Benefits of energy related building renovation in residents comfort and well-being – Vila d'Este case study

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ABSTRACT

The relevance of the building sector in the global energy use as well as in the global carbon emissions makes the improvement of the overall energy performance of existing buildings an important part of the actions to mitigate climate changes. Regardless of this potential, large scale building renovation has been found hard to trigger, with present standards mainly focused on new buildings, not responding effectively to the technical, functional and economic constraints of the existing ones. One of the common problems in the assessment of building renovation scenarios is that only energy savings and costs are normally considered, despite the fact that the investment on energy efficiency yield several benefits beyond the value of saved energy (the so-called co-benefits).

To demonstrate and highlight the relevance of co-benefits achieved in the renovation process, a Portuguese neighbourhood with nearly 17.000 inhabitants that has been recently renovated is analysed in search for evidences of the existence of these co-benefits and their relevance. Indoor temperature, humidity and noise insulation were monitored and a survey to the residents was carried out. Results clear indicate the achievement of co-benefits at the building level such as increased user comfort and reduced problems with building physics (mould and water infiltrations), but also the elimination of the feeling of gentrification by outside people to the neighbourhood. The analysis demonstrates that the decision making process can't only be based on investment costs and energy savings, being necessary that owners, investors, promoters, but also policy makers adapt their reasoning to include these additional benefits.

KEYWORDS Building renovation, Energy efficiency, Co-benefits, Thermal comfort

INTRODUCTION

In Europe, buildings are responsible for 40% of the final energy consumption and 32% of carbon emission (Boermans, Hermelink, Schimschar, Grozinger, & Offermann, 2011) making them an important target in the efforts regarding mitigation of the climate changes. Energy savings through the renovation of existing buildings is one of the most effective options to reduce the CO_2 emissions and also improve energy security (European Commission, 2011), leading to an increasing focus to this sector from European Commission.

To promote energy efficiency in buildings and long term renovation strategies for the buildings stock, in 2010, the European Commission revised the Directive on the energy performance of buildings (EPBD) (European Parliament and the Council of the European Parliament, 2010), setting numerous requirements including energy performance requirements for buildings elements, the cost optimal level methodology for the evaluation of existing requirements and established that new buildings have to be nearly zero energy, after 2020.

The EBPD promotes a life cycle approach, but only considers the energy savings and costs, which are usually the benefits valued by the investor, undervaluing the full impact and value of building renovation from the perspective of the user and the society. In fact, when the renovation is focused in the indoor climate issues and energy consumption reduction, the renovation of the existing building stock may bring a range of co-benefits beyond financial aspects, for users, society and the environment (Urge-Vorsatz D, Novikova A, Sharmina M., 2009). To take full advantage of all the renovation benefits, it is important, not only to use a life cycle approach when analysing the renovation scenarios but additionally consider the co-benefits resulting from the renovation measures.

In this context, the lack of know-how and information on the additional benefits of the energy related building renovation and financial difficulties, are responsible for many missed opportunities to improve comfort conditions and energy performance of the existing building stock. In fact, building renovation measures improving the energy performance of buildings usually trigger benefits to the residents such as increased comfort, reduced problems related to the building physics, improved air quality or reduced exposure to energy price fluctuations. These benefits improve the building quality and the residents' well-being and presents economic benefits beyond the reductions of the energy bill.

The added value of energy related renovation measures for a certain building refers to the difference in the market value of this building before and after the improvement of its energy performance and results from the valuation from the market of the future energy related costs and of the other resulting benefits (co-benefits). From this, the inclusion of the co-benefits results crucial for decision makers involved in these projects. Besides these decision makers, also policy makers have to consider the impacts of policies and actions promoting the renovation of the existing building stock in several areas of the policy action such as health, employment, energy security or climate change (Organisation for Economic Co-operation and Development, 2003; International Energy Agency, 2014).

