HI-SMART

HI-SMART: HIGHER EDUCATION PACKAGE FOR NEARLY ZERO ENERGY AND SMART BUILDING DESIGN

MODULE #6

CHAPTER 3: LIFE CYCLE ANALYSIS, LIFE CYCLE COSTING

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6.3.1 INTRODUCTION

For several decades, various political and professional forums have been talking about the unsustainability of the current way of building construction and operation, precisely because of the significant negative effects on the environment. Notorious are data on the demands of buildings for 25 to 40% of total energy consumption, 30-50% of extracted raw materials, 20-30% of water, buildings and their operation account for about 35% of solid waste and are responsible for 30% -40% of greenhouse gases. Sustainable construction experts emphasize energy and material efficiency, as well as energy and resource efficiency. The determining factors of sustainable or ecological construction are - the use of renewable energy sources and their optimal use, the right choice of location and the choice of materials so as to minimize damage to air, water and soil during their production, use and disposal [4].

The first sustainability assessment systems began in the 1990s, with the aim of creating societal pressure to build environmentally friendly buildings that are both energy-efficient and resource-efficient. Evaluation systems take into account the impacts of buildings throughout the life cycle of buildings, from the extraction of raw materials, the production of building materials, their transport, the construction and operation of the building itself, the demolition of the building at the end of its life, waste management and recycling.

The tools for environmental assessment are different, depending on the assessment of different phases of the life cycle of buildings and different areas, type of buildings and construction or recovery. Some tools are global, some national, local, can be designed for different users - architects, consultants, building owners, etc. In recent years, investors' interest in assessing the sustainability of buildings has increased, conditioned (so far) mainly by the increased competitiveness of the assessed building compared to ordinary buildings of the same purpose (these are mainly office buildings).

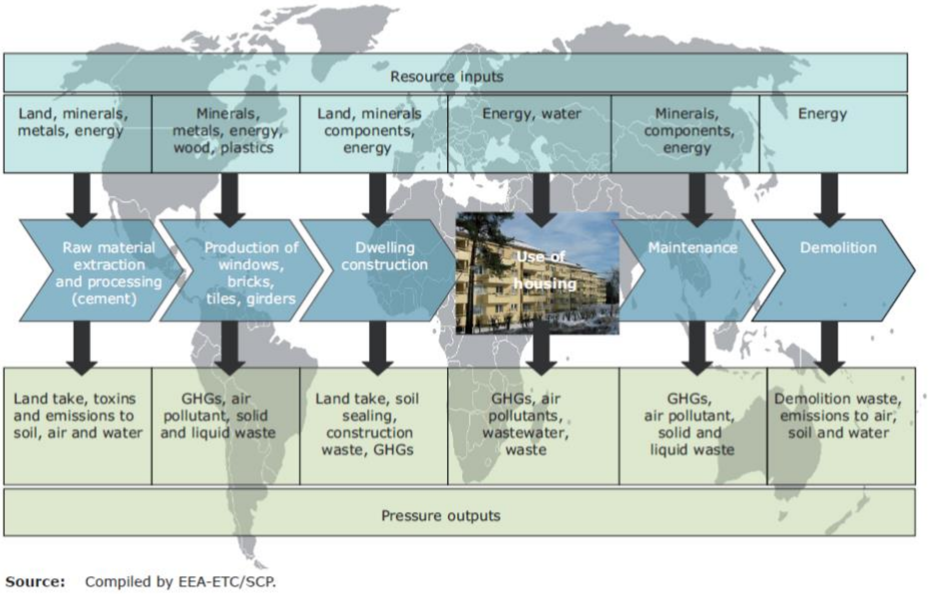


Figure 6.3.1 – Life cycle of housing, The European environment -2012 update. State and outlook 2010. Consumption and the environment. Housing. EEA 2010

The most widespread are application-oriented assessment systems, based on comparing the life cycle of a building and obtaining all quantitative and qualitative indicators of environmental assessment of buildings. Some of them are specialized for certain types of buildings or are adapted to the priorities of users, others are focused on simplified communication to the client, the trend is to include facility management to the assessment. The assessment considers economic, social and environmental criteria that are interlinked and their impacts should be balanced.

6.3.2 BASIC AREAS OF SUSTAINABILITY ASSESSMENT OF BUILDINGS AND CIVIL ENGINEERING WORKS

The European Union has long sought to find meaningful solutions to the unsustainability of construction. Energy Performance of Buildings Directives were adopted (EPBD I in 2002 and EPBD II in 2010). In EPBD II the requirement No.7 for constructions was implemented - "sustainable use of natural resources": Buildings must be designed, constructed and demolished in such a way that the use of natural resources is sustainable and in particular ensures: (a) the re-use or recyclability of buildings, their materials and parts after demolition; b) durability of buildings; (c) the use of organic raw materials and secondary materials in construction. "

European committee for standardization (CEN) established technical committee CEN/TC 350 Sustainability of construction works with the aim to develop voluntary harmonized method for the assessment of the sustainability aspects of new and existing construction works and for the assessment of construction products.

