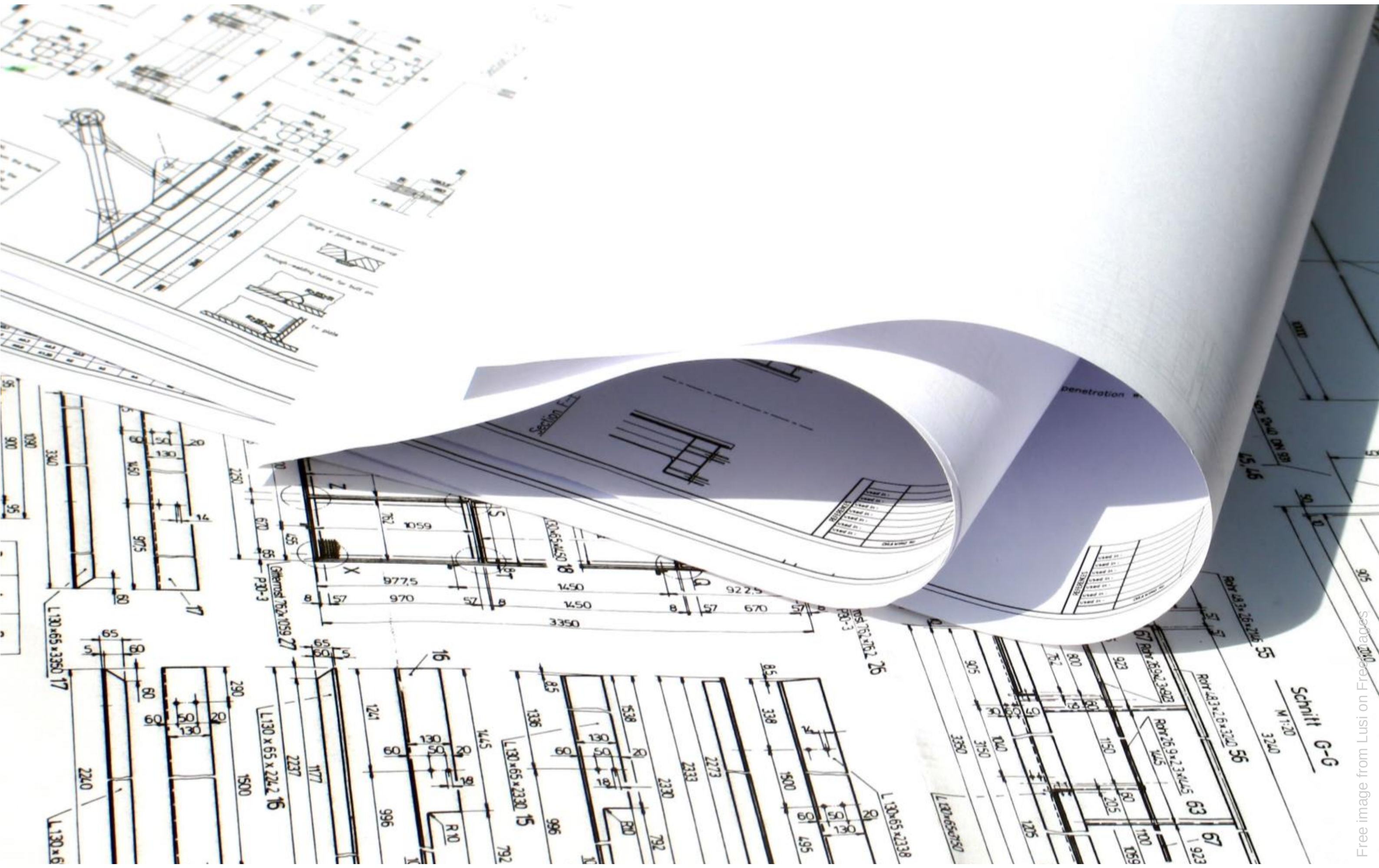
Potentials and requirements for implementing LCA across different design steps, project phases and life cycle stages

A Contribution to IEA EBC Annex 72

April 2023



International Energy Agency

Potentials and requirements for implementing LCA across different design steps, project phases and life cycle stages

A Contribution to IEA EBC Annex 72
Part 1 - Common definition of design steps & project phases

April 2023

Authors

Martin Röck, Graz University of Technology, Austria; KU Leuven, Belgium
(martin.roeck@tugraz.at)

Thomas Lützkendorf, Karlsruhe Institute of Technology, Centre for Real Estate, Germany

Contributing Authors

Endrit Hoxha, Graz University of Technology, Austria; Aalborg Universitet København, Denmark
Alexander Passer, Graz University of Technology, Austria
Claudiane Ouellet-Plamondon, École de technologie supérieure, Canada
Vincent Roy, École de technologie supérieure, Canada

Martin Michaud, École de technologie supérieure, Canada
Sébastien Lasvaux, University of Applied Sciences of Western Switzerland, Switzerland
Guillaume Habert, ETH Zürich, Switzerland
Alexander Hollberg, ETH Zürich, Switzerland; Chalmers University of Technology, Sweden
Maria Balouktsi, Karlsruhe Institute of Technology, Centre for Real Estate, Germany
Antonin Lupisek, Czech Technical University in Prague, Czech Republic
Martin Volf, Czech Technical University in Prague, Czech Republic
Jakub Veselka, Czech Technical University in Prague, Czech Republic
Antonio García-Martínez, University of Seville, Spain
Bernardette Soust-Verdaguer, University of Seville, Spain
Carmen Llatas, University of Seville, Spain
Juan Carlos Gómez de Cózar, University of Seville, Spain
Bruno Peuportier, ARMINES, France
Zsuzsa Szalay, Budapest University of Technology and Economics, Hungary
Benedek Kiss, Budapest University of Technology and Economics, Hungary
Tajda Potrc Obrecht, Slovenian National Building and Civil Engineering Institute, Slovenia; Graz University of Technology, Austria

Imprint:

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

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

DOI: 10.3217/978-3-85125-953-7-12

Cover picture: Free image from Lusi on FreeImages

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

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

1 Table of Contents

Abbreviations and Glossary

Abbreviations	Meaning
BIM	Building Information Modelling
BOM	Bill of Materials
BOQ	Bill of Quantities
EIA	Environmental Impact Assessment
GHG	Green House Gases
LCA	Life Cycle Assessment
LCC	Life Cycle Costs
LCI	Life Cycle Inventory
LOD	Level of Development
LOG	Level of Geometry
LOI	Level of Information
CAD	Computer Aided Design
CED	Cumulative energy demand
CO_2eq	CO_2 equivalent
EE	Embodied Energy
EOL	End of life
EPD	Environmental Product Declaration
GFA	Gross Floor Area
GWP	Global Warming Potential
IEA	International Energy Agency
IEA-EBC	Energy in Buildings and Communities Programme of the IEA
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LC	Life Cycle
LCIA	Life Cycle Impact Assessment
$LCCO_2$	Life Cycle CO_2 equivalent
NZEB	Nearly zero energy building or nearly zero emissions building
NRE	Non-Renewable Energy (fossil, nuclear, wood from primary forests)
NRPE	Non-Renewable Primary Energy
OECD	Organization for Economic Co-operation and Development
PE	Primary Energy
RSL	Reference Service Life
RSP	Reference Study Period

ZEB	Zero Energy Building
ZEH	Zero Energy House
ST1	Annex 72 Subtask 1: Harmonised methodology guidelines
ST2	Annex 72 Subtask 2: Building assessment workflows and tools
ST3	Annex 72 Subtask 3: Case studies
ST4	Annex 72 Subtask 4: Building sector LCA databases
ST5	Annex 72 Subtask 5: Dissemination

Term	Definition
CO_2 Intensity	The total CO_2 emission embodied, per unit of a product or per consumer price of a product. [kg CO_2eq /unit of product or price]
CO_2eq	CO_2 equivalent - a unit of measurement that is based on the relative impact of a given gas on global warming (the so-called global warming potential). [kg CO_2eq]
Contractor	Synonym: Service provider
Clients	Synonyms: financer, building owner, tenant, user
Cradle	Where building materials start their life
Cradle to Gate	This boundary includes only the production stage of the building. Processes taken into account are: the extraction of raw materials, transport and manufacturing
Cradle to Site	Cradle to gate plus delivery to site of use.
Cradle to Handover	Cradle to site boundary plus the processes of construction and assembly on site
Cradle to End of Use	Cradle to handover boundary plus the processes of maintenance, repair, replacement and refurbishment, which constitute the recurrent energy. This boundary marks the end of first use of the building.
Cradle to Grave	Cradle to handover plus use stage, which includes the processes of maintenance, repair, replacement and refurbishment (production and installation of replacement products, disposal of replaced products) and the end-of-life stage, which includes the processes of demolition, transport, waste processing and disposal.
Embodied Energy	Embodied energy is the total amount of non-renewable primary energy required for all direct and indirect processes related to the creation of the building, its maintenance and end-of-life. In this sense, the forms of embodied energy consumption include the energy consumption for the initial stages, the recurrent processes and the end-of-life processes of the building. [MJ/reference unit/year of the RSP]
Embodied GHG emissions	Embodied GHG emissions is the cumulative quantity of greenhouse gases (CO_2, emissions methane, nitric oxide, and other global warming gases), which are produced during the direct and indirect processes related to the creation of the building, its maintenance and end-of-life. This is expressed as CO_2 equivalent that has the same greenhouse effect as the sum of GHG emissions. [kg-CO_2eq /reference unit/year of the RSP]
Energy Intensity	The total energy embodied, per unit of a product or per consumer price of a product. [MJ/unit of product or price]

Energy carrier	Substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes
Energy source	Source from which useful energy can be extracted or recovered either directly or by means of a conversion or transformation process
Gross Floor Area (GFA)	Gross Floor Area [m^2]. Total floor area inside the building external wall. GFA includes external wall, but excludes roof. GFA is measured from the exterior surfaces of the outside walls.
Global Warming Potential (GWP)	A relative measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is measured against CO_2eq which has a GWP of 1. The time scale should be 100-year.
Greenhouse gases (GHG)	They are identified in different IPCC reports
Input and Output Tables	The Input-Output Tables are systematically present and clarify all the economic activities being performed in a single country, showing how goods and services produced by a certain industry in a given year are distributed among the industry itself, other industries, households, etc., and presenting the results in a matrix format.
Input and Output Analysis	The use of national economic and energy and CO2 data in a model to derive national average embodied energy/CO2 data in a comprehensive framework.
LCA	Life Cycle Assessment
PE_{nr}	Primary Energy non-renewable. Nuclear Energy is included.
PE_t	Primary Energy total. Renewable + Non-renewable Primary Energy. Nuclear Energy includes in the Primary Energy total.
Project commissioning	Synonyms: project commissioners, authority, policy makers
RSP	Reference Study Period. Period over which the time-dependent characteristics of the object of assessment are analysed (EN15978:2011)
Sustainability and certification expert	Synonyms: consultant, auditor

Summary

Introduction

To provide a common basis for the related activities of the different subtasks, this report presents:

- a set of terms and definitions of project management phases and building design steps in relation to life cycle stages of construction works as well as milestones from perspective of building design professionals based on the current plans of work and definitions used in the participating countries. This includes the specification and description of terms and definitions as well as additional insights into the national situation of selected countries.

Objectives

This document relates to a joint activity of ST1 and ST2. It serves to offer terms and definitions of phases in the project management process as well as steps[1] in the building design process for new construction and retrofit/refurbishment projects. Those terms and definitions shall provide the basis for:

- an assignment of methodological questions, rules and recommendations for action in individual design steps, with particular attention to earlier and later project phases (pre-/post-design) as well as the tasks related to the documentation and handover of buildings (in the context of ST1)
- a discussion of different approaches for integrating environmental assessment along the design process, including questions of responsibilities, flow of information and information exchange requirements as well as possible ways of presenting results (in the context of ST2)
- an allocation of environmental assessment tools and workflows to individual design steps (in the context of ST 2)
- an assignment of case studies to individual project phases and/or design steps where necessary and sensible (in the context of ST3)
- a discussion on the suitability of data and databases for calculation and evaluation tasks in different design steps (in the context of ST 4).

