

# **SUCCESS FOR ENERGY EFFICIENT RENOVATION OF DWELLINGS**

## **-Learning from private homeowners**

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### **Abstract**

Large scale energy efficient renovation of buildings is one of the most important tools to realize the society's need of a more sustainable building stock. Most Norwegians own their own homes. Therefore private homeowners are a focus group for the government urging to accelerate the dwelling energy efficiency rates. Success factors were identified in the in-depth study of the decision process of eleven homeowners. Large differences in energy use due to the building's condition and the occupants' behavior was encountered in the sample. Only homeowners who were conscious consumers and did not trust expert advice or that had special knowledge due to their professions succeeded in realizing energy efficiency by renovation. Lack of knowledge, bad advice from craftsmen or priority to work that they can do themselves stopped other homeowners from implementing energy efficiency. Increased knowledge on all the gains from energy efficiency, the availability of attractive products and services as well as easy access to reliable advice on the better renovation solutions have a large potential to get more homeowners to make energy

efficient choices in the process of renovation. Coordination of more of policy strategies including specific information and incentives are needed to facilitate this.

**Keywords:** dwelling, renovation, energy efficiency

## ***Introduction***

Homeowners are most likely to improve the energy efficiency of their homes when they are already in a process of making changes (Enova, 2012, Strandbakken, 2006). Therefore, every engagement with the building that does not include energy efficiency improvements is a missed opportunity. What is even worse, those who renovate without including energy efficiency measures, are likely to experience an energy lock-in since it is not likely that *any* changes to the building will be made until the next time renovation is needed.

We know from earlier research that homeowners wanting to renovate energy efficiently face several barriers related to low energy prices, lack of attractive products and services, priority to comfort and other non-energy aspects, and insufficient coordination of initiatives, incentives and regulations (Reddy, 1991, Strandbakken, 2006, BarEnergy, 2011). In this contribution, which of these barriers actually influence the decision process leading to home improvements is analyzed in depth. These decisions are made as part of a stepwise process constituted by initiation, planning, designing, contracting-/bidding process, financing and ordering the work or doing the work themselves. Different complications can emerge at the different steps of the decision process (Enova, 2012).

In the present paper we focus on those homeowners that have overcome the barriers towards energy efficiency. After an introduction into the Norwegian context in the next chapter and a general description of the studied buildings' condition and energy use, success criteria are identified. Finally, policy strategies are discussed based on the identified success criteria to demonstrate how policy instruments can facilitate large scale energy efficient renovation of dwellings.

### ***The Norwegian context:***

#### ***World champions in home improvement***

Every year when new statistics is published, Norwegian newspapers celebrate Norwegians as the world champions of home improvement. A steady influx of revenue based on oil and gas exports combined with an active welfare state and low unemployment rates has made the average Norwegian a wealthy home owner. A significant part of this wealth, more than €6.2 billion in 2011, is spent on upgrading the 2.3 million Norwegian dwellings (Statistisk sentralbyrå, 2010).

These upgrades are not primarily motivated by energy or climate related concerns. They include redecoration such as new floors/wall coverings and bathroom fixtures, but also renovation including repairs and replacement of components and improvement of the qualities of the dwelling. Whereas the redecoration measures result in an aesthetical upgrade of the home and do not have a direct energy saving potential, renovation deals with the technical condition of the dwelling and are directly relevant. In fact, a recent report concluded that incremental renovation and especially improvements of the building envelope can explain 37% of the stabilization of Norwegian household energy use since the 1990s (Hille et al., 2011).

However, this stabilization has been achieved on a high level of electricity use placing Norwegians after Iceland on second rank in per capita electricity use.

30 TWh of the Norwegian energy use in 2009 was related to the 1.2 million single family houses (Statistisk sentralbyrå, 2010). Sustainable renovation of single family houses has huge potential to reduce Norway's energy use if it is done on a massive scale (Dokka et al., 2009, Thyholt et al., 2009).

Norwegian dwellings from the 1980s have the highest energy use compared to dwellings from other construction periods (Bøeng, 2005) probably due to the large areas of these dwellings compared to dwellings from previous periods. Buildings built in the 1980s are also at a stage in their lifetime where major renovation actions, such as new windows and ventilation system, are needed during the next 10 years (SINTEF Building and Infrastructure, 2010).

In a previous study effective measures to reduce the heating requirement in this type of building were analyzed: improved insulation of the facades, better windows, improved air tightness of the building envelope and installation of ventilation with heat recovery were identified to be the most interesting candidates for energy efficient renovation (Risholt et al., 2011). It was also demonstrated that a net or nearly zero energy balance for operation of this kind of renovated 1980s single family house is theoretically possible even in Norwegian climate. Improvement of facades, new windows with three layers glazing, ventilation with heat recovery and installation of renewable heat production have been shown to potentially be cost effective for such a 1980s house if it has high heating loads (Risholt and Time, 2012).

