Rehabilitation and Energy

COST EFFECTIVE ENERGY AND CARBON EMISSIONS OPTIMIZATION IN BUILDING RENOVATION

Reabilitação em direção aos edifícios de energia e emissões zero

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ABSTRACT

In order to mitigate climate changes induced by human action, the European Union settled a long term goal of reducing, up to 2050, the carbon emissions to 80 to 95% of 1990 values. At the level of the built environment it is expected to reduce carbon emissions to about 90% of the values of 1990 in that period.

In order to promote this achievement, EU established the "nearly-zero energy" buildings concept that emerged in the context of the EPBD recast. This directive determines that by 31 December 2020, all new buildings must be nearly zero-energy buildings and all member states must develop policies and take measures to stimulate the transformation of the building stock also into nearly zero-energy buildings.

In the actual context, this is a major challenge since there isn't yet enough knowhow to do it and the existing standards and regulations regarding energy consumption are mainly focused on new buildings and do not respond effectively to the numerous constraints of the existing ones. It is then urgent to develop new renovation approaches that take into consideration the characteristics and limitations of existing buildings as well as to develop tools and good-practices guides, hold on appropriate, applicable and cost effective technologies, to support the different decision makers involved in this sector.

The great challenge is to find sustainable ways of renovate in a cost-effective and massive way the huge and high energy consumer building stock.

Key words: nearly-zero emissions building; building renovation; cost effectiveness

I. THE CHALLANGE OF RENOVATING TOWARDS ZERO CARBON EMISSIONS

Climate changes are evident all over the planet and it is no longer possible to ignore its relationship with the carbon emissions, deeply related to energy production and use. To tackle this problem different measures are being taken worldwide to promote energy efficiency and expand the use of renewable energy sources in all areas and in particular in the building sector, one of the most relevant energy consumers.

The EU has been taking relevant measures for the reduction of energy consumption in buildings, with a target to improve the energy efficiency of buildings, decrease carbon emissions and to increase the use of energy from renewable sources, each one in 20% by 2020. On the long term, at the level of the built environment, responsible for consumption of 40% of primary energy and by 24% of carbon emissions, it is expected by the European Comission [2011] to reduce emissions until 2050 to about 90% of the values of 1990.

Several standards regarding energy consumption have emerged in the last decade [Thomsen & Wittchen 2008], defining increasing levels of exigency, like Minergie in Switzerland, Effinergie in France, Passive House in Germany, Code for Sustainable Homes in UK or DK Low Energy Class 1 in Denmark. The "nearly-zero energy" buildings concept emerged recently to define tangible limits and, although its borders are not yet fully clarified, prospects point to a hierarchical approach that will value energy conservation and efficiency measures, which implies a strong investment on the envelope and in building systems as well as the use of on-site renewables [Sartori, I., Napolitano, A., et al., 2010].

However, these standards are mainly focused on new buildings ignoring, most of the time, the existing ones that will have to face similar challenges in the near future, and represent the least efficient, the largest consumers and the largest share of the building stock [Xing, Y., Hewitt, N., et al., 2011]. Existing standards do not respond effectively to the numerous technical, functional and economic constraints of this kind of buildings and many times, the requirements, mainly targeted to energy efficiency measures, result in very expensive measures and complex procedures, hardly accepted by owners or promoters.

It is then urgent to promote the development of new standards that take into consideration these constraints as well as to develop tools and good-practices guides that take advantage of cost effective technologies and solutions [Boermans et al. 2011] while constituting reliable sources of information and good examples.

The practical implementation of this concept implies, however, deep changes of current practices and also in mentalities. It is needed to work at the development of effective renovation techniques where innovation and technical progress are still needed, as well as actively involve the decision makers, multipliers and policy makers, to whom must also be provided differentiated tools and guides enabling them to make better decisions and to choose the best options.

