Innovation in early planning and design for energy efficient retrofitting

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Abstract

The research and development work within the EU-project E2ReBuild, covers the whole renovation process, from early planning to operation of the building following completion and the behaviour of the people living there. This paper will focus on early planning and design and how to create decision criteria for energy efficient retrofitting of resident buildings in cold climates. The aim is a formalised process for early integration of production planning, cost estimation, environmental impact, design and socio-architectural parameters.

Many Swedish and European apartment buildings are about 40 – 60 years old, and in an urgent need of extensive renovation and modernisation. However, clear criteria for choosing a renovation strategy are often missing, and decisions are based on emotions and short-term investment costs, rather than on a thorough analysis. Renovation works are therefore not always optimal; they may even hinder future renovations. This project will provide in-depth information of the European building stock in order to analyse and evaluate the refurbishment potential of different building types and to identify successful renovation strategies.

Within E2ReBuild, seven different demonstration buildings, from Finland and Sweden in the north to the alp region in southeast France, serve as best practice examples of retrofitting strategies for buildings in cold climates. Information about building location, construction and energy use as well as ownership structures of these demos, are systematically recorded and evaluated. The replication potential for retrofit measures as well as the potential for added values are investigated and mapped. A socio-architectural method will be developed with the aim of bringing the issues of technical refurbishment and added value for tenants up at the same time, providing the opportunity to make energy-efficient retrofitting socially attractive. The energy and environmental impact of the proposed retrofit strategies will be evaluated using Life Cycle Assessment and energy simulations to ensure that the chosen renovation strategies can meet the energy goal of 30-50 kWh/m² for heating, ventilation and domestic hot water.

The building typology, socio-architectural model, collaboration models and environmental impact of the chosen retrofit strategies result in an early decision tool: the European Retrofit Advisor. This excel-based tool can be used for a quick evaluation of renovation potential, environmental and social issues, possible solutions and their costs. This paper will present and discuss this European Retrofit Advisor as an early decision tool for sustainable renovation concepts.

Keywords: Renovation, retrofit, energy-efficiency, design tool, decision tool, LCA

Introduction

Large parts of the European multi-family houses are from the post war era and are now about 40–60 years old. Many of these are in an urgent need of an extensive renovation and modernisation. Also in Sweden, a majority of the existing apartment buildings were built during these boom years, 1950-1975, [SCB 2013] when the government's target was to build one million new homes within a decade.

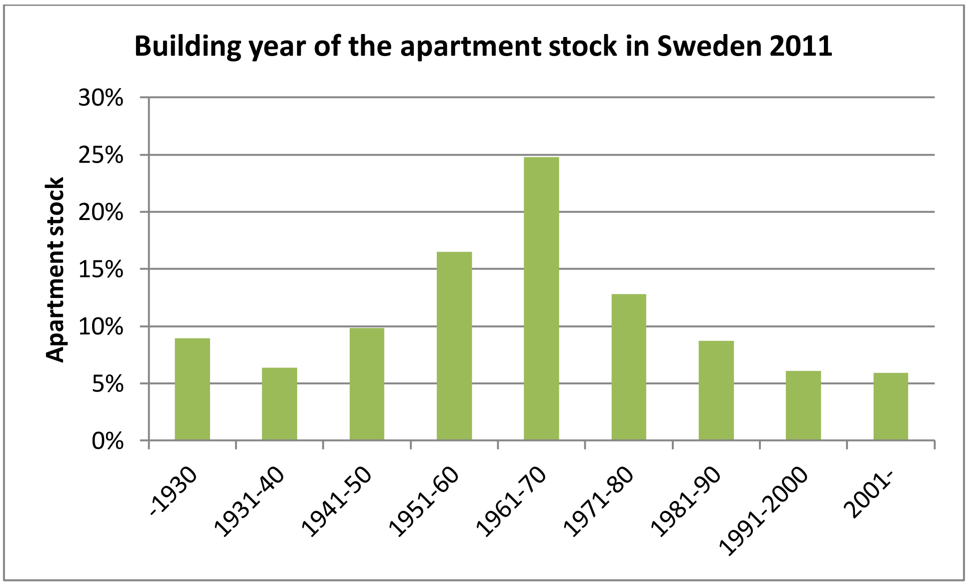

Figure 1 Building year of existing apartments in the Swedish housing stock in 2011

These buildings have become so old that they are in need of extensive renovation and modernisation Today, roughly 700 000 apartments in Sweden are in need of extensive renovation [Sveriges Byggindustrier 2010]. Especially wet areas and other installations like pipes, electricity and ventilation need replacement, but also windows, balconies and facades need attention [Boverket 2005].

