Evaluation tools: cost-optimal and cost-benefit analysis

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Starting with a review of the current implementation state of the cost-optimal methodology in European Member States, this paper offers an outline of the cost-benefit analysis and future developments. It shows how the overall goal of a zero-carbon building stock by 2050 can be accomplished by synergic efforts involving a multi-dimensional approach.

Keywords: Energy Performance of Buildings Directive (EPBD), cost-optimal methodology, cost-benefit analysis, energy efficiency, energy performance requirements, human-centric approach, zero-carbon society

The recently revision of the Energy Performance of Buildings Directive (EPBD) of 2018 [1] is an essential component of the European strategy to achieve a zero-emission and fully decarbonised building stock by 2050. The new proposal reiterates the key role of the cost-optimal methodology introduced in the EPBD [2] and, at the same time, stresses the importance to improve the quality of life, health and performance of building occupant, and introduced the Smart Readiness Indicator, the calculation of which is based on eight impact criteria. Two of these criteria, indeed, are comfort and health. In this scenario, resulted essential to take into account not only the improvement of building energy efficiency, but also the indoor environmental quality and the interaction between the building, its systems and the occupant. Consequently, concerning the analysis of the built environment the new subject of the investigation is the building-systems-occupant complex. In this framework, the challenge in renovation planning is the definition of proper metrics and tools able to take in consideration the multiple benefits related to the renovation itself. If the cost-optimal methodology is built on two indicators (an energy one and a financial one), considering the occupant-centred investigation, energy, financial, environmental and socio-economic impacts are needed to be taken into account in the decision-making process at the foundation of energy planning. Cost-Benefit Analysis (CBA) is an analytical tool that can be used in energy projects decision-making process in order to assess design alternatives from a social point of view. In theoretical terms, the CBA introduces the economic dimension in the financial analysis, allowing positive and negative externalities to be examined in the assessment. This paper offers a review of the current state of the cost-optimal methodology implementation and outlines the CBA as a possible development.

Cost-optimal methodology

Despite wide debated topics arisen around the cost-optimal approach [3], it is not questionable that its introduction signed an important milestone towards the renovation of the existing building stock and a substantial transformation towards a zero-carbon society.

Cost-optimal level means the energy performance level which leads to the lowest cost during the estimated economic lifecycle (i.e. 20–30 years), where the lowest cost is determined taking into account the building use and category, energy-related investment costs, maintenance and energy, and operating costs. Member States set minimum requirements for the energy performance of buildings and building elements with a view to achieving the cost-optimal balance between the investments involved and the energy costs saved throughout the building lifecycle. Member States use that framework to compare the results with the minimum energy performance requirements in force and, in case of significant discrepancies higher than 15%, justify the difference or plan appropriate steps to reduce the gap.

According with the latest cost-optimal reports provided by Member States in 2018–2020, the average cost-optimal level is 80 kWh/(m²·year) for new residential sector, 140 kWh/(m²·year) for the new non-residential, 130 kWh/(m²·year) for existing residential and 180 kWh/(m²·year) for existing non-residential. About the gaps with current energy performance requirements, few Member States provided gaps greater than 15%, and the picture is more critical for new multi-family buildings.

Reaching cost-optimal levels of minimum energy performance requirements challenged Member States [4] also in the light of the heterogeneity of European countries in relation to the variability of building types and climates [5]. However, the analysis of the first reported cost-optimal calculations to the Commission revealed an overall rather positive picture regarding both the conformity to the official requirements and the plausibility of the final outputs [6]. Regardless of the progress achieved through European legislations [7], the envisaged match between cost-optimal and nearly zero-energy building (NZEBs) energy performance level remains questioned. The link with NZEBs is also reiterated in the EPBD revision: it cannot be lower than the cost-optimal level that will be reported in 2023 by Member States in accordance with Article 6(2).

Figures 1 and 2 show cost-optimal and NZEBs levels for new and existing buildings, respectively, as assessed by the JRC in 2020 [8]. The area of an acceptable gap is the green, where the NZEB net primary energy is lower than the cost-optimal.

