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IEA EBC Annex56 vision for cost effective energy and carbon emissions optimization in building renovation

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Abstract

Building sector has become an important target for carbon emissions reduction, energy consumption and resources depletion. Due to low rates of replacement of the existing buildings, their low energy performances are a major concern. Most of the current regulations are focused on new buildings and do not account with the several technical, functional and economic constraints that have to be faced in the renovation of existing buildings. Thus, a new methodology is proposed to be used in the decision making process for energy related building renovation, allowing finding a cost-effective balance between energy consumption, carbon emissions and overall added value.

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Keywords: Building Renovation, Energy Efficiency, On-site renewable energy systems, Optimization, Decision process, Energy policy

1. Introduction

The European Union is responsible for 40% of the primary energy consumption and 35% of the carbon emissions [1]. In an attempt to reduce these numbers, EU has established the 2020 targets, which intend to reduce the energy consumption and consequently the carbon emissions in 20% and increase in 20% the contribution of renewable energy sources [2].

Many of the energy related policies have their main focus on new buildings but, most of the European building stock has more than twenty years old and present low energy performance. Most of these buildings may not be able to reach the new energy standards due to design and construction constraints [3]. Besides the buildings age, the lack of know-how and short term perspectives regarding the cost effectiveness of building renovation measures, restrict

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the exploitation of the potential for energy and carbon emissions reduction in the building sector [3]. Therefore, cost effective renovation measures should be analyzed in order to achieve the best energy performances with the less effort and the less disturbance to the occupants.

In this context, the optimization of reductions in energy consumption and carbon emissions must be developed in energy related building renovation. IEA EBC launched the Annex 56 project to explore the cost-effective optimization of energy and carbon emissions related building renovation, exploring the best balance between the highest efficiency of the buildings envelope, the technical building systems and deployment of renewable energy.

The purposes of this Annex are the following:

- Define a methodology for the establishment of cost optimized targets for energy use and carbon emissions in building renovation;
- Clarify the relationship between the emissions and the energy targets and their eventual hierarchy;
- Determine cost effective combinations of energy efficiency measures and carbon emissions reduction measures;
- Highlight the relevance of co-benefits achieved in the renovation process;
- Develop and/or adapt tools to support the decision makers in accordance with the methodology developed;
- Select exemplary case-studies to encourage decision makers to promote efficient and cost effective renovations in accordance with the objectives of the project [3] e [4].

The developed methodology provides the basis for the assessment and evaluation of packages of renovation measures which intend to improve the energy performance of existing residential buildings, including the possibilities of going beyond the cost-optimal and cost-effective reduction of energy and carbon emissions and also considering the co-benefits and overall added value achieved in the renovation process. It also includes a methodological framework for the integration of embodied energy use in the lifecycle impact assessment.

This paper intends to give a glimpse of the latest updates on IEA EBC Annex 56.

2. Opportunities and constraints of energy and carbon emissions related building renovation

The deployment of buildings with high energy performance is becoming more and more technologically accessible, mainly for new buildings. The main problem lies in existing buildings. Existing buildings with low energy performance compared with today’s standards are the majority of the European building stock and most of them need renovation. This makes an excellent opportunity to improve their energy performance. Many times, as the investment is supported by owners, and because of the high investment costs, the first option is a renovation solution that just improves the buildings aesthetics and restores their functionality. In a long term perspective, this reduced initial investment in the renovation works usually ends up in a more expensive process than when a life cycle approach is considered and the operational costs are also taken into account.

These buildings have their own physical constraints and the owners/promoters play a decisive role in the choice of the solution to be undertaken in a renovation intervention. The achievement of significant reductions of energy consumption and carbon emissions may not always require a highly efficient solution for the envelope, which sometimes may involve complex construction works that discourage the owners. Thus, the use of renewable energy sources harvested on site may also be used to foster the reduction of non-renewable energy consumption and also the reduction of carbon emissions.

Thereby, the main challenge is to understand how far it is possible to go with energy conservation and efficiency measures, in order to promote the energy efficiency among the stakeholders [3] and when start using renewable energy produced on site.

Acting with new renovation solutions that prove to be cost-effective and add value to the building, it is crucial to promote the energy efficiency in buildings, taking also advantage of the non-energy benefits of a building renovation.

3. Methodology

IEA EBC Annex 56 scope is residential buildings and office buildings without complex HVAC technologies. It aims at evaluating and assessing energy renovation activities in a cost-effective way, optimizing the energy use and carbon emissions reduction. The methodology goes beyond cost-effective reduction of carbon emissions and energy use by considering co-benefits and overall added value achieved in the renovation process.

