ANNEX 72

EBC

Energy in Building and Communities Programme

International Energy Agency

Guidelines for Establishing an Easy-to-use National LCA Database for the Construction Sector

Energy in Buildings and Communities Technology Collaboration Programme

February 2023

Technology Collaboration Programme by iea

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February 2023

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Photo on front page: Construction site in Chennai (Madras), India, Sivakumar Palaniappan © 2023

Preface

The International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster international co-operation among the 30 IEA participating countries and to increase energy security through energy research, development and demonstration in the fields of technologies for energy efficiency and renewable energy sources.

The IEA Energy in Buildings and Communities Programme

The IEA co-ordinates international energy research and development (R&D) activities through a comprehensive portfolio of Technology Collaboration Programmes (TCPs). The mission of the IEA Energy in Buildings and Communities (IEA EBC) TCP is to support the acceleration of the transformation of the built environment towards more energy efficient and sustainable buildings and communities, by the development and dissemination of knowledge, technologies and processes and other solutions through international collaborative research and open innovation. (Until 2013, the IEA EBC Programme was known as the IEA Energy Conservation in Buildings and Community Systems Programme, ECBCS.)

The high priority research themes in the EBC Strategic Plan 2019-2024 are based on research drivers, national programmes within the EBC participating countries, the Future Buildings Forum (FBF) Think Tank Workshop held in Singapore in October 2017 and a Strategy Planning Workshop held at the EBC Executive Committee Meeting in November 2017. The research themes represent a collective input of the Executive Committee members and Operating Agents to exploit technological and other opportunities to save energy in the buildings sector, and to remove technical obstacles to market penetration of new energy technologies, systems and processes. Future EBC collaborative research and innovation work should have its focus on these themes.

At the Strategy Planning Workshop in 2017, some 40 research themes were developed. From those 40 themes, 10 themes of special high priority have been extracted, taking into consideration a score that was given to each theme at the workshop. The 10 high priority themes can be separated in two types namely 'Objectives' and 'Means'. These two groups are distinguished for a better understanding of the different themes.

Objectives - The strategic objectives of the EBC TCP are as follows:

– reinforcing the technical and economic basis for refurbishment of existing buildings, including financing, engagement of stakeholders and promotion of co-benefits;
– improvement of planning, construction and management processes to reduce the performance gap between design stage assessments and real-world operation;
– the creation of 'low tech', robust and affordable technologies;
– the further development of energy efficient cooling in hot and humid, or dry climates, avoiding mechanical cooling if possible;
– the creation of holistic solution sets for district level systems taking into account energy grids, overall performance, business models, engagement of stakeholders, and transport energy system implications.

Means - The strategic objectives of the EBC TCP will be achieved by the means listed below:

– the creation of tools for supporting design and construction through to operations and maintenance, including building energy standards and life cycle analysis (LCA);
– benefitting from 'living labs' to provide experience of and overcome barriers to adoption of energy efficiency measures;
– improving smart control of building services technical installations, including occupant and operator interfaces;
– addressing data issues in buildings, including non-intrusive and secure data collection;
– the development of building information modelling (BIM) as a game changer, from design and construction through to operations and maintenance.

The themes in both groups can be the subject for new Annexes, but what distinguishes them is that the 'objectives' themes are final goals or solutions (or part of) for an energy efficient built environment, while the 'means' themes are instruments or enablers to reach such a goal. These themes are explained in more detail in the EBC Strategic Plan 2019-2024.

The Executive Committee

Overall control of the IEA EBC Programme is maintained by an Executive Committee, which not only monitors existing projects, but also identifies new strategic areas in which collaborative efforts may be beneficial. As the Programme is based on a contract with the IEA, the projects are legally established as Annexes to the IEA EBC Implementing Agreement. At the present time, the following projects have been initiated by the IEA EBC Executive Committee, with completed projects identified by (*) and joint projects with the IEA Solar Heating and Cooling Technology Collaboration Programme by (☼):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviourwith Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)
Annex 16: BEMS 1- User Interfaces and System Integration (*)
Annex 17: BEMS 2- Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi Zone Air Flow Modelling (COMIS) (*)
Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HVAC Simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: ☼ Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy-Related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-Aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT) (*)
Annex 36: Retrofitting of Educational Buildings (*)
Annex 37: Low Exergy Systems for Heating and Cooling of Buildings (LowEx) (*)
Annex 38: ☼ Solar Sustainable Housing (*)
Annex 39: High Performance Insulation Systems (*)
Annex 40: Building Commissioning to Improve Energy Performance (*)
Annex 41: Whole Building Heat, Air and Moisture Response (MOIST-ENG) (*)
Annex 42: The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (FC+COGEN-SIM) (*)
Annex 43: ☼ Testing and Validation of Building Energy Simulation Tools (*)
Annex 44: Integrating Environmentally Responsive Elements in Buildings (*)
Annex 45: Energy Efficient Electric Lighting for Buildings (*)
Annex 46: Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo) (*)
Annex 47: Cost-Effective Commissioning for Existing and Low Energy Buildings (*)
Annex 48: Heat Pumping and Reversible Air Conditioning (*)
Annex 49: Low Exergy Systems for High Performance Buildings and Communities (*)
Annex 50: Prefabricated Systems for Low Energy Renovation of Residential Buildings (*)
Annex 51: Energy Efficient Communities (*)
Annex 52: ☼ Towards Net Zero Energy Solar Buildings (*)
Annex 53: Total Energy Use in Buildings: Analysis and Evaluation Methods (*)
Annex 54: Integration of Micro-Generation and Related Energy Technologies in Buildings (*)
Annex 55: Reliability of Energy Efficient Building Retrofitting - Probability Assessment of Performance and Cost (RAP-RETRO) (*)
Annex 56: Cost Effective Energy and CO2 Emissions Optimization in Building Renovation (*)
Annex 57: Evaluation of Embodied Energy and CO2 Equivalent Emissions for Building Construction (*)

Annex 58: Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements (*)
Annex 59: High Temperature Cooling and Low Temperature Heating in Buildings (*)
Annex 60: New Generation Computational Tools for Building and Community Energy Systems (*)
Annex 61: Business and Technical Concepts for Deep Energy Retrofit of Public Buildings (*)
Annex 62: Ventilative Cooling (*)
Annex 63: Implementation of Energy Strategies in Communities (*)
Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles (*)
Annex 65: Long-Term Performance of Super-Insulating Materials in Building Components and Systems (*)
Annex 66: Definition and Simulation of Occupant Behavior in Buildings (*)
Annex 67: Energy Flexible Buildings (*)
Annex 68: Indoor Air Quality Design and Control in Low Energy Residential Buildings (*)
Annex 69: Strategy and Practice of Adaptive Thermal Comfort in Low Energy Buildings
Annex 70: Energy Epidemiology: Analysis of Real Building Energy Use at Scale
Annex 71: Building Energy Performance Assessment Based on In-situ Measurements
Annex 72: Assessing Life Cycle Related Environmental Impacts Caused by Buildings
Annex 73: Towards Net Zero Energy Resilient Public Communities
Annex 74: Competition and Living Lab Platform
Annex 75: Cost-effective Building Renovation at District Level Combining Energy Efficiency and Renewables
Annex 76: ☼ Deep Renovation of Historic Buildings Towards Lowest Possible Energy Demand and CO_2 Emissions
Annex 77: ☼ Integrated Solutions for Daylight and Electric Lighting
Annex 78: Supplementing Ventilation with Gas-phase Air Cleaning, Implementation and Energy Implications
Annex 79: Occupant-Centric Building Design and Operation
Annex 80: Resilient Cooling
Annex 81: Data-Driven Smart Buildings
Annex 82: Energy Flexible Buildings Towards Resilient Low Carbon Energy Systems
Annex 83: Positive Energy Districts
Annex 84: Demand Management of Buildings in Thermal Networks
Annex 85: Indirect Evaporative Cooling
Annex 86: Energy Efficient Indoor Air Quality Management in Residential Buildings
Annex 87: Energy and Indoor Environmental Quality Performance of Personalised Environmental Control Systems
Annex 88: Evaluation and Demonstration of Actual Energy Efficiency of Heat Pump Systems in Buildings

Working Group - Energy Efficiency in Educational Buildings (*)
Working Group - Indicators of Energy Efficiency in Cold Climate Buildings (*)
Working Group - Annex 36 Extension: The Energy Concept Adviser (*)
Working Group - HVAC Energy Calculation Methodologies for Non-residential Buildings (*)
Working Group - Cities and Communities
Working Group - Building Energy Codes

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Summary

This technical report presents a set of guidelines for developing an easy to use national LCA database targeting the construction and real estate sector. First, the motivation for establishing a national LCA database and the benefits of such database are outlined. This is followed by a detailed presentation on the methodological guidelines needed for establishing a national LCA database. In general, it is recommended that the methodological guidelines should adhere to the international standards such as EN 15804 A2:2019 and ISO 21930:2017.

Methodological guidelines are presented for establishing the life cycle inventory data with reference to the following aspects: definition of system boundaries, LCA modeling approaches, definition of environmental indicators, contents of the LCA database, data quality parameters, core methodological aspects, specific methodological aspects, LCA data on future construction material manufacturing, product groups, scope of data to be collected, recommendations for using LCA data from other countries, interoperability of LCA datasets and LCA database and suggested templates for data collection. Among these, the guidelines are presented for addressing the core methodological aspects such as the definition of declared unit and functional unit, allocation, cut-off rules, emission certificates, biogenic carbon, carbon offset, carbon storage and delayed emissions, carbonation, electricity mix applied in manufacturing, packaging, default transport distances, default waste management practice, production waste and waste generated on the construction site. Further, specific methodological aspects related to prefabricated building elements, imported construction materials and overheads are also presented.

The participation of the industry stakeholders, database users and the government is critical for the long term success of the LCA database in terms of data collection, data review and funding support. Details on the roadmap development are covered including the vision and goals, governance and management, funds and financing, human resources, database hosting, data needs and availability, data quality requirements, data format and interoperability, and the application in policy making. In addition, the key elements of the governance structure highlighting the role of advisory council, governing board, operational working group and the IT management and database implementation are discussed.

Table of contents

Abbreviations

Abbreviations	Meaning
BIM	Building Information Modelling
CED	Cumulative Energy Demand
DQA	Data Quality Assessment
DQI	Data Quality Indicators
EPD	Environmental Product Declaration
GLAD	Global LCA Data Access
GoO	Guarantee of Origin
GWP	Global Warming Potential
ILCD	International Reference Life Cycle Data
INDC	Intended National Determined Contribution
LCA	Life Cycle Assessment
LCDN	Life Cycle Data Network
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
OEF	Organizational Environmental Footprint
PEF	Product Environmental Footprint
SDG	Sustainable Development Goals
UNSPSC	United Nations Standard Products and Services Code
XML	Extensible Markup Language

Definitions

A brief description of terminologies referred in this document are presented (reproduced) as per ISO 14044: 2006, ISO 21930:2017, EN 15804:2012+A2:2019 and UNEP (2011).

life cycle assessment (LCA): compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle

life cycle inventory (LCI): phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle

life cycle impact assessment (LCIA): phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product

co-product: any of two or more products coming from the same unit process or product system

process: set of interrelated or interacting activities that transforms inputs into outputs

unit process: smallest element considered in the life cycle inventory analysis for which input and output data are quantified

feedstock energy: heat of combustion of a raw material input that is not used as an energy source to a product system

ancillary input: material input used by the unit process producing the product, but does not constitute part of the product

allocation: partitioning the input or output flows of a process or a product system between the product system understudy and one or more other product systems

cut-off criteria: specification of the amount of material or energy flow or the level of environmental significance associated with unit processes or product system to be excluded from a study

data quality: characteristics of data that relate to their ability to satisfy stated requirements

functional unit: quantified performance of a product system for use as a reference unit

process energy: energy input required for operating the process or equipment within a unit process, excluding energy inputs for production and delivery of the energy itself

reference flow: measure of the outputs from processes in a given product system required to fulfill the function expressed by the functional unit

sensitivity analysis: systematic procedures for estimating the effects of the choices made regarding methods and data on the outcome of a study

system boundary: set of criteria specifying which unit processes are part of a product system uncertainty analysis: systematic procedure to quantify the uncertainty introduced in the results of a life cycle inventory analysis due to the cumulative effects of mode! imprecision, input uncertainty and data variability

completeness check: process of verifying whether information from the phases of a life cycle assessment is sufficient for reaching conclusions in accordance with the goal and scope definition

consistency check: process of verifying that the assumptions, methods and data are consistently applied throughout the study and are in accordance with the goal and scope definition performed before conclusions are reached

sensitivity check: process of verifying that the information obtained from a sensitivity analysis is relevant for reaching the conclusions and giving recommendations

evaluation: element within the life cycle interpretation phase intended to establish confidence in the results of the life cycle assessment (This includes completeness check, sensitivity check, consistency check, and any other validation that may be required according to the goal and scope definition of the study)

critical review: process intended to ensure consistency between a life cycle assessment and the principles and requirements of the International Standards on life cycle assessment

type III environmental declaration: environmental declaration providing quantified environmental data using predetermined indicators and, where relevant, additional environmental information

co-product: any of one or more products (ISO 14050:2009) from the same unit process, but which is notthe object of the assessment.

by-product: co-product from a process (ISO 14040:2006) that is incidental or not intentionally producedand which cannot be avoided. Wastes are not by-products.

data quality: characteristics of data that relate to their ability to satisfy stated requirements

biogenic: produced in natural processes by living organisms but not fossilized or derived from fossil resources

biogenic carbon: carbon derived from biomass

inventory dataset: A set of input and output data of a process, which can be a unit process or an aggregated process. An inventory dataset contains metadata describing the geography, time reference, and ownership of the dataset.

life cycle dataset library: A global database of registered and searchable life cycle datasets.

life cycle inventory database: A system intended to organize, store, and retrieve large amounts of digital LCI datasets easily. It consists of an organized collection of LCI datasets that completely or partially conforms to a common set of criteria, including methodology, format, review, and nomenclature, and that allows for interconnection of individual datasets that can be specified for use with identified impact assessment methods in application of life cycle assessments and life cycle impact assessments.