## ***Research approach***

The research presented here was done as a case study (Flyvbjerg, 2011, Yin, 2003, Stake, 1995) of Norwegian privately owned single family houses from the period 1980-1990.

In a first step, the energy efficiency status for 102 dwellings was mapped. Condition reports from visual examination (Standard Norge, 1995) were analyzed for 91 single family houses. The technical condition and the home upgrade status of the 91 houses were analyzed and categorized (Risholt et al., 2012). In addition, energy efficiency data of eleven buildings was studied through a detailed analysis of the technical condition of the houses, the dwellers' energy behavior, their renovation decision processes and their experiences from renovation. These buildings were chosen by contacting home owners in a suburban location outside of Trondheim and selecting houses with a large floor area requiring substantial energy quantities for heating in the cold season. Houses were chosen to represent different renovation status and different owner occupancy periods.

This data, which is reported here, was obtained from in depth interviews (Kvale and Brinkmann, 2009, Tjora, 2010) of the homeowners and visual observation (Standard Norge, 1995) of the inside and the outside of the dwelling. The interviews took place in November 2011. An interview guide including questions on energy use, energy efficiency, the quality of living in the house, the technical condition of the house and the renovation experiences was the basis for the semi-structured interviews. The interviews were transcribed, coded using an inductive scheme, and grouped according to contents and associated concepts.

Table 1 summarizes the renovation status for the eleven dwellings and table 2 shows the constructional details.



Table 1 Renovation status for eleven Norwegian single family houses built in the period 1986 -1990

Dwelling	Floor area [m <sup>2</sup> ]	No. of dwellers	Renovation and energy efficiency status
A	190	4	Balanced ventilation with heat recovery, air-air heat pump, Interior partition wall, new windows, renovated bathrooms, upgraded kitchen, new flooring, redecorated and insulated basement
B	150	2	Renovated bathroom, new roof windows, upgraded outside entrance area
C	200	2	Air-air heat pump, new flooring in basement, upgraded outdoor area
D	200	2	Air-air heat pump, some new windows, renovated bathroom, interior surface renewal
E	250	2	Air-air heat pump, some new windows, new flooring in basement, new roof
F	180	3	As built
G	180	2	Air to air heat pump, renovated bathroom
H	220	4	Renovated laundry, renewal of interior surfaces
I	200	3	New windows, repaired moisture damages, renovated bathroom, new fireplace and chimney
J	230	4	Two air-air heat pumps
K	260	5	100 m <sup>2</sup> extension, major renovation including new floor plans, balanced ventilation with heat recovery, new windows

Table 2 Constructional details for eleven single family houses built in the period 1986-1990

Building element	Wall	Roof	Floor	Window	Ventilation	Heating system
Constructional details	Wood frame construction with 15 cm mineral wool	Wood frame construction with 20 cm mineral wool <sup>1)</sup>	Concrete slab on ground with 5 cm polystyren insulation	Wooden window with 2-layered glazing <sup>2)</sup>	Exhaust ventilation <sup>3)</sup>	Direct electric and fire wood

- 1) House E is built with 25 cm mineral wool in the roof
- 2) House A and I has new windows with 3-layer glazings. House B has original windows with 3-layered glazing.
- 3) House A and K have installed balanced ventilation with heat recovery

## ***Variations in energy use in the sample***

One of the eleven interviewees had no knowledge of the energy use and did not have access to the households' electricity invoices. Table 3 shows the energy use of the other ten inspected dwellings based on the homeowner's own information. The numbers give an average energy use of 150 kWh/m<sup>2</sup> with a standard deviation of

40 kWh/m<sup>2</sup>. 140 kWh/m<sup>2</sup> average energy use for single family houses from the 1980s was found in a study by Enova (Enova, 2012). These real life energy use numbers are lower than those obtained from nominal calculations. The Norwegian norm for energy calculations in dwellings NS 3031(Standard Norge, 2007) assumes an indoor temperature of 21°C in all occupational rooms, including bedrooms, in the heating season. This is not the case in real life where bedroom temperatures often are kept lower than 21°C. NS 3031 also set nominal values for air exchange rates and domestic hot water production that are higher than a real life situation for a single family house built in the 1980s.

