HI-SMART

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

MODULE #6

CHAPTER 2: WHOLE LIFE COSTING

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6.2.1 ECONOMIC PERFORMANCE AND LIFE CYCLE COSTING

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).

Figure 6.2.1 – Refurbishment of prefabricated panel residential building resulted in increase of the value and service life prolongation (Bratislava, 2016)

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 6.2.2.

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.

The general framework regarding the assessment of the economic performance of buildings are defined on international level in ISO 15686-5 and on European level in EN 15643-4.

Principles and guidance regarding the calculation of life cycle cost on building level are defined in EN 16627.

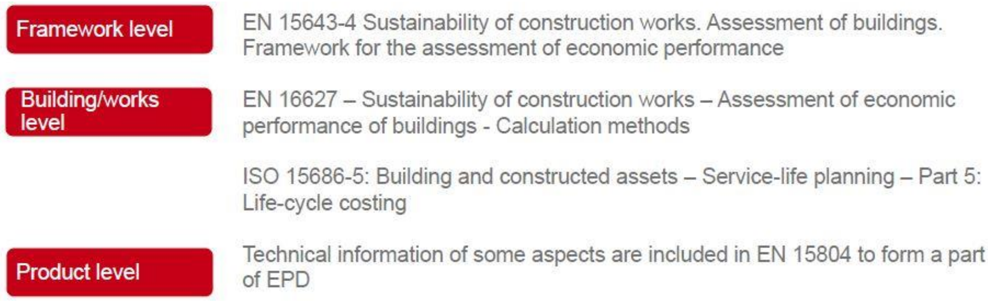

Figure 6.2.2 – Economic performance of buildings/CE works in standards

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.**

Figure 6.2.3 – Subjects and targets of protection of sustainability according to J. L. Moro: DETAIL practice Flooring Volume2, Edition Detail, 2016

6.2.2 LIFE CYCLE COSTING AND WHOLE LIFE COSTING

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.**

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

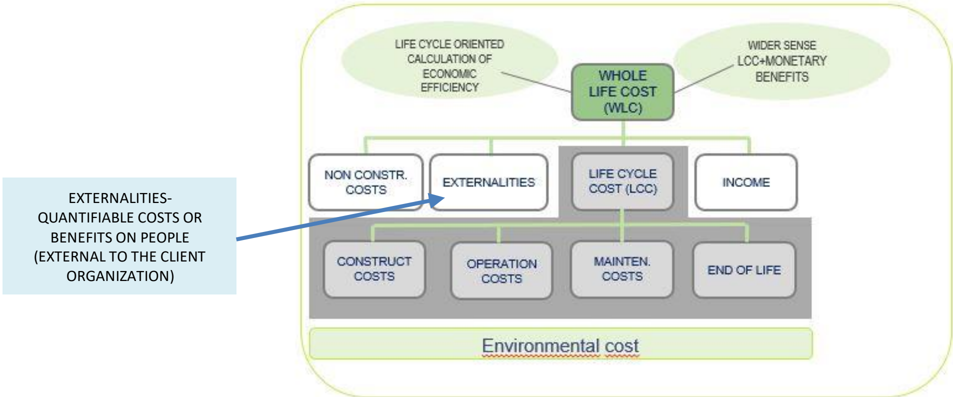

Figure 6.2.4 – LCC and WLC elements according to ISO 15686-5

Whole Life Costing (WLC) represents an effective tool used to reduce long-term costs and maximize savings on any building project. Clients often do not distinguish between LCC and WLC, but they want in practice:

- to deliver energy cost reductions for customers
- to assess and improve durability/specification choices
- to help customers to produce (and reduce) facility management and operational budgets for their buildings
- to measure whole life carbon and environmental cost impacts

- to meet funding criteria and gain access to funding

In many construction projects, initial investments costs may only account for around 20% of the total costs which the owner will incur during the period of ownership – particularly when energy bills and maintenance costs are taken into account. Whilst many sustainable construction solutions may require higher initial investments, once running costs are taken into account they will generally provide a return on investment over time. This is further emphasised when a value is given to sustainability benefits, which may also include improving occupier performance through creating a more comfortable working environment. The strongest opportunity to use WLC is during early design stages. Over the course of the project the authority's ability to influence cost decreases. It has been estimated that 80-90% percent of the cost of running maintaining and refurbishing a building is determined at the design stage.