[1] Also known as design stage (like early design stage) or design phase

1. Basic concepts

1.1 Project management, design process, building life cycle – different perspectives on one object of assessment

An important basis for understanding the potentials and requirements for implementing environmental performance assessments (such as the use of LCA) along the design and decision-making process is an appropriate definition of the design steps and milestones (decision-situations). Such a definition of the design steps and milestones enables the assignment of related tasks, available information and data, useful tools and deliverables from the perspective of specific professionals. The starting point of such considerations is the choice of a perspective and system boundaries. If considering the full life cycle of a building from a project-management perspective, post-design life cycle stages such as the use phase (building operation, maintenance and replacement), building retrofit or refurbishment, as well as decommissioning at the end of the service life, have to be addressed. If, on the other hand, the focus is put exclusively on the design and construction process, e.g., from the perspective of architects and engineers as well as construction companies, it may suffice to address exclusively the design steps. The perspective chosen here is a combination of both approaches. It should allow addressing the initial design process as well as design interventions embedded along the life cycle of a building, such as, re-design or extension, refurbishment and, as well as – eventually – the design and management for a controlled decommissioning process towards re-use and recycling.
Figure 1 shows the phase model of a project management process parallel to the design process and physical life cycle of a building. It becomes clear that the development of the design task (project identification/clients brief), the building design and its realization (i.e., construction, use stage) are part of one overall process.

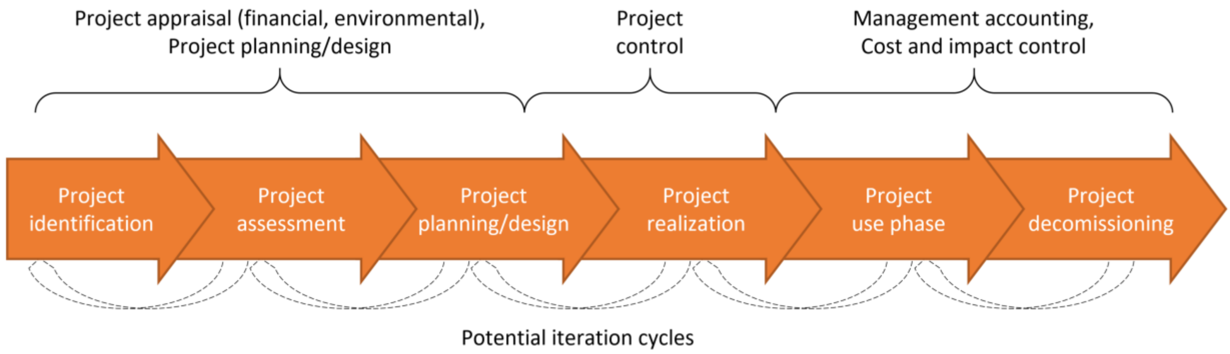


Figure 1: Project management process and building life cycle

1.2 Methodology for developing a common definition

The definition of a generic model of steps in building design and phases / milestones in the management process, which offers a common basis for the participating Annex countries, followed a four-iteration approach:

1) A survey amongst participating Annex countries asking to document the structure and definition of design steps and milestones as well as related tasks and deliverables for their respective country;
2) An analysis of existing and well-established definitions of design steps and project phase models;
3) The synthesis of 1) and 2) to propose a generic definition as a common reference for Annex 72;
4) The option for Annex countries to review their definitions with reference to the common model for future refinement and revision towards increased harmonization.

2. Common definition of design steps, tasks and milestones

2.1 Survey amongst Annex participants

Using a spreadsheet-based survey, the design and project step[2] definitions were compiled for 13 countries. Respondents from participating countries were asked to provide the definitions in their respective country, including a detailed description of the tasks and deliverables. Furthermore, participants reported on the presence and timing of relevant milestones, which provide a potential for the implementation of environmental target setting, environmental performance assessment and reporting of environmental performance assessment results. Five milestones were suggested for allocation:

(1) Definition of environmental performance targets
(2) Architectural design competition
(3) Building permit application
(4) Procurement of construction works
(5) Hand over and commissioning
(6) Decommissioning and deconstruction

[2] Often called design phases in the national definitions

2.2 Analysis of existing definitions

	Pre-Design		Design				Construction	Handover	In Use	End of Life
RIBA (UK)	0	1	2		3	4	5	6	7	
	Strategic Definition	Preparation and Brief	Concept Design	NOT USED	Developed Design	Technical Design	Construction	Handover & Close Out	In Use	NOT USED
ACE (Europe)	0	1	2.1	2.2	2.3	2.4	3		4	5
	Initiative	Initiation	Concept Design	Preliminary Design	Developed Design	Detailed Design	Construction	NOT USED	Building Use	End of Life
AIA (USA)			-		-	-	-			
	NOT USED	NOT USED	Schematic Design	NOT USED	Design Development	Construction Documents	Construction	NOT USED	NOT USED	NOT USED
APM (Global)	0	1	2		3	4	5	6	7	
	Strategy	Outcome Definition	Feasibility	NOT USED	Concept Design	Detailed Design	Delivery	Project Close	Benefits Realisation	NOT USED
Spain			-			-	-	-		
	NOT USED	NOT USED	Proyecto Básico	NOT USED	NOT USED	Proyecto de Ejecución	Dirección de Obra	Final de Obra	NOT USED	NOT USED
NATSPEC (Aus)		-	-	-	-	-	-		-	
	NOT USED	Establishment	Concept Design	Schematic Design	Design Development	Contract Documentation	Construction	NOT USED	Facility Management	NOT USED
NZCIC (NZ)		-	-	-	-	-	-		-	
	NOT USED	Pre-Design	Concept Design	Preliminary Design	Developed Design	Detailed Design	Construct	NOT USED	Operate	NOT USED
Russia			-	-	-	-	-			
	NOT USED	NOT USED	AGR Stage	Stage P	Tender Stage	Construction Documents	Construction	NOT USED	NOT USED	NOT USED
South Africa		1	2	3	-	4	5			
	NOT USED	Inception	Concept and Viability	Design Development	NOT USED	Documentation	Construction	Close Out	NOT USED	NOT USED

Figure 2: Comparison of international plans of work (RIBA 2020 [Royal Institute of British Architects (RIBA), 2020]).

The responses from Annex participants were reviewed in comparison with the well-established building design step? definition of the Royal Institute of British Architects (RIBA). The RIBA Plan of Work (RIBA 2020 [Royal Institute of British Architects (RIBA), 2020]) was considered well suited for the purpose of providing a generic definition of design phases or steps, core objectives and related tasks of individual design professionals in the various design steps. In the 2020 version of its Plan of Work, RIBA presents a comparison with other international building design and project phase definitions (Figure 2). These checkpoints have been further integrated in the 2020 version.

The 2020 RIBA Plan of Work itself defines eight design and project phases, and for each phase the expected outcomes, core tasks as well as exchange requirements, among other aspects (See Appendix Figure A5).

2.3 Synthesis: Proposal for harmonized terms and definitions

2.3.1 Mapping of design step and project phase definitions

As highlighted in the initial phase / step model concept (Figure 1), the various decisions relevant for improving the performance of buildings across their life cycle are not limited to design steps. They include other relevant stages of the building life cycle, such as the construction stage, the use stage – including maintenance and interventions, such as modernizations and refurbishments – as well as, eventually, the decommissioning of the building for recycling and end-of life treatment.

The survey showed that most countries are structuring design steps,project phases and related tasks based on a more refined structure than initially suggested. Based on the findings of the survey as well as the review of existing definitions from RIBA, this report hence proposes a generic definition of five design steps, including the pre-design (0-5) and three post-design steps (6-8) incl. definition of related key tasks (Figure 3).

0	1	2	3	4	5	6	7	8
Strategic definition	Preliminary studies	Concept design	Developed design	Technical design	Manufacturing and construction	Handover and comissioning	Operation and management	End of use, re-cycling
Requirements & target setting, review of project risks & alternatives, site appraisal, clients brief	Feasibility studies, call for design competition	Concept, sketches, competition design	Elaboration of design, building permit application	Detailed technical design, procurement of construction works	(Pre)-Fabrication of construction products, Construction and supervision	As-built documentation, hand over, comissioning and testing	Facilities Management and Asset Management, Evaluation and improvement of building performance	Decommissioning of the building, deconstruction, reuse and recycling

Figure 3: Common definition of design steps and project phases with related key tasks.

Based on the responses to the survey amongst Annex participants, a mapping of the generic definition of design steps and project phases with the national definitions was prepared (Figure 4). This mapping aims at providing a visual overview for Annex countries to relate their national situation and definitions to the general definitions and recommendations formulated in the works of IEA EBC Annex 72.

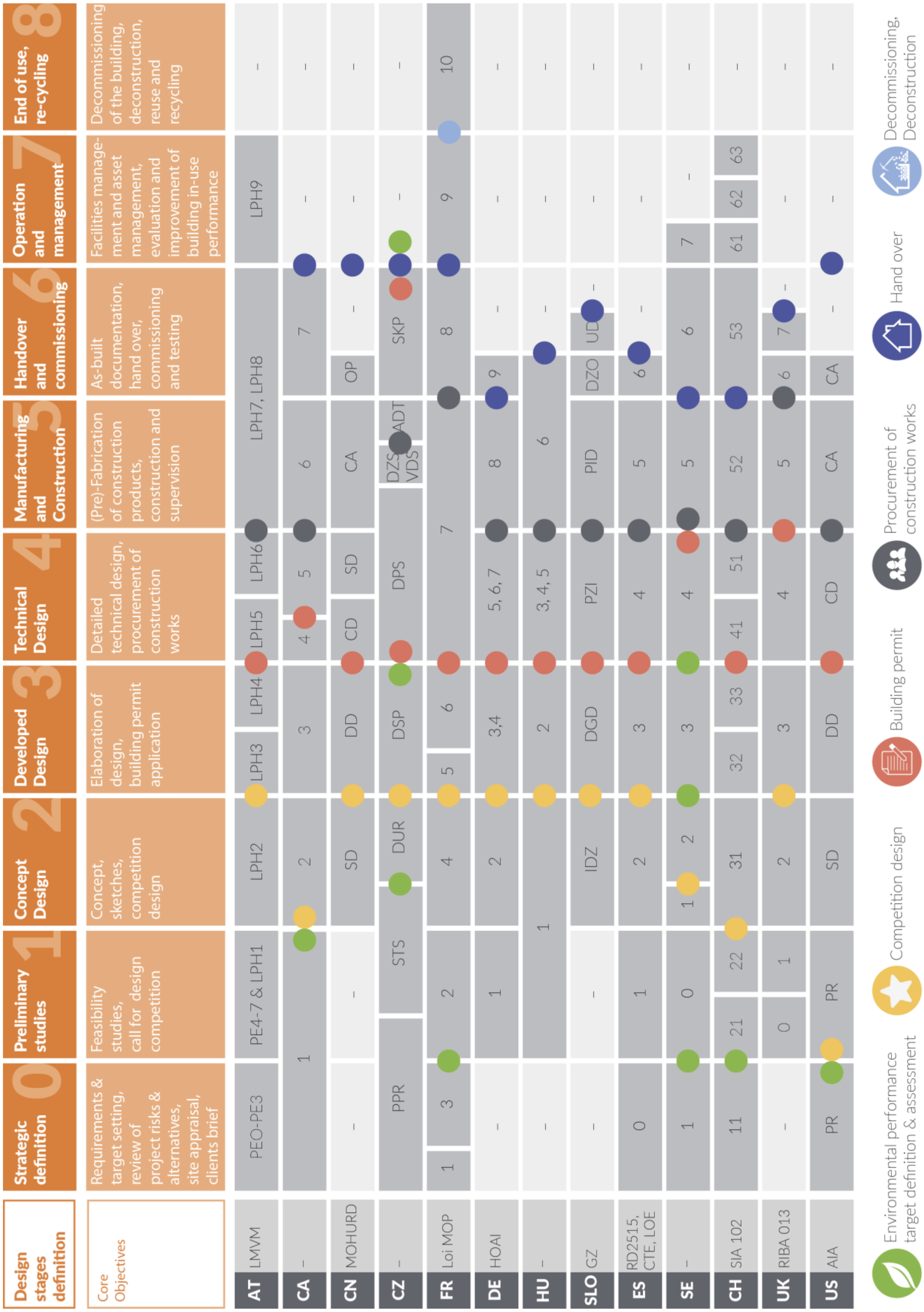


Figure 4: Overview and mapping of the common definition of design steps and project phases and typical tasks in relation to specific design tasks and milestones in the participating Annex countries.

2.3.2 Milestones for improving environmental performance

The milestones proposed in the survey were localised within the mapping of the common and national definitions from Annex countries (Figure 4). The majority of participating countries stated and allocated existing milestones related to '*design competition*', '*building permit application*', '*procurement of construction works*' as well as '*hand over and commissioning*'. At the same time, only very few countries to-date explicitly specify milestones for '*environmental target definition*' as well as '*decommissioning and deconstruction*'.

