISO 14040 (ISO 2006) defined feedstock energy as the “heat of combustion of a raw material input that is not used as an energy source to a product system, expressed in terms of higher heating value or lower heating value.” Feedstock energy is the heat of combustion or the energy content of raw material inputs used as ingredients in the process of manufacturing a product (Dixit, 2017). For instance, petrochemicals may be used as raw materials, i.e. feedstock, to manufacture plastics and rubber. This energy (calorific value) is not released but retained (contained in the product) throughout the product lifecycle, and therefore, is available for use as fuel energy outside the system boundary. This must be accounted for as non-renewable feedstock energy. Similarly, wood is used to produce a wide variety of building products and the energy contents of wood can be accounted for as renewable feedstock energy.

Methods considering non-renewable feedstock energy are the ones applied in North American and Oceanian countries, as well as China, while in Europe the situation is mixed: only France, Netherlands, Slovenia, Switzerland and United Kingdom do consider it. The consideration of renewable feedstock energy is even less common.

As earlier shown in Figure 3.5, some countries consider only non-renewable energy sources (specifically certification-based methods SBToolCZ and BREEAM), but among the ones which consider both renewables and non-renewables, most of them report them separately as two indicators (Figure 3.8). This shows that most methods at least present an aggregation level 2.

Some approaches that stand out in general:

– The method in the French tool EQUER does not include solar, because “using solar energy does not reduce the resource for others”[51].
– Methods which report non renewable energy sources via the indicator ADP fossil, include uranium (i.e. nuclear energy) in ADP elements
– Spanish method reports fossil and nuclear separately; hydropower and biomass separately; solar and geothermal jointly.

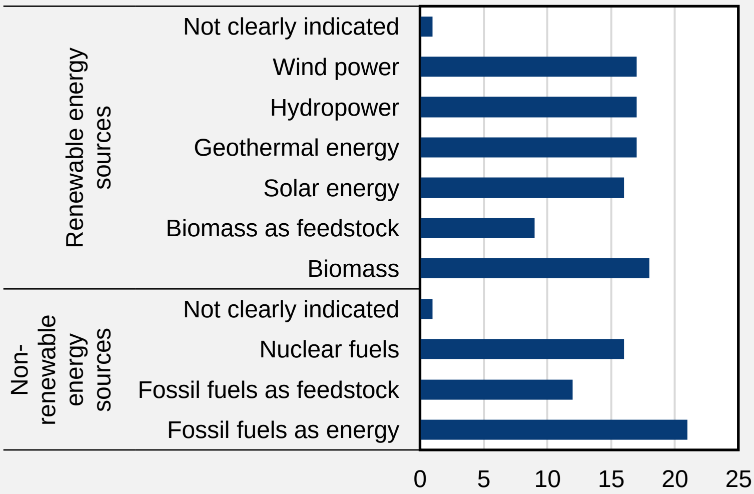

Figure 3.7. Considered sources of renewable and non-renewable energy

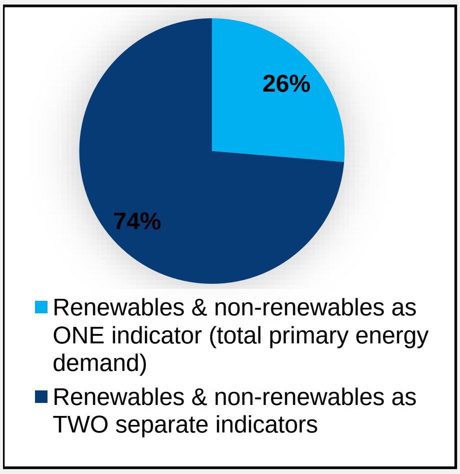

Figure 3.8: Total primary energy demand vs presentation of renewable and non-renewable sources as two indicators.

[51] Answer by B. Peuportier

Regarding the scope of the indicator GWP which is the most widely used, Figure 3.9 shows the variations among the different methods. Besides the fossil fuel-related GHG emissions, nearly 90% of methods also consider process emissions. For concrete products, process emissions occur due to calcination and carbonation. Calcination reactions of concrete products only occur during the production of cement in the kiln, while carbonation occurs throughout the life cycle of concrete products. Calcination emissions are quite important as constitute more than 60% of manufacturing related emissions (Sanjuán et al. 2020). This share changes dependent on the type of concrete and its mixtures. However, the carbonation results in an uptake corresponding to 45 percent of the emissions through calcination.

More than 1/3 of the methods (9/25) consider biogenic carbon (removals from atmosphere). A more detailed specification on how the different methods differ and the implications can be found in the study by Ouellet-Plamondon et al. (2023) which compares the life cycle assessment of the same wood-based multi-residential building from the perspective of 16 countries participating in Annex 72. In terms of land use, only four methods consider GHG emissions due to land use, with only one of them being an official national method (SIA 2032); The other three are academic/company-based methods. It is not clear though whether both direct and indirect land-use change are considered.

3.4 Assessment Standards, Databases, Tools and Benchmarks

Table D.1 shows that most of the methods are based on the European standard EN 15978, even in the case of non-European countries. Only about 50% of the investigated countries have a national standard in place in addition.

In terms of the databases in place, around one third of the methods analysed are not connected to a national database. To calculate LCA results some methods either apply Ecoinvent or databases from other countries such as Ökobau.dat. Regarding the tools, only a few countries have developed national ones; most of the methods are supported by multiple tools.

In relation to benchmarks, several countries have already benchmarks in place or are in the process of developing them to support assessments. Existing benchmarks are presented in a special background report by Rasmussen et al. (2023).

3.5 Market Conditions and Driving Forces

Despite most countries have some kind of method in place, official, voluntary or more academic, with some methods being almost a decade old, the level of acceptance and application of these methods still lags behind (Figure 3.10). An example of a country with "high" acceptability is Sweden since the method is already part of the public procurement and will have a legal character soon; this means that 100% of developers of new buildings (the types included in the regulation) in Sweden will have to use it. An example for "medium" acceptance and application is BREAAM method; despite its overall voluntary nature in the UK, obtaining a BREEAM rating can help with the planning approval as well as has become a mandatory requirement for many Local Planning Authorities (LPAs). Some reasons for "low" or "very low" acceptability and application are that, despite LCA methods are increasingly being part of public procurement, individual investors and builders are often confused about the real benefit of using such methods. They also often consider related certification expensive and time consuming. Therefore, without clients or the regulators demanding such results, architects are not motivated to apply such methods. The overall dissemination of LCA methods among architects and their level of knowledge in this topic are also discussed in another A72 background report by Lützkendorf, Balouktsi and Röck et al. (2023).

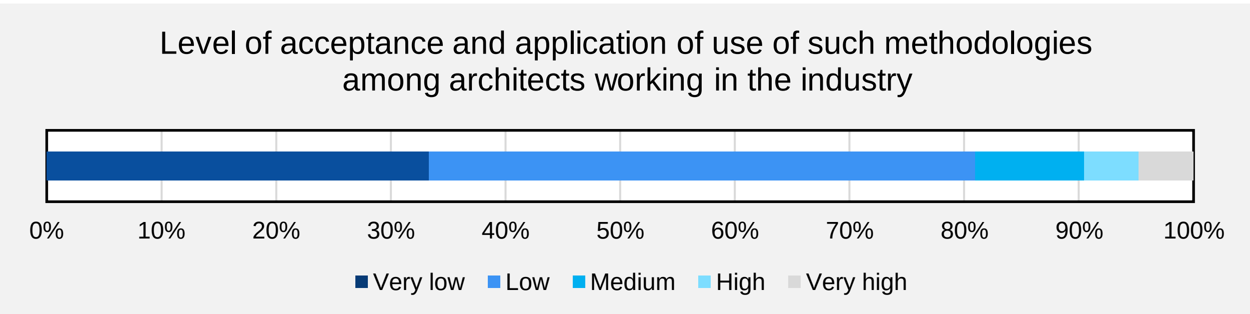

Figure 3.10. Level of acceptance and application of LCA methods among architects working in the industry. Details are given in Table G1 (Appendix)

Having specific requirements either in legislation or funding programmes always drives application and request for such results. More than 60% of the countries have legal requirements in place for operational primary energy, while for operational GHG emissions only about 20% have such requirements in place (e.g. Austria, Portugal, United Kingdom and Australia). It should be noted though that some methods are focused on embodied impacts, which does not necessarily mean that there are no legal requirements for operational impacts. In terms of embodied impacts legal requirements are only in place for GHG emissions in one country, the Netherlands, as of late 2020. However, legal requirements are in preparation in Sweden, France and Denmark among others (see also report by Lützkendorf, Balouktsi, Frischknecht et al. 2023).

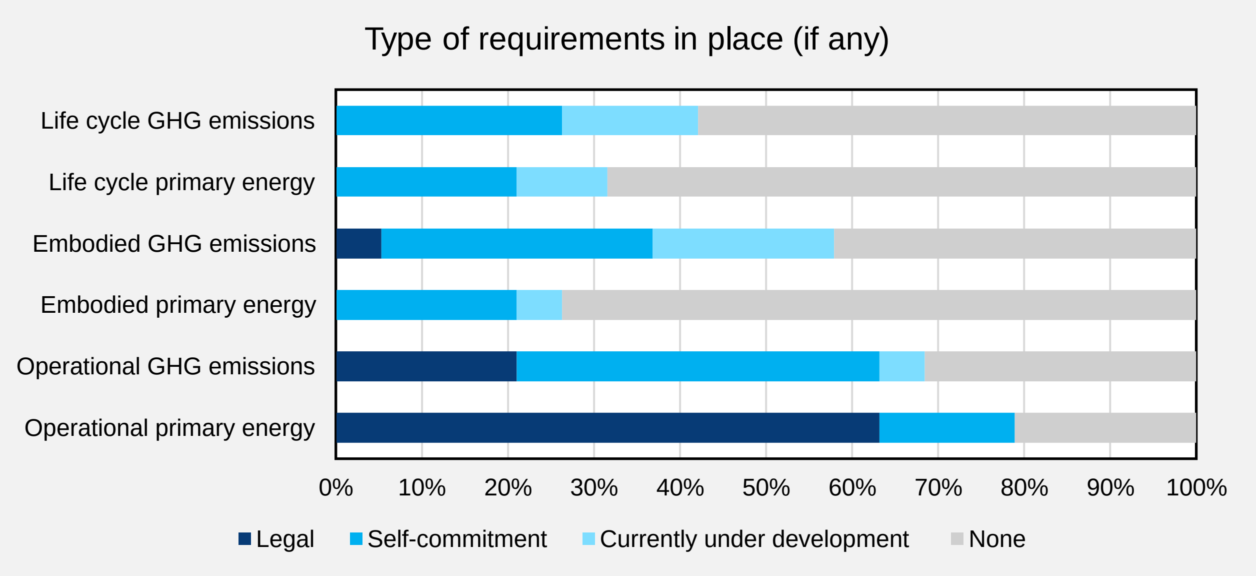

Figure 3.11. Percentage of countries having different types of requirements in place to reduce operational, embodied or lifecycle energy and GHG emissions. Details are given in Table G1.

4. Overall Findings & Recommendations

The following key points arise from the survey among A72 experts and analyses:

- Despite most countries having some kind of method in place, some of them official, voluntary (e.g. part of a certification system) or more academic, and some are almost a decade old, the level of acceptance and application of these methods still lags behind. The highest acceptance is mostly seen for methods that are already part of the public procurement and have or will have a legal character soon (e.g. Sweden and Denmark). Therefore, having specific requirements either in legislation or funding programmes always drives application and request for such results.
- While most countries have legal requirements in place for operational primary energy, only a few have such requirements for operational GHG emissions and even fewer for embodied impacts. Particularly, legal limits for the embodied GHG emissions are currently only in place in the Netherlands and France, while they are soon expected to be in force in Denmark, Sweden, Finland and the UK among others (see: Lützkendorf & Balouktsi, 2022).
- The most common reference study period (RSP) indicated by the various national methods is 50 years irrespective of the type of building. What changes is the range of the RSPs considered, with the largest ranges seen for residential buildings.
- Most methods focus on residential and office buildings. This can be the case because most assessments have been so far done for these types of buildings. Only a few methods go beyond these two types and consider e.g. industrial and/or educational buildings.
- Transport and construction processes have started being more and more integrated into the scope of national methods. Modules A4-5 are now considered by a significant number of methods. This trend can be observed especially in countries where transport distances seem to be non-negligible, such as Spain and New Zealand or in countries where the methods are or will be part of building regulations. Such a trend is not the case for C1-2 modules (deconstruction and transport to landfill or waste processing) with the justification that these activities happen far into the future.
- Although replacements typically constitute the most important embodied share after product stage impacts, especially in the case of buildings with a significant share of technical equipment, some methods prefer to focus on emissions that happen today in the short-term. This means that replacement (module B4) is not considered by all methods at least not in the minimum scope.
- Modules such as B1, B2 and B3 are the least considered. This may be the case because they are still unclear to method developers, and/or are considered unimportant.
- The overwhelming majority of methods focus for the operational part on regulated building-related energy use (B6.1 in the context of recent standard updates like EN 15643). An extended scope of operational energy use including user-related energy consumption is considered in only a few countries at the moment, despite its importance in dealing with questions of the dimensioning of PV systems and the determination of the degree of self-use of solar-generated electricity.
- The physical system boundaries of the different methods show great variance, especially when it comes to the inclusion of building services like HVAC-systems. Most methods show completeness in the consideration of substructure, superstructure and finishes. The inclusion/exclusion of elements that cause variance are (1) stairs and ramps, as well as internal doors, perhaps due to the use of simple building geometric models by some methods; (2) building systems, due to the lack of data; (3) furniture, especially user furniture as it is hard to predict not only during a building's design, but also at the handover, since it is dependent on the tenant's choices.
- Due to climate emergency, some methods now focus exclusively on GHG emissions. This will cause problems with burden-shifting. In any case, most methods choose a limited list of indicators, e.g. also including indicators such as Photochemical Ozone Creation Potential (POCP), Acidification potential (AC), Ozone Depletion Potential (ODP) and non-renewable primary energy demand/use. A lower acceptance/consideration of the dis-aggregated indicators ADPfossil and ADPelements can be especially

observed. On the one hand, this subdivision is still very new - see EN 15804 - on the other hand, hardly any data is available so far.