6.2.3 LIFE CYCLE COSTING METHODS

Buildings always represent a long-term investment. Positive value development is therefore an important characteristic of economic quality.
The economic assessment always aims at holistic optimisation of economic parameters. This means that measures designed to optimise life cycle costs must be **reasonably in line with the value of the building and its maintenance.**

The major challenge is that the economic parameters may be influenced by variable factors. Such influences include, in addition to the type of building use and service quality, user behaviour, climatic conditions as well as the functional and technical characteristics of the building. Furthermore, each of these factors can vary during the observation period.

Future price developments depend on the development of international commodity prices, exchange rates as well as costs for domestic production factors. This means that annual price increase rates must be determined and subsequently applied in a uniform manner. A cost assessment must additionally consider the effects of the use period if this differs from the technical service life of the building, which is usually the case if the building is strongly dependent on specific uses (Guideline for sustainable building). Figure 6.2.4 shows that the consequential costs exceed the costs of construction of a building during its lifetime**. A high quality of the finished building should lead to significantly lower costs during the use phase**. This may mean higher construction, planning and design costs. That's why it is important to deal with assessment during the early planning phase in order to determine the potential for optimisation and savings.

In order to assess the life cycle cost of buildings several tools for calculation and guidances are available. First steps towards common user standard for LCC-reporting for buildings have been taken in the area of facility management. For example IFMA have developed guidelines and calculation models for LCC. IFMA is the world's largest and most widely recognized association for facility management professionals. **Facility management** is according to ISO 41011:2017 organizational function which integrates people, place and process within the built environment with the purpose of improving the quality of life of people and the productivity of the core business, in other words facility management ensures by appropriate maintenance and repair required quality of the building and costs for operation as low as possible during its life time. Next to construction and building operation costs must be end-of-life costs taken into account.

The results of LCC can be aggregated i.e. in EUR/m2 GFA (Gross floor area) to use for example as a benchmark in early planning decision making process. Therefore all the cost that examine over the life cycle of a building are summed up according to the chosen microeconomic calculation method. The difference between these methods is, that dynamic approaches consider the development of cash flows over the time period.

Existing risks, unforeseen cost, inflation/deflation can be included depending on the chosen method. In practice the **net present value method** as dynamic method is the most commonly adopted approach for the LCCA of a building. Static methods are generally not suitable for assessing the economic efficiency of the building/property.

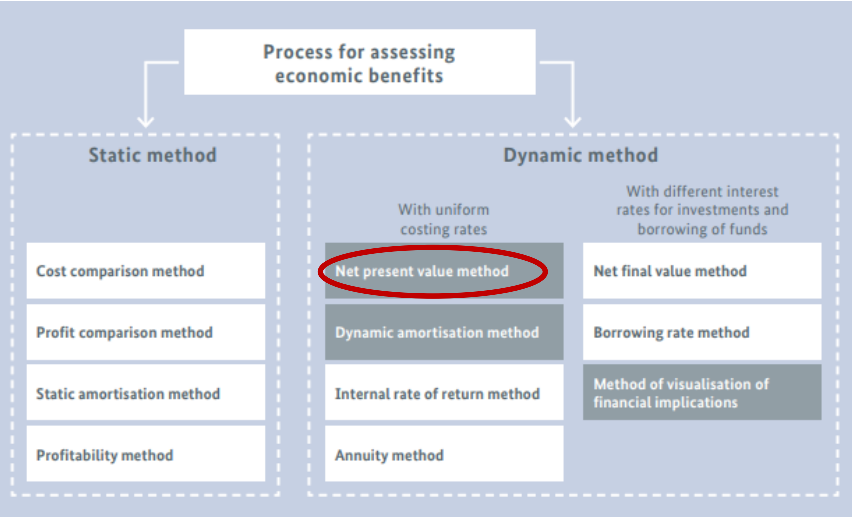

Figure 6.2.5 – Static and dynamic methods of microeconomic analysis (https://www.nachhaltigesbauen.de/fileadmin/pdf/Sustainable Building)

EN 15643-4 provides two different approaches to the assessment of economic performance. Thereby two indicators help to describe and evaluate the economic performance of a building - Live cycle cost (obligatory) and Life cycle success (voluntary).