Guidelines for establishing an easy to use national LCA database for the construction sector

1. Introduction

Life cycle assessment is used as a scientific method to evaluate the environmental impacts in a holistic manner considering all stages of a product life cycle, from the resource extraction to product manufacture, use and waste management after the end-of-life stage of the product. LCA is useful to identify the major contributors of environmental impacts (or hotspots) and formulate steps to improve the environmental performance. LCA based studies are useful to achieve selected sustainable development goals (SDG) and make informed choices to achieve the Intended National Determined Contribution (INDC)regarding greenhouse gas emissions at the national level. The availability of accurate, interoperable, and context specific Life Cycle Inventory datasets for construction materials, products, building elements and processes is a pre-requisite for the successful application of LCA in the construction industry.

Many developed countries have been successful in establishing LCI datasets related to the construction sector, such as the KBOB recommendation 2009/1:2021and its underlying database used in Switzerland or the Ökobaudat database used in Germany. The LCI database such as the Ecoinvent database or other respective national life cycle inventory databases form the basis for commercially available LCA software tools such as the SimaPro (Netherlands), GaBi(Germany), Brightway 2 (Switzerland),or Athena Impact Estimator (Canada).

However, the development of reliable, comprehensive and open-access LCI datasets covering wide range of construction materials and products is a challenging task in many developing nations. Several reasons are cited including the absence of guidelines or a protocol for establishing a simplified LCA datasets and database, lack of awareness on advanced concepts related to LCA methodologies as well as unavailability of a consistent & standardized template for data contributors across different sectors. This study aims to address these challenges and focuses on developing the methodological guidelines needed to establish a simplified national LCA database for the construction sector in developing nations.

Availability of reliable and accurate LCI datasets is the basis for demonstrating the environmental performance of manufacturing and construction processes, evaluating supply chain processes and promoting the development of green materials and products, green markets and green economy. This would assist the policy makers to reduce the level of pollution and impacts on the eco-system and promote resource efficiency, sustainable production and sustainable consumption. The end-users can be empowered to make informed choices in choosing sustainable products. Access to reliable LCI datasets will enable the architects, clients and designers to utilize such datasets and integrate sustainability considerations in the early phases of the building design. This would also promote the application of life cycle thinking among various stakeholders involved in the built environment.

The significance of building a high quality LCA database is shown in Figure 1. Life cycle inventory database is the basis for formulating strategies on environmental sustainability of products. Based on the LCA data, key indicators such as the cumulative energy demand (CED), carbon footprint and water footprint are determined. These key indicators form the basis for programs such as the eco-label and environmental product declaration (EPD). Policies related to life cycle management and environmental sustainability of products are derived from these programs.

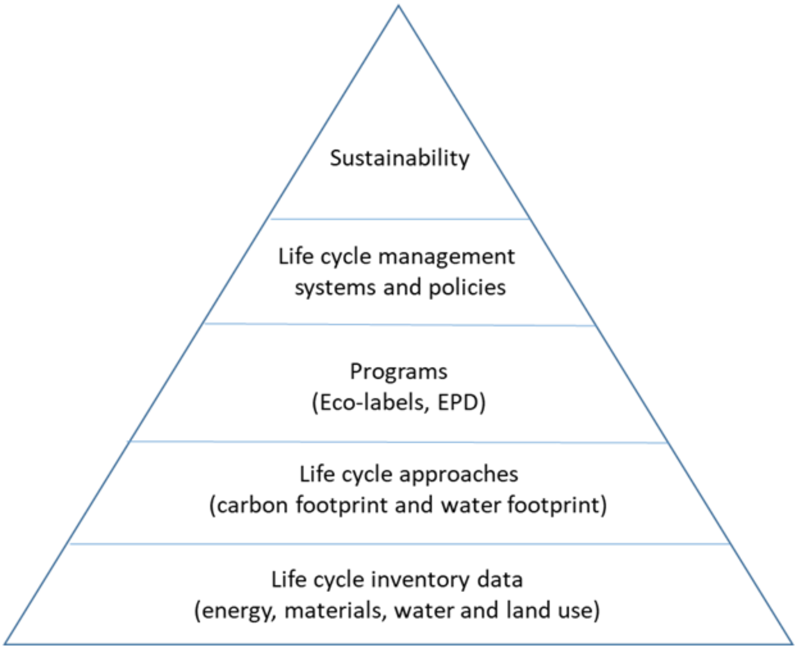

Figure 1. Life cycle inventory data as a base for moving towards environmental sustainability of products(adapted from Shonan Guidance Principles, Sonnemann & Vigon 2011)

The need for establishing a national LCA database is highlighted in several technical reports:

- To address the environmental and social impacts and facilitate the movement towards green economy.
- LCA data is the base for implementing the Sustainable Development Goals and promoting sustainable production and consumption.
- To develop new materials by considering the sustainability performance.
- To understand and reduce the emissions released into air, land and water and thereby undertake initiatives to address the health of the people and the planet.
- To facilitate life cycle thinking, circular economy, resource efficiency and conservation of natural resources while progressing towards new development.

2. Contents overview

This report aims to present a set of guidelines for the development of an easy-to-use national LCA database consisting of reliable data for the stakeholders in the building construction sector, for example, the architects, designers and engineers in the early stages of building planning and design. This report is organized into the following sections:
Chapter 1 presents the need for the development of an easy-to-use LCA database development and the expected benefits to the construction industry stakeholders. Chapter 2 presents the content overview.
Chapter 3 presents the technical aspects of database development including the scope of the database, data quality parameters, methodological guidelines for inventory data, templates for data collection, recommendations for using LCA data from other countries and interoperability of data with BIM tools.
Chapter 4 presents the methodology for the assessment of the current status and the maturity level.
Chapter 5 presents the key elements of a roadmap for LCA database development.
Chapter 6 presents a generic governance structure for the development of an easy-to-use LCA database for the construction sector.
Chapter 7 presents the conclusions.

3. Methodological guidelines for establishing life cycle inventory data

3.1 Introduction

LCA database consists of unit process datasets and aggregated (system) process datasets. Unit process datasets are Gate to Gate datasets for which the inputs of raw materials, semi-finished products, fuel etc. and the direct outputs (in-situ emission of pollutants to air, water bodies and soil) are reported. These inputs are linked to other unit process datasets, which represent the manufacture of the raw materials. The life cycle inventory result of a unit process is stored in LCA databases as aggregated (system) processes. Some databases offer both the unit and aggregated (system) process data, whereas others prefer to only publish the aggregated (system) process data. The concept of Gate to Gate boundary condition and Cradle to Gate boundary condition are illustrated in Figure 2 using precast concrete product manufacturing.
The methodological framework for generation of unit process dataset from raw data is shown in Figure 3.The procedure used for translating the raw data into unit process dataset is called Dataset modeling. It consists of three steps namely: (a) Goal and scope definition, (b) Generation of unit process dataset, and (c) Validation of unit process dataset.

The intended application of the dataset is outlined in the goal and scope definition. To enhance flexibility in dataset modelling, unallocated datasets are preferred as far as possible. But, it will be necessary to allocate to produce the database. Development of unit process datasets is a time consuming process and it should be carried out by individuals with the necessary experience in LCA methodology and knowledge about the discipline the dataset deals with. The quality of datasets directly influences the credibility of the LCA database.

The goal and scope definition describes the kind of process represented by the dataset. The database developer considers the following while defining the goal and scope of the unit process dataset: specific size of the process to be modelled, impact categories to be considered, technology, time period, geographical area, cut-off rules, provision of uncertainty information for inputs and outputs, the intended use of the unit process dataset and many more.

The development of various elements of the unit process dataset requires the use of common and agreed-upon nomenclature and naming schemes. For example, the nomenclature systems such as the ecoinvent system 3.0 (released in 2013) and the International Reference Life Cycle Data (ILCD) system may be considered. It is recommended that multi-product unit process datasets be provided as unallocated datasets as far as possible to enhance flexibility in modelling.

The generation of unit process dataset involves the following steps as per the guidelines prescribed in ISO 14040 and ISO 14044.

Step-1: Preparation of inventory list consisting of inputs and outputs
Step-2: Definition of mathematical relations
Step-3: Collection of raw data: primary data, secondary data or data generation
Step-4: Calculations to determine inventory parameters
Step-5: Presentation of supporting information

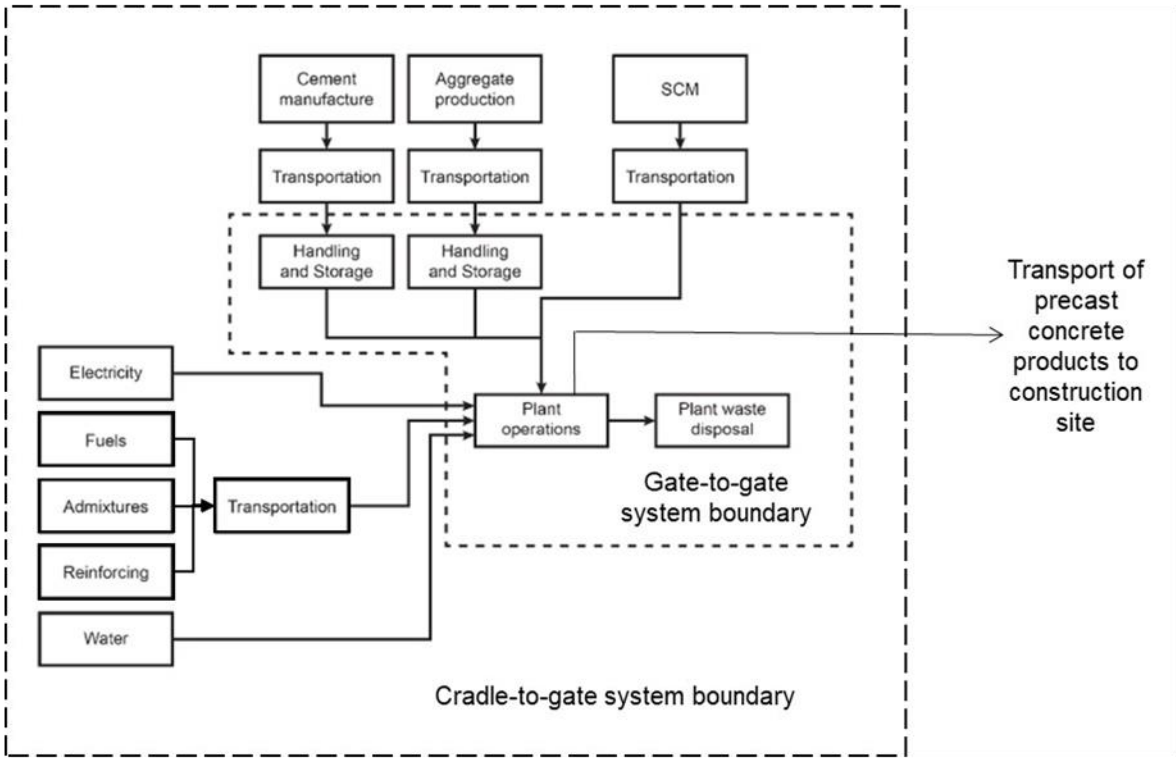

Figure 2:System boundary conditions for precast concrete elements, illustrating the difference between unit process (gate to gate) dataset and system process (cradle to gate) dataset (Source: ASTM Product Category Rules for Precast Concrete)