Considering the described background and because existing standards do not take into account these co-benefits, it is important to analyse examples of renovated buildings in search for links between the implemented renovation measures and the co-benefits resulting from the renovation process. These analyses may allow highlighting the relevance of the co-benefits and provide guidance on how to consider them in the decision making process, with the main goals of guiding the policy makers in the energy related policies and assist the owners and promoters in the choice of the best renovation measures, considering the overall added value.

For policy makers the societal perspective is more relevant, once it highlights the effects of the building energy renovation in areas of the political action dealing with health issues, economy, employment, energy security and climate change mitigation as examples (Goodacre, C, Sharples S. & Smith P., 2001). For the owners and promoters the private perspective is more relevant and it considers the benefits at the building level such as the increase of comfort, less problems with the buildings physics and improved aesthetics.

To demonstrate the role of co-benefits related with the user comfort and well-being in the definition of the added value from energy related renovation of existing buildings, and using an ongoing renovation in a Portuguese neighbourhood, indoor temperature, humidity and noise insulation were monitored in two of the buildings, after the renovation and a survey to the residents was carried out. This monitoring gives clues on the potential of energy related renovation measures to improve indoor comfort and air quality and how important is to take it into consideration in the decision-making process. The neighbourhood was built in the seventies and consists in 109 multi story buildings for low income households, with a total of 2085 dwellings and 17000 inhabitants and presented significant pathologies including humidity and mould in almost every building, which led to the decision of renovate the complex.

METHODS

The co-benefits are hard to quantify and most of all, very difficult to include in a traditional cost-benefit analysis. Their relevance depends on the context of the building and also on specific characteristics and interest of the evaluator. Therefore, the first step was the development of a survey, in order to understand people's perception of the intervention results. The survey included questions related to the co-benefits identified as arising from a renovation process where the energy performance of the building is improved. The survey tried to establish a connection between the co-benefits and the specific renovation measures that have been applied in the renovation.

Based on the peoples answer, it was possible to identify two co-benefits that can be measured, namely the improvement of thermal and acoustic comfort. In order to verify the improvement of the thermal comfort, the indoor temperatures and humidity were monitored. For the acoustic comfort, the airborne sound reduction index for the façade was measured.

For that, two apartments considered as representative of the average conditions, were selected. The measurements were carried out during the 18th and the 24th of November of 2015. Portable probes were placed in the dwellings, more specific in the living room, kitchen and bedroom. These spaces were chosen because normally they present higher thermal load (given the rates of occupancy). The selected probes have a data logger and USB transmitter. In each division where the monitoring was carried out, the probes were placed at the distance of 1m from the centre of the walls. The same distance was used for the independent sensors in accordance with ISO 7730:2005.

For the measurements of the acoustic comfort, the procedure was based on Decree-Law nº 96/2008, EN ISO 140:5, EN ISO 354:2007 and ISO 717-1. The measurements were made for a frequency band of 1/3 of octave, between 100Hz and 3150Hz. Using the $D_{2m,nT}$ value it is possible to compare the reference curve with the values that were measured. The comparison of the curves was carried out with variations of 1dB and it is considered satisfied when the sum of the deviations is as higher as possible, but under or equal to 32dB. The airborne sound reduction index ($D_{2m,nT,w}$) is determined when the ordinate of the reference curve corresponds to a frequency of 500Hz. The equipment used consisted in a sonometer, a microphone, a sound calibrator and a noise generator. The back noise was considered to be 6dB. The origin of the sound was placed outside the buildings and all the other equipment inside. In accordance with NP EN ISO 354, it was determined the reverberation time. The internal noise was also measured to make sure it does not interfere significantly in the measurements. All the monitored values were then compared to the regulations in order to check their compliance.