The life cycle success additionally includes revenues and other income induced by the building (e.g. income from rents) and non building related parameters as location.
The options to minimise risks and to create the preconditions to maintain a high value of a property must already be ensured during the planning phase through appropriate building-related features and characteristics.
Building-related factors include e.g. space efficiency, possibility of conversion and reuse (flexibility and adaptability), resilience, durability and energy characteristics These and other factors directly influence the value and its development and hence the stability of the property's value.
It should, however, be noted that building-related factors cannot be considered and assessed separate from location and market-related parameters. A property ideally has features and characteristics that enable it to respond to specific market and location conditions and to adapt or to be adapted to changes in external factors over the course of time with minimal consumption of resources as a key prerequisite for maximum value stability.
The adaptability of a property influences the total service life and hence the building specific costs over the life cycle as well as the related material flows.

Figure 6.2.5 shows the optimization potential of cost with and without intervention by life cycle-optimised planning. While consequential costs exceed, cost with life cycle optimized planning should lower significantly over the life cycle.

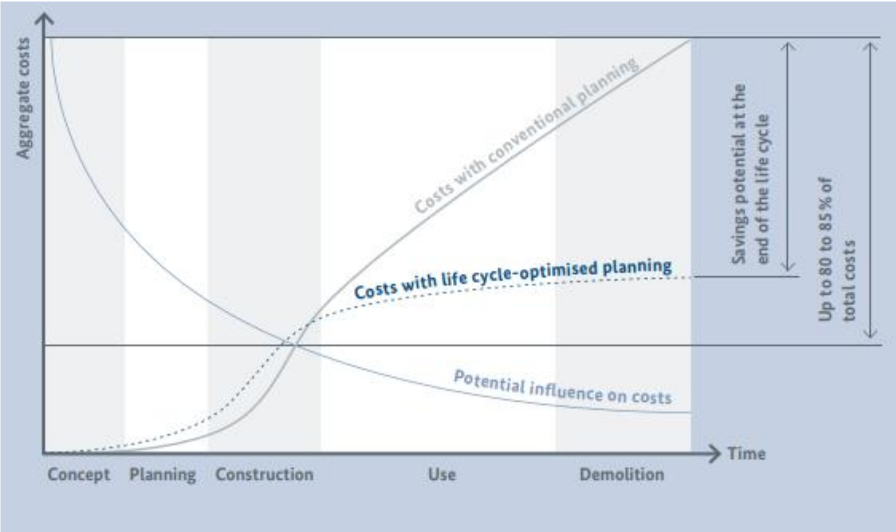

Figure 6.2.6 –Influence potential of costs according to planning quality
(https://www.nachhaltigesbauen.de/fileadmin/pdf/Sustainable Building)

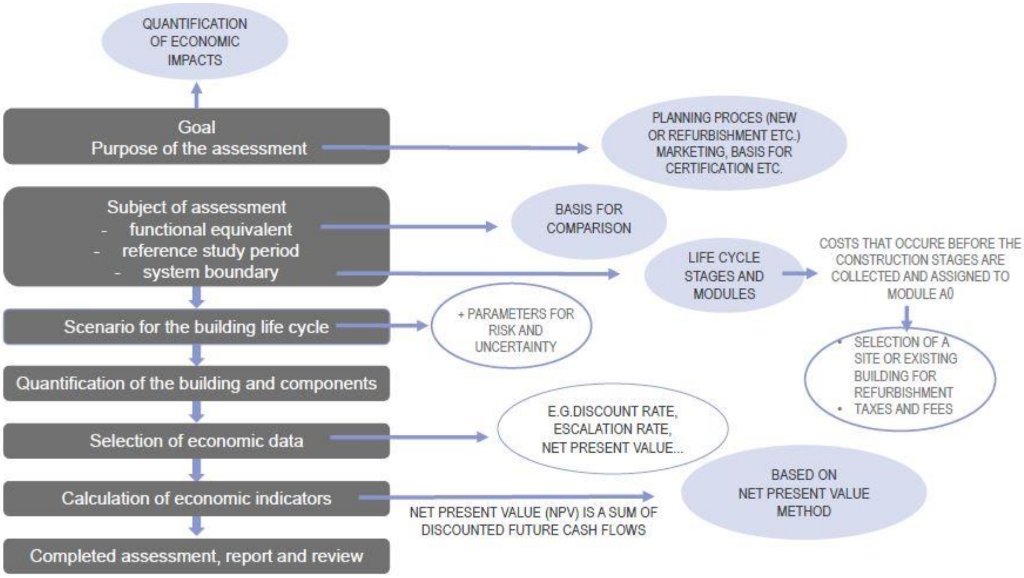

Figure 6.2.7 – simplified assessment steps for LCCA of buildings according to EN 16627