In order to implement environmental target setting, assessment and reporting (e.g., energy performance, carbon performance) along building design and project phases in the future, a set of milestones and related tasks are proposed (Table 1).

Table 1: Milestones and related tasks for implementing environmental performance assessment into the design-, decision making-, and facility management process of

Milestone	Description of proposed tasks
Environmental performance target definition	• Initial definition of the design task, related environmental performance targets by the client, as well as identification of related environmental requirements by laws and standards
Architectural design competition	• Definition of environmental targets (e.g., carbon budgets) as part of the call for design proposal • Requirement for design competition entries to provide an assessment of environmental impacts (screening assessment) • Sustainability assessment "new construction vs. refurbishment"
Building permit application	• Environmental assessment (pre check) based on a defined energy and material concept (type of structure, estimation of main construction material quantities and energy consumption for building operation) - based on a design for environment and design for deconstruction approach • Evaluation of environmental target fulfilment through public authorities as part of the building permit application process
Procurement of construction works	• Tender to include environmental requirements for construction products and building systems in-line with the specified environmental targets
Hand over and commissioning	• Commissioning / bringing into service, monitoring and refinement of the building's environmental performance in use
Use, operation management	• Continuous assessment and improvement based on monitoring, user satisfaction surveys, sustainability assessment "in use"
Decommissioning and deconstruction	• Pre-deconstruction audit, plan for deconstruction • Decommissioning and deconstruction of the building towards re-use and recycling as well as end-of-lie treatment in-line with life cycle scenarios underlying previous environmental assessments

The coherent definition of environmental targets by example of 'carbon budgets' has been the subject of a recent article by Habert et al. [Habert et al., 2020] with multiple contributions on the topic presented in the related special issue of Buildings & Cities (https://bit.ly/32sohGP).

3. Conclusions and recommendations

The definition of the design steps,milestones and related tasks, as well as deliverables may differ across building design and construction projects, as they are subject to agreement amongst the project partners. The presented generic terms and definitions offer a common understanding of the relevant steps, project phases, milestones and tasks for fostering the implementation of environmental assessment along the building design process and project phases in the participating Annex countries.

The common definition of the design steps and project phases as well as related core tasks should serve as guidance for the description and development of building assessment workflows and tools (ST2). Furthermore, it provides a framework for discussing the available information and appropriate assessment methods, and how these affect the inherent uncertainty of conducting environmental performance assessments in specific design steps and project phases (ST1).

This definition of the design steps and milestones represents a common systematic for structuring the building project cycle, that goes beyond the mere design process. It provides an overview of the core tasks as well as relevant milestones for implementing environmental targets in the process of an environmental performance assessment. Furthermore, the common understanding of the design process, specific milestones in the decision-making process and related tasks enables participants but also other actors to relate the current practice in their countries to a common structure. It supports learning from experiences in other countries, enabling the exchange of expertise and providing a common basis for future research, as well as for the clarification and further development of national definitions.

References

Habert G, Röck M, Steininger K, Lupisek A, Birgisdottir H, Desing H, et al.: Carbon budgets for buildings: Harmonizing temporal, spatial and sectoral dimensions. Build Cities 2020;1–24.

Royal Institute of British Architects (RIBA): RIBA Plan of work 2013 [Internet] 2013;Available from: https://www.ribaplanofwork.com/

Royal Institute of British Architects (RIBA): RIBA Plan of Work 2020 2020; DOI: 10.4324/9780429346637-2

Appendix

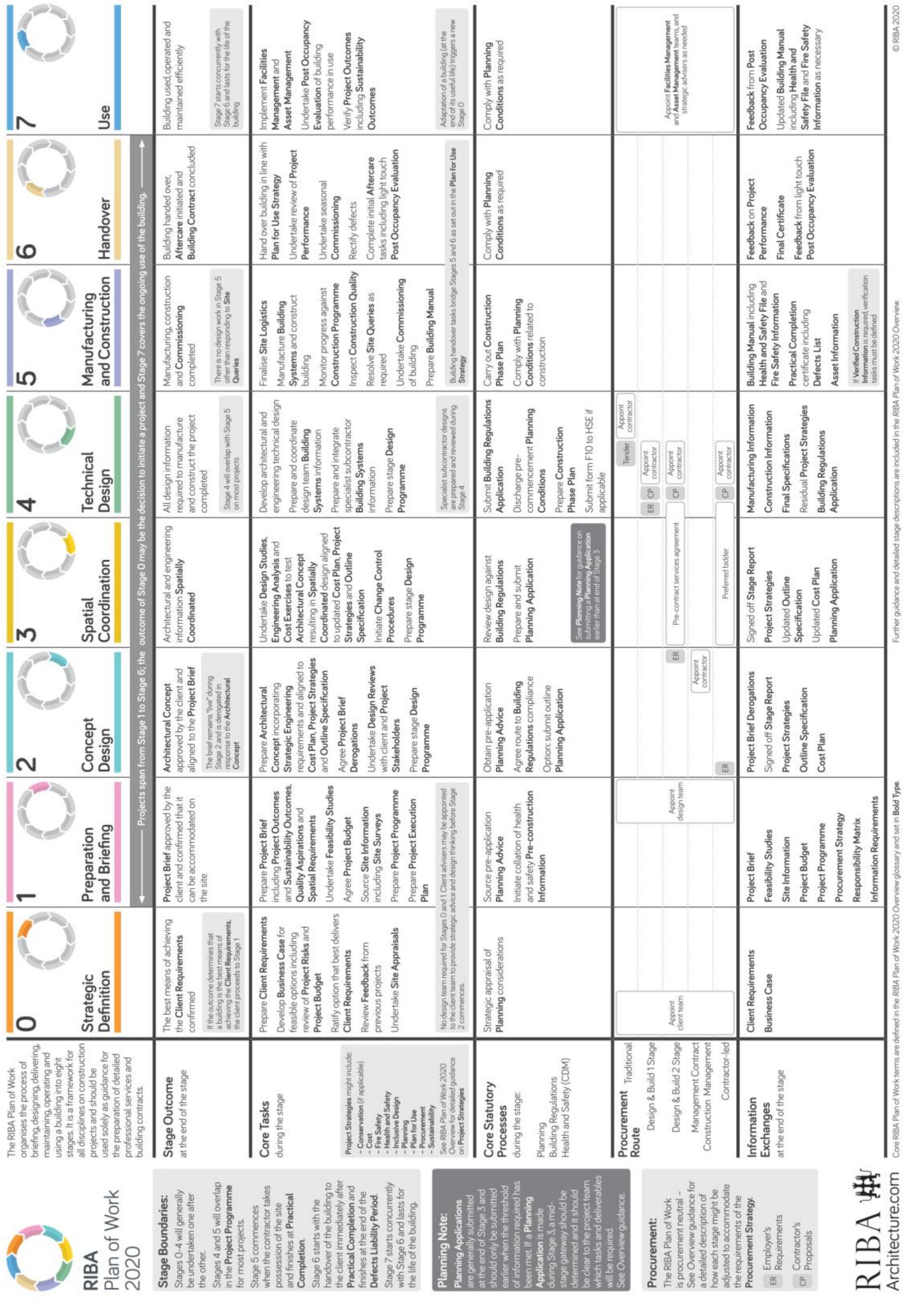


Figure A5: Overview of design phases and related tasks acc. RIBA Plan of Work (RIBA 2020 [Royal Institute of British Architects (RIBA), 2020]).

Table A2: Description of 'Sustainability Checkpoints' in the RIBA plan of work 2013 [Royal Institute of British Architects (RIBA), 2013]

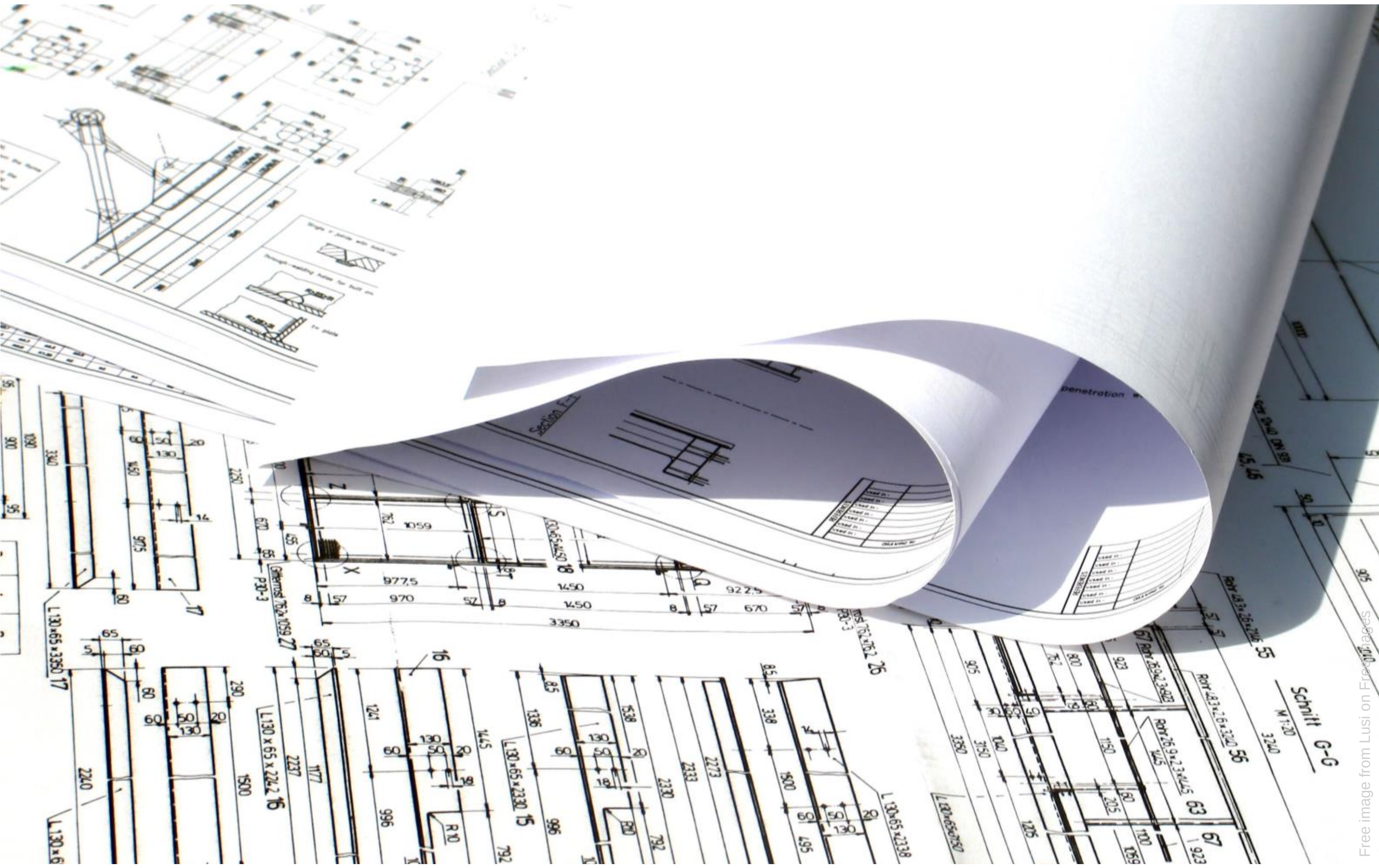
Design step	Core Objectives	Sustainability Checkpoints
Strategic definition	Identify client's Business Case and Strategic Brief and other core project requirements.	• Ensure that a strategic sustainability review of client needs and potential sites has been carried out, including reuse of existing facilities, building components or materials.
Preliminary studies	Develop Project Objectives, including Quality Objectives and Project Outcomes, Sustainability Aspirations, Project Budget, other parameters or constraints and develop Initial Project Brief. Undertake Feasibility Studies and review of Site Information.	• Confirm that formal sustainability targets are stated in the Initial Project Brief. Confirm that environmental requirements, building lifespan and future climate parameters are stated in the Initial Project Brief. Have early steps consultations, surveys or monitoring been undertaken as necessary to meet sustainability criteria or assessment procedures? Check that the principles of the Handover Strategy and post-completion services are included in each party's Schedule of Services. Confirm that the Site Waste Management Plan has been implemented.
Concept Design	Prepare Concept Design, including outline proposals for structural design, building services systems, outline specifications and preliminary Cost Information along with relevant Project Strategies in accordance with Design Programme. Agree alterations to brief and issue Final Project Brief.	• Confirm that formal sustainability pre-assessment and identification of key areas of design focus have been undertaken and that any deviation from the Sustainability Aspirations has been reported and agreed. Has the initial Building Regulations Part L assessment been carried out? Have 'plain English' descriptions of internal environmental conditions and seasonal control strategies and systems been prepared? Has the environmental impact of key materials and the Construction Strategy been checked? Has resilience to future changes in climate been considered?
Developed Design	Prepare Developed Design, including coordinated and updated proposals for structural design, building services systems, outline specifications, Cost Information and Project Strategies in accordance with Design Programme.	• Has a full formal sustainability assessment been carried out? Have an interim Building Regulations Part L assessment and a design step carbon/energy declaration been undertaken? Has the design been reviewed to identify opportunities to reduce resource use and waste and the results recorded in the Site Waste Management Plan?
Technical Design	Prepare Technical Design in accordance with Design Responsibility Matrix and Project Strategies to include all architectural, structural and building services information, specialist subcontractor design and specifications, in	• Is the formal sustainability assessment substantially complete? Have details been audited for airtightness and continuity of insulation? Has the Building Regulations Part L submission been made and the design step carbon/energy declaration been updated and the future climate impact assessment prepared? Has a non-technical user guide been drafted and have the format and content of the Part L log book