Table 3 Energy use for operation of ten Norwegian single family houses built in the period 1986-1990

Dwelling	A	B	C	D	E	F	G	H	I	K
Annual electricity use [kWh]	25000	35000	22000	25000	35000	24000	16000	28000	36000 <sup>1</sup>	25000
Annual energy from fire wood [kWh]	5000	1000	3500	0	1000	3000	5000	3500	2000	2000
Annual energy use [kWh]	30000	36000	25500	25000	36000	27000	21000	31500	38000	27000
[kWh/m <sup>2</sup> ]	159	240	128	125	144	149	118	143	189	103
Base load [kWh]	12000			12000		14000	12000	15000		
Space heating and lighting [kWh]	18000			13000		13000	9000	16500		

<sup>1</sup> before replacement of damaged windows

Five of the eleven informants could document their energy use in the summer months. The summer use represents the base load which is the season independent electricity specific need for domestic hot water, ventilation, domestic appliances and home electronics. The good access to daylight in summer results in hardly any energy use for lighting (Mysen, 2008, Standard Norge, 2007). The winter loads include lighting and space heating in addition to the base load. The annual base load in table 3 differs from 12000 to 15000 kWh constituting from 40% to 60% of the overall energy use. The winter loads for the ten houses in table 3, assuming a base



load of 13000 kWh for those not documenting it, ranges from 9000 kWh (dwelling G) to 25000 kWh (dwelling I).

Based on the interviews and visual observations, the differences in energy use in these otherwise comparable buildings are related to the condition of the building's heating system, the building envelope and the interior floor plan.

Homeowner D, for instance, uses electricity for heating and has installed an air to air heat pump and has experienced annual electricity savings of 8000 kWh. This illustrates his willingness to invest in renewable heat production. However, his willingness to do work on the building envelope to reduce the heat loss was low which is in accordance with the findings of Gireesh et al (Gireesh et al., 2010). To add on insulation to walls and the roof was looked at as negative due to the inconvenience and also uncertainty on the actual resulting energy savings.

*"Obviously I would have used less electricity for heating if we had 5 cm more insulation in the walls. But so what? It is just the way it is. I can not start tearing down the roof to add 20 cm. Because I don't believe in it. The same for the walls. So I have no potential for saving energy, within reason." Homeowner D*

The energy saving due to a renovated air tight building envelope, depends on the as built air tightness. The air tightness of the building envelopes differs between the ten houses shown in table 3. Seven of the homeowners stated that the air tightness of their house was good and three stated that the airtightness was poor, as in this example:

*"The house is an open shell/hull. The need for heating is higher when it is 0 degrees and wind than in calm weather and minus 20. We have a leaking house and*

*that's a fact. And yes, it is a 1980s house, because of the large volume. And they did not have focus on air tightness back then."*

The heating needs also differed due to the interior floor plans of the houses. The houses B and F were quite similar in size and exterior architecture, but house B had a much higher heating load than house F even though house B had windows with 3-layered glazings. The indoor temperatures were the same in the two houses. The crucial difference was in the floor plans of the houses. House B had one big open volume from the basement to the roof, see figure 1. The living rooms in the 1<sup>st</sup> floor and the loft were connected by an open stairway and only separated by a railing constituting one big volume. House F also had an open stairway allowing some heat convection between the floors, but not to the same degree as house B. The very open room plan of house B allowed the heat to rise up to the loft and there was no forced circulation or recovery of the air. This gave a constant need for heating of the basement and first floor in the cold season.