Many property owners are willing to carry out renovations, but the financial resources are not enough and hence the planned renovations are often being postponed. But as the renovation needs are increasing, the operating and maintenance costs for the property increases as well. Meanwhile it also reduces the attractiveness and potential for increased rental income. This might have led to an ethnic and socio-economic segregation which is a social problem that affects all of society. Another risk occurs when renovations are performed only on isolated building components, such as roofs, windows or heating systems, in order to save money. This can result in inefficient and in the end expensive solutions, without an appropriate long term energy reduction. Optimal results cannot be achieved by single renovation measures. The main reasons for not using energy-saving retrofits can be associated partly to the owners' perception that such energy reductions are not urgent and partly to the lack of funds. Energy-saving renovations are generally considered as risky investments by the owners who prefer simple renovation and maintenance measures over energy-efficient retrofits [Banfi et al 2012]

In order to break this negative trend, it is crucial to create profitability for the property owners when refurbishing. The property owners must see the total life cycle profitability. A sustainable solution would be to fund the renovation costs by securing great energy savings. If so, the renovation reduces maintenance and energy costs while increasing the attractiveness and rents. In other words, comfortable housing for the residents while giving the property owner a sustainable and profitable management. Energy efficient renovation of the existing building stock is also a must in order to reach the society environmental targets of 2020 and 2050. However, clear criteria for choosing a renovation strategy are often missing, and decisions are based on emotions and short-term investment costs, rather than on a thorough analysis. Renovation works are therefore not always optimal and they may even hinder future renovations. A decision tool is needed.

The research and technology development work within the EU-project E2ReBuild, covers the whole renovation process, from early planning to operation of the building following completion and the behaviour of the people living there. This paper is focusing on early planning and design and how to create decision criteria for energy efficient retrofitting of resident buildings in cold climates.

Objectives

The objective of this paper is to spread the on-going work within the E2ReBuild project, regarding the development of an easy-to-use decision tool for property owners for energy efficient retrofitting of resident buildings in cold climates. The tool helps to create a formalised process for early integration of production planning, cost estimation, design and socio-architectural parameters.

Moreover, the aim is to evaluate the refurbishment potential of different building types and to identify successful renovation strategies.

This can be achieved by developing

The overall aim of the E2ReBuild project is to demonstrate sustainable renovation solutions and an industrialised process, that will reduce energy use in existing apartment buildings, minimise technical and social disturbance for tenants and encourage energy-efficient behaviour.

Method

Within E2ReBuild, seven different demonstration buildings, from Finland in the north to the alp region in southeast of France, serve as best practice examples of retrofitting strategies for apartment buildings in cold climates. The demonstration buildings were completed in 1954-1985, and they represent different types of architecture, construction, material and standard. These buildings are now going through extensive refurbishing with focus in industrial manufacturing methods e.g., facade elements and/or a standardised building process that allow a high replication potential.

In order to develop an early decision tool, these demonstration projects are being evaluated. Questionnaires have been sent out to collect information about location, construction and current energy use as well as ownership structures. The replication potential for retrofit measures as well as the potential for added values are investigated and mapped. A socio-architectural method is being developed with the aim of bringing the issues of technical refurbishment and added value for tenants up at the same time, providing the opportunity to make energy-efficient retrofitting socially attractive. The energy and environmental impact of the proposed retrofit strategies is being evaluated using Life Cycle Assessment (LCA) and energy simulations to ensure that the chosen renovation strategies can meet the energy goal of 30-50 kWh/m² (delivered energy) for heating, ventilation and domestic hot water.

