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by

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1. INTRODUCTION

1.1. THE PHD PROJECT

Denmark has, as a member state in the European Union, committed to reducing our energy consumption and CO2 emission drastically by 2020 and since the building sector is responsible for approximately 40% of the total energy consumption this section is an obvious place to start. Buildings erected before 1979 are responsible for 75% of the section's total energy consumption [1] and are therefore particularly interesting to look at.

During the 1960's and 1970's a massive building boom took place in Denmark and approximately 440.000 single-family houses where erected within 20 years. The high demand for a house in the countryside was caused by a number of building companies who offered standardized houses, which were alike and therefore the price was relatively low and the construction fast. This also means that today the Danish building stock has a high share of uniform houses from these decades which are in need of renovation due to the age of the materials and to futureproof them by bringing them up to date. In many cases these buildings have not yet undergone extensive renovation [2] and since they were built before the building regulations were strict about energy use and insulation levels there is a huge energy saving potential awaiting to be utilized [3].

In order to utilize the potential it is important that energy saving initiatives are included in the coming renovation projects. Both to reach the saving objectives, but also because it is economically sensible to do so now since many years will pass before another renovation is necessary due of age of the constructions. If the energy saving initiatives are done only to save energy and not when a renovation is needed, the project economy will presumably not be reasonable.

In the PhD project the focus is on the Danish single-family houses from the 1960's and 1970's and how the energy saving potential of 7,811 TJ [3] found in this building category can be utilized.

The project objective is to examine both the barriers preventing the energy renovations from happening and then to define motivation factors that can increase the number of private energy renovations in the future.

The first part of the project examined the overwhelming amount of barriers for private energy renovation with the homeowner, the architect and the contractor as users. The conclusions were that there are many reasons why the amount of renovation projects is not as high as desired. The barriers vary from lacking knowledge about the theme, the possibilities and the non-economic benefits, to uncertainty about the economy and lack of interest. Not one of the barriers is predominating, but many should be treated simultaneously to have the wanted effect [4]. Both the professional actors and the private homeowners experience a number of barriers, but in the following phases of the project the focus is on the private homeowner. He is the one to initiate the project, make the investment and the final decision, and if he does not have a positive attitude towards renovations then no renovation is performed. It is at the same time expected that the professionals will adapt to the demand and overcome the barriers if necessary [4]. The second part of the project had the objective of determining if the homeowners can in fact be motivated to conduct energy renovation and defining what these motivation factors are. To do this a questionnaire survey was conducted with 4.000 invited homeowners from the four largest cities in Denmark. Of these almost 900 completed the questionnaire about energy renovation, comfort and indoor environment, architecture and economy.

1.2. OBJECTIVE OF THE REPORT

This report presents results from the questionnaire survey mainly related to the project economy of energy renovations. First the respondent group is introduced and compared to statistical data. Secondly the

homeowners' knowledge about potential subsidies and counseling is presented followed by an overview of which initiatives the homeowners have previously implemented in their houses and if the reason for the implementation was energy savings. Thirdly a wish list of what the homeowners wish for in their house is laid out to investigate if any of the initiatives can have significant impact on the motivation for energy renovation if included as part of the gain.

Finally the respondents evaluate five concepts representing five different levels of energy renovation according to the required investment versus the benefits. This is to define the economic limit, where a renovation project despite a list of benefits is no longer interesting for the homeowners and to examine how the prices of the five concepts compared to the obtained gains are evaluated.

The results presented are the results of the average homeowner, where all replies are treated together and the respondent group is viewed as one homogenous group. The replies have also been analyzed by dividing the respondents according to eight demographic parameters (gender, age, age of children, the location of the house, time lived in the house, education, occupation and income) and where significant differences occur between the average homeowner and the subdivisions the results are presented.

2. METHOD

A large literature study about barriers of various participants in the private energy renovations in Denmark [4] concluded that the homeowners are the ones to focus on in the process of breaking down barriers and increase the amount of renovations. The homeowner makes the final decision about the start-up of the renovation and therefore it is crucial that he is motivated. The barriers faced by the homeowners are many and vary from lack of knowledge and interest in the topic, to uncertainty about both investment size and savings, lack of examples and unbiased information. To generate more and deeper energy renovations these barriers need to be broken down and the homeowner motivated to initiate renovation. The survey presented in this report had the objective of examining the level of interest and knowledge of homeowners, and defining the motivation factors most likely to motivate them. To do that different approaches and methods can be used depending on the underlying aim, the needed data, the timeframe of the project and the project resources.

