Feasible Energy Saving Potentials in Renovations for Residential and Service Building Stock

Jaakko Vihola[1], Juhani Heljo[2], Antti Kurvinen[3]

The aim of the study behind this paper was to define feasible energy saving potentials of renovations in the 2010 Finnish residential and service building stock by 2050. This paper includes descriptions of the Finnish building stock and bottom-up calculation model called EKOREM, which was used to calculate different energy saving scenarios. Three different research methods that were used to determine the volume of potential renovations in the Finnish building stock are also described. Furthermore various reasons behind decisions to omit optional energy saving measures are discussed.

Finnish building stock consumes almost 40% of the total energy use in Finland. Thus it should be one of the main focus areas when trying to achieve energy efficiency goals set by the European Union. The study showed that the feasible energy saving potential in renovations for the residential and service building stock in Finland is quite low compared to the rest of Europe. Feasible annual savings in heating energy from renovations varies from 0.2-0.7%. That means that cumulative savings in 2050 would be between 8-28 %. In theory, it is possible to save more energy than is considered feasible. Calculations were completed where the whole building stock was set to correspond to the 2010 Building Regulations of Finland. That resulted to about 40% of savings in the 2010 building stock by 2050.

Low feasible saving potential is mainly due the fact that it usually pays to implement structural energy-saving measures only when the targeted elements are in a need of repair because of their physical condition. Attempts to achieve greater energy savings than can be reached with measures connected to scheduled renovations may multiply costs. Thus, the savings in energy costs will not necessarily cover the investments needed. In Finland, about 70% of the residential buildings are owner occupied. Owners cannot be forced to implement any energy saving measures that they don’t see reasonable or cannot afford. This comes to play especially in areas facing an uncertain future, and therefore financial possibilities to carry out expensive renovations are low. These are only few of the various reasons why energy-based renovations cannot be speeded up very much.

Keywords: Energy consumption, Energy saving, Renovations, Residential and service buildings, Building stock

[1] Researcher, M.Sc.; Department of Civil Engineering; Tampere University of Technology; Korkeakoulunkatu 5 P.O.Box 600 FI-33101 Tampere Finland; jaakko.vihola@tut.fi

[2] Researcher, M.Sc.; Department of Civil Engineering; Tampere University of Technology; Korkeakoulunkatu 5 P.O.Box 600 FI-33101 Tampere Finland; juhani.heljo@tut.fi

[3] Researcher, M.Sc.; Department of Civil Engineering; Tampere University of Technology; Korkeakoulunkatu 5 P.O.Box 600 FI-33101 Tampere Finland; antti.kurvinen@tut.fi

1. Introduction

At the end of 2006, the European Union pledged to cut its annual consumption of primary energy and greenhouse gas emissions by 20% compared to 1990 levels by 2020. Finland, as a part of the European Union, is required to fulfill these energy saving requirements as well. Building stock is a major contributor to energy consumption in Finland. In the year 2007 end usage of the energy in Finland was 307 TWh. Building stock's share from this was 38% (Vehviläinen et al. 2010, p.13). Because of the high share, building stock should be one of the main areas of focus when considering how required energy savings and greenhouse gas reductions could be reached.

This study focuses on feasible energy saving potentials of renovations in the 2010 Finnish residential and service building stock by 2050. In this case, feasible energy saving potential means savings achieved by energy saving measures which are carried out within scheduled renovations and are considered technically approved and economic. Plenty of earlier research has focused on the economics of energy efficiency investments. It seems that even at the present level of energy prices and without implementation of large scale policy instruments, many of energy saving measures are profitable to carry out (Amstalden et al. 2006). Profitability of different measures can increase even more if different kinds of co-benefits are considered in addition to energy-related benefits (Jakob 2004). Co-benefits include, for instance, improved indoor air quality and protection against external noise.

