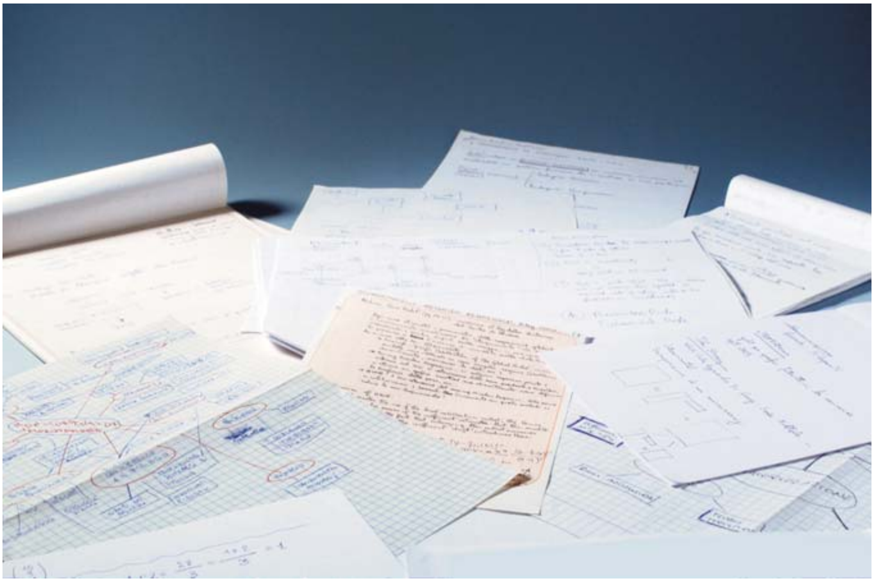
Elena Fregonara

Evaluation sustainability design

Life Cycle Thinking and international orientations



Ricerche di tecnologia dell'architettura
FRANCOANGELI

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RICERCHE DI TECNOLOGIA DELL'ARCHITETTURA

diretta da Giovanni Zannoni (Università di Ferrara)

La collana *Ricerche di tecnologia dell'architettura* tratta prevalentemente i temi della progettazione tecnologica dell'architettura e del design con particolare attenzione alla costruibilità del progetto. In particolare gli strumenti, i metodi e le tecniche per il progetto di architettura alle scale esecutive e quindi le modalità di realizzazione, trasformazione, manutenzione, gestione e recupero dell'ambiente costruito.
I contenuti scientifici comprendono la storia e la cultura tecnologica della progettazione e della costruzione; lo studio delle tecnologie edilizie e dei sistemi costruttivi; lo studio dei materiali naturali e artificiali; la progettazione e la sperimentazione di materiali, elementi, componenti e sistemi costruttivi.
Nel campo del design i contenuti riguardano le teorie, i metodi, le tecniche e gli strumenti del progetto di artefatti e i caratteri produttivi-costruttivi propri dei sistemi industriali.
I settori nei quali attingere per le pubblicazioni sono quelli dei progetti di ricerca nazionali e internazionali specie di tipo sperimentale, le tesi di dottorato di ricerca, le analisi sul costruito e le possibilità di intervento, la progettazione architettonica cosciente del processo costruttivo.
In questi ambiti la collana pubblica progetti che abbiano finalità di divulgazione scientifica e pratica manualistica e quindi ricchi di spunti operativi per la professione di architetto.

La collana nasce sotto la direzione di Raffaella Crespi e Guido Nardi nel 1974.
I numerosi volumi pubblicati in questi anni delineano un efficace panorama dello stato e dell'evoluzione della ricerca nel settore della Tecnologia dell'architettura con alcuni testi che sono diventati delle basi fondative della disciplina.
A partire dal 2012 la valutazione delle proposte è stata affidata a un Comitato scientifico, diretto da Giovanni Zannoni, con lo scopo di individuare e selezionare i contributi più interessanti nell'ambito della Tecnologia dell'architettura e proseguire l'importante opera di divulgazione iniziata quarant'anni prima.

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The book, designed by Elena Fregonara, was produced with the collaboration of Diego Ferrando. Chapter 2 was produced jointly by Diego Ferrando and Elena Fregonara. Diego Ferrando provided also a contribution to the sections 3.1.2 and 3.2.1. Furthermore, Diana Rolando provided a contribution writing the section 4.5 and, with Elena Fregonara, the section 4.4.3.