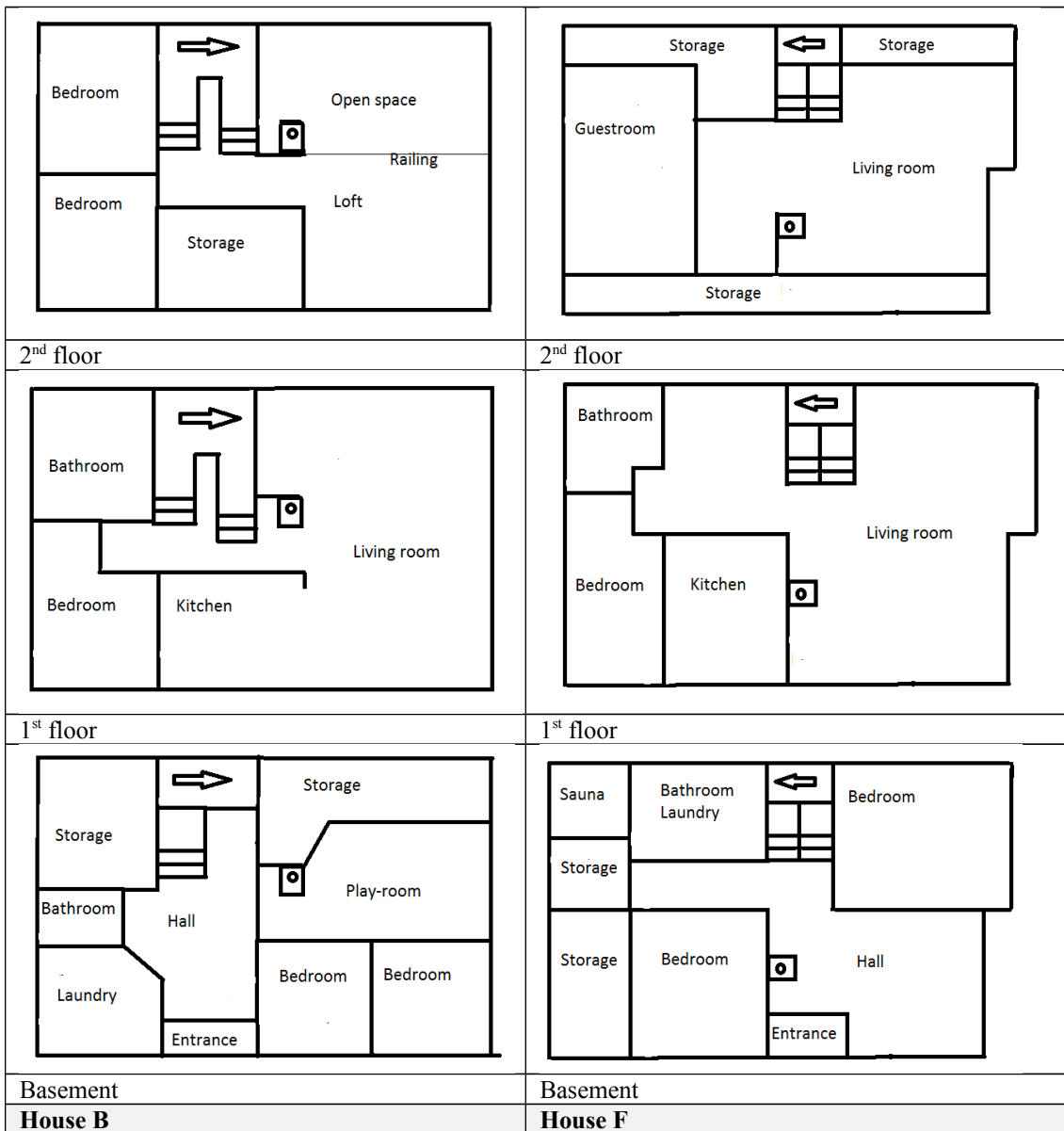


Figure 1 Floor plans for houses B and F

## ***The energy saving potential of every day life:***

### ***What is “appropriate” energy use?***

It is necessary to look at the cultural and social meaning of the homes of Norwegians to understand the energy behavior. The Scandinavian and particularly the Norwegian home has an important cultural and social function (Aune, 1998). The home is a place for family life and entertaining guests (Garvey, 2005, Garvey, 2003). The interior is a symbol of uniqueness and the exterior is a symbol of uniformity with society (Støa, 1996, Gullestad, 1989). Norwegians use energy to have a comfortable indoor temperature, good air quality, an abundance of light in the dark seasons as well as to have the electrical appliances that are deemed necessary for their standard of living. Table 3 shows that 40 – 60 % of the energy use for the ten dwellings was related to electric appliances and domestic hot water production. It is evident that for saving energy and electricity, notice should also be given to the user aspects and all the appliances in a home, not just reduced heat loss and renewable heat production.

A certain indifference of Norwegians to energy use has been documented earlier (Enova, 2012, BarEnergy, 2011, Strandbakken, 2006) but could not be confirmed in this study. All eleven informants were very conscious about their own energy use. They implied unanimously that they only used the amount of energy necessary to reach an appropriate comfort level. But what “appropriate level” means was described very different from household to household.

The comparison of two households in the same neighborhood and their efforts to save energy illustrates this. Both were two person households being retired couples. The first couple was asked whether they want to save energy, they say:

*"We do try. And I don't think we use that much electricity. If the weather is nice I dry the clothes outdoor. Except from that it is not that much to do. Refrigerator, freezer and such things have to be on. And I normally keep the TV on. The bedroom windows are always open. We want to keep it cold there. But the rest of the house needs to be nice and warm."*

This couple does not succeed in their energy saving efforts, as they don't see possible ways of saving energy without affecting their quality of living in the house. The house needs to be warm and comfortable and all the appliances are indispensable. The personal loss of saving energy is emphasized stronger than the gains for society. On the other end of the spectrum is the other couple:

*"We have found out that we use much less than most people... I think we save energy because it's not so warm inside the house. When we visit others, I think it is so warm, 23 and 24 degrees. But that is too warm for us. We like 21. Now it is 20.6. But somewhere between 21 and 22 is appropriate. I think you can get used to having one or two degrees lower"*

Compared to the other households, this couple has had great success in saving energy. They have the same appliances as the other households, but use much less electricity for heating. They have installed an efficient air to air heat pump and uses firewood for peak load heating. But the main reason for their low heating need is that they keep the indoor temperature lower than the others. They don't see the lower

indoor temperature as a loss of quality of living. It is the others that have too warm homes.