The energy saving potential calculations were made using EKOREM-calculation model (Heljo 2005). Four different scenarios were studied and the results show that feasible energy saving potential in renovations is smaller than expected and might cause some serious challenges when considering the goals set by the European Union. In the UK, similar results have been achieved regarding of CO_2 emission reductions (Johnston et al. 2004). Because of complex nature of the building stock and its energy consumption, this study focuses only on energy saving measures that consider buildings' envelope, ventilation system and hot water usage. Electricity consumption is only observed as a part of ventilation renovations. Heating system changes, new production saving potentials and energy consumption affected by user behavior are excluded from this study.

Globally thinking results might vary greatly depending on which country is studied. Savings potential in energy consumption and greenhouse gas emissions are highly dependent on characteristics of the studied building stock and climate conditions. For example, distribution of building types and age as well as heating/cooling systems used are all factors when trying to estimate feasible saving potentials. In Finland, where the climate is cold, most of the energy saving in old buildings is achieved by increasing isolation layers of building envelope within scheduled renovations or by less expensive HVAC adjustment measures. In hot climate conditions, completely different problem field must be considered. There main focus should be directed to how to minimize cooling demand of buildings. This study has been made using Finnish climate data and building stock information, and thus the results are not to be generalized globally without further examination.

Finland is situated in northern hemisphere between the latitudes 60° and 70°. The average temperature in Helsinki (capital of Finland) on the southern coast of Finland is approximately 6°C. Difference in climate conditions between seasons is remarkable changing from hot summers to cold snowy winters.

The Finnish residential and service building stock is one of the youngest in Europe. Almost 70% of the stock has been built between 1970-2010 (Figure 1). 72% of the stock consists of residential buildings where single family houses form the largest group (40% of the stock). The age distribution of the building stock is the reason why big part of the building stock is in a need of renovation.

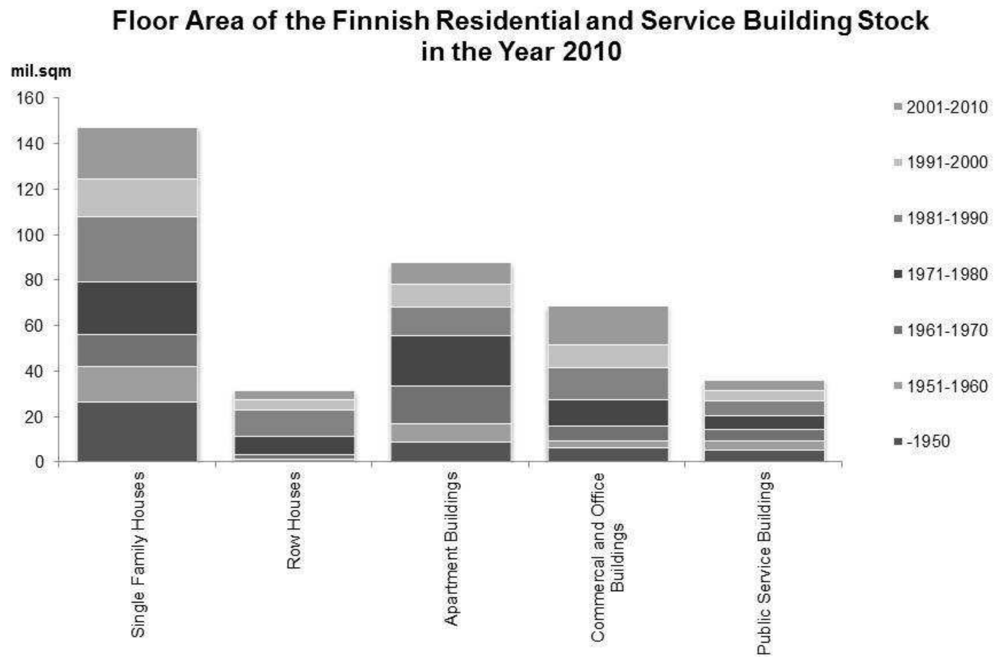

Figure 1. The Finnish residential and service building stock in the year 2010. Data is categorized into five different groups which represent different building types. Inside each of these five groups data is further divided to show when buildings have been constructed. (Statistics Finland)

Heating system distribution, especially in single family houses, is highly diversified. Most of the heating energy demand in single family houses is met either by wood/pellet, oil or electricity. Because of the new building regulations in the new production, focus will move strongly towards ground source heat pumps and other systems that utilize renewable energy resources. Rest of the residential and service building stock is almost exclusively connected to district heating except in the rural areas where service is not available.

