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Development of energy renovation packages for the Danish residential sector

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Abstract

The work presented in this paper is developed as a part of the Horizon 2020 EU project REFURB. The number of deep energy retrofits is falling behind the EU ambitious targets. The REFURB project aims at finding technical and nontechnical solutions that match the demand and supply side of the residential building renovation market. Due to the multiple significant differences at the national level, compelling offers are developed specifically for each country participant. This paper elaborates only on the Danish approach. The Danish approach to create compelling offers for pre-selected homeowner target groups is based on (I) selection of dwelling segment with high impact and energy saving potential, (II) sequenced approach in creating renovation package solutions, (III) compelling offer to be proposed with specific timing. This paper focuses mainly on the second listed component, namely, development of the renovation package solutions. The paper only briefly highlights the selection of dwelling segment and does not present the creation of compelling offer due to the length of the paper. Initially, developed renovation packages are optimized purely focusing on the least-cost optimal, theoretical, energy savings. As a result, very rational packages were developed that were not met with acceptance from the building sector stakeholders. After several surveys and meetings with renovation market stakeholders such as building owners, energy renovation contractors, financial institutions, and energy consultants, the initial renovation packages were redefined in order to take account for factors such as securing investment in the renovated real estate, comfort, architectural aesthetic, and "low hanging fruit" energy saving solutions. Finally, ten different customized renovation packages were developed ranging between up to 7.500 and 62.000 € and bringing theoretical primary energy savings between 30 and up to 80%.

Keywords: energy renovation; energy conservation; renovation packages; compelling offer

1. Introduction

The European Commission has set strict targets in relation to CO_2 and energy reduction by 2020, 2030 and 2050 [1]. The upcoming goal for 2020 with which member states must comply is to reach 20% reduction of CO_2 compared to levels in 1990. The building sector is responsible for 36% of the total CO_2 emissions in the European Union, which mainly comes from the existing building stock [2]. Because of that, the European Union is more and more interested in stimulating the renovation of existing buildings so they comply with current standards for energy use and efficiency. On the local level, some member states offer financial incentives to homeowners to renovate their home. Similarly larger cross-border projects as REFURB [3] aim to find a more holistic approach to support and encourage the renovation of selected building types.

As indicated in [4] energy saving in the majority of the cases is not the key factor that drives building owners to renovate their building. The motivation to execute renovation is much more complex and includes several aspects such as improvement of indoor comfort, and family economy to secure investment, esthetics, energy savings, simple urge to replace old and worn element with the new one, and single events such as new child in the family or children moving out from their family home.

What is more, majority of the homeowners wish to receive a renovation that, to some extent, is tailored to their specific wishes. On the other hand, they lack or have just limited overview of the sequence and scope of necessary renovation tasks to gain synergy in the entire renovation project. Home owners often experience the renovation process as very turbulent with many unexpected events, more costly than initially assumed and lacking quality assurance. This combined with a blurry expectation of the outcome with respect to return on investment, property value, and improved comfort lead many to drop their projects.

Solving barriers and deciding on what the best case is for the available investments is a challenge both for homeowners themselves, but also for the industry. Recent studies made by [5] suggest that adopting a tailored package renovation approach provides greater possibilities for reaching deep renovation, especially when separate technical solutions are in good synergy. The more and deeper renovations are reached, the greater the reduction of CO_2 and energy within the building sector.

New business models specifically developed for renovation including renovation packages are also emerging throughout northern Europe [6]. In the study by [6], assessment of such business models concluded that even though the business potential is big, it is still hard to run companies sustainably, based on such business model. According to the authors this is due to the barriers such as trustworthiness between customer and company, policy instruments for the initial phases of the process, greater support for renovations that strive for complete building solutions versus single component solutions, etc.

This paper presents the methodology to develop renovation packages for a single-family house built in the 1960-1976 period. It should be kept in mind that the presented packages are specifically tailored to the need of the selected case building; although these are a good representation of what can be expected from similar buildings from the same period. Moreover, methodology can be extruded to other building topologies.