Figures 1 and 2 allow depicting a quite positive picture. A good number of Member States are introducing NZEB requirements substantially lower (about –50%) compared to cost-optimal levels. Only in 20% cases the NZEBs and cost-optimal gap overcame 15%

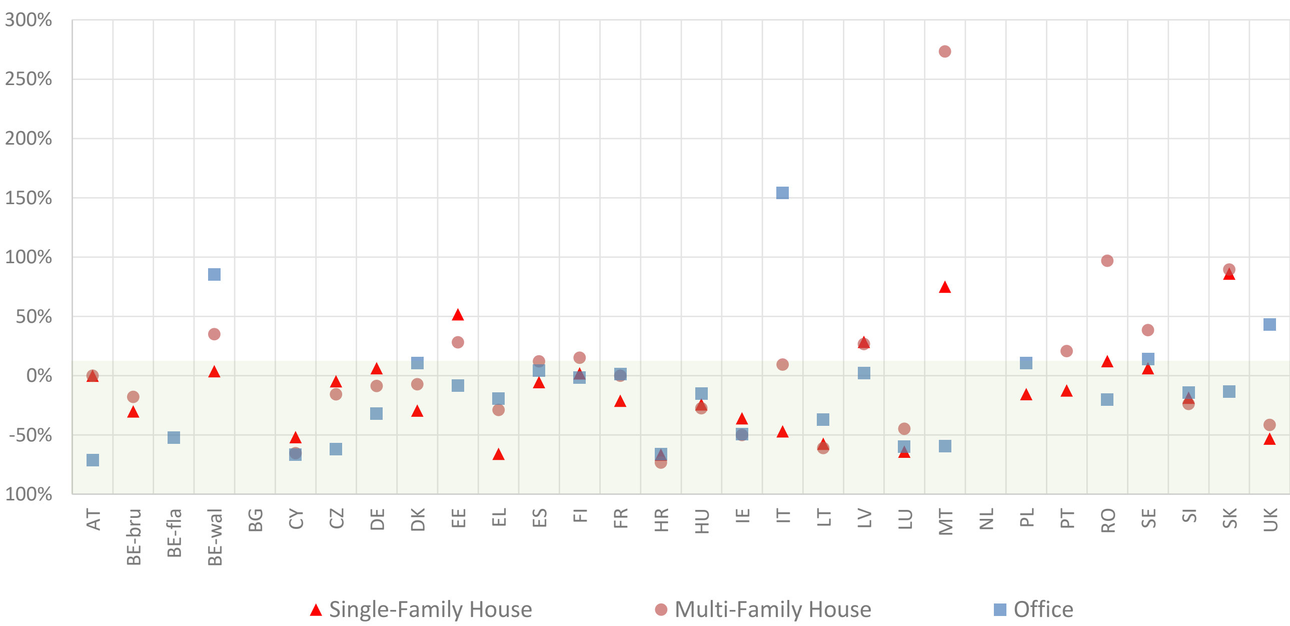


Figure 1. Cost-optimal and NZEB net primary energy levels for new buildings.

for new buildings, in 18% of cases for existing. A good number of Member States referred to the cost-optimal approach to define the NZEBs requirements.

Especially at retrofit level, studies investigating the possible energy/financial performance gaps between the two levels can inform policy-makers about how demanding the forthcoming market transition towards an energy efficient building stock will be [9]. Important novelties will be revealed with the review of the cost-optimal framework, expected by the Commission by 30 June 2026, to enable the calculation of both energy and emission performance taking into account environmental and health externalities, as well as the emissions trading system (ETS) extension and carbon prices [1].

The update of NZEB definitions for new buildings (and major renovations), the introduction of energy requirements and incentive mechanisms for renovation, in line with the Renovation Wave Strategy [10], and the environmental targets for the building sector as a whole require an update of the methodology. In compliance with Article 6 of reference [1] (ex-Article 5 of the EPBD), the calculation of cost-optimal levels will be more aligned to the Green Deal [11], as costs of greenhouse gas allowances as well as environmental and health aspects of energy use will have to be considered to derive the lowest costs. The cost-optimal level shall lie within the range of performance levels where the cost benefit analysis calculated over the estimated economic lifecycle is positive.

Cost-benefit analysis

After the revision of EPBD, the recent focus has been on incorporating co-benefits into decision frameworks to take into account the full range of stakeholders involved in energy investments such as citizens, owners, users and so. Indeed, contemplating not only the costs but also the benefits and, in particular, the co-benefits make it possible to highlight how investments in energy efficiency can provide many different benefits to various stakeholders, for example, reductions in local air pollution associated with the reduction of fossil fuels, employment creation, fuel security, improvement in productivity, illness reduction, indoor comfort increase [12].