To Professor Gabriele Brondino

Cover photography: "Gabriele's notes", by Diana Rolando

Contents

Introduction

This book aims to give university students further support in their educational paths and contribute to scientific research in the real estate appraisal and economic evaluation of projects.

The text is designed mainly for students studying “Evaluation of economic sustainability of projects”, a subject included in the syllabus of the Master’s Courses in Architecture of the Politecnico di Torino, “Architecture for the sustainable design” programme, but also addresses students of other second level Degrees, besides those undertaking their Master’s or PhD in research, and refresher course enrollees. There are in fact in-depth notions on specific theoretical and operational topics with direct impact on professional administrative practices, or directly related to the world of business and industry. These themes may also be useful to real estate operators about economic evaluation of projects.

The work contributes to the definition of methodologies that offer support in the choice of the preferred/optimal project solutions, even at the starting stages of the design of new or retrofit buildings, trace intervention policies on existing building assets in synergy with energy policies, and support Public Administrations in the planning and government of the territory. This is oriented towards construction strategies that limit energy consumption, to thus reduce the related impacts at urban level and balance interventions for the valorization of unused public buildings or those that have reached the end of their utility cycle and are about to be disposed of.

The work, after research studies and the reading of international literature on recent multidisciplinary scientific developments, focuses particularly on Italian policies, theories and practices, with highlights on the international/European experiences through referral norms/standards.

It expounds on economic and financial feasibility valuation of new construction projects, related to the residential sector, or those intended for mixed residential/tertiary/commercial uses, retrofit, and energy-efficiency requalification of existing buildings, including the reuse of historic-architectonic assets, etc. Special attention is paid to the planning/analysis/control of the cost items. The theme of project sustainability starts from the international/European framework of policies on energy and in the light of orientations set in Agenda 20-20-20. The discussions develop theories which are, however, reconsidered through practical simulation examples.

The book is divided into four chapters.

Chapter 1 examines the recent international/European energy-environmental sustainability norms in the construction field, from which the cost component emerges as one of the tenets for sustainable projects. Chapter 2 deals with economic-financial analyzes through the Discounted Cash Flow Analysis, an approach integrated with cost calculation elements in relation to specific performances for different and alternative technological components, and includes the risk/uncertainty analysis. Energy consumption is taken into account and the differentials in terms of maintenance costs and potential savings are considered. Chapter 3 starts from the Life Cycle Thinking approach. The need to integrate economic and energy-environmental sustainability indicators are hypothesized ranging from the single material/component to the building as a whole, in relation to the entire building life cycle. The objective is to analyze and compare alternative technological solutions for new construction/retrofit/energy-efficiency qualification of buildings. The Life Cycle Costing approach is proposed by tracing the operating aspects for Global Cost estimation and considering the treatment of risk and uncertainty components in the budgeting of costs within the time perspective. Chapter 4 analyzes the planning/control of costs through the Project Construction Management approach (set in relation to the Asset, Property and Facility Management strategies), and the use of suitable instruments (Cost Control, Earned Value Method). A more comprehensive proposal is presented, based on the joint economic programming and cost control/monitoring strategies associated with Cost Control, Discounted Cash Flow Analysis and Cost Risk Analysis.

1. *Costs and sustainability of project*

Cost is a key element for the development of all the choices to be made, at various time scales, starting from the first stage of the building process up to its conclusion in the life cycle perspective. In project sustainability evaluation the costs are fundamental to the construction, management and building life cycle process.

International scientific studies dedicate extensive discussions on theories and methods for dealing with cost components, as demonstrated in literature and the more recent norms. These involve engineering, architecture, and specific disciplines such as: building production, architectural technology, materials science and technology, building physics, architectonic and urban design, economic-managerial engineering, real estate appraisal and economic evaluation of projects.

1.1. Concepts of costs in international norms on energy-environmental sustainability

The objectives of sustainability, specifically with regard to energy-environment, are translated into norms, standards, regulations, guidelines and documents to support *decision-making* in the definition of strategic and tactical lines of intervention.

In the construction field the objectives of environmental-economic-energy sustainability are mainly supported by orientations towards planning and design interventions and also in the definition of standards for the measurement of the energy performances of buildings.