- The methods with the broadest list of indicators are choosing to present their final results in a partially or even fully aggregated form. Different approaches of aggregation can be observed.
- There are different perspectives on biogenic carbon consideration in life cycle assessment. Different options are currently followed in assessments and it can influence the outcome of a study and the decisions and actions of some stakeholders.

Each country has a different starting point and is at a different stage of development in this field. However, to enable comparability and usability of LCA results, the provision of a consistent and transparent basis for a methodology and reporting structure for environmental performance assessment of buildings in line with international and regional standards is needed. This background report, but especially the main A72 report by Lützkendorf et al. (2023) with its rules and recommendations, are intended to support a development in this direction. Methodologically, the approaches should be aligned in the medium term. International, and in particular, European standardization will continue to make contributions to this. Observation of developments regarding the new EN 15978-1, which is scheduled to be published in 2023, is recommended.

The standards themselves, to foster transparency and facilitate communication among different methods, should introduce typologies for system boundary description and other methodological aspects to declare the broader scope, completeness and background of a method.

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APPENDIX: Detailed reporting of 25 methods

A.0. HOW AND WHERE THE LCA METHODOLOGY CAN BE FOUND

#	Country	Name of the methodology	Years in place (since…)	Developer	Name of the source (e.g. standard, tool, ...)	Version	Source
				EUROPE			
1	AUSTRIA	DGNB/ÖGNI Certification System	Since 2009	German Sustainable Building Council	German Sustainable Building Council Certification System	2014	https://www.ogni.at/leistungen/zertifizierung/dgnbzertifizierung/
2	BELGIUM	MMG (Environmental profile of building elements)	Since 2012	KU Leuven (university), VITO (Flemish Institute for Technological Research) and BBRI (Belgian Research Institute) – research project financed by OVAM (Flemish Waste Agency)	MMG (Environmental profile of building elements)	2017	www.vlaanderen.be/nl/publicaties/detail/environmental-profile-of-building-elements-update-2017
3	CZECH REPUBLIC	SBToolCZ	Since 2013	CTU in Prague, Faculty of civil engineering	SBToolCZ Guide	-	https://www-sbtool-cz.translate.goog/online/?_x_tr_sl=cs&_x_tr_tl=en&_x_tr_hl=de
4	DENMARK (1)	DGNB LCA procedure	Since 2012	University/ Green building council	as applied in the tool LCAbyg	2018	https://www.lcabyg.dk/en/
5	DENMARK (2)	Voluntary Sustainability code LCA	Since 2020	Academia, authorities, interest organizations, companies	Baeredygtighedsklasse.dk	2020	Baeredygtighedsklasse.dk
6	FRANCE(1)	EQUER	Since 1995	MINES ParisTech	ISO 14040 and 14044, PhD thesis and articles of B. Polster, A. Guiavarch, E. Popovici, S. Thiers, G. Herfray, C. Roux, T. Recht, M.L. Pannier, P. Schalbart & B. Peuportier	4.18.7.2	www.ces.mines-paristech.fr/Logiciels/EQUER/
7	FRANCE(2)	E+C- Method	Since 2017	French ministry of environment	Référentiel « Energie-Carbone » pour les bâtiments neufs Méthode d'évaluation de la performance énergétique et environnementale des bâtiments neufs	1.0	www.ecologique-solidaire.gouv.fr/batiment-energie-positive-et-reduction-carbone
8	GERMANY(1)	Bewertungssystem Nachhaltiges Bauen (BNB)	Since 2008	BMUB		2015	https://www.bnb-nachhaltigesbauen.de/bewertungssystem.html
9	GERMANY(2)	Bewertungssystem Nachhaltiger Kleinwohnhausbau (BNK)	Since 2015	Research project	Bewertungssystem Nachhaltiger Kleinwohnhausbau (BNK)	V 1.0	www.nachhaltigesbauen.de/nachhaltige-wohngebaeude.html
10	GERMANY(3)	DGNB System	Since 2008	Joint development of academia, federal ministry and NGO	DGNB Criteria "Building Life Cycle Assessment" (ENV1.1)	2018	https://www.dgnb-system.de/en/system/version2018/criteria/building-life-cycle-assessment/

11	HUNGARY	No name, we can call it Hungarian LCA of buildings method	Since 2009	developed in a research project and further developed at the Budapest University of Technology and Economics	-	-	-
12	NETHERLANDS	Assessment Method Environmental Performance of Buildings and Civil Engineering Works (GWW)	Since 2014	Independent committee of experts	-	V.2	www.milieudatabase.nl/index.php?q=english-documents
13	PORTUGAL	Sustainability Assessment Method for Portuguese Residential Buildings (SBToolPT-H)	Since 2009	Adaptation to the Portuguese context of the international SBTool developed by the University of Minho	It is a method computed in an excel sheet	2019	LCIA database available at: http://hdl.handle.net/1822/20481
14	SLOVENIA	Slovenia has not developed its own methodology but follows the ISO standard rules	-	-	-	-	-
15	SPAIN	LCA-US Methodology	Since 2009	University of Seville & TEP 130 Research Group	excel + Ecoinvent database	V.3	US_LCA_System 1_2_V3.xls
16	SWITZERLAND	SIA 2032 "Graue Energie von Gebäuden"	Since 2008	Schweizerischer Ingenieur- und Architektenverein	SIA 2032 "Graue Energie von Gebäuden"	2010	www.shop.sia.ch/normenwerk/architekt/sia%202032/d/D/Product
17	SWEDEN	Act on climate declarations for buildings (coming regulation)	to enter into force on January 2022	national authority for housing, building and planning (Boverket)	Act on climate declarations for buildings	Draft	https://ec.europa.eu/growth/tools-databases/tris/en/index.cfm/search/?trisaction=search.detail&year=2020&num=439&mLang=EN
18	UNITED KINGDOM(1)	RICS Professional Statement "Whole life carbon assessment for the built environment"	Since 2017	Royal Institute of Chartered Surveyors	Publication	1st edition	www.rics.org/uk/upholding-professional-standards/sector-standards/building-surveying/whole-life-carbon-assessment-for-the-built-environment/
19	UNITED KINGDOM(2)	BRE Global IMPACT Building LCA methodology	Since 2013	UK Consortia led by BRE, including IES, Wilmott Dixon and AEC3 with funding from UK Government (Innovate UK)	IMPACT Specification Parts 1 and 2	v1.7	BRE Global
				OCEANIA			
20	AUSTRALIA	ALCAS Midpoint LCIA	Since 2014	Australian LCA Society	National LCA guideline	V.2	http://docs.wixstatic.com/ugd/ 9ffc42_aaa14dcc78a64ec794517aa9aa8bde3e.pdf
21	NEW ZEALAND	NZ whole-building whole-of-life framework	V1.0 since November 2016, V3.3 since September 2019	BRANZ, as part of a research project	EN15978, free tool is called LCAQuick	V.3.3	www.branz.co.nz/buildinglca
				NORTH AMERICA			
22	CANADA(1)	Groupe AGECO	Since around 2008	Consulting firm	LEED Standards (and all the standards affiliated, EN 15978++)	Internal + standards requirements	-

23	CANADA(2)	Canada does not have a singular national methodology	not in place	Athena Institute	Source standard is EN 15978 as captured in Institute's Impact Estimator for Buildings (IE4B) software	5.3	https://calculatelca.com
24	USA	AIA Guide to Building Life Cycle Assessment in Practice	Since 2010	American Institute of Architects (AIA)	American Institute of Architects (AIA)	2010	www.brikbase.org/sites/default/files/aiab082942.pdf
				ASIA			
25	CHINA	Standard for Building Carbon Emission Calculation GB/T 51366-2019	Since 2019	National standard by the Ministry of Housing and Urban-Rural Development	Standard for Building Carbon Emission Calculation GB/T 51366-2019	2019	https://www.mohurd.gov.cn/gongkai/fdzdgknr/tzgg/201905/20190530_240723.html

A - SYSTEM DESCRIPTION

Table A.1: Typically considered RSPs and LC stages and modules

Country/ Name of the methodology		SYSTEM DESCRIPTION																										
		Reference Study Period (RSP)										Life cycle stages and modules (G = Generic; D = Detailed)																
		Single-family houses (New)	Single-family houses (Existing)	Multi-family residential buildings (New)	Multi-family residential buildings (Existing)	Office buildings (New)	Office buildings (Existing)	Industrial buildings (New)	Industrial buildings (Existing)	Educational buildings (New)	Educational buildings (Existing)	Raw material supply (A1)	Transport (A2)	Manufacturing A3)	Transport (A4)	Construction/ installation process (A5)	Use (B1)	Maintenance (B2)	Repair (B3)	Replacement (B4)	Refurbishment (B5)	Operational energy use (B6)	Operational water use (B7)	Deconstruction (C1)	Transport (C2)	Waste processing (C3)	Disposal (C4)	Additional information for recovery, reuse, recycling potential (D)
Europe	**1_AUSTRIA**: DGNB/ÖGNI Certification	50	[52]	50		50[53]		20		50		D [54]	D	D						D		D	D			D	D	D
	2_BELGIUM: MMG	60		60		60						G	G	G	G	G		G		G		G		G	G	G	G	
	3_CZECH REPUBLIC: SBToolCZ	50	[55]	50		50				60		G	G	G						G		D						
	4_DENMARK(1): LCAbyg tool			120		80						D	D	D						D		D				D	D	
	5_DENMARK(2): Sustainability code	50	50	50	50	50	50	50	50	50	50	D	D	D	D	D				D		D				D	D	D
	6_FRANCE(1): EQUER	80[56]	80	80	80	80	80			80	80	G	G	G	D	G				G	[57]	D	D	G	G	G	G	G
	7_FRANCE (2): E+C-	50		50		50				50		G	G	D	G	G				G		D	D	G	G	G	G	G
	8_GERMANY(1): BNB					50	50			50[58]	50	D	D	D				D		D		D	D			D	D	D
	9_GERMANY(2): BNK	50										G	G	G			G	G	G	G	G	G		G	G	G	G	
	10_GERMANY(3): DGNB	50		50		50		20		50[59]		G [60]	G	G						G		D				G	G	G
	11_HUNGARY: Hungarian LCA	50		50		50		50				G	G	G	G	G			G	G	G	D			G	G	G	
	12_NETHERLANDS: GWW	75		75		50						D	G	D	G	D	D	D	D	G	G			D	G	D	D	
	13_PORTUGAL: SBToolPT-H	50		50								G	G	G	G		G					D	D					

[52] Certification can be pursued also for existing buildings but no certain RSP is defined in (to the respondent's knowledge) the system
[53] Other types are: Hotel (50), Hypermarket (50), Shopping Center (50), Commercial house (50), Interior Office (10), Interior Retail (5)
[54] Acc. to DGNB 2018, in the generic (simplified method) only A1-A3 are considered. The detailed method uses the LCS indicated above.
[55] it is up to the practitioner of SbTool to decide, how long is the RSP.
[56] chosen by the user, default value 80 years
[57] Refurbishment is not considered at the design phase, but it can be addressed in a specific study (e.g. comparative LCA of different retrofit strategies for a building)
[58] Universities (both new & exist., 50); Laboratories (only new, 50)
[59] Other types are: Hotel (50), Hypermarket (50), Shopping Center (50), Commercial house (50), Interior Office (10), Interior Retail (5)
[60] In DGNB, in general the use of EPDs is encouraged. The question is not 100 % clear if background data is meant or foreground data (physical model).