One of the results of the **life cycle cost analysis** is a time-adjusted sum (cash value) per unit of useful or gross floor area in euro per square metre. Variant comparison based on a life cycle cost analysis can already be used during the planning phase in order to determine the **potential for optimisation and saving** (see Figure 6.2.7)**.**

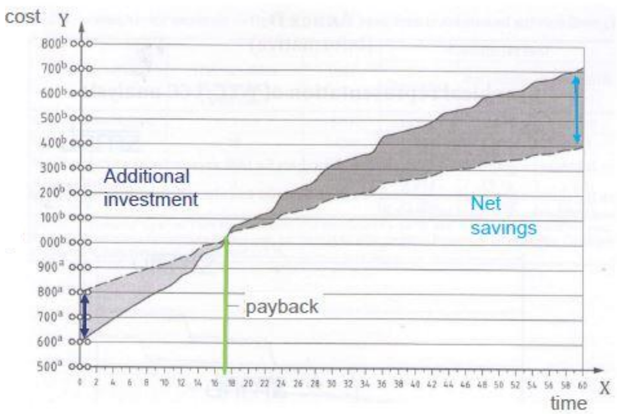

Figure 6.2.8 – Graphical reporting of whole-building level comparison accord. To ISO 15686-5:2017

Goal of the Life cycle cost assessment is the quantification of economic impacts of e.g. residential building. Purposes could be:

- decision-making process - comparison of design options and of economic performance of new construction, refurbishment etc.
- basis for building certification

- policy development decisions
- marketing issues

Functional equivalent shall include information as
- building type
- relevant technical and functional requirements
- pattern of use (i.e. occupancy)
- required service life

When the client does not specify the reference service life, the design life of building may be used (according to ISO 15686-1) provide information in context to setting of design live.

The system boundaries represent 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. System boundaries of Information modules for LCA are similar with one exception: Cost that occur before the construction stages (as plot value, charges, consultations, design etc.) are assigned to module „Planning stage A0“.

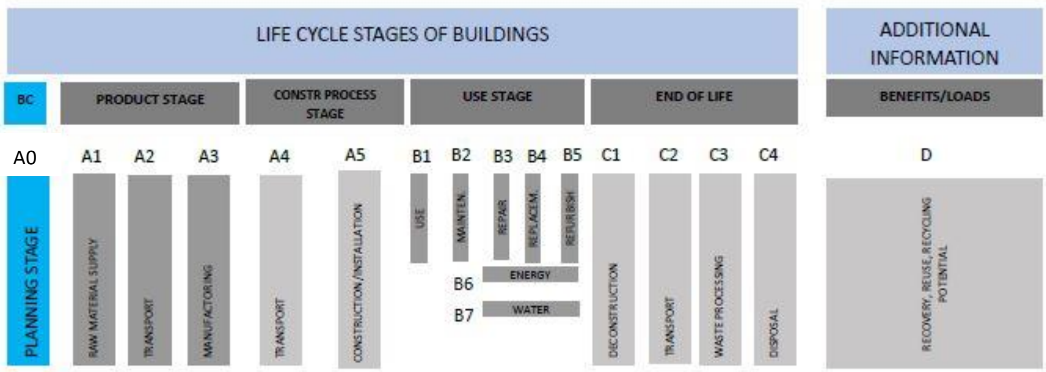

Figure 6.2.9 – Life cycle stages and system boundaries of LCCA. BC- before construction/pre construction.

Scenarios and product information

Product information differs from phase to phase:
- Scenario for the pre-construction stage (Module A0) provides descriptions and assumptions related to the start of construction work, for example selection of a site or existing building for retrofitting, site taxes, fees for professionals etc.
- Scenario for the product and construction stage (Module A1– A5) provides information about all costs from the extraction of raw materials until the completion of construction works.