	accordance with Design Programme.	been agreed? Has all outstanding design step sustainability assessment information been submitted? Are building Handover Strategy and monitoring technologies specified? Have the implications of changes to the specification or design been reviewed against agreed sustainability criteria? Has compliance of agreed sustainability criteria for contributions by specialist subcontractors been demonstrated?
Construction	Offsite manufacturing and onsite Construction in accordance with Construction Programme and resolution of Design Queries from site as they arise.	• Has the design step sustainability assessment been certified? Have sustainability procedures been developed with the contractor and included in the Construction Strategy? Has the detailed commissioning and Handover Strategy programme been reviewed? Confirm that the contractor's interim testing and monitoring of construction has been reviewed and observed, particularly in relation to airtightness and continuity of insulation. Is the non-technical user guide complete and the aftercare service set up? Has the 'As-constructed' Information been issued for post-construction sustainability certification?
Handover and close out	Handover of building and conclusion of Building Contract.	• Has assistance with the collation of post-completion information for final sustainability certification been provided?
In use	Undertake In Use services in accordance with Schedule of Services.	• Has observation of the building operation in use and assistance with fine tuning and guidance for occupants been undertaken? Has the energy/carbon performance been declared?

Potentials and requirements for implementing LCA across different design steps, project phases and life cycle stages

A Contribution to IEA EBC Annex 72
Part 2- National reports on definition of design phases

April 2023



International Energy Agency

Potentials and requirements for implementing LCA across different design steps, project phases and life cycle stages

A Contribution to IEA EBC Annex 72
Part 2- National reports on definition of design phases

April 2023

Authors

Martin Röck, Graz University of Technology, Austria; KU Leuven, Belgium
(martin.roeck@tugraz.at)

Thomas Lützkendorf, Karlsruhe Institute of Technology, Centre for Real Estate, Germany

Contributing Authors

Vincent Roy, Martin Michaud, Claudiane Ouellet-Plamondon, Ecole de Technologie Superieur, Canada
Bruno Peuportier, ARMINES, France
Tajda Potrc Obrecht, Zavod za gradbeništvo, Slovenia
Antonio García-Martínez, University of Seville, Spain
Carmen Llatas, University of Seville, Spain
Juan Carlos Gómez de Cózar, University of Seville, Spain
Bernardette Soust-Verdaguer, University of Seville, Spain

2 Table of content

Part 2 - National reports on definition of design phases

Abbreviations and glossary

Abbreviations	Meaning
BIM	Building Information Modelling
BOM	Bill of Materials
BOQ	Bill of Quantities
EIA	Environmental Impact Assessment
GHG	Green House Gases
LCA	Life Cycle Assessment
LCC	Life Cycle Costs
LCI	Life Cycle Inventory
LOD	Level of Development
LOG	Level of Geometry
LOI	Level of Information
CAD	Computer Aided Design
CED	Cumulative energy demand
CO_2eq	CO_2 equivalent
EE	Embodied Energy
EOL	End of life
EPD	Environmental Product Declaration
GFA	Gross Floor Area
GWP	Global Warming Potential
IEA	International Energy Agency
IEA-EBC	Energy in Buildings and Communities Programme of the IEA
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
LC	Life Cycle
LCIA	Life Cycle Impact Assessment
$LCCO_2$	Life Cycle CO_2 equivalent
NZEB	Nearly zero energy building or nearly zero emissions building
NRE	Non-Renewable Energy (fossil, nuclear, wood from primary forests)
NRPE	Non-Renewable Primary Energy
OECD	Organization for Economic Co-operation and Development
PE	Primary Energy
RSL	Reference Service Life
RSP	Reference Study Period
ZEB	Zero Energy Building
ZEH	Zero Energy House
ST1	Annex 72 Subtask 1: Harmonised methodology guidelines
ST2	Annex 72 Subtask 2: Building assessment workflows and tools
ST3	Annex 72 Subtask 3: Case studies

ST4	Annex 72 Subtask 4: Building sector LCA databases
ST5	Annex 72 Subtask 5: Dissemination

Term	Definition
CO_2 Intensity	The total CO_2 emission embodied, per unit of a product or per consumer price of a product. [kg CO_2eq /unit of product or price]
CO_2eq	CO_2 equivalent - a unit of measurement that is based on the relative impact of a given gas on global warming (the so-called global warming potential). [kg CO_2eq]
Contractor	Synonym: Service provider
Clients	Synonyms: financer, building owner, tenant, user
Cradle	Where building materials start their life
Cradle to Gate	This boundary includes only the production stage of the building. Processes taken into account are: the extraction of raw materials, transport and manufacturing
Cradle to Site	Cradle to gate plus delivery to site of use.
Cradle to Handover	Cradle to site boundary plus the processes of construction and assembly on site
Cradle to End of Use	Cradle to handover boundary plus the processes of maintenance, repair, replacement and refurbishment, which constitute the recurrent energy. This boundary marks the end of first use of the building.
Cradle to Grave	Cradle to handover plus use stage, which includes the processes of maintenance, repair, replacement and refurbishment (production and installation of replacement products, disposal of replaced products) and the end-of-life stage, which includes the processes of demolition, transport, waste processing and disposal.
Embodied Energy	Embodied energy is the total amount of non-renewable primary energy required for all direct and indirect processes related to the creation of the building, its maintenance and end-of-life. In this sense, the forms of embodied energy consumption include the energy consumption for the initial stages, the recurrent processes and the end-of-life processes of the building. [MJ/reference unit/year of the RSP]
Embodied GHG emissions	Embodied GHG emissions is the cumulative quantity of greenhouse gases (CO_2, emissions methane, nitric oxide, and other global warming gases), which are produced during the direct and indirect processes related to the creation of the building, its maintenance and end-of-life. This is expressed as CO_2 equivalent that has the same greenhouse effect as the sum of GHG emissions. [kg-CO_2eq /reference unit/year of the RSP]
Energy Intensity	The total energy embodied, per unit of a product or per consumer price of a product. [MJ/unit of product or price]
Energy carrier	Substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes
Energy source	Source from which useful energy can be extracted or recovered either directly or by means of a conversion or transformation process

Gross Floor Area (GFA)	Gross Floor Area [m^2]. Total floor area inside the building external wall. GFA includes external wall, but excludes roof. GFA is measured from the exterior surfaces of the outside walls.
Global Warming Potential (GWP)	A relative measure of how much a given mass of greenhouse gas is estimated to contribute to global warming. It is measured against CO_2eq which has a GWP of 1. The time scale should be 100-year.
Greenhouse gases (GHG)	They are identified in different IPCC reports
Input and Output Tables	The Input-Output Tables are systematically present and clarify all the economic activities being performed in a single country, showing how goods and services produced by a certain industry in a given year are distributed among the industry itself, other industries, households, etc., and presenting the results in a matrix format.
Input and Output Analysis	The use of national economic and energy and CO2 data in a model to derive national average embodied energy/CO2 data in a comprehensive framework.
LCA	Life Cycle Assessment
PE_{nr}	Primary Energy non-renewable. Nuclear Energy is included.
PE_t	Primary Energy total. Renewable + Non-renewable Primary Energy. Nuclear Energy includes in the Primary Energy total.
Project commissioning	Synonyms: project commissioners, authority, policy makers
RSP	Reference Study Period. Period over which the time-dependent characteristics of the object of assessment are analysed (EN15978:2011)
Sustainability and certification expert	Synonyms: consultant, auditor

3 Summary

3.1 Introduction

This report offers a summary of short-reports on the definition of design phases, milestones and steps related to the environmental assessment and use of LCA along the design process. The short-reports were provided by Annex experts of the respective countries.

The short-reports on the situation in Annex countries address, e.g.:

- National definition of design phases, milestones and deliverables: From perspective of building design professionals, which standards/guidelines are relevant for your country (might be multiple for different building design professionals) and what tasks, decisions and deliverables do they describe? Here, you will later on be able to use the figure provided for your country (see example figure of Germany below (draft)).
- Steps related to assessment and improvement of environmental performance: Description of the current state of environmental performance requirements (environmental benchmarks) and assessment in design practice, addressing in which design phases and what type of environmental performance assessment (e.g. LCA) is conducted (referring to relevant standards, guidance documents, if available). Is there any (formal) description of how environmental performance of a building project should be assessed and improved at different phases of the project?
- Other relevant aspects: If environmental assessment is not (yet) applied in practice, please describe the current state of (life cycle) cost estimation in building design practice incl. the related tasks along the design process (referring to relevant standards, guidance documents, if available).

3.2 Objectives

This document relates to a common activity of ST1 and ST2. It serves to offer a common definition of phases in the building design process for new construction and modernization projects. This definition should provide the basis for

- An assignment of methodological questions, rules and recommendations for action in individual design phases, with particular attention to earlier and later project phases (pre-/post-design) as well as the tasks related to the documentation and handover of buildings (ST1)
- A discussion of different approaches for integrating environmental assessment along the design process, including questions of responsibilities, information and exchange requirements as well as possible ways of presenting results (ST2)
- An allocation of environmental assessment tools and workflows to individual design phases (ST 2)
- An assignment of case studies to individual design phases where necessary and sensible (ST3)
- A discussion on the suitability of data and databases for calculation and evaluation tasks in different design phases (ST 4).

4. National report for Canada

Author(s): Vincent Roy, Martin Michaud, Claudiane Ouellet-Plamondon (Ecole de Technologie Superieure)

4.1 Introduction

Even if it has often been proven that using LCA in early design stages of buildings is highly beneficial for its environmental performance, no mandatory requirement exists in Canada for regular building construction until now. For most public and private contracts, the lowest bidder rule is still the norm. Projects like LCA^2 by National Research Council Canada aim at developing and eventually incorporate LCA in procurement. Started in 2019, this initiative will end in 2022. Beside standards like LEED, Envision and others, there are no incentive yet for landlords and builders. Existing environmental regulations for construction focus on aspects like soil and contamination, flora and fauna and energy efficiency while excluding embodied carbon.

4.2 National definition of design phases, milestones and deliverables

Design stages definition	Strategic definition 0	Preliminary studies 1	Concept Design 2	Developed Design 3	Technical Design 4	Manufacturing and Construction 5	Handover and commissioning 6	Operation and management 7	End of use, re-cycling 8
Core Objectives	Requirements & target setting, review of project risks & alternatives, site appraisal, clients brief	Feasibility studies, call for design competition	Concept, sketches, competition design	Elaboration of design, building permit application	Detailed technical design, procurement of construction works	(Pre)-Fabrication of construction products, construction and supervision	As-built documentation, hand over, commissioning and testing	Facilities management and asset management, evaluation and improvement of building in-use performance	Decommissioning of the building, deconstruction, reuse and recycling
CA	–	1	2	3	4 / 5	6	7	–	–

Based on Public Works and Government Services Canada 2014, Mehta, Scarborough et al. 2017, Ordre des Ingénieurs du Québec 2019

Stages	1	2	3	4	5	6	7
Name (original)	Étude de faisabilité	Phase de l'esquisse	Phase de conception	Phase de conception technique	Appel d'offres et permis de construction	Suivi de chantier	Réception de l'ouvrage
Name (english)	Predesign/ planning/ programming phase	Schematic design phase	Design development phase	Construction document phase	Preconstruction phase	Construction phase	Postconstruction phase

Figure 6: Detailed overview of design phases and milestones – Canada

Multiple definitions exist regarding design phases in Canada. Depending on the location and the type of professional, project and contract, phases vary. As an example, tasks and their timing can be quite different if the client chooses a fast track delivery mode for his project instead of the traditional mode or design-build mode. Depending on the various professional associations' standards in Canada, answers in the table below could slightly vary. Nonetheless, the table presents an accurate big picture for the definitions, milestones and deliverables of the different phases in Canada (and more globally North America). From a project's developer, owner or landlord view, there could be two additional phases regarding maintenance and operation and building's end of life which are, in most cases, completely excluded from the engineers or architects' scope of work in traditional projects. Table content is based on the engineer's association official document, government procurement guide (Public Works and Government Services Canada 2014) and academic resource (Mehta, Scarborough et al. 2017).