A REFURB renovation package is defined in [7] as:

1) An easy-to-understand commercial offer to an end-user, written in non-technical language, which satisfies his/her requirements for comfortable living but at a higher energy-efficiency of his/her dwelling.

2) An offer comprising the optimum combination of solutions/technologies to be installed in the most logical sequence, tailored to the type of dwelling, the state of the building, the geography in which the dwelling is located, and socio-economic parameters.

3) An offer that unburdens the end-user, so he/she is assured of an agreed higher energy efficiency without worrying about individual technology choices.

2. Methodology

2.1. Selection of dwelling segment

In the project each participating country has selected one or more dwelling segments representing a large share of the building stock with significant energy saving potential. In Denmark, single-family houses constructed in the period 1960-1976 are selected. These houses represent approximately 25% of the residential sector in Denmark [8]. They have typically energy label ranging from G – for houses that were not energy modernized since their erection – and up to energy label C – for houses with some improvements undertaken. These buildings are often well located in the cities and are presently at the age when the first major renovation is likely to be required. Comparing to the present building legislation and compliances, these buildings perform rather poorly with regard to energy use and indoor climate. In the Danish scenario, two dweller types with high potential for energy renovation were identified: empty nesters (EN) and young families (YF). ENs are older couples whose children have recently moved out. This opens up for new possibilities for rearranging and energy renovating the home. Second target group is YF who just bought their first house and got children. They want to renovate/rearrange the old house to the new family needs and standards. They would often seek for better indoor environment.

2.2. Sequence approach – renovation package development

The renovation packages are addressed to homeowners that might have very different professional background, thus they should be made available, usable, and understandable to all targeted homeowners. Therefore, they should be presented in a non-technical manner and still include technical methodology and knowledge behind them [7].

The process of development of renovation packages was initially very rational and focused only on documentable energy saving criteria. Cost efficiency calculations are made with the purpose of sorting the proposed renovations and solutions in respect to investment cost, lifetime, and theoretical energy saving that could be documented through energy compliance calculation. The sorting was used to choose which technical solutions are going to be included in the packages and in which order. The priority was given to technologies with high cost efficiency, see Table 31 in [9]. The initial aim was to develop five packages with value starting from 25,000 € (shallow renovation up to 40% energy saving) up to 135,000 € (deep renovation up to 80% energy savings). To achieve synergies in the renovation, the cost optimum methodology is applied alongside engineering considerations related to construction processes. For example, if the external wall is insulated, then the insulation of the foundation and change of windows is prioritized as activities would be happening in the same area of the building.

The method for selection of a renovation package is as follows:

1) Select the most cost-efficient option as presented in Table 31 [9]
2) Check the investment cost of the selected technology in Table 32 [9]
3) Compare the cost of the technologies with the available amount of funds in the package.

Investment cost of each solution proposed is elaborated in detail in [9]. The calculation is performed for the typical case house constructed in 1973 that is presented in detail in [9]. Fig. 1 presents the amount of energy saved by implementing each of the considered technical solutions. For the current calculation, lifetime of the considered technologies are taken from [10] Annex 6. Cost of proposed technical solutions is calculated using Danish Molio price database for renovation projects.

Cost efficiency is calculated by (1) and (2). Fig. 1 presents the example results from the calculation for all technologies and for the case house.

$$Annual\ investment\ cost = \frac{Investment\ cost}{Lifetime} \left[\frac{€}{year}\right] \qquad (1)$$

$$Cost\ Efficiency = \frac{Investment\ cost\ per\ year}{Saved\ energy} \left[\frac{€}{year}\ per\ saved\ \frac{kWh}{m^2}\ per\ year\right] \qquad (2)$$

Fig. 1 shows the saved energy obtained by each ‘one-at-a-time’ renovation as a function of its cost efficiency. As seen in Fig. 1, some of the renovated elements have more than one cost. This is the result of the different technical solutions provided for the same energy improvement but with different costs.