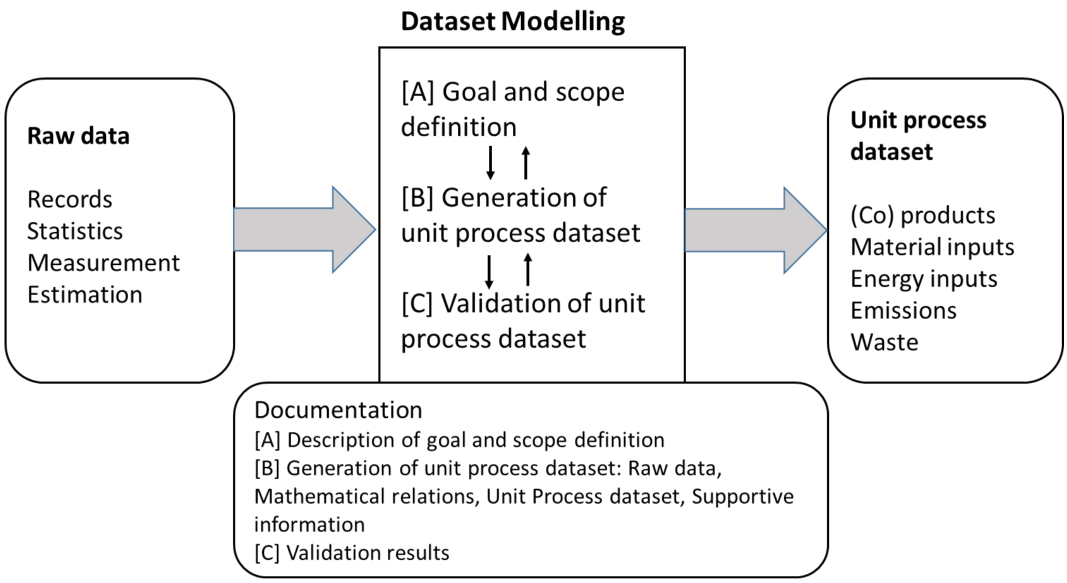

Figure 3:Dataset modelling: From raw data to unit process dataset (adapted from UNEP 2011)

There are three possible approaches to develop a national LCA database: a) use of existing LCA data (with DQA); b) adapt existing LCA data (change of electricity mix); and c) develop a completely new LCA database. Further, the database interface (interactive or not) and the functions of the database need to be finalized.

3.2 Definition of system boundaries

Different options available for defining the scope of LCA database are presented in Table 3.1. A brief description of each option is presented below.

Option-1: Cradle to Gate (A1-A3) with Modules C1-C4 and Module D. These stages are the minimum to be declared and will be based on a declared unit.

Option-2: Cradle to Gate with Modules C1-C4 and Module D with additional modules (optional) A4-A5 and B1-B7.

Option-3: Cradle to Grave with Module D (A1-A5, B1-B7, C1-C4 and D).

Option-4: Cradle to Gate: A1-A3.

Option-5: Cradle to Gate: A1-A3 with additional (optional) modules A4-A5.

Table 1:Scope of LCA database (Source: EN 15804:2012+A2:2019)

Life cycle stage	Options ('X' – mandatory; and 'O' – optional)				
	1	2	3	4	5
Product stage					
A1, raw material extraction and processing	X	X	X	X	X
A2, transport to the manufacturer	X	X	X	X	X
A3, manufacturing	X	X	X	X	X
Construction stage					
A4, transport to the building site		O	X		O
A5, on-site installation		O	X		O
Use stage					
B1, use or application of the installed product		O	X		
B2, maintenance		O	X		
B3, repair		O	X		
B4, replacement		O	X		
B5, refurbishment		O	X		
B6, operational energy use (e.g. heating system and other building services)		O	X		
B7, operational water use		O	X		
End-of-life stage					
C1, de-construction, demolition	X	X	X		
C2, transport to waste processing	X	X	X		
C3, waste processing for reuse, recovery and/or recycling	X	X	X		
C4, disposal	X	X	X		
Benefits and loads beyond the system boundary					
D, reuse, recovery and/or recycling potentials, expressed as net impacts and benefits	X	X	X		

Based on the above five options, it is recommended that Option-1 is appropriate for a simplified LCA database. The modules 'A4' and 'A5' may be excluded in the construction materials database as the transport distances and construction efforts are often unknown. This is also true for the impacts at the end-of-service life. Documenting the environmental indicators related to the end-of-life stages C1-C4 is as important as the initial product stages A1-A3 with respect to the selection of building materials in the early phases of building planning. The reader is suggested to refer to the IEA EBC Annex 72, Subtask 1.3 Technical Report on Context-specific methods for the assessment of life cycle related environmental impacts caused by buildings: Guideline for specifications issued by national authorities and private organizations (Chapters on 'Recommendations for communicating aggregated LCA results of buildings' for inputs on Indicators and Aggregation, and 'Modeling transport and construction').

3.3 LCA modeling approaches

There are two major modelling approaches namely attributional approach and consequential approach. It is recommended to follow the attributional approach for database development.
The attributional and the consequential LCA models are different with respect to the data selection and the way in which co-production processes are considered. In the attributional approach, coproduction processes are allocated based on the physical or economic relationships. In the consequential approach, system expansion including avoided processes is applied.
Further, the following two principles are considered in the definition of the system boundary for a product system (ISO 21930: 2017):
(a) Modularity principle: "*Where processes influence the construction product's environmental performance during its life cycle, they are assigned to the information module of the life cycle stage where they occur; all environmental aspects and potential impacts are declared in the life cycle stage where they can be attributed*", and
(b) Polluter pays principle: "*Processes relevant to waste processing are assigned to the product system that generates the waste until the system boundary between product systems is reached*".

3.4 Environmental indicators

The scope of the environmental indicators to be quantified for a simplified LCA database may be limited to – 1) cumulative primary energy demand (CED in MJ or kWh– renewable and non-renewable energy), 2) global warming potential (GWP in kg CO_2eq) considering both the fossil fuel and biogenic carbon (including and excluding biogenic carbon), and 3) future impact categories according to EN 15804 + A2. If the national regulation of environmental impacts of buildings is solely based on carbon footprint, then the database will only need to quantify greenhouse gas emissions. But ideally it would be important to consider (1), (2) and (3) so that LCA using EPD can be undertaken. If a national single score is used, then this should be included but the underlying data should also be available. The reader is suggested to refer to the IEA EBC Annex 72, Subtask 1.3 Technical Report on Context-specific methods for the assessment of life cycle related environmental impacts caused by buildings, Guideline for specifications issued by national authorities and private organizations (Chapter on 'Recommendations for communicating aggregated LCA results of buildings' for inputs on Indicators and Aggregation).
It could be helpful to include other indicators (e.g. EN 15804+A1, TRACI, etc.) so that data is available for use in other countries/tools using these systems. Further, water footprint, primary and secondary resource consumption such as minerals, ores and biomass should be part of the minimum list. In addition, hazardous waste, radioactive waste, non-bio degradable, hazardous and toxic substances present in the unit processes and materials may be documented. Other information should include biogenic carbon content, packaging information, etc. The reader can refer to EN 15804:2012+A2:2019 for a comprehensive list of environmental indicators suitable for building LCA databases.

3.5 Contents of the LCA database

The LCA database for the construction sector should cover the life cycle inventory data on the following areas:
construction materials,
construction processes,
deconstruction processes,
building elements (such as window frames and doors),
building components,
transport services,
building technology (Mechanical, Electrical and Plumbing services such as boiler and air-conditioning),
energy supply,
potable water production,
water supply,
waste management services,
waste water treatment, and
recycling and reuse processes.
It is suggested that the LCA database should contain generic/average LCA data and allow for accommodation of company/product specific data after successful verification. The impacts of manufacturing, transporting and the end-of-life of materials which are wasted on-site should be considered in Module A5. Default values for waste treatment and transport of building materials should reference a review of national statistics rather than the European or Swiss average from 2004. Consideration should be given to the impacts of assuming recycling or energy recovery in the countries where it is unlikely.
A review on data availability and needs, one of the steps of the scope development, is presented below based on the guidelines published by the LCA database helpdesk (UN Environment and Life Cycle Initiative, 2019).

A background LCA database consists of hundreds of unit processes to represent the key sectors and supply chain processes. While it may be challenging to develop datasets for all unit processes, identifying datasets that are of high priority is essential but challenging. The scope and the intended use of the database need to be defined clearly in order to identify data needs and data quality requirements. There are several ways in which the content goals of a national LCA database can be defined. Examples are:

- Most relevant processes or sectors based on the economic contribution (this is relevant for products manufactured within the country, but not for imported products). With respect to the construction sector LCA database, most important construction materials in terms of mass, cost or environmental impacts are considered.
- Most relevant processes or sectors in an economy based on wide-spread use (e.g. transport, electricity and cement use in the case of China)
- Processes of high environmental relevance (mining, construction and transport as in the case of Quebec, Canada)
- Processes that are unique in a country (coal based chemicals or liquid fuels as in the case of South Africa)
- Based on data availability or other regional criteria
- Based on significant imports to the country.

After the definition of the processes of high priority, the next step is evaluate the data availability. There may be several challenges such as unavailability of representative data, missing or inaccessible data, or data that does not meet the data quality requirements or database goals/intended useor data that does not meet the format requirements. It is essential to maintain the transparency of the datasets through metadata and documentation. Missing data may be replaced with a value along with justification or even considered

as zero. In such cases it is necessary to provide the information on data quality and perform sensitivity analysis if needed.
An effective way to develop a national database would be to make use of an established background database, and adapt or update the datasets to meet the country specific requirements (for example, change in electricity mix). The feasibility of this approach in terms of making the data freely available ("open access") needs to be thought out. For example, the BRE is unable to make the IMPACT database open access because the database is adapted from the eco-invent database and a license fee must be paid by each user.
Utilizing advanced concepts on data interoperability will facilitate the use of multiple complementary data sources for database development. Before exchanging datasets between databases, compatibility of the dataset protocols they rely on, needs to be ensured.

Recommended structure for the LCA database is presented below:

- generic construction product data (including ranges), which are useful for early design stages
- product-specific or company-specific construction product data
- energy and emissions factors for energy supply/potentially avoided emissions
- energy and emission factors for transport (including average distances)
- energy and emission factors for construction site activities (construction/deconstruction)
- data for cleaning products and cleaning processes
- data for items such as user furniture and carpets
- data for water supply and wastewater treatment
- factors for emissions out of products into local environment and indoor air

Further, it is suggested to discuss the overall quality of the database and/or each dataset and communicate the conditions and limits of use from the point of view of time, territory and technology.

3.6 Data quality parameters

Data quality parameters for the unit process and the aggregate process datasets are listed based on the international standards - IS 14044:2016 and EN 15804:2012+A2:2019.

a. temporal coverage: age of data and the minimum time period for data collection;
b. spatial coverage: geographical area for unit process data collection relevant to the goal and scope of the study;
c. technology coverage: specific technology or technology mix;
d. precision: measure of the variability of data values;
e. completeness: percentage of process flow that is measured or estimated; Addressing the impact categories require corresponding elementary flows in the inventory data. Hence, the elementary flows adapted to the impact categories should be considered in the database in order to ensure completeness of the inventory data.
f. representativeness: qualitative assessment of the degree to which the dataset reflects the true population (geography, time period and technology);
g. consistency: qualitative assessment on the uniform application of the study methodology to various components;
h. reproducibility: qualitative assessment of the extent to which an independent practitioner can reproduce the results using the information about the methodology and data values;
i. sources of the data;
j. uncertainty of the information (e.g. data, models and assumptions).

Data quality requirements based on the guidelines published by the LCA database helpdesk (UN Environment and Life Cycle Initiative 2019) are summarized below (http://spaces.oneplanetnetwork.org /lcahelpdesk):
There are several issues in terms of data quality. Missing data, poor representation, unreliable data source, or the need to use model outputs instead of measured data are some issues related to data quality. Mandatory requirements and optional needs may be clearly distinguished. It is important to accept the fact that the datasets vary based on the level of detail and quality. Transparency should be maintained in providing the metadata and documentation on the data quality issues. It is recommended to document the missing data for each unit process dataset during data collection. The database system should allow the users to assess the fitness of purpose based on transparent documentation, meta-information, uncertainty information, and data quality indicators. Data quality needs are directly influenced by the scope of the database and the intended application by end-users.
The definition of data quality requirements is followed by the definition of processes for data review, including the review steps, responsibilities, inputs and outputs at each step. The key questions answered during the review process for individual and aggregated processes are:

– Does the dataset meet the content requirements of the protocol established for the construction sector database in compliance with the ISO standards and the Shonan Guidance Principles?
– Does the dataset conform to the format requirement?