Building characterization and main intervention

The monitored apartments belong to a multifamily building with 8 floors and two apartments in each floor. It was built in the 1980´s and it is part of a neighbourhood located in Porto, called Vila d'Este, which was built for families with low income. The neighbourhood was in bad conditions due to economic and social constrains. In that sense, the local municipality, decided to carry out an intervention using European funds, to solve some of the buildings' physical problems and promote the integration of the neighbourhood in the city. Most of the pathologies were mould, cracks, infiltration and degradation of the neighbourhoods' reputation. The next figure shows a part of neighbourhood before and after the intervention.


a) b)

Figure 1 Buildings general aspect. a) Before the intervention, b) After

The buildings have single brick walls with no insulation and fibrocement plates in the roof also without insulation. The intervention gave priority to the roofs and facades. It was added insulation in the roofs and ETICS (External thermal insulation composite system) in the facades. In buildings facing south it was installed shading devices, such as overhangs, to help preventing overheat during the summer. The windows were not replaced. Only maintenance work was carried out on them.

RESULTS

After the monitoring process the measured values were recorded and analysed. Figure 1 show the results for the measurement of the indoor temperature for the first apartment (Apartment #1). The figure has three lines, one related to living room, other to the kitchen and another to bedrooms. In apartment #1, temperatures are very stable during most of the time and especially in the kitchen, where normally there are considerable internal gains during the cooking period. The bedrooms present the higher temperature during most of the time reaching 21ºC. The lowest temperature was around 19ºC. In average the temperature in the bedroom was 20.1ºC, 19.8ºC in the kitchen and 19.8ºC in the living room. In this apartment, during the monitoring period, the temperature was always above 18ºC in every space.

Figure 2 shows the results for apartment #2. In apartment #2, the gap between the space temperatures is smaller and they behave almost the same way. In this apartment the living room has the higher temperature during most of the time, ranging between 22ºC and 20ºC. The average temperatures in the three monitored spaces were 20.3ºC for the living room, 20.3ºC in the kitchen and 20.1 in the bedrooms. In the first days of the monitoring, the indoor temperatures were above 20ºC in every space and after the fourth day, they decreased slightly but stabilized above the 18ºC in every space.

In both apartments the average temperatures are above 18ºC which is the temperatures considered as comfort temperature in the Portuguese thermal regulation, for the winter. During the monitoring period the exterior temperatures were between 10ºC and 19ºC (IPMA, 2016). Despite the lower exterior temperatures during the night the indoor temperature didn’t suffer significant changes and there was no need of using any active system for heating.