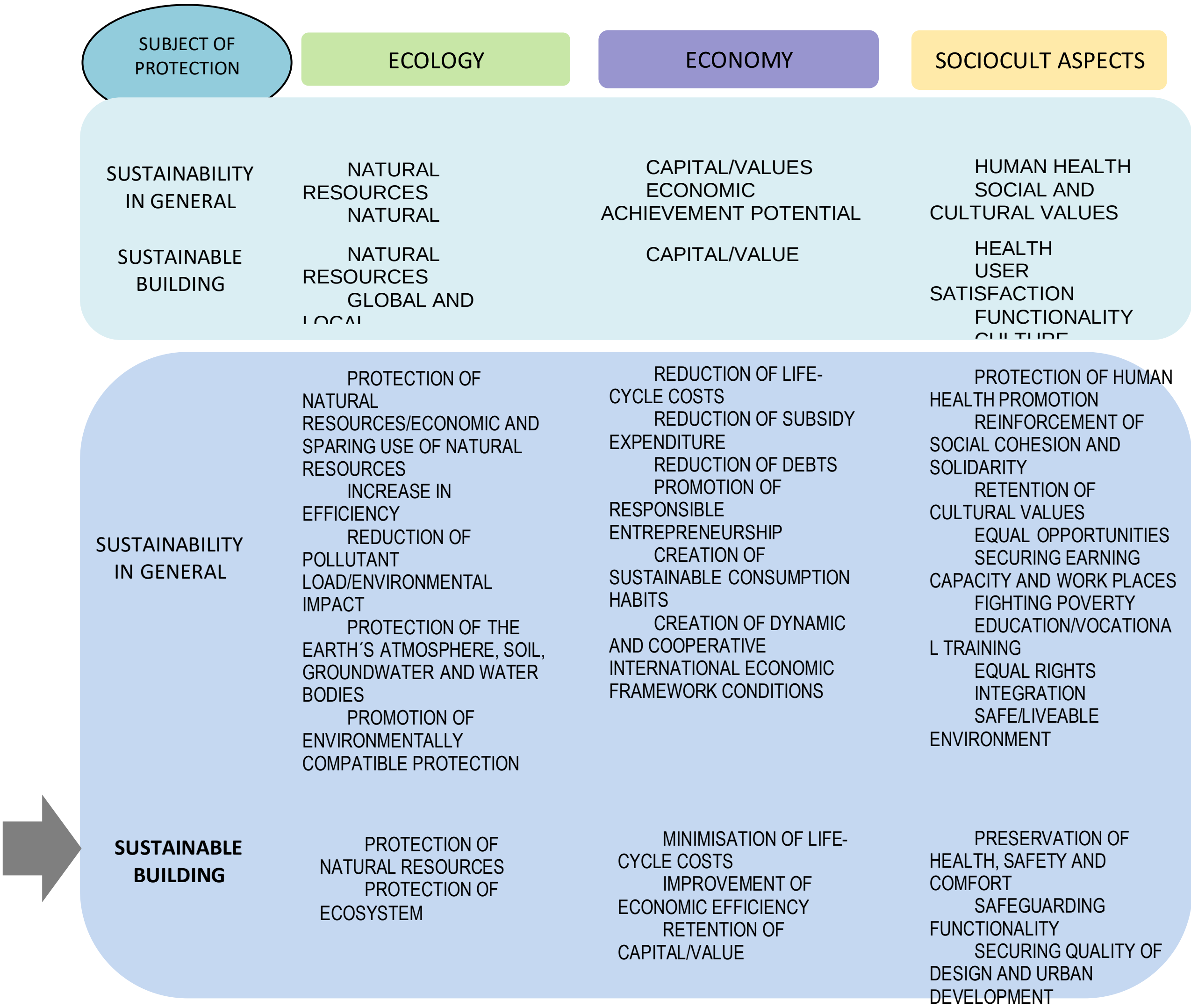


Figure 6.3.2 – Subjects and targets of sustainability (According to J. L. Moro: DETAIL practice Flooring Volume 2, Edition Detail, 2016)

The methodological basis has been developed in the context European strategies, such as mitigation, adaptation and resilience to climate change, and life cycle thinking. The standards developed by this Committee describe coherent methodologies for the assessment of sustainability of construction works covering the assessment of environmental, social and economic performance (aspect and impacts) of buildings and civil engineering works, and the provision of construction product environmental information (EPD) for materials used in construction.

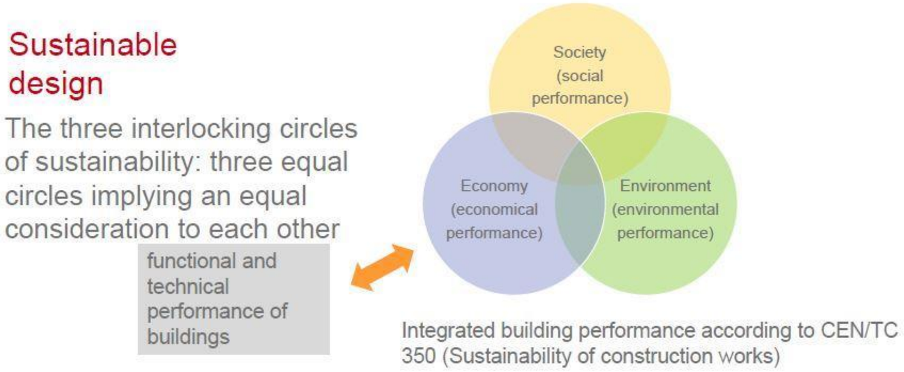


Figure 6.3.3 – Integrated building performance according to CEN/TC 350 (Sustainability of construction works). Three interlocking circles of sustainability: three equal circles implying an equal consideration to each other

The requirements set out in the set of standards are voluntary, the main aim of the set of standards is to allow comparability of evaluation results. The standards do not specify reference values or property levels. Requirements to ensure the sustainability of construction are bound in EU directives and regulations, which are transposed into national legislation in the form of laws and decrees.

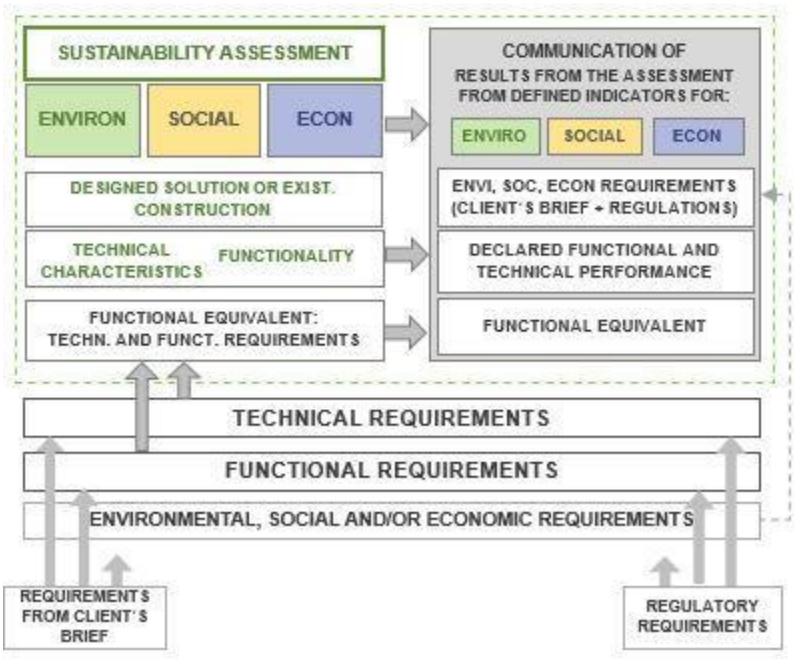


Figure 6.3.4 – Concept of integrated building performance of buildings according to CEN/TC350

6.3.3 GENERAL PRINCIPLES OF LIFE CYCLE ASSESSMENT (LCA)

Life cycle approach considers all stages from extraction of raw materials to the transport, from processing, manufacturing, packaging and distribution of construction products to their use and re-use, recycling and waste disposal.

In recent years, LCA has become an effective tool to evaluate the potential impacts buildings and their components have on the environment during their life cycle. The ISO standards 14 040 and 14 044 describe general approach and principles of life cycle assessment. The EU standard EN 15978 provides a detailed description of all aspects that are relevant in the context of property development.

The method of life cycle assessment is helpful in the design, construction and management processes. Life cycle assessment is a method to calculate the material and energy flows, where all inputs (total amount of raw materials and energy used) and outputs (total amount of waste and emissions produced) during the life cycle of a "product system" (building, construction product or service) are associated with potential environmental impacts (see Fig. 6.3.1).