(Table A.1 continues)

Region	Country/ Name of the methodology	SYSTEM DESCRIPTION: Reference Study Period (RSP)										Life cycle stages and modules (G = Generic; D = Detailed)																
		Single-family houses (New)	Single-family houses (Existing)	Multi-family residential buildings (New)	Multi-family residential buildings (Existing)	Office buildings (New)	Office buildings (Existing)	Industrial buildings (New)	Industrial buildings (Existing)	Educational buildings (New)	Educational buildings (Existing)	Raw material supply (A1)	Transport (A2)	Manufacturing (A3)	Transport (A4)	Construction/ installation process (A5)	Use (B1)	Maintenance (B2)	Repair (B3)	Replacement (B4)	Refurbishment (B5)	Operational energy use (B6)	Operational water use (B7)	Deconstruction (C1)	Transport (C2)	Waste processing (C3)	Disposal (C4)	Additional information for recovery, reuse, recycling potential (D)
Europe	**14_SLOVENIA:** No official methodology	[61]										G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	G	
Europe	**15_SPAIN:** LCA-US Methodology	50		50		50		50				G	G	G	D	G	D	G	G	G	G	D	D	G	D	D	D	D
Europe	**16_SWEDEN:** Act on climate declarations for buildings (coming law)	50[62]		50		50						D	D	D	D	D												
Europe	**17_SWITZERLAND:** SIA 2032	60		60		60						D	G	D				D		D		D		G	G	G	G	
Europe	**18_UNITED KINGDOM(1):** RICS	50		50		50						G[63]	G	G	G	G				G		D						
Europe	**19_UNITED KINGDOM(2):** BRE Global IMPACT Building LCA	60		60		60		60				G	G	G	D	D		G	D	D	D			G	G	D	D	[64]
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA	?[65]				?[66]						G	G	G	G	G	G	G		G		G		G	G		G	
Oceania	**21_NEW ZEALAND:** NZ whole-building whole-of-life framework / LCAQuick	90		90		60						G	G	G	G	G		G		G		G	G	G	G	G	G	G
N. America	**22_CANADA(1):** Groupe AGECO	60		60		60		60				D	D	D	D	D	D	D	G	D	G	D	D	G	D	G	G	G
N. America	**23_CANADA(2):** IE4B	60[67]		60		60		60				G	G	G	G	G								G	G	G	G	G
N. America	**24_USA:** AIA Guide	50		50		50		50				D[68]	D	D	D	D		G		D		G		D	D		D	D
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019	50[69]	50[69]	50[69]	50[69]	50[69]	50[69]			50[69]	50[69]	G	G	G	G	G	G[70]					G[71]		G				G

[61] Not a lot of LCAs of buildings are made in Slovenia: These, which are made, are made individually and with data derived from literature (regarding RSL). Slovenia has developed the RSL based on the materials used in the construction- online under: http://www.pisrs.si/Pis.web/pregledPredpisa?id=PRAV5263#
[62] n/a, but 50 years is common to use in Sweden
[63] The choices of the LC stages represent the "minimum" requirements as stated in this guidance documents (seen by the processor, the respondent left these question unanswered)
[64] Module D is optional.
[65] Stand-alone single dwelling family house with brick veneer
[66] Commercial office building which that are used for professional or commercial purposes (e.g., offices for lawyers, accountants, general medical practitioners, government agencies and architects)
[67] 60 to 100 years for all building types
[68] Thus information is based on ATHENA Impact Estimator, which is used in North America
[69] If the design life is not mentioned in design documents, the default value is 50 years. The tool and database are generic, which is not specially designed and applied to buildings. However, it can be used to analyse buildings based on the material decomposition approach.
[70] Only refrigerant of cooling system is included.
[71] Including carbon emissions caused by HVAC, DHW, lighting and elevators, renewable energy, carbon sink on the site.

Table A.2: Typically considered building elements

	Country/ Name of the methodology	SYSTEM DESCRIPTION																																
		Building elements (Y = Yes)																								Quantities are calculated…			
		Substructure			Superstructure									Building services									Finishes		Furniture					
		Foundations	Basement walls	Ground floor construction	External walls	External doors	Windows	Internal walls	Floors	Ceilings	Roof	Stairs and ramps	Internal doors	Water system	Sewage system	Electrical system	Heating system	Cooling system	Ventilation system	Conveying system	IT system	Fire protection system	External finishes	Internal finishes	Fixed furniture	User furniture	On the basis of the element method	Directly in the design tool	Directly in the tendering, awarding and billing software	It depends on assessor, stage…
Europe	**1_AUSTRIA**: DGNB/ÖGNI Certification	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y				Y	Y					Y	Y			Y			
Europe	**2_BELGIUM**: MMG		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y	Y			Y			
Europe	**3_CZECH REPUBLIC**: SBToolCZ	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y	Y			Y		Y	
Europe	**4_DENMARK(1)**: LCAbyg tool	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y				Y	Y	Y	Y			Y	Y						Y
Europe	**5_DENMARK(2)**: Sustainability Code LCA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y						Y
Europe	**6_FRANCE(1)**: EQUER	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	[72]	Y	Y	Y	Y	Y	Y	Y				Y	Y				Y		
Europe	**7_FRANCE(2)**: E+C-	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y				Y	Y				Y		
Europe	**8_GERMANY(1)**: BNB	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y			Y			
Europe	**9_GERMANY(2)**: BNK	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y				Y						Y	Y	Y		Y			
Europe	**10_GERMANY(3)**: DGNB	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y				Y	Y					Y	Y			Y	Y	Y	
Europe	**11_HUNGARY**: Hungarian LCA	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y				Y	Y	Y				Y	Y			Y			
Europe	**12_NETHERLANDS**: GWW	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			Y	Y	Y			Y		
Europe	**13_PORTUGAL**: SBToolPT-H		Y	Y	Y	Y	Y	Y	Y	Y	Y												Y	Y	Y		Y			
Europe	**14_SLOVENIA**: No official methodology	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y					Y						Y	Y			Y			
Europe	**15_SPAIN**: LCA-US Methodology	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y			[73]
Europe	**16_SWEDEN**: Act on climate declarations for buildings (coming law)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y											Y				Y		Y	

[72] It can be accounted for if the user adds it to the automatic quantification of the software made from the 3D modeler
[73] Building Information Model

(Table A.2 continues)

Country/ Name of the methodology		SYSTEM DESCRIPTION																												
		Building elements																									Quantities are calculated…			
		Substructure			Superstructure									Building services									Finishes		Furniture					
		Foundations	Basement walls	Ground floor construction	External walls	External doors	Windows	Internal walls	Floors	Ceilings	Roof	Stairs and ramps	Internal doors	Water system	Sewage system	Electrical system	Heating system	Cooling system	Ventilation system	Conveying system	IT system	Fire protection system	External finishes	Internal finishes	Fixed furniture	User furniture	On the basis of the element method	Directly in the design tool	Directly in the tendering, awarding and billing software	It depends on assessor, stage…
Europe	**17_SWITZERLAND**: SIA 2032	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	[74]	Y	Y	Y	Y	Y	Y	Y				Y	Y			Y	Y		
Europe	**18_UNITED KINGDOM(1)**: RICS	Y[75]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y														[76]			
Europe	**19_UNITED KINGDOM(2)**: BRE Global IMPACT Building LCA		Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y	Y			Y			
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA	Y	Y	Y	Y	Y		Y	Y	Y	Y		Y														Y			
Oceania	**21_NEW ZEALAND**: NZ whole-building whole-of-life framework / LCAQuick	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y										Y	Y				Y		
N. America	**22_CANADA(1):** Groupe AGECO	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y														Y		Y			
N. America	**23_CANADA(2):** IE4B	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y				Y	Y	Y	
N. America	**24_USA**: AIA Guide	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y										Y	Y			Y			
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y[77]	Y[77]	Y[77]	Y[77]	Y[77]	Y[77]	Y[77]		Y[77]	Y[77]	Y[77]	Y[77]			Y[78]		

[74] No with uncertainty
[75] The choices of the LC building elements represent the "minimum" requirements as stated in this guidance documents (seen by the processor, the respondent left these question unanswered)
[76] This question remained unanswered
[77] Not specified. It is specified that "the weight of materials calculated should exceed 95% of the total weight; and when more than 95% materials are calculated, materials whose weight is less than 0.1% can be ignored."
[78] There are several tools available. PKPM-CES and T20-CE are based on CAD documents, while AIARCH just use collected data (way of collection is not specified).

B – MODELLING ASPECTS

<u>Table B.1:</u> Assumptions for pre-use and use stages (A and B modules)

Country/ Name of the methodology		MODELLING ASPECTS – Assumptions					
		Assumptions and scenarios for transport (A4)	Assumptions and scenarios for construction/ installation process (A5)	Assumptions and scenarios for maintenance and repair (B2-B3)	Assumptions and scenarios for Replacement (B4)	Assumptions and scenarios for Refurbishment (B5)	Assumptions and scenarios for Operational energy and water use (B6-B7)
Europe	**1_AUSTRIA**: DGNB/ÖGNI Certification	Not covered	Not covered	Maintenance processes are represented incompletely as water consumption in ENV2.2. Not included in Building LCA	The replacement frequency of components/products according to their expected useful life are determined under the assumption of replacement with the originally calculated component/ product. Only the complete (integer) exchange (no partial exchange) is permissible.	Not covered	**B6**: Measured or simulated acc. to "OIB RL 6 - Energy saving and thermal insulation" (depending on the project stage) https://www.oib.or.at/en/node/149964 For LCA Module simulation: Austrian electricity mix taken form Ecoinvent 3.5 Database **B7**: Measured or calculated (depending on the project stage) For LCA Module simulation: Swiss tab water process taken from Ecoinvent 3.5 Database
	2_BELGIUM: MMG	Scenarios per material category (including transport routes, transport modes and average transport distances)	5% material losses - limited number of construction activities included (e.g. excavation, energy related processes and specific emissions at the construction site)	Maintenance scenarios based on a number of reference works (BCIS 2006; Jacobs et al. 2005; Ten Hagen & Stam 2000; SBR 1998; Perret 1995; den Hollander et al. 1993, Pasman et al. 1993; CSTC et al. 1991; BBRI et al. 2011)	Replacement scenarios based on a number of reference works (BCIS 2006; Jacobs et al. 2005; Ten Hagen & Stam 2000; SBR 1998; Perret 1995; den Hollander et al. 1993, Pasman et al. 1993; CSTC et al. 1991; BBRI et al. 2011)	Not covered	The operational energy use for heating due to transmission losses is calculated based on the equivalent degree-day method
	3_CZECH REPUBLIC: SBToolCZ	Not covered	Not covered	Not covered	The method provides an estimated service life of each building element. If the service life of an element is shorter than the service life of a building, its replacement is counted.	Not covered	Data from EPBD (mandatory for each building). Energy for heating, cooling and air conditioning, ventilation, domestic hot water, lighting and auxiliary energy for pumps, control and automation. Water use is not considered.
	4_DENMARK(1): LCAbyg tool	Not covered	Not covered	Not covered	National service life table of construction products is used	Not covered	Expected use of electricity and heating is estimated via the energy calculations that are mandatory to obtain a building permit
	5_DENMARK(2): Sustainability code LCA	Specific to the product	Specific to the on-site operations	Not covered	National service life table of construction products is used	Not covered	Expected use of electricity and heating is estimated via the energy calculations that are mandatory to obtain a building permit
	6_FRANCE(1): EQUER	average transport distance given by the user (default value is proposed), truck is considered	% waste given by the user (surplus, broken elements...)	Not covered	life span given by the user for building finishes (painting...), windows, equipment, default values are proposed	specific study (see previous comment)	link with energy simulation
	7_FRANCE(2): E+C-	Fixed in the EPDs	Fixed in the EPDs	Fixed in the EPDs	Fixed in the EPDs	Not covered	Link with energy calculation (regulation) calculation of water demand

(Table B.1 continues)

	Country/ Name of the methodology	MODELLING ASPECTS – Assumptions					
		Assumptions and scenarios for transport (A4)	Assumptions and scenarios for construction/ installation process (A5)	Assumptions and scenarios for maintenance and repair (B2-B3)	Assumptions and scenarios for Replacement (B4)	Assumptions and scenarios for Refurbishment (B5)	Assumptions and scenarios for Operational energy and water use (B6-B7)
Europe	**8_GERMANY(1):** BNB	Not covered	Not covered	-	Includes the production and the EoL of each component renewal. Service life data are provided by BNB.	Not covered	Operational final energy according to EnEV (B6).
Europe	**9_GERMANY(2):** BNK	[79]					
Europe	**10_GERMANY(3):** DGNB	-	-	-	Generic list of replacement cycles	-	Calculations according to energy regulation
Europe	**11_HUNGARY:** Hungarian LCA	Building materials are classified into 3 categories depending on the number and location of production plants and export. (1) 50km transport lorry 16-32t, (2) 150 km lorry 16-32t + 30 van, (3) 800km freight rail + 30 km van	Assuming cutting waste for all materials plus a default 8 MJ/m3 electricity and 50 MJ/m3 diesel consumption per m3 of building.	Repair is considered as 10% of the total replacement impact.	Replacement is considered based on default lifetimes.	Energy related refurbishment or major conversion.	Operational energy is calculated according to the Hungarian national methodology based on EPBD or by dynamic simulation. National static electricity mix is considered. Sold onsite electricity is subtracted with the same factors.
Europe	**12_NETHERLANDS:** GWW	Depends on product	Depends on product	Depends on product	Depends on product	Depends on product	Depends on product
Europe	**13_PORTUGAL:** SBToolPT-H	The real distance from the building site to the nearest manufacture	Not considered	Maintenance can be included if there are significant differences in the lifetime of the materials used in the different design scenarios.	Not considered	Not considered	Only the energy use for heating, cooling and domestic hot water is considered. Calculations are based on the method of the Portuguese thermal code.
Europe	**14_SLOVENIA:** No official methodology	mostly 50 km	-	-	-	-	Slovenian average electricity mix
Europe	**15_SPAIN:** LCA-US Methodology	Assumption regarding probable location of the building material factories in relation to the building site	Kellemberger assumptions for energy quantification - depending of building material quantities-	Kellemberger assumptions for energy quantification - depending of building material quantities	Kellemberger assumptions for energy quantification - depending of building material quantities	Kellemberger assumptions for energy quantification - depending of building material quantities	Operational Energy using specific software (DesigBuilder). Water use based on CTE assumptions
Europe	**16_SWEDEN:** Act on climate declarations for buildings (coming law)	Default scenarios in national database for typical for each material concerning transport distance, type of transport and fuel. specific values to be used for the 3 heaviest materials	specific data inserted by user	Not covered	Not covered	Not covered	Not covered