Another way of describing the difference between both households is as being locked into different practices. Practices, the nexus between what people are doing and thinking on a regular basis (Reckwitz, 2002), in the first case leave no room for less energy use. In turn, the second couple could not use more energy on space heating, even if someone would want them to, because they have become used to a lower temperature.

Within daily practices of cooking, eating, sleeping, playing etc energy per se is usually invisible (Shove, 2002). In theory there are good possibilities for saving energy by using energy efficient appliances and energy labeling is meant to make these possibilities visible. As the following quote shows – homeowners do assess energy labeling when purchasing appliances, but it is only one of many factors being evaluated:

*"It is a part of the totality you get presented. But it is not the deciding factor for our choices. Then we have rather looked for. We just bought a washing machine. And we bought a Miehle machine because we thought it was of good quality. And it was silent. But energy is a part of it."*

The informants want to save energy. But they don't want this to have negative influence on their quality of living. This quality is an effect of a complex variety of factors related to daily practices. Even though our informants state their willingness to change, the benefits of energy efficiency are not a strong enough motivator, therefore the non-energy benefits related to cost, comfort, aesthetics and convenience

should be promoted to show all the gains from energy efficiency (Mills and Rosenfeld, 1996).

## ***The renovation initiation:***

### ***When is it necessary to renovate?***

Given the adversity to change described in the previous section, the question arises why there are people that implement energy efficiency measures at all. Current energy prices are perceived as being too low to make energy efficiency investments attractive for the homeowner (Reddy, 1991, Strandbakken, 2006). Therefore, many energy efficiency measures can only be cost effective if they are done when repair or renovation is going to be done anyway (Martinaitis et al., 2007). Exterior insulation of underground basement walls when a new drainage is installed is one example of this.

This resonates well with what our informants say about when their specific renovation needs emerged. The overall common feature stated by the homeowners in this survey, is that renovation was done when it was "necessary". Moderation is an appreciated value in Norwegian culture (Gullestad, 1989) and to do renovation when it is "necessary" is in compliance with this cultural value. As with the word "appropriate" above, the word "necessary" has different meanings for different homeowners. One non-controversial understanding of the word is to renovate when an element is at the end of its technical life. The extreme end of life situation is a damaged pipe in a bathroom leading to a water leakage that needs urgent repair. But for the sneaking damage, the assessment of when an element is at the end of its technical life varies greatly:

*"It all started with a couple of punctured windows. That we had to do something about"*



*"I have a couple of punctured glazings. Two or three that I probably ought to replace. And it cost almost the same to replace the window as two replace a glass pane. When it's not unavoidable, you can do replacements little by little. "*

*"The quality of the windows was catastrophic. There was a plastic glider where the sash should glide. That was worn out and also the locking handle. So the window slipped open. The water poured in because of the poor construction."*

A punctured glazing means that the insulating properties are degraded. But more importantly it means that you have condensation between the two glass sheets with loss of transparency, view and daylight. For the first homeowner this was considered a damage that is severe enough to initiate renovation. The second does not share this opinion. Only when it is unavoidable, as in the third example where the window is a safety risk, it is necessary to do a replacement.

The end of life assessment was also done based on aesthetic qualities or on a combination of more factors as in the following quote:

*"We worry and focus on certain parts of the house. Such as the bathroom. Is the membrane defect? Plus functional aspects. And there are other things, such as windows. And there are other factors than improving insulation. We observed rotten frames in some of the old windows. And we could see out through openings between the windows. There was no sealing of the joints. And there are visual factors, aspects of the house that we appreciate."*

Functional requirements due to change in family situation was also found to be a common reason for initiating home improvements

*"The motivation for the changes in the basement was to get the room plan we wanted. We wanted to replace a long and narrow hallway and inconvenient small bedrooms. We also needed to do something with the entrance area and get more space for storage. It was a complete chaos with three small children. The house had no defects before the renovation. A larger kitchen was also a motivation. We also needed a guestroom because of the family living far away."*

Another factor considered by some homeowners was the ability to do-it-yourself. The threshold to initiate works that you can do yourself was lower, than to decide to do work that require assistance of professional craftsmen.

*"I am hurt from my experience from the roof. I am very skeptical. I almost cry when I have to get a plumber or an electrician. I am very skeptical. But then it's not. It's something about my feeling of command, to manage something. In that aspect, I am like a farmer. A farmer does most tasks himself. He doesn't know everything, but still he manages to do it."*

The final aspect to initiate renovation that was encountered in the interviews was some mandatory requirement from the authorities. An inspection of the chimney in one of the dwellings resulted in a ban to use the fireplace. The homeowner had to install a new steel chimney and at the same time they installed a more energy efficient fireplace.

The findings of this section can be summarized in that Norwegians initiate home improvements and renovation when it is "necessary". Necessities may include damages or mandatory requirements that result in the need to repair or replace building elements. The concept also includes end of life assessments of building

elements made by the homeowner based on technical, aesthetical, functional and comfort performance criteria.

