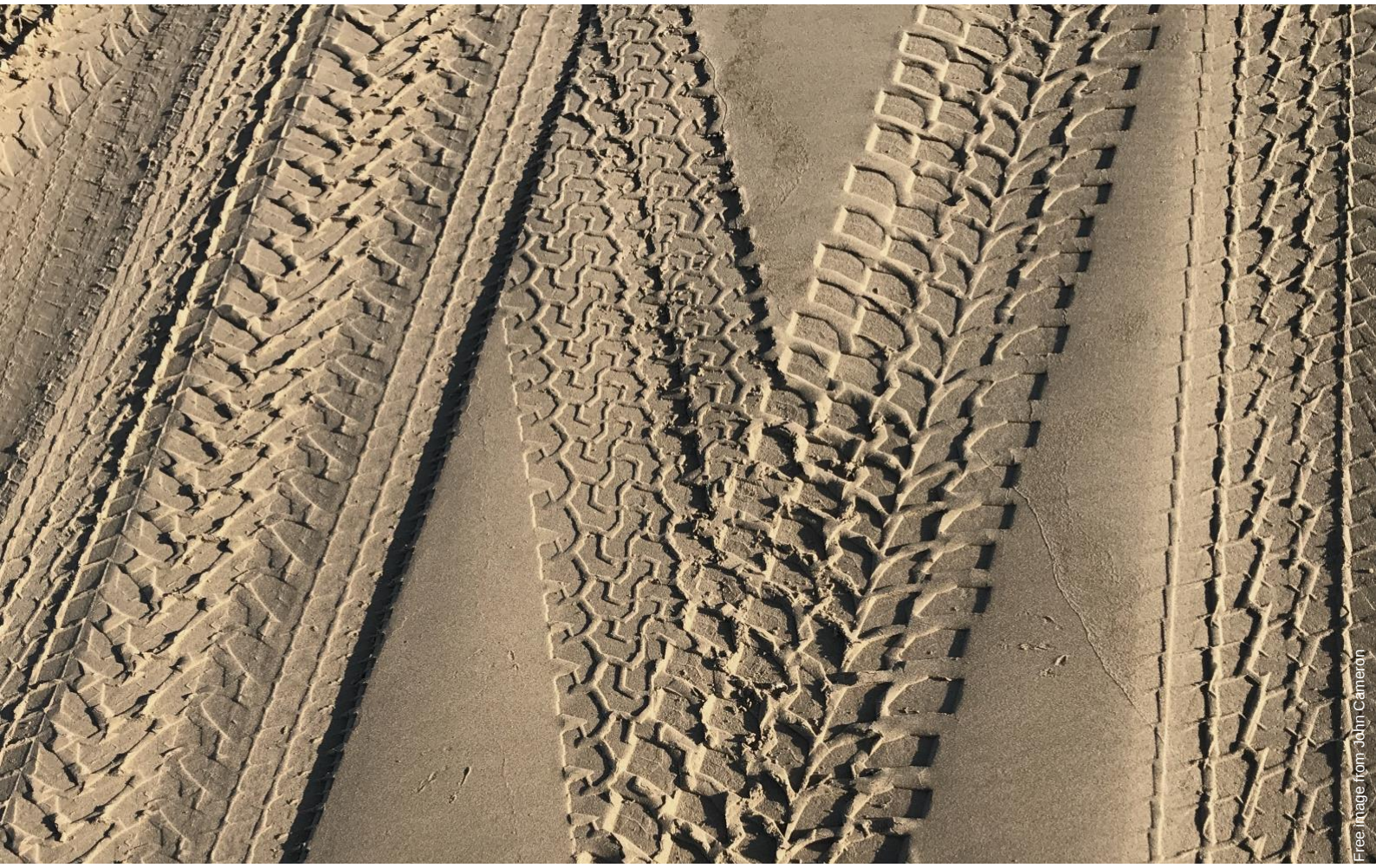
Basics and recommendations on modelling of processes for transport, construction and deconstruction in building LCA

A Contribution to IEA EBC Annex 72

February 2023



Basics and recommendations on modelling of processes for transport, construction and deconstruction in building LCA

A Contribution to IEA EBC Annex 72

February 2023

Authors

Bernardette Soust-Verdaguer, US, Spain, (bsoust@us.es)

Antonio García Martínez, US, Spain

Carmen Llatas, US, Spain

Juan Carlos Gómez de Cózar, US, Spain

Vanessa Gomes, UNICAMP, Brazil

Contributing Authors

Thomas Lützkendorf, KIT, Germany
Maria Balouktsi, KIT, Germany

Imprint:

Published by 2023 Verlag der Technischen Universität Graz, www.tugraz-verlag.at

Editors: Rolf Frischknecht, Thomas Lützkendorf, Alexander Passer, Harpa Birgisdottir, Chang-U Chae, Shivakumar Palaniappan, Maria Balouktsi, Freja Nygaard Rasmussen, Martin Röck, Tajda Obrecht, Endrit Hoxha, Marcella Ruschi Mendes Saade

DOI: 10.3217/978-3-85125-953-7-05

Cover picture: Free image from John Cameron

The official reports from IEA EBC Annex72 are available at following website:
https://annex72.iea-ebc.org/publications

Funding
The work within Annex 72 has been supported by the IEA research cooperation on behalf of the Austrian Federal Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology via the Austrian Research Promotion Agency (FFG, grant #864142), by the Brazilian National Council for Scientific and Technological Development (CNPq, (grants #306048/2018-3 and #313409/2021-8), by the federal and provincial government of Quebec and Canada coordinated by Mitacs Acceleration (project number IT16943), by the Swiss Federal Office of Energy (grant numbers SI/501549-01 and SI/501632-01), by the Czech Ministry of Education, Youth and Sports (project INTEREXCELLENCE No. LTT19022), by the Danish Energy Agency under the Energy Technology Development and Demonstration Programme (grant 64012-0133 and 64020-2119), by the European Commission (Grant agreement ID: 864374, project ATELIER), by the Agence de l'Environnement et de la Maîtrise de l'Energie (ADEME) in France (grant number 1704C0022), by the Federal Ministry of Education and Research (BMBF) and the Federal Ministry for Economic Affairs and Climate Action (BMWK, the former Federal Ministry for Economic Affairs and Energy (BMWi)) in Germany, coordinated by the project management agency PTJ (project numbers 03SBE116C and 03ET1550A), by the University of Palermo - Department of Engineering, Italy, by the Research Centre for Zero Emission Neighbourhoods in Smart Cities (FME ZEN) funded by the Norwegian Research Council (project no. 257660), by the Junta de Andalucía (contract numbers 2019/TEP-130 and 2021/TEP-130) and the Universidad de Sevilla (contract numbers PP2019-12698 and PP2018-10115) in Spain, by the Swedish Energy Agency (grant number 46881-1), and by national grants and projects from Australia, Belgium, China, Finland, Hungary, India, The Netherlands, New Zealand, Portugal, Slovenia, South Korea, United Kingdom, and the United States of America.

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/):

- Survey on the use of national LCA-based assessment methods for buildings in selected countries (Balouktsi et al. 2023);
- Level of knowledge & application of LCA in design practice: results and recommendations based on surveys (Lützkendorf, Balouktsi, Röck, 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 on discounting in LCA and consideration of external cost of GHG emissions (Szalay et al., 2023);
- Basics and recommendations in aggregation and communication of LCA-based building assessment results (Gomes 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)

The authors express special thanks to survey participants: Seo Seongwon and Greg Foliente (Australia), Vanessa Gomes (Brazil), Damien Trigaux, Belgium), Claudiane Ouellet-Plamondon (Canada) CA), Rolf Frischknecht (Switzerland), Maria Balouktsi and Thomas Lützkendorf (Germany), Bruno Peuportier (France), Szusza Szalay Hungary (HU); David Dowdell (New Zealand), José Silvestre (Portugal) and Francesco Pomponi (United Kingdom).

Summary

The method of life cycle assessment (LCA) applied to buildings involves the integration of a great amount of process along in the building life cycle. Hence, the assessment of transport, construction and deconstruction process can be a complex task. There, the modelling strategies to assess this process should consider aspects involved such as fuel consumptions, distances, loading capacity, etc.
One of the main obstacles are the difficulties in modelling, predicting, and estimating process (e.g., energy and fuel consumption, distances assumptions) before the building is built.

Thus, based on a literature review and a specific survey conducted within the Annex 72 participant countries, the present report provides an overview about the modelling of transport, construction, deconstruction strategies, and its integration in the building LCA.

The report starts with a contextualization and limitation of the scope of the process here analysed and integrated in the building LCA. Secondly, includes a literature review considering how existing works integrates the modelling of transport, construction and deconstruction processes in building and construction products (Environmental Product Declarations, EPD). Thirdly, a survey among the Annex participant is conducted to in deep analyse of the modelling strategies. Fourthly, the results of the survey are discussed and possible solutions to deal with the detected challenges are proposed. To conclude a set of recommendations and challenges based on these findings are proposed.

Table of content

Abbreviations

Abbreviations	Meaning
A72	IEA EBC Annex 72
EoL	End of Life
EPD	Environmental Product Declaration
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
T, C&D	Transport, Construction and Deconstruction process

Definitions

Definitions of general terms in the context of an environmental performance assessment are provided here. Many of these descriptions are based on definitions found in international standards. In some cases, definitions found in standards were modified. Topic-specific terms and definitions are explained in the topic-related sections of this report.

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).

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).

Refurbishment: planned large scale (substantial) modification and improvements to an existing construction works to bring it up to an acceptable condition. Refurbishment can be undertaken to facilitate continuation of the current function, including technical modernization and a change of space plan, or a change of function to new use. Synonymous: deep renovation, deep retrofit (prEN 15978-1: 2021).

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).

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).

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).

Design phase or design step or design stage: The design process is typically paced by different design steps, in which lifecycle-based environmental performance assessment can be integrated to various extents. For example, in the early design phase, the first steps are the strategic definition of the project and the preliminary studies, that have to be made in order to get to the concept design. In the detailed design phase,

the next step is the developed design, which is followed by a precise technical design step where all the detail technical solutions are developed and the documentation for the procurement is prepared. A detailed description of the various design steps can be found in A72 report by Passer et al. (2023).

1. Introduction

The application of the LCA in buildings includes the integration of different type of information about the building including all the “products, process and services related to the building and along its life cycle” (EN, 2011). While some information about the LCA modules can be directly extracted from (predefined and normalized) data sources, accountancy of inputs and outputs for Transports (T) process (Modules A4 and C2) and construction and deconstruction (C&D) (Modules A5 and C1) are complex and demand specific modelling strategies. It should be noted that these processes can also be included in several use stage modules (such as B2, B3, B4 and B5) which consists of removal and transport to disposal or recycling location of the removed building components as well as transport and installation of the replaced/repaired components (see Figure 1.1). Therefore, in the case of C1, C2 for the old component removal as well as A4, A5 for the new component installation are included in the modeling.

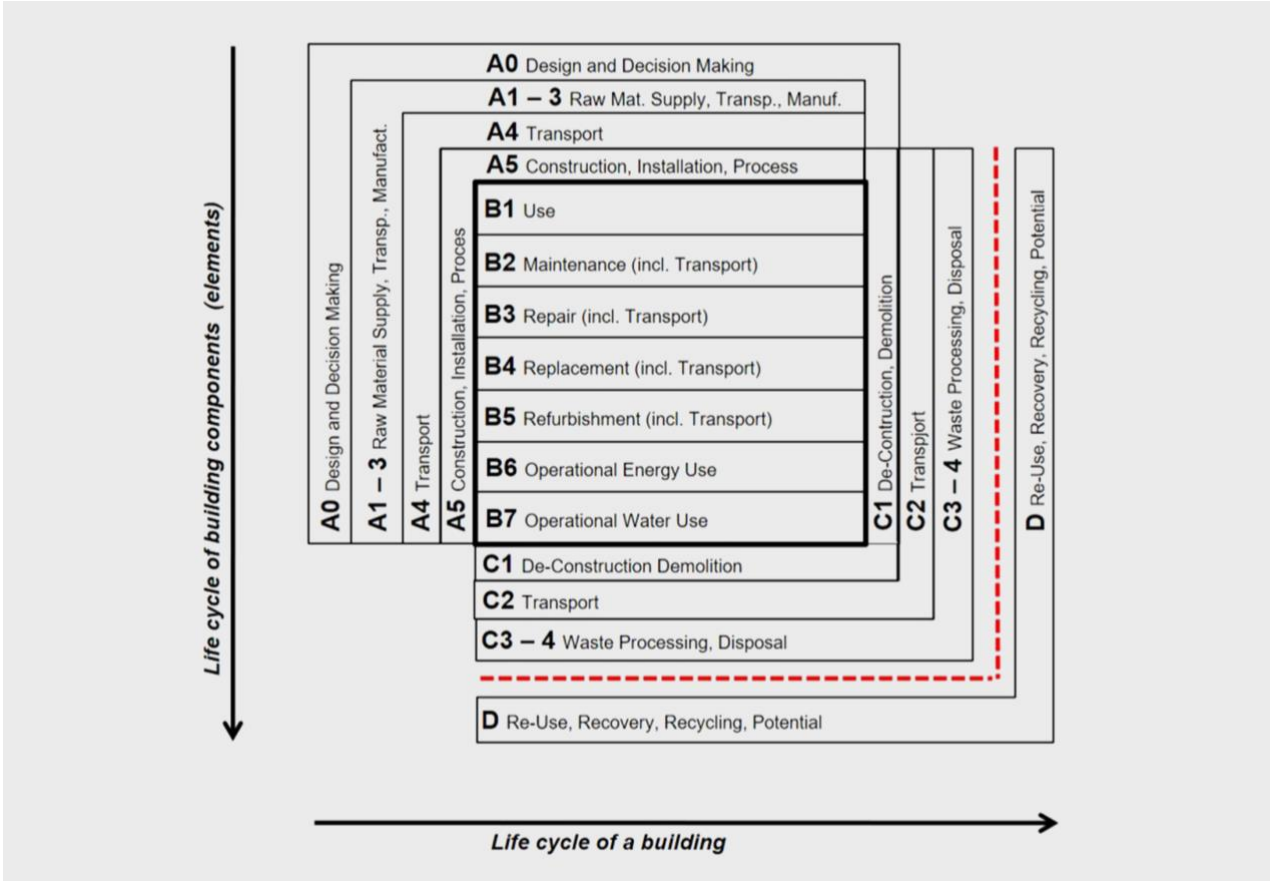


Figure 1.1. LCA information modules according to EN 15643:2021, EN 15978 (EN, 2011) building standard, and EN 15804 (EN, 2012) and ISO 21931 (ISO, 2017) building component/element standard [1](Source: (Lützkendorf, 2019).

[1] Modules C1, C2 as well as A4 and A5 are included also in B4 (and in specific cases in B5).

In order to consider the number of activities, processes and services that should be integrated in the modelling of Transport, Construction & Deconstruction (T, C&D) process in modules A4, A5, C1, C2 and T, C&D in the use stage modules (B2, B3; B4;B5) of the EN 15978 (EN, 2011) proposes a list of items to guide the process (see Table 1.1). Table 1.1 contains a description of the system boundary of each module and suggests the number and type of activities, processes and services that should be included in the LCA. The listed items show the complexity and difficulty in including them in the LCA application.

Table 1.1. According to EN 15978 (EN, 2011) system boundary of each information module should cover:

LCA Module	**System boundary extracted from EN 15978** (EN, 2011) **(activities, processes, and services to be included)**
A4	- transport of construction products and materials from the factory gate to the building site, including any transport to and return journeys of vehicles from the site, intermediate storage, and distribution, - transport of construction equipment (cranes, scaffolding, etc.) to and from the site, - all impacts and aspects related to losses due to the transportation (i.e., production, transport and waste management of the construction products and materials that are damaged or otherwise lost during transportation).
A5	- preliminary activities to prepare the site e.g., site clearance and levelling, connection to utilities, - storage of construction products and materials, including the provision of heating, cooling, humidity, etc., - transport of construction products and materials, waste, and equipment within the site, - temporary works, including temporary works located off-site as necessary for the construction installation process, - on site production and/or processing and/or assembly of materials, products, and components, - provision of heating, cooling, ventilation, humidity control etc. to site facilities during the construction process, - ground works and excavations, - works for the erection/installation of the construction products and materials into the building including ancillary materials not counted in the EPD of the products e.g., releasing agents (oils and greases) in formworks for concrete, formworks discarded at the end of the project, - energy and water use for construction processes/activities, - waste management processes of other wastes generated on the construction site. This includes all processes (including transportation from the building site) until final disposal or until end of waste state is reached, - production, transportation end of life treatment/disposal of products and materials wasted during the construction and installation process, - landscaping, and may include (as additional information) transport of construction workers to and from the site

T, C&D of B2, B3, B4 and B5	- Transport of the components and auxiliary products to replace the old ones, the impacts and aspects of loosed materials during the transport (needed for maintenance, repair, replaced, refurbishment process). - Replacement/ Maintenance/ repairing works of components and auxiliary products (deconstruction/removal of existing components and installation of replacement components). - Transport of removed components and other material/product waste to landfill or reuse/recycling locations.
C1	- on-site operations and operations undertaken in temporary works located off-site as necessary for the deconstruction processes after decommissioning up to and including on-site deconstruction, dismantling and/or demolition.
C2	- all impacts due to transportation to disposal and/or until the end-of-waste state is reached. This includes transport to and from possible intermediate storage/processing locations.

For the sake of simplification, A4-A5 and C1-C2 are dealt with in the following. This expressly includes the transports and construction site processes at use stages. An overview of the activities related to transport and construction processes dealt with in this report is provided in Table 1.2 and a related scheme in Figure 1.2.

Thus, this report discusses:

– the different ways of modelling the Transport (A4 and C2), Construction and Deconstruction (A5 and C1) modules at the beginning, during and at the end of the life cycle, including the scope of the activities described in Table 1.1.
– the implications of using different modelling options.

The report also provides an overview of the current national application in the context of the Annex 72 participant countries and analyze the possible consequences of using different modelling strategies and illustrate possible solutions to deal with them. Based on the results of survey conducted within the context of Annex 72 (where the different LCA National methods and modules included were exanimated), countries contributing to this task declared how they consider of some of these T, C&D modules when conducting LCA. Hence, the present report includes contributions from the following countries Australia (AU), Brazil (BZ), Belgium (BE), Canada (CA), Switzerland (CH), Germany (DE), Spain (ES), France (FR), Hungary (HU), New Zealand (NZ), Portugal (PT) and United Kingdom (UK).

Table 1.2. Scope of the activities related to transport and (de)-construction process discusses in this report and the correlation with the LCA modules.