Architects, engineers, consultants and other stakeholders are confronted with the problem of the collection and interpretation of life cycle costs and life cycle assessment information. This type of information must be taken into account in design decisions, reports to the client and certification system. The method of integrated design, founded on life cycle analysis, allows a holistic approach and the continuous consideration of a large number of aspects

Structures, buildings and infrastructure have the longest lives of all man made products. Buildings have to be maintained, altered and after the end of use materials have to be reused and recycled.

In general, there are 4 life cycle phases of buildings-

1. New building (from idea to handover of the building),

2. Usage (use, operation, maintenance, renewal),

3. Renewal (renewal, conversion and usage),

4. Demolition and disposal.

Each phase gives rise to material and energy flows, information and financial flows. Life cycle oriented planning should be based on the mutual dependencies and flows (Fig. 6.3.1 and 6.3.5).

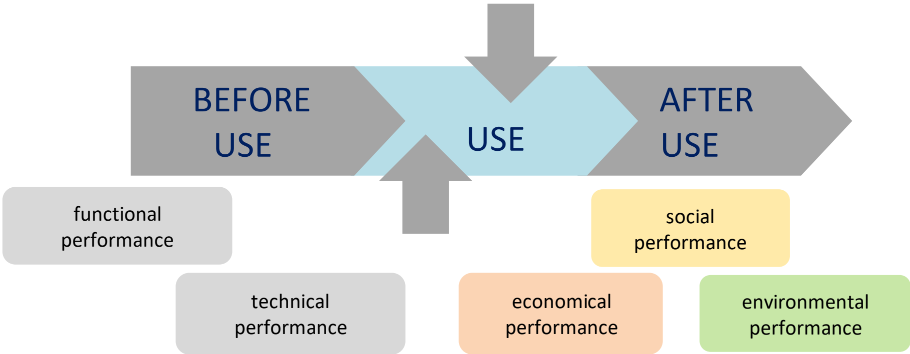


Figure 6.3.5 – Life cycle and system boundaries

Environmental quality of buildings consists of consideration of environmental impacts related to the use of resources and services required over the life cycle. Environmental impacts are defined by indicators (environmental impact categories) for construction products. Environmental product declaration (EPD) is used as transparent declaration of the life-cycle environmental impact of the product. Environmental performance of buildings and CE works related standards are shown in Figure 6.3.5.

Social performance of buildings consider for example quality of living, healthy and safe environment, future professional opportunities etc. Social performance of buildings and CE works related standards are shown in Figure 6.3.6.

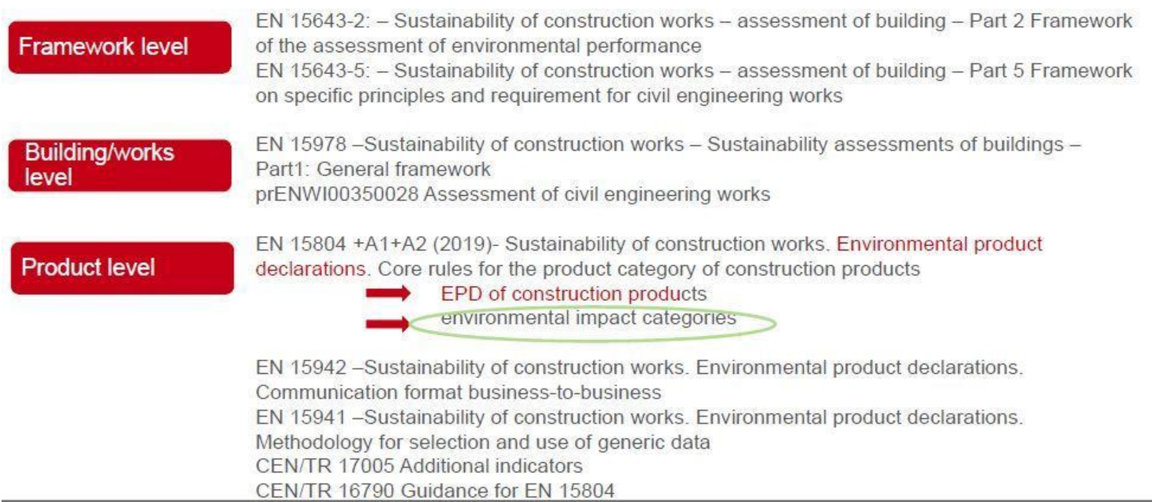


Figure 6.3.6 – Environmental performance of buildings/CE works in standards

Framework level	EN 15643-3 Sustainability of construction works - Assessment of buildings - Part 3: Framework for the assessment of social performance
Building/works level	EN 16309 Assessment of social performance of buildings. Calculation methods
Product level	Technical information of some aspects are included in EN 15804 to form a part of EPD

Figure 6.3.7 – Social performance of buildings/CE works in standards

Economic performance of buildings consider cost or financial value over the life cycle of a building with the aim of reduction of life cycle costs and costs of sustainable conservation and increase of economic value of a building. Assessment of economic performance can be worked out as Whole life cost or Life cycle cost. Environmental performance of buildings and CE works related standards are shown in Figure 6.3.7.

Framework level	EN 15643-4 Sustainability of construction works. Assessment of buildings. Framework for the assessment of economic performance
Building/works level	EN 16627 – Sustainability of construction works – Assessment of economic performance of buildings - Calculation methods
	ISO 15686-5: Building and constructed assets – Service-life planning – Part 5: Life-cycle costing
Product level	Technical information of some aspects are included in EN 15804 to form a part of EPD

Figure 6.3.8 – Economic performance of buildings/CE works in standards

Assessment of integrated building performance of buildings according to Technical committee CEN/TC 350 Sustainability of construction works considers 4 levels:

- concept level
- framework level
- building/CE works level
- product level

Standards related to the levels of assessment are presented on figures 6.3.6 – 6.3.9.

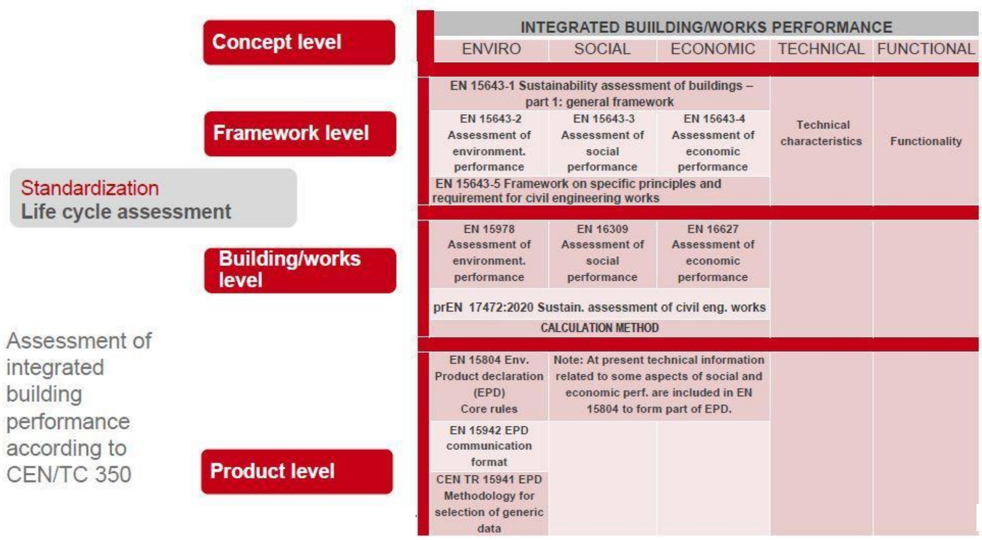


Figure 6.3.9 – Assessment of integrated building performance according to CEN/TC 350