Table 3 : Building delivery phases based on (Public Works and Government Services Canada 2014, Mehta, Scarborough et al. 2017, Ordre des Ingénieurs du Québec 2019)

PHASE	TASKS	DELIVERABLES	MILESTONES
Predesign/ planning/ programming phase	• Details of the project's program. • Economic feasibility assessment, including the project's overall budget and financing. • Site assessment and selection, including the verification of the site's appropriateness, and determining its designated land use. • Governmental constraints assessment, for example, building code and zoning constraints and other legal aspects of the project. • Sustainability ratings—whether the owner would like the project to achieve sustainability rating, such as the Leadership in Energy and Environmental Design (LEED) certification at some level. • Design team selection.	Building or project programs delivered. This includes defining the activities, functions, and spaces required in the building, along with their approximate sizes and their relationships with each other. Preparing the program is the first step in the project delivery process. It should be spelled out in writing and in enough detail to guide the design, reduce the liability risk for the architect, and avoid its misinterpretation.	Building or project program completed and design team chosen (if not already)
Schematic design phase	• Schematic design: overall design concept with documentation primarily for owner (not contractor). Emphasis on design.	Schematic design documents completed and approved by owners and other necessary authorities	Schematic drawings and probable costs
Design development phase	• Design development: Schematic design developed to greater details for cost, time and constructability considerations. Documentation primarily for the design team. Emphasis on solving design decisions.	Design development documents completed and approved by owners and other necessary authorities	More detailed drawings and costs
Construction document phase	• Construction documents: Design finalized to nuts and bolts details. Documentation for the construction team.	Construction documents completed and approved by owners and other necessary authorities	Construction plans completed
Preconstruction phase	• Bid package: Preparation of package comprising construction drawings and specifications, procurement and contracting requirements and addenda. • General contractor qualification: surety bonds (bid, performance and payment). • Contractor and project delivery type selection: methods differ depending on the project and owner (private vs. public).	Bid package documents and final contracts	General contractor's contract awarded and noticed to proceed with construction works
Construction phase	• Product sample, mockups, shop drawings and performance data submission for approval by the design team. • Construction progress documentation and inspection of work by contractor and design team. • Payment certifications and change orders.	Any required inspection approval sheet for different types of work (rebar, concrete, welding, etc.)	Certificate of occupancy secured by the contractor
Postconstruction phase	• Contractor provides all necessary warranties and guarantees from manufacturers and subcontractors. • Substantial completion inspection done by the design team (liability transfers to the owner) • Final inspection by the design team once all deficiencies are corrected. • As built documents	Substantial completion inspection, final inspection and As built drawings	As built drawings and documentation

4.3 Steps related to assessment and improvement of environmental performance

As mentioned, actual mandatory environmental performance assessments are not related to embodied carbon. Each province has its own generic law regarding environmental quality. As an example, in the province of Quebec, builders must comply with the law on environmental quality (Québec 2020). In order to receive a construction permit, they must assure that they are building on a proper site (industrial, residential, institutional, etc.). If soil on site is too contaminated to build, they must decontaminate it. Also, if they are in a fragile zone (e.g., wetlands), more studies need to be done in order to deliver permit and mitigation measures must be put in place by builders. Other regulations linked to building construction are related to energy efficiency. They are included to the national building code and specify different directives regarding building component thermal resistance value, construction of specific elements like weather stripping, how to eliminate thermal bridges and others (Canada 2010).

Despite not being mandatory, the Canada Green Building Council launched the Zero Carbon Building Standard (Canadian Green Building Council 2019). In order to obtain that standard, one of the main requirements is to conduct a LCA including modules A1-5, B1-5 and C1-4. After minimizing carbon emissions during design and construction, the projects will be required to offset their embodied carbon in order to obtain the certification (offset does not include Module D's embodied carbon). To foster material reuse, LCA shall only include new material from envelope and structural elements, including footings and foundations, and complete structural wall assemblies (from cladding to interior finishes, including basement), structural floors and ceilings (not including finishes), roof assemblies, and stairs. Parking structures are to be included; however, excavation and other site development, partitions, building services (electrical, mechanical, fire detection, alarm systems, elevators, etc.), and surface parking lots are excluded. Projects that wish to evaluate their embodied carbon more fully may elect to include materials beyond the structure and envelope at their discretion provided they are reported as a separate line item. For example, the fit-up of interior spaces may provide opportunities for embodied carbon reductions. To provide an opportunity to influence design, the standard requires that the LCA analysis begin at the schematic design phase. Project teams are encouraged to set a reduction goal as early as pre-design. The embodied carbon report submitted must include a list of recommendations that were considered and/or implemented to reduce the embodied carbon of the project and must be based on the final design. The LCA must assume a building service life of 60 years. This service life is chosen to ensure standardized reporting throughout the program and may not reflect the service life the project is designed for. If the service life of a product used in initial construction is longer than the building's assumed service life, the impacts associated with the product may not be discounted to reflect its remaining service life. Embodied carbon must be reported in kilograms of carbon dioxide equivalent (kg CO_2 e) as a total value, as well as broken down in two different ways: 1. A life-cycle stage analysis including totals for stages A, B, C, and D (if available); and, 2. A contribution analysis broken out by either material type or by building assembly. The LCA must demonstrate an embodied carbon reduction using the life-cycle stages A, B, & C. Projects that wish to expand the scope of the analysis to look for reductions elsewhere may do so provided both the baseline and the proposed building use the same scope. For building equivalence, baseline building must be equivalent to the proposed building. The following must be constant in both the baseline and proposed building: (1) Operational energy use (2) Gross floor area (3) Functional use of space (4) Building shape and orientation. Retrofit projects that use an existing structure for 50 per cent or more of the final gross floor area are deemed compliant and are not required to model a baseline building.

4.4 Other relevant aspects

As mentioned above, phase definition can slightly vary depending from which point of view we are looking at. The table 1 contains a holistic representation covering most of the phases in a more architectural point of view. Indeed, the architect is often the main responsible for environmental performance improvements on building construction projects. The schematic, design development and construction design phases are typical to architects. It has been discussed that these different points of view or definitions between stakeholders can reduce efficiency and information flows within the project substantially (Michaud, Forgues et al. 2019). To illustrate this aspect, please refer to figure 1. Indeed, not having a common understanding or design process fosters silo mentality instead of collaboration. One major issue regarding this fact is professional responsibility. Indeed, professional association regulates according to specific tasks and those rarely account for new design or delivery methods. Laws and regulations tend to follow technical innovation, but not the opposite. Also, another issue regards who pilots the project first. As an example, traditional procurement method would usually imply an architectural team first with the landlord. Then, engineering team would be chosen and finally the contractor. For other projects, landlords also act as a real estate developer. While doing public consultation, the developer could already fix different environmental targets to make the project socially acceptable before choosing a design team and contractor. In other contexts, contractors also act as a real estate developer making the situation even more complicated. Nevertheless, in most cases environmental aspects are covered in the first phase of the project for every type of professional regarding requirements and second phase for environmental design for engineers and architects. A positive development is BIM process being slowly widely adopted for economic and time concern. This adoption could enable more collaboration in the early stages of the project regarding environmental concerns. One suggestion would also be to have a representative of every party in the early stages in order to set realistic targets for everyone, reducing costs associated with design and contract changes since no party faces a *fait accompli*. Starting with a common understanding and appropriate regulations would improve environmental and overall project performance.

4.5 Outlook

Having a common language will certainly foster collaboration at an early stage of the project. Indeed, processes like BIM will indirectly solve some of these issues even if the focus is more on time and money. By including common environmental requirements, professional associations could also quickly improve that process. New regulations and initiative like the LCA^2 will foster LCA use on a national scale. Public instances must lead by example and include embodied carbon in procurement for their future projects. New standardization procedures may arise in Canada from the LCA^2 initiative. More information about the initiative can be found here[3].

References

Association des Architectes en Pratique Privée du Québec (2019). "Contrat standard entre le client et l'architecte."

Canada (2010). National Building Code of Canada.

Canadian Green Building Council (2019). Zero carbon building standard V2.

Cloutier, C. (2011). Processus d'élaboration d'un projet de construction. M. d. l. c. e. d. communications.

Mehta, M. L., W. Scarborough and D. Armpriest (2017). Building construction: Principles, Materials, and Systems.

Michaud, M., E.-C. Forgues, V. Carignan, D. Forgues and C. Ouellet-Plamondon (2019). "A lean approach to optimize BIM information flow using value stream mapping." Journal of Information Technology in Construction: 472-488.

Ordre des Ingénieurs du Québec (2019). Guide de pratique professionnelle. O. d. I. d. Québec.

Public Works and Government Services Canada (2014). Design-Build projects delivery stage roadmap. Canada.

Québec (2020). Loi sur la qualité de l'environnement. G. d. Québec.

Royal Architectural Institute of Canada (2005). Canadian Standard Form of Agreement between Client and Architect.

[3] Website: https://nrc.canada.ca/en/research-development/research-collaboration/programs/low-carbon-assets-through-life-cycle-assessment-initiative

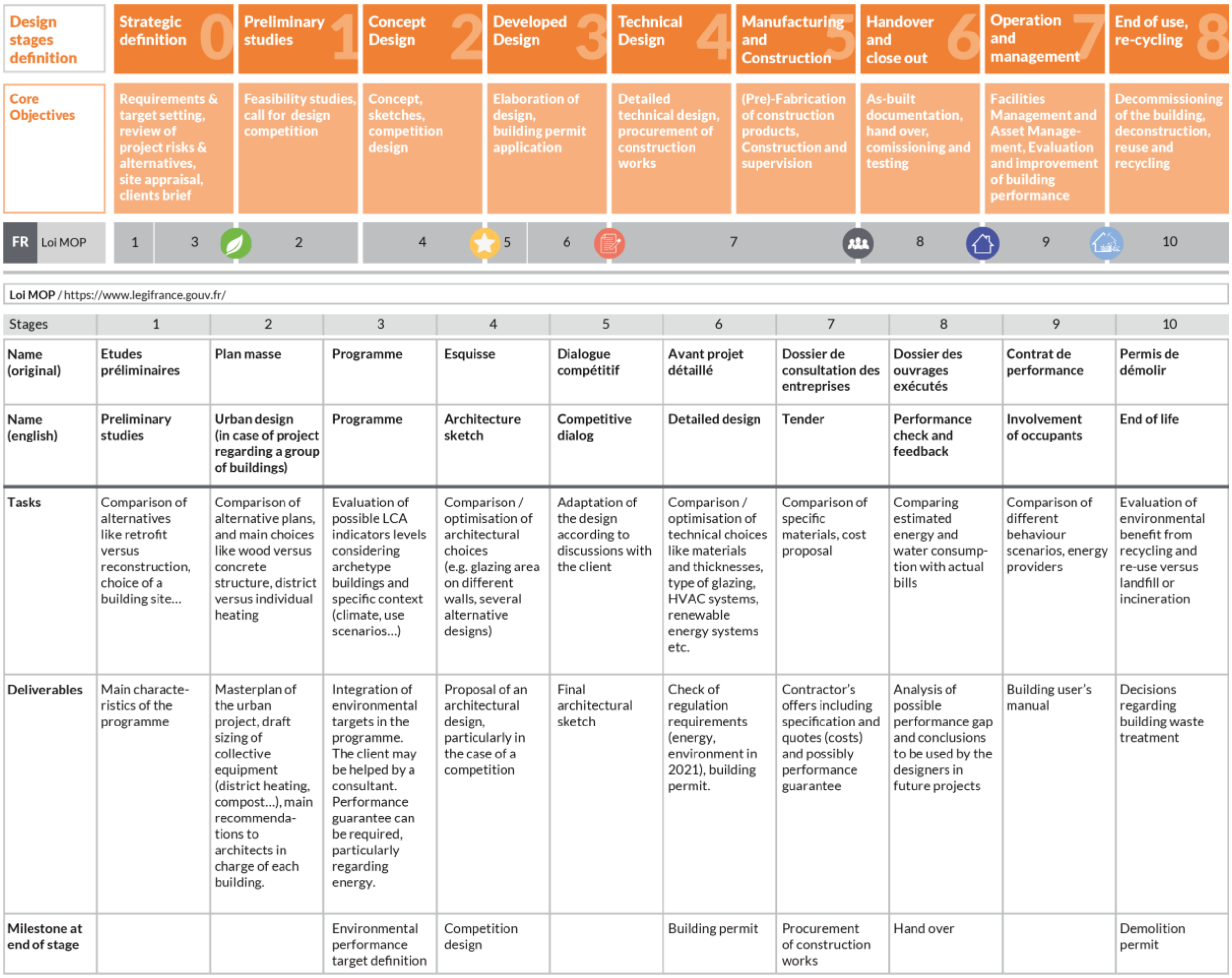
5. National report for France

Author(s): Bruno Peuportier (Institut Mines-Télécom, Centre Efficacité énergétique des systèmes (CES))

5.1 Introduction

Using LCA is more useful at early phases of a project, when the decisions made have the largest influence on environmental performance. But in most cases the resources are too limited at early phases. An interesting approach is to have one year called “competitive dialog” just after the competition. For instance three design teams are selected (each including an architect, a contractor and possibly engineers), and discuss with the clients in order to improve their project, being paid by the client who finally selects one of the teams. Each project is unique in terms of context and functional unit, so that designers in general prefer to use their own intelligence rather than just to follow a standard procedure. What is important is the result: performance should be checked by measurements (e.g. energy and water bills) and the designers can largely gain from this feedback for future projects.