Activity	Module(s) that fully or partly contain transport processes in their boundary	Here discussed
Activities related to transport processes		
Transport in the upstream chains	A2	No
Transport of construction and/or ancillary products from manufacturers, suppliers or storage facilities, construction equipment to the construction site	**A4**, B2, B3, B4, B5	Yes
Transport of construction site equipment to the construction site	**A5**, B4, B5	Yes
Transport of construction workers to/ from the construction site	**A5**, (B2), (B3), B4, B5	No*
Transport from the construction site to disposal or waste processing facilities	B3, B4, B5, **C2**	Yes
Transport of building users during building operation (mobility)	B8	No
Transport on the waste processing and/or disposal facilities	C3, C4	No
Activities related to construction processes		
Preliminary works (excavation, earthworks, etc.)	**A5**	Yes
Installation of construction products and technical systems	**A5**, B3, B4, B5	Yes
Deinstallation of construction products and technical systems	B3, B4, B5, **C1**	Yes
(Re-)application of finishes (e.g., paint) or other products	B2, (B4), (B5)	No
Heating and lighting consumed on site	**A5, (B4), (B5)**	Yes

* Not mandatory in EN 15978:2011, and not significant in the context of this guideline

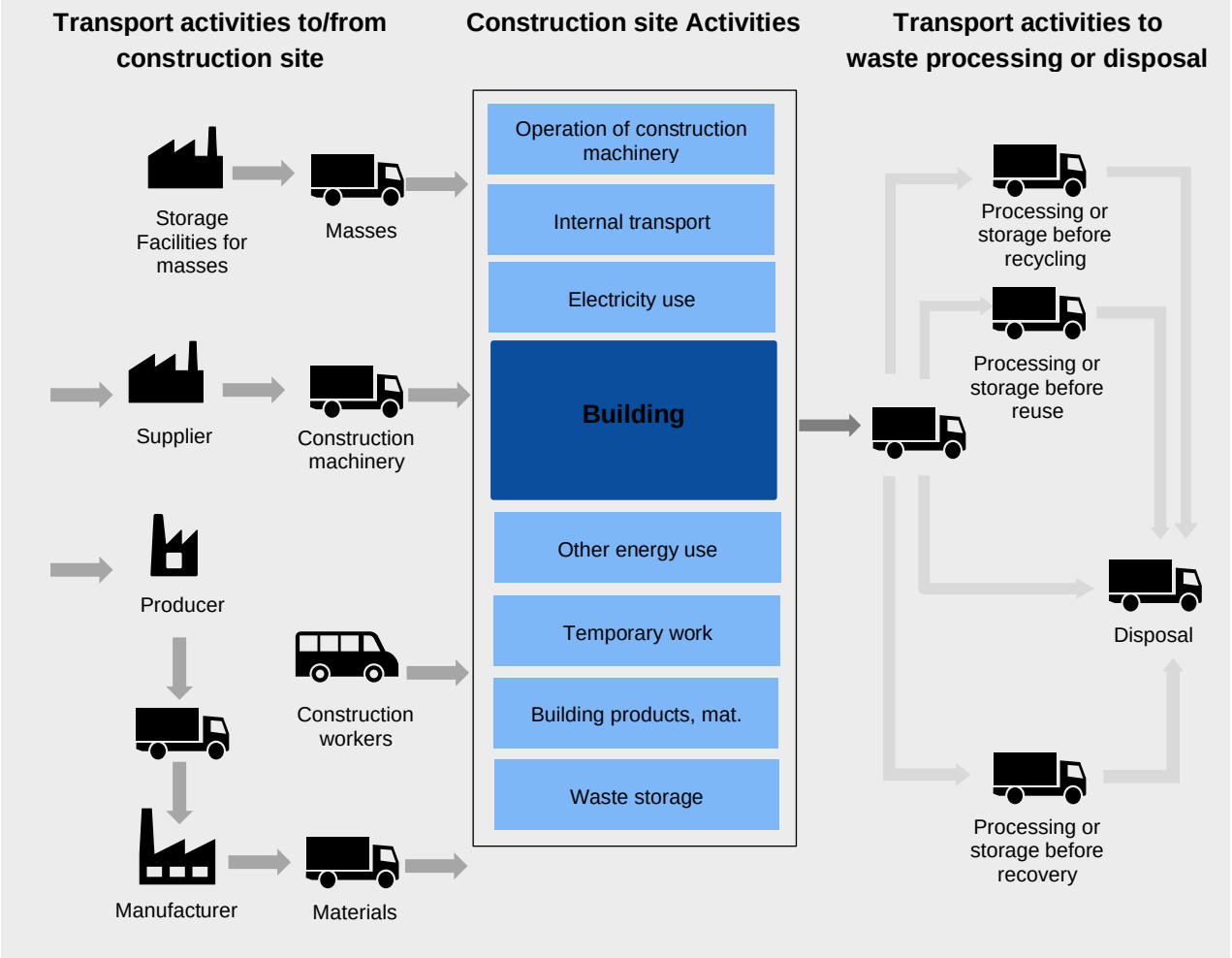


Figure 1.2. Scheme of the activities related to transport and (de) construction process (based on (Vrije Universiteit Brussel et al., 2020))

2. Status of the Discussion

2.1 Literature Review

2.1.1 Modelling of T, C & D processes in LCA

During the last years, many researches have addressed the impact calculation of the construction activities by using the LCA method (EeB Guide Project, 2012). In this vein, different related aspects have been considered, such as national and regional implementation and benchmarks (Schlanbusch et al., 2016; Schlegl et al., 2019); methodological issues such as temporal scope of buildings, uncertainties, dynamic weighting systems, probabilistic approach in retrofitting, parametrization (Favi et al., 2017; Hoxha et al., 2017; Morales et al., 2020; Østergaard et al., 2018; Steubing et al., 2020; Su et al., 2019); BIM-LCA integration (Bueno & Fabricio, 2018; Hollberg et al., 2020); construction alternatives (Balasbaneh et al., 2019; Kamali et al., 2019; Shirazi & Ashuri, 2020).

Many of these studies affect the ways to handle aspects related to the T, C & D process such as those involved in modelling A4, A5, C1 and C2 modules (EN 15978 (EN, 2011)). There, far from following a harmonised methodology to conduct the inventory analysis, different approaches and assumptions are identified. In the following paragraphs, some of the most recent and relevant LCA studies have been analysed from the point of view of the modelling and calculation procedure.

Note that in many cases, especially non-European research, the EN 15978 (EN, 2011) standard is not followed. In those cases, a distribution of the system boundaries according to the EN 15978 (EN, 2011) stages and modules of information was assumed:

1. **Construction process stage: Transport to manufacture to the site (A4 module EN 15978).**
   Even that these modules can be neglected or not included but justified reasons (EeB Guide Project, 2012), there has been detected (Asdrubali et al., 2013; Balasbaneh et al., 2019; Lavagna et al., 2018; Zabalza Bribián et al., 2011) different options to include them in the LCA implementation to buildings. Different assumptions are made to calculate the distance and means of transport involved in this module. According to Lavagna et.al 2018 (Lavagna et al., 2018), A usual practice is to consider an average distance of 50 km for massive materials (e.g. (Asdrubali et al., 2013)) and 100 km for other materials (e.g. (Zabalza Bribián et al., 2011)). Other studies such as Shirazi & Ashuri (Shirazi & Ashuri, 2020) conduct the calculation of transport distances of each material by using Google maps. Pacheco-Torres et al. (Pacheco-Torres et al., 2014) obtain the transport data from EPDs, and other study (Shadram et al., 2016) considers both. Kamali & Hewage (Kamali et al., 2019) includes the transport of workers to the construction site in this module. Many LCA studies (Favi et al., 2017; Pacheco-Torres et al., 2014) do not include a detailed description of the modelling of transport and its impact calculation procedure.
2. **Construction process stage: Construction and Installation process (A5 module EN 15978)**
   The impacts produce during construction and installation in buildings is commonly not taking into account in recent LCA studies (Favi et al., 2017; Morales et al., 2020), and when considering the calculation procedure is not clearly detailed (Balasbaneh et al., 2019; Kamali et al., 2019; Pacheco-Torres et al., 2014; Shirazi & Ashuri, 2020). Other studies (Asdrubali et al., 2013; Beccali et al., 2013; Lavagna et al., 2018; Scheuer et al., 2003) that consider this module, such as Lavagna et.al 2018 (Lavagna et al., 2018), estimate the impact of electricity consumption in the assembly phase as: a) 2%

of the embodied energy of all building materials; and b) 4% of the construction materials are wasted on the construction site.

3. **T, C and D in the Use stage: (B2, B3; B4 and B5 module EN 15978)**
   T, C & D process during the use phase are usually neglected in recent LCA researches (Favi et al., 2017; Kamali et al., 2019; Shirazi & Ashuri, 2020). In other study (Pacheco-Torres et al., 2014) the modelling assumptions and calculations procedure are not enough detailed.
4. **End of Life stage: Deconstruction/Demolition (C1 module EN 15978)**
   The impacts produced during the deconstruction/demolition process are usually considered but, generally the followed procedure is not described in detail (Balasbaneh et al., 2019; Lavagna et al., 2018; Morales et al., 2020; Pacheco-Torres et al., 2014; Shirazi & Ashuri, 2020). On the other hand, many cases (Favi et al., 2017; Kamali et al., 2019) just neglected it. This can be the end of life of the entire structure or of an individual component.
5. **End of Life stage: Transport (C2 module EN 15978)**
   The modelling of impacts produced by the transportation of demolition waste and building elements from the construction site to the final disposal (e.g. recycling plant, landfill (the most usually considered)), in many research (Morales et al., 2020; Pacheco-Torres et al., 2014; Shirazi & Ashuri, 2020) the processes under C2 are not described in detail. When the procedure is more comprehensively described such as in (Balasbaneh et al., 2019; Lavagna et al., 2018), the means of transport are defined (generally truck or lorry) and the distance to the final disposal points (landfill) is estimated (usually around 10 km). In contrast, many studies (Favi et al., 2017; Kamali et al., 2019) do not considered the transport of building materials to the final disposal/recycling points.

When considering the modelling of transport modules (A4 and C2), several aspects should be taken into account:

a. establish the location of manufacturers, site construction and final disposal/recycling points of building component/elements.
b. calculate the transport distances (there is a wide range of approaches to model the distances: from general estimations up to accurately definitions e.g. google maps);
c. calculate the mass/volume to be transported (e.g., capacity utilisation and bulk density of transported products);
d. define the means of transport, fuels type and consumption, and their environmental impacts.

The impacts related to construction and deconstruction process (A5 and C1 modules) are usually neglected. However, when they are modelled, the calculation procedure and assumptions are generic and diverse. The preliminary results of the literature review show the heterogeneity and differences in the modelling of A4, A5, C1 and C2 modules, which reinforce the statement of establishing harmonised procedures to model and calculate their impacts.

2.1.2 Modelling of T, C & D process in construction products EPDs

The modelling of transports (A4 and C2) and construction, and deconstruction process (A5, C1) is also addressed by the construction EPDs. Considering the system boundaries, different types of EPDs can be identified (see Figure 2.1). Thus, according to the EN 15804 standard (EN, 2012) there are five possible types of EPD: 1) cradle to gate; 2) cradle to gate with mandatory C1-C4 and D; 3) cradle to gate with options (C1-C4 and D); 4) cradle to gate with options (A4 and A5); and 5) cradle to grave with mandatory D.

A selection of case studies was performed to identify the main modelling strategies used in the construction products EPDs. The selection of EPDs was focused on the published in the EPD® (EPD, n.d.) and based on the contributing countries where EPDs with information on these modules were available: Australia (AU),

Brazil (BZ), Belgium (BE), Canada (CA)[2], Switzerland (CH), Germany (DE), Spain (ES), France (FR), Hungary (HU), New Zealand (NZ), Portugal (PT) and United Kingdom (UK). It included the selection of two different type of EPD per country, preferably one cradle to gate and one cradle to grave. Table 2.1 and Table 2.2 include a summary of the obtained results.

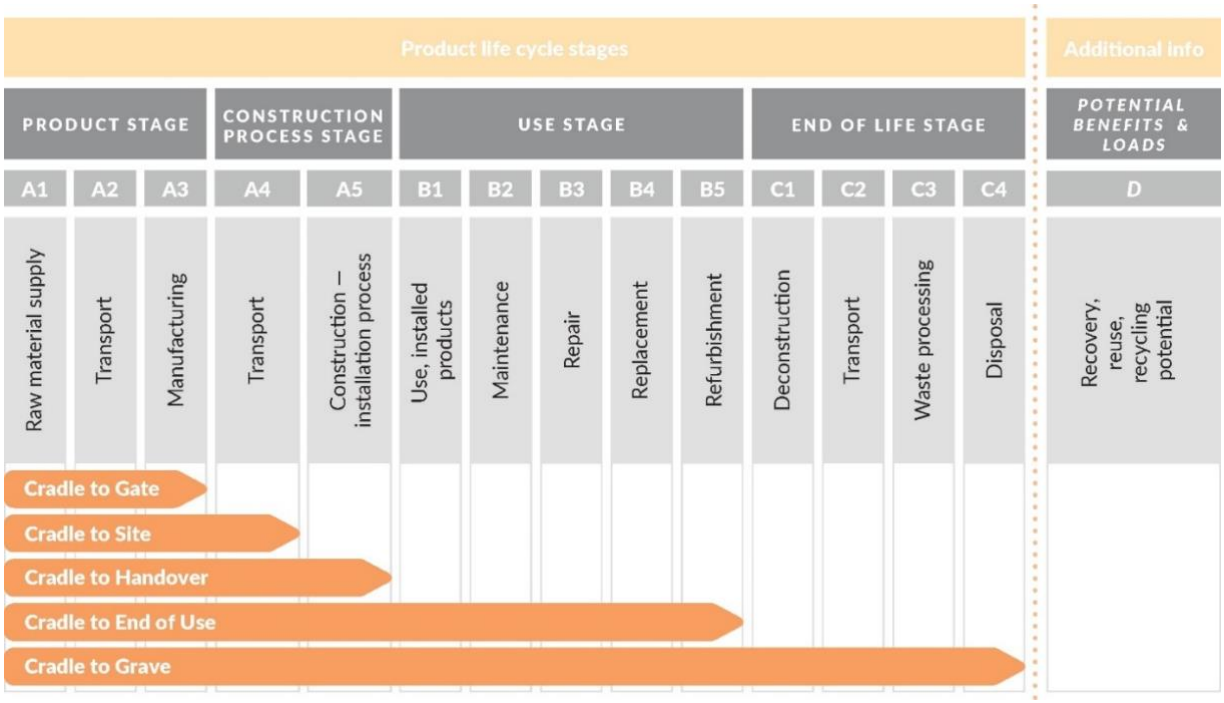


Figure 2.1. LCA system boundaries according to EN 15804 (EN, 2012) standard. (Sources: based on Overview report IEA EBC Annex 57 (IEA EBC, 2016) and (Balouktsi & Lützkendorf, 2016)

For buildings, the system boundary “cradle to handover” was already recommended in the result of Annex 57 (IEA EBC, 2016). The background is the handling of prefabricated constructions in the interest of transparency and comparability. If structures are mainly produced on the construction site, the associated impacts must be assigned to A5. In a predominantly prefabricated building, some processes are assigned to A3 and others to A5. In the latter case, it is not the transport of building materials but the transport of prefabricated parts that is assigned to module A4. System boundaries such as cradle to gate and cradle to site cannot adequately consider the special features of a construction method with prefabricated parts. A system boundary cradle to handover is also typical for the determination of construction costs.

[2] No EPD was found in the Environdec library for construction products.

Table 2.1. Modelling of transports in construction product EPDs (selected examples based on based on analysing public available EPDs of construction porducts manufactured in the countries that have particpated in the survey)

Country	Construction Product	Type of EPD	Modelling of transport modules			
			A4		C2	
AU	**External cladding products** James Hardie® Industries Ltd	Cradle to Grave with options	Distribution by truck and sea freight from James Hardie's gate calculated based on national annual sales volumes by state and conservative average transport distance assumptions. The typical cladding load per truck transport kilometer was calculated based on 100% utilization of a typical heavy truck (i.e. 30t cladding on 30t capacity truck) for national distribution, and based on 50% utilization of a typical heavy truck for local distribution (i.e. 15t cladding on 30t capacity truck)			
	Hot Dip Galvanizing Galvanizers Association of Australia	Cradle to Site with options	Transport to the customer is calculated based on a mix of transport distance data provided by galvanizers and assumed distances of 100 km by articulated truck.		Demolition waste is transported 100 km by truck for processing.	
BE	**Flexible sheet for waterproofing- Alkorplan A (1,2 mm)** Renolit	Cradle to Grave with options	Fuel type and consumption of vehicle	Truck, diesel 0,03 liter / tkm	Fuel type and consumption of vehicle	Truck, diesel 0,03 liter / tkm
			Capacity utilisation (including empty returns)	50 %	Capacity utilisation (including empty returns)	50 %
			Bulk density of transported products (packaging included)	1,95 Kg per m² (thickness 1.2mm)	Bulk density of transported products (packaging included)	1,75 Kg per m² (thickness 1.2mm)
			Distance	800km	Distance	800km
	Flexible Bitumen Sheets For Roof Waterproofing European Waterproofing Association	Cradle to Grave with options	Average distance for product delivery to the construction site was collected with the aid of EWA online tool 300 km covered by a 32-t truck		Distance covered by a European average EURO 5 lorry 16 t with diesel engine: 150 km to recycling; 100 km to incineration site; 50 km to disposal	
BZ	**Forrovid Boreal** ISOVER - Saint-Gobain do Brasil Produtos Industriais e para Construção	Cradle to Gate with options	Fuel type and consumption of vehicle	Average truck trailer with a 24t payload, diesel consumption 38 liters for 100 km	Assume that the waste going to landfill will be transported by truck with 24 tons payload, using diesel as a fuel consuming 38 liters per 100km. Distance covered is 25 km	
			Distance	1633 km		
			Capacity utilisation (including empty returns)	100 % of the capacity in volume 30 % of empty returns		
			Bulk density of transported products	60 kg/m3		
			Volume capacity utilisation factor	1		
	Concrete FCK 30 MPA BR.1 10+-2 Votorantim Cimentos	Cradle to Gate	Neglected		Neglected	
CH	**Alba® hydro 80 GYPSUM BLOCK** Rigips AG	Cradle to Grave with options	Fuel type and consumption of vehicle	Truck with a 27-ton average payload Diesel consumption 0.158l/tkm	On average, Gypsum waste is transported 220 km by truck to the recycling facility, 60 km by truck and 150 km by rail to the landfill facility and 30 km by truck, 10 km by ship and 50 km by rail to the incineration facility.	
			Distance	144 km by truck		
			Capacity utilisation (including empty returns)	85% volume capacity		
			Bulk density of transported products	1000 kg/m3		
			Volume capacity utilisation factor	1		
	BASWA Phon Baswa Acoustic	Cradle to Grave with options	Transport by road and Fuel consumption	Articulated lorry, 40 t total weight, 27 t max Diesel 0.350 kg/km	A distance of 60 km has been assumed for the transport to final disposal.	
			Transport by sea and Fuel consumption	Container ship ocean, 27.500 dwt pay load. Heavy fuel oil 99.9 kg/km		
			Distance by road	1,500 km		
			Distance by sea	3,350 km		
			Volume capacity utilization (road) - Panels	63%		

			Volume capacity utilization (road) - Plasters	32%	

Table 2.1. Modelling of transports in construction product EPDs (cont.)

Country	Construction Product	Type of EPD	Modelling of transport modules A4		C2
DE	**CONTRAFLAM LITE 30 Vetrotec. Saint Gobain**	Cradle to Gate	Neglected		Neglected
	FKD-U RS C2 Knauf insulation	Cradle to Gate with options	Average transport distance	600 km	Truck-trailer, Euro 3, 34 - 40t gross Weight / 27t payload capacity/ 40 L for 100 km. (if 100 % utilization). 50 % of the weight capacity. Average distance: 50 km
			Type of fuel and vehicle consumption or type of vehicle used for transport	Truck Euro 6 (28 – 32 t / 22 t payload). 140 L for 100 km.	
			Capacity utilization (including 30% Of empty returns)	36 % of the weight capacity	
ES	**Arena Apta** Saint-Gobain Isover Ibérica	Cradle to Grave with options	Fuel type and consumption of vehicle	Truck with a 16-32 tonne average payload Diesel consumption 0.38 litres per km	Truck with trailer with an average load of 16-32t and a diesel consumption of 38 liters per 100 km. EURO 6. 25km average distance to landfill
			Distance	450 km by truck	
			Capacity utilisation (including empty returns)	100 % of the capacity in volume 30 % of empty returns	
			Bulk density of transported products	20-200 kg/m3	
			Volume capacity utilisation factor	1	
	Exterior Paints JUNO Paint Manufacturer	Cradle to Grave with options	Fuel type and consumption of vehicle	Truck of more than 32 tn. Fuel consumption: 31,1 L/100 Km Ship transport for Canarian and Balearic Islands	16-32 tn truck. Fuel consumption: 25 l/100 Km Distance: 50 km
			Distance	Truck: 358 Km Ship: 842 km	
			Capacity utilisation (including empty returns)	% assumed in Ecoinvent	
			Bulk density of transported products	1,38 kg/l (for Junokril mate)	
			Volume capacity utilisation factor	1	
FR	**MINERVAL® A 12 mm** Saint-Gobain Eurocoustic	Cradle to Grave with options	Fuel type and consumption of vehicle	Average truck trailer with a 24t payload, diesel consumption 38 liters for 100 km	Assume that the waste going to landfill will be transported by truck with 24 tons payload, using diesel as a fuel consuming 38 liters per 100km. Distance covered is 25 km.
			Distance	1500 km	
			Capacity utilisation (including empty returns)	100 % of the capacity in volume, 30 % of empty returns	
			Bulk density of transported products	259 m² per pallet and 22 pallets per truck	
			Volume capacity utilisation factor	<1	
	Climatop triple glazing unit Saint-Gobain Glass France	Cradle to Gate	Neglected		Neglected
HU	**Rigips RBI 12.5mm Moisture Resistant Board** Saint-Gobain Construction Products Hungary	Cradle to Gate with options	Fuel type and consumption of vehicle	Truck, diesel , 0.33 litres per km	Gypsum waste is transported the following distances by road from construction / demolition sites to end of life treatment or disposal. Hungary; 20 km Slovakia; 50 km Serbia; 50 km Macedonia; 50 km Kosovo; 35 km
			Distance	250 km	
			Capacity utilisation (including empty returns)	100 %	
			Bulk density of transported products	848 (kg/m3)	
			Volume capacity utilisation factor	1	
	Rigips Habito 12.5 mm plasterboard board Saint-Gobain Construction Products Hungary	Cradle to Gate with options	Fuel type and consumption of vehicle	Truck, diesel, 0.33 litres per km	34 - 40t gross weight / 27t payload capacity Diesel driven, Euro 0 - 5 mix, cargo, average sulfur content: EU = 10 ppm 42.5 km from construction/demolition site to landfill
			Distance	774 (km) by truck 190 (km) by ship	
			Capacity utilisation (including empty returns)	100 %	
			Bulk density of transported products	960 (kg/m3)	
			Volume capacity utilisation factor	1	

NZ	**Ultracem Holcim**	Cradle to Gate	Neglected		Neglected

Table 2.1. Modelling of transports in construction product EPDs (cont.)