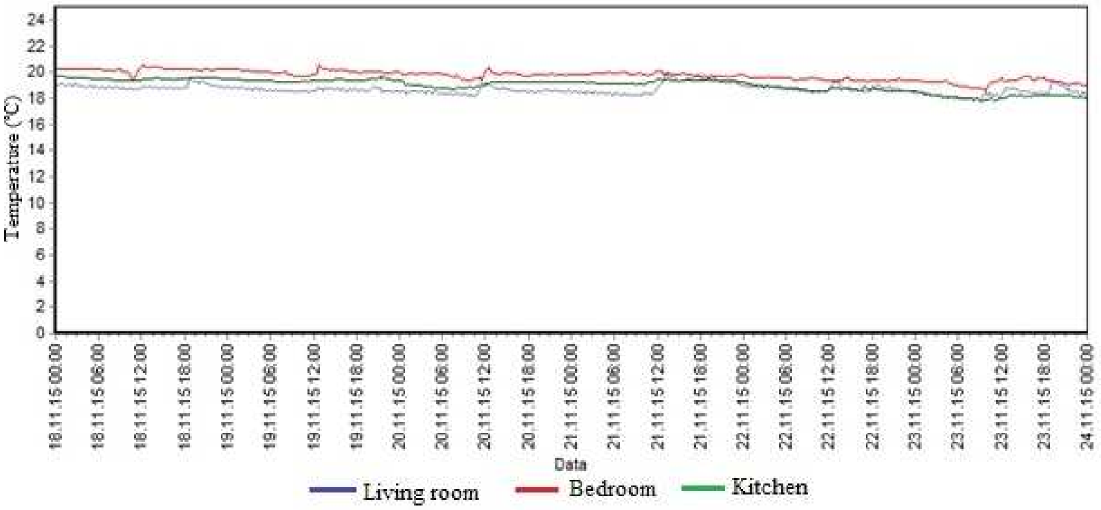

Figure 2 Results of the temperature in the apartment #1

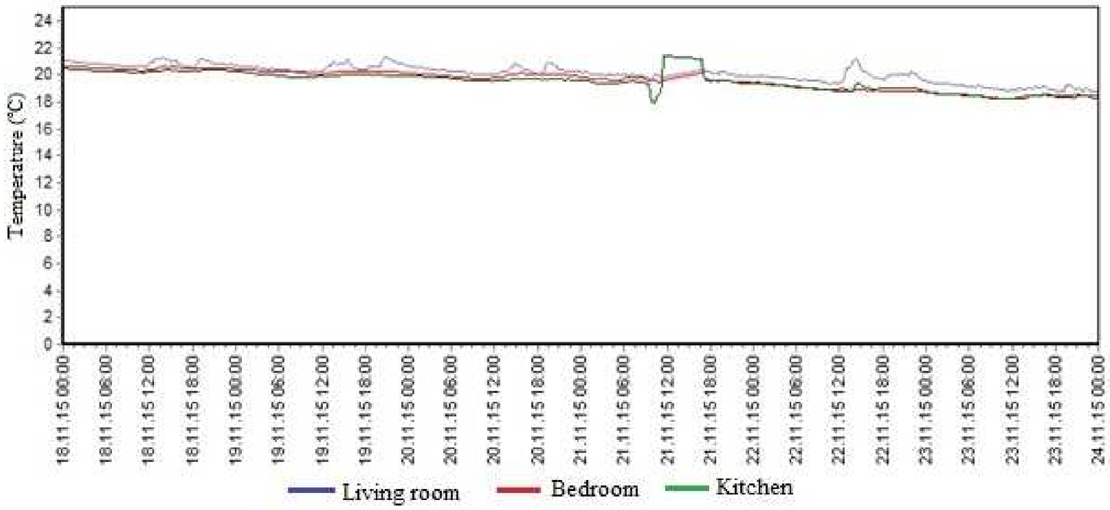

Figure 3 Results of temperature monitoring in apartment #2

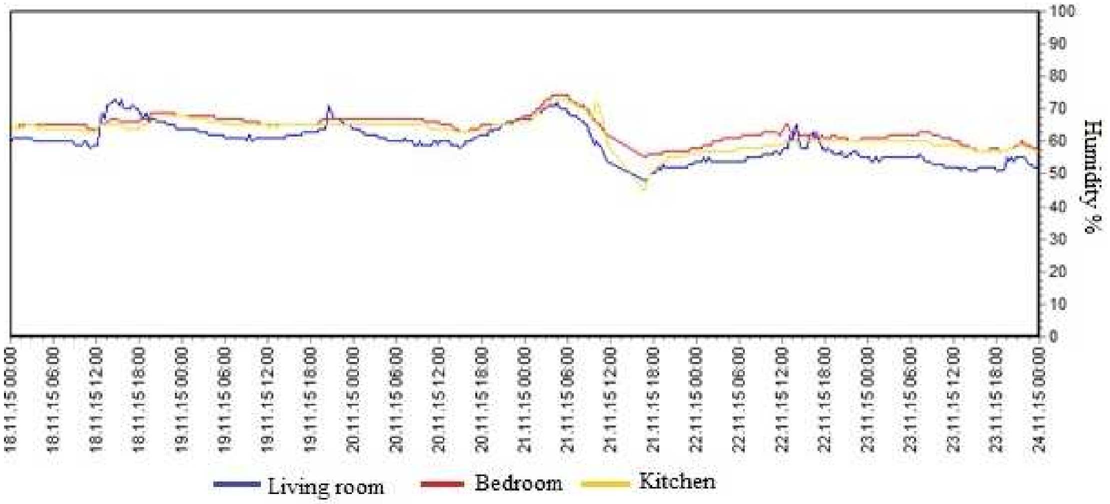

Figure 4 Humidity rate in the apartment #1

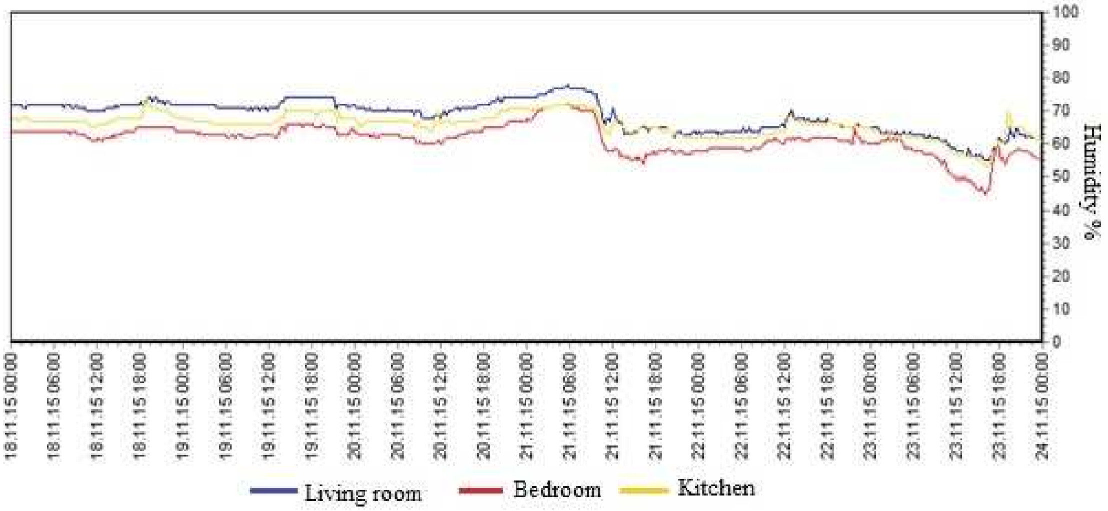

Figure 5 Humidity rate in the apartment #2

Concerning the humidity, in both apartments the rates were between 45% and 80%. Figures 4 and 5 present the results for the humidity rates in both apartments. In apartment #1 the values present some variations especially in the living room. The kitchen and bedroom present fewer fluctuations. The average values are between 57% in the living room and 62% in the bedroom. In apartment #2 the humidity in the three monitored spaces have very similar behavior, nevertheless the living room presents higher rates of air humidity and the bedroom presents lower values, during most of the time. The average values are between 64% in the kitchen and 72% in the living room. The regulation establishes an average humidity rate of 50%. The measured values are above this value, but do not reach critical values.

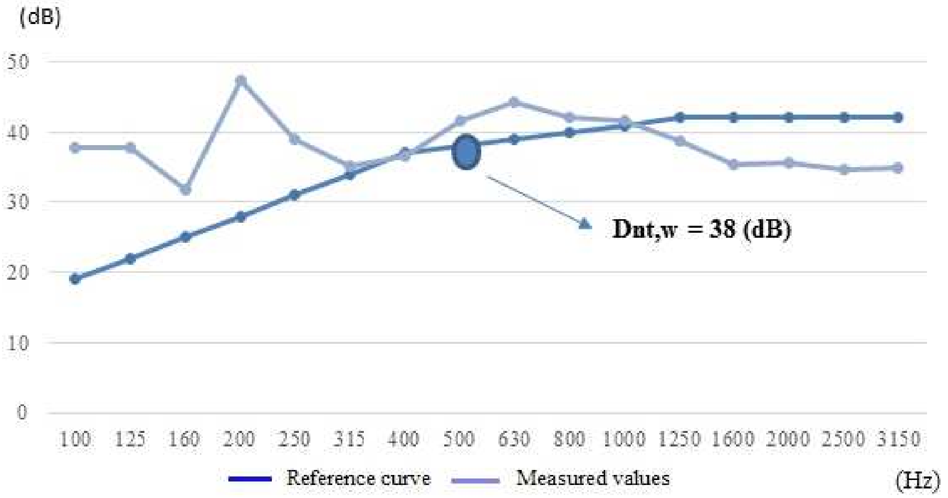

Figure 6 Calculation of the airborne sound reduction index in apartment #2

The acoustic conditions were only monitored in apartment #2. Figure 6 shows the results of the calculation of airborne sound reduction index. In the figure there are two curves, the reference and the measured values.

