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BEST PRACTICES OF DEEP ENERGY RETROFIT BUILDING PROJECTS FROM AROUND THE WORLD

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Abstract

26 deep energy retrofit (DER) case studies has been collected under the IEA EBC Annex 61 project and documented using a common template. The objectives of this work were:

- *To show successful renovation projects as inspirations in order to motivate decision makers and stimulate the market.*
- *To support decision makers and experts with profound information for their future decisions.*
- *To learn experiences and lessons learned from these frontrunner projects.*
- *To the reach these goal the case studies have been analysed to create an overview of what energy measures have been implemented, the obtained energy savings, the reasons for and costs of renovation, the financing mechanisms and the co-benefits and experiences gathered.*

This outcome of this work has then been used in the project partner's development of Deep Energy Retrofit Technical and Business Guides.

Keywords - Deep Energy Retrofit, Case studies, Energy Use Intensity, Core technology bundles

1. Introduction

Many governments worldwide are setting more stringent targets for reduction of energy use in government/public buildings, i.e. to take the lead and show the right direction for a sustainable future. However, the funding and "know-how" (applied knowledge/experience) available for owner-directed energy retrofit projects have not kept pace with the new requirements. This is easily seen from the fact that typical retrofit projects reduction of energy use varies between 10 and 20%, while experiences from executed projects around the globe show that reductions can exceed 50% and that renovated buildings can cost-effectively achieve the Passive House standard or even approach net zero energy status (1,2,3). Therefore, there is a need for good examples of Deep Energy Retrofit (DER).

IEA ECB Annex 61 includes the collection, presentation and analysis of case studies demonstrating the positive impact of energy saving technologies in public building renovation. Over the past 2 years, this effort collected and analysed information on 26 case studies from Europe: Austria, Denmark, Estonia, Germany, Ireland, Latvia, Montenegro, The Netherlands, United Kingdom and the United States using a standardized template. The analysis covered:

- Energy saving strategies
- Energy savings/reduction levels
- Reasons for renovation/anyway measures
- Co-benefits
- Business models and funding sources
- Cost effectiveness
- Experiences/lessons learned

This paper presents the results of these analyses.

2. Results of the analyses carried out

The descriptions of the 26 collected case studies constitute well over 400 pages and thus the analyses were necessary to create an overview of this large amount of information. The analyses were carried out by reading through the collected descriptions and extracting the relevant information.

Energy saving strategies

The implemented energy saving strategies were grouped in 16 categories and an overview table was created. A red frame has been drawn around the marks that add to more than half the number of case studies (table 1).

From table 1 it appears that for the majority of DER cases an energy saving bundle of technologies may consist of technologies that improve the envelope (wall, roof, floor and windows), lighting, ventilation system, supply and/or distribution system. One case study – the office in Maryland, US has implemented 12 of the 16 technologies.

Energy savings/reduction levels

The obtained energy savings were plotted to show the total energy consumption before renovation, after renovation, the solar energy contribution to that and then the net energy consumption. Both the energy consumption before and after the renovation are measured values. Two plots were generated one of the public buildings – offices and schools and another of the dwellings or family houses, see Figure 1 and 2.

The tendency is the same in both plots: Generally, the energy efficiency renovation or Rational Use of Energy (RUE) brings the energy consumption remarkably down and then for those of the case studies, where a Renewable Energy System (RES) is installed the energy consumption is further reduced. Considerable energy savings were obtained. Average net energy savings for all 26 case studies were 66.4%.