There are approximately 440.000 single-family houses in Denmark and the owners of these should preferably all be motivated to perform renovation in the future. In this case it was of great importance to gather the opinion of as many homeowners as possible to have a sound foundation and a representative picture of the user group to build the conclusions on. The choice fell on a quantitative approach, since a large number of quantitative feedback (hard data) is trusted to be more valuable to this survey, than fewer and more informative qualitative replies (soft data). The structure, identical questions and therefore relatively easy data handling, allows for a high number of participants and the more participants the more representative will the results be (if the sampling of the participants is performed correctly). Quantitative studies can be carried out in numerous ways and for this study a questionnaire survey was chosen. This was done since it provides comparative answers, the geographic spread of the homeowners is not a problem, no personal contact is required and the cost of the survey can be relatively low. Furthermore the respondents can be anonymous which is preferred as some questions revolve around their knowledge and idealistic approach to environmental aspects, which is why it is also advantageous that no interviewer effect occurs with a questionnaire [5,10,11,12]

The questionnaire was divided into five themes;

1. Background information about the respondents; who are the respondents, their age, gender, residence location, income etc.
2. Energy consumption and renovation; knowledge and attitude towards energy consumption and renovation, evaluation of the current consumption, status of what is done so far and the need for renovation.
3. Architecture; Evaluation of the current architecture and lay-out, wish for changes and evaluation of three examples of change caused by energy renovation.
4. Comfort and indoor environment; Evaluation of the current situation, what is good comfort/indoor environment, energy renovation and comfort/indoor environment.
5. Economy; Knowledge of possible subsidies and counseling, preferred advisor, value of architectural, comfort and indoor environmental improvements, evaluation of five renovation concepts.

The respondents were selected by a combination of multi-stage cluster sampling and simple random sampling [5]. The target group is all homeowners of a Danish district-heated single-family house erected between 1960 and 1979. The collected data should preferably cover the same area as the target group and therefore the first cluster sampling defined four cities across Denmark; Aalborg (Northern Jutland), Aarhus (Central Jutland), Odense (Funen) and Copenhagen (Zealand). The second cluster narrowed the respondent group down to all single-family houses connected to the district heating grid within the four cities. Inside these clusters larger uniform areas were, by the help of the district heating companies, defined. Finally a simple random sampling was made within these, where 1.000 respondents were randomly selected in each cluster.

Each of these 4.000 homeowners was then provided with a personally addressed letter with information about the survey, how to complete the questionnaire on paper or online, contact information of the researcher and a printed version of the questionnaire with an envelope to return it in.

3. QUESTIONNAIRE RESULTS

3.1. VALIDITY OF THE SURVEY

The validity of the survey is examined to verify the results. 4.000 homeowners divided between the four largest cities in Denmark were invited to participate in the survey, and of these 883 persons chose to complete the questionnaire. The response rate of the survey is consequently 22%, which for a questionnaire survey is not high [5], but the total amount of replies is very high in comparison to pervious Danish studies in this field.

The uncertainty of the survey is calculated by a random check calculator, the confidence interval is calculated at 3.3% [6] meaning that the certainty of the survey is between 91.7% and 98.3% compared to the situation where a homeowner of every one of the 440,000 households had completed the questionnaire. These results are calculated on the basis of a confidence level of 95%, a population of 440,000 (the approximate number of Danish single-family houses erected between 1960 and 1979) and 883 responses. The confidence level is set as 95% which is the typical level used, apart from in medical research where this should naturally be higher because the importance of correct results is far more significant. To reduce the confidence interval by half, and thereby reduce the uncertainty of the research, four times the amount of responses is needed. A certainty between 91.7% and 98.3% is considered acceptable and, supported by the high number of replies, the survey is reviewed as being valid and the results trustworthy.

3.2. WHO ARE THE RESPONDENTS?

The respondents are all owners of single-family houses in Denmark, but there is more to them than that. They have in the questionnaire answered the following 11 questions about themselves and their household (Table 1). The number and percentages of respondents who have marked a given response option are displayed beneath. Not all respondents have answered all questions, which is why the percentages show the distribution of replies within each question.

Question	Reply option	Number	Percentages
1. Are you female or male?	Female	304	35%
	Male	564	65%
2. How old are you?	Below 40 years	118	14%
	40-49 years	132	15%
	50-59 years	166	19%
	60-69 years	277	32%
	70 years or above	168	20%

3. How many residents are there in the household in the different age groups?[1]	0-8 years	122	14%
	9-13 years	77	9%
	14-18 years	97	11%
	More than 18 years	644	88%
4. Where in Denmark do you live?	Northern Jutland (Aalborg)	194	23%
	Central Jutland (Aarhus)	211	25%
	Funen (Odense)	230	27%
	Zealand (Copenhagen)	224	26%
5. Ownership of house	I own the house alone	189	22%
	I own the house with a person in the household	630	73%
	I own the house with a person outside the household	2	0%
	My partner owns the house	43	5%
6. How long have you lived in your current house?	0-1 year	25	3%
	1-5 years	91	10%
	5-10 years	85	10%
	10-15 years	83	10%
	15-20 years	77	9%
	More than 20 years	510	59%

[1] The percentages illustrate where the household consists of one or more persons in the age group. Some respondents can therefore be represented in more than one group. If for example they have a five-year old child and one at age 11.