***From initiation to renovation project:  
Knowledge is power***

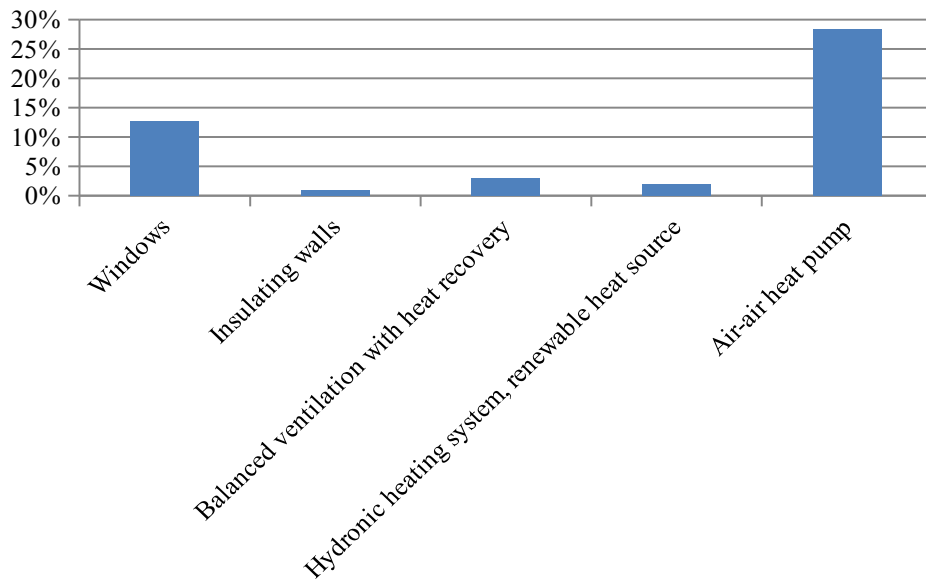


Figure 2 Energy efficiency measures for 102 Norwegian single family houses built in the period 1980-1990.

One important factor for success is the availability of products and services (Reddy, 1991). An example of this is the mass market success for air to air heat pumps in Norway. The heat pumps are available for the consumer from supermarkets and even door salesmen. An analysis of the energy saving status for 102 houses from the 1980s shows that 28 % of the houses in the sample had installed an air to air heat pump (see Figure 2).

In terms of efficiency, installation of balanced ventilation with heat recovery would have been a very good energy efficiency measure for the 1980s houses (Risholt et al., 2011). But in contrast to air to air heat pumps, ventilation aggregates are not marketed towards the end consumers. Only three of the 102 houses in this

study had installed balanced ventilation with heat recovery. The two interviewed homeowners that have made this investment were both mechanical engineers with expert knowledge in ventilation. For homeowners without this expertise, there was an absence of awareness and also a lack of availability of services.

*"I have tried to get someone to come and check the bathroom ventilation. And I have sat with the telephone book for days. Most seem to be working on large projects, something different than inspecting a house or answering my call. I did call a few, but they were busy and were going to return my call, but they never did. This was today. And I don't know who to ask. So it is the availability for the regular person."*

Without expert knowledge and without someone ready to offer this knowledge as a service, the question of risk becomes an important barrier towards energy efficiency. Risk is associated with new technology in several ways: will the energy saving be achieved? Will there be negative side effects? Additionally, there is social risk associated to innovative choices (Christie et al., 2011). Technical risk evaluation related to severity of damages was found in the interviews by priorities to renovate bathrooms that may cause damage to the wood frame construction over renovating bathroom in the masonry basement. Risk assessment was also done when professionals were hired. Many homeowners did tasks as painting and carpenter works themselves or by using their network, while they hired professionals for plumbing or electrical works:

*"Those parts of the house where we think the requirements are strict, there everything is done according to the book. It is done by certified companies. We are consistent in that. So we file reports from electricians and that kind of*

*documentation. We try to have an updated house regarding documentation. So things are traceable to avoid conflict."*

So prior to all renovation decisions are made, many factors are at play (Faiers et al., 2007). Possible energy saving is only one factor. Even for cost effective measures with short payback time, homeowners were reluctant due to other technological drawbacks as aesthetics and noise. The cost of renovation was evaluated against the known gains and drawbacks. In this phase after the initiation and before someone is hired to do the work homeowners evaluate risk and decide on which measure will be taken. This is an important time to influence the homeowners and to guide them to make the right choices.

Despite a far-reaching lack of information some homeowners still managed to make better choices than others. The decision process of homeowners A, D, I and K was analyzed to find why they were able to overcome the barriers against energy efficiency.