II. STRATEGY

Once the existing standards are not tailored to deal with the numerous constraints of existing buildings, being mainly targeted to energy efficiency measures that very often result in expensive processes and complex procedures, it is then necessary to act with new renovation solutions that prove to be cost-effective and add value to the building from the perspective of all stakeholders.

Having in mind the overall objective of slowing down climate change, carbon emissions reduction measures can be as effective as energy conservation and efficiency measures and sometimes be obtained in a more cost effective way. Therefore, in existing buildings, the mostcost-effective renovation solution is often a combination of energy efficiency measures and carbon emissions reduction measures. Hence, it is relevant to investigate where is the balance point between these two types of measures in a cost/benefit perspective for different local conditions and categories of existing buildings.

It is pertinent to identify the optimal range of “minimization of demand” and “generation of renewable energy” measures, i.e., **level a** and **level b** measures, according to Figure 1, in a cost/benefit perspective. The main question is to understand how far it is possible to go with energy conservation and efficiency measures (initially often less expensive measures) and from which point the carbon emission reduction measures become more economical taking into account the local context. It is permissible that, in certain contexts, the energy conservation and efficiency measures do not represent an added value in relation to energy production, in which case you use only the latter.

Beyond the energy efficiency concept, the renovation process must also focus on the overall added value achieved, which means also identifying global quality improvement, economic impact of the intervention, operating cost reductions and some co-benefits like comfort improvement (thermal, natural lighting, indoor air quality, acoustics, functionality, extra area achieved, etc.), increased value of the building and fewer problems related to building physics.

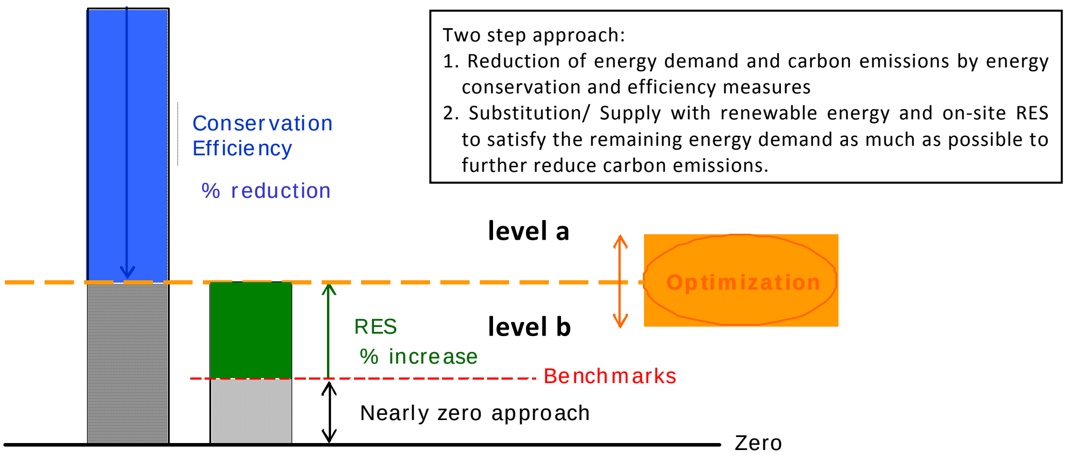

Figure 1 - Energy and carbon emissions optimized building renovation concept [Geier S. & Ott W.]

Another relevant point for this analysis is the determination of the cost optimal levels for the building renovation which implies, in first hand, the definition of the reference buildings that characterize the existing building stock and the definition of packages of renovation measures applicable to the reference buildings. These packages result from different combinations of compatible energy efficiency and energy supply measures to be applied to a building, e.g. the application of low energy windows, thermal insulation, condensing boiler and a solar thermal system. All combinations of commonly used and advanced measures should be submitted to a calculation of their energy performance and cost over their life cycle, which allows determining the economic optimum from those packages that range from compliance with current regulations and best practices to combinations that realise nearly zero-energy buildings [BPIE, 2010].