6.3.4 LIFE CYCLE ASSESSMENT OF BUILDINGS

According to EN ISO 14040, life cycle assessment (LCA) is based on compiling and evaluating the inputs and outputs and the potential environmental impacts of a product system in the course of its life. Life cycle assessments of buildings are the basis for material or component alternatives comparison, related to life cycle scenario chosen by the planner with the aim to find the potential for improvement of the building. Life Cycle Assessment (LCA) is a method in order to analyze and quantify the environmental aspects and impacts of a product system over its life cycle. Basics and requirements are described in ISO Standards 14040 and 14044. The lifecycle assessment method according to ISO 14040 is divided into 4 phases (Fig. 6.3.10):

- Goal and scope definition
- Inventory analysis
- Impact assessment
- Interpretation

Goal and scope definition is determined in the first phase. The aim is to identify issues and questions which should be dealt with in the assessment. The definition is a basis for the determination of the **system boundary** of the assessment and for the construction product processes that must be considered (construction, replacement, disposal etc.). Issues to be considered can be:

- selection of the most suitable construction material according to its function required

- optimization of materials used for construction/refurbishment with the aim to increase the service life of the building
- identification of the potential for improvement of the impact on the environment (by selection of the most suitable construction material and building component)
- identification of the building life cycle phase with the greatest environmental impact.

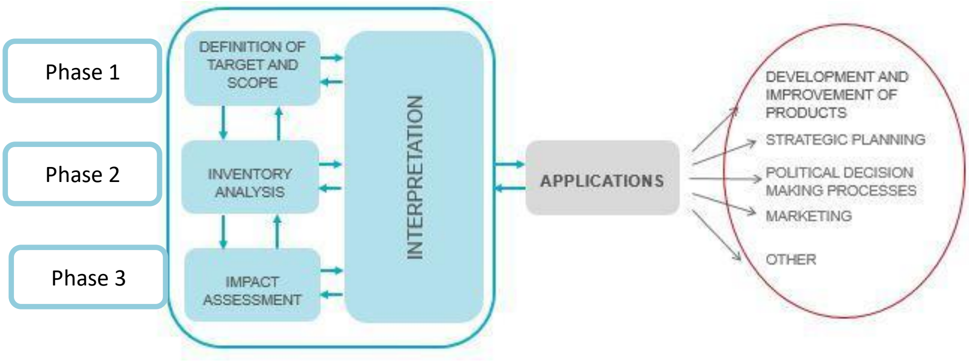


Figure 6.3.10- Life cycle phases according to ISO 14040

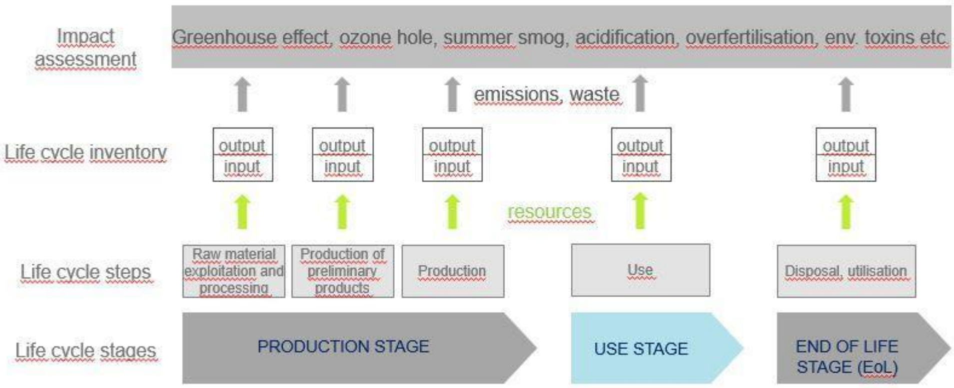


Figure 6.3.11 - LCA structure (according to König et al: A life cycle approach to buildings, Detail, 2010). Life cycle inventory encompasses inputs and outputs. Life cycle impact assessment identifies the resulting influences on the environment.

Life cycle inventory (LCI) – phase 2 - encompasses the compilation and quantification of inputs and outputs of a given product in the course of its life (14040). Input is resource consumption, output includes emissions and waste.

Life cycle impact assessment (LCIA) – phase 3 – determines and evaluates the extent and significance of potential environmental impact of a product system in the course of the life of the product (14040). Material flows give rise to environmental effects that are evaluated in terms of their global consequences. The results of LCIA can be used to determine the primary energy content, the cumulative energy demand and the embodied energy of a building.

Interpretation- phase 4 – represents evaluation of the LCI or LCIA or both with regard to the defined goal and scope, in order to reach conclusions and make recommendations (14040)

Definition of the system boundary is made according to the defined objectives of the life cycle assessment. System boundary is an interface in the assessment between a building and the environment or other product systems [EN 15643-1].

The system boundary represents the interface between the technical system of the analysed product and the environment or other product systems. Associated cut-off criteria differentiate between relevant and non-relevant factors. This is considered using quantitative threshold values (e.g. through definition of a minimum percentage of the environmental impact of the examined factor or material/energy flow, figures below this threshold are considered irrelevant).
System boundaries determine the processes that are taken into account in the life cycle assessment of buildings. **Time related system boundaries** define the life cycle stages, which are taken into account in LCA ("cradle to gate" vs. "cradle to grave" investigations). **Spatial system boundaries** define the modules that are taken into account within the investigated life cycle stage.
Development of scenarios is important step to provide a definition of the time dependent characteristics of the assessed building or component. For example the definition of the estimated service life of building components (taking into consideration maintenance and repair of components) is an important step within the definition of time relating characteristics in LCA of buildings.