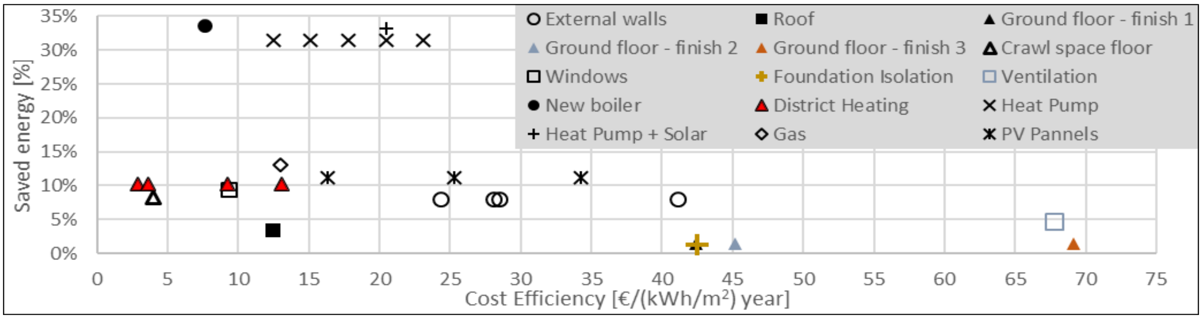

Fig. 1. Saved energy of each technology as a function of cost efficiency.

From this point on, there are few possible outcomes depending on the available funds and investment cost of the technology. Those are as follows:

1) If the cost of the technology is lower than the available funds in the package, new iteration to select additional technology can begin (as described above).
2) If the cost of the technology is equal or ± 15 % of the available funds for the representative package, the package is fulfilled and formation of the next package can begin.
3) If the cost of the technology is greater than the available funds of the package, the next most cost-effective technology is chosen and its investment cost is compared to the available funds in the package. This is done as some of the technologies may have low cost efficiency, but also low investment cost.

The initial renovation packages were subjected to a number of discussions between the Danish partners in the project. Furthermore, a stakeholder meeting with the renovation/construction industry representatives was held in order to receive feedback regarding the different renovation concepts. The following bullet points summarize these feedbacks:

- Even though gas boilers are not "green", these were included in the packages or stages when district heating (DH) was not an option. This is done on the basis that a gas boiler can be considered a transition solution for the period until 2050, and then exchanged with more sustainable option. Furthermore it was yet unknown if and to what extent the biogas would replace gas.
- Heat pump is proposed for those without DH connection and with sufficient budget for this expanse.
- At that stage, there was no distinction made between houses with and without the possibility to connect to DH. It was assumed that house has its own source of heat, e.g. boiler.
- Healthy indoor climate was listed as important parameter highly valued especially by YFs. Therefore, mechanical ventilation is prioritized higher than some more cost-effective measures.

In the consequent revision rounds several more issues were identified. These are listed below:

- Very promising low-hanging fruit solutions; for example, changing lighting to LED. Installation of radiator thermostats were omitted at the beginning since they are either not included in the compliance calculation or they require specific knowledge of the house. Supply side stakeholders indicated that those low-hanging fruits are first to be welcomed by the building owners due to low complexity of the job and relatively low cost. These low-hanging fruits are included in the final packages, presented in 3. Results.
- Despite the uncertainty of the price for different DH locations, it is integrated as a technical solution for renovation. As DH in Denmark is considered a green solution with primary energy factors lower than 1, it would be considered as one of the first steps in the renovation process. Given that in suburban areas DH network is not available, but in urban areas it usually is, there are two scenarios developed, one with and one without DH.
- Windows were moved up on the list of priorities. This decision was made as windows are fairly easy to replace. Moreover, they contribute not only to energy reduction, but also to better comfort and to architectural value of the building, significantly increasing the value of the house.

- Gas boiler was not included as a heat source possibility even though it is still allowed to install one. The reason for that is that Denmark is presently in the transition period towards free fossil energy generation and gas boiler would be only a temporary solution. Instead, a heat pump was proposed.
- Insulation of the external wall (except case with cavity wall insulation) was removed from the packages. The insulation of the external wall to nZEB level would be very costly due to the fact that in many cases requires demolition of existing external façade and its replacement with the new highly insulating solution. Although quite positive from an energy saving point of view, this activity was considered drastic and, therefore, could cause many house owners to drop their renovation plans.
- Including house owners in the renovation "journey" became one of the key identified aspects to an increased number of energy renovation projects. The financial factor is recognized as one of the major barriers to start energy renovation. Therefore, the price of the first renovation package is decreased to 7,500 € for a house without DH connection option and to 12,500 € for a house with DH connection option.