It is worth noting that the above steps were followed in the UK for the BRE environmental profiles database in the 1990s and for the Eco-invent database in Switzerland, both databases with the Government funding. Now, it is more common for default data to be provided (e.g. in Oekobaudat of Germany and Inies of France) with the incentives to get the trade associations and the manufacturers to provide the data.

It is concluded that the unallocated unit processes provide high degree of transparency and flexibility in terms of supporting the 1) database updates in the future, 2) system modelling choices – attributional or consequential studies, and 3) in-depth contribution or sensitivity analysis, thus leading to improved understanding of the system.
Aggregated datasets can be based on several production lines, sites, suppliers, regions or technologies (horizontal averaging) and/or vertical aggregation and these are easy to work with due to less complexity and calculation effort needed. The Shonan Guidance Principles (Chapter 3) presents a detailed guidance on aggregated process data development. To maintain the credibility of the aggregated process data, the following recommendations should be considered:

1. The unit process datasets are reviewed and verified independently before they are used for generating the aggregated process data.
2. Data providers should clearly document the motivation and the modeling approaches used and the intended use.

3.6.1 Temporal aspects: Time period of data collection

It is suggested that the data gathered for construction/production processes are annual values preferably from the previous twelve-month period or calendar year. It is noted from the EN 15804 that the most current data shall be used, and the primary data shall be no more than 5 years old. The average generic data should not be older than ten years. In case of older data, a statement on the validity of the data should be provided (EN 15804:2012+A2:2019).

3.6.2 Representativeness

Representativeness refers to qualitative assessment of the degree to which the dataset reflects the true population of interest in terms of the geographical location, time period and production technology (ISO 14044:2006). The following aspects are considered in evaluating the representativeness: a) time-related

coverage: age of data and the minimum period of time over which the data should be collected; b) geographical coverage: geographical area from which the data for unit processes should be collected to satisfy the goal of the study; and c) technological coverage: specific technology or technology mix (ISO 14044:2006).
The technological coverage should reflect the actual production/construction methods used for the declared product (ISO 21930:2017). The geographical coverage should take into account the technology representativeness, input materials representativeness, input energy representativeness for the chosen region (EN 15804:2012+A2:2019).
The LCA database for the construction sector of a country should contain the data which is representative of the market in that country. Representativeness is expressed as the share of the national market of a construction product for which the primary data is available. Whether or not a given share is considered representative should be assessed individually. Safety factors may be applied for the share for which no primary data is available.

If a manufacturer produces a construction product at several locations and markets it in the country of interest, the LCA of this construction product should take into account site specific data according to the market shares (and not according to the production volumes), for example, as presented in Table 2.

3.6.3 Background data

It is recommended that the same source (i.e. both the database and the version) for background data are used for all datasets irrespective of the LCA software tools.
Background data are all data that complement a product system. A few examples of background data are listed below:
– the electricity supply (from distribution, transmission, power plants operation, to fuel supply and finally fuel extraction) is in the background system of the manufacture of secondary steel with an electric arc furnace.
– the coal supply chain (including transport) is in the background system of clinker production.
– waste management services are in the background system of construction and demolition activities.

Table 2: Example of production mix based on production volumes, and market mix in the country of interest based on the quantities sold in that country; the market shares in the country are decisive for the life cycle assessment of the construction product sold in that country.

Production site	Production volume (tonnes / year)	Production Share (%)	Sales in the country of interest (tonnes)	Market share for that country (%)
A	100’000	28.6	200	*3.8*
B	50’000	14.3	4’000	*76.9*
C	200’000	57.1	1’000	*19.2*
Total	350’000	100.0	5’200	*100.0*

3.7 Core methodological aspects

The following sub-sections present the list of topics for which methodological guidelines need to be established in order to create the life cycle inventory datasets for the construction sector. While the core methodological aspects outlined in this section are useful for the LCA database development, it is important to acknowledge and utilize the methodological rules outlined in the standards – EN 15804 and ISO 21930. As of now, there are more than 10000 EPDs available based on EN 15804 and more than 30000 EPDs based on ISO 21930. This will facilitate the incorporation of these EPDs in the LCA database development. The methodological differences between ISO 21930 and EN15804 are limited.

3.7.1 Declared unit and functional unit

Both the functional and declared units provide a reference by means of which the material flows for each information module of a construction product are normalized to produce data, expressed on a common basis (EN 15804:2012+A2:2019 (E)).
The functional or declared unit provides the reference for combining material flows attributed to the construction product and for the addition of environmental impacts for the selected stages of the construction product's life cycle at the building level (EN 15804:2012+A2:2019 (E)). This highlights the need for clear definition of any functional unit or declared unit.
Examples of declared unit are (EN 15804:2012+A2:2019 (E)):

- An item (piece), an assemblage of items or component, e.g. 1 brick, 1 window (dimensions need to be specified);
- Mass (kg), e.g. 1 kg or 1 ton of cement;
- Length (m), e.g. 1 m of pipe, 1 m of a beam (dimensions need to be specified);
- Area (m^2), e.g. 1 m^2 of wall elements, 1 m^2 of roof elements (dimensions need to be specified);
- Volume (m^3), e.g. 1 m^3 of timber, 1 m^3 of ready-mixed concrete.

The functional unit of a product may incorporate certain aspects of functionality that are not always required for a particular use case of that product (ISO 21930:2017 (E)). For example, a concrete block can have a structural performance functionality, acoustic functionality or thermal functionality. The functional unit is used as the basis for comparison of two or more products for a given use case (ISO 21930:2017 (E)).
Example of a functional unit: a roofing product sufficient to cover 100 m^2 of a building, maintain a barrier to water penetration into the building and to include any repair, refurbishment or replacement of replaceable components over a required service life of 50 years (ISO 21930:2017 (E)).

3.7.2 Allocation

3.7.2.1 Allocation in multi-output processes

Allocation refers to partitioning of inputs and outputs to multiple (co)products generated from a unit process. The sum of allocated inputs and outputs should be equal to the inputs and outputs of a unit process before allocation. Sensitivity analysis may be used to illustrate the consequences of adopting a specific allocation procedure when there are several options available for allocation.
It is recommended that multi-product unit process datasets are provided as unallocated datasets to enhance flexibility in the usage later. As a result, allocation should be avoided wherever possible using any of the following options:

1. divide the unit process to be allocated into two or more sub-processes and collect the input and output data for these sub-processes
2. expand the product system to include the additional functions related to the co-products (system boundary expansion)

While the above concepts are valid for unit process development, an appropriate allocation methodology needs to be chosen at the national database level (e.g. based on EN 15804).
The recommended allocation procedures for the shared unit processes are (in order):

- based on physical relationships (for joint co-production processes where the differences in the revenue are low)
- based economic relationships (for joint co-production processes with differences between the co-product revenues being higher).

Material flows carrying specific inherent properties, e.g. energy content, elementary composition (e.g. biogenic carbon content), shall always be allocated reflecting the physical flows, irrespective of the allocation chosen for the process.
In the case of outputs containing partly co-products and partly waste, the ratio between co-products and waste should be identified and the inputs and outputs are allocated only to the co-products. This is the only difference between EN 15804 and ISO 21930 – as ISO 21930 follows the wastes through recovery to the system boundary and considers their benefit in Module D, whereas EN 15804 allocates impacts to all the co-products leaving the system boundary, though for low value co-products, this can be ignored as conservative when assessing the impact of the high value co-product.
Further, there should be uniformity in the allocation procedures used for usable products (e.g. intermediate or discarded products) leaving the system and products entering the system.
We recommend not to allow avoided burden approaches in life cycle inventories of construction material manufacture and their supply chains.
Alternate school of thought reflecting the industry perspective: The idea that the database would include unallocated datasets is unrealistic. It is suggested that the datasets should be produced according to EN 15804 or another methodology.

3.7.2.2 Allocation applied on recycling

The allocation applied on recycling as described in EN 15804+A2 is recommended. It is described as follows (excerpts from the clauses 6.3.5.5 and 6.4.3.3): The end-of-life system boundary of a construction product system is set where outputs of the system under study, e.g. materials, products or construction elements, have reached the end-of-waste state. Therefore, waste processing of the material flows are included up to the system boundary of the respective module as defined above. All recovery or recycling processes beyond this system boundary are attributed to the next life cycle phase.

The end of waste state is reached when all the following criteria are met:
– the recovered material, product or construction element is commonly used for specific purposes;
– a market or demand, identified e.g. by a positive economic value, exists for such a recovered material, product or construction element;
– the recovered material, product or construction element fulfils the technical requirements for specific purposes and meets the existing legislation and standards applicable to products;
– the use of the recovered material, product or construction element will not lead to overall adverse environmental or human health impacts.

Recovered material and energy do not carry allocated burdens and have no impacts when they cross the system boundary between the product systems. In EN 15804, this is not the case for pre-consumer waste leaving product systems from A1-A3 which can have impact allocated at the system boundary. In ISO 21930, this is correct as these flows would be considered in Module D.
As per the ISO 21930:2017 standard, Module D is not a form of allocation and does not show allocated impacts. Module D only shows the optional/supplementary information. For secondary material, secondary fuel or recovered energy flows arising from waste, it is recommended that there is no shift of burdens across the system boundary (from one product system to the other).

3.7.3 Cut-off rules

Cut-off rules specify the criteria for the inclusion and exclusion of inputs and outputs during the compilation of life cycle inventory data specific to facilitate efficient calculation procedure. It is recommended to justify and document the cut-off rules used to develop the dataset. Cut-off rules for environmental impacts will be related to the respective material flows.
The procedure for inclusion and exclusion of inputs and outputs are listed below [ISO 21930: 2017]:
All inputs and outputs to a (unit) process shall be included in the calculation, for which data are available. It is recommended to fill the data gaps by conservative assumptions with average, generic or proxy data. Assumptions for such choices should be documented.

We recommend to implement the following rules:
Material and energy flows that are known or suspected to release substances into the air, water or soil in quantities that contribute significantly to any of the pre-set indicators should be taken into account.
In the case of insufficient input data, the cut-off criteria shall be 1% of the renewable primary resource (energy), 1% of the nonrenewable primary resource (energy) usage, 1% of the total mass input of that unit process and 1 % of environmental impacts. The total of neglected input flows per module shall be a maximum of 5 % of energy usage, mass and environmental impacts.
All substances with hazardous and toxic properties that are a source of concern for human health and/or the environment should be identified and declared.

3.7.4 Emission certificates

It is recommended not to include carbon offset certificates in the aggregated process datasets (ISO 14067, 2011). Mechanisms for compensating for the environmental impacts of products are outside the boundary of the product system (ISO 14067, 2011).

3.7.5 Biogenic carbon

The biogenic carbon refers to the carbon derived from biomass. The biogenic carbon content present in a construction product should be declared for the product leaving the factory gate as well as for any related packaging content. The standards EN 16449 and EN 15804+A2 may be used to measure and report the biogenic carbon content of wood based products. The reader is suggested to refer to the IEA EBC Annex 72, Subtask 1.3 background technical report on ‘Guideline for specifications issued by national authorities and private organizations: Chapter on Biogenic carbon’ for detailed inputs.
The declaration of biogenic carbon content is not needed if the mass of biogenic carbon containing materials in a product is less than 5% of the product mass. Similarly, the declaration of biogenic carbon content of the packaging is not necessary if the mass of biogenic carbon containing materials in the packaging is less than 5% of the total mass of the packaging.
It is recommend to report the biogenic carbon content embedded in construction materials and products in “kg Carbon”. The indicator ‘biogenic carbon content’ shall not be converted to CO_2, but, the biogenic carbon flows should be addressed in GWP biogenic. The biogenic carbon content shall not be converted to (negative) CO_2 emissions nor added to the greenhouse gas emissions caused in the supply chains, during the use and the end-of-life stages. However, the biogenic carbon should be considered when quantifying the indicator, biogenic global warming potential (GWP-biogenic described in EN 15804+A2 C.2.4), which is a sub-category of the indicator, Total global warming potential (GWP-total).The situation is the same in ISO 21930 which also accounts for the biogenic carbon in the same way.

3.7.6 Carbon offset, carbon storage and delayed emissions

A carbon offset refers to reduction in carbon dioxide emissions or other greenhouse gases made in order to compensate for emissions elsewhere. It is recommended not to include the following aspects in the calculation of the GWP as per the standard EN15804:2012+A2:2019: (a) carbon offsets, and (b) the effect of temporary carbon storage and delayed emissions (i.e. discounting of emissions and removals). However, it is recommended to take into account the effect of permanent biogenic carbon storage. The reader is suggested to refer to the IEA EBC Annex 72, Subtask 1.3 background technical report on ‘Guideline for specifications issued by national authorities and private organizations: Chapter on Biogenic carbon’ for further information.