According to the RRAE (Portuguese regulation for the acoustic performance of buildings), article nº11, the $D_{2m,nT,w} \geq 28$ dB is considered the minimum value for the airborne reduction index in sensitive zones. The spaces within a residential buildings are included in sensitive zones Therefore, the measured value of $D_{2m,nT,w}$ of 38 dB complies with that definition with a certain margin (Portugal, 2008), once the measured value of the airborne sound reduction index is 10 dB higher than the minimum established by the regulation for residential spaces.

DISCUSSIONS

The renovation measure which affected the majority of the apartments was the addition of insulation to the exterior walls. The insulation of the roof affects directly the top apartments, not having influence on the others. In this sense and as proven by the measurements carried out in filed, when insulation is added to the building's exterior walls and even by the end of November, the indoor temperatures present small fluctuations and guarantee the comfort temperatures predicted by the Portuguese thermal regulation of at least 18ºC, without the use of any active heating system. The air humidity is slightly above, but it is not reported as problem. More effective ventilation may stabilize these values. The variations occur during a small period of time.

The acoustic comfort is also assured once the measured values comply with the relations limits, despite not having altered the windows.

Besides the improvement of the thermal and acoustic comfort, there are other co-benefits that are not to be measured by instruments, but also arise from this type of interventions and are mentioned by the users. Some are visible, such as the reduction of the problems related to building physics, namely humidity patches or cracks and aesthetics/architectural integration. Others are not so visible and depend on user's opinion or behavior.

For these last co-benefits the survey was essential. Through the surveys it was confirmed that besides the aesthetics, the intervention also helped to increase pride/prestige in the neighborhood. These two items were highlighted as very positive outcomes of this intervention. Concerning the reduction of the exposure to energy price fluctuations the renovation intervention did not have a major effect, once most users do have the habit of heating/cooling the spaces and have special electricity rates given their economic condition.

Safety was never considered to be an issue in the neighborhood, but the improvement of the buildings aesthetics and surrounding areas creates a different impact on the people who do not know the reality of the neighborhood. Before the renovation this neighborhoods was seen as poor and decadent. After the renovation, there is a sense of normality just like any other neighborhood.

CONCLUSIONS

The renovation of the existing building stock represents a huge potential in actions to mitigate climate change, not only by the improvement of the overall energy performance of the built environment, but also by the reduction of resource depletion and minimization of waste production related with new construction. Nevertheless, this potential hasn't been fully explored. One of the reasons is that the evaluation of building renovation normally considers only the energy savings and costs, disregarding other relevant benefits, underestimating the full value of improvement and re-use of buildings at several levels of the economy.

The renovation of Vila d'Este neighborhood, although not very ambitious in the depth of the intervention, provides an example of the relevant benefits that can be felt at the building level (like increased user comfort, elimination of problems with building physics like mold and water infiltrations, improved aesthetics), but also at the neighborhood level with the elimination of the feeling of gentrification by outside people to the neighborhood. Regarding the benefits at the building level, it was possible to confirm the thermal and acoustic comfort levels that have been achieved, which allow having internal temperatures very stable and inside the comfort levels without the use of heating systems, during the monitoring period.

These results show that in energy related building renovation, the decision making process should not only be based on investment costs and future reduced costs on energy bills and building operation, but also on other benefits not related with energy and costs. Private owners, investors and promoters, have to consider this holistic perspective in order to maximize the willingness to pay from the customer whether in a sale process or in a rental one. Also policy makers, in the preparation of regulations and subsidy programs, must be aware of how energy policies not only lead to energy savings or carbon emissions reductions but also create impacts on a broad range of areas of the political action, from environmental aspects, such as those related to pollution or climate change, to economic aspects, as employment or economic growth, and social aspects, as health or fuel poverty.

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