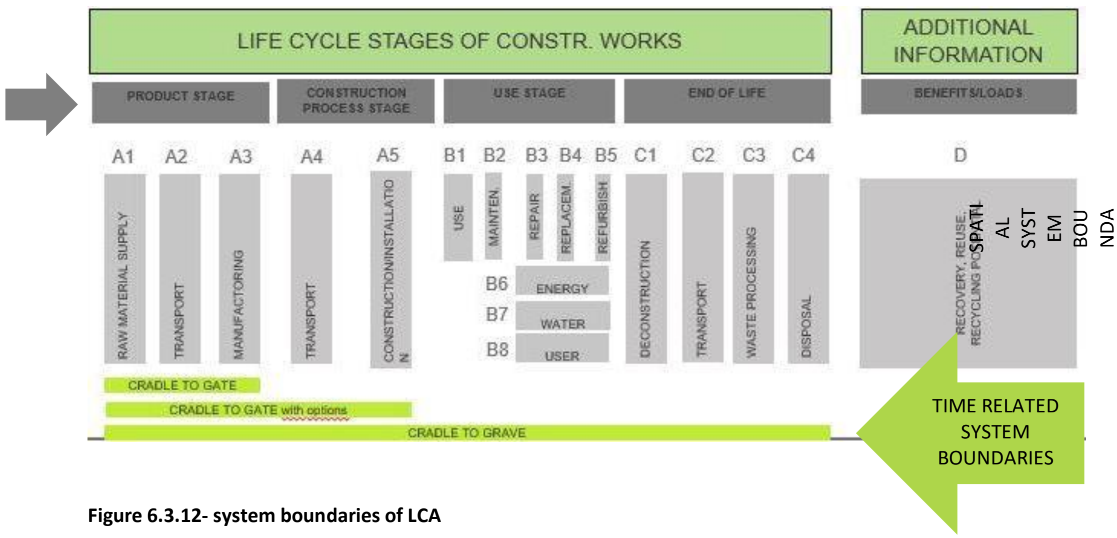


Figure 6.3.12- system boundaries of LCA

Example of life cycle assessment – Goal and scope definition (according to S. El Khouli et al: Sustainable construction techniques, Detail, 2015, p. 25):

- **Question**: Throughout the total building life cycle, which building life cycle, which building components and life cycle phases have the most influence on the total building´s environmental impact?
- **Goal**: identification of the building components and life cycle phases with the greatest potential for improvement.
- **Procedure**: examination of 12 different multi-unit dwellings. The same system boundary is used for all buildings in order to ensure better comparability of the results.
- **System boundary**: at the end of service life, most materials are usually disposed of (that cannot be reused). These materials are disposed of at a landfill during construction site preparation.
- **Allocation method**: cut off approach at end of life. (so called cut off criteria determination means which materials due to their small amount can be excluded from the evaluation, except of hazardous compounds)
- **Functional unit**: 1m^2 of treated floor area per year of the building's design life.
- **Data source and data quality**
- **Assumptions**: e.g. thickness of layers in components, service life of individual materials, transport distances etc.
- **Impact categories and impact indicators**:
  - **Embodied energy** (non-renewable energy for production, transport and disposal of building materials) and non-renewable energy for building operation
  - **Embodied emissions** (from production, transport and disposal of building materials) and emissions from building operation (GWP 100a).

Allocation method in life cycle assessment means consideration of the inputs and outputs of the product and co-products or product systems and sharing these environmental impacts among them. This is important in a building context when producing a life cycle inventory analysis for building materials. Another allocation method takes place at the end of life disposal phase – if the product is considered for reuse or recycling. In order to model the energy processes and the component and material processes, the designer should use life cycle inventory data sets only from reliable sources, that are clear and unambiguous (for example ecoinvent).

Definition of functional unit determines the specific functions that a product or product system must fulfil during its service life, according to the future use of the building, including both quantitative and qualitative aspects (in other words- function, quantity, duration and quality).
Thus, it is more meaningful to compare components that fulfil the same qualitative functions a building (e.g. thermal resistance, noise protection properties etc.). All inputs and outputs

of the life cycle inventory analysis as well as the impact analysis results **refer to the functional unit.** The functional unit represents the quantified performance of a product system for use as a reference unit for the LCA study.

Selection of a suitable database and quality of data (according to EN 15804) for all material and energy flows is very important. The quality of data influences the depth and detail of the whole life cycle assessment. In the case of data that do not meet the requirement of EN 15804 (e.g. no EPD available) at least (generic) data with at least minimum data quality requirements (i.e. validation of data should not exceed 10 years, plausibility and consistent check of data, technology and geographical coverage check etc.) have to be applied.
Suitable data can be obtained from professional inventory databases (such as ecoinvent – e.g. general data concerning material and energy flows).

The Environmental product declaration (EPD) is based on LCA (Life cycle assessment) methodology; it means assessment from the origin to termination of the product. The advantage of the EPD is the ability to compare products made from different materials, it presents transparent declaration of the life-cycle environmental impact of the product.

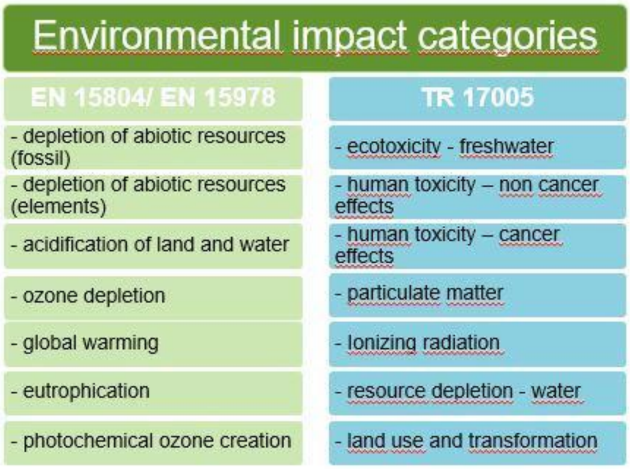
Increasing demand for LCA based product declarations have generated a need for rules for making declarations on products within the same category. These rules are defined as Product Category Rules (PCRs) in ISO 14025, Product Rules in the GHG Protocol Product Life Cycle Accounting and Reporting Standard and Supplementary Requirements in PAS 2050. The Product Category Rules (PCR) are set by an independent organization and monitored by an independent organization.

A number of **assumptions** for life cycle assessment modelling have to be made during the performance of a life cycle assessment. The assumptions consider material quantities, thickness, density and design service life of materials, frequency of replacement of selected materials, transport distances form factories etc.

Impact categories and impact indicators help to illustrate the environmental impacts of all products and processes examined. Impact categories in a building construction context are presented in Figure 6.3.13 and 6.3.14.