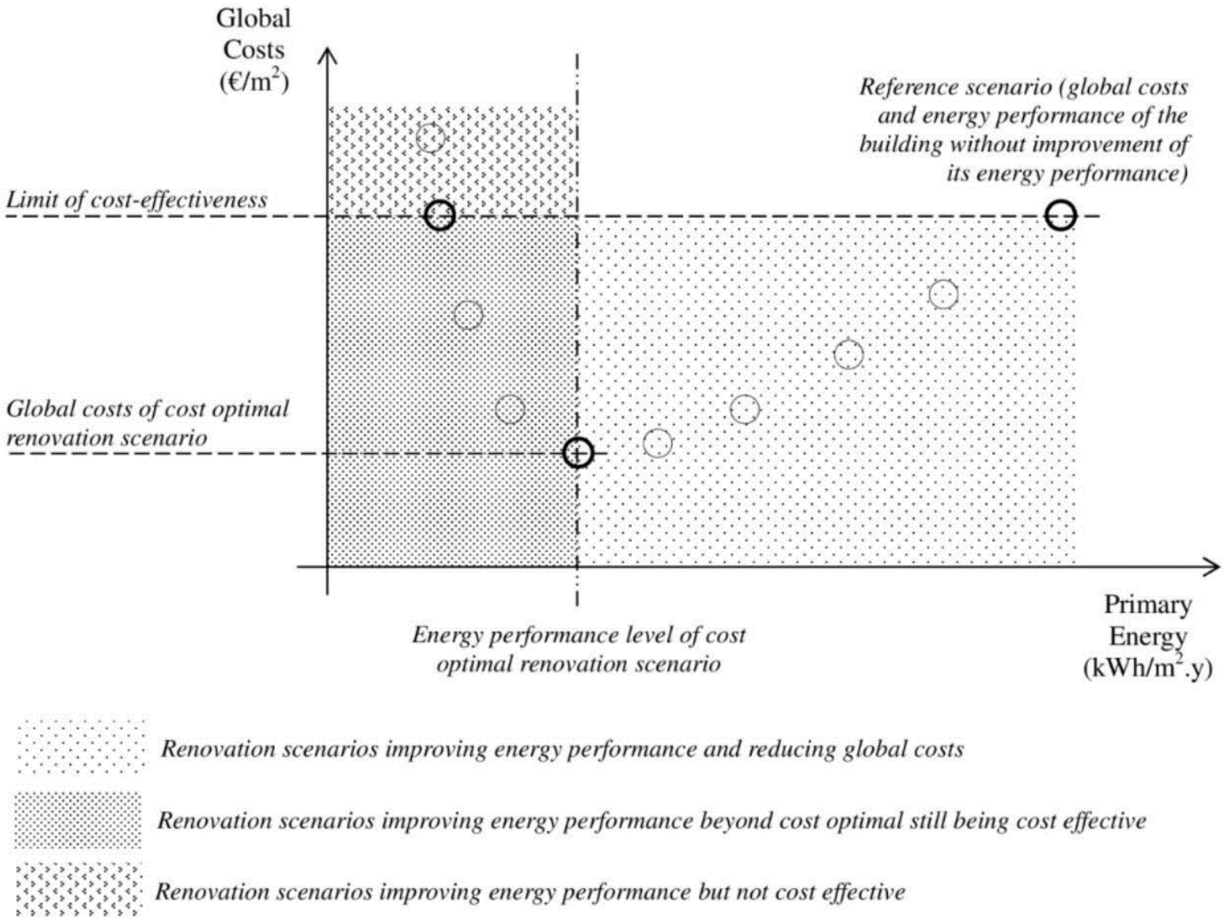

Figure 1 Identification of cost optimal and cost effective level.

Figure 1 shows a generic graphic definition of the cost optimality and cost-effectiveness evaluation. IEA EBC Annex 56 focuses on the measures with energy performance beyond the cost-optimal renovation scenarios, approaching the zero energy and zero carbon emissions levels. The goal is to start with the cost-optimal approach and go further, balancing energy efficiency measures and measures making use of renewable energy sources to reach the lowest energy use and carbon emissions level, lowest embodied energy in materials and the most achievable co-benefits.