5.2 National definition of design phases, milestones and deliverables



Design stages definition	Strategic definition 0	Preliminary studies 1	Concept Design 2	Developed Design 3	Technical Design 4	Manufacturing and Construction 5	Handover and close out 6	Operation and management 7	End of use, re-cycling 8
Core Objectives	Requirements & target setting, review of project risks & alternatives, site appraisal, clients brief	Feasibility studies, call for design competition	Concept, sketches, competition design	Elaboration of design, building permit application	Detailed technical design, procurement of construction works	(Pre)-Fabrication of construction products, Construction and supervision	As-built documentation, hand over, comissioning and testing	Facilities Management and Asset Manage-ment, Evaluation and improvement of building performance	Decommissioning of the building, deconstruction, reuse and recycling

FR Loi MOP 1 3 2 4 5 6 7 8 9 10

Loi MOP / https://www.legifrance.gouv.fr/

Stages	1	2	3	4	5	6	7	8	9	10
Name (original)	Etudes préliminaires	Plan masse	Programme	Esquisse	Dialogue compétitif	Avant projet détaillé	Dossier de consultation des entreprises	Dossier des ouvrages exécutés	Contrat de performance	Permis de démolir
Name (english)	Preliminary studies	Urban design (in case of project regarding a group of buildings)	Programme	Architecture sketch	Competitive dialog	Detailed design	Tender	Performance check and feedback	Involvement of occupants	End of life
Tasks	Comparison of alternatives like retrofit versus reconstruction, choice of a building site…	Comparison of alternative plans, and main choices like wood versus concrete structure, district versus individual heating	Evaluation of possible LCA indicators levels considering archetype buildings and specific context (climate, use scenarios…)	Comparison / optimisation of architectural choices (e.g. glazing area on different walls, several alternative designs)	Adaptation of the design according to discussions with the client	Comparison / optimisation of technical choices like materials and thicknesses, type of glazing, HVAC systems, renewable energy systems etc.	Comparison of specific materials, cost proposal	Comparing estimated energy and water consump-tion with actual bills	Comparison of different behaviour scenarios, energy providers	Evaluation of environmental benefit from recycling and re-use versus landfill or incineration
Deliverables	Main characte-ristics of the programme	Masterplan of the urban project, draft sizing of collective equipment (district heating, compost…), main recommenda-tions to architects in charge of each building.	Integration of environmental targets in the programme. The client may be helped by a consultant. Performance guarantee can be required, particularly regarding energy.	Proposal of an architectural design, particularly in the case of a competition	Final architectural sketch	Check of regulation requirements (energy, environment in 2021), building permit.	Contractor's offers including specification and quotes (costs) and possibly performance guarantee	Analysis of possible performance gap and conclusions to be used by the designers in future projects	Building user's manual	Decisions regarding building waste treatment
Milestone at end of stage			Environmental performance target definition	Competition design		Building permit	Procurement of construction works	Hand over		Demolition permit

Figure 7: Detailed overview of design phases, milestones and tasks - France

The phases differ according to the project, for instance the process is simpler for smaller buildings. In the case of a renovation project, the architecture sketch is generally not needed.

Design phases	Milestones	Deliverables
Preliminary studies	Comparison of alternatives like retrofit versus reconstruction, choice of a building site…	Main characteristics of the programme
Urban design (in case of project regarding a group of buildings)	Comparison of alternative plans, and main choices like wood versus concrete structure, district versus individual heating	Masterplan of the urban project, draft sizing of collective equipment (district heating, compost…), main recommendations to architects in charge of each building.
Programme	Evaluation of possible LCA indicators levels considering archetype buildings and specific context (climate, use scenarios…)	Integration of environmental targets in the programme. The client may be helped by a consultant. Performance guarantee can be required, particularly regarding energy.

Architecture sketch	Comparison / optimisation of architectural choices (e.g. glazing area on different walls, several alternative designs)	Proposal of an architectural design, particularly in the case of a competition
Competitive dialog	Adaptation of the design according to discussions with the client	Final architectural sketch
Detailed design	Comparison / optimisation of technical choices like materials and thicknesses, type of glazing, HVAC systems, renewable energy systems etc.	Check of regulation requirements (energy, environment in 2021), building permit.
Tender	Comparison of specific materials, cost proposal	Contractor's offers including specification and quotes (costs) and possibly performance guarantee
Performance check and feedback	Comparing estimated energy and water consumption with actual bills	Analysis of possible performance gap and conclusions to be used by the designers in future projects
Involvement of occupants	Comparison of different behaviour scenarios, energy providers	Building user's manual
End of life	Evaluation of environmental benefit from recycling and re-use versus landfill or incineration	Decisions regarding building waste treatment

5.3 Steps related assessment and improvement of environmental performance

The phases considered and the main actions to be done are summarized in the table given in annex (Peuportier B., 2015) but they should be adapted in line with the project, see also the ADEME guide aimed at building contractors and stakeholders (Bornarel A. et al., 2002).

Examples of LCA applications at various design phases can be found in the literature, e.g.

- Comparison of building sites (Polster B. et al., 1996)
- Comparison between retrofit and rebuilding (Palacios-Munoz B. et al., 2019)
- Design of an urban project (Roux C. et al., 2016), (Herfray G. et al., 2011)
- Design of a new construction (Oyarzo J. et al., 2014), (Thiers S. et al., 2012), (Recht T. et al., 2016)
- Renovation project (Peuportier B., 2002)
- Comparison of users behaviours (Polster B. et al., 1996)

5.4 Other relevant aspects

Performing LCA should include checking functional requirements when comparing alternatives. This induces the use of other tools in the design phase (e.g. thermal simulation, lighting and acoustic calculations to check comfort, structure calculation etc.). Cost calculation is of course also part of the design work.
An important aspect in eco-design is to identify main contributions in environmental impacts. This objective requires choosing an appropriate reference study period (RSP). Some LCA practitioners consider a 50 years period whereas a structure may last more than 200 years (Palacios-Munoz B. et al., 2019). Considering a shorter RSP gives more importance to products fabrication and end of life. Focusing on products leads to limit e.g. the use of insulation and solar systems, with the risk of higher energy consumption and higher impacts over the whole life cycle. In a design tool, the user should be allowed to choose the RSP according to the use of the building and the context even if the RSP is fixed in a regulation. Calculation according to the regulation are performed at the end of the design.

5.5 Outlook

The new regulation in preparation, following the E+C- experimentation, will probably impose a CO2 equivalent threshold on products and lower performance requirements regarding energy consumption (as the primary energy factor and CO2 emissions have been decreased for electricity with poor scientific justification). The risk is to limit the use of energy efficient or renewable techniques, leading to higher energy consumption during operation. It will be useful to compare the same building designed according to this regulation and the previous one, in order to know the variation of environmental impacts (which will probably increase). Eco-design should therefore be based upon more physical assessment and not just respecting regulation thresholds.

References

Use the "Insert Citation" button to add citations to this document.

Bornarel A. et al. (2002). *Qualité environnementale des bâtiments, manuel à l'usage de la maîtrise d'ouvrage et des acteurs du bâtiment.* Valbonne: ADEME.

Herfray G. et al. (2011). Life cycle assessment applied to urban settlements and urban morphology studies. *CISBAT.* Lausanne.

Oyarzo J. et al. (2014). Life cycle assessment model applied to housing in Chile. *Journal of Cleaner Production*, Volume 69, Pages 109–116.

Palacios-Munoz B. et al. (2019). The importance of estimating lifespan in LCA of buildings: The case of refurbishment vs. new construction. *Building and Environment*, vol 160, Article 106203.

Peuportier B. (2002). Assessment and design of a renovation project using life cycle analysis and Green Building Tool. *Sustainable Building Conference.* Oslo.

Peuportier B. (2015). *Eco-design for buildings and neighbourhoods.* London: Taylor & Francis Group.

Polster B. et al. (1996). Evaluation of the environmental quality of buildings - a step towards a more environmentally conscious design. *Solar Energy*, vol. 57 n°3, pp 219-230.

Recht T. et al. (2016). Ecodesign of a "plus energy" house using stochastic occupancy model, life cycle assessment and multi-objective optimisation. *Building Simulation & Optimization.* Newcastle: Hamza N and Underwood C. (Ed).

Roux C. et al. (2016). Life cycle assessment as a design aid tool for urban projects. *Sustainable Built Environment (SBE) regional conference.* Zurich.

Thiers S. et al. (2012). Energy and environmental assessment of two high energy performance residential buildings. *Building and Environment*, Volume 51, Pages 276–284.

Appendix

Steps related to assessment and improvement of environmental performance, from (Peuportier B., Eco-design for buildings and neighbourhoods, 2015).

TABLE 5.13: INTEGRATING ENVIRONMENTAL QUALITY IN THE DIFFERENT PROJECT PHASES

Phases	**Actions and objectives**
Feasibility of the operation	Evaluate needs, size a project adapted to these needs, estimate the investment and operation costs, (integrate energy and water saving)
Site	Choose a site, minimize environmental impacts (transport resulting from choice of site, presence of public transport, waste collection, exposure to sun, availability of energy – gas, district heating, etc.), minimize nuisance linked to the site (noise, pollution sources, etc.)
Choice of technical assistance	Seek out skills to put together a programme, monitor the building's design and construction and possibly monitor for one year after completion, recommended skills: lighting, acoustic and thermal calculations (preferably simulation) life cycle assessment
Programme	Define objectives and establish priorities through a participative approach involving all stakeholders, oversee construction costs by including optimization of life cycle cost (including use stage), integrate environmental quality targets in the programme, for example:
	- primary energy consumption (for heating, hot water, ventilation and lighting) < 50 kWh/m^2/yr, - low-flow sanitary equipment and equipment to sort activity waste, - minimal daylight factor > 2 in main rooms, - no. of days per year where temperature exceeds 27°C < 5 in main rooms for a typical climate year, - air renewal rate > 0.6 air changes / hour in main rooms