(Table B.1 continues)

[79] Question skipped by the respondent

Country/ Name of the methodology		MODELLING ASPECTS – Assumptions					
		Assumptions and scenarios for transport (A4)	Assumptions and scenarios for construction/ installation process (A5)	Assumptions and scenarios for maintenance and repair (B2-B3)	Assumptions and scenarios for Replacement (B4)	Assumptions and scenarios for Refurbishment (B5)	Assumptions and scenarios for Operational energy and water use (B6-B7)
Europe	**17_SWITZERLAND:** SIA 2032	Not covered	Not covered	-	generic service life of building elements	starts a new life cycle	onsite electricity fed into the grid bears the impacts of the power plant (PV) producing this electricity
	18_UNITED KINGDOM(1): RICS	Specific distance from manufacturer to site. Defaults before specification: Locally manufactured e.g. concrete, aggregate, earth 50km; Nationally manufactured e.g. plasterboard, blockwork, insulation 300km; European manufactured e.g. CLT, façade modules, carpet 1,500km by road; Globally manufactured e.g. specialist stone cladding 200km by road, 10,000 km by sea.	Specific data to be used. Average for building construction site emissions, in the absence of more specific information: 1400kgCO2e/£100k of project value (BRE Meeting Construction 2025 Targets – SMARTWaste KPI p.3, footnote 9). Default wastage rates and disposal routes based on Sweett, C. (2008) Reference guide: Net Waste Tool User Guide, Version 1.1. London: WRAP.	Based on EPD. B3 = B2*25% if no other data.	Table 9 in document provides default service lives for major elements.	-	Regulated energy use based on SAP or SBEM (EPBD for UK).
	19_UNITED KINGDOM(2): BRE Global IMPACT Building LCA	Based on UK freight statistics reviewed by BRE. Varies for different products. Includes import where relevant. Not publicly available. Can be varied by user.	Wastage % based on UK research by BRE. varies for different products. Not publicly available. Can be varied by user.	Based on service life data provided by BRE. Not publicly available. can be varied by user.	Based on service life data provided by BRE. Not publicly available. can be varied by user.	Based on service life data provided by BRE. Not publicly available. can be varied by user. Covers planned replacement/ refurbishment of facades, roofs, windows etc. Includes flooring replacement?	Impact is considered based on data produced from separate energy modelling programmes to UK regulations.
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA	Assumed 100 km by rigid truck	Assumed negligible	Considered based on replacement rates of key components	Key components replacement rates (e.g., 50 years for external cladding, internal wall for 100 years, concrete for 100 years, windows & doors 25 years, 10 years of painting for external/internal	Not covered	Only heating and cooling energy
	21_NEW ZEALAND: NZ whole-building whole-of-life framework / LCAQuick	Varies according to material - see Module A4 datasheet at www.branz.co.nz/buildinglca under "Data"	Waste rates and end-of-life routes vary with material - see Module A5 datasheet at www.branz.co.nz/buildinglca under "Data"	Varies with material (used for enclosure) - see Module B2 datasheet at www.branz.co.nz/buildinglca under "Data"	Varies according to material - see Module B4 datasheet at www.branz.co.nz/buildinglca under "Data"	Not covered	Grid electricity dataset available at www.branz.co.nz/buildinglca under "Data". Also default approach to energy simulation for offices available in Module B6 datasheet at www.branz.co.nz/buildinglca under "Data". Water use defaults in offices in Module B7 datasheet at www.branz.co.nz/buildinglca under "Data"

(Table B.1 continues)

Country/ Name of the methodology		MODELLING ASPECTS – Assumptions					
		Assumptions and scenarios for transport (A4)	Assumptions and scenarios for construction/ installation process (A5)	Assumptions and scenarios for maintenance and repair (B2-B3)	Assumptions and scenarios for Replacement (B4)	Assumptions and scenarios for Refurbishment (B5)	Assumptions and scenarios for Operational energy and water use (B6-B7)
N. America	**22_CANADA(1):** Groupe AGECO	[80]					
	23_CANADA(2): IE4B	based on regional analyses	crane operation + other on-site energy use (hot welding of seams, etc.)	-	based on product service lives in various regions and building archetypes	-	-
	24_USA: AIA Guide	The transportation distances are based on regional surveys. Only material transportation covered.	Construction & installation, waste factors for materials, loss factors for formwork.	Typical frequency of maintenance for each of the urban centers supported in the software Typical transportation mode and distance by region from the distributor to the site for the relative components. Waste factors included for materials.	Typical life expectancy (service life) of each material/product by region, based on empirical evidence and or product warranty periods. Typical transportation mode and distance by region from the distributor to the site for the relative components. Waste factors included for materials. Replacement materials assumed to be the same as new construction	-	-
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019	Based on empirical data[81]	Actual/predicted number of construction machine, and default energy consumption data of each machine[82]	Not covered	Not covered	Not covered	Calculate according to the method provided in the standard[83]. (energy consumption every year is constant)

[80] Question skipped by the respondent
[81] If no empirical data is available, default data provided in Annex E of Standard for Building Carbon Emission Calculation GB/T 51366-2019 should be used. Default transport distance of concrete is 40km while that of other materials is 500km. Carbon emissions [Kg CO2e/(t·km)] of different transport vehicles are specified in Annex E.
[82] Energy consumption (kg diesel/machine or kwh electricity/machine) for every type construction machine is specified in Annex C.
[83] Reference values are provided, including room temperature setpoints, RH, illumination, equipment power density, lighting power density, Lighting hours per month, Fresh air volume per capita.

Table B.2: Assumptions for after use stages (C modules)

	Country/ Name of the methodology	MODELLING ASPECTS – Assumptions				
		Assumptions and scenarios for deconstruction (C1)	Assumptions and scenarios for Transport (C2)	Assumptions and scenarios for waste processing (C3)	Assumptions and scenarios for disposal (C4)	(D)
Europe	**1_AUSTRIA**: DGNB/ÖGNI/ Austrian PCRs	Scenarios based on Austrian PCRs, where available, else based on Belgium scenario	Scenarios per waste category (including transport routes, transport modes and average transport distances)	Scenarios per waste category (including share of reuse, recycling and energy recovery)	Scenarios per waste category (including share of landfilling and incineration)	Not covered
	2_BELGIUM: MMG	Scenarios based "Ecoinvent 2 rapport 13 part V Building material disposal"	Scenarios per waste category (including transport routes, transport modes and average transport distances)	Scenarios per waste category (including share of reuse, recycling and energy recovery)	Scenarios per waste category (including share of landfilling and incineration)	Not covered
	3_CZECH REPUBLIC: SBToolCZ	Not covered	Not covered	Not covered	Not covered	Not covered
	4_DENMARK(1): LCAbyg tool			Typical waste scenario for each material is predefined	Typical waste scenario for each material is predefined	
	5_DENMARK(2): Sustainability code	-	-	Product specific or according to waste regulations	Product specific or according to waste regulations	Product/material specific
	6_FRANCE(1): EQUER	processes indicated by the user for some materials	transport distance to landfill, incinerator and recycling given by the user (default values are proposed), truck is considered	recycling processes chosen by the user	generic data for incineration of wood, plastics etc, landfill	50% avoided impacts by recycling at end of life, 50% at fabrication
	7_FRANCE(2): E+C-	Fixed in the EPDs	Fixed in the EPDs	Fixed in the EPDs	Fixed in the EPDs	1/3 of module D
	8_GERMANY(1): BNB	Not covered	Not covered	Fixed in the EPDs	Fixed in the EPDs	Module D is not balanced in the end of life phase.
	9_GERMANY(2): BNK					
	10_GERMANY(3): DGNB	-	-	material specific waste scenarios (typical scenarios)	material specific disposal scenarios (typical scenarios)	material specific recovery, reuse, recycling scenarios (typical scenarios)
	11_HUNGARY: Hungarian LCA	-	Transport (C2) is considered by a default value.	Waste processing/ disposal is considered based on a probable end-of-life scenario for each material.	-	-
	12_NETHERLANDS: GWW	Depends on product	Depends on product	Depends on product	Depends on product	Depends on product
	13_PORTUGAL: SBToolPT-H	-	Deconstruction waste is transported by road (medium-size truck) for 50km to a waste sorting facility	Only metals are recycled (95% for profiles and 80% for reinforcing steel). The other materials are placed in landfills.	All materials, except metals, are treated to be placed in landfills	Not considered. In situ energy production from renewables is used to offset energy consumption.
	14_SLOVENIA: No official methodology	-	mostly 50 km	-	-	-
	15_SPAIN: LCA-US Methodology	Kellemberger assumptions for energy quantification - depending of building material quantities	Assumption regarding probable location of the final disposal site in relation to the building site	Depending on the technical scenario (mean or best practice)	Depending on the technical scenario (mean or best practice)	Depending on the technical scenario (mean or best practice)
	16_SWEDEN: Act on climate declarations for buildings (coming law)	Not covered	Not covered	Not covered	Not covered	Not covered

(Table B.2 continues)

Country/ Name of the methodology		MODELLING ASPECTS – Assumptions				
		Assumptions and scenarios for deconstruction (C1)	Assumptions and scenarios for Transport (C2)	Assumptions and scenarios for waste processing (C3)	Assumptions and scenarios for disposal (C4)	(D)
	17_SWITZERLAND: SIA 2032	generic, simplified assumptions and data		material dependent "modal" split of waste processing technologies	dito	explicitly not allowed to account for benefits occurring after end of life of the building
	18_UNITED KINGDOM(1): RICS	An average rate of 3.4 kgCO2e/m2 GIA (rate from monitored demolition case studies in central London)	Defaults: Reuse on site 0km, recycling elsewhere, 50km by road, landfill: average of 2 closest landfill sites.	Default waste route is landfill if no other information available.	Where no other data, Landfilling – no landfill gas recovery: 2.15 kgCO2e/kg of timber product (Weight 2011) (Symons, Moncaster and Symons 2013).	-
	19_UNITED KINGDOM(2): BRE Global IMPACT Building LCA	Based on data provided by BRE. Not publicly available.	Based on data provided by BRE. Not publicly available.	Based on data provided by BRE. % varies by material. Not publicly available. % to recycling can be varied by user.	Based on data provided by BRE. % varies by material. Not publicly available. % to landfill and to incineration can be varied by user.	Optional to include.
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA	Assumed negligible	Assumed 50 km to recycling or landfill site considering material recovery rate	Not considered	Landfill processes employed (GHG emissions of organic products)	Not considered
	21_NEW ZEALAND: NZ whole-building whole-of-life framework / LCAQuick	End-of-life routes for materials in Module C1 datasheet at www.branz.co.nz/buildinglca under "Data"	-	-	-	-
N. America	**22_CANADA(1):** Groupe AGECO	[84]				
	23_CANADA(2): IE4B	demolition/deconstruction analyses	preset by region	various third-party commercial datasets (e.g., ecoinvent)	Final disposition of each product based on recycling	applies primarily to metals recycling and biogenic carbon sequestration in landfill
	24_USA: AIA Guide	At the user-defined expected building end of life, the software first estimates the energy required to deconstruct/demolish the major structural systems of the building (wood, steel and/or concrete). It is assumed that the envelope materials are demolished during the structural demolition, but have little influence on the demolition energy use.	Transportation to the landfill assuming typical distances to landfill for the region	-	The IE4B assumes that materials commonly landfilled today will continue to be landfilled, and those currently recycled or re-used will continue to be recycled and reused.	-
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019	Actual/predicted number of construction machine, and default energy consumption data of each machine[85]	Not covered	Not covered	Not covered	Default value[86]

[84] Question skipped by the respondent
[85] Energy consumption (kg diesel/machine or kwh electricity/machine) for every type construction machine is specified in Annex C.
[86] If scrap materials/products of low value are used for construction, GWP caused by their upstream process should be ignored; If other scrap renewable materials/products are used for construction, 50% GWP of their upstream process should be calculated; If there are scrap materials/products at construction and deconstruction stages, 50% GWP of their upstream process should be cut off from the total GWP of construction and deconstruction.