Table 1 – Overview of implemented energy saving measures

>13

	Core bundles of technologies															
	Building Envelope						Lighting & Electrical		HVAC					Renewable energy systems		
	Wall insulation	Roof insulation	Floor insulation	New window/ door	Roof lights	Daylight Strategy/external shading	Efficiency lighting/control	BEMS	MVHR	New ventilation system	New heat–cooling supplier/distribution system	New heat supply: radiators, floor heating	Air source heat pump	Ground coupled heat pump	Solar thermal system	Photovoltaic panels
1. Social house Kapfenberg. AT	√	√	√	√					√		√				√	√
2. School Egedal. DK	√						√	√	√	√	√					√
3. OfficeVester Voldgade. DK	√			√		√	√		√		√			√	√	
4. Kindergarten Valga. EE	√	√	√			√	√		√		√				√	
5. Passivehaus LudMun. GE	√	√	√	√						√		√				√
6. Apartments Nûrnberg. GE	√	√	√	√					√		√				√	
7. Gym Ostildern. GE	√	√		√	√		√		√							
8. School BaWû. GE	√	√		√			√			√	√					√
9. School Osnabrueck. GE	√	√	√	√			√		√	√	√			√		
10. School Olbersdorf. GE	√	√	√	√	√	√	√			√				√		
11. Passivehaus Office Darmstadt. GE	√	√	√	√			√		√	√						
12. Town Hall- Baviera. GE	√	√	√	√	√		√		√		√					
13. Passivehaus High school NordWest. GE	√	√	√	√		√	√		√					√		√
14. Social housing Dún Laoghaire. IE	√	√	√	√					√		√					
15. Apartments.Riga. LV	√	√	√	√			√		√		√	√				
16. Primary school Plevlja. MON	√			√			√	√			√					
17. Student Dormitory Kontor. MON	√	√		√			√				√	√			√	
18. Shelter home. Leeuwarden. NL	√	√	√	√		√	√		√	√	√				√	
19. Mildmay Center London. UK		√	√	√		√	√		√	√				√	√	√
20. Federal building Grand Junction. USA	√	√			√		√			√	√	√		√		√
21. Office/Federal building Maryland. USA		√		√			√	√	√	√	√	√	√	√	√	√
22. Intelligence Community Maryland. USA	√	√	√	√		√	√		√	√					√	
23. Office. Seattle WA. USA				√		√	√		√				√			√
24. Beardmore Priest River. USA	√	√		√	√		√			√			√			
25. Office/Warehouse Indio. USA	√	√		√	√	√	√		√	√	√		√			√
26. Federal building Denver-Colorado. USA	√	√	√	√			√				√		√		√	