Estimation of costs	Refine estimated construction cost, preferably taking a life cycle cost approach (including usage, maintenance, possibly "external" costs (environmental and social)
Design competition and choice of winner	Require skills from building project teams, in particular: lighting, acoustic and thermal calculations (preferably by simulation), life cycle assessment, pre-select teams taking into account their references (performance of previous constructions) and their note of intention Set up a jury and a technical commission that takes environmental criteria on board in their appraisal, set out selection criteria in a transparent manner, including explicit environmental criteria Select the winning team after analyzing "enhanced preliminary sketch": preliminary sketch accompanied by a note describing the main technical choices so that the most significant performances can be quantified (energy and water consumption, daylight factors, acoustic insulation, summer comfort, environmental impacts, life cycle cost), enhanced preliminary sketches constitute an intermediate level between the preliminary sketch and the basic preliminary design
Sketch	Define the general part of the construction (morphology), fit the building into the site, anticipate outside equipment (compost or waste sorting, bicycle garage, etc.), optimize ground waterproofing to manage rainwater, organize main functions, make key technical choices, respect economic constraints Optimize environmental quality by taking advantage of building's exposure, compactness, balance between glazed and opaque surfaces depending on direction of surfaces and spaces, reduce consumption of matter (e.g. lightweight surfaces in zones that do not require thermal mass): the tools described in chapter 3 can be used from this stage to refine and validate a sketch
Basic Preliminary Design	Describe the project with plans (1/200, possibly details at 1/100) showing each premises (including technical areas, circulation, etc.), justify technical measures, calculate a provisional estimate of the provisional cost of the work, Evaluate more precisely, using the tools described above, energy and water consumption, comfort levels (thermal, visual and acoustic), environmental impacts, life cycle cost, refine some parameters (insulation thickness, materials, glazing quality, etc.) to optimize environmental quality
Detailed Preliminary Design	Describe the project in a detailed manner (plans at 1/100, details at 1/50), write up precise technical notes (thermal, acoustic, lighting simulation), optimize equipment, e.g. ventilation (air flow ensuring satisfactory air quality, heat recovery, possibly night-time ventilation to cool in summer, hygro-adjustable or time-set ventilation, etc.), sanitary equipment (reduced flow), heating equipment (e.g. condensing, high-efficiency, or low NOx emission boilers, solar systems, control, emitters), lighting systems (low-energy lamps and efficient light fittings, control), compare different energies to reduce environmental impact and costs (gas, wood, district heating, etc.), provide final estimate of provisional cost of the work

Tendering Package	Draw up the Special Technical Terms and Conditions by lot, preparing the order for contractors, and including detailed plans (1/50 or 1/20, in particular to deal with thermal bridges and air-tightness of the envelope), technical specifications (e.g. choice (of glazing and joinery) and block diagram schemes explaining how systems function Size installations (heating, ventilation, hot water, air conditioning), avoid over-sizing which can reduce performances (e.g. efficiency of boilers or air-conditioning units) Choose, for the same functionality, materials and Components (insulation, masonry, coatings, joinery, etc.) offering the highest environmental quality possible (c.f. life cycle assessments, environmental and health declaration sheets, FSC wood certification), consider recycled, renewable or re-used materials that are easy to recycle, take into account impacts from cleaning products (especially when choosing coatings) Motivate partner companies (e.g. sub-contractors) by informing them of the quality approach and objectives, especially the "green worksite" approach (waste sorting, limited nuisances – noise, dust, liquid waste, etc.)
Assistance to building contracts	Select contractors based on responses to tendering package, taking into account environmental aspects in the responses (commitment to green worksite charter, choice of products, techniques proposed such as using recycled materials for foundations, reduction of thermal bridges, etc.), and possibly company references, oversee additional costs of eco-techniques reassuring companies about manufacturers' guarantees, facility of implementation and any references
Worksite	Prepare the worksite to limit nuisances to local residents (select access areas to manage traffic, limit noise and dust), reduce risks of accidents and pollution (collect used oil, polluting waste), anticipate storage zones to sort waste and for backfill, Inform stakeholders about environmental quality objectives at worksite meetings, inform local residents, Ensure that worksite operations conform to green worksite charter commitments (the presence of an environment monitor is required on-site), ensure that workers are trained (efficiency of sorting waste, appropriate pictograms, air-tightness), identify waste recuperation channels and control relationships between contractors Verify some technical parameters (reduction of thermal bridges, insulation thickness, air permeability, etc.)
Acceptance and follow-up	Check whether the construction conforms with initial programme and special terms & conditions (e.g. quality of windows, sanitary equipment, lighting systems, etc.), verify correct operation of the building, its components (windows, solar protection, etc.) and its equipment (heating, hot water, ventilation, lighting), carry out tests (blower door for air tightness, infra-red thermography) Send future occupants notices, plans and information on managing and maintaining the building, inform them about environmental quality objectives and their role in the building's actual performance

	(temperature settings, ventilation, water and energy consumption, waste sorting, building maintenance, etc.) Monitor the building's performance during the first year (full guarantee of perfect completion for the year): note energy consumption (measurements may be perturbed in year 1 as some components dry out and controls are refined, and measuring during the second year is recommended), measure water consumption, temperatures, lighting levels, noise levels, and other more qualitative parameters with a satisfaction survey of occupants
Interior and exterior furnishings	Choose interior furnishings and equipment not included in the actual construction (light fittings, domestic and office appliances, etc.), taking into account water and energy savings (energy label for domestic appliances, priority for classes A & B), potential emissions from these appliances (e.g. formaldehyde or other VOCs linked to some glues or varnishes used on furniture), reduced packaging, easier maintenance and impacts generated at this stage, use of recycled or renewable materials, re-used or recyclable products Install appliances that generate electro-magnetic flows so as to limit human exposure (avoid placing this kind of appliance close to beds, work stations, etc.) Choose plantations for green areas so as to limit impacts from maintenance and the need for watering
Building management	Ensure occupants' comfort and the building's smooth running while limiting environmental impacts, especially: - adjust temperatures over time so as to avoid over-heating and reduce heating during unoccupied periods, - reduce ventilation during unoccupied winter periods, increase it in summer if night cooling is necessary, - inform occupants of their role in managing the building (managing lighting, water consumption, sorting waste, car-pooling or use of public transport, cycling, etc.), - maintain the building so as to increase the lifespan of components (e.g. regularly paint woodwork, maintain equipment for heating, hot water, ventilation, etc.) , - maintain the building so as to limit health risks (check domestic hot water installation, clean filters and vents, clean premises using products with low environmental impact, etc.), - measure energy and water consumption to detect excesses (fault in the boiler or heating control, water leak, etc.), - link up the building's equipment with municipal management (waste sorting), - choose consumables with low environmental impact (e.g. recycled paper)
Retrofit	Retrofit operations follow a fairly similar process to new construction projects: at the feasibility phase, an audit can evaluate requirements by consulting inhabitants and making technical assessments (e.g. energy audit); resources that can be mobilized are evaluated (common equity, loan repaid in line with rents, grants, etc.). It is not common for this operation to be open to competition since the building's architecture is rarely called into question. An architect is however involved in designing the façades. Analysis tools (for heat, lighting, acoustics, life cycle) can be used to compare

	alternatives and optimize choices, from basic preliminary design to special terms and conditions. Subsequent phases are similar to those of a new construction (company contracts, worksite, acceptance, management)
Deconstruction	Ensure that the building's deconstruction is necessary (possibly compare with a retrofit scenario) Prefer deconstruction to demolition, i.e. dismantling all components that can be separated, e.g. windows, possible re-use of components, sorting and recycling of waste Manage the worksite taking a green approach (c.f. worksite phase), with even more emphasis on waste management (volume and cost).

6. National report for Slovenia

Author(s): Tajda Potrc Obrecht (Zavod za gradbeništvo (ZAG))

6.1 Introduction

The design phases are defined with Rules on the detailed content of documentation and forms related to construction (Pravilnik o podrobnejši vsebini dokumentacije in obrazcih, povezanih z graditvijo objektov) which have to be followed in the design process of construction works.
The Rules specify the detailed content, form and method of preparation of documentation for complex, less demanding and non-demanding construction. It is used for particular types of buildings, civil engineering structures and other constructions.

6.2 National definition of design phases, milestones and deliverables

Design stages definition	Strategic definition 0	Preliminary studies 1	Concept Design 2	Developed Design 3	Technical Design 4	Manufacturing and Construction 5	Handover and close out 6	Operation and management 7	End of use, re-cycling 8
Core Objectives	Requirements & target setting, review of project risks & alternatives, site appraisal, clients brief	Feasibility studies, call for design competition	Concept, sketches, competition design	Elaboration of design, building permit application	Detailed technical design, procurement of construction works	(Pre)-Fabrication of construction products, Construction and supervision	As-built documentation, hand over, comissioning and testing	Facilities Management and Asset Manage-ment, Evaluation and improvement of building performance	Decommissioning of the building, deconstruction, reuse and recycling
SLO GZ	- - -	- - -	IDZ	DGD	PZI	PID	DZO, UD -	- - -	- - -

GZ - Gradbeni zakon (GZ)-Pravilnik o podrobnejši vsebini dokumentacije in obrazcih, povezanih z graditvijo objektov / http://www.pisrs.si/Pis.web/pregledPredpisa?id=PRAV13306

Stages		IZP	DGD (PGD)	PZI			PID	DZO	UD	
Name (original)		Idejna zasnova za pridobitev projektnih in drugih pogojev	Projektna dokumentacija za pridobitev menj in gradbenega dovoljenja	Projektna dokumentacija za izvedbo gradnje			Projektna dokumentacija izvedenih del	Dokazilo o zanesljivosti objekta	Uporabno dovoljenje	
Name (english)		The concept for obtaining the project and other conditions	Project documentation for obtaining construction permit	The project documentation for the construction			Project documentation for the comleted work	Proof of the reliability of the object	Operating permit	
Tasks	design concept, preliminary time schedule, cost estimation (+/-20%)		building plans 1:100 or 1:200,building permit application	constructive details, plans from 1:50 to 1:1, detailed schedule for construction	Coordination of tendering, bill of quantities, procurement documents	Tendering, controlling, cost calculation	designed to obtain an operating permit, recording facility and the use and maintenance of the facility (shows possible deviation from the project documentation)			Taking care of construction defects
Deliverables				leading plan (bill of quantities, cost calculation)				instruction for operation and maintaince		
Milestone at end of stage		Competition plans	Building permit							

Figure 8: Detailed overview of design phases, milestones and tasks - Slovenia

According to the purpose of use, the documentation is classified into:

1. Concept design- Idejna zasnova za pridobitev projektnih in drugih pogojev (IZP) ,
2. Approval design- Projektna dokunetacija za pridobitev mnenj in gradbenega dovoljenje (DGD),
3. Detailed design- Projektna dokumentacija za izvedbo gradnje (PZI),
4. Project Documentation of Completed Works- Projektna dokumentacija izvedenih del (PID),
5. Proof of the Reliability of the object- Dokazilo o zanesljivosti objekta (DZO)

1. Concept design- Idejna zasnova za pridobitev projektnih in drugih pogojev (IZP)

INTENT: obtain project idea and other conditions for the execution of construction and use of the facility.

DELIVERABLES: the details of the participants, general information on the facilities and location views

MILESTONES: Competition design

2. Approval design- Projektna dokumetacija za pridobitev mnenj in gradbenega dovoljenje (DGD)

INTENT: the compliance of the documentation and plans with the regulations

DELIVERABLES: information on the participants, a statement by the designer and the project manager general information on the facilities the technical report, graphical representations.

MILESTONES: Building permit

3. Detailed design- Projektna dokumentacija za izvedbo gradnje (PZI)

INTENT: provide information about the execution of the construction work

DELIVERABLES: the master plan and plans.

MILESTONES: Procurement

4. Project Documentation of Completed Works- Projektna dokumentacija izvedenih del (PID)

INTENT: to obtain the operating permit, evident all the change happened during the construction process

DELIVERABLES: plans with highlighted changes that happened during the construction process

MILESTONES: /

5. Proof of the Reliability of the object (DZO)

INTENT: documentation that proves that the construction project fulfils all the requirements, basis for issuing the operation permit

DELIVERABLES: proofs of building quality collected, instruction for operation and maintenance

MILESTONES: Hand over

6.3 Steps related to assessment and improvement of environmental performance

The Approval design has to provide information about energy efficiency of the project. It has to deliver data about the methods used; calculation that prove that construction is aligned with the legislative requirements, annual primary energy consumption for the technical systems in the building; CO2 emissions that are emitted by the use of the technical equipment in the building.

In the Detailed design- Projekt za izvedno (PZI) the bill of quantities are delivered. These can be than used to make an LCA calculation, but LCA ins not mandatory in Slovenia.

6.4 Outlook

Within a project the certification process for sustainable buildings will be developed in within this project it is foreseen that the use of LCA in building should be implemented.