Country	Construction Product	Type of EPD	Modelling of transport modules A4		C2
NZ	**Gypsum plasterboard** Winstone Wallboards	Cradle to Grave with options	Includes distribution from Winstone Wallboards manufacturing sites in Auckland and Christchurch through its distribution centres. GIB® plasterboard is distributed through builder's merchants and direct delivery to construction sites.		Includes transport of waste plasterboard to landfill after demolition of the wall or building where it was used. 100% of plasterboard waste and the waste from installation materials is assumed to be sent to landfill (i.e. worst case). Plasterboard is assumed to be disposed of in a municipal landfill rather than an inert demolition waste landfill as plasterboard is not required to be separated from other waste in New Zealand. The assumed transport distance is 50 km with capacity utilisation of 50%.
PT	**Stamped pre painted steel ceiling plate** Gabelex	Cradle to Grave with options	Fuel type and consumption of vehicle or vehicle	Truck, diesel, Average 27 tons payload. Driving share 70% motorway, 23 % rural, 7% urban.	Transport to waste processing a distance of 50 km by truck has been taken into account
			Distance	493 (km)	
			Capacity utilisation (including empty returns)	85 %	
			Bulk density of transported products	-	
			Volume capacity utilisation factor	1	
UK	**Glasroc F FIRECASE** BPB United Kingdom Limited	Cradle to Grave with options	Fuel type and consumption of vehicle or vehicle	44 tonne articulated large goods vehicle (including payload of 24 tonnes) Diesel consumption 38 litres per 100 km travelled	44 tonne articulated large goods vehicle (including payload of 24 tonnes) Diesel consumption 38 litres per 100 km travelled 32 km from construction/demolition site to waste handler
			Distance	240 km	
			Capacity utilisation (including empty returns)	100% volume capacity 30% empty returns	
			Bulk density of transported products	904 kg/m3 (13.56 kg/m2)	
			Volume capacity utilisation factor	1	

	Carpet tile EcoWorx®	Cradle to Grave with options	The modelling derives from three factors: 1. Transport by truck from the Shaw production facility to port (542 km) by truck. Calculated as Ecoinvent v 3.4 Cut-off - transport, freight, lorry, unspecified//[GLO] market for transport, freight, lorry, unspecified 2. Transport by ship from Savannah, GA USA to Southampton, UK (6643 km). Calculated as Ecoinvent v 3.4 Cut-off: transport, freight, sea, transoceanic ship//[GLO] market for transport, freight, sea, transoceanic ship 3. The average distance EcoWorx® carpet tile travels from the ports of arrival to installation sites is 200 km by road to the use site. The assumed means of transport is a generic truck (Ecoinvent v 3.4 Cut-off: transport, freight, lorry, unspecified//[GLO] market for transport, freight, lorry, unspecified). This process assumes a load factor of 50%. In other words, the truck is assumed to be fully loaded on the way to the construction site and empty upon return.	To model a representative scenario, it is assumed that 100% will go to landfill and that the transport distance is 250km by road.

Table 2.2. Modelling of construction and deconstruction in construction product EPDs

Country	Construction Product	Type of EPD	Modelling of construction / deconstruction modules			
			A5		C1	
AU	**External cladding products** James Hardie® Industries Ltd	Cradle to Gate with options	Energy (electricity) consumption for construction	0.2 kWh of electricity per m2	Energy (electricity) consumption for deconstruction	0.2 kWh of electricity per m2
			Diesel fuel consumption for machinery	included	Diesel fuel consumption for machinery	included
			Waste disposed to landfill.	5% of the cladding delivered to site		
	Hot Dip Galvanizing Galvanizers Association of Australia	Cradle to Grave with options	Neglected		Neglected	
BE	**Flexible sheet for waterproofing- Alkorplan A (1,2 mm)** Renolit	Cradle to Grave with options	Additional material consumption	300g polyurethane (PU) is used per m2, overlaps (5%) and installation losses (3%)	Neglected	
			Waste and packaging materials	Distance 50 km		
			Fuel type and consumption of vehicle	Truck, diesel 0,03 liter / tkm		
			Products (packaging and installation losses only)	0,26 Kg per m² (thickness 1.2mm)		
	Flexible Bitumen Sheets for Roof Waterproofing European Waterproofing Association	Cradle to Grave with options	Include the cutting waste production, transport and waste processing and Disposal. The transportation of the waste generated at the building site takes into account a European average EURO 5 lorry 16 t with diesel engine 150 km to recycling 100 km t incineration site 50 km to disposal)		Neglected	
BZ	**Forrovid Boreal**	Cradle to Gate with options	Wastage of materials on the building site before waste processing, generated by the product's installation	5 %	Neglected	
			Distance	25 km to landfill by truck		

	ISOVER - Saint-Gobain do Brasil Produtos Industriais e para Construção		Output materials	Packaging wastes are 100 % collected and modeled as recovered matter Glass wool losses are landfilled	
	Concrete FCK 30 MPA BR.1 10+-2 Votorantim Cimentos	Cradle to Gate	Neglected		Neglected
CH	**Alba® hydro 80 GYPSUM BLOCK** Rigips AG	Cradle to Grave with options	Ancillary materials for installation	Jointing compound 0.77 kg/m^2	Not detailed
			Water use	0.64 litres/m^2	
			Wastage of materials on the building site before waste processing	Gypsum Blocks: 4 kg, 0.04 kg jointing compound	
			Output materials	Gypsum Blocks: 0.424 kg to internal recycling, 3.4 kg to landfill, 0.176 kg to incineration Jointing compound: 0.004 kg to internal recycling, 0.034 kg to landfill, 0.002 kg to incineration	

Table 2.2. Modelling of construction and deconstruction in construction product EPDs (cont.)

Country	Construction Product	Type of EPD	Modelling of construction / deconstruction process A5		C1
CH	**BASWA Phon** Baswa Acoustic	Cradle to Grave with options	Water	1.01E-03 m^3	No contribution on impact categories of this module
			Energy consumption	Global mix power (low tension) 2.38E-01 MJ / 4.16E-01 MJ	
			Packaging	Plastic (29% recycling - 32% incineration - 39% landfill) Carboard (75% recycling - 12% incineration - 13% landfill) Wood - Pallet (30% recycling - 32% incineration - 38% landfill) Metal (74% recycling - 12% incineration - 14% landfill	
DE	**CONTRAFLAM LITE 30 Vetrotec. Saint Gobain**	Cradle to Gate	Neglected		Neglected
	FKD-U RS C2 Knauf insulation	Cradle to Gate with options	Loss of materials in construction site	2%	The common manual dismantling impact of insulation is considered as very small and can be neglected in C1.
			Packaging Wooden pallet	40% recycled, 60% incinerated	
			Packaging Plastic sheet	40% recycled, 60% incinerated	
ES	**Arena Apta** Saint-Gobain Isover Ibérica	Cradle to Grave with options	Product packaging waste is 100% collected and processed into recovered material. Mineral wool losses or waste are transport to landfill. A distance of 50km has been considered both to the manager (recoverable material) and to the landfill (in the case of final disposal). Wastage of materials on the building site 5%.		No contribution on impact categories of this module
	Exterior Paints JUNO Paint Manufacturer	Cradle to Grave with options	Auxiliary materials for installation	Brush, roll or spray gun	No contribution on impact categories of this module
			Use of water	0,029 L/FU (for Junokril mate)	
			Wastage of materials on the building site before waste processing	Product wastage (2%): kg / FU Wooden pallet: 9,18E-03 kg / FU Polyethylene container with metal handle (15L): 2,93E-02 kg / FU	

				Polyethylene Film: 2,60E-03 kg / FU	
			Output materials	Product losses are 100% landfilled, Packaging waste is 100% recycled	
FR	**MINERVAL® A 12 mm** Saint-Gobain Eurocoustic	Cradle to Grave with options	Wastage of materials on the building site before waste processing	5 % of stone wool 58 g of pallets (packaging)/m² of ceiling slabs 4 g of cardboard (packaging)/m² of ceiling slabs 10 g of polyethylene (packaging)/m² of ceiling slabs	Neglected
			Output materials	Packaging wastes are 100 % collected and recycled Stone wool losses are landfilled	
			Energy use in this stage is neglected due to the low contribution.		
	Climatop triple glazing unit Saint-Gobain Glass France	Cradle to Gate	Neglected		Neglected

Table 2.2. Modelling of construction and deconstruction in construction product EPDs (cont.)

Country	Construction Product	Type of EPD	Modelling of construction / deconstruction process A5		C1
HU	**Rigips Rigips RBI 12.5mm** Saint-Gobain Construction Products Hungary	Cradle to Grave with options	Ancillary materials for installation	Jointing compound 0.33 kg/m2 board, tape 1.60m /m2 board, screws 11 /m2 board	No information is provided
			Water use	0.165 litres/m2 board	
			Wastage of materials on the building site before waste processing	Board: 0.41 kg (5 % scrap rate at installation) Screws: 0 kg Jointing Compound: 0.0165 kg Jointing Tape 0.0003 kg	
		Cradle to Grave with options	Output materials as results of waste processing at the building site	Board: 0.41 kg to landfill Screws: 0 kg. Jointing Compound: 0.0165 kg to landfill. Jointing Tape: 0.0003 kg to landfill	No information is provided
		Cradle to Gate with options	Materials for installation	Jointing tape: 1.60 linear metres Joint filler: 0.33kg. 11 Screws	No information is provided
			Water use	0.165 m3	
			Wastage of materials on the building site before waste processing	Rigips Habito: 0.60 kg Pallet: 0.52 kg. Jointing tape: 0.08 linear metres. Joint filler: 0.0165kg. 0.4 Screws	
			Output materials	Rigips Habito: 0.60 kg to landfill Pallet: 0.52 kg to landfill Jointing tape: 0.08 linear metres to landfill. Joint filler: 0.0165kg to landfill 0.4 Screws to landfill	
NZ	**Ultracem** Holcim	Cradle to Gate	Neglected		Neglected

	Gypsum plasterboard Winstone Wallboards	Cradle to Grave with options	Includes the materials used to install the plasterboard (plaster, jointing tape, screws and water) and the production and disposal of offcuts from installation, including a combination of composting and landfill. During installation, 15% of the plasterboard is assumed to be lost as offcuts. 25% of these offcuts are sent to industrial composting and 75% to landfill. The transport distance to landfill and composting is assumed to be 50 km with capacity utilization of 50%. The consumables materials assumed per m^2 in the installation are: Jointing compound (0.1924 kg), Jointing tape (0.0108 kg), Screws (8 screws, each 2.6 g) (0.0208 kg), Water (0.1202 L).		Neglected
PT	**Stamped pre painted steel ceiling plate** Gabelex	Cradle to Grave with options	**Materials for installation**	Not considered	The de-construction and/or dismantling of products take part of the demolition of the entire building. For ceiling tiles and grids the environmental impact is assumed to be very small. Thermal energy for deconstruction is included at 0.05 MJ per kg of deconstructed material.
			Water use	None	
			Wastage of materials on the building site before waste processing	0,21 kg of steel 0,161 kg of packaging waste	
			Output materials	0,20 kg of steel for recycling (95%) 0,011 kg of steel send to landfill (5%) 0,161 kg of packaging waste landfilled 0,110 kg of wood pallet for re-use	

Table 2.2. Modelling of construction and deconstruction in construction product EPDs (cont.)

Country	Construction Product	Type of EPD	Modelling of construction / deconstruction process A5		C1
UK	**Glasroc F FIRECASE** BPB United Kingdom Limited	Cradle to Grave with options	**Materials for installation**	Screws: 0.015 kg Jointing Compound: 0.35 kg Jointing Tape: 0.00063 kg	Neglected
			Water use	0.11 m^3	
			Wastage of materials on the building site before waste processing	15mm Glasroc F FIRECASE: 1.356 kg Screws: 0 kg Jointing Compound: 0.035 kg Jointing Tape: 0.000063 kg Pallet: 0.487 kg	
			Output materials	15mm Glasroc F FIRECASE: 0.231 kg to recycling 15mm Glasroc F FIRECASE: 1.125 kg to landfill Screws: 0 kg Jointing Compound: 0.035 kg to recycling Jointing Tape: 0.000063 kg to landfill Pallet: 0.487 kg to recycling	
			Materials EoL scenarios	83% of construction and demolition waste is sent to landfill with the remaining 17% recycled.	
	Carpet tile EcoWorx®	Cradle to Grave with options	No energy use is allocated to the installation process because the fitting of EcoWorx® on site is manual work. During the installation process approximately 90ml of adhesive is used per unit.		It is assumed that no materials or energy is used for de-constructing EcoWorx®. Removal of tiles is a manual process requiring no energy or chemical use as a release bond adhesive or loose lay is the normal installation method.

Considering the modelling of transport in A4 and C2 modules, it is noticed that similar type of information is provided to describe the modelling and scenario definition such as fuel consumption, type of vehicle, dataset, distances, capacity utilization (including empty returns), bulk density of transported products, volume capacity utilization factor. It is also noted that the assumptions for distances and means of transports are related to the country and the geographical scope of the EPD, it means that the most "frequent scenarios" are considered. The assumptions for A4 and C2 mostly includes similar scenario (vehicles: trucks and fuel consumptions: diesel 0.33 per km). However, the representativeness of these "frequent scenario" regarding the real/actual scenario (including distances between the manufacturer and the construction site /type of transport/ fuel consumption) cannot be assured. In this vein, it was detected that the information about the real location of the manufacturing point (production site) is not explicitly included all the EPD analyzed.

Results showed in Table 2.1 indicate that the modelling of A5 module is mostly considered (in all cradle-to-grave EPDs), in contrast use stage modules and C1, are mostly neglected. It is noticed that the provided information to describe the modelling and scenario definition for A5 module mostly included: ancillary materials for installation, water use, wastage of materials on the building site before waste processing, output materials. In some cases, information about energy consumption (BASWA Phon, CH) is provided, as well as material EoL scenarios (Glasroc F FIRECASE, UK). Other cases such as Gypsum plasterboard (NZ), Arena Apta (ES), Flexible Bitumen Sheets (BE) include information about the transportation of waste (e.g., distance). The module C1 is hardly considered, except for example, **External cladding products (AU**), that considers similar information for deconstruction and construction process.

Table 2.1 and Table 2.2 confirm that the information contained in the selected EPDs to model A4, A5, C1 and C2 include similar variables (such as fuel consumption, distances, wastage, bulk density of transported products, output materials), and consider a similar level of detail for assumptions and scenario definition. Thus, it can be assumed that for modelling the stages (A4, A5, C1 and C2) it was considered a detailed number of input and output process (in several cases illustrated by flowcharts or schemas), as far as possible to real situation. The relevance of considering an accurate and detailed modelling is mainly to avoid double-counting and reduce unexpected mistakes.

2.1.3 Relevant questions

In contrast with the previously analyzed construction EPDs, in the building, the amount of information and the complexity to manage it can be higher. Thus, at present and according to previous Sections **2.1.1 and 2.1.2**, different modelling alternatives to deal with the Transport (T) and Construction and Deconstruction (C&D) process in a building LCA. When modeling the life cycle of buildings, the following detected options exist regarding the transport processes (A4 and C2) and the processes on the construction site (A5 and C1), whereby different approaches are possible in each case and can be organized into four groups, described below (Table 2.3):

Table 2.3. Recognition of the rage of possible options to deal with modelling T, C&D process.

Option	General definition of the modelling Option	Modelling alternatives that can involve the option
Option 0: Not modelled	Not modelling of distances and process.	• Not modelled or Ignored • Deliberately neglected because they are negligibly small
Option 1: Generic modelling	One or two generic values covering different building elements/components or building materials. Appropriate for: – When distances and means of transports are not relevant, the data is missing, or products stem from the same location. – Construction and deconstruction processes are not relevant, or the data is missing.	• Consideration via default values. Example: (Kuittinen & Häkkinen, 2020)
Option 2 Simplified modelling	Values for different building elements/components or building materials are grouped and modelled in a simplified way. Appropriate for: – When distances and means of transports can be grouped or simplified for similar products. – When the comparison of different materials and technical solution is relevant for the decision-making. – When construction and deconstruction process have similar characteristics for certain products.	Modeled at building level using different scenarios. Examples: (Asdrubali et al., 2013; Soust-Verdaguer et al., 2018)
Option 3 Detailed modelling	Specific values for elements/components or building materials are used. Appropriate for: – When distances and means of transports are known / close to real scenario, for all the products and ser-vices. – When construction and deconstruction processes are known / close to real scenario, for all the products and services. – When transport scenarios in product-related EPDs are appropriate and consistent.	• Modelled in detail and on a case-by-case basis at the building level. Example: (Shadram et al., 2016) • Modeled in detail and on a case-by-case basis at the building level using for example the real fuel consumption in transport of In both cases EPDs for transport processes and for construction site processes can be extracted for example from the Ökobaudat (Federal Ministry of the Interior Building and Home Affairs (BMI), n.d.).

Regarding the different strategies used for the modelling of T, C & D process (see Table 2.3) several aspects are identified as crucial for the analysis:

1. Calculation methods, assumptions, and scenarios for modelling the process.
2. The calculation methods define the complexity or simplicity
3. Treatment of the uncertainties and variabilities in the modelling of transport, and construction, deconstruction, and replacement processes. Depending on the availability of information a modelling option can be more appropriated for a certain phase of the building (design, pre-construction, post-construction). Early design stages require generic scenarios, detailed design stages and post - construction stages detailed scenarios. Through the analysis of different national methods, can this statement be confirmed?
4. Relevance and consequences of its integration in the LCA results. The use of a certain option can be related to the relevance or irrelevance in the total LCA results in a certain context.

In this context, the following questions arise:

a. What are all the possible options to model T, C & D modules?
b. Which are the main causes of neglection of the modules? How big is the error if transports and construction / deconstruction site processes are neglected?
c. Which default values are there in which country?
d. Should the processes be modeled using information from EPDs or, better, directly?
e. Are there EPDs for transport and construction site processes that can be used?
f. Would it be possible to define harmonized guidelines to model them?

2.1.4 Main Problems

When conducting the building LCA, the problem arises that the effort required to describe and calculate the process involved in modules A4, A5, C1 and C2 can be considerable, especially to model and systematize these complex processes. The present section is focused on detection the main aspects and characteristics of the modelling principles applied in the different national methods, analyses differences and similarities, and propose recommendations to address the detected challenges.

2.2 Existing Approaches in Annex Participant Countries

2.2.1 Overview on national application based on the results obtained from National methods survey

The present section is focused on identifying the current status on the integration of modules A4, A5, C1 and C2 (EN 15978) and T, C & D process in use stage (EN, 2011) to implement the LCA in the context of Annex 72 participating countries. Based on results obtained in the national survey about LCA methodologies conducted in the context of the IEA EBC Annex 72 (see report “Survey on the use of national LCA-based assessment methods for buildings in selected countries” (Balouktsi & Lützkendorf 2022)), countries which are integrating and not integrating T, C & D process in the LCA application were identified

2.2.2 Survey focused on the modelling of T, C & D modules

Following the results of the national survey about LCA methodologies (see (Balouktsi & Lützkendorf 2022)), another expert survey (see Appendix) was conducted to collect the most relevant aspects on the

national application of T, C & D modules. It involved the draw up and send out of a questionnaire to the Annex 72 participant countries, focused on two possible cases: countries which include T, C & D modules and countries that neglect them. For those countries which includes T, C & D modules, the survey was focused on identifying: the basis of the scenario definition, the main assumptions, the data sources, and the data granularity. For those countries which has not included T, C & D modules in the application of LCA, the survey search for detecting the basis/reasons of the neglection.
The survey contained eight main questions and explores the different ways of integration and modelling of the LCA modules and systematize the information obtained. Ten IEA-EBC Annex 72 participant countries contributed to the survey including: Australia (AU), Brazil (BZ), Belgium (BE), Canada (CA), Switzerland (CH), Germany (DE), Spain (ES), France (FR), Hungary (HU), New Zealand (NZ), Portugal (PT) and United Kingdom (UK).

2.2.3 Results regarding transport modules

The first part of the results obtained from the questionnaire was based on identifying which countries include or NOT the modelling of the transport modules and on describing the modelling options.

Table 2.4. Answers to Q1 and Q2. Modelling options used to integrate modules A4 and C2 in the assessment

	NOT model	Model		
LCA Module		Option 1	Option 2	Option 3
A4	CH, DE	AU, BZ, CA, FR	BE, ES, HU, UK, NZ	(BE), PT
C2	UK, DE	AU, CA, FR, HU, UK	BE, BZ, ES, NZ	(BE), PT

Option 1. Generic modelling, **Strategy 2**. Simplified modelling, **Strategy 3.** Detailed modelling

Regarding Q1 (Table 2.4) countries mostly modelled A4 and C2 modules, however countries such as Switzerland expressed those transports to regional storage site in Switzerland (this applies also for construction products manufactured abroad) is covered in the construction materials datasets, and do not include the modelling of transport in A4 module. Delivery to building site is often unknown and of low importance. In exceptional cases (helicopter transports) A4 may be included. In the national method of UK module A4 is a mandatory stage to be included in order to meet the minimum requirements laid out in the RICS Professional Statement (RICS, 2017). Although module C2 is not mandatory and exceeds the minimum requirement in the document linked above but its inclusion is nonetheless strongly encouraged.

Q2 (Table 2.4), Q4 (Table 2.5) and Q5 (Table 2.6) are focused on identifying which type of Option (**Option 1.** Generic model, **Option 2**. Simplified model, **Option 3.** Detailed model) is used for modelling transport A4 and C2, and if default locations of the manufacturers of the main building materials and the sorting/recycling or end of life disposal points are assumed, in case for example there is no available information about it. The **Generic modelling** (Option 1) means that the method only can consider a possibility, or a range of possibilities based on the variability of the supplier, manufacturer or sorting/recycling or end of life disposal points regardless the location of the construction site. The **Simplified modelling** (Option 2) means that the method can include a range of variables for the location of the supplier, manufacturer or sorting/recycling or end of life disposal points and a range of variables of the construction site. The **Detailed modelling** (Option 3) means that a more exact calculation procedure is proposed.