The EN 15804 and EN 15978 standards state that the impact assessment must be carried out for the following **impact categories**:

- global warming
- ozone depletion
- acidification of land and water
- eutrophication
- photochemical ozone creation
- depletion of abiotic resources (elements)
- depletion of abiotic resources (fossil)



Environmental impact categories	
EN 15804/ EN 15978	TR 17005
- depletion of abiotic resources (fossil)	- ecotoxicity - freshwater
- depletion of abiotic resources (elements)	- human toxicity – non cancer effects
- acidification of land and water	- human toxicity – cancer effects
- ozone depletion	- particulate matter
- global warming	- Ionizing radiation
- eutrophication	- resource depletion - water
- photochemical ozone creation	- land use and transformation

Figure 6.3.13- Environmental impact categories according to EN 15804 and EN 15978 (mandatory according to CEN/TC 350) and additional environmental impact categories that can be used for environmental assessment - according to (TR 17005). Now all categories are implemented in EN 15804:2019

Life cycle impact assessment analyses potential environmental effects by mathematical modelling. So called equivalents are used to determine the harmful effects of the various environmental factors and relate these to generally applicable values allowing mutual comparison. The effect of a specific greenhouse gas emitted during manufacture of a product can be measured by means of the effect of a kilogram carbon dioxide (CO_2) and expressed in kg of CO2 equivalents (CDE). For a building life cycle assessment is usually applied a period of 100 years defined as GWP 100a (impact on Global warming potential for 100 years)

Calculation of environmental indicators, which represent quantified environmental impacts and effects caused by the subject of assessment during its life cycle.

- **Indicators which describe environmental impacts** and the environmental information on impacts is expressed with the **impact category indicators** of LCIA using characterisation factors according to EN 15978:

  - **Global warming potential** (GWP), [kg CO_2 equivalent]- greenhouse gases (CO2, methane, CFC) that give rise to increased atmospheric warming.
  - **Ozone depletion potential (ODP),** [kg CCl_3F equivalent] –depletion of vital stratospheric ozone that protects from UV radiation effects.
  - **Acidification potential** (AP), [kg SO_2 equivalent] – acidification of soil and water bodies in result to transformation of air pollutants to acids causing damage to ecosystems and building structures.
  - **Eutrophication potential** (EP), [kg $(PO_4)^{3-}$ equivalent]- accumulation of nutrients in soil and water bodies through the action of air pollutants, waste water and agricultural fertilisation.

- **Photochemical ozone creation potential** (POCP), [kg C_2H_4 equivalent] – ozone near the ground(tropospheric ozone) is harmful to humans, plants and materials. Also referred as summer smog potential.
- **Abiotic depletion potential** (ADP elements), [kg Sb equivalent]- shortage of abiotic resources, in relation to non-fossil resources
- **Abiotic depletion potential** (ADP fossil fuels), [MJ]- shortage of abiotic resources, in relation to fossil resources

● **Indicators which describe use of resources**, they apply data based on input flows of the LCI. They describe use of renewable and non-renewable primary energy and water resources according to EN 15978:

- renewable primary energy consumption [MJ]
- non-renewable primary energy consumption [MJ]
- consumption of reused materials [kg]
- consumption of reused renewable fuels [MJ]
- consumption of reused non-renewable fuels [MJ]
- potable water consumption [m^3]

● **Additional indicators which describe use of untreated and treated waste** for reuse, recycling, energy recovery etc.

The value of each of the indicators is calculated for several modules in the life cycle stages based on a calculation method according to EN 15804.

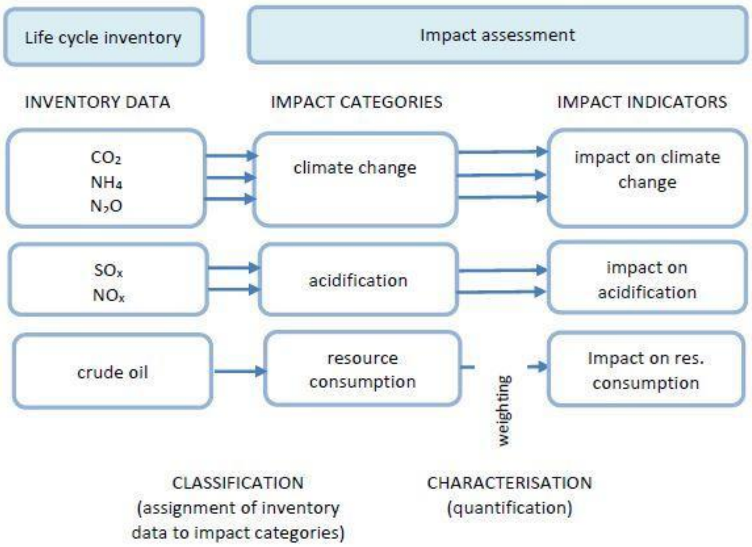


Figure 6.3.14 – relation between life cycle inventory and impact assessment according to S. El Khouli et al: Sustainable construction techniques, Detail, 2015

6.3.5 ENVIRONMENTAL PRODUCT DECLARATIONS (EPD)

Environmental products declarations are data sets available to planners for use in practice. They form the basis of data for ecological assessment of buildings according to EN 15978 and EN 15804. EPDs provide quantified comparable environmental information on building products or services that have been standardized on a scientific basis. The purpose of an EPD in the construction sector is to provide the basis for assessing buildings and other construction works, and identifying those, which cause less stress to the environment.

EPDs are supplied by manufacturers. They must publish verifiable and consistent technical data, for which they assume responsibility and liability. EPDs data are defined under the guidance of Product category rules (core PCR defined in EN 15804 Sustainability of construction works - Environmental product declarations - Core rules for the product category of construction products). EPDs include information according to 1 of 3 stages of a product's life cycle (see figure 6.3.16):

- PRODUCTION PHASE – means raw material supply, transport, manufacture and associated processes (FROM CRADLE TO GATE)
- PRODUCTION PHASE and individual other life cycle phases (FROM CRADLE TO GATE WITH OPTIONS)
- COMPLETE LIFE CYCLE according to the defined system boundaries (FROM CRADLE TO GRAVE) – from raw material supply, to installation, use, maintenance, replacement, demolition, waste treatment

EPD information is expressed in information modules (A-D), they are divided according to life cycle phases (see Figures 6.3.16 and 6.3.17):

- A1-A3 Production stage
- A4-A5 Construction stage
- B1-B5 Use stage related to building fabric
- B6-B7 Use stage related to operation of the building
- C1-C4 End of life stage
- D benefits and loads beyond the system boundary

Figure 6.3.15 shows which modules are mandatory according to EN 15804:2019.