In 2010 the Finnish residential and service building stock was using energy about 91 TWh. Residential buildings' share of this was approximately 64% and the rest 36% was consumed in different kind of service buildings. In residential buildings, most of the total energy consumption goes to heating of spaces and hot water. In service buildings, proportion of electricity consumption is noticeably higher because of the lightning requirements and demand of effective cooling caused by large amount of electric devices and people using the spaces.

The objective of this paper is to give a scientific estimation of feasible energy saving potentials in the Finnish residential and service building stock. Whenever saving potentials are referred to, for example by the politicians or the press, usually the magnitudes are way off. Statements are often based on sophisticated guesses rather than data produced by scientific methods. That is because of challenging nature of the building stock as a research object and the lack of statistical data considering renovations in the building stock.

2. Research Methods

Analysis of energy saving potentials was made by using bottom-up calculation model called EKOREM developed in Tampere University of Technology (Heljo et al. 2005). EKOREM is a building stock calculation model which can be used to determine energy consumption and greenhouse gas emission of the building stock in different cross-section years. Calculation method of the model is based on the part D5 (2007) of the National Building Code of Finland called “Calculation of Power and Energy Needs for heating of Buildings” (Finnish Ministry of Environment 2007).

In the model, building stock is divided in building type categories similar to used by Statistics Finland so that official statistical data can be easily used in calculations. Inside each building type buildings are further divided to age groups so that different groups can be given different kind of describing technical base values (for example U-values of different structural elements), which represent the methods of construction in each era as an average.

The main purpose of the EKOREM-model has been to create data for the EU-reporting needs to show how development of the National Building Code of Finland has reduced building stock’s energy consumption and greenhouse gas emissions. Besides this, many regional studies have also been made.

2.1 Studied Energy Saving Measures

In this study, the following energy saving measures were included: adding insulation to external walls, adding insulation to roofs, improving energy effectiveness of windows, improving air tightness of building envelope, improving/adding heat recovery unit to ventilation systems and installing flow meters to decrease consumption of hot water.

When trying to estimate energy saving potential in renovations of the building stock, studies must be based on an assumption that different building elements are only renovated when they are in need of a repair because of their physical state. Carrying out renovations, considering only energy saving aspect and without real technical or physical needs will lead to significant additional costs (Heljo & Vihola 2012). In figure 2 is simplified linear presentation which shows how energy saving measure’s share of total costs increases if trying to implement it before there is a need of renovation because of the physical state of the structure. From the economic point of view, energy renovations are most profitable when carried out within scheduled renovations.