Table B.3: Consideration of future changes (dynamic elements)

Country/ Name of the methodology		MODELLING ASPECTS – Consideration of future changes				
		Variation in occupancy behaviour	Changes to the building's layout	Changes in the climate	Technological progress	Discounting of future impacts
Europe	**1_FRANCE(1)**: EQUER	Statistical model[87]	No	IPCC scenarios[88]	energy mix[89]	No
	2_FRANCE(2): E+C-	No	No	No	No	No
	3_GERMANY(1): BNB	No	No	No	No	No
	4_GERMANY(2): BNK	No	No	No	No	No
	5_GERMANY(3): DGNB	No	No	No	No	No
	6_DENMARK: LCAbyg tool	No	No	No	B6: Forecasting of electricity and district heating mixes towards more renewable energy in 2050, as visioned by the energy authorities	No
	7_DENMARK: Sustainability code LCA	No	No	No	B6: Forecasting of electricity and district heating mixes towards more renewable energy in 2040, as adopted by the parliament	No
	8_NETHERLANDS: GWW	No	No	No	No	1) better allocation procedure of impact from recycling, to avoid double counting. 2) improved specification of product recycling and reuse
	9_HUNGARY: Hungarian LCA	No	No	No	No	No
	10_SPAIN: LCA-US Methodology	No	No	No	No	No
	11_SWITZERLAND: SIA 2032	No	No	No	No	No
	12_SWEDEN: Act on climate declarations for buildings (coming law)	No	No	No	No	No
	13_BELGIUM: MMG	No	No	No	No	No
	14_UNITED KINGDOM(1): RICS	No	No	No	No	No
	15_UNITED KINGDOM(2): BRE Global IMPACT Building LCA	No	No	No	No	No
	16_CZECH REPUBLIC: SBToolCZ	No	No	No	No	No
	17_SLOVENIA: No official methodology	No	No	No	No	No

[87] Source: Vorger E., Schalbart P., Peuportier B., Integration of a Comprehensive Stochastic Model of Occupancy in Building Simulation to Study how Inhabitants Influence Energy Performance, 30th International PLEA Conference, Ahmedabad, December 2014
[88] Source: Roux C., Schalbart P., Assoumou E. and Peuportier B., Integrating climate change and energy mix scenarios in LCA of buildings and districts, Applied Energy 184 (2016), pp. 619-629
[89] Source: Roux C., Schalbart P., Assoumou E. and Peuportier B., Integrating climate change and energy mix scenarios in LCA of buildings and districts, Applied Energy 184 (2016), pp. 619-629

(Table B.3 continues)

Country/ Name of the methodology		MODELLING ASPECTS – Consideration of future changes				
		Variation in occupancy behaviour	Changes to the building's layout	Changes in the climate	Technological progress	Discounting of future impacts
Europe	**18_AUSTRIA**: DGNB/ÖGNI Certification	No	No	No[90]	No[30]	No
	19_PORTUGAL: SBToolPT-H	No	No	No	No	No
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA	No	No	No	No	No
	21_NEW ZEALAND: NZ whole-building whole-of-life framework / LCAQuick	No	No	No	Grid electricity based on the Mixed Renewables scenario to 2050, published by the Ministry of Business, Innovation & Employment (MBIE) in its 2016 *Electricity demand and generation scenarios* report. The scenario assumes a mix of geothermal and wind plant built, starting in 2020. Annual electricity demand growth is 1%, reflecting moderate GDP and population growth. Grid impacts in 2050 assumed to continue beyond 2050.	No
N. America	**22_CANADA(1):** Groupe AGECO	No	No	No	No	No
	23_CANADA(2): IE4B	No	No	No	No	No
	24_USA: AIA Guide	No	No	No	No	No
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019	No	No	No	No	No

[90] These aspects are included in the latest DGNB guidelines and will be included in our assessments in the future.

C – ENVIRONMENTAL INDICATORS

Table C.1: Indicators typically considered, including their assessment and aggregation

	Country/ Name of the methodology	ENVIRONMENTAL INDICATORS																							
		Minimum according to the standards									Additional indicators													Method	Aggregation
		Primary energy demand/ use renewable	Primary energy demand/ use non-renewable	Abiotic resource depletion, fossil	Abiotic resource depletion, elements	Global warming potential	Ozone depletion potential	Photochemical ozone creation potential	Acidification potential	Eutrophication, aquatic fresh water	Eutrophication, aquatic marine	Eutrophication, terrestrial	Total eutrophication	Human toxicity, cancer effects	Human toxicity, non-cancer effects	Ecotoxicity, freshwater	Land use	Particulate matter/ Respiratory inorganic	Ionising radiation/human health	Biotic production	Water demand/ Net use of fresh water	Radioactive waste	Other	For the selected environmental impact indicators, according to which method?	Is there the possibility of partial or full aggregation?
Europe	**1_AUSTRIA**: DGNB/ÖGNI Certification	Y	Y			Y	Y	Y	Y				Y								Y			Indicators and LCIA method acc to ÖNORM EN 15804	Yes, full aggregation[91]
	2_BELGIUM: MMG			Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y				Y[92]	CML version 2012 and others[93]	Yes, full aggregation
	3_CZECH REPUBLIC: SBToolCZ		Y			Y	Y	Y	Y			Y												CML-IA	No
	4_DENMARK: LCAbyg tool	Y	Y			Y	Y	Y	Y			Y												CML 2001 as practiced in Ökobau dat	No
	5_DENMARK: Sustainability code LCA					Y																		GWP100, IPCC 2013	
	6_FRANCE: EQUER		Y	Y	Y	Y		Y	Y				Y				Y				Y	Y	Y[94]	CML 2001, Eco-indicator 99 (will soon be updated)	No
	7_FRANCE(2): E+C-	Y	Y	Y	Y	Y	Y	Y	Y[95]				Y								Y		Y[96]	CML 2001, IPCC, CED	?
	8_GERMANY(1): BNB		Y			Y	Y		Y															CML	No
	9_GERMANY(2): BNK	Y	Y			Y																		CML 2002	Yes, partial aggregation
	10_GERMANY(3): DGNB	Y	Y			Y	Y	Y	Y			Y									Y				
	11_HUNGARY: Hungarian LCA	Y	Y			Y	Y	Y	Y	Y	Y	Y												CML and ReCiPe aggregated values	Yes, partial aggregation
	12_NETHERLANDS: GWW	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y								CML Impact Assessment method, 2013	Yes, partial aggregation

[91] Weighting of Checklist points following the DGNB System
[92] Water resource depletion
[93] CML version 2012 (Global warming, Ozone depletion, Acidification, Eutrophication, Photochemical Ozone Formation, Abiotic depletion of non-fossil resources, Abiotic depletion of fossil resources); Rosenbaum et al., 2008 (Human toxicity); Rabl et al, 2004 (Particulate matter); Frishknecht et al., 2000 (Ionising radiation); Rosenbaum et al., 2008 (Ecotoxicity, freshwater); Frishknecht et al, 2006 (Water scarcity); Milà i Canals et al., 2007 (Land use occupation and transformation – soil organic matter); Köllner, 2000 (Land use occupation and transformation – biodiversity)
[94] other waste, damage to health, damage to biodiversity, odour
[95] In practice, only energy and carbon indicators are used
[96] Other waste, pollution of air and water (critical volumes method).

(Table C.1 continues)

Region	Country/ Name of the methodology	ENVIRONMENTAL INDICATORS																								
		Minimum according to the standards									Additional indicators														Method	Aggregation
		Primary energy demand/ use renewable	Primary energy demand /use non-renewable	Abiotic resource depletion, fossil	Abiotic resource depletion, elements	Global warming potential	Ozone depletion potential	Photochemical ozone creation potential	Acidification potential	Eutrophication, aquatic fresh water	Eutrophication, aquatic marine	Eutrophication, terrestrial	Total eutrophication	Human toxicity, cancer effects	Human toxicity, non-cancer effects	Ecotoxicity, freshwater	Land use	Particulate matter/ Respiratory inorganic	Ionising radiation/human health	Biotic production	Water demand/ Net use of fresh water	Radioactive waste	Other	For the selected environmental impact indicators, according to which method?	Is there the possibility of partial or full aggregation?
Europe	**13_PORTUGAL**: SBToolPT-H	Y	Y			Y	Y	Y	Y	Y	Y	Y												CML baseline 2000, V3.04	Yes, full aggregation
	14_SLOVENIA: No official methodology	[97]																						Mostly the researchers use the CML method.	No
	15_SPAIN: LCA-US Methodology	Y	Y			Y	Y	Y	Y	Y						Y		Y						CML 2001 and CED	No
	16_SWEDEN: Act on climate declarations for buildings (coming law)					Y																		EN 15804/15978, IPCC GWP100	Yes, partial aggregation
	17_SWITZERLAND: SIA 2032	Y	Y			Y																	Y[98]	CED[99], GWP[100], environmental impacts according to ecological scarcity method	Yes, full aggregation
	18_UNITED KINGDOM(1): RICS					Y																		GWP 100 years (IPCC 4th AR), as per EN 15804+A1:2013[101]	No
	19_UNITED KINGDOM(2): BRE Global IMPACT Building LCA			Y	Y	Y	Y	Y	Y				Y								Y[102]	Y	Y[103]	GWP, POCP, ODP, EP, AP, ADPE, ADPF - CML v4.2 based on EN 15804. Net water consumption based on ISO 14046; inventory indicators based on aggregated total of inventory flows.	Yes, full aggregation
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA	Y	Y			Y	Y	Y	Y		Y						Y							LCIA (midpoint approach) based on ISO 14044	Yes, partial aggregation
	21_NEW ZEALAND: NZ whole-building whole-of-life framework / LCAQuick	Y	Y	Y	Y	Y	Y	Y	Y	Y														Based on EN15804	No

[97] Slovenia has no regulations which environmental indicators to use since it has not developed its own method
[98] total environmental impacts according to ecological scarcity method
[99] Frischknecht et al. 2015
[100] IPCC 2013 (not including short term climate forcers
[101] Additionally, operational emissions are also considered using a National Decarbonisation scenario: slow progression from the National Grid Future Energy Scenarios 2015.
[102] Net use of fresh water,
[103] Hazardous waste disposed, Non-hazardous disposed

(Table C.1 continues)

Region	Country/ Name of the methodology	ENVIRONMENTAL INDICATORS: Minimum according to the standards									ENVIRONMENTAL INDICATORS: Additional indicators													Method	Aggregation
		Primary energy demand/ use renewable	Primary energy demand /use non-renewable	Abiotic resource depletion, fossil	Abiotic resource depletion, elements	Global warming potential	Ozone depletion potential	Photochemical ozone creation potential	Acidification potential	Eutrophication, aquatic fresh water	Eutrophication, aquatic marine	Eutrophication, terrestrial	Total eutrophication	Human toxicity, cancer effects	Human toxicity, non-cancer effects	Ecotoxicity, freshwater	Land use	Particulate matter/ Respiratory inorganic	Ionising radiation/human health	Biotic production	Water demand/ Net use of fresh water	Radioactive waste	Other	For the selected environmental impact indicators, according to which method?	Is there the possibility of partial or full aggregation?
N. America	**22_CANADA(1):** Groupe AGECO	Y	Y			Y	Y	Y	Y	Y	Y	Y		Y	Y		Y	Y	Y	Y				Impact 2002+ or TRACI 2.1	Yes, partial aggregation
N. America	**23_CANADA(2):** IE4B	Y	Y			Y	Y	Y	Y	Y		Y						Y						Primarily US EPA TRACI but also CED model/method (CML)	Yes, partial aggregation
N. America	**24_USA:** AIA Guide	Y	Y			Y	Y	Y	Y		Y	Y		Y	Y	Y					Y			Athena, BEES, EIO-LCA, AIA Guide to Building LCA in Practice	Yes, partial aggregation
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019					Y																		IPCC2006	Yes, full aggregation

Table C.2: Details of the primary energy use indicator – what is in and what is out?

Country/ Name of the methodology		ENVIRONMENTAL INDICATORS – Primary energy demand/use indicator																											
		Non-renewable energy sources				Renewable energy sources							Building-related items during operations considered									User-related items during operations considered					Method		
		Fossil fuels as energy	Fossil fuels as feedstock	Nuclear fuels	Other	Biomass	Biomass as feedstock	Solar energy	Geothermal energy	Hydropower	Wind power	Other	Space heating	Space cooling	Ventilation	Hot water supply	Fixed lighting	Auxiliary energy (e.g. for heat pumps)	Indoor transportation	Building auxiliary devices	Other	Plug-in supplem. lighting	Household/office appliances	Refrigerator	Devices in data centre	Other specific functional devices	Only non-renewables	Renewables & non-renewables as **ONE** indicator (total primary energy demand)	Renewables & non-renewables as **TWO** separate indicators
Europe	**1_AUSTRIA**: DGNB/ÖGNI Certification	Y				Y		Y	Y	Y	Y		Y[104]	Y	Y	Y	Y[105]	Y	Y										Y
	2_BELGIUM: MMG												Y																
	3_CZECH REPUBLIC: SBToolCZ	Y		Y									Y	Y	Y	Y	Y	Y									Y		
	4_DENMARK: LCAbyg tool	Y[106]				Y		Y	Y	Y	Y		Y	Y	Y	Y	Y	Y											Y
	5_DENMARK: Sustainability code LCA																												
	6_FRANCE: EQUER	Y	Y	Y		Y	Y		Y	Y	Y		Y	Y	Y	Y	Y	Y				Y	Y	Y	Y	Y		Y[107]	
	7_FRANCE(2): E+C-	Y	Y	Y		Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y				Y	Y	Y	Y	Y			Y
	8_GERMANY(1): BNB	Y		Y		Y							Y	Y	Y	Y	Y	Y										Y	
	9_GERMANY(2): BNK	Y				Y		Y	Y	Y	Y		Y	Y	Y	Y		Y											Y
	10_GERMANY(3): DGNB	Y				Y		Y	Y	Y	Y		Y	Y	Y	Y	Y	Y											Y
	11_HUNGARY: Hungarian LCA	Y		Y		Y		Y	Y	Y	Y		Y	Y	Y	Y	Y	Y											Y
	12_NETHERLANDS: GWW	Y	Y	Y		Y	Y	Y	Y	Y	Y		[108]																Y
	13_PORTUGAL: SBToolPT-H	Y[109]		Y		Y[110]		Y	Y	Y	Y		Y	Y	Y	Y		Y											Y