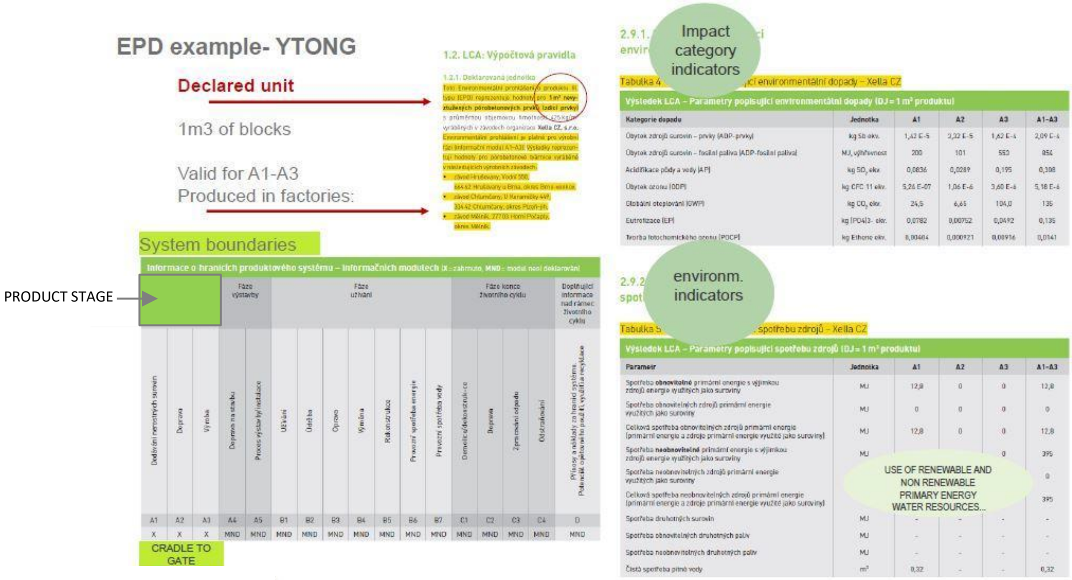


Figure 6.3.15 – Example of EPD for 1m³ Ytong calcium silicate blocks, valid for time limited period

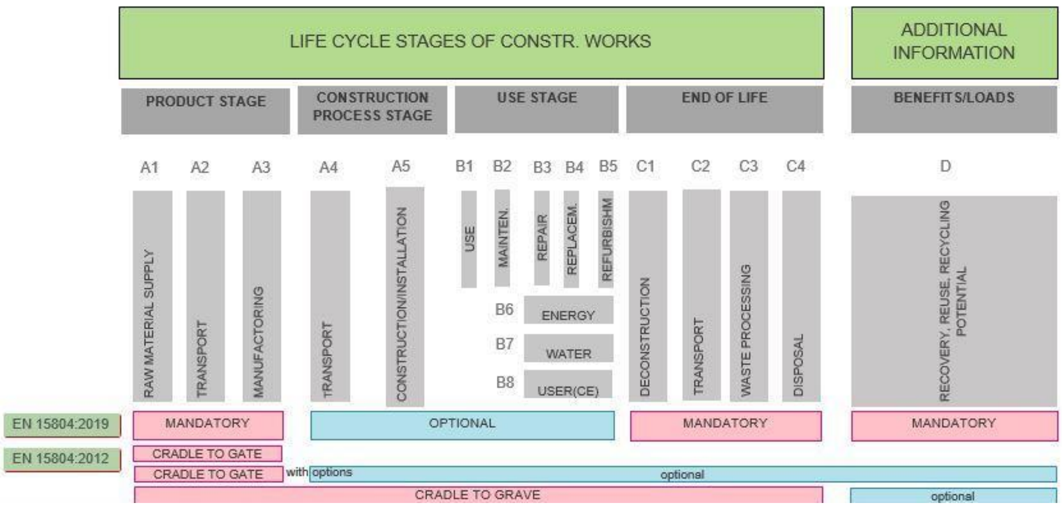


Figure 6.3.16 – Life cycle stages for EPDs. EPD information is expressed in information modules, some of them are mandatory, some are optional

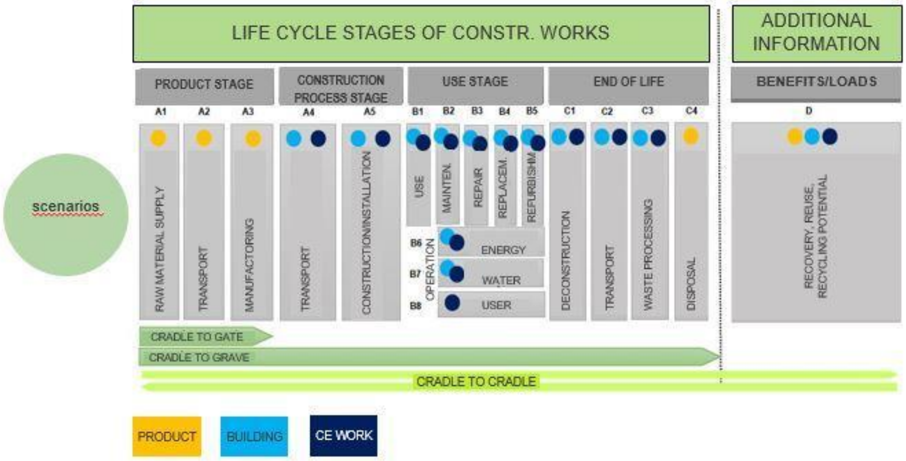


Figure 6.3.17 – Life cycle stages and their relationship to the product, building and civil engineering work context

Functional equivalent used for LCA represents quantified functional requirements and/or technical requirements for a building or an assembled system (part of works) for use as a basis for comparison [EN 15978].

The functional equivalent of a building shall include information as

• building type
• relevant technical and functional requirements
• pattern of use (i.e. occupancy)
• required service life

Example:

- New residential building
- Technical and functional requirements
- Required service life –e.g. 80 years

Functional unit is a quantified performance of a product system for use as a reference unit [EN ISO 14040], relates to the given function of the product, or to the future use of the building, comprises a function, a quantity, a duration and a quality.

Declared unit

- is used instead of a functional unit when the precise function of the product at the building level is not stated or known, or when the LCA does not cover a full life cycle

- declared unit is used - for raw materials (e.g. cement, gravel) that are not implemented directly in the building,

  - for non-application-specific products (products that can be used in a wide variety of different or simultaneous functions in the building or construction works (concrete block, timber etc.)

  examples:

  - by item, e.g. 1 brick, 1 window (dimensions to be specified), 1 lighting-fitting, 1 radiator;
  - by mass, e.g. 1 kg of cement;
  - by length, e.g. 1 m of pipe, 1 m of a beam (dimensions must be specified);
  - by area, e.g. 1 m2 of wall elements, 1 m2 of roof elements (dimensions must be specified);
  - by volume, e.g. 1 m3 of timber, 1 m3 of ready-mixed concrete.

There is a distinction between functional unit and declared. Under special conditions (e.g. If the building product has a large number of possible applications in a building), then the declared unit may be more appropriate than the concept of functional unit.