Table 2.5 Answers to Q3 (end of 2019) Specifications on the modelling of A4 and C2 modules.

Country	AU	BE	BZ	CA	CH	ES	FR	HU	NZ	PT	UK
Which are the considered products and materials? Do you have any cut-off rules for that?	Basically, all building materials which counted embodied impacts. If not considered in the A1-A3, it is not considered in A4.	For each product and material, a transport and waste category are selected. Based on the transport and waste category, transport scenarios are calculated for both A4 and C2.	All products and materials are included.	All material used in the building were included (including materials for the use stage and A5 – loss during construction modules). Transport of the construction equipment was not included.	-	All products and materials are included.	All products are concerned	Data taken from Ecoinvent	The main materials in structures, walls, roofs, floors (for example), are included Currently, we do not consider fixings, sealants, adhesives.		Information in Table 3 of the document (RICS, 2017).
Which transport distances do you considered?	If not specified, it is, in general, assumed less than 200km away of building material supplied to the site.	Transport distances depend on the selected material category. 3 transport steps are considered (directly from factory to site, from factory to supplier and from supplier to site)	Depends on the location of the construction site	See Q2	10 to 20 km	Depends on the location of the construction site	See annex	described above	From manufacturer gate to construction site in central Auckland, Wellington or Christchurch.		Information in Table 7 (for A4) and Table 11 (for C2) of the document (RICS, 2017).
Which means of transport do you considered?	Basically 'rigid truck'.	Depending on the transport step, the materials are subdivided according to 4 means of transport * Lorry > 32 ton (EURO 5) * Lorry 16-32 ton (EURO 5) * Lorry 7.5-16 ton (EURO 5) * Lorry 3.5-7.5 ton (EURO 5)	All means potentially applicable: within the country: lorry; international transport by ship to port of entrance plus road transport within the country.	See Q2	Lorry, 20-28 tons, fleet average	Depend on the mean of transport: truck, lorry, ship or rail	truck	described above	Road, ship, rail		This information can be found in Table 7 (for A4) and Table 11 (for C2) of the document (RICS, 2017).
Which fuels and consumption hypothesis do you considered?	Mainly diesel	Diesel (EURO 5)	Taken from Ecoinvent latest version available at the time of assessment, calibrated by national annual reports	Average consumption per ton kilometer from the Ecoinvent datasets were used.	diesel, 24.57kg/100km (=29.42 litre/100km)	Taken from Ecoinvent 1.2	Like in Ecoinvent 2.2	Taken from Ecoinvent	Underlying data for fuel consumption, based on data in EcoInvent 3.1.		Carbon conversion factors are taken from official UK government publications.
Do you include the return load (return trip of transports)?	Yes	This included in the average load assumed in the Ecoinvent records	Yes, this is assumed by Ecoinvent datasets	Yes, datasets rely on average load factors that include the average share of empty return trips.	Average payload: 5.8tons, including return trip	Yes	Average load factor of Ecoinvent	Yes	No	Lorry loading factor of 85% and does not consider average lorry journeys to consider the return trips. Therefore, the environmental impact of each transport per km is divided by this amount (85% of the payload of each vehicle). This assumption allows the modelling of empty return trips (up to 200 km) by considering a simulated full load (85%) transport along an additional distance equal to 70% of the coming trip, resulting in a total distance of 1.7 times the latter. Only a parcel of 70% of the environmental impacts of the return trip is considered because an	Partially. In fact, the carbon conversion factors consider average rigid HGV with average laden. This means that the mode of transport that should be assumed is an average heavy goods vehicle (HGV) with 50 per cent load to account for the vehicles coming to site empty and leaving with a 100 per cent load.

										unloaded truck has a consumption of about 70% of a fully loaded truck.	
Which data sources or database do you considered for impacts calculation?	Australian national LCI data (called AusLCI) and Ecoinvent version 3.0 (if not available in AusLCI)	Ecoinvent 3.3	Ecoinvent latest version available at the time of assessment	For the small size lorry transport, an ecoinvent dataset was used. For the regular lorry transport, an internal model from Groupe AGÉCO which is representative of transport in North America is used.	KBOB LCA data DQRv2:2016 (retrieved from www.ecoinvent.org, https://db.ecoinvent.org/download/KBOB%20DQRv2_2016.zip?area=3e2c0806caa3c Most recent version available: UVEK LCA data DQRv2:2018	Ecoinvent 1.2	Ecoinvent 2.2	Ecoinvent 3.5	CML	ELCD v3 database	This information is given in Section 3.3.1 of the document (RICS, 2017). In short: Type III environmental declarations and datasets in accordance with EN15804 or ISO21930 or ISO 14067 or ISO 14025, 14050, 14044 or PAS 2050.
Do you include any other relevant aspects? Can you specify?		More information in (Allacker et al., 2018)	Includes only transport of material that ends up in the building, including incorporated wastage. Replacement waste is included in the operational phase.	All aspects from the Ecoinvent datasets were used.	Demolishing efforts are included in C1, same efforts and emissions per kg material.			no	Includes transport of material that ends up in the building, as well as transport of the material that becomes waste at the construction site.	**Use of ELCD datasets**	

Table 2.5 includes the resulting answers for Q3, provide a detail description of how each national method considered the range of products and materials included, the cut-off rules, the transport distances considered, means of transport considered, the fuels and consumption hypothesis considered, the integration or not of return load (return trip of transports), the data sources or database considered for impacts calculation, finally is focused on identifying other relevant aspects related.

For modelling A4 the UK propose (Option 2) a calculation method for the transport emissions based on [A4] = Material or system mass (a) × transport distance (b) × carbon conversion factor (c).", proposed in the document (RICS, 2017). For reuse/recycling elsewhere a 50km local transport is assumed whereas for landfill/incineration the average between the two closest landfill sites is assumed, more detailed information about it is provided in (RICS, 2017). Average distances and means of transport are used, if project-specific information is unavailable; it is based on groups of materials (e.g. locally manufactured vs. globally manufactured). Table 11 of the document (RICS, 2017) include more information about it. For Q5, C2 the scenarios are not material-specific but EoL-specific.

Table 2.6. Answers to Q4. Consideration of default location of the manufacturers of the main building materials

	Country
Yes	BE, CA, ES, FR, HU, NZ, UK
No	AU, BZ, CH

For modelling A4 New Zealand propose a simplified calculation (Option 2) method based on a spreadsheet that include example transport distances (Branz, n.d.; Dowdell et al., 2016). The model considers default transport distances depending on the location of the construction site (Auckland, Wellington, Christchurch) and the manufacturer. The model also defines two urban distances, two regional distances, four inter-regional distances and three international distances. More information about the model is provided in the SR351 study (Dowdell et al., 2016). For modelling C2 New Zealand assume a 20 km distance to landfill/clean fill (Option 2). Distances to recycling facilities vary depending on the material, for example, steel and aluminum scrap are exported overseas by ship. Australia uses a simplified average (Option 1) distance delivered from distributor and site, and transportation distance is quantified with return.

In France (Option 1) the user can choose between 4 transport distances; the following default values are proposed: Distance from manufacture to building site, 100 km, Distance from Building site to landfill, 20 km, Distance from Building site to incineration, 20 km, Distance from Building site to recycling, 100 km. Transport by truck is considered. A similar criterion is used by Hungary (Option 1), where materials are classified into 4 transportation categories depending on the number and location of manufacturing plants (50 km lorry for materials produced locally; 150 km lorry+30 km van for national production with 1-2 factories; 800 km freight rail+30 km van for imported products transported by rail; 800 km lorry+ 30 km van for imported materials transported on road). Nationally produced materials are checked where the factories are in the country and based on the number of factories, classify materials into categories. These categories are used for each material independent of the actual location of the building. For C2 only one transport category is considered: 20 km lorry.

Table 2.7. Answers to Q5. Consideration of default location of the sorting/recycling or end of life disposal points.

	Country
Yes	BE CA, ES, FR, UK, NZ
No	AU, BZ, CH, HU

Spain and Brazil (Option 2) use for A4 an average distance and transport distances depending on the project location and for C2 distances are defined according to the location of the final disposal point and the building site. Canada uses an average (Option 1) distance according to project location (urban, suburban, rural, etc.). A distance of 25 km for concrete with a small size lorry transport truck was used and a distance of 225km was used for all the other material with a regular lorry transport truck. For A4 use default distances between the supplier and the site construction and for C2 use an average distance of 50km with regular lorry truck transportation.

Switzerland does not consider a default location of manufacturers of the main building materials, but foreign production and import transports are taken into account. It is applied a generic option for modelling C2 which use one default transport distance and one means of transport per waste management option (landfill, incineration, separation/recycling).

Belgium (Option 3) considered that the location of the manufacturers is indirectly included based on the average transport distances which are assumed for each material category. The location of the sorting/ recycling or EOL disposal plants is indirectly included based on the average transport distances which are assumed for each waste category. More details about the modelling Option of both LCA modules is provided in (Allacker et al., 2018). Portugal defined specific rules for modelling the return (empty or full) trips in A4 and C2 modules. It is used ELCD datasets, which defines a lorry loading factor of 85% and does not consider average lorry journeys to consider the return trips. Therefore, the environmental impact of each transport per km is divided by this amount (85% of the payload of each vehicle). This assumption allows the modelling of empty return trips (up to 200 km) by considering a simulated full load (85%) transport along an additional distance equal to 70% of the coming trip, resulting in a total distance of 1.7 times the latter. Only a parcel of 70% of the environmental impacts of the return trip is considered because an unloaded truck has a consumption of about 70% of a fully loaded truck. Thus, it is possible to estimate and consider the environmental impacts of the empty return trip (considering the real distances provided by the manufacturer) and allocate them to each ton of raw material delivered at the factory (or to each ton of waste stream collected in the same place or ton of construction material supplied on site).

2.2.4 Results in 2.2.2 modules A5, C1 and T, C&D process in use stage

The second part of the questionnaire was focused on identifying which countries include or NOT the modelling of the modules **A5, C1 and T, C&D process in use stage,** and on describing the modelling options.

Regarding Q1 (Table 2.8) countries mostly modelled C&D process, however countries such as Switzerland considered A5 of minor importance; cutting losses (wastes during construction) are neglected because the amounts of materials needed are determined coarsely and generously. Furthermore, there are no empirical data on material specific cutting losses/wastes. In UK national method modules A5 and B4 (use stage) are mandatory stages to be included in order to meet the minimum requirements laid out in the RICS Professional Statement (RICS, 2017). However, C1 is not mandatory and exceeds the minimum requirement in the document linked above but its inclusion is nonetheless strongly encouraged. In Hungary C1 is neglected due to the missing data for modelling this stage.

Table 2.8 (answers to Q7) shows that the mostly used strategies to model C&D process (A5, use stage, C1) modules were **Option 1** and **Option 2**. The **Generic modelling** (Option 1) means that the method only can consider a possibility or a limited range of possibilities. The **Simplified modelling** (Option 2) means that the method can include simplified formulas for the calculation of impacts of the process depending on

a variable (e.g., weight of materials, price of the building construction, etc.). The **Detailed modelling** (Option 3) means that a more exact calculation procedure is proposed.

Table 2.8. Answers to Q1 and Q7. Strategies to integrate model C&D process.

LCA Module	NOT model	Type of Option		
		Option 1	Option 2	Option 3
A5	CH, DE	AU, BZ, CA, UK, HU, ES	AU, BE, NZ, FR	(AU)
T, C&D process in use stages	-	AU, ES	AU, BE, NZ, UK.	(AU)
C1	FR, HU,DE	AU, CA UK, ES	AU, BE, NZ, FR	(AU), BZ

Option 1. Generic modelling, Option 2. Simplified modelling, Option 3. Detailed modelling

Table 2.9 shows the resulting answers for Q6 and includes the modeling options mainly use to model C&D process (A5, use stage and C1 modules). The table includes a summary of the principles and more data sources containing further information about it. Results show the diversity on the modelling of C&D process. Regarding module A5, countries such as Belgium and Hungary include the energy consumption and fuel (diesel consumption) and materials losses, Canada define a fixed percentage of impacts and do not include fuel consumption, and Switzerland neglect it integration. Australia and Belgium define different modelling options depending on the type of LCA application (generic, simplified, or detailed). The UK method (RICS, 2017) considers mandatory the integration of any energy consumption for site accommodation, plant use and the impacts associated with any waste generated through the construction process, its treatment and disposal and provide, in absence of more specific information about the emissions of the construction process the average for building construction site emissions, a general value related to the project value, and a table with the elements service life. For Germany A5 and C1 are not considered in BNB/DGNB. However, Ökobau.dat (*ÖKOBAUDAT*, n.d.) provides data for a few selected construction activities: excavators per m^3, pumping of concrete per m^3.

For modelling T, C&D process at use stages several countries include the impact of the demolition, waste transport and waste management of the removed components and the production, transportation and construction of the new components, such as Belgium (OVAM et al., 2018). The UK includes transportation to site and installation of the replacement items (RICS, 2017). On the other hand, Switzerland, Canada, Australia, France, Hungary are not including T&C processes in use stage (B4 module). Other countries such as the UK include an average rate in absence of more specific information. Canada (crusher use) based on concrete volume in the building. Other machinery is modeled with average consumptions per m^2 of floor based on Groupe AGECO experience.

Table 2.10 includes the resulting answers for Q8, provide a detail description of how each national method considered the range of construction, deconstruction and replacement works considered, the type of machinery and machinery works considered, the fuels and energy machinery consumption assumptions, the data sources or database considered for impacts calculation, finally is focused on identifying other relevant aspects related.

Table 2.9. Answers to Q6. Modeling principles mainly used to include **C&D modules.**

LCA module	Country	Modelling principle
A5	**AU**	For detailed LCA for A5, use productivity of major equipment (e.g., hour/unit of work, m^3 etc. for crane, electric ladder etc.) then quantified the energy consumption of its equipment. For simplified LCA, use an assumption taken from literature (5-10% of whole LCA).
	BE	This module includes the following processes: • Impact of material losses (global add-on of 5% on all material quantities) • Impact of construction activities (e.g. excavation and electricity consumed for cellulose blowing)
	BZ	Literature data per m2 of construction of office buildings. Average national information per m2 of residential buildings. Other building typologies would use the best fit among the mentioned approaches.
	CA	For A5, we used a fixed percentage of the impacts from A1 to A4 (10%). No calculation regarding fuel consumption was included for this module.
	CH	Not taken into account.
	DE	Not taken into account. National data for excavations per m^3 and pumping concrete per m^3 is available.
	ES	Modelled following Kellenberger et al. (Kellenberger et al., 2007).
	FR	The user chooses a surplus % of materials, 5% is proposed as default value. This corresponds to broken elements on the construction site, surplus of ready mixed concrete at the end of the day, parts of panels that remain unused after cutting the right size etc.
	HU	Material losses are included (2-5% depending on material) and in the previous version of the tool 8 MJ/m^3 electricity + 50 MJ/m3 diesel was included for the construction process of the building.
	NZ	The Construction site waste (module A5) v1, and Building end-of-life (module C1) v1 datasheets can be downloaded from (Branz, n.d.). For more information about how these have been developed in the document (Dowdell & Berg, 2016).
	UK	The average for building construction site emissions, in the absence of more specific information is 1400kgCO2e/£100k of project value. The carbon emissions associated with any waste generated during the construction process should be accounted for in accordance with the principles outlined for the product and transport stage [A1–A3] and [A4]. More specifications about it is detailed in (RICS, 2017).
T, C&D process in use stages	**BE**	It covers the impact of the demolition, waste transport and waste management of the removed components and the production, transportation, and construction of the new components. Information related to the life span of work sections can be found on the TOTEM website (OVAM et al., 2018).
	BZ	**No information related to the modelling of T, C&D process is provided**
	CA	**No information related to the modelling of T, C&D process is provided**
	CH	No energy consumption for replacement but for demolishing work of replaced building elements and materials.
	ES	Modelled following Kellenberger et al. (Kellenberger et al., 2007) and reference service life of products.

	FR	**No information related to the modelling of T, C&D process is provided**
	HU	**No information related to the modelling of T, C&D process is provided**
	NZ	The Construction site waste (module A5) v1, and Building end-of-life (module C1) v1 datasheets can be downloaded from (Branz, n.d.). For more information about how these have been developed in the document (Dowdell & Berg, 2016).
	PT	**No information related to the modelling of T, C&D process is provided**
	UK	Specifications about it is detailed in (RICS, 2017).
C1	**AU**	Used equipment productivity for detailed LCA or assumption for simple LCA.
	BE	Module C1 includes the impact of the deconstruction and demolition. The composition of the materials and the method of connecting with other materials/work sections determines the type of demolition process
	BZ	Used generic values for machinery, under a specific time, applicable to the case, as instructed by local demolition companies surveyed each time. Typically, a crusher for the concrete demolition and scissors for steel frame.
	CA	Used a generic value for machinery under a specific time. One machinery was for the concrete demolition (crusher) and another regular machinery for all the other demolition works.
	CH	-
	ES	Modelled following Kellenberger et al. (Kellenberger et al., 2007).
	FR	Not included.
	HU	Neglected due to missing data.
	NZ	The Construction site waste (module A5) v1, and Building end-of-life (module C1) v1 datasheets can be downloaded from (Branz, n.d.). For more information about how these have been developed in the document (Dowdell & Berg, 2016).
	UK	An average rate of 3.4 kgCO2e/m2 GIA (rate from monitored demolition case studies in central London) based on aggregated data should be used in the absence of more specific information. Section 3.5.4.1 page 26 for C1, in the document (RICS, 2017).

Table 2.10. Answers to Q8. Specifications on the modelling C&D process.

Country	AU	BZ	BE	CA	CH	ES	FR	HU	NZ	UK
Which construction, deconstruction and replacement works do you considered?		**Inclusions:** We include construction of all elements set out in the module A5 datasheet. We use data from literature and average national data for construction equipment/machinery. Shuttering/formwork. We include all construction activities as long as sufficiently informed (such as excavation) **Exclusions:** We do not include smaller items (fixings, sealants, adhesives) and corresponding wastage. unless clearly identified in the bill of materials. Other current exclusions include: Packaging of construction materials. We do not include construction office activities.	Various deconstruction processes have been defined for different materials based on Ecoinvent 3.3. The impact of replacement is calculated as the sum of the impact of the demolition, waste transport and waste management of the removed components and the production, transportation and construction of the new components	A5: no construction work was modeled C1: Concrete crushing, material handling	Replacement works are not considered, only replacement materials	Based on Kellenberger et al. (Kellenberger et al., 2007)	Waste production	For construction only material losses are included, plus a general value for the construction process taken from an Ecoinvent report. For replacement only the materials, their transport and disposal are considered, not the replacement process itself.	We include construction of the elements set out in the module A5 datasheet. We do not include smaller items such as fixings, sealants, adhesives, therefore wastage of these materials is also not included currently. Other current exclusions include: Packaging of construction materials. Energy used for site machinery/power tools/site office. Shuttering/formwork. Excavation activities.	**A5**: As mentioned this is a weak point of the RICS document where an average tablelinked to project value is used. Even if detailed and project-specific assessments are encouraged I suspect that in practice the average figure is most often used. Use stage: must take into account any carbon emissions associated with the anticipated replacement of building components, including any emissions from the replacement process. All emissions arising from the production, transportation to site and installation of the replacement items must be included. This extends to cover any losses during these processes, as well as the carbon associated with component removal and EoL treatment. **C1**: again, an area of weakness of the document which suggests an average figure. The risk is that in practice most people would just use the suggested figure although the standard does encourage to collect project-specific data.
Which type of machinery and machinery works do you considered?	Excavator, backhoe etc. for foundation (earth) work, Crane hoist, conveyer, forklift for construction material handling	Average fuel/electricity/water data per m2 of construction from literature or national reports.	The impact of construction activities is limited to a few processes such as excavation works, and the electricity consumed for cellulose blowing	Machinery for material handling (lifts, air compressors, cranes…) and concrete crusher during deconstruction.	General diesel consumption of building machines used in demolishing	Based on Kellenberger et al. (Kellenberger et al., 2007)	None	Only a general value is considered	See above. For deconstruction, we include energy required for this, which is allocated to structural materials only. Data are based on an Athena Institute publication. For further information (Dowdell & Berg, 2016), (Appendix D4)	**A5**: See previous answer and section 3.5.2.2 of the document linked in Q1. 3.5.3.4 of the document linked in Q1 and below. **C1**: N/A
Which fuels and energy machinery consumption hypothesis do you considered?	Mainly fueled with diesel for machinery.	Diesel for machinery and equipment, unless clearly informed otherwise (electricity). Fuel datasets from Ecoinvent.	The fuels and consumption values are based on Ecoinvent 3.3	Average consumption per hour from the Ecoinvent datasets were used.	see above	Based on Kellenberger et al. (Kellenberger et al., 2007)	None	Only a general value is considered	Machinery is powered by diesel. Use of secondary data from EcoInvent 3.1, in particular the dataset called “Diesel, burned in building machine”.	**A5**: N/A **C1:** N/A
Which data sources or database do you considered for impacts calculation?	Mainly AusLCI (national LCI database) or ecoinvent (ver 3.0 if not available in AusLCI)	Ecoinvent (latest version publicly available)	Ecoinvent 3.3	Average machine operation from the ecoinvent database were used.	see above	Ecoinvent 1.2	Ecoinvent 2.2	Ecoinvent 3.5	EcoInvent 3.1	**A5**: site waste rates for different materials should be determined based on the standard wastage rates provided by the WRAP Net Waste Tool (UK specific). **Use stage**: scenarios should be based on data from facilities management and maintenance Option reports, façade access and maintenance Option, life cycle cost reports, O&M manuals, guidance (e.g. CIBSE Guide M and BCIS Life expectancy of building components), international standards (e.g. ISO 15868-5: 2008 Buildings and constructed assets – service life planning, and manufacturers’ documentation). Also lifespans value are given in Table 9 of the document. **C1**: N/A/
Do you include any other relevant aspects? Can you specify?	Australian team has worked for some missing impacts from A3, A5 and B1. Please see the attached.		More information in (Allacker et al., 2018)	-	-	-	Treatment of building site waste	No	Please see SR351 study report and Appendix D of the SR350 study report.	-

3. Suggested Solutions and Typologies

3.1 Analysis of Results and Layout of Possible Solutions for Modelling Transports

Based on the results obtained in the previously described survey, this section includes the compilation of the information about the modelling of modules A4 and C2 (EN 15978) (EN, 2011).

a) Level of consideration of the modules A4 and C2 in the LCA application
The results confirm that most of the contributing countries include the modelling of A4 and C2 modules. The causes of neglection of A4, in the Swiss method are because delivery to building site is often unknown and of low importance, however exceptional cases that include helicopter transports, can consider the A4 impacts. For the German method A2 and C2 are not taken into account in BNB/DGNB (System, 2019). However, Ökobau.dat (*ÖKOBAUDAT*, n.d.) provides average environmental data in tonnes*km for different types of transport to assist in calculations. For example, for small truck: "The dataset refers to the transport of 1000 kg cargo on a distance of 1 km by truck (EURO 5) with 12-14 t permissible total weight and 9.3 t payload in forwarding traffic with a utilisation ratio of 85%. The extraction and processing of the fuel is included. The production of the vehicle is not included in the balancing".

b) General assumptions
Regarding the obtained results, the number of modelling options varies between countries, but is similar for both modules in each national method. Most of the contributing countries use Option 1[3] (AU, CA, FR, HU, UK) and Option 2 (ES, NZ, UK, BE), (the same Option for both), except the UK that applies Option 1 (for A4) and Option 2 (for C2). Despite Belgium applies the most detailed model, the use of simplifications and average distances is also detected.