Considering the continual development of norms on matters of the energy performance of buildings and environmental policies in the international and European framework, the main reference documents are:

- *Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings, Official Journal of the Communities*, known as the *Energy Performance of Buildings Directive* (EPBD), which introduced the Energy Performance Certificate (EPC) to measure the energy performance of buildings;
- *Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings (recast), Official Journal of the European Union*, which was promulgated by the European parliament and Council, establishing the obligation of energy performance certificates for all buildings in the EU;
- *Guidelines accompanying the Commission Delegated Regulation (EU) n.244/2012 of 16 January 2012 supplementing Directive 2010/31/EU of the European Parliament and of the Council on the energy performance of buildings by establishing a comparative methodology framework for calculating cost-optimal levels of minimum energy performance requirements for buildings and building elements*. It institutes a comparative methodological framework to calculate the optimal levels in terms of costs for the minimum requisites of energy performance of building and building elements;
- *Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC*), on energy efficiency;
- Standard ISO 14040:2006, *Environmental Management – Life Cycle Assessment – Principles and Framework* (prepared by the Technical Committee ISO/TC 207, Environmental Management, Subcommittee SC 5, Life Cycle Assessment);
- Standard ISO 15686:2008, *Buildings and constructed assets– Service-life planning*, in particular *Part 5: Life Cycle Costing*, prepared by the Technical Committee ISO/TC 59, Building construction, Subcommittee SC 14, Design life;
- Standard EN 15459:2007 - *Energy performance of buildings - Economic evaluation procedure for energy systems in buildings;*
- Standard EN 15643-2: 2011, *Sustainability of construction works - Assessment of buildings - Part 2: Framework for the assessment of environmental performance*;
- Standard EN 15643-4: 2011, *Sustainability of construction works - Assessment of buildings - Part 4: Framework for the assessment of economic performance*;

- Standard EN 16627:2015 - *Sustainability of construction works. Assessment of economic performance of buildings - Calculation methods.*

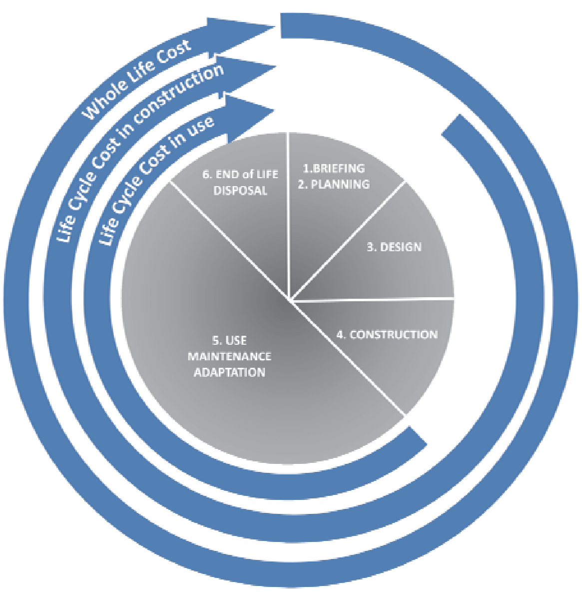
In Italy, the ISO Standards are currently contained in part of the UNI (Italian body for standardization). The directives on matters of energy are translated into specific norms.

The documents cited highlight some important evolutions of the concept of cost.

1.1.1. Whole Life Cost

In ISO 15686 - *Part 5, for Life Cycle Costing*, the Whole Life Cost (WLC) concept is regulated by a norm which is connected to those of Life Cycle Cost (LCC), Global Cost and Cost Optimal. The WLC and LCC components relate to each other at different phases of the life cycle in construction works as illustrated in Figure 1.

Fig. 1 – Life cycle in construction and WLC and LCC (or Total LCC or Global Cost).