The methodology uses a life cycle costs approach (LCC), which balances the energy consumption and global costs for a life cycle of 30 to 60 years, for each renovation measure analyzed. The comparison between the measures is always related to a reference case, known as “anyway renovation”, which does not consider any energy related improvements.

To perform the assessment, different renovation scenarios improving the energy performance of the building envelope and using different combinations of building integrated technical systems are created, and their energy use and related carbon emissions calculated.

The next step is to calculate the global costs, including the investment costs, energy cost, carbon emissions cost, maintenance and eventually the disposal of the buildings elements at the end of the building life cycle. As it is a life cycle analysis, the value for the money and future costs of energy have to be calculated and brought to the present moment using annuity method or net present value.

In order to include the environmental impact of the solutions in the LCC, a simplified LCIA analysis may be performed allowing assessing the global warming potential (GWP) and embodied energy of each renovation scenario. With these results, not only the energy and carbon emissions related to building operation are considered in the assessment but also those related with the materials used in the renovation process.

Besides this, IEA EBC Annex 56 has also adopted a qualitative way of relating the energy renovation measures with co-benefits that potentially result from the application of those measures. The owner/user's interests are considered by placing their willingness to pay for added co-benefits against the results from the life cycle costs assessment.

At the end of the process it is possible to compare and rank the best solutions in terms of energy, emissions, global costs and co-benefits and identify the packages that add more value to the building according to the decision maker interests. The results may be presented using a graphic similar to the one shown in figure 1. Graphically, each point represents the final total energy (or GWP) and the global costs. To clarify the analysis performed within the IEA EBC Annex 56 methodology, the next topic presents an example of the application of this methodology to a case study from one of the participating countries, Portugal, specifically.

4. Example of the results obtained using IEA EBC Annex 56 methodology

The following example is a Portuguese case study. The building to be renovated has two apartments, one in each floor and it was built in the sixties. It is part of a social neighborhood and was highly degraded. As part of the renovation plan for the neighborhood, the building has undergone into renovation. The renovation works that have been implemented include insulation on the external walls and roof, replacement of the windows and installation of new building technical systems (BITS). IEA EBC Annex 56 methodology has been used to compare the chosen renovation solution with other renovation scenarios progressively moving towards zero energy and zero emissions and increasing the potential co-benefits.

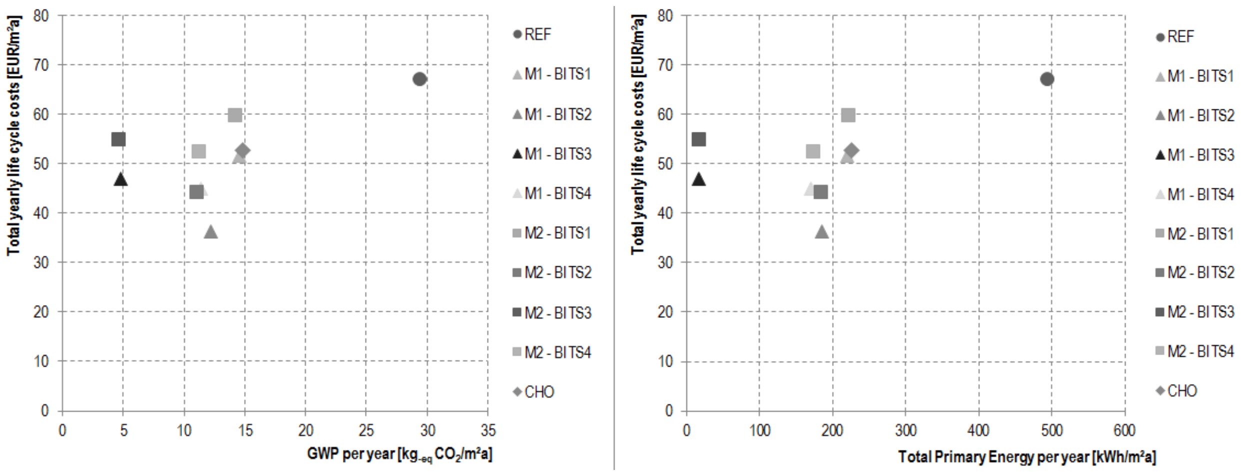

Figure 2 Assessment of total yearly life cycle costs versus GWP and total primary energy use for several renovation scenarios

Figure 2 shows the life cycle cost analysis performed for this building. The reference case refers to the so called "anyway renovation" which refers to a renovation scenario with measures just to restore its appearance and functionality, not improving the energy performance.