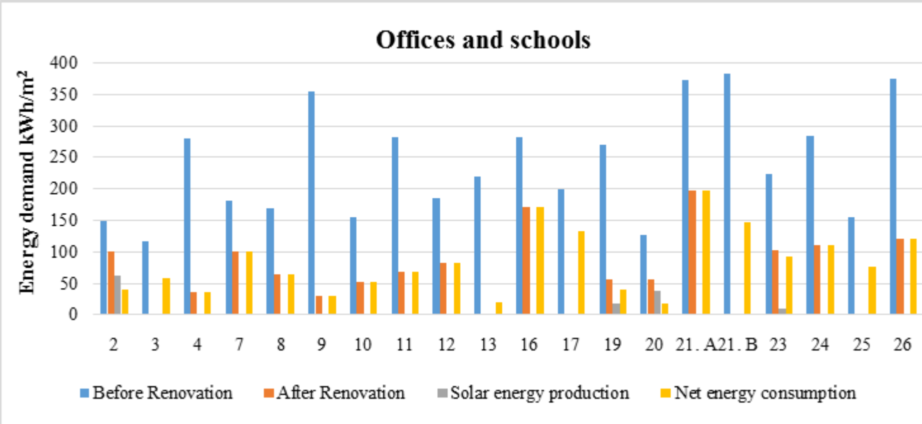

Figure 1 – Energy consumption before and after of the schools and offices

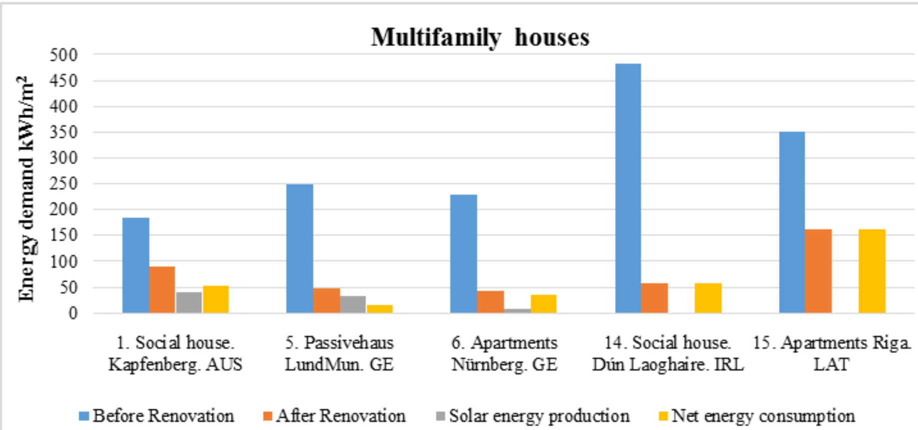

Figure 2 – Energy consumption before and after of the multifamily houses

Reasons for renovation

The reasons for renovation were categorized in two main groups: energy related and not energy related. Within the latter group case studies were distributed within these four main reasons:

- Poor architectural quality/appearance (35%)
- Historic preservation (15%)
- Maintenance of building envelope or interior – building worn down (88%)
- Change of layout of the occupied space / increase of floor area – repurposing of the building use (35%)

- Poor indoor working/living condition: Poor thermal comfort / low indoor temperatures in winter. High indoor temperatures in summer. Bad air condition in rooms. Poor daylighting/lighting/poor acoustic (69%)
- Maintenance of building technology: Heat/ cooling supply, lighting, ventilation system (69%)

The number in parenthesis shows the percentage of the case studies for which this was the case. Obviously, general maintenance ranks the highest with 88%. The interesting aspect of this high percentage is that most of the case studies were not only renovated to save energy. Therefore many of the implemented renovation measures had to be implemented anyway – that is to say that the costs of these renovation measures should not be included in a cost efficiency calculation of the energy renovation.

The energy related reasons for energy renovation were:

- Too high energy consumption / energy cost / Building does not comply with renewable energy goals (100%)
- Poor thermal performance of building elements / Thermal bridges /Condensation in external walls / Air leaks - primarily in windows and a top-floor ceiling (65%)
- Energy supply system in need for repair / Worn-out and old domestic hot water system with high circulation loses (54%)
- Research on energy efficiency in buildings (12%)

These reasons are obviously related to some extent. All 26 case studies have been renovated for a combination of reasons, some energy related and some not. This is supporting a "rule of thumb" for energy renovation that it makes much sence always to consider energy renovation, when a building is undergoing renovation anyway. In relation to this Figure 3 shows the renovation costs – total, non-energy and energy related. For those case studies where both the non-energy and energy related costs were available it can be seen that the non-energy related costs in general are considerable higher than the energy related costs.

Co-benefits

Also the co-benefits can be categorized into energy - and non-energy related co-benefits. The histogram in Figure 4 shows in a quick glance that three of the energy related co-benefits: improvement of thermal comfort, improved green building image and reduced dependency of fuel price fluctuations were identified for all the case studies. In addition: In 85% of the cases, an improved operational comfort has been observed.

Of the non-energy related co-benefits the upgrade of equipment was found for all case studies. Next comes improved air quality due to an improved ventilation system. Better weather protection of the building and improved use of space are also observed for more than half of the case studies. Obviously, some of the points listed can be classified as related or not related at the same time depending on the point of view.