- Scenario for the use stage (Module B1 – B7) provides assumptions for the use phase, for example replacement strategies of major components used for heating, cooling, lightning and hot water.
- Scenarios for End-of-life stage (Module C1 – C4) provides information for scenarios on deconstruction, transport, waste processing and disposal of the building at the end of it´s required service life.

Due to the relatively high reference service lives in the construction sector risk management regarding assumptions and omissions is important. Possible parameters for risk and uncertainty should be taken into consideration as service life expected income and cost during observation period, changes during use-phase of the facility, technical development, development of building site, future funding and taxation etc.

Selection of economic data – use of consistent cost data and their right assignment to the life cycle stages is a crucial point. Volume and availability of data is continuously increasing in course of a construction project.

The specification of **the discount rate** has major influence on the results of life cycle costing. A specific discount rate must be defined in order to include time-related value-change of money. The higher the discount rate the less influence costs have that occur later in the life cycle (e.g. End-of life cost). The choice of discount rate must correspond with the inflation rate.

Escalation rates must be set depending on the estimated escalation scenario of different cost groups (water, energy, construction products, services, etc.). Due to major influence by varying discount rates and/or escalation rates in LCC calculations, scenario should be used in any case. In general assumptions and omissions made in LCC must be handled carefully and
must be fully and transparently documented.

Net present value (NPV) is defined in EN 16672 as the sum of all future cash flows both, cost and benefits. If there are only costs concluded this may be termed Net Present Cost (NPC)

A comprehensive register concerning cost-data, which have to be taken into account in LCC is provided by EN 16627.

The estimated or assumed **lifetime** of a product is an important parameter influencing the calculation of life cycle costs. The forecast allows quantification of expected building operation expenditures and evaluation of the environmental related quality. It is assumed that individual components such as windows, doors, cladding, flooring etc. have to be exchanged a number of times during the service life of the whole building (in general 50-100 years). Service life of components is estimated to 5-80 years, so it is assumed they need several renewal cycles. The **technical lifetime** is the period in which a product can completely fulfil its allocated functions, assuming that it was manufactured in compliance with accepted rules of building technology and that maintenance was adequate. The **effective service life** of a product is not necessarily same as its technical lifetime. It may be shorter (or longer) because of economic reasons, obsolescence or is used intensively.

Service life is a period of time after installation during which a building or its parts meets or exceeds the performance requirements.

Reference service life (RSL) is an average technical lifetime of components or according to EN 15643-1 service life of a construction product which is known to be expected under a particular set, i.e., a reference set, of in-use conditions and which may form the basis of estimating the service life under other in use conditions.

Estimated service life (ESL) is expected/assumed lifetime of components, taking into account aspects influencing performance and degradation of the components.

Reference study period (RSP) is a period which should be agreed with the client for the observation of the building /component.

Ageing is the loss or reduction of properties (load-bearing capacity, elasticity etc.) due to physical, chemical and biological influences or accidents. **Durability** is the capacity to retain the demanded technical quality over a service life considering required maintenance. **Obsolescence** means loss in value due to lacking maintenance, change of standards, regulations, interior styling or lack of cost efficiency.

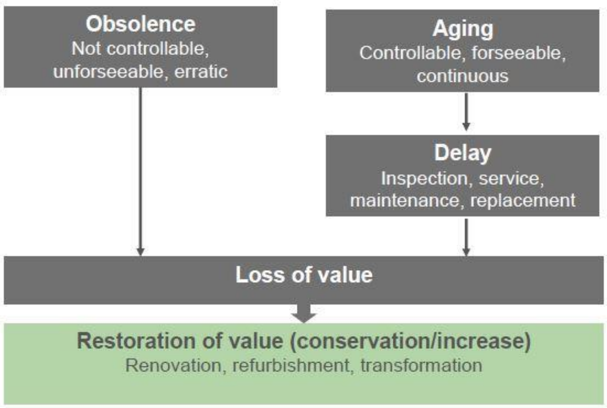

Figure 6.2.10 –Difference between obsolescence and aging

Use phase of the building is interlinked with its operation, required comfort of the building operation is related to proper fulfilment of the function of each component. To avoid degradation or failure of building components it is crucial to adhere to regular and systemic maintenance.