The results show that the national methods that integrate **Option 1**, have the following common statements: all countries included all the materials and products, the Option is the same for all the materials and products, distances are generic and not so detailed (due to the high level of uncertainty), trucks and lorries are mostly considered as mean of transports, and return trips are always considered.

Regarding **Option 2**, countries that apply it have the following common statements: all included all the materials and products, different manufacturing points and intermediate points are considered, different means of transports are considered (except the air transports) and retry of transport is partially considered.

[3] The **Generic modelling** (Option 1) means that the method only can consider a possibility, or a range of possibilities based on the variability of the supplier, manufacturer or sorting/recycling or end of life disposal points regardless the location of the construction site. The **Simplified modelling** (Option 2) means that the method can include a range of variables for the location of the supplier, manufacturer or sorting/recycling or end of life disposal points and a range of variables of the construction site. The **Detailed modelling** (Option 3) means that a more exact calculation procedure is proposed.

c) Particular statements, detected hotspots and proposal possible solutions

c.1) Consideration of transport distances

Regarding the consideration of transport distances, it is noticed that there is a high influence of the local characteristics of each country, which can be related to the location of natural resources (raw materials), location of manufacturers, location of recycling/final disposal points, type of transports, distribution networks, and also the existence of previous studies, references and other data sources, the level of maturity in the LCA application in the construction sector, among others. For example, in the definition of default distances it can be considered that the average transport distances are proportional to the most frequent distances between the construction site and the manufacturers/final disposal points and the size of the country (Switzerland use 20km approx. and Australia use 200km). Thus, the influence of the related impacts can be considered as relevant or neglected such as in Switzerland.

Furthermore, other aspects that can be relevant in modelling of transport distances are the level of complexity in the distribution networks and the consideration of manufacturers/final disposal points. For example, in countries such as New Zealand with a limited number of cities and distribution networks, the developed model can easily identify manufacturers/final disposal points to calculate transport distances. On the other hand, countries such as Spain, with a great number of manufacturers and complex distribution networks, more difficulties are detected to define a model that allows to obtain reliable results for transport distances. Therefore, it is recommended for defining simplified modelling options **(in Option 1 and Option 2)** to develop tables with average/most frequent locations for both manufacturing points (including distribution points, if exist) and final disposal points (and recycling points, if exist) of the most frequent materials. Thus, depending on the level of detail and level of accuracy of the information provided can be **Option 1** or **Option 2**. It is also recommended to harmonize the methods to identify and simplify the distribution networks and manufacturing/final disposal points, in order obtain impacts values as far as possible to the real situation, reducing uncertainties and possible undesirable mistakes.

For detailed strategies (**Option 3**) which mostly uses real or close to real transport distances, it is recommended to harmonize the methods to measure and calculate the impacts of real distances. As well as the consideration of intermediary suppliers and the distribution networks and the consideration of manufacturers/final disposal points.

c.2) Data sources

Results show that regardless the modelling Option the most used data source (for transport impacts and fuel consumption) is the Ecoinvent database. Depending on the country the version of the database can be different. For example, New Zealand use Ecoinvent 3.1 and Belgium Ecoinvent 3.3 (Ecoinvent, 2016). However, two exception has been detected, UK uses their own datasource and Austrailia use their own national database AusLCI (Australian Life Cycle Inventory, n.d.), and Ecoinvent version 3.0 in case there is not available data. When modelling transports, the use of different data sources and databases can conduct to different results, it is recommended to verify the data consistency of the transport related data sources to control possible differences and unexpected variations.

c.3) Means of transport

Results show that the trucks are considered the most used mean of transport, and other means of transports such as the railway and air transports were scarcely considered. This can be due to the extensive use of this mean of transport in the construction sector, or because it can be a simplification of the supply chain of materials and products. It is also noticed that each country uses the means of transports according to their own requirements and characteristics. Countries with a great dispersion in the location of cities such as New Zealand can obtain more significant transport impacts than other countries with a more compact city network, such as Switzerland or Belgium. It is detected that depending on the modelling Option the

level of accuracy in the definition of the mean of transport increases. Countries such as Belgium, detailly organised trucks transports based on the tonnage. A possible solution to deal with the uncertainties related to the means of transports, can be to make tables that relate products/materials/distances considering the most frequent means of transport, adapted to the design phases and type of LCA (simplified or complete) and depending on the level of detail and level of accuracy of the information.

c.4) Consideration of impacts of transports in design stages

The possibility of considering the transport impacts in the selection of materials/products can be relevant in several context and for several building materials (such as timber). How can transport impacts be considered in design stages? Can be the selection of materials and products conditioned by them? The local context in modelling A4 and C2 modules can completely change the LCA results. In this vein, the same building can obtain very different impact values depending on the country where it is located, and the materials and products that were used. It is recommended to develop robust and reliable models that can help designer to guide the decision-making specially for those countries where the impacts of transports are relevant.

c.5) Modelling options and design stages

Probably the main differences in the modelling of A4 and C2 modules can be related (as previously mentioned) to the pre-existence of studies on the field, references and other data sources, the level of maturity in the LCA application in the construction sector, among others. It is important to highlight that the modelling Option should be related to the level of definition and data granularity about the building and depending on the type of LCA application (simplified or complete). The scope of the strategies is different when working in early design stage (LCA is a decision-making tool) than when the building is detailly design. Thus, it is recommended to correlate the modelling option with the design stage, level of definition and granularity of the information about the building. Moreover, the integration of experts on the area can avoid making simplifications that conduct to undesirable mistakes. It is also recommended that each country define the scope of the design stage and type of LCA application (from early design stage up to construction/use stage) to establish most properly modelling Option based on the existing certainties and the needed data accuracy.

Other alternative to deal with the modelling options of transports and the design phases, is the one proposed to be implemented in Sweden (out of the scope of the survey participant countries) for the “Climate declarations for buildings” (Sweden National Board of Housing Building and Planning, 2020). The document proposes to focus the effort on detailed modelling options for transports of the **three** more relevant materials and components (greatest proportion of weight or volume). For the rest of materials and components both generic and actual/specific data can be used when modelling A4 module (see section 4.3.11-12).

3.2 Analysis of Results and Layout of Possible Solutions for Modelling C&D Process

Based on the results obtained in previous survey, this section is focused on compile the information obtained on the modelling C&D process (EN 15978)) (EN, 2011).

a) Level of consideration of C&D process in the LCA application

The results confirm that most of the contributing countries consider modules A5 and C1, with few exceptions. For example, Switzerland considered A5 of minor importance, cutting losses (wastes generated during construction) are neglected because the amounts of materials needed are previously determined coarsely and generously during the design stage. For Germany A5 and C1 are not considered in BNB/DGNB. However, Ökobau.dat (*ÖKOBAUDAT*, n.d.) provides data for a few selected construction activities: excavators per m^3 and pumping of concrete per m^3. Furthermore, there are no empirical data on material specific cutting losses/wastes. In other countries, such as the UK this is a mandatory stage to be included in order to meet the minimum requirements laid out in the RICS Professional Statement (RICS, 2017). France and Hungary neglect C1, mostly due to missing data. In other countries, such as the UK, despite being not a mandatory, its inclusion is nonetheless strongly encouraged.

b) General assumptions

Results shows that the number of modelling options also varies between countries and between LCA modules. Thus, the most common situation is to alternate strategies (Option 1, Option 2, Option 3[4]) according to the modules considered. For example, countries such as Australia, use these three modelling options in these three modules. However, not much detailed about the strategies and further information about them is provided. Other countries apply different strategies according to the modelled modules. For example, Belgium uses a generic option for modelling construction process and more detailed modelling for modules B4 (use stage) and C1 (Option 2). The UK uses a generalized modelling for A5 and C1, and a simplified modelling for T, C&D process in module B4. Spain uses generic and simplified modelling strategies.

<u>b.1) Construction process (Module A5)</u>

The assumptions considered for the quantification of impacts in A5 module are diverse. The main Option in most countries is to consider a percentage of construction wastes applied to the material supplied to the work. France, for example, uses a percentage of surplus materials chosen by the user, and in other case a 5% is proposed as default value. This corresponds to broken elements on the construction site, surplus of ready mixed concrete at the end of the day, parts of panels that remain unused after cutting the right size. Belgium includes the processes related to impacts of material losses (global add-on of 5% on all material quantities) and the impacts of construction activities (e.g., excavation and electricity consumed for cellulose blowing). Hungary uses similar Option; material losses are included (2-5% depending on material) and in the previous version of the tool 8 MJ/m3 electricity + 50 MJ/m3 diesel is included for the construction process of the building.

Canada uses a fixed percentage of the impacts from A1 to A4 (10%) and no calculation regarding fuel consumption is included in this module. Some countries such as Australia, through detailed LCA, uses productivity of major equipment (e.g., hour/unit of work, m^3 etc. for crane, electric ladder etc) for quantifying the energy consumption of its equipment, and through simplified LCA, uses an assumption to estimate it (5-10% of whole LCA).

New Zeeland includes the construction process of the elements set out in the module A5 datasheet (Branz, n.d.). However, smaller items such as fixings, sealants, adhesives, and material waste of these process are not included. Other exclusions are the packaging of construction materials, the energy used for site machinery/power tools/site office, the shuttering and formworks, and the excavation activities. The UK uses

[4] The **Generic modelling** (Option 1) means that the method only can consider a possibility or a limited range of possibilities. The **Simplified modelling** (Option 2) means that the method can include simplified formulas for the calculation of impacts of the process depending on a variable (e.g., weight of materials, price of the building construction, etc.). The **Detailed modelling** (Option 3) means that a more exact calculation procedure is proposed.

in case of inexistence of specific data, a generic assumption where a simplified average figure of 1400kgCO2e/£100k of project value (RICS, 2017).

b.2) T, C&D process in Use Stage

The modelling of T, C&D process in Use Stage (Module B2-B5) is scarcely detected. Countries such as Belgium, Spain or UK are examples of its integration. For example, Belgium includes a complete list of replacement of worn building components elements that can found in (OVAM et al., 2018). It covers the impact of the demolition, waste transport and waste management of the removed components and the production, transportation, and construction of the new components. However, no energy consumption for replacement is considered, but for demolishing work of replaced building elements and materials.

b.3) Deconstruction (Module C1)

The assumptions taken into account for modelling C1 module are diverse. Australia uses equipment productivity for detailed LCA and assumptions for simplified LCA. Belgium includes the impact of the deconstruction and demolition. The composition of the materials and the method of connecting with other materials/work sections define the type of demolition process. Canada uses a generic value for machinery under a specific time. One machinery is considered for the concrete demolition (crusher) and another regular machinery for all the other demolition works. Crusher use is based on concrete volume in the building. Other machinery is modelled with average consumptions per m^2 of floor based on experience of construction companies (e.g. Groupe AGECO). Switzerland considers general diesel consumption of building machines used in demolishing. New Zealand defines building end-of-life datasheets (Branz, n.d.), energy required for deconstruction is included, allocated to structural materials only. Data are based on an Athena Institute publications (*Athena Sustainable Materials Institute*, n.d.) , contained in the SR350 study report (Appendix D4) (Berg et al., 2016). The UK considers a generic assumption, based on an average rate of 3.4 kgCO2e/m2 GIA (monitored from demolition case studies in London is suggested).

c) Specific statements, detected hotspots and proposal for possible solutions

c.1) Construction, deconstruction works

The results show that the consideration of construction, deconstruction and replacement works are different among the contributing countries. Australia for example, considers all construction, replacement and deconstruction works. Belgium includes various deconstruction processes defined for different materials and based on Ecoinvent (Ecoinvent, 2016). The impacts of replacement are calculated as the sum of the impact of the demolition, waste transport and waste management of the removed components and the production, transportation and construction of the new components. Canada does not model construction work; however, in demolition works (C1 module) construction concrete crushing and material handling are considered. Switzerland do not consider replacement works, only include the replaced materials. France considers waste production, therefore, treatment of building site waste, and C1 is not considered. Hungary for construction process only consider material losses, plus a general value for the construction processes taken from an Ecoinvent reports (ecoinvent, 2020). For replacement only the materials, their transport and disposal are considered, the replacement works (installation of materials and products) are not included. New Zealand for construction of the elements propose a datasheet (Branz, n.d.), which exclude some small items and works (such as excavation activities). Although the UK encourage detailed and project-specific assessments for A5 and C1 module, it propose an average figure linked to project value in (RICS, 2017), which promote a simplification of the calculation of the impacts regardless, for example the materials and products, type of building construction, among others. It can be considered a weak point to be applied in complete LCA and detailed design stage. For use stage all emissions arising from the production, transportation to site and installation items must be included. This extends to cover any losses during these processes, as well as the carbon associated with component removal and EoL treatment. It is

recommended to harmonize the criteria to define the considerations for construction, replacements and deconstruction works. The harmonization can include a common definition of the works and process and establishing different levels of detail and accuracy in the modelling of the process. These can be related to the definition of default values, which is also proposed to be implemented in Sweden (out of the scope of the survey participant countries) for the “Climate declarations for buildings” (Sweden National Board of Housing Building and Planning, 2020). There, default values for different types of buildings are under development, real values might be used as well (Sweden National Board of Housing Building and Planning, 2020).

c.2) Type of machinery and machinery works

Results shows that the consideration of type of machinery and machinery works are heterogeneous. Australia mainly considers excavator, backhoe for foundation (earth) works and crane hoist, conveyer, forklift for construction material handling. Belgium method included other impact of construction activities, limited to a few processes such as excavation works, and the electricity consumed for cellulose blowing. Canada includes machinery for material handling (lifts, air compressors, cranes, etc.) and concrete crusher during deconstruction (Allacker et al., 2018). Switzerland use in demolishing general diesel consumption of building machines. France do not consider this aspect and Hungary considered only a general value. New Zealand, for deconstruction include energy consumption to demolish structural materials only, based on (Berg et al., 2016). As in the previous point c.1) it is recommended to harmonize the criteria to define the type of machinery and machinery works. The harmonization can include a common definition of the works (e.g., excavation) and sources (e.g., electricity) and establishing different levels of detail and accuracy in the modelling of the process.

c.3) Data sources and database considered for impacts calculation

The results show that data sources about fuel consumption, among others, are mostly extracted from Ecoinvent databases. Australia mainly considers fuelled with diesel for machinery, and mainly considers AusLCI (AusAgLCIinitiative, 2011) and Ecoinvent 3.0 (Babaizadeh et al., 2015) (if not available in AusLCI). Belgium includes the fuels and consumption values based on Ecoinvent 3.3 (Ecoinvent, 2016). Canada uses an average consumption per hour from the Ecoinvent datasets. Switzerland general diesel consumption of building machines used in demolishing also based on Ecoinvent. France do not include any specific hypothesis for fuel consumption and use Ecoinvent 2.2 (Dupuis et al., 2017) as a data source. Hungary only consider a general value for fuel consumption and use Ecoinvent 3.5. New Zealand use machinery powered by diesel use from secondary data from Ecoinvent 3.1. Canada average machine operation from the Ecoinvent.

The survey also collected information about other data sources used by national methods. The results show difference in the level of maturity and definition of the data sources and scenarios definition. Countries such as the UK declare the use of various data sources (BCIS, n.d.; British Standards, 2008; CIBSE, 2008; RICS, 2017) for defining for example wastage rates, lifespan, among others. As previously detailed above (for modelling transports), the use of different data sources and databases can conduct to different results, it is recommended to verify the data consistency of the fuels consumption and other related data sources to control possible differences and unexpected variations.

c.4) Modelling options and design stages

Results obtained demonstrate the heterogeneity in the modelling of C&D process, specially related to the integration of wastage, the data sources, the consideration of transports, fuel consumptions, among others. The key aspects of the problem are not only related to the modeling itself but also about the accuracy and

level of detail of the data and how all the variables and aspects involved in these complex processes are included.
A possible solution to deal with the different modelling options can be to relate them with the level of detail of the building information or design phase. Hence, the modelling options can be applied depending on the design phase, and considering the joint model proposed within IEA EBC Annex 72 (ST2) “Common definition of design steps & project phases”, generic and simplified options should be used in the early design phases and the detailed modelling options in detail design phases. Thus, the accuracy and reliability of results will be aligned with the level of detail of the building information.

3.3 Final Recommendations and Conclusions

The present study illustrated and compared the different options to model T, C & D process in the LCA of buildings and products (EPD). The study was based on the description of the current references and main studies on this field, as well as a collection of modelling options conducted among the Annex 72 participant countries (survey). The results of this survey show the heterogeneity in the modelling of T, C & D process and the strong incidence of local data sources, national methods, and geographical and regional characteristics. There, it has been detected that the main causes of neglection of transport are related to the use of local or regional materials (such as Switzerland) and the C&D process causes of neglection were related to the missing data (inexistence of data) such as France or Hungary. The errors regarding their neglection depend on the context characteristics and the type of construction technology. This report provides evidence of several examples related.

The use of default values for C&D process has been detected in countries such as UK, Finland, Spain or Sweden (with some specific characteristics), other modelling options such as the generic EPD (e.g. Ökobaudat (Federal Ministry of the Interior Building and Home Affairs (BMI), n.d.)) can be useful to adapt the specific countries characteristics to modeling C & D. While, for modelling transport the use of default values and simplified scenarios were related to reducing efforts on modelling the supply and distribution chain, which has been detected in countries such as New Zealand or Spain.

The review of the information about modelling of T, C & D process contained in the construction products EPD provide evidence of the heterogeneity in the level of detail of the information (see Table 1.1 and 2.1). Despite that current EN 1580:2012 + A2:2019 (Fernández-García et al., 2016) standards include (in Section 7.3) a (dataset) description of the scenario assumptions which can be useful to harmonize and to increase guaranties when comparing different products, the information related to T, C & D of construction products was not presented on a systematic/heterogeneous way. It means that not all the EPDs include the modelling of T, C & D process (e.g., cradle-to-gate EPD type), and also because the provided information is not enough to adapt the modelling of the process to the specific characteristics of the buildings and construction products. Thus, in case that the information included in the EPD is not enough to complete the required information the use of specific EPDs of transport and C&D process (e.g. Ökobaudat (Federal Ministry of the Interior Building and Home Affairs (BMI), n.d.)) is also possible solution.