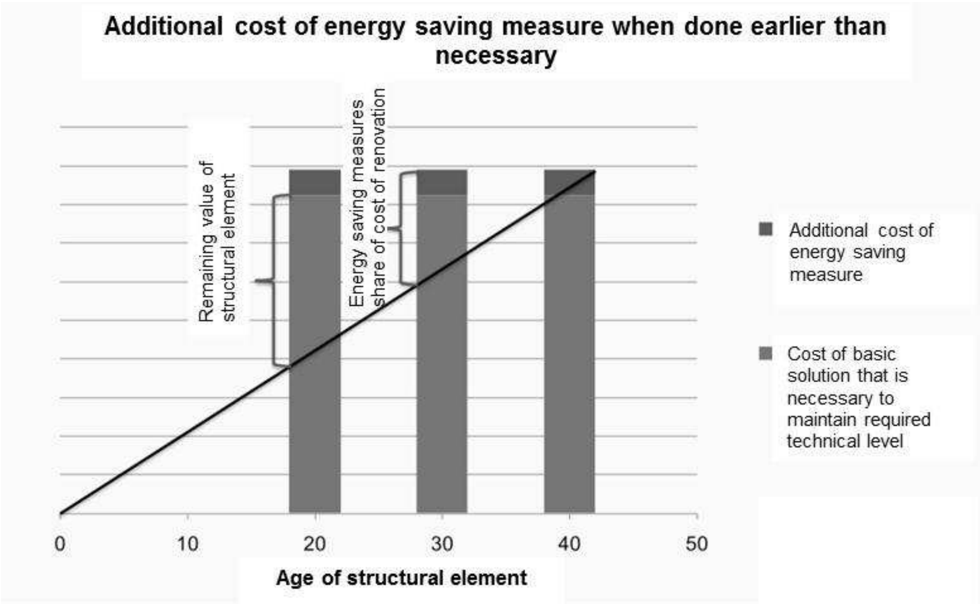

Figure 2. Simplified presentation of how additional cost of energy saving measure grows when trying to implement a measure earlier than is required from the technical and physical point of view. (Heljo & Vihola 2012)

2.2 Volume of Renovations

To know the volume of different kind of completed renovations is essential for estimating building stock's energy saving potentials. Within this study, three different estimations were created about the volume of renovation projects in the complete national building stock. First estimate is based on the very comprehensive research made by Technical Research Centre of Finland (Vainio et al. 2002). This research claims that approximately 2% of the studied building elements are renovated yearly (Figure 3). When comparing the results of this study to data of today, it shows that the volume of renovations has stayed almost the same.

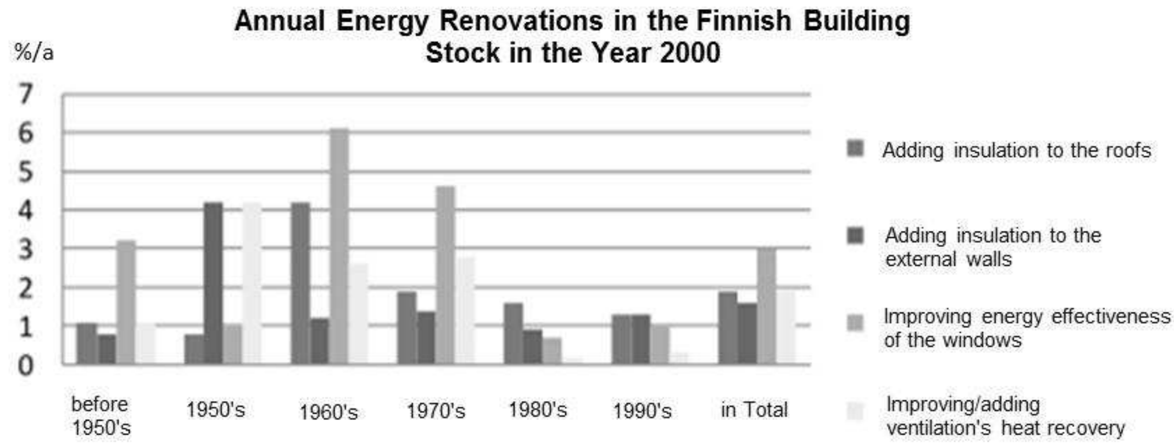

Figure 3. Annual energy refurbishments in the Finnish building stock in the year 2000. On average about 2% of measures are carried out annually. Windows are being improved more often than that. (Vainio et al. 2002)

Other way of predicting the volume of refurbishment projects was to estimate life cycles of different building components and then to link these estimations with the building stock data. For example, window areas for different building types and different age groups can be found from the EKOREM-calculation model. Window area of apartment buildings by the year of construction can be found from figure 4.