7. National report for Spain

Author(s): Antonio García-Martínez, Carmen Llatas, Juan Carlos Gómez de Cózar, Bernardette Soust-Verdaguer (University of Seville, Seville)

7.1 Introduction

In the Spanish context, the architects are responsible of the project and construction management of building construction and civil engineering works including (such as urban services: streets, sidewalks, lighting, distribution networks, gardening, etc., hydraulic constructions for lighting and water supply to towns, sewerage works, neighbourhood and private utility roads; bridges, reservoirs, canals, irrigation ditches and bracelets for private service and urban development of the underground) The design stages of the projects are defined in the RD. 2512/1977 [1] , the phase of the work are: Preliminary stage (*Estado previo*), Preliminary Project (*Anteproyecto*), Basic project (*Proyecto Básico*), Execution Project (*Proyecto de Ejecución*), Construction Management (*Dirección de obra*) and Reception and Settlement (*Liquidación y recepción de obra*). However, based on current practice a stage before the Preliminary stage can be identified, which is called Preliminary architectural program or Program requirements (*Programa Preliminar Arquitectónico).* Regarding these design stages, little requirements, experience and regulations about the integration of building environmental performance assessment and LCA application at the phases of a project in current practice are detected.

7.2 National definition of design phases, milestones and deliverables

Design stages definition	Strategic definition 0	Preliminary studies 1	Concept Design 2	Developed Design 3	Technical Design 4	Manufacturing and Construction 5	Handover and commissioning 6	Operation and management 7	End of use, re-cycling 8
Core Objectives	Requirements & target setting, review of project risks & alternatives, site appraisal, clients brief	Feasibility studies, call for design competition	Concept, sketches, competition design	Elaboration of design, building permit application	Detailed technical design, procurement of construction works	(Pre)-Fabrication of construction products, Construction and supervision	As-built documentation, hand over, commissioning and testing	Facilities management and asset management, evaluation and improvement of building in-use performance	Decommissioning of the building, deconstruction, reuse and recycling
ES RD2515, CTE, LOE	0	1	2	3	4	5	6 -	-	-

RD 2515/1977*, CTE and LOE.

Stages	0	1	2	3	4	5	6
Name (original)	Programa Preliminar Arquitectónico	Estudio Previo	Anteproyecto	Proyecto Básico	Proyecto de Ejecución	Dirección de obra	Liquidación y recepción
Name (english)	Program requirements	Preliminary stage	Preliminary project	Basic Project	Execution project	Construction management	Supervision of object
Tasks	This stage is mainly developed by the client. Here, the main program requirements are defined, and aims to define the building program's specific requirements.	This stage aims to guide about the scale, building typology and building area of the future building. It mostly aims to estimate the allowed building area / volume according to the urban regulations. Includes the proposal of the technical needs, the list of requirements and an approximate cost estimation.	The preliminary project aims to define the shape and internal distribution of the building. It is a more consistent stage to estimate the building area / volume and the main building characteristics.	The basic project aims to define the main characteristics of the building, including the internal distribution, main materials, structure and main technical characteristics.	The executive project aims to define the technical characteristics of the building, face to the construction stage. It includes all the technical characteristics and drawings of the building as well as the demonstration of the compliance of National (CTE 2006) and regional regulations.	It involves thecoordination of the technical team and the technical,economic and aesthetics interpretation of executive project of the building.	In this phase the definition of the final economic status of the building is made. It also includes the receipt of the building on behalf of the client.
Deliverables	List of preliminary requirements which can include for example the number of rooms, specific technical installations, etc.	1. Report including the technical needs and the list of requirements. 2. Sketch or drawings (with or without scale). 3. Cost estimation (guide values).	1. Report justifying of the proposal of building design. 2. Drawings (unbounded plans, sections, façades). 3. Cost estimation (based on approx. built area)."	1. General description of building. 2. Constructive description of building. 3. Drawings (Plans, Sections, Façades). 4. Compliance of CTE (CTE 2006) (Basic). 5. Cost estimation (by group of item).	1. General description of building. 2. Constructive description of building. 3. Compliance of CTE (CTE 2006). (Complete). 4. Compliance with other regulations. 5. Annex. 6. Execution Drawings (Plans, Sections, Façades, Details). 7. Technical Specifications Document. 8. Bill of quantities and detailed cost estimation. 9. Use and Maintenance Manual.	1. Work orders (graphic and written). 2. Work certifications.	1. Final economic state of the building. 2. Certificate of receipt of the building.
Milestone at end of stage			Competition plans	Building permit			Hand over

*At the time of this survey, RD 2515/1977 (Real Decreto 2512/1977 - Art. 1.4 Fases del trabajo / https://www.boe.es/boe/dias/1977/09/30/pdfs/A21750-21769.pdf) is partially derogated, yet it is the only available reference complementing the contents of CTE and LOE regarding the definition of building design stages.

Figure 9: Detailed overview of design phases, milestones and tasks - Spain

The main regulatory framework for architects in Spain is the CTE (*Código Técnico de la Edificación*) [2], the document contains the main requirements that the buildings should comply in security and habitability, defined in the Law 38/1999 *de 5 de noviembre, de Ordenación de la Edificación* (LOE). The documnet is composed by the following parts:

1. *Royal Decree* and Part 1
2. Structural security
3. Fire security
4. Utility and accessibility security
5. Energy savings (energy and environmental aspects)
6. Noise protection
7. Healthiness
8. Legal provisions (*Disposiciones legales*)

7.3 Steps related to assessment and improvement of environmental performances

In current practice, the building environmental performance requirements are provided by the CTE [2]. There, general and the regional specific requirements of the buildings during the design stages, are mostly focused on the operational energy. The energy demand of the building is estimated and certified along the design stages.

For research purposes, the assessment of the environmental performance of the building is based on the LCA application. According to the information provided, the uncertainties during the design stages falls as the level of definition of the building information increase. Thus, during the “Preliminary Project”, “Basic Project” and “Executive Project” design phases the environmental impacts produced by the building can be estimated by using for example BIM-based LCA methods [3–8]. Due to the fact that the design process mostly includes 3D models of the building, these methods can adapt the workflow and available data from the BIM model to the LCA application. The studies mostly focused the LCA application at an approx. LOD 300 because at this level the most relevant building elements and components has been already defined [9]. The “Concept stage” needs another method to deal with these uncertainties, especially to estimate the environmental impacts of buildings. In the Spanish context it is possible to estimate the cost of the building adapted to regional characteristics by using a simplified method [10] developed by the associations of architect (COA). Thus, a similar method to estimate the environmental impacts of buildings can be developed.

7.4 Other relevant aspects

Another recent contribution (for research purposes) to calculate the CO2 emissions of building sector, during the concept stage of design in Spain is the CO2 tool [11]. In the Open Educational Resource OERCO2 [11] the calculations of CO2 emissions at each phase of the building are unified to get an overall picture about footprint from the concept stage and decide on each construction variable.

7.5 Outlook

The current national regulations are mostly focused on the operational energy demand based on simplified calculation tools (called HULC) CTE [2]. Hoverer, differences has been detected in the environmental requirements (the use of other tools or sources) and specific regulations along the different regions and “Autonomous Communities” in Spain. In design practice, lack of knowledge and maturity, and little requirements related to the environmental performance of the building in design stages are detected. In spite of the fact that progress has been detected in research works, there are several aspects that require attention, such as the a lack of harmonisation in the data sources related to the environmental impact categories such as CO2 emission and the energy consumption (contained in commercial tools e.g., BEDEC, CYPE).

References

[1] Ministerio de la Vivienda de España. RD 2512/1977. 1977.

[2] CTE. Spanish Building Technical Code. Real Decreto 314/2006 17 Marzo 2006;BOE 74:11816–31. doi:CTE-DB-SE.

[3] Mesa González A. Análisis de ciclo de vida de soluciones arquitectónicas ligeras de rápido montaje: el sistema florín. Master Thesis. Tutors: Juan Carlos Gómez de Cózar & Atonio García Martínez. MIATD, University of Seville, 2013.

[4] García-Martínez A, Gómez de Cózar JC, Ruiz Alfonsea M. Using BIM-based methods to obtain life cycle environmental benchmarks for buildings. Life Cycle Anal. Assess. Civ. Eng. Towar. an Integr. Vis., 2018.

[5] Ruiz Alfonsea M. Análisis del ciclo de vida de modelos de habitación construidos en entorno de clima tropical (Colombia, s. XX-XXI). 2016.

[6] Soust-Verdaguer B. Análisis del Ciclo de Vida de edificios residenciales. Propuesta metodológica para el diseño de una herramienta simplificada. Tesis Doctoral. Universidad de Sevilla, 2017.

[7] Soust-Verdaguer B, Llatas C, Moya L. Comparative BIM-based Life Cycle Assessment of Uruguayan timber and concrete-masonry single-family houses in design stage. J Clean Prod (Accepted) 2020.

[8] Soust-Verdaguer B, Llatas C, García-Martínez A, Gómez de Cózar JC. BIM-based LCA method to analyze envelope alternatives of single-family houses: case study in Uruguay. J Archit Eng 2018;24:05018002. doi:10.1061/(ASCE)AE.1943-5568.0000303.

[9] Soust-Verdaguer B, Llatas C, García-Martínez A. Critical review of BIM-based LCA method to buildings. Energy Build 2017;136:110–20. doi:10.1016/j.enbuild.2016.12.009.

[10] COAS. Método para el cálculo simplificado de los Presupuestos estimativos de ejecución material de los distintos tipos de obras. 2018.

[11] OERCO2. OERCO2 2018. http://oerco2.eu/.

Appendix

In the Spanish context the design stages of an architectural project can be organized according to the following criteria (Source RD. 2512/1977 [1]):

DESIGN STAGE	**Preliminary architectural program or Program requirements (Programa Preliminar Arquitectónico)**	**Preliminary stage (*Estado previo*)**	**Preliminary project *(Anteproyecto)***	**“Basic Project” (*Proyecto Básico*)**	**“Execution project” (*Proyecto de Ejecución*)**	**Construction management (*Dirección de obra*)**	**Reception and settlement (*Liquidación y recepción de obra*)**
Definition	This stage is mainly developed by the client. Here, the main program requirements are defined, and aims to define the building program’s specific requirements.	This concept stage aims to guide about the scale, building typology and building area of the future building. It mostly aims to estimate the permitted building area / volume according to the urban regulations and to quick estimate the building costs.	The preliminary project aims to define the shape and internal distribution of the building. It is a more consistent stage to estimate the building area / volume and the main building characteristics.	The basic project aims to define the main characteristics of the building, including the internal distribution, main materials, structure and main technical characteristics.	The executive project aims to define the technical characteristics of the building, face to the construction stage. It includes all the technical characteristics and drawings of the building as well as the demonstration of the compliance of National [2] and regional regulations.	The architect coordinates the construction management of the building, the technical, economic and aesthetic interpretation of the “Execution project”.	The architect determinate the “final economic state” of the building construction works, by using the prices of the real products and real measurements. The reception of the building is also performed in the name of the client, according to the documents and technical specifications contained in the “Execution project” and the rest of the documents included during the construction works.
Content	The contents and scope of this primary estimation are not regulated by National regulations.	The contents and scope of this primary estimation are not regulated by National regulations.	The contents and scope of this primary estimation are not regulated by National regulations.	The contents and scope of this design stage are established by the associations of architect (“Colegios de Arquitectos”) and complies with National [2] and regional regulations for buildings.	The contents and scope of this design stage are established by the associations of architect (“Colegios de Arquitectos”) and complies with National [2] and regional regulations for buildings.	The contents and scope of this stage complies with National [2] and regional regulations for buildings construction works.	The contents and scope of this stage complies with National [2] and regional regulations for buildings construction works.

Deliverable	List of preliminary requirements which can include for example the number of rooms, specific technical installations, etc.	Documents and drawings are needed during the decision-making, mostly to guide the client. - Report including the list of requirements - Drawings and schemes (without scale) - Cost estimations	Documents and drawings are needed during the decision-making, mostly to guide the client. - Report and justification of the decisions - Plans, facades and sections (without scale) - Cost estimations (updated)	These documents and drawings are needed to the building permit application. The main content of the "Basic project" are: 1. Description of the building. 2. Constructive description of the building. 3. Drawings (Plans, Sections, Façades). 3. Compliance of the CTE [2] (Basic). 4. Cost estimations (updated).	The main content of the "Executive project" are: 1. Description of the building. 2. Constructive description of the building. 3. Compliance of the CTE [2]. (Complete). 4. Compliance with other regulations. 5. Annex. 6. Drawings for the execution (Plans, Sections, Façades, Details). 7. Technical Specifications Document 8. Measurements and cost estimations (updated). 9. Usage and Maintenance Manual.	The main contents of this phase are: - "Orders of Construction Works", graphics and specifications. - "Construction attestation"	The main contents of this phase are: - Final Economic state of the building construction works - Hand over minute.
Milestone			Competition Plan	Building permit 1rst step Tendering	Building permit 2nd step	Construction attestation	Hand over