The objectives of building maintenance are:

- to ensure that the buildings and their associated services are in a safe condition,
- to ensure that the buildings are fit for use,
- to ensure that the condition of the building meets all statutory requirements,
- to carry out the maintenance work necessary to maintain the value of physical assets,
- to carry out the work necessary to maintain the quality of the building

Types of maintenance according to ISO 15686-5:

- preventive maintenance,
- corrective maintenance,
- deferred maintenance

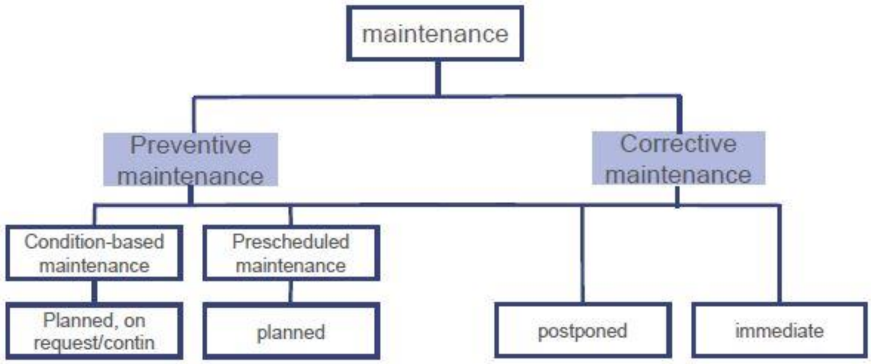

Figure 6.2.11 -Types of maintenance according to EN 13306:2017

6.2.4 INPUT VARIABLES TO BE REQUIRED FOR LCC

- Building and use type, functional equivalents, service level
- Conditions and peculiarities of the location
- Period of observation in years
- Information on the type and scope of cost types to be considered - building costs, operating costs
- Determination of the type and treatment with –
  - Costs of deconstruction and removal
  - A residual value (end of period of observation)

  - Income and revenue
  - Outputs
- Stipulation or information on the level of detail of the cost appraisal
- Reference values
- Discount rate
- Price level of construction costs
- Price level of operating costs
- Information about VAT
- Determination of building costs, energy costs, fresh and waste water costs, cleaning costs, operating costs, maintenance and inspection costs, renovation costs, costs of deconstruction and removal
- Sources for the calculated service life of the components
- Hourly rates for selected services
- Prices for – energy supply, water supply, waste water disposal
- Annual price increase for heating energy, electrical energy, water and wastewater, hourly rates, operational management, inspection and maintenance work, renovation work

6.2.5 SUSTAINABILITY POLICY

There are lots of campaigns and polices in the world to encourage clients to build/renovate sustainable buildings. One of them is platform Renovate Europe.

Aim of the **Renovate Europe campaign** is ambitious:

- to reduce the energy demand of the building stock in the EU by 80% by 2050, in order to reach nearly Zero Energy Buildings (nZEB) standard by mid-century.
- Ensure long-term commitment on ambitions and policies (Support and help to implement an actionable Long-Term Renovation Strategy (LTRS) at national/ regional/ local level)
- Improve access to financing (tax incentives, low-interest loans, or removing regulatory barriers for example in rent regulation)
- Support capacity building (Facilitation, information, training and education)
- Lead by example – start renovating public buildings

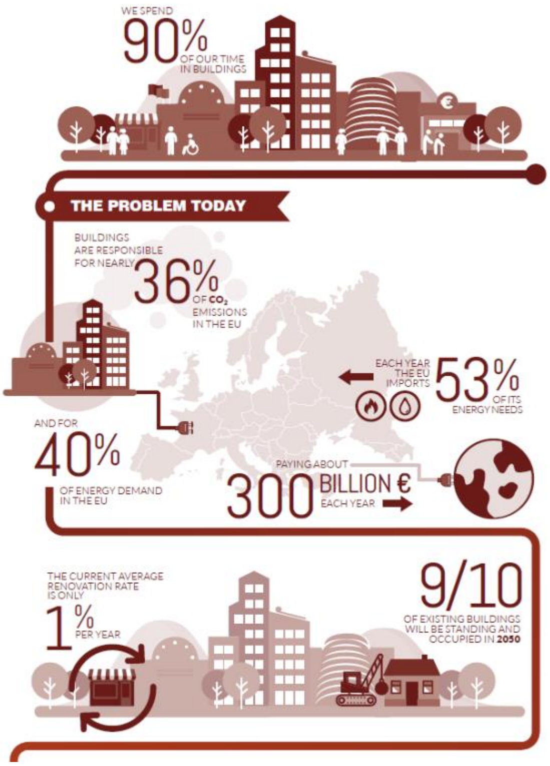

Figure 6.2.12 –graphical presentation of renovate Europe campaign https://www.renovate-europe.eu