6.3.6 ECONOMIC CONSIDERATION (LIFE CYCLE COSTS)

One of the aims of sustainable building is also to keep the long-term overall costs of a building as low as possible. Planners used to take into consideration merely initial investment (building costs) required for a new construction. Costs of operation and deconstruction at the end of the service life were ignored. Today it is necessary to take into consideration also costs arising from the use stage (operation, maintenance, repair etc.) and final utilization or disposal of building structures and products. This should be determined during the planning stage in the form of Life cycle costing (LCC) or Life cycle cost analysis (LCCA). **Life cycle costs** are according to EN 15643-4 costs arising through a building or component over the entire life cycle by fulfilment of the technical and functional requirements. **Life cycle cost** is according to ISO 15686-5 cost of an asset, or its part throughout its cycle life, while fulfilling the performance requirements. In other words, subject of LCC is calculation and assessment of construction costs, operating costs and costs at the end of the life cycle. **The aim of Life cycle costing (LCC)** is minimising life cycle costs, improving economic efficiency and protecting capital and (building) value. Life Cycle Costing is associated directly with constructing and operating the building; **this approach is used mainly in construction industry.**

Difference in use of terms **Whole Life Costing (WLC) and Life cycle costing (LCC)** is often not clear. **Whole Life Costing (WLC**) means an economic assessment considering all agreed projected significant and relevant cost flows over a period of analysis expressed in monetary value. The projected costs are those needed to achieve defined levels of performance, including reliability, safety and availability (according to ISO 15686-5). In other words, estimation of the total cost of ownership over the anticipated lifespan of an asset; including capital, operational and end-of-life costs, that is typically **used for presentation to the client.**

Figure 6.3.18 – relation between LCC and WLC

In practice it is very often that LCC and WLC presented as one common parameter (see Figure 6.3.20).

Both methods are used to determine the most cost-effective option among comparable alternatives for purchasing, operating, maintaining and disposing any project or processes and for cost optimization strategies in early planning decision making process. Decisions are related to:

- to adapt /redevelop existing facility or to provide new one (investment planning stage)
- choice between alternative designs (design and construction stage)
- choice of alternative components (construction and in use stage)
- comparison of previous decisions
- estimation of future costs

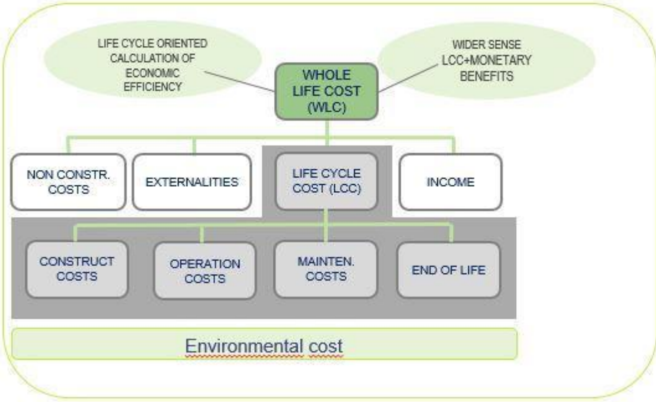


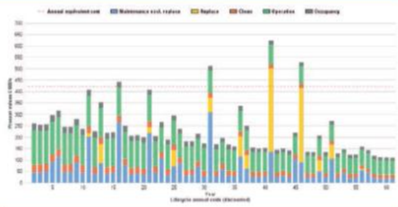
Figure 6.3.19 – LCC and WLC elements according to ISO 15686-5 Building and constructed assets – Service-life planning – Part 5: Life-cycle costing

Project example

£2,250/m² Sports Centre =
60-year life cycle cost of £5,600/m²

Saving potential was highest in:

1. **Construction (£11.5m)**
2. **Energy costs (£4m)**
3. **Repair/replace (£2.8m)**
4. **Maintenance (£1.9m)**



Options	Savings (£/m²) (GIFA)	Life cycle savings (£)	Who benefits?	Comments/benefits
Flexible Design Conditions (internal set points/ HVAC)	£30/m²	£140K	End-user/ Bill payer Design teams/ Developer/ Contractor/ End-user/ FM teams	Reduced the operational energy consumption – lower bills. Alternative HVAC specs considered - further potential savings/flexibility with capital cost, lead/install times, system efficiencies, maintenance and achieving other energy targets (Part L, London Plan, LZC).
Alternative façade options (cladding and glazing)	£35/m²	£160K	Design teams/ End-user Developer/ Contractor End-user/ FM teams	Difference in thermal performance impacted the operational energy consumption. Time to install on site reduced build time and thus contract costs. Repair and maintenance costs and instances were reduced.
Ceiling Void vs Exposed finish	£84/m²	£380K	Developer/ Contractor End-user/ FM teams Design teams/ End-user	Reduced procurement and installation costs/time. Reduced repair/replacement costs. Impact on energy consumption observed.
Macadam vs Asphalt	£0.7/m²	£3.25K	Design teams/ End-user/ Developer/ Contractor /FM teams	Minimal difference allowed the project freedom to consider the aesthetics and practicalities of the different install/application techniques without significant concern over lifecycle costs.

Life Cycle Costing (LCC) & Whole Life Costing (WLC): Technical Bulletin
stroma.com/built-environment

STROMA BUILT ENVIRONMENT

Figure 6.3.20 – LCC and WLC according to https://www.stroma.com/

6.3.7 REFERENCES

H. König et al: A life cycle approach to buildings, Detail (2010)

J. L. Moro: Flooring Volume 2, Detail practice (2016)

S. El Khouli et al: Sustainable construction techniques, Detail (2015)

Life-cycle assessment (LCA) – a guide to approaches, experiences and information sources), Environmental Issues Series, No. 6, EEA, 1997

EEA, 2015, The European environment — state and outlook 2015: synthesis report, European Environment Agency, Copenhagen.

Green construction products, IMBT-TU Graz, Build Up Skills ingREeS, 2016

The European environment — state and outlook 2010 (SOER 2010), EEA, 2010

Millenium Ecosystem Assessment, 2005; EEA, 2010.

Construction Product Directive (CPD) and Regulation (EU) No. 305/2011.

Assessing the environmental impacts of construction – understanding European Standards and their implications, BRE Trust, UK, 2014

ISO 14040 Environmental management — Life cycle assessment — Principles and framework

EN 15643-1 Sustainability of construction works. Sustainability assessment of buildings. Part 1 General framework

EN 15643-2 Sustainability of construction works. Sustainability assessment of buildings. Part 2 Framework for the assessment of environmental performance

EN 15643-3 Sustainability of construction works. Assessment of buildings. Part 3 Framework for the assessment of social performance

EN 15643-4 Sustainability of construction works. Assessment of buildings. Part 4 Framework for the assessment of economic performance

EN 15643-5 Sustainability of construction works - Sustainability assessment of buildings and civil engineering works - Part 5 Framework on specific principles and requirement for civil engineering works

EN 15643 Sustainability of construction works. Sustainability assessment of buildings.

EN 15804+A1Sustainability of construction works. Environmental product declarations.

CEN/TR 17005 Sustainability of construction works - Additional environmental impact categories and indicators - Background information and possibilities - Evaluation of the possibility of adding environmental impact categories and related indicators and calculation methods for the assessment of the environmental performance of buildings.

EN 15978 Sustainability of construction works. Assessment of environmental performance of buildings. Calculation method.

ISO 15686-5 Building and constructed assets – Service-life planning – Part 5: Life-cycle costing

EPD of III. type for 1m3 lightweight concrete elements (blocks) YTONG, 2014-2019

www.stroma.com