An excel-based tool for quick evaluation of renovation potential and LCA was released already in 2007 by Empa, the Swiss Federal Laboratories for Materials Science and Technology [Empa 2013]. Within this E2ReBuild project, the tool is further developed as the European Retrofit Advisor, and the participating countries will integrate their own key figures and building types to adapt the tool to a wider range of European building types.

Early evaluation results

The main work of the E2ReBuild project will be completed by the end of 2013. Two years in to the project the demonstration buildings are in different development phases, from planning and early construction to completed construction and monitoring. The evaluation is therefore on-going but this section will present some early results, with main focus on the Swedish demo Giganten in Halmstad, built in 1963 and renovated in 2011-2012 (see figure 2).

Figure 2 Giganten, Halmstad (Foto: E2ReBuild)

Table 1 shows the seven demonstration buildings and their planned renovation measures [E2ReBuild 2013]. The net energy demand before renovation is presented for each building, but for most buildings only space heating was measured before. The target energy demand after renovation has been estimated with different methods and tools by each participant. The net energy demand includes space heating, domestic hot water and building electricity demand for fans etc., based on heated floor area. Free energy from renewable sources (solar thermal for example) has been withdrawn. Almost all demonstration projects but Halmstad had a very ambitious target of reaching passive house standard. The property owner of the Halmstad demonstration building, on the other hand, decided energy level after evaluating different retrofitting actions in relation to investment costs and savings in operation.

One obvious difference in renovation strategy is that all demonstration buildings in the E2ReBuild project except the Halmstad demonstration building decided to improve their façades by adding prefabricated well-insulated timber elements. The other demonstration buildings had a great focus in making the exterior design more attractive while the Halmstad demonstration building put more emphasis on the interior which can justify a rent increase in Sweden. Besides, the façade of the Halmstad demo was already insulated and in good condition while many of the other European demo buildings were not insulated at all.

Table 1 The seven demonstration buildings and their planned renovation measures [E2Rebuild 2013].

	Augsburg	Halmstad	Munich	Oulu	Roosendaal	London	Voiron
Construction year	1966	1963	1954	1985	1960	1974	1961
Owner type	Public	Private	Public	Public	Public	Private	Public
Energy demand before/after*	220(heat) /30	174 /53	220(heat) /20	148(heat) /30	150(heat) /25	237(heat) /25	330 /60

*estimated

Improved measures:

Facade	x		x	x	x	x	x
Windows	x	x	x	x	x		
Roof	x	x	x	x	x	x	x
Floor	x			x			x
Thermal bridges	x		x	x	x	x	x
Air tightness	x	x	x	x			
Ventilation	x	x	x	x	x		x
Heating	x	x	x		x		
Renewable energy					x		x
Added rental space	x		x			x	
Interior (e.g. bathroom/kitchen)	x	x		x			

The choice of prefabricated façade elements (see figure 3) among the other demonstration projects is part of an ambition to develop industrial manufacturing methods which have a high replication potential and cause less disturbance for the tenants during the construction phase. In the Halmstad demonstration project prefabricated components were not used, but a "partnering contracting" process was applied as a new strategic and repetitive collaboration model in retrofitting projects.

Figure 3 Prefabricated wall elements (TES EnergyFacade), Augsburg (Foto: Frank Lattke)

Other noteworthy renovation measures are the Munich and London demonstration projects, which replaced the attic with an additional floor in order to create more rental space. In the Augsburg project, extra apartment space was created by converting the existing balconies into insulated winter gardens, mainly as an attempt to reduce the thermal bridges.

Most of the demos decided to replace the windows with modern highly insulated windows with U-values of 0.8-1.0 W/m^{2}K. Solar collectors for hot water production were inserted in Voiron and Roosendaal (see figure 4)

Figure 4 Solar collectors in Roosendaal, before (left) and after (right) retrofit. (Foto: Chiel Boonstra)

The adaption work of the Retrofit Advisor

Already in 2007, Empa launched a free test version of the online tool "Retrofit Advisor", allowing Swiss building owners to evaluate different retrofit options for their apartment buildings. A beta-version has been available since 2011 [CCEM 2013]. Based on few input-data, the actual value of the property, its value after renovation and the estimated cost for refurbishment may be evaluated. The main function of the tool is to indicate whether it is most profitable to repair only, carry out energy-efficient renovations or even demolish and reconstruct the building.