[104] All taken from OIB RL 6
[105] For non-residential buildings
[106] The included items for non-renewable and renewable energy sources is a guess as Danish method is based on DGNB procedure, and is built on Ökobau. In reality, there is no access to documents describing what really is in the PE category.
[107] Not all renewables, because using solar energy does not reduce the resource for others
[108] all operational energy use for the building is excluded
[109] All energy is reported in one figure for embodied energy and operational energy
[110] All energy is reported in one figure for embodied energy and operational energy

(Table C.2 continues)

Country/ Name of the methodology		ENVIRONMENTAL INDICATORS – Primary energy demand/use indicator																											
		Non-renewable energy sources				Renewable energy sources							Building-related items during operations considered									User-related items during operations considered					Method		
		Fossil fuels as energy	Fossil fuels as feedstock	Nuclear fuels	Other	Biomass	Biomass as feedstock	Solar energy	Geothermal energy	Hydropower	Wind power	Other	Space heating	Space cooling	Ventilation	Hot water supply	Fixed lighting	Auxiliary energy (e.g. for heat pumps)	Indoor transportation	Building auxiliary devices	Other	Plug-in supplem. lighting	Household/office appliances	Refrigerator	Devices in data centre	Other specific functional devices	Only non-renewables	Renewables & non-renewables as **ONE** indicator (total primary energy demand)	Renewables & non-renewables as **TWO** separate indicators
Europe	**14_SLOVENIA:** No official methodology	Y	Y	Y		Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y											Y
	15_SPAIN: LCA-US Methodology	Y		Y		Y		Y	Y	Y	Y		Y	Y	Y	Y	Y				Y[111]	Y	Y	Y					Y[112]
	16_SWEDEN: Act on climate declarations for buildings (coming law)												[113]																
	17_SWITZERLAND: SIA 2032	Y	Y	Y		Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y		Y									Y
	18_UNITED KINGDOM(1): RICS												Y	Y	Y	Y	Y												
	19_UNITED KINGDOM(2): BRE Global IMPACT Building LCA	Y	Y	Y									Y		Y	Y	Y				[114]						Y[115]		
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA	Y	Y			Y	Y	Y	Y	Y	Y		Y	Y														Y	
	21_NEW ZEALAND: NZ whole-building whole-of-life framework / LCAQuick	Y	Y	Y		Y	Y	Y	Y	Y	Y		Y	Y	Y	Y	Y	Y	Y	Y		Y	Y	Y					Y
N. America	**22_CANADA(1):** Groupe AGECO	Y	Y	Y		Y	Y	Y	Y	Y	Y		Y	Y		Y	Y	Y	Y										Y
	23_CANADA(2): IE4B	Y	Y	Y		Y		Y	Y	Y	Y																	Y	
	24_USA: AIA Guide	Y	Y	Y		[116]							Y	Y	Y	Y	Y	Y			[117]	Y	Y						Y
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019	Y[152]	Y[152]	Y[152]		Y[152]	Y[152]	Y[152]	Y[152]		Y[152]		Y[152]	Y[152]	Y[152]	Y[152]	Y[152]		Y[152]									Y[152]	

[111] occupants out door transportation, waste transportation, water consumption
[112] Fossil and nuclear are reported separately; Hydropower and Biomass are reported separately; wind solar and geothermal are reported jointly
[113] all operational energy use for the building is excluded
[114] Based on UK implementation of EPBD in SBEM and SAP.
[115] only non-renewable energy sources reported as ADP Fossil (excluding uranium) and with uranium included in ADP Elements.
[116] No clearly indicated which renewables are included
[117] In ATHENA, user inputs data for each category of fuel using energy simulation

Table C.3: Details of the GWP indicator – what is in and what is out?

Country/ Name of the methodology		ENVIRONMENTAL INDICATORS – GWP indicator									
		Sources of GHGs considered				Types of GHG emissions considered					
		Carbon dioxide (CO_2) alone	The 7 main (groups of) GHGs identified in the Kyoto Protocol	All the GHGs specified by the 5th IPCC report	The F-gases regulated under Montreal Protocol	Fuel-related GHG emissions	Non-fuel related GHG emissions – process emissions	Non-fuel related GHG emissions – Freon gases due to insulation	GHG emissions due to land use	CO_2 removals from atmosphere	Other
Europe	**1_AUSTRIA:** DGNB/ÖGNI Certification System			Y	Y[118]	Y	Y	Y			
Europe	**2_BELGIUM:** MMG			Y		Y	Y	Y			
Europe	**3_ CZECH REPUBLIC:** SBToolCZ			Y		Y	Y	Y			
Europe	**4_DENMARK:** LCAbyg tool			Y[119]	Y	Y	Y	Y			
Europe	5_**DENMARK**: Sustainability code LCA			Y	Y	Y	Y	Y		Y	
Europe	**6_FRANCE(1)**: EQUER			Y		Y	Y	Y		Y	
Europe	**7_FRANCE(2):** E+C-			Y		Y	Y	Y			
Europe	**8_GERMANY(1):** BNB			Y		Y					
Europe	**9_GERMANY(2):** BNK		Y			Y	Y				
Europe	**10_GERMANY(3):** DGNB			Y	Y	Y	Y	Y			
Europe	**11_HUNGARY:** Hungarian LCA			Y		Y					Y[120]
Europe	**12_NETHERLANDS:** GWW			Y	Y	Y	Y	Y		Y	
Europe	**13_PORTUGAL**: SBToolPT-H			Y		Y[121]	Y	Y			
Europe	**14_SLOVENIA:** No official methodology					Y	Y	Y	Y	Y	
Europe	**15_SPAIN:** LCA-US Methodology		Y			Y	Y	Y	Y		
Europe	**16_SWEDEN:** Act on climate declarations for buildings (coming law)			Y		Y	Y				
Europe	**17_SWITZERLAND:** SIA 2032			Y		Y	Y	Y	Y		

118 Educated guess
119 The same applies as in the previous table. The included types of emissions is a guess
120 according to the ecoinvent methodology
121 All types of emissions are reported together

(Table C.3 continues)

Country/ Name of the methodology		ENVIRONMENTAL INDICATORS – GWP indicator									
		Sources of GHGs considered				Types of GHG emissions considered					
		Carbon dioxide (CO_2) alone	The 7 main (groups of) GHGs identified in the Kyoto Protocol	All the GHGs specified by the 5th IPCC report	The F-gases regulated under Montreal Protocol	Fuel-related GHG emissions	Non-fuel related GHG emissions – process emissions	Non-fuel related GHG emissions – Freon gases due to insulation	GHG emissions due to land use	CO_2 removals from atmosphere	Other
Europe	**18_UNITED KINGDOM(1):** RICS	Y	Y	Y	Y	Y	Y	Y		Y	
	19_UNITED KINGDOM(2): BRE Global IMPACT Building LCA		Y	Y	Y	Y	Y	Y		Y	
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA			Y		Y					
	21_NEW ZEALAND: NZ whole-building whole-of-life framework / LCAQuick			Y		Y	Y	Y		Y	
N. America	**22_CANADA(1):** Groupe AGECO			Y		Y	Y	Y	Y	Y	
	23_CANADA(2): IE4B			Y		Y	Y			Y	
	24_USA: AIA Guide			Y		Y	Y				
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019			Y		Y	Y				

Table C.4: Reference units

Country/ Name of the methodology		ENVIRONMENTAL INDICATORS - Normalisation																																		
		Reference Unit																																		
		Single-family houses							Multi-family residential buildings							Office buildings							Industrial buildings							Educational buildings						
		GFA[122]	NFA[123]	ERA[124]	RFA[125]	NRA[126]	Person	Other	GFA	NFA	ERA	RFA	NRA	Person	Other	GFA	NFA	ERA	RFA	NRA	Person	Other	GFA	NFA	ERA	RFA	NRA	Person	Other	GFA	NFA	ERA	RFA	NRA	Person	Other
Europe	**1_AUSTRIA:** DGNB/ÖGNI Certification System		Y							Y							Y							Y							Y					
	2_BELGIUM: MMG	Y							Y							Y																				
	3_CZECH REPUBLIC: SBToolCZ			Y							Y							Y																		
	4_DENMARK: LCAbyg tool								Y							Y														Y						
	5_DENMARK: Sustainability code LCA	Y							Y							Y							Y							Y						
	6_FRANCE(1): EQUER		Y	Y						Y	Y						Y	Y													Y	Y				
	7_FRANCE(2): E+C-		Y	Y						Y	Y						Y	Y													Y	Y				
	8_GERMANY(1): BNB																Y																			
	9_GERMANY(2): BNK		Y							Y																										
	10_GERMANY(3): DGNB		Y							Y							Y							Y							Y					
	11_HUNGARY: Hungarian LCA			Y							Y							Y							Y											
	12_NETHERLANDS: GWW	Y							Y							Y							Y													
	13_PORTUGAL: SBToolPT-H			Y							Y																									
	14_SLOVENIA: No official methodology		Y							Y							Y							Y												
	15_SPAIN: LCA-US Methodology	Y					Y		Y					Y		Y					Y		Y					Y								
	16_SWEDEN: Act on climate declarations for buildings (coming law)	Y							Y							Y														Y						
	17_SWITZERLAND: SIA 2032	Y		Y					Y			Y				Y		Y																		

122 Gross Floor Area (GFA)
123 Net Floor Area (NFA)
124 Energy Reference Area (ERA)
125 Rentable Floor Area (RFA)
126 Net Rentable Floor Area (NRA)

(Table C.4 continues)

Region	Country/ Name of the methodology	ENVIRONMENTAL INDICATORS - Normalisation																																		
		Reference Unit																																		
		Single-family houses							Multi-family residential buildings							Office buildings							Industrial buildings							Educational buildings						
		GFA[127]	NFA[128]	ERA[129]	RFA[130]	NRA[131]	Person	Other	GFA	NFA	ERA	RFA	NRA	Person	Other	GFA	NFA	ERA	RFA	NRA	Person	Other	GFA	NFA	ERA	RFA	NRA	Person	Other	GFA	NFA	ERA	RFA	NRA	Person	Other
Europe	**18_UNITED KINGDOM(1):** RICS							Y							Y							Y [132]							Y							
Europe	**19_UNITED KINGDOM(2):** BRE Global IMPACT Building LCA	[133]																																		
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA	Y	Y			Y										Y	Y			Y																
Oceania	**21_NEW ZEALAND:** NZ whole-building whole-of-life framework / LCAQuick	Y	Y				Y		Y	Y				Y		Y	Y			Y	Y															
N. America	**22_CANADA(1):** Groupe AGECO	Y							Y							Y							Y													
N. America	**23_CANADA(2):** IE4B	Y							Y							Y							Y													
N. America	**24_USA:** AIA Guide	Y							Y							Y							Y													
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019Ebalance	Y							Y							Y														Y						

[127] Gross Floor Area (GFA)
[128] Net Floor Area (NFA)
[129] Energy Reference Area (ERA)
[130] Rentable Floor Area (RFA)
[131] Net Rentable Floor Area (NRA)
[132] see http://www.rics.org/uk/knowledge/bcis/about-bcis/forms-and-documents/gross-internal-floor-area-gifa-and-ipms-for-offices/
[133]The respondent skipped this question

Table C.5: Detailed description of the reference unit

	Country/ Name of the methodology	Definition of the reference unit
Europe	**1_AUSTRIA:** DGNB/ÖGNI Certification System	According to ÖNORM EN 15221-6 Net floor area ; Nettogeschossfläche (NGF) The net floor area is the calculated area difference from the inner floor area and inner wall construction floor area. For clarification: The inner floor area is the area calculated from the gross floor area minus the exterior wall construction floor area. The interior wall construction floor area is a measuring surface consisting of the load-bearing interior construction of the building (e.g. columns and load-bearing walls).
	2_BELGIUM: MMG	no clear definition of gross floor area in MMG publications
	3_CZECH REPUBLIC: SBToolCZ	Floor area in this case means the total internal floor area of all floors of the building, defined by the inner surface of the outer walls. Inhabited and separated unheated areas are excluded.
	4_DENMARK: LCAbyg tool	GFA is heated+unheated space, measured to the outside of the walls. This is used for assessing the embodied impacts. Heated floor area (heated space, measured to the outside of the walls) is used for assessing the B6 impacts.
	5_DENMARK: Sustainability code LCA	
	6_FRANCE(1): EQUER	The floor area is defined by the user. It can be the net floor area (the user draws the plans or uses a BIM and the net floor area is calculated by the software), the area considered in the energy regulation, or the inhabitable area.
	7_FRANCE(2): E+C-	area considered in the energy regulation for the energy indicators, net floor area for other indicators
	8_GERMANY(1): BNB	NFA according to DIN 277 – The net floor area is the sum of all areas on all storeys of a building minus the construction area. The net floor area can be subdivided into usable area UA, service area SA and circulation area CA.
	9_GERMANY(2): BNK	
	10_GERMANY(3): DGNB	
	11_HUNGARY: Hungarian LCA	Net heated/ cooled floor area without the area or partition walls
	12_NETHERLANDS: GWW	The Dutch standard NEN 2580 (no English version available)
	13_PORTUGAL: SBToolPT-H	-
	14_SLOVENIA: No official methodology	Usable area of the building (m2) representing the internal floor area of the heated floor premises according to the project, is determined according to the standard SIST ISO 9836.
	15_SPAIN: LCA-US Methodology	Gross Floor Area (GFA). Surface covered by ceiling included the surface of vertical building partitions and walls. Person. One occupant of the assessed building. The number of people in the building is determined following the Building Technical Code in case of office and industrial buildings and statically in residential cases.
	16_SWEDEN: Act on climate declarations for buildings (coming law)	The proposal of mandatory regulation suggests GFA: Gross floor area is the measurable space of the floor plan. Gross area is limited by the exterior wall exterior and no account is taken of minor profiling and moldings. In the gross area, the recessed middle floor (mezzanine floor) or the like is counted with the front edge of the floor as a limitation
	17_SWITZERLAND: SIA 2032	-
	18_UNITED KINGDOM(1): RICS	-
	19_UNITED KINGDOM(2): BRE Global IMPACT Building LCA	-