The reference buildings should be representative of groups with common and similar properties like age, type of use, size, climate conditions, weather exposure or orientation, so the results of the cost optimal analyses can be largely replicated. The packages of measures must take into account compatible technologies related to the building envelope (reduce heat transmission and improve air tightness), space heating, domestic hot water, ventilation systems, cooling, lighting, building automation and control, as well as other building-related measures with impact on thermal performance [Boermans, T., Bettgenhauser, K., et al., 2011].

III. CONSTRAINTS AND OPPORTUNITIES

The practical implementation of the nearly zero emissions and energy concept in existing buildings implies deep changes of current practices and a different approach to the problem as well as new and effective renovation techniques where, despite relevant developments, innovation is still needed.

At the level of the stakeholders it is crucial to understand what owners and promoters want and value and are wiling to invest on. Factors like the reduction of energy consumption, the reduction of carbon emissions, the after renovation operating costs, the economic impact, the technical difficulties, the user's disturbance and the overall comfort achieved, are probably the most common reasons taken into consideration by owners and promoters when evaluating the opportunity of a rehabilitation process. However, it is necessary to identify and quantify as much as possible, the most valued parameters by each one of the performers, identify their preferences and define an overall criteria for rating the quality of the rehabilitation process.

At the technical level, relevant case-studies, available or emerging efficient technologies and best practices must be inventoried. These must be analyzed and enhanced whenever possible and studied the possibility of replication in different circumstances. It is also necessary to understand why some solutions are effective and others not, even having potential, when they can or cannot work and why and why some solutions have good acceptance and others not, even when having a good performance.

Among the most promising techniques are some emerging insulation materials like aerogel, multiple-layer insulation, transparent insulation materials, gas-filled panels, and vacuum insulation, as well as new traditional and pre-fabricated envelope solutions and PCM's. In the area of the high energy efficient building equipments we have the lighting sources, the heating sources and the ventilation systems, where some of the most relevant systems are low energy lighting, passive lighting sources, electrochomistic materials, solar thermal, biomass, heat pumps, combined heat and power, district heating, thermal storage, natural ventilation and mechanical ventilation with heat recovery, etc. [Xing, Y., Hewitt, N., et al., 2011]. At the last step towards zero carbon renovation, there is a big potential of micro-generation technologies, such as wind, solar, PV panels, and hydro, either commercially available or at an advanced stage of development allowing integration of renewables at building and probably at community level, which must be fully potentiated with the use of building energy and indoor environment management and control systems (BEMS).

IV. MEANS

Taking into account the problems identified, the International Energy Agency established an Implementing Agreement within the Energy Conservation in Buildings and Community Systems (ECBCS) Program to undertake research and provide an international focus on Cost Effective Energy and Carbon Emissions Optimization in Building Renovation (ECBCS Annex 56). This is an ongoing project (2010-2015) that aims at developing a new methodology, as the basis for future standards, to enable cost effective renovation of existing buildings while optimizing energy consumption and carbon emissions reduction. At the end of the project it is expected to have a flexible methodology, to be used by interested private entities and agencies for their renovation decisions as well as by governmental agencies for the definition of regulations and their implementation, able of establishing cost optimized targets for energy consumption and carbon emissions in building renovation, of clarifying the relationship between the emission and the energy targets and their eventual hierarchy and of determining cost effective combinations of energy efficiency measures and carbon emissions reduction measures. It is also expected to have a renovation guide book based on cost effective solutions and on an optimal value concept supported by flexible tools.

Although this is a global problem, this project will be mainly focused on residential buildings, both single and multifamily houses once these account for 75% of the total stock in Europe and were, in 2009, responsible for 68% of the total final energy use in buildings [BPIE, 2011], comprising yet a less heterogeneous sector compared to the non-residential sector, which suggests a higher potential for improvement.