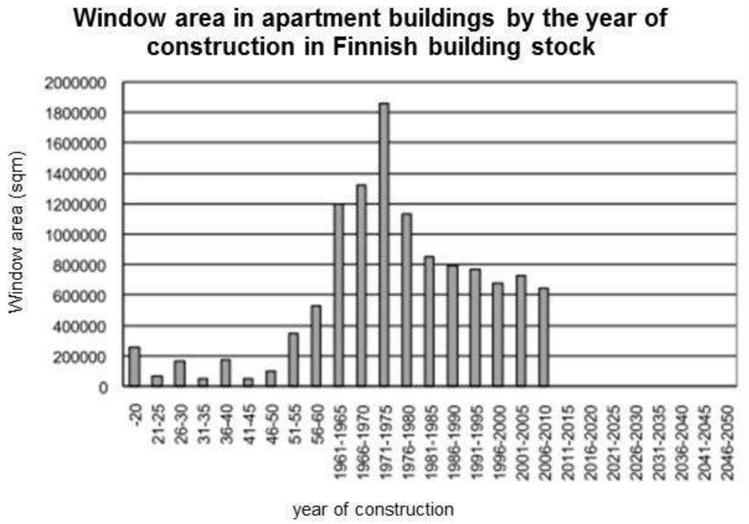

Figure 4. Window area in apartment buildings by the year of construction in the Finnish building stock as presented in EKOREM calculation model. (Heljo & Vihola 2012)

Different renovation profiles of structural elements were created for this study. In figure 5 is presented an estimation in which age windows are usually renovated.

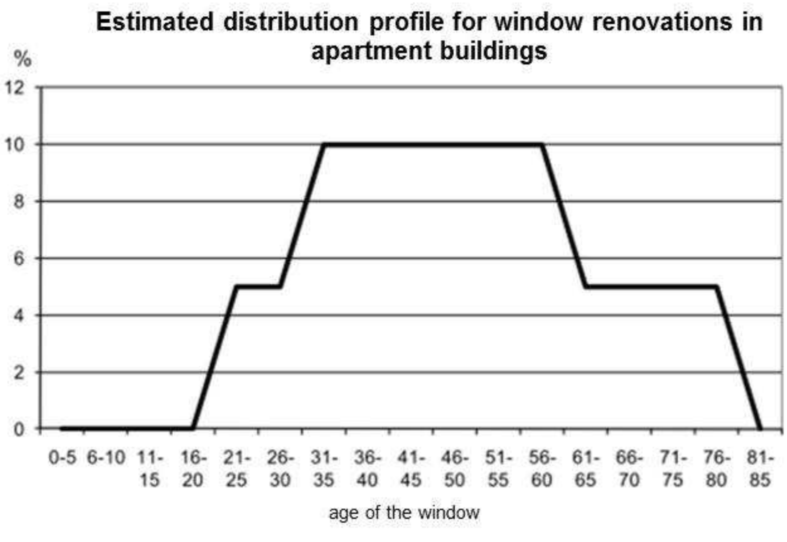

Figure 5. Histogram representing the age distribution when windows are usually renovated in apartment buildings. (Heljo & Vihola 2012)

When combining these two sets of data, one can make a theoretical distribution of window renovations as shown in figure 6. Some of the windows go through two rounds of renovations before the year 2050. In Finnish climate conditions this basically means that in a first round really old double-glazed windows (U-value=2,7 W/K,m^2) are changed to tripleglazed windows (U-value = 1,4-1,8 W/K,m^2) and in the second round of renovations these are replaced by four-glazed windows (U-value = 0,85 W/K,m^2).