Hence, we conclude that (at least at the moment) it cannot be possible to define one harmonized option to model T, C & D process. It would be possible to define a range of harmonize options and provide some recommendations to define them, thus, two possible paths arise. The FIRST one relates the definition of harmonized modelling options with the design phases; therefore, the generic and simplified modelling

options can be applied in early design phases, and detailed modelling stages can be used at detailed design phases, therefore, three correlations can be implemented by following these criteria:

a. Harmonized Generic Modelling (Option 1) for being applied during the early design phases of the project (Preliminary Concept), where the GFA and the volume of the building are known. A generic Option could be to quantify the impacts per square meter and LCA modules, depending on the type of building and main materials. Another Option could be obtaining impacts in each module by applying a percentage to the whole LCA or to another LCA module (such as A1-A3).

b. Harmonized Simplified Modelling (Option 2) for being applied during the early design phases of the building project, when the building systems and the main building elements and components are known (for example, the type of foundation, structure, envelope, etc.). This simplified modelling option could be classified according to the type of module. For example, in the case of module A5, the construction wastes generated could be obtained from a percentage of materials.

c. Harmonized Detailed Modelling (Option 3) for being used during the detailed design stage of the project, when the building systems and materials are defined and detailly measured. This detailed option could be classified according to the LCA module. For example, in the case of module A5, the construction wastes generated could be obtained in a detailed way using detailed construction waste quantification models, as close as possible to real situation and similar for example to those applied in the construction products EPD.

The SECOND path can relate the modelling of T, C & D process with the element/component's representativeness in the building, and combine generic, simplified and detail modelling options regarding their relevance in the building. Thus, detailed modelling options can be used for the main building materials/elements/components and generic and simplified for those that are lees representative. There, the accuracy of impact results of transport/ construction/deconstruction can be proportional to the number of materials involves.

The following recommendations for action are proposed grouped by actors (stakeholder) involved.

Policy, regulation and law makers, developers / providers of sustainability assessment systems, national standardization bodies:

– include transport and construction processes (A4-5) in the minimum assessment scope and provide default values to compensate for possible lack of data and assist the method users during early design stages. These are activities to be controlled and verified today when new buildings are constructed, together with A1-3.
– determine, publish, and periodically update LCA data for transport and construction processes.
– determine, publish, and periodically update reference values for mean transport distances.
– determine, publish, and periodically update LCA data for construction machinery, essential construction processes, the operation of the construction site equipment and typical construction site activities (e.g. pumping water, heating buildings).

Construction product manufacturers:

– in EPDs specify several variants for modules A4, A5, C1 and C2 or provide calculation rules for A4 and C2 (depending on transport distances and means of transport).

Researchers:

– develop default values for modules A4-5 and C1-2 expressed per m2 of building per kg of product (other units can also be used depending on the product).

What is important to consider when modelling transport related modules A4/C2, as well as construction process related modules A5/C1?

- the scope of transport and construction activities covered by the method shall be clearly declared.
- In order to prevent misinterpretations when comparing variants with a high level of prefabrication with variants with assembling on the construction site, the initial embodied impacts represented by the system boundary “cradle to handover” (A1-5) *B4, C3-4* shall be fully covered as part of the minimum requirements.
- For early design stages generic or simplified modelling shall be allowed (see Table 3, Option 1 and 2) and supported by providing de-fault values and/or fixed assumptions to the users of the method. For late design stages detailed modelling shall be mandated for A4 at the minimum. There, a clear description on how to consider empty returns shall be included.
- The use of different data sources and databases can lead to different results; therefore, the method shall recommend specific allowable data sources or provide such values.
- If the inclusion of activities C1/C2 is mandated by a method for completeness, default values shall be provided per m^2 (built area) or m^3 or tons. For far-future activities such as C1/C2 is unreasonable to mandate putting time and resources into calculating them even at late design stages. They are too uncertain. The module C1 could be estimated using impact factors or resources consumtion by m^2 (built area), m^3 (voluem of demolished materials) or tons. The module C2 could be estimated using impact factors or resources consumption per ton, ideally there should still be parameters for t/m^3.
- To increase transparency and provide a systematic approach for modelling complex processes A5-C1 shall be use guidelines/rules for the data collection and data set (e.g., list of activities and energy consumption per activity or building element).

References

Allacker, K., Debacker, W., Delem, L., De Nocker, L., De Troyer, F., Janssen, A., Peeters, K., Servaes, R., Spirinckx, C., & Van Dessel, J. (2018). *Environmental Profile of Building elements*.

Asdrubali, F., Baldassarri, C., & Fthenakis, V. (2013). Life cycle analysis in the construction sector: Guiding the optimization of conventional Italian buildings. *Energy and Buildings*, *64*, 73–89. https://doi.org/10.1016/j.enbuild.2013.04.018

Athena Sustainable Materials Institute. (n.d.). http://www.athenasmi.org/

AusAgLCIinitiative. (2011). *AusLCI*. http://auslci.com.au/

Australian Life Cycle Inventory. (n.d.). *AusLCI*. http://www.auslci.com.au/

Babaizadeh, H., Haghighi, N., Asadi, S., Broun, R., & Riley, D. (2015). Life cycle assessment of exterior window shadings in residential buildings in different climate zones. *Building and Environment*, *90*, 168–177. https://doi.org/10.1016/j.buildenv.2015.03.038

Balasbaneh, A. T., Bin Marsono, A. K., & Gohari, A. (2019). Sustainable materials selection based on flood damage assessment for a building using LCA and LCC. *Journal of Cleaner Production*, *222*, 844–855. https://doi.org/10.1016/J.JCLEPRO.2019.03.005

Balouktsi, M., & Lützkendorf, T. (2016). Energy Efficiency of Buildings: The Aspect of Embodied Energy. In *Energy Technology*. https://doi.org/10.1002/ente.201500265

BCIS. (n.d.). *BCIS Life expectancy of building components*.

Beccali, M., Cellura, M., Fontana, M., Longo, S., & Mistretta, M. (2013). Energy retrofit of a single-family house: Life cycle net energy saving and environmental benefits. *Renewable and Sustainable Energy Reviews*, *27*, 283–293. https://doi.org/10.1016/J.RSER.2013.05.040

Berg, B., Dowdell, D., & Curtis, M. (2016). *New Zealand whole-building whole-of-life framework: Development of reference office buildings for use in early design. BRANZ Study Report SR350*.

Branz. (n.d.). *Building LCA*. www.branz.co.nz/builidnglca

British Standards. (2008). ISO 15686-8:2008 Buildings and constructed assets —Service-life planning — Part 8: Reference service life and service-life estimation. In *British Standards*.

Bueno, C., & Fabricio, M. M. (2018). Comparative analysis between a complete LCA study and results from a BIM-LCA plug-in. *Automation in Construction*, *90*, 188–200. https://doi.org/10.1016/J.AUTCON.2018.02.028

CIBSE. (2008). CIBSE Guide M - Maintenance engineering and management. In *Zhurnal Eksperimental'noi i Teoreticheskoi Fiziki*.

Dowdell, D., & Berg, B. (2016). *New Zealand whole-building whole-of-life framework: An overview.*

BRANZ Study Report SR349.

Dowdell, D., Berg, B., Marstson, N., Shaw, P., Burgess, J., Roberti, J., & White, B. (2016). *New Zealand whole-building whole-of-life frmework: Development of datasheet to support building life cycle assessment. BRANZ Study Report SR351*.

Dupuis, M., April, A., Lesage, P., & Forgues, D. (2017). Method to Enable LCA Analysis through Each Level of Development of a BIM Model. *Procedia Engineering*, *196*, 857–863. https://doi.org/10.1016/j.proeng.2017.08.017

ecoinvent. (2020). *ecoinvent*. https://www.ecoinvent.org/

Ecoinvent. (2016). Ecoinvent Database 3.3. In *Ecoinvent Centre*. https://doi.org/10.4018/978-1-59140-342-5.ch003

EeB Guide Project. (2012). *Operational Guidance for Life Cycle Assessment Studies of the Energy Efficient Buildings Initiative*. http://www.eebguide.eu/

EN. (2011). EN 15978:2011 - Sustainability of construction works - Assessment of environmental performance of buildings - Calculation method. *International Standard*, *November*.

EN. (2012). EN 15804:2012 + A2:2019 - Sustainability of construction works — Environmental product declarations — Core rules for the product category of construction products. *International Standard*, *February*, 70.

EPD. (n.d.). *EPD*. www.environdec.com

Favi, C., Meo, I., Di Giuseppe, E., Iannaccone, M., D'Orazio, M., & Germani, M. (2017). Towards a probabilistic approach in LCA of building retrofit measures. *Energy Procedia*, *134*, 394–403. https://doi.org/10.1016/J.EGYPRO.2017.09.584

Federal Ministry of the Interior Building and Home Affairs (BMI). (n.d.). *Ökobaudat*. 2021. https://www.oekobaudat.de/

Fernádez-García, A., Ibáñez-Forés, V., & Bovea, M. D. (2016). Eco-efficiency analysis of the life cycle of interior partition walls: A comparison of alternative solutions. *Journal of Cleaner Production*, *112*(1), 649–665. https://doi.org/10.1016/j.jclepro.2015.07.136

Hollberg, A., Genova, G., & Habert, G. (2020). Evaluation of BIM-based LCA results for building design. *Automation in Construction*, *109*, 102972. https://doi.org/10.1016/j.autcon.2019.102972

Hoxha, E., Habert, G., Lasvaux, S., Chevalier, J., Le Roy, R., Hoxh, Endrit, Habert, G., Lasvaux, S., Chevalier, J., & Le Roy, R. (2017). Influence of construction material uncertainties on residential building LCA reliability. *Journal of Cleaner Production*, *144*, 33–47. https://doi.org/10.1016/j.jclepro.2016.12.068

IEA EBC. (2016). *IEA EBC ANNEX 57*. http://www.annex57.org/

ISO. (2017). *ISO 21930:2017 Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services*.

Kamali, M., Hewage, K., & Sadiq, R. (2019). Conventional versus modular construction methods: A comparative cradle-to-gate LCA for residential buildings. *Energy and Buildings*, *204*, 109479.

Kellenberger, D., Althaus, H.-J., Künniger, T., Lehmann, M., Jungbluth, N., & Thalmann, P. (2007). Life Cycle Inventories of Building Products. Final report ecoinvent Data v2.0 No.7. In *Database*.

Kuittinen, M., & Häkkinen, T. (2020). Reduced carbon footprints of buildings: new Finnish standards and assessments. *Buildings and Cities*. https://doi.org/10.5334/bc.30

Lavagna, M., Baldassarri, C., Campioli, A., Giorgi, S., Dalla Valle, A., Castellani, V., & Sala, S. (2018). Benchmarks for environmental impact of housing in Europe: Definition of archetypes and LCA of the residential building stock. *Building and Environment*, *145*, 260–275. https://doi.org/10.1016/j.buildenv.2018.09.008

Lützkendorf, T. (2019). Application of "Element"-Method in Sustainability Assessment. *Central Europe towards Sustainable Building 2019 (CESB19)*, 1–8.

Lützkendorf, T., Balouktsi, M., Frischknecht, R., Peuportier, B., Birgisdottir, H., Bohne, R. A., Cellura, M., Cusenza, M. A., Francart, N., García, A., Gomes, V., Gomes da Silva, M., et al. (2023). *Context-specific assessment methods for life cycle-related environmental impacts caused by buildings*. treeze Ltd. ISBN: 978-3-9525709-0-6; DOI: 10.5281/zenodo.7468316

Morales, M. F. D., Reguly, N., Kirchheim, A. P., & Passuello, A. (2020). Uncertainties related to the replacement stage in LCA of buildings: A case study of a structural masonry clay hollow brick wall. *Journal of Cleaner Production*, *251*, 119649. https://doi.org/10.1016/J.JCLEPRO.2019.119649

ÖKOBAUDAT. (n.d.). Retrieved October 30, 2021, from https://www.oekobaudat.de/en.html

Østergaard, N., Thorsted, L., Miraglia, S., Birkved, M., Rasmussen, F. N., Birgisdóttir, H., Kalbar, P., & Georgiadis, S. (2018). Data Driven Quantification of the Temporal Scope of Building LCAs. *Procedia CIRP*, *69*, 224–229. https://doi.org/10.1016/J.PROCIR.2017.11.057

OVAM, SPW, BE, VITO, KU Leuven, & BBRI. (2018). *Totem tool*. https://www.totem-building.be/

Pacheco-Torres, R., Jadraque, E., Roldán-Fontana, J., & Ordóñez, J. (2014). Analysis of CO2 emissions in the construction phase of single-family detached houses. *Sustainable Cities and Society*, *12*, 63–68. https://doi.org/10.1016/J.SCS.2014.01.003

RICS. (2017). *Whole life carbon assessment for the built environment*. http://www.rics.org/Global/Whole_life_carbon_assessment_for_the_BE_ PG_guidance_2017.pdf

Scheuer, C., Keoleian, G. A., & Reppe, P. (2003). Life cycle energy and environmental performance of a new university building: modeling challenges and design implications. *Energy and Buildings*, *35*(10), 1049–1064. https://doi.org/10.1016/s0378-7788(03)00066-5

Schlanbusch, R. D., Fufa, S. M., Häkkinen, T., Vares, S., Birgisdottir, H., & Ylmén, P. (2016). Experiences with LCA in the Nordic Building Industry – Challenges, Needs and Solutions. *Energy Procedia*, *96*, 82–93. https://doi.org/10.1016/J.EGYPRO.2016.09.106

Schlegl, F., Gantner, J., Traunspurger, R., Albrecht, S., & Leistner, P. (2019). LCA of buildings in Germany: Proposal for a future benchmark based on existing databases. *Energy and Buildings*, *194*, 342–350. https://doi.org/10.1016/J.ENBUILD.2019.04.038

Shadram, F., Johansson, T. D., Lu, W., Schade, J., & Olofsson, T. (2016). An integrated BIM-based framework for minimizing embodied energy during building design. *Energy and Buildings*, *128*, 592–604. https://doi.org/10.1016/j.enbuild.2016.07.007

Shirazi, A., & Ashuri, B. (2020). Embodied Life Cycle Assessment (LCA) comparison of residential building retrofit measures in Atlanta. *Building and Environment*, *171*, 106644. https://doi.org/10.1016/J.BUILDENV.2020.106644

Soust-Verdaguer, B., Llatas, C., García-Martínez, A., & Gómez de Cózar, J. C. (2018). BIM-based LCA method to analyze envelope alternatives of single-family houses: case study in Uruguay. *Journal of Architectural Engineering*, *24*(3), 05018002. https://doi.org/10.1061/(ASCE)AE.1943-5568.0000303

Steubing, B., de Koning, D., Haas, A., & Mutel, C. L. (2020). The Activity Browser — An open source LCA software building on top of the brightway framework. *Software Impacts*, *3*, 100012. https://doi.org/10.1016/J.SIMPA.2019.100012

Su, S., Zhu, C., & Li, X. (2019). A dynamic weighting system considering temporal variations using the DTT approach in LCA of buildings. *Journal of Cleaner Production*, *220*, 398–407. https://doi.org/10.1016/J.JCLEPRO.2019.02.140

Sweden National Board of Housing Building and Planning. (2020). *Draft Act on Climate declarations for buildings*. https://ec.europa.eu/growth/tools-databases/tris/en/index.cfm/search/?trisaction=search.detail&year=2020&num=439&mLang=EN

System, D. (2019). *Certificate for Sustainable and Green Building; DGNB GmbH: Stuttgart, Germany, 2019.*

Vrije Universiteit Brussel, SINTEF Community, & Bygninger Og Installasjoner. (2020). *Methodologies for impact assessment of on-site and off-site construction logistics. MIMIC Deliverable 2.1 - SINTEF*. https://www.sintef.no/publikasjoner/publikasjon/?pubid=1835971

Zabalza Bribián, I., Valero Capilla, A., & Aranda Usón, A. (2011). Life cycle assessment of building materials: Comparative analysis of energy and environmental impacts and evaluation of the eco-efficiency improvement potential. *Building and Environment*, *46*(5), 1133–1140. https://doi.org/10.1016/J.BUILDENV.2010.12.002

Appendix. Questionnaire of modeling of Modules A4, A5, C1 and C2

Q1 Do you include the following EN 15978 modules (mark with X)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes		No		
A5	Yes		No		
Use stage (B2-B5)	Yes		No		
C1	Yes		No		
C2	Yes		No		

Q2 Which Option do you mainly use to model EN 15978 transport modules *(A4 and C2) (mark with X):

Generalize hypothesis [1]		Provide reference document or brief description (if possible)
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for A4 and C2 you should include A4 and C2 separately answers.

[1] include 1 or 2 general distances, means of transport, etc.
[2] include more than 2 or 3 possible distances, means of transport, etc.
[3] include a detailed modeling of transports.

Q3 Can you specify how do you integrate the following aspects in the previous (Q2) Option:

Which are the considered products and materials? Do you have any cut-off rules for that?	
Which transport distances do you considered?	
Which means of transport do you considered?	
Which fuels and consumption hypothesis do you considered?	
Do you include the return load (return trip of transports)?	
Which data sources or database do you considered for impacts calculation?	
Do you include any other relevant aspects? Can you specify?	

Provide reference document (if possible)

Q4 Concerning the previous (Q2) Option, do you consider a default location of the manufacturers of the main building materials?
If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.

	YES		NO	
	Provide reference document or brief description (if possible)			
Q5	Concerning the previous (Q2) Option, do you consider a default location of the sorting/recycling or end of life disposal points? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.			
	YES		NO	
	Provide reference document or brief description (if possible)			
Q6	Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):			
	* in case you use a different Option for each LCA module you should include separately answers.			
	Provide reference document (if possible)			
Q7	Is this previous Option* (Q6) close to (mark with X):			
	Generalize hypothesis [1]		Provide reference document or brief description (if possible)	
	Simplified modeling [2]		Provide reference document or brief description (if possible)	
	Detailed modeling [3]		Provide reference document or brief description (if possible)	
	* in case you use a different Option for each LCA module you should include separately answers.			
	[1] include a general hypothesis. [2] include more than 2 scenarios/hypothesis. [3] include a detailed modeling.			
Q8	Can you specify how do you integrate the following aspects in the previous Option*(Q6):			
	Which construction, deconstruction and replacement works do you considered?			
	Which type of machinery and machinery works do you considered?			
	Which fuels and energy machinery consumption hypothesis do you considered?			
	Which data sources or database do you considered for impacts calculation?			
	Do you include any other relevant aspects? Can you specify?			
	* in case you use a different Option for each LCA module you should include separately answers.			
	Provide reference document (if possible)			

(AU) AUTRALIA

Q1 Do you include the following **EN 15978 modules** (mark with **X**)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes	X	No		
A5	Yes	X	No		
Use stage (B2-B5)	Yes	X	No		
C1	Yes	X	No		
C2	Yes	X	No		

Q2 Which Option do you mainly use to model **EN 15978 transport modules** *(A4 and C2) (mark with **X**):

Generalize hypothesis [1]	X	Simplified average distance delivered from distributor and site. Then, transportation distance is quantified with return.
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for each LCA module you should include separately answers.

[1] include 1 or 2 general distances, means of transport, etc.
[2] include more than 2 or 3 possible distances, means of transport, etc.
[3] include a detailed modeling of transports.

Q3 Can you specify how do you integrate the **following aspects** in the previous (Q2) Option:

Which are the considered products and materials? Do you have any cut-off rules for that?	Basically all building materials which counted embodied impacts. If not considered in the A1-A3, it is not considered in A4.
Which transport distances do you considered?	If not specified, it is, in general, assumed less than 200km away of building material supplied to the site.
Which means of transport do you considered?	Basically 'rigid truck'.
Which fuels and consumption hypothesis do you considered?	Mainly diesel.
Do you include the return load (return trip of transports)?	Yes we does.
Which data sources or database do you considered for impacts calculation?	Australian national LCI data (called AusLCI) and Ecoinvent ver 3.0 (if not available in AusLCI)
Do you include any other relevant aspects? Can you specify?	

Provide reference document (if possible)

Q4 Concerning the previous (Q2) Option, do you consider a default location of the **manufacturers of the main building materials**?
If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.

	YES		NO	X	
	Provide reference document or brief description (if possible)				
Q5	Concerning the previous (Q2) Option, do you consider a default location of the **sorting/recycling or end of life disposal points**? If your answer is YES, please indicating the estimate location and a brief description of the hypotheses.				
	YES		NO	X	We don't have any default location for recycling or sorting.
	Provide reference document or brief description (if possible)				
Q6	Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):				
	For detailed LCA for A5, we use productivity of major equipment (e.g., hour/unit of work, m3 etc. for crane, electric ladder etc.) then quantified the energy consumption of its equipment. But simple version of LCA, we use an assumption taken from literature (5-10% of whole LCA). For B4, it is quantified the lifespan of each element and products of building. For example, it will be replaced every 10 years for glass, 15 years repainting etc. For C1, we use equipment productivity for detailed LCA or assumption for simple LCA.				
	* in case you use a different Option for each LCA module you should include separately answers.				
	Provide reference document (if possible)				
Q7	Is this previous Option*** (Q6)** close to (mark with **X**):				
	Generalize hypothesis [1]	X	Provide reference document or brief description (if possible)		
	Simplified modeling [2]	X	Provide reference document or brief description (if possible)		
	Detailed modeling [3]	X	Provide reference document or brief description (if possible)		
	* in case you use a different Option for each LCA module you should include separately answers.				
	[1] include a general hypothesis. [2] include more than 2 scenarios/hypothesis. [3] include a detailed modeling.				
Q8	Can you specify how do you integrate the **following aspects** in the previous Option***(Q6)**:				
	Which construction, deconstruction and replacement works do you considered?				
	Which type of machinery and machinery works do you considered?	Excavator, backhoe etc. for foundation (earth) work, Crane hoist, conveyer, forklift for construction material handling			
	Which fuels and energy machinery consumption hypothesis do you considered?	Mainly fueled with diesel for machinery.			