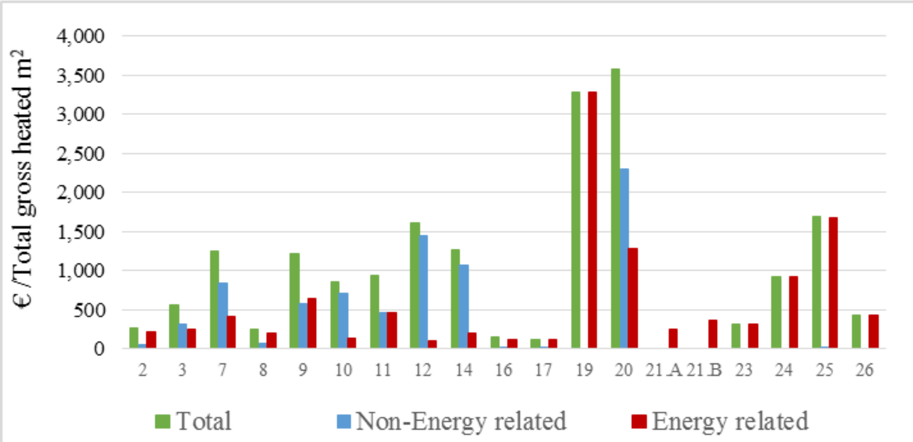

Figure 3 – Renovation costs. Total, non-energy and energy related.

Linking these observations to the reasons for renovation and the relation between non-energy and energy related renovation costs it is tempting to say that often energy savings are co-benefit of an anyway renovation!

Business models and funding sources

Financing deep energy retrofit is recognized as a major barrier for a large scale implementation of DER projects. In spite of the above observations concerning the reasons for renovation and the resulting co-benefits - it is still most often a requirement that DER has to "pay-off" in not too many years or phrased differently: Be cost-efficient. This has a close relation to the business models and funding sources used for the implementation of the case studies. These were therefore identified. It turned out that they could be grouped in the following main categories:

- Self-financing. Standard monthly "Maintenance and improvement contribution" by the tenants- funding model. Loan at low interest rates for Danish municipalities. Other loans – i.e. bank loans. private funding. (58%)
- EU or internationally supported Project (15%)
- National research program: American Recovery and Reinvestment Act of 2009; Agency provided funds (RWA); ARRA funding time-frame for completion (12%)
- National/Regional/local funding program (46%)
- Subsidies: For implementation of ecological and sustainable measures; Subsidised feed-in tariff for electricity generated by PV; Subsidy loans for social housing companies – interest rate =0.5 % over 25 years (12%)
- EPC Energy Performance Contracting; Design-build business model (12%)