The CBA analysis includes five successive steps: identification of costs and benefits of the project, estimation of the monetary values, distribution of the estimated costs and benefits over the time and construction of the cash flow, definition of the discount rate, calculation of the performance indicators such as Net Present Value (NPV) and benefit/cost ratio (B/C). This tool can be exploited at different scale of analysis: at technological component level, at the building level and at district/city level.

Innovative technologies that can be deployed in the renovation process should be evaluated taking into account their impacts not only in terms of energy efficiency, but also on the matters mentioned in the updated regulation panorama (i.e. indoor air quality, comfort, health, etc.). The CBA can demonstrate how higher investment costs of innovative technologies can

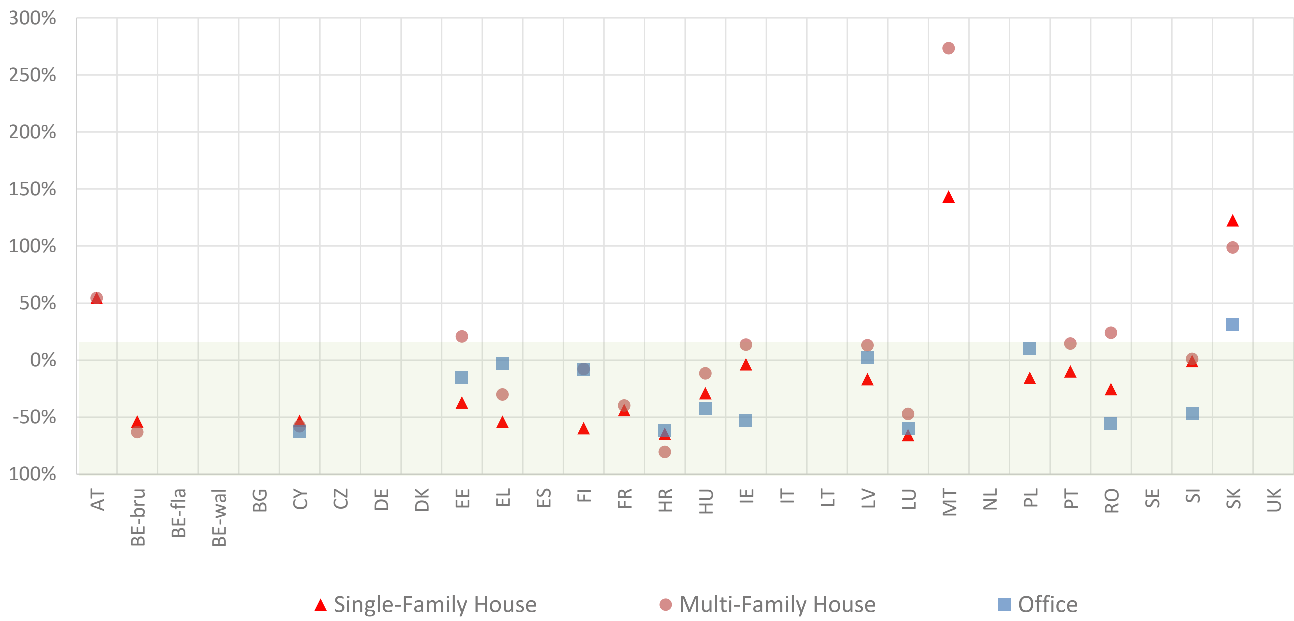


Figure 2. Cost-optimal and NZEB net primary energy levels for existing buildings.