The Retrofit Advisor is based on a Life-Cycle Assessment (LCA) which also, apart from the environmental evaluation, considers life-cycle costs (discounted cash flow analysis) and social aspects. The tool is connected to an LCA database, with ecological data for energy and materials (from raw material extraction to final disposal), from ecoinvent, the Swiss Centre for Life Cycle Inventories. The ecoinvent database is built on the method of LCA as standardised in the international ISO standards 14040 and 14044 [Weidema et al 2012]. The Retrofit Advisor also contains building cost and life-cycle data, for instance for construction, maintenance and renewal.

Figure 5 Example of user interface in the online beta-version of the Retrofit Advisor (Empa)

The Retrofit Advisor is presently an Excel-based tool which consists of an input-generator that uses pre-defined building types and renovation scenarios (see figure 5). The tool works as follows:

1. The user fills in general data about the actual building before renovation. There are a number of default residential buildings, of different type and age, with suggested data to choose from. However, adjustments are possible, to allow for adaptation to the selected building type and renovation scenario to the real situation. The more information is provided, the more precise the evaluation will be. Information about size, age, apartment standard, constructions, heating and ventilation systems, general condition, attractiveness of building location, urgent renovation needs and approximately energy use are requested.
2. Financial key figures are given, i.e. site value, rental income, funding, bank loans, possible tax reduction, energy prices etc. These figures are presented together with pre-defined and calculated figures for periodic costs, new-investment costs and return of investment.
3. The user decides upon the desired renovation level. The building envelope and installations can be improved according to a pre-defined "standard renovation", to Minergie standard or to Passive house standard. Additionally, the building can be refurbished with new balconies, a new roof with added rentable space as well as an extensive renovation of the interior.
4. The social aspects are handled through a questionnaire where the user describes if, for instance, the quality of living, handicap access, common social areas, playgrounds, architecture, constructions and indoor comfort will be improved or remain the same after the potential renovation.
5. The Retrofit Advisor estimates potential energy savings, based on the existing energy use and the renovation strategies selected. The annual primary energy use for heating is estimated and labelled, as well as the potential effect on global warming (CO2-Equivalents) and the contribution of renewable energy (see figure 6). It is possible to see more detailed charts in the program. More detailed cost results for different categories are shown in the program.

6. The final result is a total evaluation where the environmental evaluation is combined with the social and financial evaluation. The total points are weighted after how important, for instance, the financial aspects are to the owner, in relation to environmental and social aspects. Figure 7 shows a fictive example where it is more favourable to reconstruct the building rather than to renovate or repair the building. In this case, the financial aspects are important to the building owner (and hence get more points) while the social aspects are relatively important and the environmental aspects are less important. The social benefits and the possible rental increase when reconstructing seem to outweigh the large investment cost.

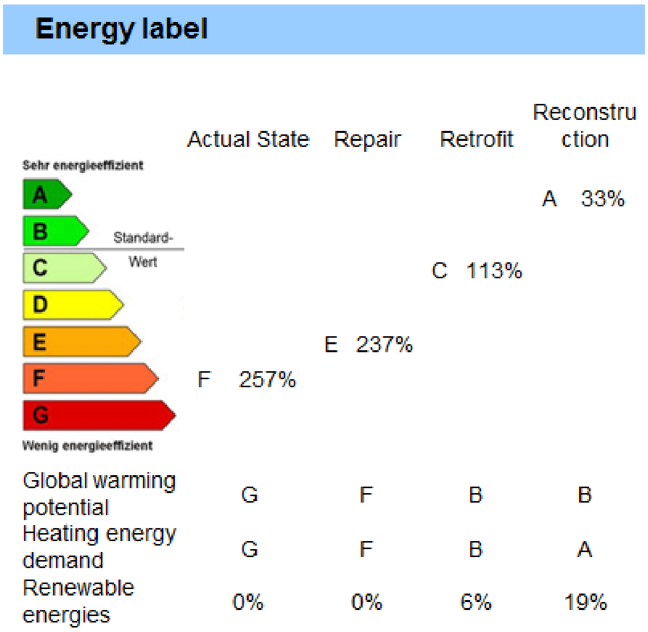

Figure 6 The environmental results are presented with an indicative energy label (Empa)