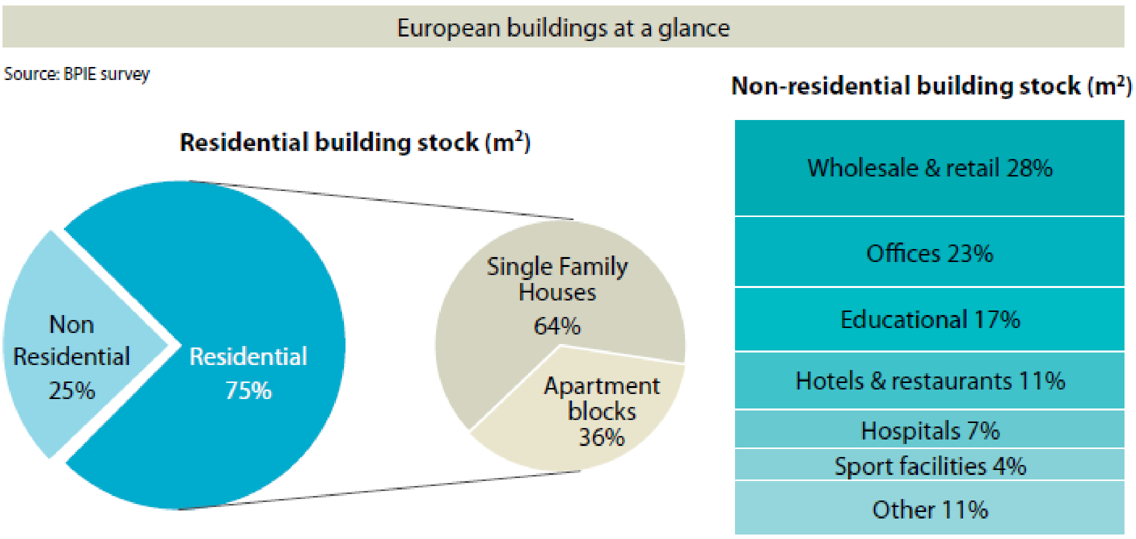

Figure 2- European building stock [Buildings Performance Institute Europe]

Non-residential sector comprises a more complex and heterogeneous sector where the wholesale and retail buildings are the largest portion with 28% of the building area while office buildings are the second biggest category with 23%. Variations in usage pattern, energy intensity, and construction techniques are some of the factors adding complexity at the sector. Nevertheless, some other buildings like simple office buildings without complex HVAC systems will also be presented as case-studies in this project whenever relevant and useful information can be extracted from them and these cases will also be used to prove the applicability of the developed methodology and tools to other buildings' categories in order to increase the variety of solutions and innovations analysed and to promote public awareness.

The work to be done under this project will consist in defining the best renovation strategies in a cost-effective perspective for existing buildings of different categories, typologies, age, construction or building characteristics, architectonic restrictions, use patterns, different climates (including buildings with heating and/or cooling needs), etc..

V. CONCLUSIONS

Although zero energy buildings concept does not yet have a universal definition, the principle of a hierarchical approach that values energy conservation and efficiency, which implies major investment on the envelope and in building systems, as well as in the use of onsite renewables and offsite low carbon supplies, is well established worldwide as a path for the built environment to reduce carbon emissions.

The large scale renovation of existing buildings in a nearly-zero emissions and cost-effective perspective, with the integration of renewable energy and innovative technologies and systems, is crucial for the international commitments to reduce carbon emission and climate change mitigation. However, the hierarchy of this two step approach, clear for new buildings, can be questionable for existing buildings. Due to the numerous constraints of these buildings, the most cost-effective renovation solution is many times a combination of energy efficiency measures and use of onsite produced renewable energy dependent of the local/regional context. The determination of cost optimal levels for the building renovation implies identifying different packages of energy performance measures that combine conservation and efficiency measures with generation of renewable energy, and compare them in terms of their energy and financial performance over its life cycle.

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