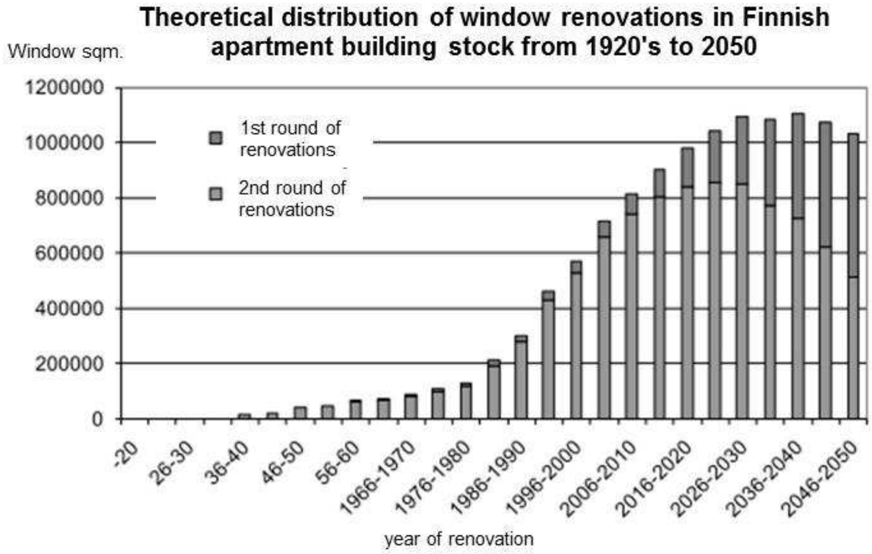

Figure 6. Theoretical distribution of window renovations in the Finnish building stock based on combining the data presented in figures 4 and 5. This can be used as an estimate to calculate feasible energy saving potentials. (Heljo & Vihola 2012)

This type of an examination is only possible in the case of windows and external walls. That is because adding insulation to roofs is not in all cases tied to scheduled renovations. Same goes for ventilation renovations.

Third source of information was so called "Expert Day" which was held during the project. Participants were from different organizations from the fields of construction research, consulting and planning. As a result following table (Table 1) was created of different energy saving measures.

Table 1. Volume of different energy saving measures in different building types in the Finnish residential and service building stock that are done already or will not be done by 2050 according to "Expert Day".

Experts' estimations of implementation of energy saving measures 2010-2050	Window Exchange		External walls' supplementary insulation		Roof's supplementary insulation		Improving air tightness of building envelope		Adding heat recovery unit to ventilation system		Installing flow meters to reduce hot water consumption	
	Done	Will not be done	Done	Will not be done	Done	Will not be done	Done	Will not be done	Done	Will not be done	Done	Will not be done
Single family houses	15 %	20 %	15 %	40 %	20 %	15 %	5 %	70 %	30 %	10 %	100 %	
Row houses	15 %	10 %	15 %	40 %	5 %	20 %	5 %	70 %				5 %
Apartment buildings	15 %	15 %	8 %	40 %	3 %	75 %	5 %	80 %	5 %	80% / 20%		10 %
Commercial and office buildings	15 %	15 %	10 %	50 %	0 %	75 %	5 %	80 %	50 %	5 %		100 %
Public service buildings	15 %	15 %	10 %	50 %	0 %	75 %	5 %	80 %	50 %	5 %		100 %

Table represents the perception of the experts considering different energy saving measures, and in which scale they might be implemented to the building stock in the future. Feasible energy saving potential is reduced by the fact that some percentage of the measures has already been done and some percentage will never be done because of various reasons. Potential volume of different measures by 2050 can be easily calculated by reducing from 100% the amount of measures already done and the amount of measures that will not be done.

There is a significant amount of uncertainty relating to ventilation renovations. Expert opinions considering on how many of heat recovery unit installations will not be done by 2050 vary from 20 to 80%. Pessimistic opinion of 80% is based on the assumption that technical solutions of ventilation renovations will not be developed profitable and easy enough to put into practice. Calculations of feasible energy saving potentials have been made by using more optimistic view of 20%.

2.3 Reasons for Omitting Energy Saving Measures

One of the main topics during the Expert Day was figuring out reasons holding back implementation of energy saving measures. Plenty of different factors were found and those can be categorized to five groups.

First group includes problems regarding properties of buildings. Building can be too young or in good condition so renovations are unnecessary. In some cases, building might be close to end of its life cycle so there is no reason to renovate. There are plenty of buildings which are considered as architectural monuments and because of that they are protected from any renovations that might change the appearance of the building. There are also buildings that are planned for only temporary use. (Heljo & Vihola 2012)

In second group there are buildings that are situated in areas where economic outlook is bad. Situation there is that even the most profitable energy saving measures are not implemented because funding is not available. Usually when an energy-saving measure is implemented within scheduled renovation additional cost caused by the measure varies around 5-15%. (Heljo & Vihola 2012)