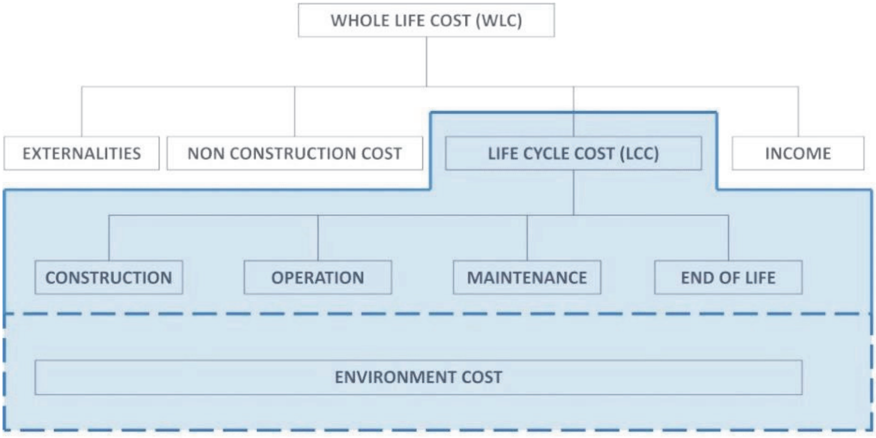
Source: Author’s elaboration based on ISO/FDIS 15686-5:2008 (E), Figure 4, p. 9.

The term WLC refers to the overall set of important initial or future costs and benefits, that come up in the course of the entire construction life cycle in response to the foreseen performance requisites. The concepts of WLC and LCC differ, as evidenced in the international ISO 15686 Standard itself – Part 5. In fact, as illustrated in Figure 2:

- the Whole Life Cost is a "broadened" concept of cost which covers items that may include external factors, costs not directly related to construction, and income (in terms, for example, of savings on management expenditures or "negative costs");
- the Life Cycle Cost regards costs of an asset or its components during its life cycle, to meet the performance required.

Both consider the components of environmental costs.

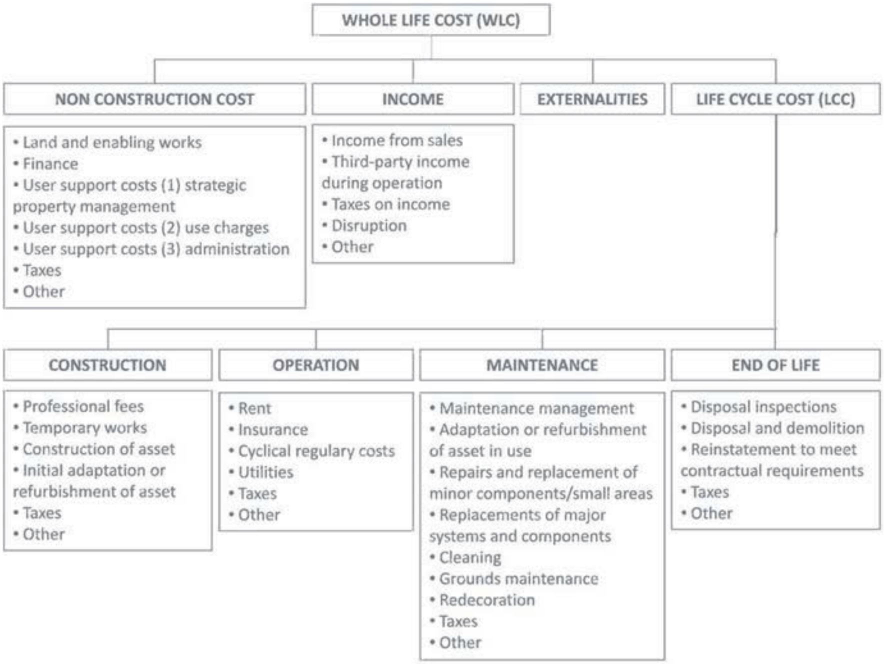
Fig. 2 – Different components of the Whole Life Cost and Life Cycle Cost.



Source: Author's elaboration based on ISO/FDIS 15686 – Part 5: 2008 (E), Figure 2, p. 6.

The Whole Life Cost concept may be further detailed into specific items, as in Figure 3.

Fig. 3 – Whole Life Cost (WLC): detailed items.



Source: Author's elaboration based on ISO/FDIS 15686 – Part 5: 2008 (E), Figure 3, p. 7.

1.1.2. Global Cost

The Global Cost concept is defined in the CEN (Committé Européen de Normalisation) document, *Energy performance of buildings – Economic evaluation procedure for energy systems in buildings, Standard EN 15459:2007, Brussels, CEN, 2007*. This document is the fundamental methodology for its calculation.