Country/ Name of the methodology		Definition of the reference unit
Oceania	**20_AUSTRALIA:** ALCAS Midpoint LCIA	NFA: Net floor area of building excluding garage Gross floor area: total floor area including garage Net rentable floor area: Net letable area, which is conditioned
Oceania	**21_NEW ZEALAND:** NZ whole-building whole-of-life framework / LCAQuick	Gross floor area (GFA) - area measured over all the exterior walls of the building, over partitions, columns, interior structural or party walls, stair wells, lift wells, ducts, enclosed roof top structures and basement service areas. All exposed areas such as balconies, terraces, open floor areas and the like are excluded. Generally, projections beyond the outer face of the exterior walls of a building such as projecting columns, floor slabs, beams, sunshades and the like are excluded. Net rentable area (or "net lettable area (NLA)") - sum of the floors of a building measured from the exterior faces of the exterior walls or from the centrelines of walls separating two uses within a building, excluding all common areas such as hallways, elevators, voids and unused parts of buildings.
N.America	**22_CANADA(1):** Groupe AGECO	-
N.America	**23_CANADA(2):** IE4B	Gross floor area as measured at the exterior of the building
N.America	**24_USA:** AIA Guide	-
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019Ebalance	Total floor area of the building, including all the spaces enclosed by the outer surface of exterior walls and facades. Balconies without roofs are not counted in GFA. Balconies with roof and without exterior wall is counted in as half of the areas. Basement area is included in the GFA.

D, E & F – ASSESSMENT STANDARDS, DATA, TOOLS & BENCHMARKS

Table D.1: Instruments connected to the method

	Country/ Name of the methodology	Is the assessment methodology described in the previous questions linked to…				
		…a specific national standard	…a specific regional or international standard, such as ISO 21931-1	…a specific national, regional, or other database?	…any software tool(s) supporting this methodology?	…a specific set of benchmarks?
Europe	**1_AUSTRIA:** DGNB/ÖGNI Certification System	ÖN EN 15978	EN 15978	Ecoinvent	Excel-based workflow using information from e.g. energy certificate and quantities from BIM model, custom scripts for hotspot analysis	No
	2_BELGIUM: MMG	No	CEN/TC 350 standards (EN 15804:2012+A1 and EN15978), PEF guide (EC, 2013), ILCD handbook (EC-JRC, 2011)	Ecoinvent (version 3.3)	TOTEM tool (https://www.totem-building.be/) No BIM-enabled	No
	3_CZECH REPUBLIC: SBToolCZ	No	No	Envimat (based on Ecoinvent 2)	No	Yes
	4_DENMARK: LCAbyg tool 3.2	No	EN15978	Ökobau.dat 2016	LCAbyg (www.lcabyg.dk) No BIM-enabled	Yes
	5_DENMARK: Sustainability code LCA	No	EN15978	Ökobau.dat 2020	LCAbyg v 4.0	No
	6_FRANCE(1): EQUER	No	mostly EN 15978 but with a few differences	Ecoinvent	EQUER, http://www.ces.mines-paristech.fr/Logiciels/EQUER/ EQUER is the calculation engine of PLEIADES ACV BIM-enabled: IFC4 (with requirements about specific options) or gbXML	Yes
	7_FRANCE(2): E+C-	No	mostly EN 15978 but with a few differences	INIES	ELODIE, PLEIADES E+C-, OneClick LCA, ThermACV, Bea, Archiwizard, Vizcab	Yes
	8_GERMANY(1): BNB	DIN EN 15978	EN 15978	ökobau.dat	ELCA; LEGEP No BIM-enabled	Yes
	9_GERMANY(2): BNK	No	No	ökobau.dat	eLCA, https://www.bauteileditor.de/ No BIM-enabled	Yes
	10_GERMANY(3): DGNB	DIN EN 15978	EN 15978	ökobau.dat	■ CAALA: Software für eine ganzheitliche energetische Optimierung und Lebenszyklusanalyse (www.caala.de) ■ eLCA: Online Ökobilanz-Tool vom Bundesinstitut für Bau-, Stadt- und Raumforschung (BBSR) (www.bauteileditor.de) ■ GaBi-Software (www.gabi-software.com) ■ LEGEP Bausoftware: Software für die integrale Planung nachhaltiger Gebäude (www.legep.de) ■ oekobilanz-bau.de (www.tool.oekobilanz-bau.de) ■ SBS Online Tool (www.sbs-onlinetool.com) No BIM-enabled	Yes

(Table D 1 continues)

	Country/ Name of the methodology	Is the assessment methodology described in the previous questions linked to…				
		…a specific national standard	…a specific regional or international standard, such as ISO 21931-1	…a specific national, regional, or other database?	…any software tool(s) supporting this methodology?	…a specific set of benchmarks?
Europe	**11_HUNGARY:** Hungarian LCA	No	EN 15978	ecoinvent database adapted to national conditions	Excel tools: Belso Udvar E-P-LCA-LCC, KESZ-LCC-LCA No BIM-enabled	No
	12_NETHERLANDS: GWW	MPG - Milieu Prestatie van Gebouwen ("Environmental Performance of Buildings")	EN 15804:2012 + Amendment A1 (2013)	Nationale Milieu database (NMD) - National Environmental database	GPR Building,see http://www.gprgebouw.nl/ No BIM-enabled	Yes
	13_PORTUGAL: SBToolPT-H	-	European CEN TC 350 standards	The assessment of the potential environmental impacts is based on a specific LCIA database: http://hdl.handle.net/1822/20481	There is an Excel sheet No BIM-enabled	Yes
	14_SLOVENIA: No official methodology	No	ISO and EN standards	No	No	No
	15_SPAIN: LCA-US Methodology	No	EN 15978, EN 15804	No	Autodesk Revit, Microsoft excel and Ecoinvent V.2 database BIM-enabled: Autodesk Revit	No
	16_SWEDEN: Act on climate declarations for buildings (coming law)	The proposed mandatory climate declaration for buildings. https://www.boverket.se/sv/om-boverket/publicerat-avboverket/publikationer/2018/klimatdeklaration-av-byggnader2/	EN 15804/EN 15978	A database is being developed that will be launched in 2021. It includes primarily generic data that shall be used for making the climate declaration, unless specific EPD´s are used.	Byggsektorns miljöberäkningsverktyg No BIM-enabled	is under development and will be launched in 2021
	17_SWITZERLAND: SIA 2032	SIA 2032 and SIA 2040, and KBOB guidelines for construction material and building LCA	Except for the indicators, KBOB guidelines adhere to EN 15804:2012+A1:2013	KBOB LCI data DQRv2:2016 and KBOB recommendation 2009/1:2016	Bauteilkataklog, Eco-Devis, Enerweb/1 eco, Greg, Lesosai, Thermo No BIM-enabled	Yes
	18_UNITED KINGDOM(1): RICS	No	EN 15978 and EN 15804:2012+A1:2013	The sources below are listed in order of preference: Type III environmental declarations (EPDs and equivalent) and datasets in accordance with EN 15804 • Type III environmental declarations (EPDs and equivalent) and datasets in accordance with ISO 21930 • Type III environmental declarations (EPDs and equivalent) and datasets in accordance with ISO 14067 • EPDs and datasets in accordance with ISO 14025, ISO 14040 and 14044 • Type III environmental declarations (EPDs and equivalent) and datasets in accordance with PAS 2050.	No	Yes

(Table D 1 continues)

Country/ Name of the methodology		Is the assessment methodology described in the previous questions linked to…				
		…a specific national standard	…a specific regional or international standard, such as ISO 21931-1	…a specific national, regional, or other database?	…any software tool(s) supporting this methodology?	…a specific set of benchmarks?
Europe	**19_UNITED KINGDOM(2):** BRE Global IMPACT Building LCA	Additional inventory indicator and normalisation and weighting approach set out in BRE paper "BRE global Environmental weighting for construction products using Selected parameters from EN 15804, (2017) bit.ly/2P0V9we	BS EN 15804:2012+A1:2013.	BRE EN 15804 IMPACT Database	OneClickLCA (BREEAM) version, eTool (IMPACT) version. BIM-enabled: Various, including Revit, ArchiCAD, Tekla Structures, Simplebim and Naviate Simple BIM, DesignBuilder, plus IES-VE and output as IFC 2x3 and IFC4 and gbXML.	?
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA	No	No	Australian and Australasian	Etool LCA, SimaPro No BIM-enabled	No
	21_NEW ZEALAND: NZ whole-building whole-of-life framework / LCAQuick	No	Based on EN15978.	BRANZ has developed a database to support the assessment. Some of the materials data are published in the BRANZ CO_2NSTRUCT database, available at www.branz.co.nz/co2nstruct. Scenario or activity data available in "Data" at www.branz.co.nz/buildinglca.	LCAQuick (downloadable from www.branz.co.nz/buildinglca and select "LCAQuick" BIM-enabled: No direct links to BIM, but a material take-off from any BIM software can be pasted into LCAQuick	No
N. America	**22_CANADA(1):** Groupe AGECO	No	No	No	SIMAPRO No BIM-enabled	No
	23_CANADA(2): IE4B	No	EN15978 for building and ISO21930 for products	The Athena Institute's own database	The Impact Estimator for Buildings - see link https://calculatelca.com No BIM-enabled	No
	24_USA: AIA Guide	No	ISO 21930/21931; ISO 14040/14044; ISO/TC 14067; EN 15804/15978; PAS 2050; US EPA Guidelines from Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI)	ATHENA Database; US Life Cycle Inventory (USLCI) Database by National Renewable Energy Lab (NREL); Building for Environmental and Economic Sustainability (BEES) by the National Institute of Standards and Technology (NIST); EIO-LCA by Carnegie Mellon University.	ATHENA Impact Estimator; ATHENA EcoCalculator; BEES Software; Tool for Reduction and Assessment of Chemicals and Other Environmental Impacts (TRACI)	No
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019	Standard for Building Carbon Emission Calculation GB/T 51366-2019	No	Annexes of the Standard[134]	PKPM-CES; T20-CE, AIARCH	No

[134] Original database is unclear.

G – MARKET CONDITIONS AND DRIVING FORCES

Table G.1: Instruments connected to the method

	Country/ Name of the methodology	METHOD DISSEMINATION AND DRIVING FORCES		Are there already requirements in place to limit… (L= Yes, Legal; SC= Yes, self-commitment; UD= Currently, under development)					
		What is the level of acceptance and application of such methodologies among architects working in the industry?	Who is primarily asking for such results? And why?	Operational primary energy	Operational GHG emissions	Embodied primary energy	Embodied GHG emissions	Life cycle primary energy	Life cycle GHG emissions
Europe	**1_AUSTRIA:** DGNB/ÖGNI Certification System	Low	**Property developers/ investors** WHY: ÖGNI is a national certification methodology based on DGNB. A high certification can result in a higher property value.	L	L	UD	UD	UD	UD
	2_BELGIUM: MMG	Low	**Public sector** WHY: it is part of the public procurement.						
	3_CZECH REPUBLIC: SBToolCZ	Low	**Public sector** WHY: Confidence in the evaluation method developed at the Czech University and adapted to the Czech conditions (SbToolCZ). In the private sector, companies prefer international BREEAM.	L	SC				
	4_DENMARK: LCAbyg tool	Low	**Companies/ firms** WHY: Driven by building organisations, representing architect/engineering firms as well as building material producers	SC	SC	SC	SC	SC	SC[135]
	5_DENMARK: Sustainability code LCA	-	**-**						
	6_FRANCE(1): EQUER	Very low	**Companies/ firms/ clients** WHY: social responsibility	SC	SC			SC	SC
	7_FRANCE(2): E+C-	Very low	**Public sector** WHY: future regulation	L			UD		UD
	8_GERMANY(1): BNB		**Public sector** WHY: It is part of the public procurement.	L	SC	SC	SC	SC	SC
	9_GERMANY(2): BNK	Very low	**Property developers/ investors** Pre-fabricated housing developers						
	10_GERMANY(3): DGNB	Low	**Public sector** WHY: It is part of the public procurement Private sector uses LCA only in the context of DGNB certification (because they have to obtain a certificate), seldom used for optimization or communication	L			SC		SC[136]

[135] Currently only as part of the Danish DGNB certification. Voluntary 'sustainability building code' under development.
[136] Various initiatives, DGNB developed the "Framework for carbon neutral buildings and sites" in 2018, which is basis for self-commitments: https://issuu.com/dgnb1/docs/dgnb_framework_carbon-neutral_build?e=32742991/66043810

(Table G.1 continues)