In third group, there are problems regarding lack of know-how and sceptical attitudes towards energy saving measures. These kinds of problems are, for instance, ones regarding ownership of the buildings. 75 % of the Finnish residential building stock is owner occupied which means that there are lots of decision makers and they cannot be forced to implement energy saving measures which they do not see profitable. One of the major problems is lack of experiences considering energy renovations. This reflects straight to level of know-how in the field of construction. Used technologies might be strange and not understandable enough and at the same time there might be a feeling of uncertainty regarding physical functionality of the new structure. Old structural components are also often considered valuable. In most projects, there is not enough time or resources to go through positive effects of energy renovations. (Heljo & Vihola 2012)

Fourth group includes technical and architectural difficulties. In some cases, energy saving measures are hard to carry out from the technical perspective. Especially in old buildings renovations linked up to building's envelope are hard to implement while retaining architectural and physical properties of the building. (Heljo & Vihola 2012)

Fifth and final group includes problems that are connected to profitability and the lack of resources. Usually there is lots of contradictory information available regarding of the profitability of energy saving measures. False information is usually caused by too short-sighted way of evaluating the effects of the energy saving measures. Every decision-making situation that is connected to large scale renovations should involve life cycle analysis of the building to make sure that the most profitable measures are implemented (Kurvinen et al. 2012).

2.4 Different Calculation Scenarios

When the volume of energy saving measures has been estimated, it is possible to use EKOREM-model to calculate energy saving potentials. For the study, four different calculation scenarios were created. These scenarios are:

1. **Basic development** where decrease in building units is included but different energy saving measures are not put into practice. Basic development must be known so that the saving potential of energy renovations can be calculated.

2. **Theoretical saving potential** which is calculated on an assumption that life cycle of the building elements determine the moment of different refurbishment measures. Limitations set by information from the Expert Day have been taken into account.

3. Calculation where **the volume of refurbishments is based on realization of energy-saving measures in the past**. Limitations set by information from the Expert Day have been taken into account.

4. **Theoretical maximum saving potential** where whole 2010 residential and service building stock has been refurbished to be equivalent to current Finnish National Building Code requirements for new production by 2050.

Scenarios 2 and 3 describe situations that are considered feasible. However, they are challenging as well. In calculations an assumption has been made that whenever scheduled renovations are carried out profitable and technically valid energy saving measures are implemented. Yet it has been estimated that at the present time only half of the time that actually realizes.

Scenarios 1 and 2 are made for the comparisons. Basic development without energy saving measures is presented so that feasible savings achieved by energy saving measures could be calculated. Theoretical maximum is possible to reach in single projects where conditions are right, but several factors mentioned before prevent renovations of such a large scale in building stock level.

3. Results and Discussion

The results of the different calculation scenarios have been presented in the figure 7. In the year 2010 the Finnish residential and service building stock is using energy 91 TWh/year. Because of decrease in building stock units, this value is reduced to 56 TWh/year by 2050. However, this reduction in the energy consumption cannot be counted as savings because disposed buildings will be replaced by new production at the same sites or somewhere else. It has been estimated that nearly 30% increase in the residential and service buildings stock is needed by 2050 to cover space requirements set by growth of population and increased demand of services (Vehviläinen et al. 2010, p. 44).