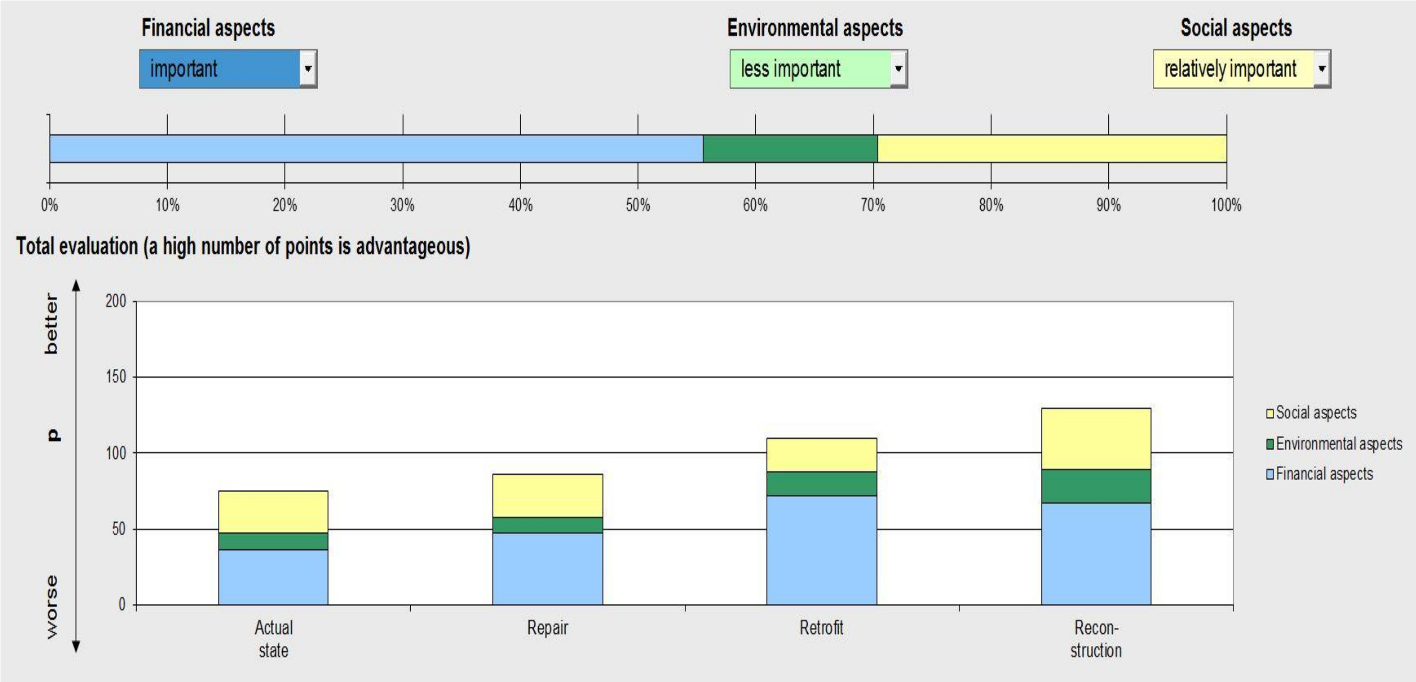

Figure 7 The result from the total evaluation, given in full aggregation points where a higher value is advantageous (Empa).

Further development

During this E2ReBuild project, a European adaption of the Retrofit Advisor is being implemented and tested. Different national data has been collected and the programme has been translated into English and French. The E2ReBuild participating countries have integrated their own key figures and building types to adapt the tool to a wider range of European building types.