Country/ Name of the methodology		METHOD DISSEMINATION AND DRIVING FORCES							
		What is the level of acceptance and application of such methodologies among architects working in the industry?	Who is primarily asking for such results? And why?	Are there already requirements in place to limit… (L= Yes, Legal; SC= Yes, Self-Commitment; UD= Under Development)					
				operational primary energy	operational GHG emissions	embodied primary energy	embodied GHG emissions	life cycle primary energy	life cycle GHG emissions
Europe	**11_HUNGARY:** Hungarian LCA	Very low	**Individuals/ homebuilders** WHY: The tool is currently used for education and research, and in a very limited way in the architectural practice by a few designers designing smaller buildings. But investors are also increasingly interested in such results as part of a BREEAM or LEED certification. However, for that they use international tools and not our methodology.	L[137]					
	12_NETHERLANDS: GWW	Low	**Public sector** WHY: It is part of the public procurement. There is a limit value applicable in order to receive a building permit, but most architects will not perform the assessment themselves. In most cases they will request an external consultant to perform the calculations				L[138]		
	13_PORTUGAL: SBToolPT-H	Very low	**Property developers/ investors** WHY: Most of existing tools are market driven and individuals are confused about the real benefit of using such methods. The assessment/ sustainability certification is expensive and time consuming.	L[139]	L				
	14_SLOVENIA: No official methodology	Low[140]	**Public sector** WHY: it is part of the public procurement.	L[141]	SC				
	15_SPAIN: LCA-US Methodology	Very low	**Public sector** WHY: it is part of the public procurement. Sometimes LCA is condition given by the specification of the public contest						
	16_SWEDEN: Act on climate declarations for buildings (coming law)	High[142]	**Public sector** WHY: it is part of the public procurement. The interest is increasing, and requirements are sometimes set by municipalities	L	SC		UD[143]		

[137] Primary energy is calculated in the national energy performance methodology based on the EPBD. However, primary energy factors are not based on LCA results. Operational GHG emissions are not compulsory by the law, but in many cases it is compulsory in the application for grants and funding.
[138] There is a limit value in place, but this applies to an aggregated indicator (MPG score) which includes embodied GHG as well as other environmental impacts (see Assessment method p.37, table 5). In practice embodied GHG can contribute 40-70% of the MPG score.
[139] The source is the Portuguese thermal regulation that limits the operational energy consumption during the operation phase of the building. The method is based on the EPBD.
[140] There is a growing interest in EPDs from the industry, but no demand for LCA of buildings (except in research area)
[141] The government set a target point how much energy per m2 is suitable for new or refurbished buildings. There are factors developed how much CO2 the building is producing regarding the source used for heating and cooling. Online under: http://www.energetika-portal.si/fileadmin/dokumenti/publikacije/an_snes/an_snes_slovenija_en.pdf
[142] 100% of developers of new buildings (included in the regulation) will use it
[143] https://ec.europa.eu/growth/tools-databases/tris/en/index.cfm/search/?trisaction=search.detail&year=2020&num=439&mLang=en&CFID=995299&CFTOKEN=e0e52b5820b0e82e-F0A573AB-F2C2-EC14-02289396E7B15E26

(Table G.1 continues)

		METHOD DISSEMINATION AND DRIVING FORCES							
Country/ Name of the methodology		What is the level of acceptance and application of such methodologies among architects working in the industry?	Who is primarily asking for such results? And why?	Are there already requirements in place to limit… (L= Yes, Legal; SC= Yes, Self-Commitment; UD= Under Development)					
				operational primary energy	operational GHG emissions	embodied primary energy	embodied GHG emissions	life cycle primary energy	life cycle GHG emissions
Europe	**17_SWITZERLAND:** SIA 2032	Low	**Public sector** WHY: it is part of the public procurement. Many communities care for environment and climate and ask for increased requirements regarding GHG emissions etc.	SC[144]	SC	SC	SC	SC	SC
	18_UNITED KINGDOM(1): RICS								
	19_UNITED KINGDOM(2): BRE Global IMPACT Building LCA	Medium	**Property developers/ investors** WHY: Use of this method is required by BREEAM to obtain up to a maximum of 10% optional credits. Property developers/investors are the major group requesting BREEAM.		L		SC[145]		
Oceania	**20_ AUSTRALIA:** ALCAS Midpoint LCIA	Medium	**Public sector** WHY: it is part of the public procurement.	L[146]	L	SC	SC	UD	UD
	21_NEW ZEALAND: NZ whole-building whole-of-life framework / LCAQuick	Very low	**Companies/firms** WHY: for recognition in building environmental rating tools **Public sector** WHY: interest to include in procurement.[147]						
N. America	**22_CANADA(1):** Groupe AGECO	Very high	**Companies/ firms** WHY: LEED points are given for construction projects involving the use of material products for which an EPD was performed. As a result, producing an EPD gives the manufacturer a competitive edge.		L[148]				
	23_CANADA(2): IE4B	Low	**Public sector** WHY: it is part of the public procurement. Public sector is leading the advancement and use of LCA as an evidenced based decision-making method	L[149]	UD		UD		
	24_USA: AIA Guide	Low	**Public sector** WHY: it is part of the public procurement. Some states as well as private companies require LCA	L[150]	SC				

[144] In general, ALL requirements are documented in SIA technical bulletin 2040 SIA energy efficiency path, 2017
[145] Some developers have put in place requirements to reduce embodied impact, for example Landsec (https://sciencebasedtargets.org/case-studies/case-study-land-securities/).
[146] Minimum residential building energy requirements (operational heating/cooling) is mandatory by building code. Embodied energy and GHG emissions are not but it is included in the national building rating tool (e.g., Green Star by Green Building Council Australia)
[147] Christchurch City Council (CCC) has a target to be carbon neutral by 2030. CCC is looking at using LCAQuick as a mandatory tool to understand the greenhouse gas impacts of new Council buildings.
[148] There are Canadian regulations on GHG emissions for the renewable fuels and electricity sectors. There are also regulations on exhaust emissions from passenger and heavy-duty vehicles, light-weight trucks. For more information: https://www.canada.ca/en/environment-climate-change/services/climate-change/greenhouse-gasemissions/regulations.html#X-201105241638261
[149] National Building code stipulates operational energy performance. Embodied carbon is now discussed with likely targets coming in the future
[150] American Society for Heating Refrigerating and Air-conditioning Engineers (ASHRAE) publishes mandatory energy codes for residential and commercial buildings

(Table G.1 continues)

Country/ Name of the methodology		METHOD DISSEMINATION AND DRIVING FORCES											
		To what percentage is the methodology described here used by…			What is the level of acceptance and application of such methodologies among architects working in the industry?	Who is primarily asking for such results? And why?	Are there already requirements in place to limit… (L= Yes, Legal; SC= Yes, Self-Commitment; UD= Under Development)					
		researchers/ universities	Public authorities	Daily practice of architects			operational primary energy	operational GHG emissions	embodied primary energy	embodied GHG emissions	life cycle primary energy	life cycle GHG emissions
Asia	**25_China:** Standard for Building Carbon Emission Calculation GB/T 51366-2019	[151]			Low	**Companies/ firms** WHY: A bonus can be achieved for the calculation of life cycle GWP according to Assessment Standard for Green Buildings GB/T 50387-2019. But investors are also increasingly interested in such results as part of a Green Building certification.	SC[152]	SC	UD	SC	UD	SC

[151] It is relatively new and under development.
[152] It was specified in Technical Standard for Nearly Zero Energy Building GB/T 51350-2019.

Table G.2: National definitions for net zero building concepts, carbon budgets for building stock and requirements for circular economy.

	Country/ Name of the methodology	NATIONAL REQUIREMENTS					
		Is there any national definition with regard to…				Is there already a specific carbon budget(s) in your country for building stock?	Are there any specific requirements in your country for building stock relating to the promotion of circular economy?
		Net zero energy buildings	Net zero emissions buildings	Carbon neutral buildings	Climate neutral buildings		
Europe	**1_AUSTRIA**	Yes	Under dev.	Under dev.	Under dev.	No (UD)	No
	2_BELGIUM	No	No	No	No	No	No
	3_ CZECH REPUBLIC: SBToolCZ	No	No	No	No	No	No
	4/5_DENMARK	Yes[153]	No	No	No	No	Recent governmental strategy (September 2018) on circular economy sets out to implement: - A voluntary sustainability building class - Encourage selective demolition of buildings
	6/7_FRANCE[154]	Under dev.[155]	No	Under dev.[156]	No	No	No
	8/9_GERMANY(1): BNB BNK					Yes 2030 and 2050 targets defined in "Klimaschutzplan"	Private initiatives, e.g. DGNB promotes circular buildings
	10_GERMANY(3): DGNB	Yes[157]	No	Yes	Yes		
	11_HUNGARY: Hungarian LCA	No	No	No	No	No	No
	12_NETHERLANDS: GWW	Yes[158]	No	No	No		only target values for reuse of building materials Information: https://www.circulaireeconomienederland.nl/rijksbreed+programma+circulaire+economie/Programma+documenten/handlerdownloadfiles.ashx?idnv=806449 But this document is not very specific about the targets for the construction sector. Also there are more specific covenants for certain subsectors, e.g. the concrete products industry
	13_PORTUGAL: SBToolPT-H	Under dev.	Under dev.	Under dev.	Under dev.	No	No
	14_SLOVENIA: No official methodology	Yes[159]	No	No	No	No	No

[153] NZEB is the upper level of building classifications from the current building regulations (called '2020 building class').
[154] National requirements concern only E+C-
[155] French regulation, only in French
[156] French regulation, only in French
[157] Various initiatives, Effizienzhaus Plus, Aktivhausplus https://aktivplusev.de/, ... DGNB developed the "Framework for carbon neutral buildings and sites" in 2018, which is basis for self-commitments:https://issuu.com/dgnb1/docs/dgnb_framework_carbon-neutral_build?e=32742991/66043810
[158] There is a standard in place for Nearly Zero Energy Buildings, in order to comply with EPBD. But this only considers operational energy use, not embodied.
[159] Slovenia has developed an action plan for building nearly nZEB until 2020. Online under: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwjK2rOgjengAhWO-aQKHfx5AYMQFjAAegQIABAB&url=http%3A%2F%2Fwww.energetika-portal.si%2Ffileadmin%2Fdokumenti%2Fpublikacije%2Fan_snes%2Fan_snes_slovenija_en.pdf&usg=AOvVaw2Tg8OPqWEBKf-CHojSX9m5

(Table G.2 continues)

Country/ Name of the methodology		NATIONAL REQUIREMENTS					
		Is there any national definition with regard to…				Is there already a specific carbon budget(s) in your country for building stock?	Are there any specific requirements in your country for building stock relating to the promotion of circular economy?
		Net zero energy buildings	Net zero emissions buildings	Carbon neutral buildings	Climate neutral buildings		
	15_SPAIN	Under dev.	Under dev.	No	No	No	No
	16_SWEDEN	Yes	Yes[160]	No	No	No	No
	17_SWITZERLAND	No	No	No	No	GHG emission benchmark values of SIA 2040 derived from carbon budget.	No
	1819_UNITED KINGDOM	No	No	No	No	UK Government target of 80% reduction in GHG emissions in the built environment vs 1990 levels by 2050. (https://www.greenconstructionboard.org/index.php/resources/routemap) A 50% reduction in greenhouse gas emissions in the built environment – supporting the Industrial Strategy's Clean Growth Grand Challenge https://www.gov.uk/government/publications/construction-sector-deal Halve the energy use of new buildings by 2030: https://www.gov.uk/government/publications/construction-sector-deal	
Oceania	**20_ AUSTRALIA**	Yes[161]	Yes	Yes	No	No specific carbon budget for building, but many other academic or research publications exist by regional.	No
	21_NEW ZEALAND	No	Yes[162]	No	No	Massey University and BRANZ are developing absolute, science-based greenhouse gas design thresholds for residential and office buildings.	No
N. America	**222/23_CANADA**	Yes[163]	Under dev.	No	No	No	No
	24_USA	No	No	No	No	No	No
Asia	**25_China**	Yes[152]	No	No	No	No official data. CO_2 emission reduction was predicted by several institutions, such as Energy Foundation China [164]	No

[160] The Sweden Green building council has launched a test version of a new certification system called ZeroCO2: https://www.sgbc.se/utveckling/utveckling-av-nollco2/. Unfortunately, no info in English so far. It is linked to the WGBC initiative on this, but this is a version developed in Sweden for the Swedish context (and also embracing embodied GHG emissions).

[161] Net zero energy: The annual on-site renewable energy generation is equal to or more than the annual energy consumption (operational only); Zero carbon: Refers to a building with no net annual greenhouse gas emissions resulting from on-site energy or energy procurement (Scope 1 and Scope 2) from its operation; Net zero emissions: No clear definition in Australia. But Australia in general share the global definition such as Net zero carbon footprint, which refers to achieving net zero carbon emissions by balancing a measured amount of carbon released with an equivalent amount sequestered or offset, or buying enough carbon credits to make up the difference; Carbon neutral: Zero net greenhouse gas emissions (source: National Carbon Offset Standard, Carbon Neutral Program.

[162] New Zealand Green Building Council launched Net Zero Carbon Roadmap for Aotearoa in 2019. Online under: https://www.nzgbc.org.nz/zerocarbon/roadmap

[163] Net zero energy housing, definition from Natural Resources Canada: https://www.nrcan.gc.ca/energy/efficiency/housing/research/5131

[164] Synthesis Report 2020on China's Carbon Neutrality. Online under: https://www.efchina.org/Attachments/Report/report-lceg-20201210/Synthesis-Report-2020-on-Chinas-Carbon-Neutrality.pdf.