Besides supporting the essential requisites of Directive 2002/91/EC (EPBD), it tends to harmonize at European level the calculation methodology for the energy performance of buildings. The approach to the calculation of Global Cost is suitable to all types of buildings and may be used in the construction sector for various aims: to consider the economic feasibility of energy saving options, compare different solutions, assess the economic performance of a complex overall scale model of a building, and quantify the effect of energy savings interventions on existing buildings by comparing the different energy levels used. The main points faced in the document regard: the structure of all the types of costs to be considered, the data needed for their definition, calculation method, ways of expressing the economic calculation result, and definition of some key concepts (for example, lifetime maintenance costs, etc.).

With respect to operations, document EN 15459:2007 provides two calculation modes: the global cost method and the annuity method.

By analogy with other assessment tools illustrated in the text, we consider the first method. This is based on the calculation of the sum of the actual value of all the costs referred to the starting year, including investments. At the end of the estimation period, to determine the final costs, also the dismantling costs or the residual value of the components have to be taken into account. The formula will result as follows:

$$C_G(\tau) = C_I + \sum_j \left[\sum_{i=1}^{\tau} \left(C_{a,i}(j) \cdot R_d(i) \right) - V_{f,\tau}(j) \right]$$

where: C_G (τ) represents the Global Cost, referred to in the initial year τ_0; C_I stands for initial investment costs; $C_{a,i}$ (j) the annual cost at year i, for the j component (including running costs and the periodic or replacement costs); R_d (i) is the discount factor at year i, $V_{f,\tau}$ (j) is the final value of the j component at the end of the calculation period (referred to the initial year τ_0).

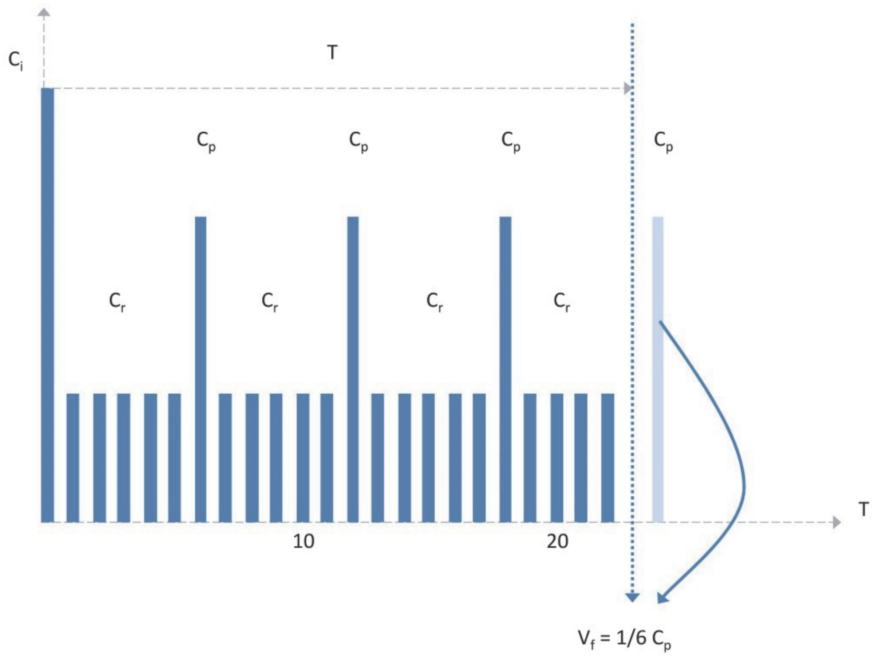
The discount factor Rd may be expressed as:

$$R_d = \frac{1}{(1 + R_r)^p}$$

where R_r is the real discount rate, and p is the reference period.

The method's scheme is shown in the following Figure:

Fig. 4 – Calculation of the global cost, highlighting the final value concept.



Source: Author's elaboration based on Final Draft prEN 15459:2007, Energy performance of buildings – Procedure for economic evaluation of energy systems in buildings, Brussels, CEN, 2007, p. 13.