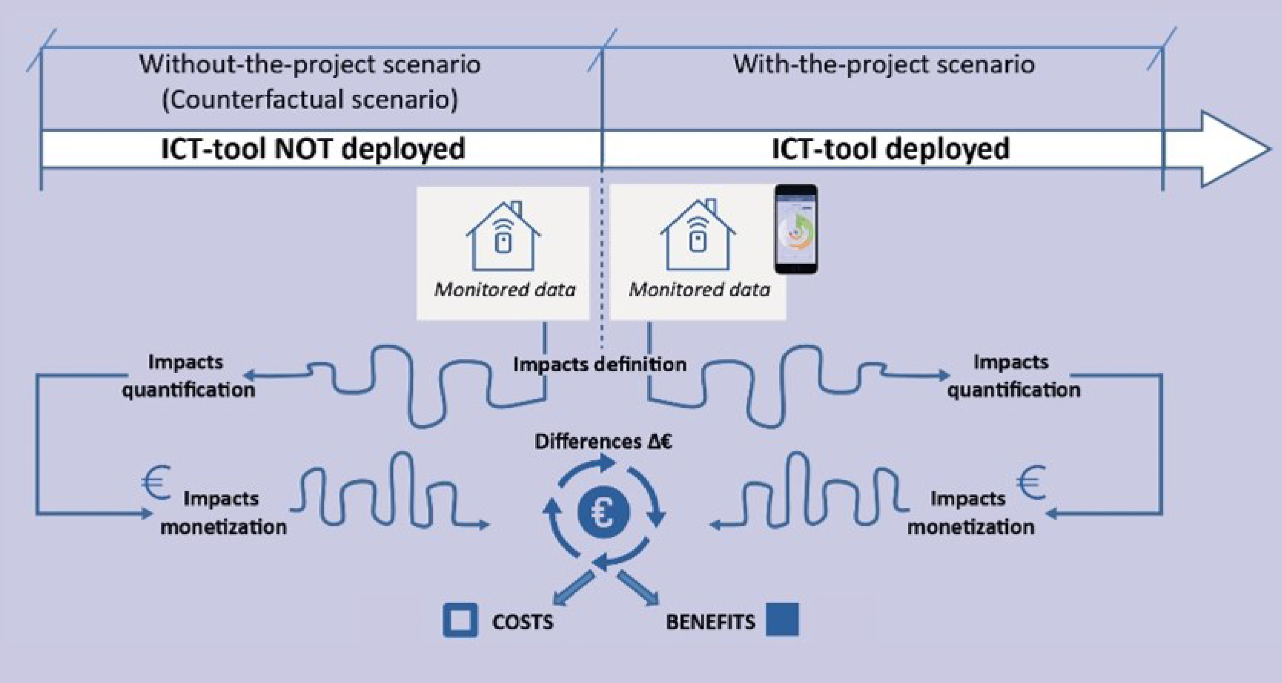
be repaid by socio-economic benefits. In reference [13] the CBA underlines that regarding the use of an innovative antibacterial filter for air handling units in office building, the investment and replacement costs are higher than reference filter ones but they are totally repaid by the improvement of workers' productivity and by the decreasing in respiratory diseases.

At the building level, the CBA can be exploited for evaluating and comparing different energy scenarios for new or existing buildings in terms of energy consumptions, water consumptions, productivity, IEQ improvement, GHG emissions, PM emissions, health (headache cases), as done for the pilots of MOBISTYLE EU project (financed by European Community, grant agreement No. 723032) [14]. The aim of the project was to motivate behavioural change by raising consumer awareness through a provision of attractive personalized information on user's energy use, indoor environment and health, through information and communication technology-based services. The multi-dimensional approach of the CBA (**Figure 3**) was use to assess the effectiveness of consumer awareness in each case study evaluating the impacts above mentioned.

At district scale, there are some examples of utilization of CBA for evaluates alternative retrofit scenarios with respect to energy, environmental and social criteria. In reference [15] after the assessment of the energy status of the district, the second step of the analysis consists in establishing the alternative retrofit scenarios for enhancing the energy efficiency. The third phase involves the identification of costs and benefits for each hypothetical scenario, and the related translation in monetary terms (investment costs, running costs, energy consumption, GHG emissions, green jobs, asset value). The step four aggregates the impacts within a framework based on CBA and evaluates the indicators of profitability, in particular the Social Return On Investment (SROI). The final steps consist in the development of some sensitivity analyses in order to test the stability of the obtained results.

Conclusions

To summarize the paper proposes a review of the current state of the implementation of cost-optimal methodology that represents a solid evaluation tool



$$NPV = \sum_{t=1}^{n} a_t S_t = \frac{S_n}{(1+i)^n}$$

- S_t: difference between **BENEFITS** and **COSTS** at time t
- $a_t = \frac{1}{(1+i)^t}$: discounting formula
- n: time horizon

If **NPV > 0** benefits overcome costs

If **NPV < 0** costs overcome benefits.

Figure 3. Cost-benefit analysis applied in MOBISTYLE EU Project.

for managing the existing building stock renovation. Moreover, it outlines the CBA as a possible evolution underlining its potentialities with some examples of applications at different scales. In a season characterized by the human-centric approach, exploiting new multi-dimensional evaluation metrics that consider not only the costs of the renovation project but also the multiple benefits for the multiple involved stakeholders becomes indispensable. ■

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