A common element in these four cases was that these informants were heavily involved in the design and planning of the renovation measures. None of them was indifferent to renovation and technical aspects and just hired someone to come and do a job. These homeowners realized the need to renovate and to do the wanted improvements. They searched for information, planned and decided what to do and finally got the work done by hiring professionals or they did it themselves. They shared a strong commitment to the decisions to optimize the result in relation to the efforts and resources spent.

In addition to these commonalities, there were differences regarding what these homeowners actually decided to do, even though the reasons and needs for the renovation were similar. Window replacement was one example:

*"I knew there was something called three layered. But then I tried to check. And those who sold me the windows took it for granted that I should buy two layered. But if there had been any discussion, I would have checked it further."* Homeowner D

*"In the basement we bought two layered. We have three layered on this floor (1<sup>st</sup> floor). Here we have seating close to the windows. And there are large glazed surfaces everywhere. When we finally decided on that's what we wanted. But it was not an easy choice. The window manufacturer and the carpenters were indifferent. There was little advice on what where the better choice regarding energy and economy. They said that a two layer window is so good that it's more than you need."* Homeowner I

Both homeowners were told by the experts that windows with a two layered glazing would be a good choice for their home. Homeowner I, being the conscious consumer, did not take the advice for granted and ended up with a better product after making her own investigations. Homeowner D trusted the carpenter, being the expert, and got the worse product. This example shows the importance of being a conscious consumer in order to succeed in making innovative choices. It also identifies a structural barrier (BarEnergy, 2011). Carpenters have the role as experts on renovation of single family houses, but according to our informants they have little access to information on innovative products and little knowledge on the gains for the homeowner from energy efficiency. The carpenter's role is to fit the new windows in the wall. He earns no more money from installing a window with three

layer glazing than a window with a two layer glazing. But the three layered windows weigh more and are heavy to handle. The better energy efficiency measure is therefore actually less attractive for the carpenter making him an important barrier towards energy efficiency.

The lack of knowledge on the experts' side has to be compensated with knowledge on the side of the homeowner. As was indicated above, some homeowners are competent buyers due to their profession. Homeowners A and K are mechanical engineers and have installed balanced ventilation with heat recovery to save energy and to get cleaner indoor air. Homeowner D had calculated the savings meticulously to purchase an air-air heat pump that would work under the local climatic conditions:

*"I made a spreadsheet before I bought this heat pump. What pump should I buy? I looked into it and calculated. So I found out that I ought to buy this pump. It gave the best. And when I calculated, that was based on hourly, no day average temperatures for a couple of years that I found on the web. And I compared them with the characteristics of the different heat pumps and adjusted to our need. I calculated that I could save approximately 9000 kWh annually with this pump."*

Homeowner D

This is the same person that trusted the carpenter and ended up with two layered windows. This illustrates the case that a homeowner can have special knowledge regarding one element or technical system, but may lack knowledge on other parts. This also shows that the complex interplay between the components of an energy efficient house poses great challenges to homeowners who cannot rely on external expertise.

## ***A preliminary taxonomy of renovation styles***

Based on the interviews four categories of homeowners can be distinguished among the eleven informants (see table 4). These categories represent typical combinations of

- how the renovation is initiated,
- how information is sought, and
- how the renovation is executed.

The conscious consumers do not trust experts, but make their own investigations to make optimal decisions. They are open for advice and new technology, but need to verify the effects themselves before deciding. Different from this group is what we call the category of confident homeowners. They trust their own assessments and choose solutions based on their existing knowledge and advice from their network and craftsmen. Within this group we find different degrees of knowledge, ranging from ignorance to a sufficient amount. Informants within the “handy” category trust in their own assessment and give additionally priority to work they can do themselves. This group of homeowners will most likely renovate using traditional technical solutions.

The unaware category corresponds to The ignorant category defined by Reddy (Reddy, 1991) thus representing an information barrier. As the example of the homeowner D showed above a homeowner might belong to both the informed and unaware category depending on the situation and the renovation task.

Only the conscious and the informed have sufficient knowledge and make the optimal choice which reduces the risk for energy lock in. Both the unaware and the



“handy” homeowners, however, have a high risk for energy lock-in since they risk ending up with outdated energy efficiency technology.

Table 4 Categories of private homeowners and their ability to realize energy efficiency in renovation

The conscious	The confident		
	The informed	The unaware	The handy
<ul style="list-style-type: none"> <li>-looks for more information, using internet and their network</li> <li>- open for advice and new solutions</li> <li>-low/medium risk for energy lock-in</li> </ul>	<ul style="list-style-type: none"> <li>- repair and replace</li> <li>- aware of the condition of elements</li> <li>-aware of energy efficiency possibilities</li> <li>-low risk for energy lock-in</li> </ul>	<ul style="list-style-type: none"> <li>-does not have valid knowledge</li> <li>-unaware of own lack of knowledge</li> <li>-unaware of real condition of elements</li> <li>-high risk of energy lock-in</li> </ul>	<ul style="list-style-type: none"> <li>-give priority to do it yourself tasks</li> <li>-risk assessment if necessary to do works and hire professional</li> <li>-high risk for energy lock-in</li> </ul>

## ***Policy discussion***

The renovation project is a window of opportunity for the homeowner to realize energy efficiency and also to gain from the following non-energy benefits. In this contribution we have identified strong barriers for these opportunities to become realized. A set of strategic efforts is needed for market success for energy efficiency including regulatory, financial and communicative instruments (Reddy, 1991, Weiss et al., 2012).