The renovation scenario corresponding to the implemented solution is identified in Figure 2 as CHO. This solution allows reducing the primary energy use and GWP in about 50% when compared with the reference case. Renovation scenarios M1 and M2 (also identified in Figure 2) refer to packages of measures further improving the energy performance of the elements of the building envelope. These renovation scenarios use different insulation materials in order to assess their relevance regarding the environmental impact. These two packages were tested with four combinations of BITS that are presented in table 1.

Table 1 Summary of the analysed combinations of building integrated technical systems

BITS	Heating	DHW	Renewable
BITS1	Electric heater	Electric heater with storage tank	Solar thermal
BITS2	Gas boiler	Gas boiler	-
BITS3	Heat pump	Heat pump	Photovoltaic
BITS4	Biomass boiler	Biomass boiler	-

The cost optimal package refers to package M1 combined with BITS2 which includes wall, roof and floor insulation.

All measures are cost-effective, once they present lower yearly costs than the reference scenario.

Comparing the implemented scenario (CHO) with the scenario with the best energy performance (M1 combined with BITS3) it is possible to conclude that this last one presents better results in all parameters, with less energy use, less global warming potential and lower total yearly cycle costs.

Also comparing the cost optimal scenario with the one with best energy performance, the reduction of energy use is very significant, with the last one reaching values very close to zero. Regarding the reduction of GWP, although relevant, it is not as expressive as in the case of energy due to the environmental impacts of PV panels. The increase in total yearly life cycle costs is near 10€/m^2.a.

To better evaluate this difference in costs, it must also be considered that the package with better energy performance includes the introduction of windows with better protection against external noise and the reduced energy use leaves the users more protected from eventual significant energy price fluctuations. The added value from these co-benefits depends on the building and user context and their comparison with the gap in life cycle costs analysis should be carefully considered.

In fact, interviews with residents of renovated dwellings show that the evaluation of the added value related with co-benefits emerging from renovation measures is not always straightforward. As an example, in the CHO renovation scenario, the applied measures potentially help increasing security and reducing external noise, due to the windows replacement. Despite appearing a positive co-benefit, interviews carried out among users revealed that the external noise and safety was not a problem because the building is placed in a quiet area. Some even complained that the noise from next door neighbors became louder because of the increase in insulation from external noise. In some cases the interviews with the residents also pointed out that internal shading and larger windows had a negative impact in thermal comfort and natural lighting which affected the functionality of the living areas.

These examples show how the valuation of a co-benefit can vary according to the building and residents context and this must be carefully taken into consideration in the evaluation of the renovation process.

5. Main conclusions

Existing buildings with low energy performance represent the majority of the European building stock. Therefore, in order to improve their performance to the current energy standards and to achieve the energy and carbon emissions reduction targets, it is necessary to perform deep changes in the consumption patterns.

For these buildings, the range of available technical solutions is shorter than for new buildings once their technical and functional constraints many times lead to a relevant increase of costs due to the need for ancillary work. It is then necessary to make use of all available technologies allowing to significantly reducing the carbon emissions with a view to the final goal of contributing to climate change mitigation. The use of IEA EBC Annex 56 methodology in several representative residential buildings in the participating countries allows concluding the following:

- The cost optimal level does not lead to nearly zero energy or emissions levels. So, it is essential to go a step further and explore the full potential of the cost-effective energy related renovation measures. Thus, all renovation packages that have lower costs than the reference case are considered cost effective and should be considered;
- In most of the cases, the cost optimal renovation solution of the envelope is the same whatever the BITS used.
- Despite the use of renewable energy sources, the buildings renovation should always integrate improvement of the buildings envelope to a minimum level according to the local climate in order to assure comfort and prevent damages resulting from problems with building physics;
- The results show that when the target is to reduce the carbon emissions at the least cost, it is advisable to use renewable energies. Renewable energies reduce the emissions in a more cost-effective way.
- It is better to improve the energy performance of several elements of the envelope than to costly maximize the performance of just one. If monetary resources are scarce, the best solution is to improve several elements of the envelope even if with lower energy efficiency targets;
- In order to benefit from the synergies between energy related measures and BITS, it is favorable to combine renewable energy systems with conservation measures on the buildings envelope;
- The inclusion of embodied energy in materials in the assessment of the buildings energy performance has an increasing impact on the environmental performance of highly-efficient insulation measures, as the zero energy targets become more relevant. However, this impact in a renovation process is low and plays a much smaller role than in the case of construction of new buildings.

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