The final version of the adapted European Retrofit Advisor will be ready in 2014. The remaining work is to involve an external software developer for programming. The final layout and user interface will be upgraded and finally, all national data must be verified and the final programme must be tested and evaluated. The tool will be free to use and download from the E2ReBuild homepage.

Discussion

One of the goals within the E2ReBuild project is to create an easy-to-use decision tool for property owners, which allows evaluation of sustainable retrofitting concepts in an early design stage. The European Retrofit Advisor is a thorough tool with a striking number of underlying data and equations. It is also an innovative and rather unique tool since it brings social, economic and environmental aspects together, which are the foundations of sustainability. Many other refurbishing decision tools focus only on the Life-Cycle-Cost (LCC) and compare savings in operation costs in relation to the investment costs. The LCA analysis in the Retrofit Advisor makes it possible to identify the environmental consequences of a decision or a proposed renovation strategy. LCA is a technique to assess environmental impacts associated with all the stages of a product's life, “from-cradle-to-grave”, which helps to prevent narrow and short term decision-making. In addition, the Retrofit Advisor also considers social aspects by giving improving measures extra points in the total evaluation.

Recently, BeBo Lönsamhetskalkyl ("the BeBo profitability calculation") was released in Sweden [BeBo 2013]. This is a free, web-based decision tool developed by, and for, Swedish property managers when investigating energy-efficient renovation measures at an early stage. The tool is a cost-benefit analysis showing the impact on cash flow. It is clear that this tool was created by property managers and not environmental researchers, since the results are very focused in financial numbers. It does, however, also involve public social benefits that are wholly or partly the result of the renovation. One example of public benefits occurs when, for instance, different types of obstacles are removed, so that the elderly can live longer in their own apartments, and the municipality no longer has to arrange special accommodations for these persons. The tool shows how the cash flow would be affected if the project could be credited with these benefits. This approach differs from the approach in the Retrofit Advisor which rather calculates the direct social benefits, enabling more satisfied tenants and maybe a possible rent increase.

The result from the Retrofit Advisor, a recommended renovation strategy based on social, economic and environmental aspects, is based on data given by the user, but also by numerous default values given by the programme. The recommendation should therefore be considered as an advice and not the absolute truth. A life cycle analysis is only as valid as its data and therefore, it is crucial that the data used are accurate and current. Data validity is an on-going concern for LCA analyses. New materials and manufacturing methods are continually being introduced to the market. This makes it both very important and very difficult to use up-to-date information when performing an LCA but the data-gathering process takes time. When comparing different LCA with one another, it is crucial that equivalent data are available for both products and processes in question. If one material has a much higher availability of data, it cannot be justly compared to another material which has less detailed data. The ecoinvent LCA database which the Retrofit Advisor is connected to is built on the method of LCA as standardised in the international ISO standards 14040 and 14044, which probably reduces risks of false comparisons. Still, not even the ecoinvent database is complete and it is impossible to see in the Retrofit Advisor if the data is old or insufficient.

The European Retrofit Advisor is designed for easy access by non-professionals as well as for detailed analysis by professional users. The idea of first choosing a similar default building type with default building data and then adjust the data to match the actual building, makes the tool easy to use for quick evaluation. Even though some parameters and features are un-known for the time being, an indicative result can be given. However, the beta-version of the Retrofit Advisor is very detailed and requires a certain amount of basic knowledge since the user is allowed to adjust many of the numbers himself. The user interface in the final version will hopefully be clearer and more "fool proof". This degree of detail also makes the simulation speed in the beta-version quite slow, but this will most likely disappear in the final programming phase.

It will be interesting to see how the European version of the Retrofit Advisor will be embraced in Sweden and other countries. Will other default building typologies and renovation strategies be needed or can it be used straight away? In order to reach the society's environmental goals of 2020 and 2050 we must perform drastic measures in the existing housing stock. Almost one million apartments in Sweden are now in a phase where extensive renovation is needed, and a roughly 200 million people in Europe live in similar buildings. Optimal and long term results cannot be achieved by single renovation measures. Economical attractive renovation packages must be developed and spread with a highly repetitive process in order to be cost- and resource efficient. Hopefully this Retrofit Advisor and other similar tools can speed up the process and assist good decision making.

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