3.7.7 Carbonation

Cementitious building materials can carbonate during the use and disposal stages. During carbonation, part of the geogenic CO_2 released during production is removed from the atmosphere and is incorporated into the building material.

The extent of carbonation depends on various influencing variables, in particular the exposure of the component, the geometry and thickness of the component, the presence of water, any measures taken against carbonation and any coatings.
Due to this strong dependence on component-specific characteristics, it is not possible to state a general carbonation effect (expressed as CO_2 removal) for cement-containing building materials.
If necessary, the carbonation of cement-containing building components can be quantified in the use phase. However, an estimation on a real building has shown that the CO_2-binding effect is only between 1 in 1000 or 0.1% (best estimate) and 1 % (maximum value), related to the greenhouse gas emissions of the construction of the building (Werner & Frischknecht 2018).

3.7.8 Electricity mix applied in manufacturing (A1-A3)

The actual production mix is used wherever possible in determining the elementary flows related to production. For example, the electricity mix, the efficiencies of fuel combustion, conversion, transmission and distribution losses are taken into account for modelling the production and the delivery of the electricity (ISO 14044: 2006). The assumptions and calculation procedures used for modelling the electricity use should be documented clearly. To maintain consistency, it is recommended to use the same calculation procedures throughout the database.
In some electricity markets like the one in the European Union, the Guarantees of Origin (GoO) are available and sold separately from the electricity production. The GoO documents the purchase of a certain quality of electricity (e.g. electricity produced with hydroelectric power plants). The following cases may be distinguished:

- A manufacturer purchases electricity and GoO independent from each other;
- A manufacturer purchases electricity and GoO coupled, i.e. the electricity purchased is produced in the same powerplants like the GoOs purchased.
- If the Guarantee of Origin (GoO) is allowed, then the residual mix should be used for any energy not provided with the GoO to avoid double counting of the benefits of renewable energy.

Manufacturers purchasing electricity on the free market shall couple the purchase of electricity production and GoO. This allows them to apply the corresponding power plant mix in the life cycle inventory data of their construction materials.
If they purchase electricity and GoO separately, they shall apply the mix of the electricity production in the life cycle inventory of their construction materials. If unknown, the respective average country mix shall be applied. In this case, GoO may be reported as an improvement measure. This rule is similarly applicable on biogas certificates and guarantees of origin. As for electricity, tracking and the prevention for double counting is required as per ISO 14067. Residual mix (natural gas) should be used if there is no GoO. For additional inputs, the reader is suggested to refer to the IEA Annex 72 subtask 1.3 report titled "Electricity mix models applied in the use stage of buildings' LCA".
The EcoPlatform has now required that if the programme accepts the use of GoO, then the residual mix shall be used for all electricity that is not accompanied by GoO. This follows the approach in ISO 14067 in preventing double counting of the benefits of GoO in both the consumption mix and those using GoO. It will be part of EN 15941, which is expected to be voted in 2022 (data quality requirements for EPD and Building LCA).

3.7.9 Packaging

For certain building materials, the use of packaging minimizes the waste and transportation impacts. The production stage includes the manufacturing of packaging materials (A3) in addition to the manufacturing of materials. In such cases, the amount of packaging materials used along with the technical specification of the packaging materials shall be considered. In case of completeness check performed to compare multiple options, packaging is considered along with material production, energy supply, transport and processing. The mass of the packaging waste generated during the site installation (Module A5) should be quantified (in kg or other appropriate unit) with reference to the functional or declared unit. The construction process stage includes the following optional modules with reference to packaging:A4-A5 processing of the

waste from product packaging during the construction processes up to the end-of-waste state or disposal of final residues (EN 15804:2012+A2:2019).
The mass of the packaging materials shall always be declared. The declaration of the biogenic carbon content of the packaging material is required if the mass of biogenic carbon containing materials in the packaging is more than 5 % of the total mass of the packaging.

3.7.10 Default transport distances

The information module ‘A4 - transport to site’ includes the following components:
- transport from the factory gate to the central warehouse or other intermediate storage location
- transport to the construction site.

The transport distance used in the information module ‘A4’ should be as specific as possible including the type of transport. The distance to the construction site may be estimated based on weighted average distance to the market (ISO 21930:2017). In the absence of specific data, the assessment of 100 km of a typical transport may be provided. Although this is not the most likely scenario, this would enable the users to scale the results and represent the transport to a particular construction site.
Supply logistics of raw materials and intermediate products to construction material manufacturing sites may be represented by default transport distances and modes of transport in the case of lack of data. Examples of such default values are given in Table 3 (excerpt from Frischknecht et al. 2004).

3.7.11 Default waste management practice

The building material waste is generated during the construction, use/operation and demolition of buildings. To quantify the amount of waste generated, the following life cycle stages are considered:
- the construction (installation) stage (A5). It needs to be clear that for the calculation of impacts from construction waste in A5, the impact of manufacturing the wasted product, transporting it, as well as disposing of it should be included.
- the end-of-life stages (C1-C4): de-construction / demolition (C1), transport to waste processing (C2), waste processing for reuse, recovery and/or recycling (C3) and disposal (C4).The end-of-life- stage also includes the transport, provision of all materials, products and related energy and water use.
- the recurring construction activities during the operation stage - maintenance (B2), repair (B3), replacement (B4) and refurbishment (B5).

Among the above three life cycle stages, the waste generated during the end-of-life stage assumes more significance due to the large quantity of waste generated. The quantity and the relative percentage of construction and demolition waste treated using different methods such as landfilling, recycling and incineration should be documented for materials such as concrete, steel, plastics and wood.

It is recommended to apply material specific default waste management practices according to the waste management practice today such as 100% recycling of structural steel, 30% landfill and 70% recycling of concrete, 50% incineration and 50% recycling of wood and wood based materials. Table 3 presents the default transport distances for various materials. It is important to acknowledge that these values vary based on the country and the geographical location within each country.
Most EPDs for steel do not assume 100% recycling. For concrete, the recycling is generally higher. For timber, recycling is probably lower than 50% and energy recovery is probably higher, but there is a lot of variation by country, and by product. It is recommended to use national statistics where possible, if the EU average is not available.

3.7.12 Production waste and waste generated on the construction site

If a part or 100 % of the production waste and construction site waste and the offcuts of a building product is recycled and reused in the production of this same building product, the expenses for recycling (logistics, cleaning and processing) are attributed to the recycled part. The expense should be allocated according to the end-of-waste state, though if it is reused in the same building, it doesn't really matter where it is attributed. When modeling the production, the raw material input needs to cover the amounts of products plus the amounts of production wastes. For waste on the construction site, the manufacture of the waste needs to be accounted in A5, together with its transport and disposal.

Table 3: Densities and standard transport distances of materials (from the place of production to its use), (excerpt from Frischknecht et al. 2004)

Item	Density	consumption in Europe	
	kg/m³	km train	km lorry 32t
mineral products:			
gravel / sand	2'000	-	50
cement	3'150	100	100
concrete (w/o reinforcing steel)	2'200	-	50
float glass	2'500	600	100
metals:			
steel/ cast iron	7'900	200	100
copper	8'900	200	100
aluminium	2'700	200	100
plastics:			
PVC	1'400	200	100
PE	950	200	100
PP	900	200	100
wood (from Swiss forests):			
sawn timber (softwood)	450 [1]	100	50
structural timber (softwood)	450 [1]	-	100
particle board	680 [1]	200	50
basic chemicals, inorganic (carrier substance to be considered additionally):			
caustic soda	1'045	600	100
soda (sodium carbonate)	2'532	600	100
hydrochloric acid	909	200	100
sulphuric acid	1'840	600	100
nitric acid	1'383	600	100
phosphoric acid	1'685	600	100
hydrofluoric acid	993	600	100
basic chemicals, organic:			
ethylene		600	100
naphtha		600	100
refrigerants		600	100
organ. solvents		600	100
pesticides		600	100
gases (if not produced on the spot)			
if bought in cylinders: doubling of transport distances (due to tare weight)			
oxygen		100	50
nitrogen		100	50
hydrogen		100	50
helium		100	50

[1] absolutely dry.

Notes:

a. The relevance of data with respect to time i.e. 2021 or 2022 needs to be taken into account.

b. The applicability of transport distance with reference to the geographical location and the construction sector need to be noted.

c. The differences in the transport distances between domestic products and imported products need to be taken into account.

3.8 Specific methodological aspects

3.8.1 Prefabricated building elements

The efforts and emissions of prefabrication shall be part of the production LCI (Module A3). The efforts and emissions of fabricating building elements on the construction site are part of the construction process (Module A5), which in some countries are not part of the buildings' LCA. When comparing prefabricated alternatives to in-situ construction solutions, on-site efforts and emissions should be included.

3.8.2 Imported construction materials

Imported construction materials should be modelled according to the national guidelines. Future development of an international harmonised database could be proposed in order to facilitate the exchange of high environmental quality products.The import transport distance should be defined between the places of manufacture and a dedicated location in the country of destination (e.g. the capital, or geographical centre of the country). The embodied footprint of imported materials (A1-A3) should be based upon the domestic market mix in the country of manufacturing. Further, the shipping (transport) to the country of destination (A4) is taken into account.

3.8.3 Overheads

Efforts of overhead activities of construction material manufacture (administration, research and development, marketing) should be disregarded. This is only if they are not within the cut-off rule. If they are significant they should be included.

3.9 LCA data on future construction material manufacturing

This refers to establishing an LCI database with data on future electricity mix (e.g. 2040-2050), manufacturing of construction materials/products, building technology manufacture, energy supply, transport services, and waste management services (for example, Alig et al. 2020; Zhang, 2022).

These future LCA data may be used in sensitivity analyses to represent the energy consumption (module B6) via forecast data for future energy mix and replacements (module B4) via forecast date for low carbon products in the use phase. LCA data is used for modeling future scenarios in many countries, for example, in Austria (future construction material manufacturing), France (research design; data regarding PV production), Denmark (regulation, B6), Germany (data available but only energy, not applied so far, dynamic assessment is under discussion) and Switzerland (transport data, B8). Further guidance is required on how to carry out this - for example, consulting BREF, Industry and Government Decarbonisation plans and Net Zero Roadmaps of industry associations.

3.10 Product Groups

If a company produces a large number of similar products at one location, an average life cycle assessment can be prepared for these products. If necessary, individual product life cycle assessments can be created with the help of key parameter models. The main influencing parameters can be entered in the key parameter models. For example, in the case of sanitary pipes, there are a large number of plastic pipes made of the same material with different diameters and wall thicknesses. The life cycle assessments of these pipes can be presented by means of a key parameter model in which diameter, wall thickness,

weight per metre and other parameters can be entered individually. In this case, an impact per kg would very likely be the most representative way to provide impact.
If the individual products manufactured at a site differ significantly, LCAs of product groups should be provided with a suitable and sufficiently justified categorisation.
In the example of window frame manufacturers (plastic and wood-metal window frames), the following options are available:

– One average balance each for plastic and wood-metal window frames
– In addition, within the two frame types, a distinction between double and triple insulating glazing.
– In addition, a differentiation into window frames of different formats

In this example, we consider a differentiation at the level of different frame materials to be a suitable categorisation.
Due to the increasing level of detail, the effort required to create and document the balances increases.
The appropriate categorisation should adequately take into account the requirements of the national LCA database for the construction sector and the needs of the manufacturers.
The deviation in the environmental parameters per kg (or per functional or declared unit) should be used as a reference value for differentiating the products. In the following cases, similar construction products shall be declared separately:

– An environmental performance indicator of a specific product variant deviates by more than 15 % from the mean value of all products;
– All environmental parameters of a specific product variant deviate by at least 10 % from the mean value of all products.

The allocation of the site's expenditures and emissions to the individual products and product groups shall be made according to the following criteria:

1. physical laws: The mass balance (total inputs equal total outputs) should be largely fulfilled for individual products and product groups (Example: windows with the products wood frame and wood chips - the process "production of one tonne of wood chips" must have at least one tonne of wood as input).
2. economic laws: If no reasonable and plausible physical laws can be derived, the income generated with the various products or product groups should be used as a basis (Example in the case windows: for energy expenditures (electricity for machines and lighting), the relative prices of the products should be used for allocation).
3. The granting of credits for by-products produced at the same time, which are sold to third parties and used in other production processes (this also includes steam and electricity), is not permitted.

Actually, EN 15804 6.3.5.2 explicitly states that co-product allocation should be used for co-products from production processes.