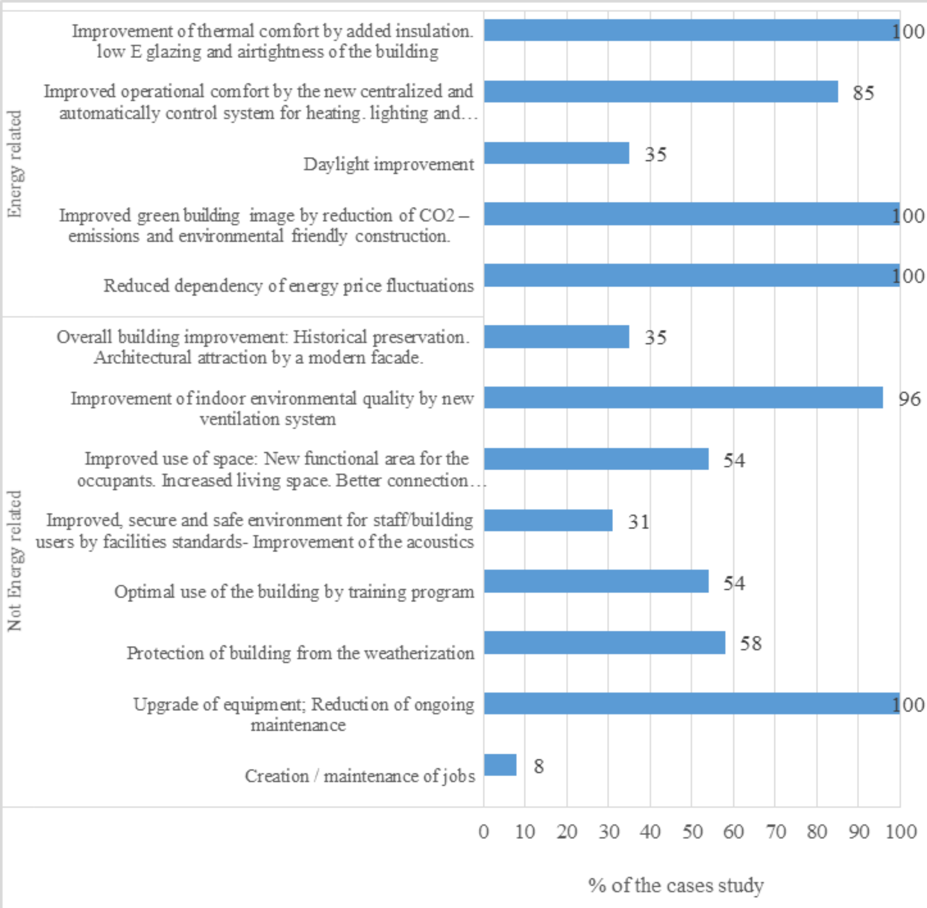

Figure 4 – Co-benefits overview

Cost effectiveness

Due to the fact that the case studies are located in different countries the way the calculations of cost effectiveness varies quite a lot. Some focus on Net Present Value (NPV) and some on Simple Payback (SPB). Obviously. Also the financial parameters such as interest rate and inflation vary from country to country. To get the overall picture it was decided to calculate the NPV (4) using the same parameters for discount rate and inflation for all the cases of 2%, but use the investments costs and energy savings values provided in each case study. The expected economic lifetime and expected lifetime was set to 30 years.12 of the 26 case studies present sufficient information for this calculation. The results are presented in figure 5.

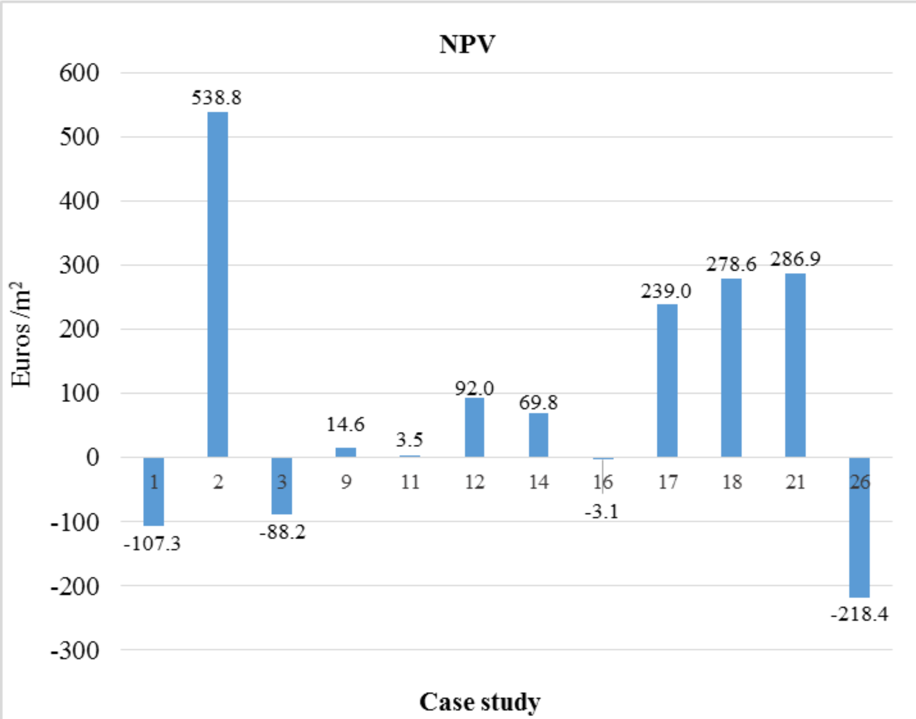

Figure 5 – Net present value of 12 case studies calculated with rates for discount and inflation of 2%.

From figure 5 it appears that 8 of the 12 case studies represented here have a positive NPV. For four of them the NPV is negative, however for one of them, no. 16, it is only slightly negative, so a simple statement can be made that the financial result is acceptable for three-fourths of these case studies. What can also be observed from figure 5 is that there is a large variation between these 12 case studies. For no.2 the NPV is as high as 538,8 Euro/m² and for no. 26 it is – 218,4 Euro/m². This probably mostly reflects the fact that the investments costs vary a lot – depending on many factors. It may also reflect the issue that has mentioned above, namely that for those case studies which exhibit high, positive NPV – no. 2, 17, 18 and 21 – a high fraction of the renovation costs has been assigned to non-energy measures – leaving a smaller fraction to the energy related measures.