In recent years, a wide range of studies and reports have outlined elements of the „business case" for green buildings. **The business case for green building**- a Review of the costs and benefits for developers, investors and occupants was published at www.worldgbc.org.

The study dealt with

- Design and Construction Costs
- Asset Value
- Operation Costs
- Workplace Productivity and Health
- Risk Mitigation

Results of the study can be summarized as:

- Green Building doesn't necessarily cost more
- Green buildings are easier to let, purchasers will pay more (and expect a discount for non-sustainable buildings)
- Green buildings save money through reduced energy and water use, lower long term operations and maintenance costs

- Energy savings normally exceed any premium on design and construction, with reasonably short payback periods
- Good indoor environment can improve worker productivity and occupant health and well-being, resulting in business benefits.
- Sustainability risk factors can affect rental income, asset value and return on investment, increasing risk of obsolescence
- Reduced maintenance requirements provide less disruption to normal operation
- as investors and occupiers become more knowledgeable about and concerned with the environmental and social impacts of the built environment, buildings with better sustainability credentials will enjoy increased marketability.
- green buildings are able to more easily attract tenants and to command higher rents and sale prices.
- where green buildings have generated higher sales prices, this increase in value is largely driven by higher rental rates, lower operating costs, higher occupancy rates and lower yields.
- in markets where green is more mainstream, there are indications of emerging 'brown discounts', where buildings that are not green may rent or sell for less.
- an understanding of what defines green buildings and drives demand in each context is essential as local market conditions have a significant impact on the valuation of these buildings.

Figure 6.2.13 –life cycle of office green building (https://www.worldgbc.org/)

The concept of a building's „asset value" has a different meaning for the various stakeholders in the property sector (see Figure 6.2.14).