3.11 Scope of data to be collected

The life cycle inventory of production of construction materials/products requires collection of the following data:

– Description of the (manufacturing) process;
– Production volume (reference unit for all other data);
– Consumption of primary raw materials[1] and secondary materials, semi-finished products and working materials;
– Provenience and transports of raw materials, semi-finished products and working materials;
– Consumption of energy (specified for electricity, fuels, district-heat etc.); electricity and district-heat including information about technology/fuel shares;
– Consumption of water (specifying ground water, surface water, water from water works - tap water);

[1] To support the management of primary resources this information should be subdivided into minerals, ore, biomass and fossil energy carrier.

- Amount of water discharged with sewage pipes, to rivers, lakes and the sea, evaporated and embedded in product, respectively;
- Process specific emissions of airborne pollutants;
- Amount of waste water and its pollutants concentration;
- Production wastes (amounts, further treatment, i.e. recycling, incineration, landfilling, hazardous waste[2] treatment);
- Packaging materials and the waste treatment for these materials;
- distribution of the products to regional storage facilities;
- Data about the site: area covered with production halls, buildings, traffic area, green area, volume and number of storeys of buildings and halls.

  It is suggested to consider mean values (and range as additional information) along with geometric standard deviation during data collection to allow uncertainty assessment through techniques such as Monte-Carlo simulation.

  In addition, the following items are useful beyond the regular LCI data:
  a. Technical characteristics
  b. Service life
  c. Recommendations for inspection and repair
  d. Maintainability
  e. Option for disassembly
  f. Option for take back by the producer (options for refurbishment/modernization for technical systems)
  g. Option for reuse and recycling
  h. Link to the sustainability report of the producer

3.12 Recommendations for using LCA data from other countries

Adaptation of LCA datasets from other countries can be based upon ‘contextualisation’. Changes in the electricity production mix used for manufacturing materials (if electricity is used), fuel supply mix, transport distances and waste management processes should be assessed specific to a particular location/country and this data can be used for modifying specific aspects of datasets (Peuportier and Schalbart, 2018). Further, the adaptation of indicators may be considered if needed (the use of different technology - for example in some countries, products are manufactured using electricity, in others using natural gas; there may also be different use of raw materials and recycled content). This would require recalculation of indicators considered for adaptation from an inventory.

Steps for adapting data would include: 1) identification of processes that differ (e.g. electricity production mix, waste treatment, and local transport distances); 2) data collection on corresponding quantities (kWh electricity consumption, kg treated waste, and t-km transport); 3) subtract the corresponding elementary flows or impacts; and 4) replace with the elementary flows or impacts corresponding to national processes. In addition, the guidelines are available to use existing datasets (EPDs) of building products as generic data in the national context using the ‘NativeLCA’ methodology (Silvestre et al. 2015).

The adaptation purely based on electricity mix is inappropriate without the consideration of differences in the technologies.Other methods which could be considered are based on averaging (sometimes including weighting) of existing EPD and datasets, for example, the Inventory of Carbon and Energy Database v3 used in the UK (Jones, 2019). Also, common is the use of "safety factors", uplifts, etc. - e.g. applying dif-

[2] Including nuclear waste as a result of the use of nuclear power in the up- and/or downstream processes

ferent safety factors to a single specific EPD, several specific EPD, or an existing dataset from the Eco-invent database or GaBi (examples are the approach used in the Inies database of France and the Oekobaudat database of Germany).

3.13 Interoperability of LCA datasets and LCA database

This section presents an adapted version of interoperability related guidelines provided by the LCA database helpdesk (UN Environment and Life Cycle Initiative (2019), URL: http://spaces.oneplanetnetwork.org/lcahelpdesk).

Dataset development involves handling a large amount of data and meta-data and there are a number of life cycle formats available. The ISO standard – ISO/TS 14048: 2002 provides guidance on data documentation for developers. It is common for users and practitioners to use multiple databases and data sources as a product under consideration consists of hundreds of unit processes and gathering background data for all unit processes would be time and resource intensive. Also, it is common for the database developers to use different formats across the world although they follow the ISO standard for data documentation. As a result, it is highly important for the national LCA databases to be interoperable with the existing databases to promote widespread use.

The advantage of using multiple databases (through data interoperability) is that it improves the completeness of the LCA study. At the same time, the user is suggested to take care of the differences in modelling and methodology (including system boundary), and in data quality requirements from multiple sources. Several standardized data formats are available to facilitate data exchange based on Extensible Markup Language (XML) and data formats suggested in the ISO/TS 14048 standard. A brief description of few examples for data format are presented below.

International Reference Life Cycle Data System (ILCD): This was originally started as the ELCD in the year 2005 and later revised or adapted as ILCD under the coordination of the Joint Research Centre of the European Commission (EC-JRC). The Life Cycle Data Network (LCDN) later superseded the function of the ELCD. The ILCD data format supports data exchange i.e. import and export across many LCA databases and software tools. This format is also useful for projects related to Product/Organization Environmental Footprint (PEF/OEF). Detailed guidelines are available on the application of ILCD data format at the EC-JRC web portal. Several LCA software tools support the ILCD format. In addition to LCDN, the ILCD format has been used for the national databases in Brazil (SICV), Malaysia (MYLCID) and Thailand.The ILCD format is also required for background data in EN 15804+A2.

ecoSpold: The ecoSpold data format (ecoSpold v1 and v2) is primarily associated with the eco-invent and the UVEK database. This is based on XML and is an open-source format. This format is supported by many LCA software tools and has been used in Australia (AusLCI), Peru (PeruLCA) and Canada (Quebec LCI) for development of the national LCA databases.

JSON-LD: JSON-LD data format refers to JavaScript Object Notation for Linked Data format which has been designed and implemented by Green Delta. The advantages of this data format are reduced effort and time for implementation, removal of inconsistencies in the data format, human-readable format, and ease of integration into web-applications. This format is supported in the openLCA software tool and GLAD data format. There is limited support for this data format in other LCA software tools.

It is not a challenging issue to read any of the above formats. The most important aspect is the completion of inventories (number of elementary flows) allowing a calculation of impact indicators, or the precision of these indicators if they are provided by the database.

Interoperability with the GLAD network: The Global LCA Data Access (GLAD) network, hosted by the UN Environment, facilitates improved data accessibility and interoperability among multiple data sources. The GLAD network presents the users an interface to access LCI datasets from multiple independent LCA databases (referred as nodes). Interoperability of data across nodes in different data formats is achieved by meta-data descriptors. Requirements to join the GLAD network are - 1) use of ILCD or ecoSpold data format, 2) adherence to a common flow nomenclature, 3) searchable meta data information in English and 4) free access to datasets. The GLAD web portal provides the guidelines for dataset developers on establishing a node and linking the datasets to GLAD network. It is suggested to use the United Nations Standard Products and Services Code (UNSPSC) for mapping the process datasets. It is necessary to recognize that the interoperability is one of the primary requirements of new database initiatives which would increase the visibility of the database through the platform provided by GLAD network. Few key functions expected by the LCA database users are ability to search and find datasets, import datasets and use datasets for LCA case studies.

Workflow for integration of BIM and LCA database: At the moment, BIM tools provide sometimes wall composition names (e.g. external wall, roof, etc.) and not always the material names in different layers. The material properties are rarely addressed in BIM models. The LCI data are to be associated with the materials in the second step, after importing a BIM model/data into the LCA tool.

The main need for interoperability is in terms of use in BIM and building LCA. There is the ILCD+EPD format which has been adopted by EcoPlatform and builds on ILCD to provide the EN 15804 indicator data. There is also the work of ISO TC59 SC17 WG3 (led to the development of EN ISO 22057), which provides a digital format for EPD to EN 15804 and ISO 21930 as well as for generic databases. This uses the data template format as set out in the BIM Standards.

From the industry perspective, the ILCD+EPD are currently considered as the best option, although the Open EPD (buildingtransparency.org) has some merits. The ISO 22057 standard will provide a digitized format for EPD to EN 15804+A1, +A2, ISO 21930 and for generic data, and is developed using the approaches set out in the BIM standards developed by ISO TC59 and CEN TC 442. It extends both the ILCD+EPD and OpenEPD formats.

There are various data formats available which facilitate data exchange on different levels (unit process, life cycle inventory results, and environmental impact category indicator results). For a simplified LCA database that should be used on the building level, a simple format of LCA data (e.g. 14 LCIA indicators and their values, etc.) could be sufficient. Additional information is available through the reports published by the Annex 72 Subtask 2 group on building assessment workflows and tools.

3.14Templates for data collection

In this section, a few templates for building the LCA database are provided, adapted from the ISO standard on LCA (IS/ISO 14044: 2006). These include:

– Data sheet for unit process inputs from and outputs to other technical processes (Table 4)
– Data sheet for unit process upstream transportation (Table 5)
– Data sheet for unit process internal transportation (Table 6)
– Data sheet for unit process in-situ emission of pollutants and extraction of resources (Table 7)

Table 4: Data sheet for unit process inputs from and outputs to other technical processes

Completed by:	Date of completion			
Unit process identification:	Location:			
Time period: Year	Starting month:	Ending month:		
Description of the unit process:				
Material inputs (direct use of resources):	Units	Quantity	Description of sampling procedures	Origin
Water use:	Units	Quantity		Water at source (own source) Delivered water (by water suppliers)
Energy inputs:	Units	Quantity	Description of sampling procedures	Origin
Waste treatment services (list of wastes and their treatment):	Units	Quantity	Description of sampling procedures	Treatment (for example: landfilling, incineration, underground repository, recycling)
Material Outputs including products:	Units	Quantity	Description of sampling procedures	Destination
Note: Data in this data collection sheet refer to all unallocated inputs and outputs during the specific time period.				
Examples of water use are surface water and drinking water.				
Examples of energy inputs are fuel oil, kerosene, gasoline, natural gas, propane, coal, biomass and grid electricity. Specify electricity mix, if different from supply mix of the country.				

Table 5: Data sheet for unit process upstream transportation

Name of the intermediate product	Road Transport			
	Distance (km)	Truck capacity (tonnes)	Actual load (tonnes)	Empty return (Yes/No)

Note: Equivalent datasheets should be used for rail or water transport (for example, shipping from China may be significant).

Table 6: Data sheet for unit process internal transportation in a plant for a specific period of time

	Total amount of input transported	Total consumption of fuel
Diesel oil		
Gasoline		
Liquified Petroleum Gas (LPG)		

Note: Additional columns may be used for determining the minimum and the maximum values from different time periods.

Table 7: Data sheet for unit process in-situ emission of pollutants and extraction of resources

Unit process identification:			Reporting location:
Direct releases (Emissions) to air (For example inorganics: CO, CO_2, dust/particulates, F_2, H_2S, H_2SO_4, HCl, HF, N_2O, NH_3, NO_X, SO_2; and organics:hydrocarbons, PCB, dioxins, phenols; metals Hg, Pb, Cr. Fe, Zn. Ni, radionuclides such as Rn222)	Units	Quantity	Description of Sampling Procedures
Direct releases (discharge) to water (For example: BOD. COD, acids, Cl_2, CN_2", detergents/oils, dissolved organics, F^- Fe ions, Hg ions, hydrocarbons, Na^+, NH_4^+, NO_3^-, organochlorides, other metals, other nitrogen compounds, phenols, phosphates, SO_4^{2-}, suspended solids, radionuclides such as C_{14})	Units	Quantity	Description of Sampling Procedures
Direct releases (waste) to soil (For example: pesticides applied in agriculture and on railway tracks, heavy metals(contaminants in fertilizers applied in agriculture).)	Units	Quantity	Description of Sampling Procedures
Other releases (For example: noise)	Units	Quantity	Description of Sampling Procedures
Describe any unique calculations, data collection, sampling, or variation from description of unit process functions (attachadditional sheets if necessary).			
Resource extraction (For example: gravel, gypsum, iron, gold, lithium)	Units	Quantity	Description of Sampling Procedures

Land use (For example: arable, permanent crops, pasture and meadows, built-up land, road and rail networks, forests (extensive, minimal impact logging, intensive)	Units	Quantity	Description of Sampling Procedures

4. Assessment of current status

The current status assessment helps to identify where to start in the development of a national LCA database for the construction sector. It would involve discussion on the following aspects:

- Analysis of the current state of LCA application in the country.
- Identification of the needs regarding LCA in the construction sector.
- Use of LCA in the construction sector (yes/no; in which cases, nationally or in selected provinces?).
- Governmental bodies currently in charge of environmental aspects of buildings and construction.
- Available LCI/LCA datasets and databases in the country or in selected provinces.
- LCA experts, research organisations and consulting companies active in the country.

The results of this assessments help to identify the technology readiness level and may be used to establish a roadmap. This roadmap takes into account the current national context and situation as well as the level of expertise. How such a roadmap may look like and what it should cover is presented in the next Chapter.