Which data sources or database do you considered for impacts calculation?	Mainly AusLCI (national LCI database) or ecoinvent (see 3.0 if not available in AusLCI)
Do you include any other relevant aspects? Can you specify?	Australian team has worked for some missing impacts from A3, A5 and B1. Please see the attached. We are happy to contribute our work for this if required.

* in case you use a different Option for each LCA module you should include separately answers.

Provide reference document (if possible)

(BE) BELGIUM

Q1 Do you include the following **EN 15978 modules** (mark with **X**)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes	x	No		
A5	Yes	x	No		
Use stage (B2-B5)	Yes	x	No		
C1	Yes	x	No		
C2	Yes	x	No		

Q2 Which Option do you mainly use to model **EN 15978 transport modules** *(A4 and C2) (mark with **X**):

Generalize hypothesis [1]		Provide reference document or brief description (if possible)
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]	x	Allacker K, Debacker W, Delem L, De Nocker L, De Troyer F, Janssen A, Peeters K, Van Dessel J, Servaes R, Rossi E, Deproost M, Bronchart S (2018) Environmental profile of building elements [update 2017]. OVAM, Mechelen

* in case you use a different Option for each LCA module you should include separately answers.

[1] include 1 or 2 general distances, means of transport, etc.
[2] include more than 2 or 3 possible distances, means of transport, etc.
[3] include a detailed modeling of transports.

Q3 Can you specify how do you integrate the **following aspects** in the previous (Q2) Option:

Which are the considered products and materials? Do you have any cut-off rules for that?	For each product and material, a transport and waste category is selected. Based on the transport and waste category, transport scenarios are calculated for both A4 and C2
Which transport distances do you considered?	Transport distances depend on the selected material category. 3 transport steps are considered (directly from

	factory to site, from factory to supplier and from supplier to site)
Which means of transport do you considered?	Depending on the transport step, the materials are subdivided according to 4 means of transport * Lorry > 32 ton (EURO 5) * Lorry 16-32 ton (EURO 5) * Lorry 7.5-16 ton (EURO 5) * Lorry 3.5-7.5 ton (EURO 5)
Which fuels and consumption hypothesis do you considered?	Diesel (EURO 5)
Do you include the return load (return trip of transports)?	This included in the average load assumed in the Ecoinvent records
Which data sources or database do you considered for impacts calculation?	Ecoinvent 3.3
Do you include any other relevant aspects? Can you specify?	/

Provide reference document (if possible)
Allacker K, Debacker W, Delem L, De Nocker L, De Troyer F, Janssen A, Peeters K, Van Dessel J, Servaes R, Rossi E, Deproost M, Bronchart S (2018) Environmental profile of building elements [update 2017]. OVAM, Mechelen

Q4 Concerning the previous (Q2) Option, do you consider a default location of the **manufacturers of the main building materials**?
If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.

The location of the manufacturers is indirectly included based on the average transport distances which are assumed for each material category.

YES	x	NO	

Provide reference document or brief description (if possible)
Allacker K, Debacker W, Delem L, De Nocker L, De Troyer F, Janssen A, Peeters K, Van Dessel J, Servaes R, Rossi E, Deproost M, Bronchart S (2018) Environmental profile of building elements [update 2017]. OVAM, Mechelen

Q5 Concerning the previous (Q2) Option, do you consider a default location of the **sorting/recycling or end of life disposal points**?
If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.

The location of the sorting/ recycling or EOL disposal plants is indirectly included based on the average transport distances which are assumed for each waste category.

YES	x	NO	

Provide reference document or brief description (if possible)
Allacker K, Debacker W, Delem L, De Nocker L, De Troyer F, Janssen A, Peeters K, Van Dessel J, Servaes R, Rossi E, Deproost M, Bronchart S (2018) Environmental profile of building elements [update 2017]. OVAM, Mechelen

Q6 Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):

Model A5

This module includes the following processes:

- Impact of material losses (global add-on of 5% on all material quantities)
- Impact of construction activities (e.g. excavation and electricity consumed for cellulose blowing)

Use stage (Module B4)

This module includes the replacement of worn building components. It covers the impact of the demolition, waste transport and waste management of the removed components and the production, transportation and construction of the new components. Information related to the life span of work sections can be found on the TOTEM website (https://www.totem-building.be/)

Module C1

Module C1 includes the impact of the deconstruction and demolition. The composition of the materials and the method of connecting with other materials/work sections determines the type of demolition process

* in case you use a different Option for each LCA module you should include separately answers.

Provide reference document (if possible)

Allacker K, Debacker W, Delem L, De Nocker L, De Troyer F, Janssen A, Peeters K, Van Dessel J, Servaes R, Rossi E, Deproost M, Bronchart S (2018) Environmental profile of building elements [update 2017]. OVAM, Mechelen

Q7 Is this previous Option*** (Q6)** close to (mark with **X**):

Generalize hypothesis [1]	x	Provide reference document or brief description (if possible)
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]	x	Provide reference document or brief description (if possible)

* in case you use a different Option for each LCA module you should include separately answers.

Generic option for module A5

Detailed modeling for modules B4 and C1

[1] include a general hypothesis.

[2] include more than 2 scenarios/hypothesis.

[3] include a detailed modeling.

Q8 Can you specify how do you integrate the **following aspects** in the previous Option***(Q6)**:

Which construction, deconstruction and replacement works do you considered?	• Various deconstruction processes have been defined for different materials based on Ecoinvent 3.3 • The impact of replacement is calculated as the sum of the impact of the demolition, waste transport and waste management of the removed components and the production,

		transportation and construction of the new components
	Which type of machinery and machinery works do you considered?	The impact of construction activities is limited to a few processes such as excavation works and the electricity consumed for cellulose blowing
	Which fuels and energy machinery consumption hypothesis do you considered?	The fuels and consumption values are based on Ecoinvent 3.3
	Which data sources or database do you considered for impacts calculation?	Ecoinvent 3.3
	Do you include any other relevant aspects? Can you specify?	/
	* in case you use a different Option for each LCA module you should include separately answers.	
	Provide reference document (if possible) Allacker K, Debacker W, Delem L, De Nocker L, De Troyer F, Janssen A, Peeters K, Van Dessel J, Servaes R, Rossi E, Deproost M, Bronchart S (2018) Environmental profile of building elements [update 2017]. OVAM, Mechelen	

(BZ) BRAZIL

Q1 Do you include the following EN 15978 modules (mark with X)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes		No	
A5	Yes		No	
Use stage (B2-B5)	Yes		No	
C1	Yes		No	
C2	Yes		No	

Q2 Which Option do you mainly use to model EN 15978 transport modules *(A4 and C2) (mark with X):

Generalize hypothesis [1]		Provide reference document or brief description (if possible)
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]		Provide reference document or brief description (if possible)
* in case you use a different Option for each LCA module you should include separately answers.		
[1] include 1 or 2 general distances, means of transport, etc. [2] include more than 2 or 3 possible distances, means of transport, etc. [3] include a detailed modeling of transports.		

Q3 Can you specify how do you integrate the following aspects in the previous (Q2) Option:

Which are the considered products and materials? Do you have any cut-off rules for that?	

	Which transport distances do you considered?	
	Which means of transport do you considered?	
	Which fuels and consumption hypothesis do you considered?	
	Do you include the return load (return trip of transports)?	
	Which data sources or database do you considered for impacts calculation?	
	Do you include any other relevant aspects? Can you specify?	
	Provide reference document (if possible)	
Q4	Concerning the previous (Q2) Option, do you consider a default location of the manufacturers of the main building materials? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.	
	YES ☐ NO ☐	
	Provide reference document or brief description (if possible)	
Q5	Concerning the previous (Q2) Option, do you consider a default location of the sorting/recycling or end of life disposal points? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.	
	YES ☐ NO ☐	
	Provide reference document or brief description (if possible)	
Q6	**Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):	
	* in case you use a different Option for each LCA module you should include separately answers.	
	Provide reference document (if possible)	
Q7	Is this previous Option* (Q6) close to (mark with X):	
	Generalize hypothesis [1] ☐	Provide reference document or brief description (if possible)
	Simplified modeling [2] ☐	Provide reference document or brief description (if possible)
	Detailed modeling [3] ☐	Provide reference document or brief description (if possible)
	* in case you use a different Option for each LCA module you should include separately answers.	
	[1] include a general hypothesis. [2] include more than 2 scenarios/hypothesis. [3] include a detailed modeling.	
Q8	Can you specify how do you integrate the following aspects in the previous Option*(Q6):	

Which construction, deconstruction and replacement works do you considered?	
Which type of machinery and machinery works do you considered?	
Which fuels and energy machinery consumption hypothesis do you considered?	
Which data sources or database do you considered for impacts calculation?	
Do you include any other relevant aspects? Can you specify?	
* in case you use a different Option for A5, B4 and C1 you should include A5, B4 and C1 separately answers.	
Provide reference document (if possible)	

(CA) CANADA

Q1 Do you include the following **EN 15978 modules** (mark with **X**)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes	X	No		
A5	Yes	X	No		
Use stage (B2-B5)	Yes	X	No		
C1	Yes	X	No		
C2	Yes	X	No		

Q2 Which Option do you mainly use to model **EN 15978 transport modules** *(A4 and C2) (mark with **X**):

Generalize hypothesis [1]	X	Provide reference document or brief description (if possible) •For A4, we used an average distance according to project location (urban, suburban, rural, etc.). For this specific project, a distance of 25km for concrete with a small size lorry transport truck was used and a distance of 225km was used for all the other material with a regular lorry transport truck. •For C2, we used an average distance of 50km with regular lorry truck transportation.
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for each LCA module you should include separately answers.

[1] include 1 or 2 general distances, means of transport, etc.
[2] include more than 2 or 3 possible distances, means of transport, etc.
[3] include a detailed modeling of transports.

Q3 Can you specify how do you integrate the **following aspects** in the previous (Q2) Option:

Which are the considered products and materials? Do you have any cut-off rules for that?	All material used in the building were included (including materials for the B4 and A5 – loss during construction

		modules). Transport of the construction equipment was not included.
	Which transport distances do you considered?	See Q2
	Which means of transport do you considered?	See Q2
	Which fuels and consumption hypothesis do you considered?	Average consumption per ton kilometer from the ecoinvent datasets were used.
	Do you include the return load (return trip of transports)?	Yes, datasets rely on average load factors that include the average share of empty return trips.
	Which data sources or database do you considered for impacts calculation?	For the small size lorry transport, an ecoinvent dataset was used. For the regular lorry transport, an internal model from Groupe AGÉCO which is representative of transport in North America is used.
	Do you include any other relevant aspects? Can you specify?	All aspects from the ecoinvent datasets were used.
	Provide reference document (if possible)	

Q4	Concerning the previous (Q2) Option, do you consider a default location of the **manufacturers of the main building materials**? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.				
	YES	X	NO		We used default distances between the supplier and the site construction (see Q2).
	Provide reference document or brief description (if possible)				
Q5	Concerning the previous (Q2) Option, do you consider a default location of the **sorting/recycling or end of life disposal points**? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.				
	YES	X	NO		We used default distances between the building and the end-of-life facilities.
	Provide reference document or brief description (if possible)				
Q6	Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):				
	•For A5, we used a fixed percentage of the impacts from A1 to A4 (10%). No calculation regarding fuel consumption was included for this module. •For B4, we used a ratio according to material lifespan (round up (building lifespan / material lifespan))-1) *(material impacts A1 to A5). •For C1, we used a generic value for machinery under a specific time. One machinery was for the concrete demolition (crusher) and another regular machinery for all the other demolition works.				
	* in case you use a different Option for each LCA module you should include separately answers.				
	Provide reference document (if possible)				
Q7	Is this previous Option*** (Q6)** close to (mark with **X**):				

Generalize hypothesis [1]	X	Provide reference document or brief description (if possible) •For C1, crusher use was based on concrete volume in the building. Other machinery was modeled with average consumptions per m2 of floor based on Groupe AGECO experience.
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for each LCA module you should include separately answers.

[1] include a general hypothesis.
[2] include more than 2 scenarios/hypothesis.
[3] include a detailed modeling.

Q8 Can you specify how do you integrate the **following aspects** in the previous Option***(Q6)**:

Which construction, deconstruction and replacement works do you considered?	A5: no construction work was modeled C1: Concrete crushing, material handling
Which type of machinery and machinery works do you considered?	Machinery for material handling (lifts, air compressors, cranes…) and concrete crusher during deconstruction.
Which fuels and energy machinery consumption hypothesis do you considered?	Average consumption per hour from the ecoinvent datasets were used.
Which data sources or database do you considered for impacts calculation?	Average machine operation from the ecoinvent database were used.
Do you include any other relevant aspects? Can you specify?	

* in case you use a different Option for each LCA module you should include separately answers.

Provide reference document (if possible)

(CH) SWITZERLAND

Q1 Do you include the following **EN 15978 modules** (mark with **X**)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes		No	X	Transports to regional storage site in Switzerland (this applies also for construction products manufactured abroad) is covered in the construction materials datasets. Delivery to building site is often unknown and of low importance. In exceptional cases (helicopter transports) A4 may be included.

	A5	Yes		No	X	Considered of minor importance; cutting losses (wastes during construction) are neglected because the amounts of materials needed are determined coarsely and generously. Furthermore, there are no empirical data on material specific cutting losses/wastes.
	Use stage (B2-B5)	Yes	X	No		
	C1	Yes	X	No		
	C2	Yes	X	No		

Q2 Which Option do you mainly use to model **EN 15978 transport modules** *(A4 and C2) (mark with **X**):

Generalize hypothesis [1]	X	This only applies for C2 transports, for which 1 default transport distance and one means of transport per waste management option (landfill, incineration, separation/recycling) is used.
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for A4 and C2 you should include A4 and C2 separately answers.

[1] include 1 or 2 general distances, means of transport, etc.
[2] include more than 2 or 3 possible distances, means of transport, etc.
[3] include a detailed modeling of transports.

Q3 Can you specify how do you integrate the **following aspects** in the previous (Q2) Option:

Which are the considered products and materials? Do you have any cut-off rules for that?	
Which transport distances do you considered?	10 to 20 km
Which means of transport do you considered?	Lorry, 20-28 tons, fleet average
Which fuels and consumption hypothesis do you considered?	diesel, 24.57kg/100km (=29.42 litre/100km)
Do you include the return load (return trip of transports)?	Average payload: 5.8tons, including return trip
Which data sources or database do you considered for impacts calculation?	KBOB LCA data DQRv2:2016 (retrieved from www.ecoinvent.org, https://db.ecoinvent.org/download/KBOB%20DQRv2_2016.zip?area=3e2c0806caa3c Most recent version available: UVEK LCA data DQRv2:2018
Do you include any other relevant aspects? Can you specify?	demolishing efforts are included in C1, same efforts and emissions per kg material.

	Provide reference document (if possible)				
Q4	Concerning the previous (Q2) Option, do you consider a default location of the **manufacturers of the main building materials**? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.				
	YES		NO	X	Foreign production and import transports are taken into account.
	Provide reference document or brief description (if possible)				
Q5	Concerning the previous (Q2) Option, do you consider a default location of the **sorting/recycling or end of life disposal points**? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.				
	YES		NO	X	
	Provide reference document or brief description (if possible)				
Q6	Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):				
	A5: not taken into account B4: standard lifetimes per building element as reported in SIA 2032, Annex C (normative), no energy consumption for replacement but for demolishing work of replaced building elements and materials.				
	* in case you use a different Option for each LCA module you should include separately answers.				
	Provide reference document (if possible)				
Q7	Is this previous Option*** (Q6)** close to (mark with **X**):				
	Generalize hypothesis [1]				Provide reference document or brief description (if possible)
	Simplified modeling [2]				Provide reference document or brief description (if possible)
	Detailed modeling [3]				Provide reference document or brief description (if possible)
	* in case you use a different Option for each LCA module you should include separately answers.				
	[1] include a general hypothesis. [2] include more than 2 scenarios/hypothesis. [3] include a detailed modeling.				
Q8	Can you specify how do you integrate the **following aspects** in the previous Option***(Q6)**:				
	Which construction, deconstruction and replacement works do you considered?				replacement works are not considered, only replacement materials
	Which type of machinery and machinery works do you considered?				general diesel consumption of building machines used in demolishing
	Which fuels and energy machinery consumption hypothesis do you considered?				see above

	Which data sources or database do you considered for impacts calculation?	see above
	Do you include any other relevant aspects? Can you specify?	
	* in case you use a different Option for each LCA module you should include separately answers.	
	Provide reference document (if possible)	

(DE) GERMANY

Q1 Do you include the following **EN 15978 modules** (mark with **X**)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes		No	**X**	Both the latest BNB and DGNB systems in Germany do not include modules A4-5 as well as C1-2 in their minimum system boundaries. Reasons for this exclusion are not clearly stated in BNB/DGNB guidelines but lie in problems with data acquisition and an assumed insignificance of such impacts with regard to the overall result. The possible inclusion in the next version is currently investigated.
A5	Yes		No	**X**	See above under A4
Use stage (B2-B5)	Yes	**X**	No		Both the latest BNB and DGNB systems in Germany do include module B4. The basis is default values for the service life of building components and building equipment
C1	Yes		No	**X**	See above under A4
C2	Yes		No	**X**	See above under A4

Q2 Which Option do you mainly use to model **EN 15978 transport modules** *(A4 and C2) (mark with **X**):

Generalize hypothesis [1]		Provide reference document or brief description (if possible)
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]	**(X)**	A4 and C2 are not taken into account in BNB/DGNB. Therefore, since default distances are not provided per material type by BNB/DGNB systems, it is assumed that if one wishes to include these modules in an assessment, detailed modelling will be applied in relation to this parameter. Ökobau.dat provides average environmental data in tonnes*km for different types of transport to assist in calculations. For example, for small truck: *"The dataset refers to the transport of 1000 kg cargo on a distance of 1 km by truck (EURO 5) with 12-14 t permissible total weight and 9.3 t payload in forwarding traffic with a utilisation ratio of 85%. The extraction and processing of the fuel is included. The production of the vehicle is not included in the balancing."* (see: https://oekobaudat.de/OEKOBAU.DAT/datasetdetail/process.xhtml?uuid=510e8761-8b2d-46a5-b8df-

		6d1ac321ce92&version=20.19.120&stock=OBD_2021_II&lang=en)
	* in case you use a different Option for A4 and C2 you should include A4 and C2 separately answers.	
	[1] include 1 or 2 general distances, means of transport, etc. [2] include more than 2 or 3 possible distances, means of transport, etc. [3] include a detailed modeling of transports.	
Q3	Can you specify how do you integrate the **following aspects** in the previous (Q2) Option:	
	Which are the considered products and materials? Do you have any cut-off rules for that?	
	Which transport distances do you considered?	
	Which means of transport do you considered?	
	Which fuels and consumption hypothesis do you considered?	
	Do you include the return load (return trip of transports)?	
	Which data sources or database do you considered for impacts calculation?	
	Do you include any other relevant aspects? Can you specify?	
	Provide reference document (if possible)	
Q4	Concerning the previous (Q2) Option, do you consider a default location of the **manufacturers of the main building materials**? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.	
	YES	NO **X**
	Provide reference document or brief description (if possible)	
Q5	Concerning the previous (Q2) Option, do you consider a default location of the **sorting/recycling or end of life disposal points**? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.	
	YES	NO **X**
	Provide reference document or brief description (if possible)	
Q6	Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):	
	A5 and C1 are not taken into account in BNB/DGNB. However, Ökobau.dat provides data for a few selected construction activities: (1) excavators per m^3 (e.g. https://oekobaudat.de/OEKOBAU.DAT/datasetdetail/process.xhtml?uuid=f4d930b5-ebe0-4b12-9de0-e2ee391be029&version=20.19.120&stock=OBD_2021_II&lang=en) (2) pumping of concrete per m^3 (e.g. https://oekobaudat.de/OEKOBAU.DAT/datasetdetail/process.xhtml?uuid=f	

	dcb26f9-1f0c-4766-ad94-c093e5d259e1&version=20.19.120&stock=OBD_2021_II&lang=en)
	* in case you use a different Option for each LCA module you should include separately answers.
	Provide reference document (if possible)

Q7 Is this previous Option*** (Q6)** close to (mark with **X**):

Generalize hypothesis [1]		Provide reference document or brief description (if possible)
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for each LCA module you should include separately answers.

[1] include a general hypothesis.
[2] include more than 2 scenarios/hypothesis.
[3] include a detailed modeling.