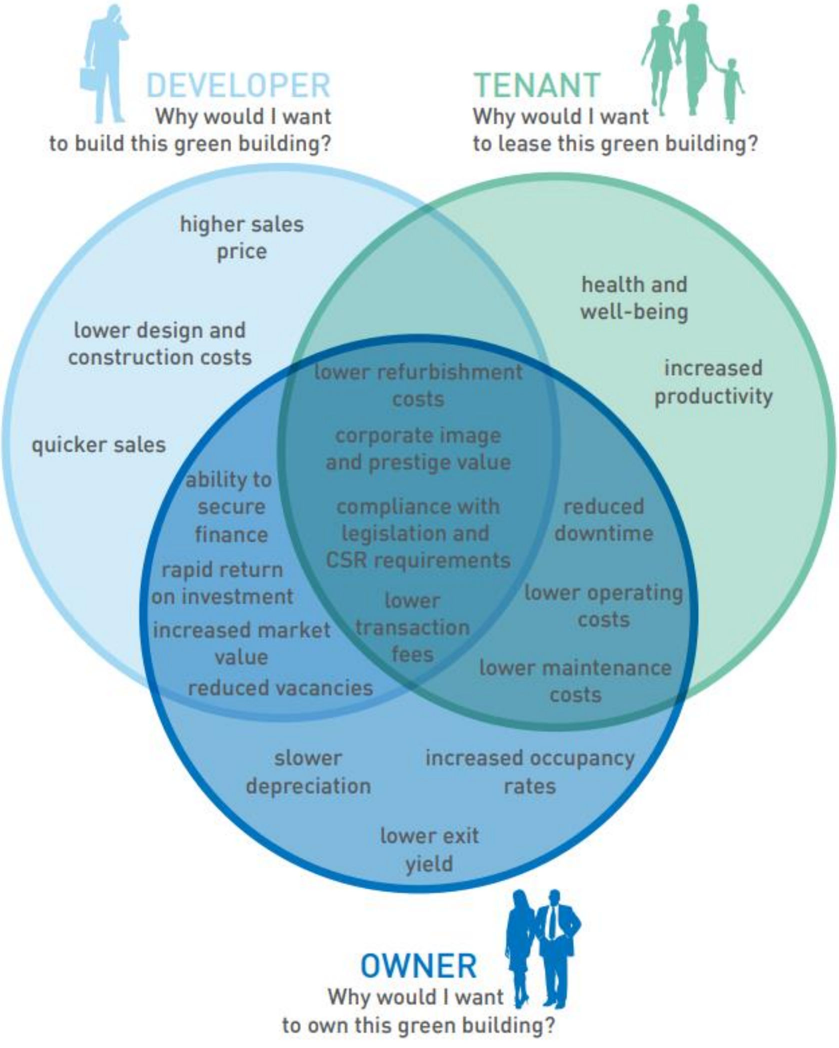

Figure 6.2.14 – Stakeholder perceptions that affect the value of green buildings (https://www.worldgbc.org/)

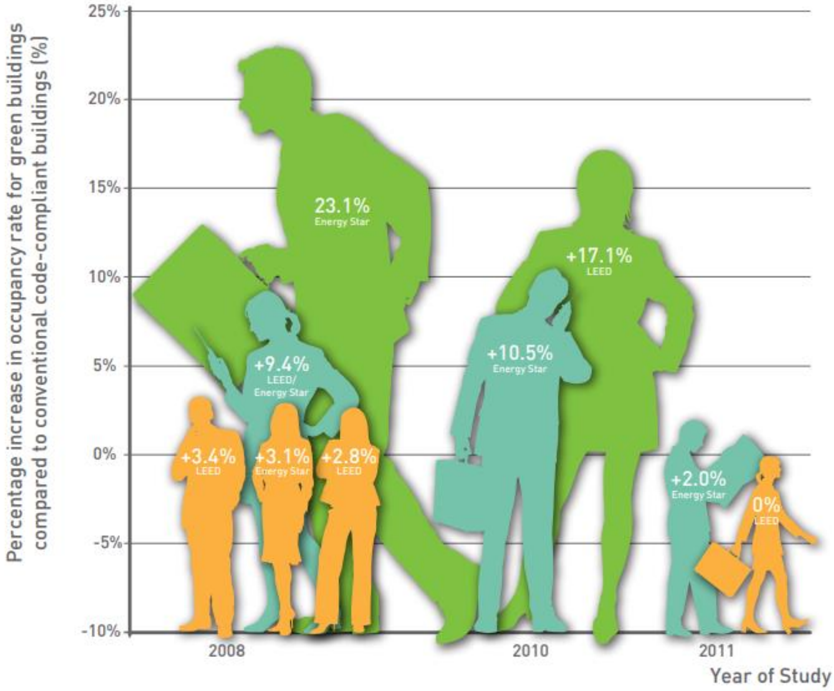

Figure 6.2.15 - Reported occupancy rate increases of green certified office buildings as compared to conventional code-compliant office buildings (https://www.worldgbc.org/)

From a business perspective, Green building design is a basis for improving employee health and productivity.

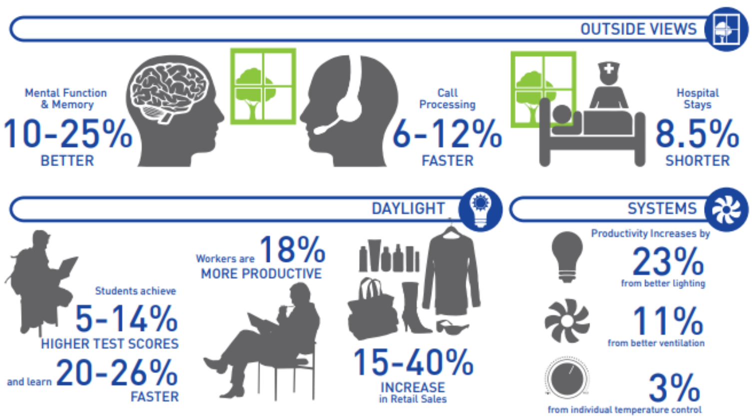

Figure 6.2.16 - Net present value analysis of the operational cost and productivity and health benefits of LEED certified buildings (https://www.worldgbc.org/)

6.2.6 REFERENCES

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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

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

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