5. Development of a roadmap

The roadmap development for an LCA database would involve answering a set of “preparatory questions” listed below (FICCI Quality Forum, 2016):

- Why do we need the LCA database?
- Who would host the database (location) and maintain?
- Who are the potential stakeholders and what are their roles?
- What is the contribution of the database with reference to the Sustainable Development Goals (SDG's) and the Intended National Contribution?
- What are the potential benefits mapped to specific stakeholders?
- What are the linkages for strengthening the business case for the national LCA database?
- What are the benefits of the national LCA database in general?
- What are the concerns and inhibitors related to database development?
- What is the role of the Government?
- What are the capacity building initiatives needed for database development?

- What type of database protocol would be used?[3]
- What are the challenges related to the maintenance and update of the database?
- How the database development is linked with the CSR and Sustainability initiatives?
- How are the stakeholders contributing towards the database development?
- How is the coordination with the international efforts planned?
- How is the proposed development linked with the existing protocols?
- How are the data collection efforts planned?
- How is the quality of the datasets controlled?
- How do you identify the priorities for the database development in terms of products, materials and processes to be studied?
- How do you plan the capacity development related initiatives?
- How do you plan the financial aspects of database development? How do you assess the budget requirements?
- How to adapt the supply chain related datasets from other countries?

The maturity level of the LCA database development at different time periods can be assessed using the following indicators:
governance, capacity building efforts, application, funding/fund raising, IT infrastructure/formats used, datasets quality, and interoperability of datasets.

5.1 Overview

This chapter is an adapted version of the guidelines published by the UN Environment and Life Cycle Initiative (2019). The elements of a roadmap for establishing a national LCA database consists of the following steps:
- Vision and goals
- Governance and management
- Funds and financing
- Human resources
- Database hosting
- Data needs and availability
- Data quality requirement and overview
- Data format and database interoperability
- LCA application in policy making

5.2 Vision and goals

The vision, strategy and goals are formulated based upon the following:
- Context and motivation to create a database
- Needs of the potential users and the country
- Awareness of stakeholders and consensus building among them on the proposed vision and goals
- Purpose of the database and the expected role of the database in solving specific problems / challenges
- Realistic assessment of the current situation and the projected scenario
- Role of the LCA database in supporting public policies related to Sustainable Development Goals, environmental performance improvement and other applications

[3] See section 3 of this report for a list of topics covered by such a protocol.

5.3 Governance and management

In addition to the initial development of the LCA database, maintenance and update of datasets over time and the long-term management of the database have to be taken into consideration. It is also important to maintain consistency among the datasets and meet the data quality requirements. It is also necessary to document the roles and responsibilities of the stakeholders who would manage and use the database. Chapter 6 provides an overview of governance structure and management for the national LCA database development.

5.4 Funds and financing

The cost of establishing LCA database is related to the following functions: manpower for operation and management of the database, capacity building, database development, and review/update of datasets. Financing of an LCA database can be either through public funds (for example, LCA database development in Australia, Brazil, Switzerland, Malaysia, Thailand and Peru) or private industry funds. Privately funded LCA database will often be run by consultants or corporations with a background in sustainability and the access to such databases will be based on a license fee. In several developing countries, seed money for capacity building is provided by the European commission, UN Environment, the Life Cycle Initiative and standardization institutes.
It is recommended that the initial phase of the national LCA database development should identify the specific needs of one or a few stakeholder groups and provide necessary resources to meet their requirements. There are several global background LCA databases available and these can be utilized to provide supplementary data for sectors not covered or supply chain processes outside the boundary of a country. The need for free access to the database for certain user groups can be implemented in parallel with the development of a commercial model (based on license fee) for other user groups. It is necessary to highlight the value created by the database for user groups in order to promote the development of the commercial model. The number of users of the database, sustainability benefits and sustainability innovation achieved in the industry are some indicators used to assess the value created by the LCA database.

5.5 Human resources

The human resources are required for information technology support and the development and review of datasets and the whole database. The goal and scope of an LCA database directly influences the human resources requirements. Development of an LCA database based on primary data is expected to require more human resources compared to the database development based on secondary data. In addition to the direct resources used, it is useful to get support from the academic institutions for the development of datasets.
Promoting effective collaboration among the IT team, dataset developers and dataset reviewers is necessary to make sure the basic principles of LCA database development are taken into account.
LCA database development in developing economies requires realistic assessment of human resources and the level of effort and skills needed. In the beginning, efforts can be distributed across a number of collaborating organizations with in-kind support at a moderate level. It is preferred to deploy full time staff members once the requirements are clear.
Success of an LCA database depends on the value created (decision making it supports) and the user base (number of users). Human resources are needed to create demand for the LCA database through capacity building and enable a stable user base. In this regard, research projects by the post graduate and doctoral research students are required to provide support on data creation, data analysis and demonstra-

tion of dataset application. Free of charge online training provided by the Life Cycle Initiative can be utilized for capacity building in developing countries.

5.6 Database hosting

The database system should be easy to use and access (from the perspective of designers and architects as the main users) and reliable and secure (from the administration perspective). The database hosting can be done by the government organizations (for example, Brazil, Peru, USA, Europe, Thailand and Malaysia), NGOs (for example, Australia) or academic and research institutions (China and Sweden). The ecoinvent LCA database is offered by the ecoinvent association with the support for hosting the data by an external IT service provider.

The level of infrastructure needed for database hosting depends on the level of service that is expected to be offered. It is necessary to arrive at a realistic assessment of time and resource requirements for database hosting. Few options are listed below:

1. Simple format: An archive of datasets in a given format and supporting explanatory documents distributed through file sharing platforms.
2. Advanced format: A database system like a Product/Organization Environment Footprint (PEF/OEF) node with features such as user management (login, change password), search engine, visualization of dataset and options to download selected datasets. Advanced database system require web design and server management knowledge. The free service provided by the Global Lifecycle Database Network (GLAD) and open source software can be used to host the database and meet the interoperability requirements.
3. Fully digitized database provided with APIs so that BIM and Building LCA tools can be used to search and download particular datasets or the current database.

5.7 Data needs and availability

Data needs and availability is one of steps to define the scope of the LCA database within the roadmap development. A review on the data needs and availability is presented in the Chapter 3 - Section 3.5.

5.8 Data quality requirement and overview

Chapter 3 on methodological guidelines, in particular, Section 3.6 presents a review of data quality requirements with reference to temporal aspects, representativeness and background data. Further, the reader can refer to the Life Cycle Data Network (LCDN) of the EC-JRC or eco-invent version 3.

5.9 Data format and interoperability of the datasets

LCA database users and practitioners depend on multiple databases and data sources as a material or building component consists of hundreds of unit processes and gathering background data for all unit processes is time and resource intensive. Database developers use various data formats in compliance with the ISO standard. This highlights the need for interoperability of LCA datasets and database with the existing databases in order to support widespread application. Detailed discussion on data format and interoperability is provided in the Section 3.13. Discussion on ISO 22057 and its ability to provide EPD and generic datasets for use in BIM and Building LCA needs to be noted. The use of API to search / access the data from tools is also extremely necessary in a digitized world.

5.10 LCA application in policy making

The availability of a reliable and interoperable LCA database would support the implementation of sustainability related public policies at the product, organization, consumer and the region levels. There are several ways in which LCA databases are used – for example, sustainability reporting, identification of processes for improvement and innovation, public procurement regulations and facilitating competitiveness of organizations in restricted markets. Examples are sustainability requirements of biofuels to receive government support, environmental labelling, and incentives for manufacturers with improved environmental performance. It is necessary to engage the representatives of the government organizations throughout the database roadmap development and implementation. This would be useful to formulate strategies for increased policy uptake, define priorities and requirements for data and obtain the funds and official support. Table 8 presents a way to assess the maturity level of the LCA database development.

Table 8: Assessment of the maturity level of LCA database development (UN Environment and Life Cycle Initiative, 2019)

Item	Maturity level		
	Level 1: Entry level	Level 2: Intermediate	Level 3: Advanced
Governance	No formal structure created	-	Formal governance structure created with roles and responsibilities defined
Capacity building	Studies by M.Sc. and Ph.D. students	Training	Integrated training in all courses at all levels
Use of LCA	Academic institutions	Few cases implemented in organizations	Public users (including policy development) and private users
Funding for LCA database	Seed grant from international and research organizations	Initial efforts funded by Government organizations	Financially stable independent of external funding
Infrastructure	Worksheets developed by individuals and team	Worksheets developed by several groups	Implementation of IT technology
Datasets	Academic studies	Non harmonized datasets without updates	Frequently updated LCA database
Interoperability	Poor or no data interoperability	Datasets used across different types of platforms but with some work	Interoperable LCA datasets and database connected to GLAD

Source: LCA Databases Helpdesk at http://spaces.oneplanetnetwork.org/lcahelpdesk

6. Governance Structure regarding the simplified LCA database for the construction sector

This chapter presents the governance structure based on the guidelines published by the LCA database helpdesk (UN Environment and Life Cycle Initiative 2019).

The governance structure for establishing an LCA database involves defining the roles, relationships, authorities, and responsibilities of the stakeholders involved. This includes the following three bodies - Governing Board (or Steering Committee), Advisory Council and a Database working group. The Governing Board is the prime authority and makes the key decisions related to database development. It is recommended that the construction companies and the industry associations are invited to give their advice on the database development and the final decisions are taken by the board in which the companies and industry associations are not part of – in order to avoid the influence of business interests. The advisory council is a sounding board and provides comments on the database protocol. The database working group is responsible for finalizing the technical/operational aspects, preparing proposals regarding modelling, methodology and data and drafting the database protocol. The proposals and protocols developed by the database working group will be submitted to the board for approval.

It is recommended that the advisory council would include the LCA representatives from multiple organizations such as the government, private industry, industry associations, research institutes, academic institutes, agencies responsible for creating national standards and consulting organizations.

The design of the database involves the definition of the following technical aspects: 1) inventory and system modeling support, 2) impact methods supported, 3) data quality requirements, 4) format, nomenclature, interoperability and the level of documentation, 5) validation and review procedures for submission of datasets, and 6) integrity of the whole database.

The stakeholders need to decide the level of service to be offered for multiple types of users – either the database access is offered for free or membership fee is needed. It is important to provide a realistic assessment of the demand for the database and the capacity needed to support the users. Further, it is necessary to clearly define and communicate what the users can expect from the database management. The availability of guaranteed funds is needed to support capacity building for development, maintenance and update of datasets.

It is recommended to create an action plan consisting of goals, key milestones to be achieved, work schedule, responsibilities, resource requirements, indicators for progress monitoring and funding sources. The plan-do-check-act (PDCA) method can be utilized to support the database development, maintenance and update.

Good governance structure would include an operator (either public or private) and a mechanism for independent verification of data quality. It would be ideal if this is taken care in a governmental context. It is important to ensure that necessary technical capacity is available within the government administration. Balanced representation of different industries is needed in the advisory council. The services of nongovernmental organizations can be taken into account in the advisory role. The services of industry can be taken into account for independent external critical review.

Figure 4 shows a schematic representation of governance structure for LCA database development.The Governance Structure should involve the manufacturers, users of the database such as the architects, engineers, and consultants, and also the tool developers.The industry should be part of the consultation (advisory committee) and the strategic decision making process (governing board). There could be a scenario where the Government do not wish to be involved (which may be appropriate). The manufacturing

companies and the users (representing the industry) should be involved and feel positive about the LCA database to ensure the success of the LCA database development and application.
It is desirable that the main administrator of the database is a governmental organization to ensure the long term sustainability of the database (for example, in the Indian context, this can be the Building Materials Technology Promotion Council or the Ministry of Environment or the Ministry of industry and trade). Cooperation is needed among the research institutes and the private parties that have the relevant know-how in LCA. These parties should be financed by the ministry to develop the database and to keep the database current and functional.