In the case of an energy efficiency intervention for the application of the method we have to consider some assumptions as a premise: the financial data (for example the duration period of the calculation, inflation rates, market interest rates, energy costs, inflation rates); investment costs deduced from the suitable sources (e.g. the regional price lists); periodic replacement costs (with considerations on the average life of the components); annual costs for maintenance (expressed in percentage over the cost of components) and costs related to energy consumption (heating, lighting, obligatory electrical uses, etc.).

1.1.3. Cost Optimal

The Cost Optimal concept stands at the base of a standardized methodology in the calculation of costs for optimal energy performance levels. The optimal level "sets" the minimum level of energy performance required for buildings, taking into account the relative Energy efficiency Class. It is defined by Directive 2010/31/EU (EPBD recast) and the related guidelines, and the succeeding Delegate Regulation 244/2012/EU, transposed in Italy in the document published in the Official Gazzette C115 of the European Union, 19 April 2012, Communications and information, *Orientations that accompany the delegate regulation (EU) no. 244/2012, of 16 January 2012, of the Commission that integrates the directive 2010/31/EU of the European Parliament and the Council on energy performance in construction, instituting a comparative methodological framework to calculate optimal levels in view of the costs for the minimum energy performance requirements of buildings and construction elements.* The EPBD recast furnished to the EU Member States the comparative methodological framework to be followed for the calculation of the optimal level of energy performance in the buildings taken as reference. On the basis of the methodological indications, the norm provides that each Member State, at national or regional level must develop a series of building types to be taken as references and on which they have to simulate interventions or energy "packages" (see Corrado *et al.*, 2011 and 2014; Becchio et *al.*, 2015).

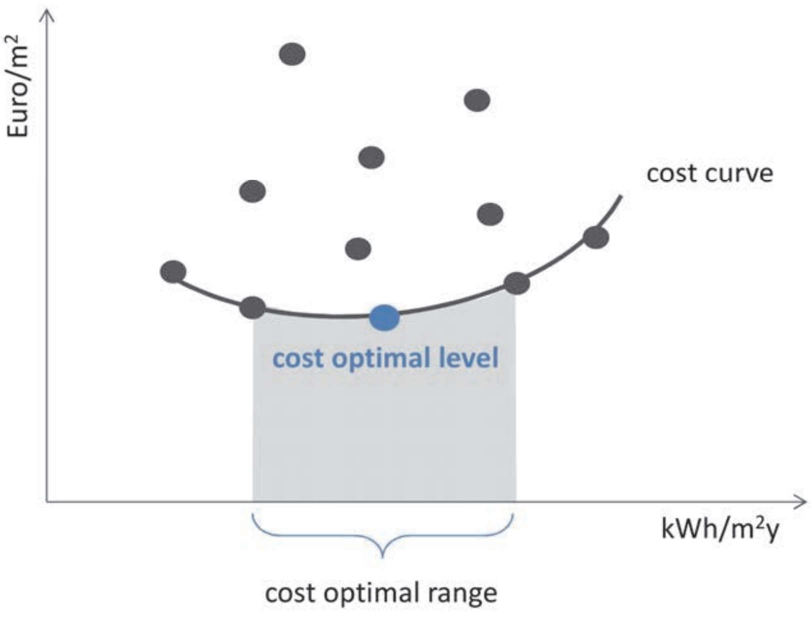
For the simulation operations at energetic level, there are support software, for example, Energy Plus – Energy Simulation Software, U.S. Department of Energy, developed starting from 2001 (see http://apps1.eere.energy.gov/buildings/energyplus).

At economic levels instead, the application of the method is foreseen for the calculation of global costs traceable to the document Standard EN 15459:2007.

With reference to a "near zero" energy building, that is, with high energy performance (low need for primary energy and high coverage from renewable sources), the Optimal Cost represents the level of optimal energy performance in view of the costs, that is, it is the lowest cost that may guarantee the quantity of energy necessary to meet the energy needs of the building during its estimated economic life cycle.

In a simplified form the concept is expressed in Figure 5, which shows, in order, the global cost value (expressed in €/m^2), in relation to diverse solutions (intervention packages), each associated to a different energy efficiency level according to the primary energy necessary (expressed in kWh/m^2 year). The points of the graph correspond to diverse packages and, on joining the points at the lower ends the cost curve is obtained. On the cost curve it is possible to identify, in correspondence with the minimum point, the Cost Optimal level, and on highlighting the interval of the minimum values of the same curve, the Cost Optimal range.