Private homeowners need to be able to plan, design and order the renovation works. In this study, only conscious consumers or those that have knowledge in buildings and technical systems were successful. These groups are innovators, but not representative for the average homeowner. Information and knowledge on the possibilities and gains from energy efficiency is a key factor to make more homeowners successful in realizing energy optimal choices.

## ***Efficient Guidelines***

According to the interviews, the information needs to be trustworthy, easily accessible and specific. Information from the government and public institutions of today is often on a generic level. Previous research has shown that the and the effect of information on this level is positive in short term but diminishes after few weeks (Henryson et al., 2000). The positive sides of being more specific are well documented (Desmedt et al., 2009, Ellegaard and Palm, 2011).

The present study underlines the need for publicly supported guidelines for energy efficient renovation of dwellings, showing the specific gains and possibilities from a stepwise sustainable renovation process.

The present study contains four lessons that should be included into these guidelines to make them more successful.

First, it was shown that daily routines and practices and concerns for the overall quality of living are able to choke energy efficiency measures altogether. Therefore, these guidelines should also show the non-energy benefits of the renovation measures such as aesthetics, comfort, sound insulation, safety, maintenance, climate robustness, better functionality, flexibility and universal design (Mills and Rosenfeld, 1996).

Second, home owners have different renovation styles. The “handy” category of homeowner wants to be involved in the planning, design and execution of the renovation. Other groups such as the “conscious” category only wants to control the planning and design. Therefore, the guidelines for energy upgrades should offer different degrees of engagement.

Third, in order to destabilize established notions of “appropriate” energy use levels, demonstration of very ambitious energy standards can be effective (Reddy, 1991). Based on objections mentioned in the interviews, these demonstrators should focus on making homeowners experience low noise levels from modern balanced ventilation systems, the aesthetics of a solar collector and feel the comfort of a window with three layered glazing.

Fourth, for the initiation of renovation, it was demonstrated above that homeowners mean very different things when they unanimously say that they start renovation when it is “necessary”. To associate a lack of energy efficiency of components with a state of necessity for renovation should be a crucial message of the guidelines proposed here.

### ***Mediating actors***

Nine out of eleven home owners said that the Internet was their most important source for information in the renovation process. Guidelines published online can only be specific up to a certain point since they address an unknown recipient. As mediating actor between products, possible renovation measures and the specific end user, craftsmen play an important role. As was shown above, craftsmen feature in the interviews as barrier rather than as enabling mediator. Today, the craftsman has no gains from energy efficiency. What should be looked into is if the craftsman could be the one assessing the dwelling and preparing the plan for energy saving renovation. This would be a new service that would give the craftsman an economic incentive in energy efficiency. Training courses in energy efficiency of houses for carpenters could be a good strategy to make this possible. Moreover, the role of project managers for energy efficient renovation is a new business model that are being

introduced in the Norwegian market (Tommerup et al., 2010). The concept is a one-stop-shop where the homeowner has one contact point the project manager. The project manager plans and designs, is the manager of the building works, contracting and coordinating the craftsmen. Homeowner J used a project manager for their major renovation and experienced a smooth building process with little inconvenience for the family.

## ***Conclusion***

Large scale ambitious energy efficiency renovation of buildings is one tool to realize the society's need of a more sustainable building stock. Most Norwegians own their own homes. Therefore private homeowners are a key group to accelerate the dwelling energy efficiency rates.

Private homeowners identify the renovation need and decide upon renovation based on their needs, desires and capabilities. Homeowners that are conscious consumers or that have special knowledge due to their professions are the only ones that have succeeded in realizing energy efficiency. Lack of knowledge, trust in bad advice from craftsmen or priority to work they can do themselves stop other homeowners from energy efficiency.

Those homeowners that have decided to do renovation, and are in a planning phase on what to do, are in a window of opportunity for energy efficiency. Increased knowledge on all the gains from energy efficiency, the availability of attractive products and services as well as easy access to reliable advice on the better renovation solutions for their home can get more homeowners to choose energy efficient solutions. Today, due to a lack of knowledge and incentives, craftsmen are

an important barrier to energy efficiency. But they could play an important role as mediators between available products and the specific building that has to be renovated.

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