Experiences/lessons learned

For the support of decision makers not only the hard facts – energy savings and cost efficiency - are relevant. The experiences and lessons learned can be of significant importance when deciding for or against a new renovation project. Here these have been grouped with respect to energy or use and comfort.

Energy

- The heating energy consumptions were halved by the refurbishment of the building envelope and overall heating energy savings or 80 to 90% have been achieved by the building and systems renovation combined with change of supply.
- Energy exchange between buildings with different user/load profiles offer potential for further energy reductions.
- Continues commissioning after the completion is important to avoid decrease of performance.
- Especially in mid and north European countries a DER requires ventilation systems with heat recovery, which have not been in place before. Resulting in increased electricity consumption for the fans. Based on German experiences this may often be +10-15 kWh/m²yr.

Use and comfort

- The indoor air quality increased strongly. a more stable humidity and a lot less pollution was achieved. Sometimes too dry air results from high ventilation rates.
- A VOC sensor had to be installed in some classrooms to reduce high CO_2-levels
- New layout of the occupied space was integrated in the planning process from the beginning
- The impact on the users was positive (staff. students and parents)
- Most importantly, the quality of the indoor climate was improved with respect to air quality and temperature control. This observation is a confirmation of the co-benefits mentioned above.
- For schools and office buildings this could be one of the most important reasons for the renovation work as more efficient workers or improved learning of the pupils easily may have a higher financial value than the energy savings.

3. Conclusions

The 26 case studies form an interesting collection of Deep Energy Retrofit building projects from around the world. The reader will find valuable information about the actually implemented energy renovation technologies – often in terms of both technical parameters and costs.

It may be self-evident but none-the-less it is worth stating that from the overview of which technologies have been implemented it is clear that to reach DER it is necessary to carry out the implementation of a bundle of technologies including as well building envelope renovation as the retrofit of mechanical systems.

The investigation of the achieved energy savings shows that Deep energy renovation is quite possible – as an average these 26 case studies achieve 66.4% energy savings.

The analysis of reasons for renovation shows that the non-energy related reasons are dominating. Buildings are renovated mainly because of need for maintenance. It might also come from the fact that use of the building is to change, so in order to accommodate the changes of use the building will have to be renovated/refurbished to some degree.

The cost of “anyway” renovation need to be established and documented in order to make sure that the energy part of the renovation is not required to “pay back” these elements of the renovation costs.

In this context it is also worth noting that optimization not always is a straightforward financial optimization of the Net Present Value (NPV) of the energy saving measures. It is heavily dependent on the parameters/assumptions used – energy prices, interest rates, etc. and might quickly change. Therefore, it is advisable to look also at what is cost-efficient and what uncertainty interval should be considered. The cost-efficient energy renovation may have a less advantageous NPV than the optimized, but as long as the NPV is positive, the financial result is better or equal to the outset situation and it will result in higher energy savings than the cost-optimized renovation.

Following this line of argumentation: When identifying the possible energy renovation measures it is useful to include the following in the considerations:

1. In the long run it may be advantageous to carry out the energy renovation to the full possible extent - a deep energy renovation, as it will almost always be costlier to go further in a second step or more steps.
2. The savings resulting from selecting the bundle of energy saving technologies should be calculated in energy and financial terms.
3. Co-benefits stemming from each energy saving measure should be noted and to the degree possible given an economical value. A simple calculation assuming that 100 employees work in the 3000 m² building with an average yearly salary of 50,000 € shows that an 1% increase in productivity over 10 years would result in a financial value of the improved working conditions is 500,000 €.

The collection and analysis of the 26 case has proven a valuable activity to understand the mechanisms behind deep energy renovation building projects and how to advance the implementation of such projects.

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