Fig. 5 – Intervention packages according to costs (schematic example): identification of the cost curves, Cost Optimal level, Cost Optimal range.



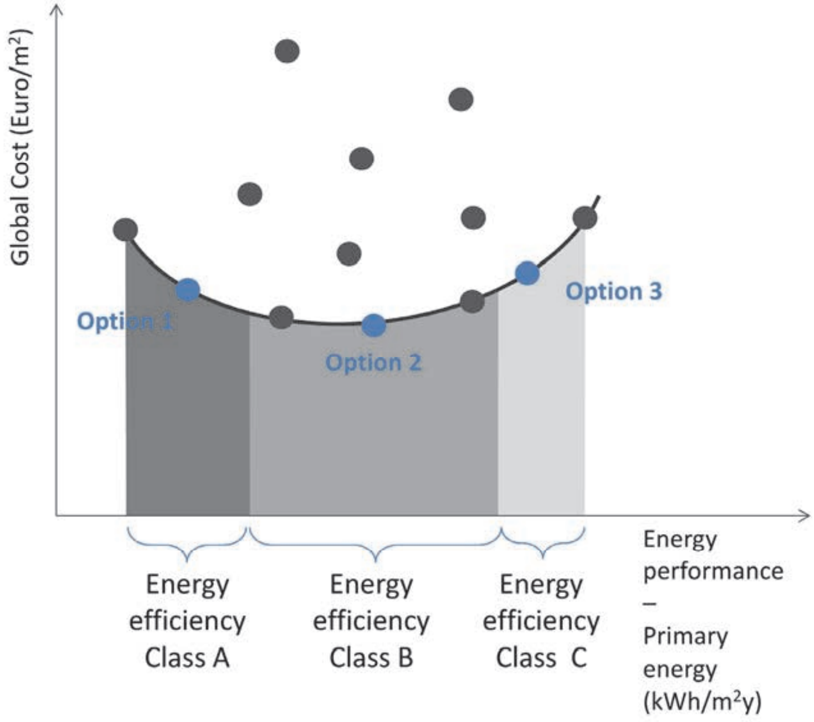
Source: Author's elaboration based on the Official Gazzette C115 of the EU, 19 April 2012, p. 25.

Associating the related Energy Class to each package as in Figure 6, the cost curve can be segmented in view of the optimal solutions by sections (Classes).

This passage is interesting for the analysis of the real estate market. The Cost Optimal intended as the best solution is not, in fact, a cost category but an "option criteria" between alternatives, for both interventions of new constructions/total renovations, and also in cases of interventions on existing assets.

For example, it can support the definition of project scenarios to then verify, with the discounted cash flow analysis (see chapter 2), the earnings and savings related to the specific technical solution, to which the optimal cost is referred.

Fig. 6 – Intervention packages according to global cost for energy performance. Schematic example: optimal costs according to Energy Classes.



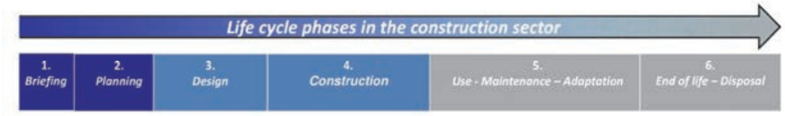
Source: Author's elaboration based on the Official Gazzette C115 of the EU, 19 April 2012, p. 25.

1.2. Economic-financial sustainability and construction life cycle

The concepts of global cost, life cycle cost and optimal cost are found in the construction process, or more simply, in the "building life cycle". The building life cycle may be schematized in six phases over time (Figure 7):

1. Briefing;
2. Planning;
3. Design;
4. Construction;
5. Use-Maintenance-Adaptation;
6. End-of -life-Disposal.

Fig. 7 – Phases of a construction project's life cycle.



This graphic representation is important since it acts as the basis for many tables given in the text. It is underlined that the process is to be considered as cyclical as indicated in the original documents.

In the next Figure the building life cycle phases are set in relationship to those of the real estate development process and life cycle of the project.

Fig. 8 – Phases of the construction life cycle, phases of the real estate development, phases of the project life cycle.