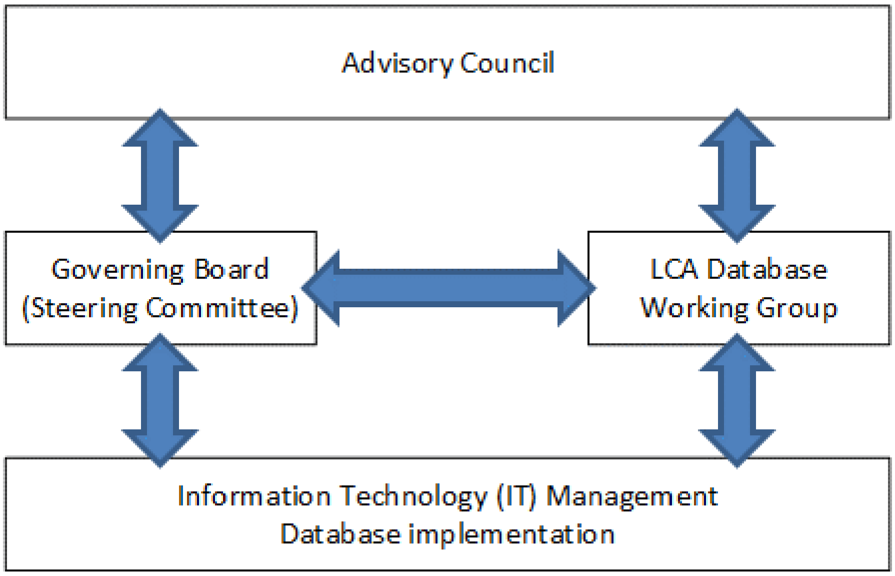

Figure 4: Governance structure for database development

The governance structure consists of the following:

1. Advisory council (consultation): Balanced representation of different stakeholders such as the Government, private industries, industry associations, research organizations, and academic institutes, organizations formulating national standards/codes, and consulting organizations.
2. Governing board (steering committee / strategic decision making): Decision making related to database development, approval of proposals from the database working group. The role of the industry should be balanced by the public authorities, scientists, and the NGOs. The Governing board would include NGOs and scientists with technical expertise in LCA database development.
3. LCA database working group (operations management): Finalize the technical and operational aspects; prepare proposals on modeling, methodology and data; drafting the database protocol and submit to the board for approval.
4. Information technology management and database implementation: Infrastructure for the database (availability, usability, integrity, data security, and data interoperability).

Figure 5 shows the roles, responsibilities and interaction among the primary stakeholders. The Government (or non-government organizations) would play the role of formulating data rules. The industry / member organizations provide the data. The academic organizations, research institutes, and the consulting/industry organizations would be responsible for independent external critical review of data.

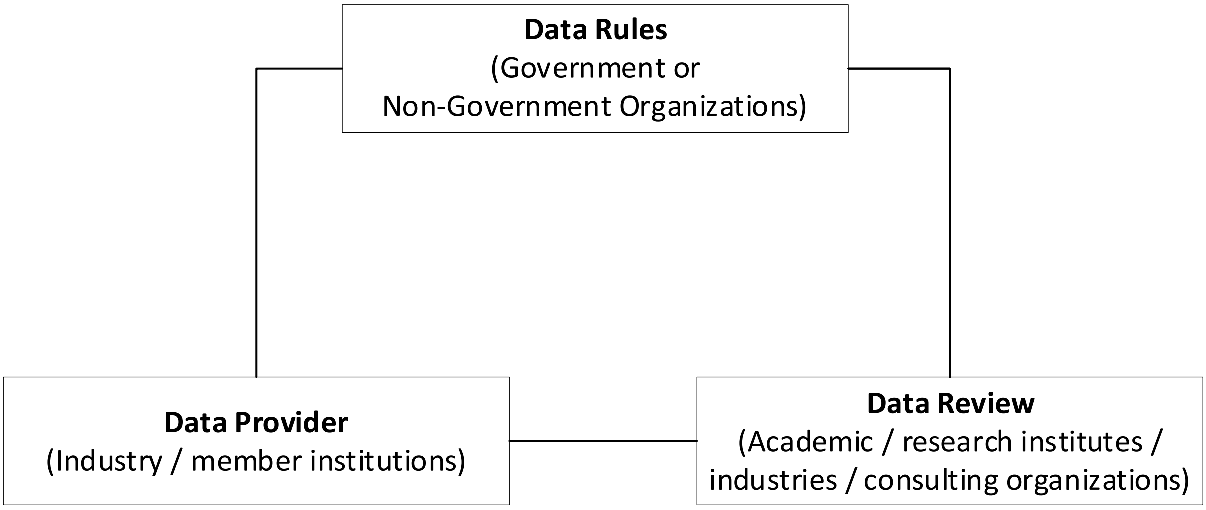

Figure 5: Roles, responsibilities and interaction among the primary stakeholders

7. Conclusions

Reliable, consistent and transparent life cycle inventory and life cycle impact assessment data are a key basis for quantifying life cycle related environmental impacts and greenhouse gas emissions of buildings. At the same time, these data should be easily available and applicable in the standard design processes. This is achieved by embedding the data into existing design tools.

Easy-to-use LCA databases for the construction sector should cover construction materials, building technology, energy supply as well as transport and waste management services. These databases should at least cover the manufacture and end-of-life stages and address greenhouse gas emissions, water scarcity, primary mineral resource use as well as further environmental impacts. Depending on the national context and requirements, single score environmental indicators may also be included.

Several modelling aspects such as allocation, biogenic carbon, electricity mixes etc., need to be defined to ensure consistent and comparable LCA data. Current European and international standards leave room for interpretation and choices, which are recommended to being closed when establishing a national LCA database. The list of aspects described in this report cover the main topics and may be considered as a checklist for the implementation of a national LCA database.

The creation of the LCA database is preceded by outlying a roadmap. The roadmap is the central document and helps in preparing the ground for the database development. Working on this document helps to clarify and agree on the vision and mission, on the governance and management, on funds and financing, and on the human resources needed. Database hosting, data needs and availability, data quality requirements and data format issues may be clarified upfront. And finally, clarity should be reached about the application of the LCA data in a policy context (e.g. legally binding life cycle related benchmarks for greenhouse gas emissions of buildings).

One key factor for the success, credibility and acceptance of a national LCA database is the governance structure. Ideally, the governance structure applies a decent division of power. The data rules should be established by a governmental or non-governmental body independent of those providing the data (industry associations and companies). Rules and data are reviewed in general by scientific organisations and consulting companies.

References

Alig M., Frischknecht R., Krebs L., Ramseier L. and Stolz P. (2020) LCA of climate friendly construction materials. treeze Ltd., Uster, Switzerland.

EN 15804:2012+A2:2019 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products, CEN-CENELEC Management Centre, B-1040 Brussels.

FICCI Quality Forum (2016) Report of consultations with key stakeholders on Readiness for development of Indian LCA database, Quality Forum Division, Federation of Indian Chambers of Commerce and Industry (FICCI), New Delhi. Available at: http://www.indialca.com/pdf/2016-indian-lca-database-project-report.pdf

Frischknecht R., Jungbluth N., Althaus H.-J., Doka G., Dones R., Heck T., Hellweg S., Hischier R., Nemecek T., Rebitzer G. and Spielmann M. (2004) Overview and Methodology. Final report ecoinvent 2000 No. 1. Swiss Centre for Life Cycle Inventories, Dübendorf, CH, retrieved from: www.ecoinvent.org.

GLAD (2018) Supporting document for nodes interested to join GLAD. UN Environment/Global LCA Data Access Network, GLAD. Available at: https://www.globallcadataaccess.org/uploads/Guidance%20for%20GLAD%20metadata%20descriptors.pdf

IEA Annex 72 Subtask 1.3 report on "Electricity mix models applied in the use stage of buildings LCA (Annex 72)".

IEA EBC Annex 72, Subtask 1.3 report by Xiaojin Zhang (2022) The Influence of Future Electricity Supplies in Life Cycle Assessment (LCA) of Buildings.

IEA EBC Annex 72, Subtask 1.3 Technical Report on 'Context-specific methods for the assessment of life cycle related environmental impacts caused by buildings, Guideline for specifications issued by national authorities and private organizations: Chapter on Biogenic carbon'.

IEA EBC Annex 72, Subtask 1.3 Technical Report on 'Context-specific methods for the assessment of life cycle related environmental impacts caused by buildings, Guideline for specifications issued by national authorities and private organizations: Chapter on 'Recommendations for communicating aggregated LCA results of buildings - Indicators and Aggregation'.

IEA EBC Annex 72, Subtask 1.3 Technical Report on 'Context-specific methods for the assessment of life cycle related environmental impacts caused by buildings, Guideline for specifications issued by national authorities and private organizations: Chapter on Modelling of Transport and Construction.

IS/ISO 14040:2006 Environmental Environmental management — Life cycle assessment - Principles and framework, International Standards Organization, Geneva, Switzerland.

IS/ISO 14044:2006 ENVIRONMENTAL MANAGEMENT — LIFE CYCLE ASSESSMENT — REQUIREMENTS AND GUIDELINES (Reaffirmned in 2017), International Standards Organization, Geneva, Switzerland.

ISO/TR 14047 Environmental management — Life cycle impact assessment — Examples of application of ISO 14042, International Standards Organization, Geneva, Switzerland.

ISO/TS 14048 Environmental management — Life cycle assessment — Data documentation format, International Standards Organization, Geneva, Switzerland.

ISO 21930:2017, Sustainability in buildings and civil engineering works — Core rules for environmental product declarations of construction products and services, International Standards Organization, Geneva, Switzerland.

KBOB, eco-bau and IPB (2016a) KBOB-Recommendation 2009/1:2016: Life Cycle Assessment Data in Constructon, Status as at September 2016. Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren c/o BBL Bundesamt für Bauten und Logistik, retrieved from: https://www.kbob.admin.ch/kbob/it/home/publikationen/nachhaltiges-bauen/oekobilanzdaten_baubereich.html.

KBOB, eco-bau and IPB (2016b) KBOB Ökobilanzdatenbestand DQRv2:2016; Grundlage für die KBOB-Empfehlung 2009/1:2016: Ökobilanzdaten im Baubereich, Stand 2016. Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren c/o BBL Bundesamt für Bauten und Logistik, retrieved from: www.ecoinvent.org.

KBOB, eco-bau and IPB (2021a) UVEK Ökobilanzdatenbestand DQRv2:2021. Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren c/o BBL Bundesamt für Bauten und Logistik, retrieved from: www.lc-inventories.ch.

KBOB, eco-bau and IPB (2021b) KBOB-Recommendation 2009/1:2021: Life Cycle Assessment Data in Constructon, Status as at December 2021. Koordinationskonferenz der Bau- und Liegenschaftsorgane der öffentlichen Bauherren c/o BBL Bundesamt für Bauten und Logistik, retrieved from: https://www.kbob.admin.ch/kbob/it/home/publikationen/nachhaltiges-bauen/oekobilanzdaten_baubereich.html.

Peuportier, B., Schalbart, P., Building life cycle assessment tools developed in France, Sixth International Symposium on Life-Cycle Civil Engineering, Ghent, Belgium, October 2018

Silvestre, J.D., Lasvaux, S., Hodková, J. et al. NativeLCA - a systematic approach for the selection of environmental datasets as generic data: application to construction products in a national context. Int J Life Cycle Assess 20, 731–750 (2015). https://doi.org/10.1007/s11367-015-0885-8

Simone, F., O. Kusche, L. Zampori (2016) Life Cycle Data Network — Handbook for data developers and providers. JRC Technical Reports, EUR 28251. Joint Research Centre of the European Commission. Available at: http://eplca.jrc.ec.europa.eu/PERMALINK/JRC104371_lb-na-28251-en-c.pdf

Sonnemann G. and Vigon B. (ed.) (2011) Global guidance principles for life cycle assessment databases; A basis for greener processes and products. United Nations Environment Programme, UNEP, Paris.

UN Environment and Life Cycle Initiative (2019) Development of National LCA Database Roadmaps, including further Development of the Technical Helpdesk for National LCA Databases: Deliverable D 3.1: General guidelines and recommendations for establishing roadmaps aimed at national LCA database development, Available at: http://spaces.oneplanetnetwork.org/lcahelpdesk

UNEP (2011) Global guidance principles for life cycle assessment databases - A basis for greener processes and products. United Nations Environment Programme, UNEP. Available at: https://www.lifecycleinitiative.org/wp-content/uploads/2012/12/2011%20-%20Global%20Guidance%20Principles.pdf.

UNEP (2016) Opportunities for national life cycle network creation and expansion around the world. United Nations Environment Programme, UNEP. Available at: http://www.oneplanetnetwork.org /sites/default/files/unep-lci_mapping-publication-9.10.16-web.pdf

Werner F. and Frischknecht R. (2018) Technische Grundlagen zur Prüfung eines Wechsels auf die europäischen EPD Normen für die ökologische Bewertung von Baustoffen und Gebäuden. cemsuisse, Lignum, Stahlbau Zentrum Schweiz, KBOB, BAFU, AHB Stadt Zürich, Zürich & Uster.

Werner F. and Frischknecht R. (2018) Technische Grundlagen zur Prüfung eines Wechsels auf die europäischen EPD Normen für die ökologische Bewertung von Baustoffen und Gebäuden. cemsuisse, Lignum, Stahlbau Zentrum Schweiz, KBOB, BAFU, AHB Stadt Zürich, Zürich & Uster.

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