Q8 Can you specify how do you integrate the **following aspects** in the previous Option***(Q6)**:

Which construction, deconstruction and replacement works do you considered?	replacement works/construction processes are not considered, only replacement materials and components
Which type of machinery and machinery works do you considered?	So far data are provided only for excavation and pumping of concrete. Diesel Excavators are considered, e.g. for Excavator of 15kW "*The dataset includes the production and consumption of diesel necessary for the excavation of 1m³ of dirt (0.305 kg diesel per m3 of sand soil)*"
Which fuels and energy machinery consumption hypothesis do you considered?	n.a.
Which data sources or database do you considered for impacts calculation?	See Q6
Do you include any other relevant aspects? Can you specify?	n.a.
* in case you use a different Option for each LCA module you should include separately answers.	
Provide reference document (if possible)	

(ES) SPAIN

Q1 Do you include the following EN 15978 modules (mark with X)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes	X	No		
A5	Yes	X	No		

	Use stage (B2-B5)	Yes	X	No		
	C1	Yes	X	No		
	C2	Yes	X	No		

Q2	Which Option do you mainly use to model EN 15978 transport modules *(A4 and C2) (mark with X):		
	Generalize hypothesis [1]		Provide reference document or brief description (if possible)
	Simplified modeling [2]	X	Provide reference document or brief description (if possible)
	Detailed modeling [3]		Provide reference document or brief description (if possible)
	*** in case you use a different Option for each LCA module you should include separately answers.**		
	[1] include 1 or 2 general distances, means of transport, etc. [2] include more than 2 or 3 possible distances, means of transport, etc. [3] include a detailed modeling of transports.		
Q3	Can you specify how do you integrate the following aspects in the previous (Q2) Option:		
	Which are the considered products and materials? Do you have any cut-off rules for that?		
	Which transport distances do you considered?		
	Which means of transport do you considered?		
	Which fuels and consumption hypothesis do you considered?		
	Do you include the return load (return trip of transports)?		
	Which data sources or database do you considered for impacts calculation?		
	Do you include any other relevant aspects? Can you specify?		
	Provide reference document (if possible)		
Q4	Concerning the previous (Q2) Option, do you consider a default location of the manufacturers of the main building materials? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.		
	YES		NO
	Provide reference document or brief description (if possible)		
Q5	Concerning the previous (Q2) Option, do you consider a default location of the sorting/recycling or end of life disposal points? If your answer is YES, please indicating the estimate location and a brief description of the hypotheses.		
	YES		NO

	Provide reference document or brief description (if possible)
Q6	Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):
	* in case you use a different Option for each LCA module you should include separately answers.
	Provide reference document (if possible)

Q7 Is this previous Option* (Q6) close to (mark with X):

Generalize hypothesis [1]	X	Provide reference document or brief description (if possible)
Simplified modeling [2]	X	Provide reference document or brief description (if possible)
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for each LCA module you should include separately answers.

[1] include a general hypothesis.
[2] include more than 2 scenarios/hypothesis.
[3] include a detailed modeling.

Q8 Can you specify how do you integrate the following aspects in the previous Option*(Q6):

Which construction, deconstruction and replacement works do you considered?	
Which type of machinery and machinery works do you considered?	
Which fuels and energy machinery consumption hypothesis do you considered?	
Which data sources or database do you considered for impacts calculation?	
Do you include any other relevant aspects? Can you specify?	

* in case you use a different Option for each LCA module you should include separately answers.

Provide reference document (if possible)

(FR) FRANCE

Q1 Do you include the following **EN 15978 modules** (mark with **X**)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes	X	No		
A5	Yes	X	No		
Use stage (B2-B5)	Yes	X	No		
C1	Yes		No	X	
C2	Yes	X	No		

Q2 Which Option do you mainly use to model **EN 15978 transport modules** *(A4 and C2) (mark with **X**):

Generalize hypothesis [1]	X	Provide reference document or brief description (if possible) See annex of this document
Simplified modeling [2]		Provide reference document or brief description (if possible)
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for each LCA module you should include separately answers.

[1] include 1 or 2 general distances, means of transport, etc.
[2] include more than 2 or 3 possible distances, means of transport, etc.
[3] include a detailed modeling of transports.

Q3 Can you specify how do you integrate the **following aspects** in the previous (Q2) Option:

Which are the considered products and materials? Do you have any cut-off rules for that?	All products are concerned
Which transport distances do you considered?	See annex
Which means of transport do you considered?	truck
Which fuels and consumption hypothesis do you considered?	Like in ecoinvent 2.2
Do you include the return load (return trip of transports)?	Average load factor of ecoinvent
Which data sources or database do you considered for impacts calculation?	Ecoinvent 2.2
Do you include any other relevant aspects? Can you specify?	

Provide reference document (if possible)

Q4 Concerning the previous (Q2) Option, do you consider a default location of the **manufacturers of the main building materials**?
If your answer is YES, please indicating the estimate location and a brief description of the hypotheses.

YES		NO		The user is free to choose this location and the corresponding transport distance, see annex

Provide reference document or brief description (if possible)

Q5 Concerning the previous (Q2) Option, do you consider a default location of the **sorting/recycling or end of life disposal points**?
If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.

YES		NO		The user is free to choose this location and the corresponding transport distance, see annex

	Provide reference document or brief description (if possible)
Q6	Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):
	See annex
	* in case you use a different Option for each LCA module you should include separately answers.
	Provide reference document (if possible)
Q7	Is this previous Option*** (Q6)** close to (mark with **X**):

Generalize hypothesis [1]		Provide reference document or brief description (if possible)
Simplified modeling [2]	X	Provide reference document or brief description (if possible)
Detailed modeling [3]		Provide reference document or brief description (if possible)

	* in case you use a different Option for each LCA module you should include separately answers.
	[1] include a general hypothesis. [2] include more than 2 scenarios/hypothesis. [3] include a detailed modeling.
Q8	Can you specify how do you integrate the **following aspects** in the previous Option***(Q6)**:

Which construction, deconstruction and replacement works do you considered?	Waste production
Which type of machinery and machinery works do you considered?	none
Which fuels and energy machinery consumption hypothesis do you considered?	none
Which data sources or database do you considered for impacts calculation?	Ecoinvent 2.2
Do you include any other relevant aspects? Can you specify?	Treatment of building site waste

	* in case you use a different Option for each LCA module you should include separately answers.
	Provide reference document (if possible)

Annex: French EQUER method

Q2: The user informs 4 transport distances, the following default values are proposed:

Distance from manufacture to building site, 100 km
Distance from Building site to landfill, 20 km
Distance from Building site to incineration, 20 km

Distance from Building site to recycling, 100 km

Transport by truck is considered.

Q6: For A5, the user chooses a surplus % of materials, 5% is proposed as default value. This corresponds to broken elements on the construction site, surplus of ready mixed concrete at the end of the day, parts of panels that remain unused after cutting the right size etc.

For B4, the user informs 8 life spans, the following default values are proposed:

Doors and Windows (inside and facades), 30 years

Painting and finishes (inside and facades), 10 years

Equipment, 20 years

Other elements, same as whole building = 80 years or other value, 100 years

(HU) HUNGARY

Q1 Do you include the following **EN 15978 modules** (mark with **X**)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes	X	No		
A5	Yes	X	No		
Use stage (B2-B5)	Yes	X	No		
C1	Yes		No	X	We have no data for this stage.
C2	Yes	X	No		

Q2 Which Option do you mainly use to model **EN 15978 transport modules** *(A4 and C2) (mark with **X**):

Generalize hypothesis [1]		Provide reference document or brief description (if possible)
Simplified modeling [2]	X	Provide reference document or brief description (if possible): A4: Materials are classified into 4 transportation categories depending on the number and location of manufacturing plants (50 km lorry for materials produced locally; 150 km lorry+30 km van for national production with 1-2 factories; 800 km freight rail+30 km van for imported products transported by rail; 800 km lorry+ 30 km van for imported materials transported on road) C2: only one transport category: 20 km lorry
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for each LCA module you should include separately answers.

[1] include 1 or 2 general distances, means of transport, etc.
[2] include more than 2 or 3 possible distances, means of transport, etc.
[3] include a detailed modeling of transports.

Q3 Can you specify how do you integrate the **following aspects** in the previous (Q2) Option:

	Which are the considered products and materials? Do you have any cut-off rules for that?	data taken from ecoinvent
	Which transport distances do you considered?	described above
	Which means of transport do you considered?	described above
	Which fuels and consumption hypothesis do you considered?	taken from ecoinvent
	Do you include the return load (return trip of transports)?	yes
	Which data sources or database do you considered for impacts calculation?	ecoinvent 3.5
	Do you include any other relevant aspects? Can you specify?	no
	Provide reference document (if possible)	
Q4	Concerning the previous (Q2) Option, do you consider a default location of the **manufacturers of the main building materials**? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.	
	YES X NO	
	Provide reference document or brief description (if possible) For nationally produced materials we check where the factories are located in the country and based on the number of factories we classify materials into categories. These categories are used for each material independent of the actual location of the building.	
Q5	Concerning the previous (Q2) Option, do you consider a default location of the **sorting/recycling or end of life disposal points**? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.	
	YES NO X	
	Provide reference document or brief description (if possible) Only one transport category is used	
Q6	Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):	
	A5: material losses are included (2-5% depending on material) and in the previous version of the tool 8 MJ/m3 electricity + 50 MJ/m3 diesel was included for the construction process of the building B4: replacement is calculated based on default lifetime of materials/ elements C1: neglected due to missing data	
	* in case you use a different Option for each LCA module you should include separately answers.	
	Provide reference document (if possible)	

Q7	Is this previous Option*** (Q6)** close to (mark with **X**):		
	Generic modelling[1]	X	Provide reference document or brief description (if possible) see above
	Simplified modeling [2]		Provide reference document or brief description (if possible)
	Detailed modeling [3]		Provide reference document or brief description (if possible)
	* in case you use a different Option for each LCA module you should include separately answers.		
	[1] include a general hypothesis. [2] include more than 2 scenarios/hypothesis. [3] include a detailed modeling.		

Q8	Can you specify how do you integrate the **following aspects** in the previous Option***(Q6)**:	
	Which construction, deconstruction and replacement works do you considered?	For construction only material losses are included, plus a general value for the construction process taken from an ecoinvent report. For replacement only the materials, their transport and disposal are considered, not the replacement process itself.
	Which type of machinery and machinery works do you considered?	only a general value is considered
	Which fuels and energy machinery consumption hypothesis do you considered?	only a general value is considered
	Which data sources or database do you considered for impacts calculation?	ecoinvent 3.5
	Do you include any other relevant aspects? Can you specify?	no
	* in case you use a different Option for each LCA module you should include separately answers.	
	Provide reference document (if possible)	

(NZ) NEW ZEALAND

Q1	Do you include the following **EN 15978 modules** (mark with **X**)? If your answer is NO justify by describing the reason of neglection.				
	A4	Yes	X	No	
	A5	Yes	X	No	
	Use stage (B2-B5)	Yes	X	No	
	C1	Yes	X	No	
	C2	Yes	X	No	

Q2 Which Option do you mainly use to model **EN 15978 transport modules** *(A4 and C2) (mark with **X**):

Generalize hypothesis [1]		Provide reference document or brief description (if possible)
Simplified modeling [2]	X	Provide reference document or brief description (if possible) – **please see Module A4 Summary worksheet in the accompanying "Construction transport (module A4) v1.xlsx" spreadsheet for example transport distances**
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for each LCA module you should include separately answers.

[1] include 1 or 2 general distances, means of transport, etc.
[2] include more than 2 or 3 possible distances, means of transport, etc.
[3] include a detailed modeling of transports.

Q3 Can you specify how do you integrate the **following aspects** in the previous (Q2) Option:

Which are the considered products and materials? Do you have any cut-off rules for that?	**Please see materials/products listed in the "Construction transport (module A4) v1 datasheet. We include the main materials in structures, walls, roofs, floors (for example). Currently, we do not consider fixings, sealants, adhesives.**
Which transport distances do you considered?	**From manufacturer gate to construction site in central Auckland, Wellington or Christchurch.**
Which means of transport do you considered?	**Road, ship, rail**
Which fuels and consumption hypothesis do you considered?	**Underlying data for fuel consumption, based on data in EcoInvent 3.1.**
Do you include the return load (return trip of transports)?	**No.**
Which data sources or database do you considered for impacts calculation?	**CML**
Do you include any other relevant aspects? Can you specify?	**Includes transport of material that ends up in the building, as well as transport of the material that becomes waste at the construction site.**

Provide reference document (if possible)

Q4 Concerning the previous (Q2) Option, do you consider a default location of the **manufacturers of the main building materials**?
If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.

Please look at Section 3 of the accompanying SR351 study report for an explanation of how we have derived these transport distances.

	YES	X	NO	
	Provide reference document or brief description (if possible) **- SR351 study report accompanies this questionnaire**			
Q5	Concerning the previous (Q2) Option, do you consider a default location of the **sorting/recycling or end of life disposal points**? If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.			
	YES	X	NO	
	Provide reference document or brief description (if possible) We assume a 20 km distance to landfill/cleanfill. Distances to recycling facilities vary depending on the material, for example, steel and aluminium scrap are exported overseas by ship.			
Q6	Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):			
	Please go to www.branz.co.nz/builidnglca and select "Data". In there, you will see a list of all our datasheets, which provide scenario information for building LCA. You can download the Construction site waste (module A5) v1, Building materials replacement (module B4) v2 and Building end-of-life (module C1) v1 datasheets, to see how we have provided these data. **For information about how these have been developed, please see the accompanying SR351 study report.**			
	* in case you use a different Option for each LCA module you should include separately answers.			
	Provide reference document (if possible)			
Q7	Is this previous Option*** (Q6)** close to (mark with **X**):			
	Generalize hypothesis [1]		Provide reference document or brief description (if possible)	
	Simplified modeling [2]	X	Provide reference document or brief description (if possible)	
	Detailed modeling [3]		Provide reference document or brief description (if possible)	
	* in case you use a different Option for each LCA module you should include separately answers.			
	[1] include a general hypothesis. [2] include more than 2 scenarios/hypothesis. [3] include a detailed modeling.			
Q8	Can you specify how do you integrate the **following aspects** in the previous Option***(Q6)**:			
	Which construction, deconstruction and replacement works do you considered?	**We include construction of the elements set out in the module A5 datasheet.** **We do not include smaller items such as fixings, sealants, adhesives, therefore wastage of these materials is also not included currently.** **Other current exclusions include:**		

		Packaging of construction materials. **Energy used for site machinery/power tools/site office.** **Shuttering/formwork.** **Excavation activities.**
	Which type of machinery and machinery works do you considered?	**See above.** **For deconstruction, we include energy required for this, which is allocated to structural materials only.** **Data are based on an Athena Institute publication.** **For further information, please see accompanying SR350 study report (Appendix D4)**
	Which fuels and energy machinery consumption hypothesis do you considered?	**Machinery is powered by diesel. We use secondary data from EcoInvent 3.1, in particular the dataset called "Diesel, burned in building machine".**
	Which data sources or database do you considered for impacts calculation?	**EcoInvent 3.1**
	Do you include any other relevant aspects? Can you specify?	**Please see SR351 study report and Appendix D of the SR350 study report.**
	* in case you use a different Option for each LCA module you should include separately answers.	
	Provide reference document (if possible) **Key documents are SR351 study report and SR350 study report (Appendix D). Also, for data, please see datasheets (as set out above)**	

(UK) UNITED KINGDOM

Q1 Do you include the following **EN 15978 modules** (mark with **X**)?
If your answer is NO justify by describing the reason of neglection.

A4	Yes	X	No		This is a mandatory stage to be included in order to meet the minimum requirements laid out in the RICS Professional Statement available here.
A5	Yes	X	No		This is a mandatory stage to be included in order to meet the minimum requirements laid out in the RICS Professional Statement available here.
Use stage (B2-B5)	Yes	X	No		This is a mandatory stage to be included in order to meet the minimum requirements laid out in the RICS Professional Statement available here.
C1	Yes	X	No		This is not mandatory and exceeds the minimum requirement in the document linked above but its inclusion is nonetheless strongly encouraged.
C2	Yes	X	No		This is not mandatory and exceeds the minimum requirement in the document linked above but its inclusion is nonetheless strongly encouraged.

Q2 Which Option do you mainly use to model **EN 15978 transport modules** *(A4 and C2) (mark with **X**):

Generalize hypothesis [1]		Provide reference document or brief description (if possible)
Simplified modeling [2]	X	Provide reference document or brief description (if possible) From the standard above: "Transport emissions should be calculated as follows: [A4] = Material or system mass (a) × transport distance (b) × carbon conversion factor (c)."
Detailed modeling [3]		Provide reference document or brief description (if possible)

* in case you use a different Option for each LCA module you should include separately answers.

[1] include 1 or 2 general distances, means of transport, etc.
[2] include more than 2 or 3 possible distances, means of transport, etc.
[3] include a detailed modeling of transports.

Q3 Can you specify how do you integrate the **following aspects** in the previous (Q2) Option:

Which are the considered products and materials? Do you have any cut-off rules for that?	You can find this information in Table 3 of the document above.
Which transport distances do you considered?	You can find this information in Table 7 (for A4) and Table 11 (for C2) of the document above.
Which means of transport do you considered?	Also this information can be found in Table 7 (for A4) and Table 11 (for C2) of the document above.
Which fuels and consumption hypothesis do you considered?	Carbon conversion factors are taken from official UK government publications.
Do you include the return load (return trip of transports)?	Partially. In fact, the carbon conversion factors consider average rigid HGV with average laden. This means that the mode of transport that should be assumed is an average heavy goods vehicle (HGV) with 50 per cent load to account for the vehicles coming to site empty and leaving with a 100 per cent load.
Which data sources or database do you considered for impacts calculation?	This information is given in Section 3.3.1 of the linked document. In short: Type III environmental declarations and datasets in accordance with EN15804 or ISO21930 or ISO 14067 or ISO 14025, 14050, 14044 or PAS 2050.
Do you include any other relevant aspects? Can you specify?	

Provide reference document (if possible)

Same link of Q1.

Q4 Concerning the previous (Q2) Option, do you consider a default location of the **manufacturers of the main building materials**?
If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.

YES	X	NO	

Provide reference document or brief description (if possible)

Please see Table 7 (for A4) of the document linked in Q1. Basically, if project-specific information is unavailable, average distances and means of transport are provided based on groups of materials (e.g. locally manufactured vs. globally manufactured).

Please see Table 11 (for C2) of the document linked in Q1. Basically, for C2 the scenarios are not material-specific but EoL-specific.

Q5 Concerning the previous (Q2) Option, do you consider a default location of the **sorting/recycling or end of life disposal points**?
If your answer is YES, please indicate the estimate location and a brief description of the hypotheses.

YES	x	NO	

Provide reference document or brief description (if possible)

From the document linked in Q1:

For reuse/recycling elsewhere a 50km local transport is assumed whereas for landfill/incineration the average between the two closest landfill sites is assumed.

Q6 Which Option, modeling principles or hypothesis do you mainly use to include T, C&D process in **A5, C1 EN 15978 modules and use stage*** (provide brief description, if possible):

Please see the following sections of the documents linked above:

Section 3.5.2.2 page 20 for **A5**
Section 3.5.3.4 page 22 for **Use stage**
Section 3.5.4.1 page 26 for **C1**

* in case you use a different Option for each LCA module you should include separately answers.

Provide reference document (if possible)

Q7 Is this previous Option*** (Q6)** close to (mark with **X**):

Generalize hypothesis [1]	X	Provide reference document or brief description (if possible) This is the answer for **A5** where a simplified average figure (taken from a BRE publication) of 1400kgCO2e/£100k of project value is given in absence of more specific information.

			This is also the answer for **C1** where an average rate of 3.4 kgCO2e/m^2 GIA (monitored from demolition case studies in London is suggested)
	Simplified modeling [2]	X	Provide reference document or brief description (if possible) This is the answer for **B4**, where indicative component lifespans are given (see Table 9 of the document linked above).
	Detailed modeling [3]		Provide reference document or brief description (if possible)
	* in case you use a different Option for each LCA module you should include separately answers.		
	[1] include a general hypothesis. [2] include more than 2 scenarios/hypothesis. [3] include a detailed modeling.		
Q8	Can you specify how do you integrate the **following aspects** in the previous Option***(Q6)**:		
	Which construction, deconstruction and replacement works do you considered?		**A5**: As mentioned this is a weak point of the RICS document where an average figure linked to project value is used. Even if detailed and project-specific assessments are encouraged I suspect that in practice the average figure is most often used. **Use stage**: from the document above "Module [B4] must take into account any carbon emissions associated with the anticipated replacement of building components, including any emissions from the replacement process. All emissions arising from the production, transportation to site and installation of the replacement items must be included. This extends to cover any losses during these processes, as well as the carbon associated with component removal and EoL treatment. **C1**: again, an area of weakness of the document which suggests an average figure. The risk is that in practice most people would just use the suggested figure although the standard does encourage to collect project-specific data.
	Which type of machinery and machinery works do you considered?		**A5**: See previous answer and section 3.5.2.2 of the document linked in Q1. **Use stage**: see previous answer and section 3.5.3.4 of the document linked in Q1 and below. **C1**: N/A

Which fuels and energy machinery consumption hypothesis do you considered?	**A5**: N/A **Use stage**: N/A **C1:** N/A
Which data sources or database do you considered for impacts calculation?	**A5**: site waste rates for different materials should be determined based on the standard wastage rates provided by the WRAP Net Waste Tool (UK specific). **Use stage**: scenarios should be based on data from facilities management and maintenance Option reports, façade access and maintenance Option, life cycle cost reports, O&M manuals, guidance (e.g. CIBSE Guide M and BCIS Life expectancy of building components), international standards (e.g. ISO 15868-5: 2008 Buildings and constructed assets – service life planning, and manufacturers' documentation). Also lifespans value are given in Table 9 of the document. **C1**: N/A/
Do you include any other relevant aspects? Can you specify?	
* in case you use a different Option for each LCA module you should include separately answers.	
Provide reference document (if possible) Always the same document linked here once more: www.rics.org/globalassets/rics-website/media/news/whole-life-carbon-assessment-for-the--built-environment-november-2017.pdf	