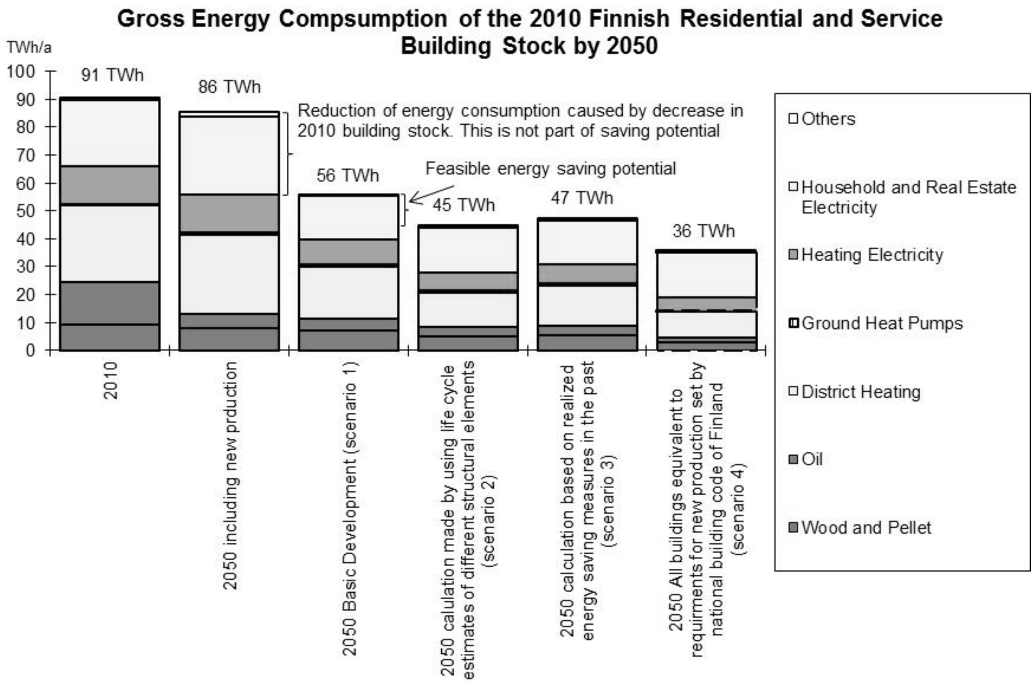

Figure 7. The results of the different calculation scenarios. Scenarios considered feasible are number 2 and 3. Reduction of energy consumption caused by decrease in the 2010 building stock is also represented in the figure.

The calculations show that feasible energy saving potential in renovations is somewhere between 9-11 TWh by 2050. This is approximately 20% from the basic development level (56 TWh) where energy saving measures were not implemented. Annual saving potential is approximately 0,5% per year. If the whole 2010 residential and service building stock were renovated to correspond the requirements for new production presented in the national building code of Finland, then by 2050 its energy consumption would be 36 TWh. Klobut and Tuominen (2010) estimated energy savings potential of nine European Union countries' residential building stock (Finland included). They claimed that on average in these countries 10% energy savings could be reached by 2020 and 20% by 2030.

In table 2, savings from different energy saving measures have been presented separately. Most savings can be achieved through improving heat recovery of the ventilation. However, the problem is that the prediction of ventilation renovation volume includes most uncertainty. The rise in the use of electricity can be explained with the fact that usually when building's quality standard is improved it also means implementing new technical systems and adjustments of old ones, which increase the electricity consumption in the building. In this study, only electricity consumption related to ventilation renovations is considered. Electricity consumption rises because old natural ventilation systems are replaced with mechanical systems equipped with heat recovery unit. Regarding of measures related to building envelope, it seems that improving energy effectiveness of windows and external walls will have the biggest effect on building stock level.

Table 2. Feasible energy saving potentials of different energy saving measures in the 2010 Finnish residential and service building stock by 2050

Measure	Savings
Roof	2,0 %
External Walls	4,3 %
Windows	5,1 %
Doors	0,2 %
Ventilation	9,3 %
Hot Water	0,7 %
Real Estate Electricity	-1,6 %
Total	20,1 %

4. Conclusion

The calculation results indicate that it is more difficult to save energy in the Finnish building stock than in Europe on average. By 2050 the feasible energy saving potential of the 2010 Finnish residential and service building stock is approximately 20%. This estimation is based on the current volume of renovation projects in the Finnish building stock. For various economic and technical reasons, it seems highly unlikely that energy-based renovations could be speeded up much. However, it should be noted that primary energy saving potential is much bigger than 20%. On July 2012 Finland adopted new energy effectiveness regulations for new production. These regulations present new challenges for new production by the form of requirement called E-value. E-value requirement varies depending on a building type and in single family houses depending on building's size. Basically what regulations did was to set E-value limits (kWh/sqm/year) that building must fulfill. The most significant change related to calculation of the E-value are primary energy factors. These factors are used to multiply energy bought in the building with a specific factor depending on how energy is produced. These primary energy factors are strongly favoring the use of renewable energy resources. At the same time they will steer towards low-energy buildings if electricity is used as a primary source of heating energy. In the future this will surely change heating system distribution in the Finnish building stock in a way that primary energy savings will be larger than 20%.

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