Creation of renovation packages in total included five major revisions. The presented conclusions were implemented afterwards in the final version of the renovation packages.

3. Results

This section presents the final 10 renovation packages (5 for DH connected and 5 for buildings without DH). Those were developed taking into account listed in previous chapter issues. Fig. 3 presents the final packages.

	Comfort	Arch. value	Pack. 1	Pack. 2	Pack. 3	Pack. 4	Pack. 5
LED light			✓	✓	✓	✓	A la carte
Pipe insulation			✓	✓	✓	✓	
New circulation pump			✓	✓	✓	✓	
Radiator thermostats	↑		✓	✓	✓	✓	
District heating connection			✓	✓	✓	✓	
Roof insulation			✓	✓	✓	✓	
Wall cavity insulation	↑		✓	✓	✓	✓	
New windows	↑	↑		✓	✓	✓	
Mechanical Ventilation	↑			✓	✓	✓	
Floor above crawl basement insulation	↑			✓	✓	✓	
Heat pump with integrated storage					✓	✓	
Floor on the ground insulation	↑	↑			✓	✓	
18 m² PV cells						✓	
Smart heating control system	↑					✓	
Energy saving no district heating (up to)			15%	30%	70%	80%	
Energy saving with district heating (up to)			40%	45%	50%	70%	

Fig. 3 Final, renovation packages – with and without DH.

4. Discussion

Fig. 3 presents renovation packages with their recommended technical solutions towards nZEB. The content of the renovation packages is developed gradually, creating so called renovation steps. The package approach is expected to appeal more to YFs who would rather execute renovation and move in as fast as possible. The step approach is expected to appeal better to ENs who have more time and would rather gain trust in the process and gradually observe consequences of their choices.

As seen in Fig. 3, the energy saving potential for the proposed packages ranges between 15 % for the smallest package and up to 80% for the large package. What is more, for a house with DH connection the potential theoretical savings seem much more promising for the first two packages than in the case where the house has no option for DH connection. This is because the connection to DH is not too expensive and there is budget for that action starting from the smallest packages. Furthermore, energy saving refers to primary energy use, and in the

Danish context DH is rewarded with primary energy factor of 0.8. The situation changes for packages three and four as soon as there is budget to install a heat pump in the house without possibility of DH connection. A heat pump due to its competitive coefficient of performance (COP) is a feasible alternative to old boilers, which are used in the calculation as a reference. However, installation of a heat pump is costly and, therefore, is not recommended in the first packages. Moreover, installation of the heat pump is recommended first after completion of energy improvements to the house envelope. A decreased required energy for heating automatically results in savings related to purchase and installation of the smaller heat pump.

5. Conclusions

This section presents focal conclusions drawn throughout the process of developing the renovation packages:

1) Securing the renovation journey for the house owner is the key factor to decrease number of dropouts. It is believed that transparent process based on package solution is the right manner to communicate renovation scope and objectives. Packages, however, must be presented in nontechnical manner that is understandable to the majority of house owners.
2) Energy saving is not sufficient motivation for people to renovate. Rational scientific/economic approach oriented on energy savings has a low success rate since people base their decisions on other aspects such as comfort, securing healthy environment for the family, real estate value assurance, and architectural aesthetics.
3) Developed packages support the renovation process and should be considered as tools to gain the house owner's interest and awareness regarding energy renovation. However, they do not provide final tailored solutions. This paper presents methodology rather than ready solutions. These solutions should still be specified for a particular business model and with the assistance of an energy consultant.
4) Indoor climate has become a strong driver for energy retrofit in Denmark, and it is expected that in upcoming years it might be the key important driver for energy retrofit in buildings.

Acknowledgements

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