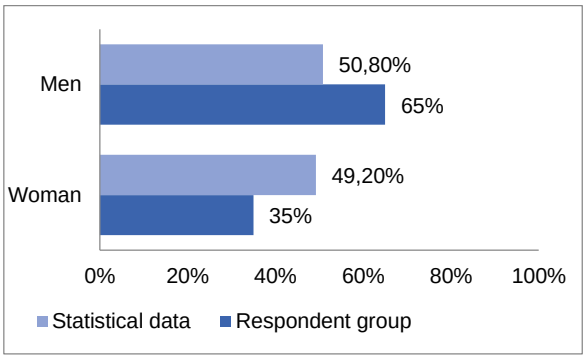
7. Is your current house the first house you own?	Yes	461	53%
	No	408	47%
	I don’t own the house	3	0%
8. Is your house heated by district heat?	Yes	815	94%
	No	56	6%
	I don’t know	0	0%
9. Please mark your latest finished education	Primary school	59	7%
	High school	27	3%
	Craftsman education	174	20%
	Short further education	289	33%
	Long further education	253	29%
	Other	65	7%
10. What is your occupation?	Enrolled in education <5%	8	1%
	Unskilled worker <5%	18	2%
	Semi-skilled worker <5%	11	1%
	Skilled worker	71	8%
	Salaried employee	212	24%
	Academic	126	14%
	Self-employed	44	5%
	Receive unemployment benefit <5%	20	2%

	Pensioner	365	42%
	Other <5%	16	2%
11. Please specify the total yearly household income before taxes	Less than 200,000 DKK	55	6%
	200,000 – 499,999 DKK	320	37%
	500,000 – 749,999 DKK	304	35%
	750,000 – 999,999 DKK	130	15%
	1,000,000 DKK and above	56	6%

Table 1. The 11 questions about the respondents demography, the reply options and the number and percentages of the total respondent group who have selected each option.

3.3. RESPONDENTS COMPARED TO STATISTICAL DATA

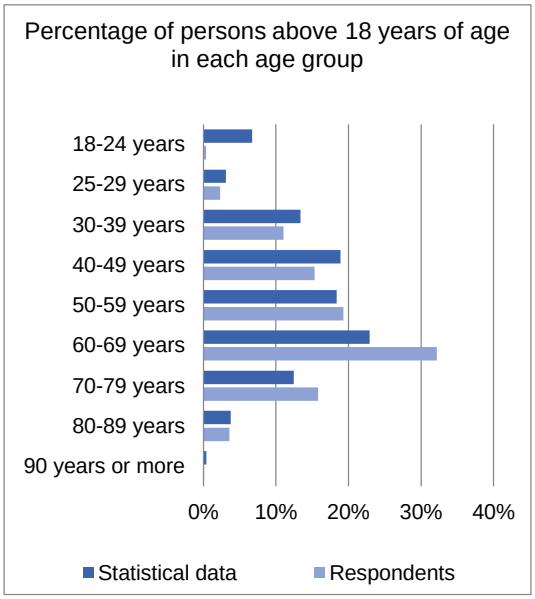
The aforementioned demographic variables which the respondents are divided by in table 1 are compared to statistical material were this was available. Three areas have been compared to the statistical data for Danish single-family houses erected 1960-1979; gender, age and place of residence. The difference between the data and the respondents is largest when gender is examined. Here the difference is approximately 15% in the distribution of women and men (ill.1). The respondent group consists of more men than the statistical data and a reason for this picture can be that the questionnaires were distributed to the owners of the house. Traditionally the man was the owner of the house and so a majority of the questionnaires can have been addressed to men. The consequence of this will be an overabundance of men replying. Since the survey was addressed to homeowners and the statistical data illustrates the distribution of gender in the households and not the distribution of gender among homeowners, this is assumed to be a reasonable conclusion.



ill.1. Distribution of gender in the respondents group compared to statistical data from Statistics Denmark of the distribution in Danish single-family houses erected between 1960 and 1979, for persons over 18 years of age [7].

The second parameter examined is the age of the homeowners and here the differences cannot be explained by who owns the house, who receives the letter and replies. Among the respondent group a larger share of persons above the age of 60 years is present than in the statistical data set (ill.2). The group aged 50 to 59 is identical and below the age of 50, the statistical data has higher percentages than the respondents group. Two reasons for this variance are found sensible; First it is possible that the sample of homeowners did not consist of enough homeowners below the age of 50 or above the age of 60. The age of the homeowners was not studied in the sampling process and therefore this can be a credible reason. Secondly the homeowners below 50 years can have choosen not to complete the questionnaire or a large number of those above 60 years could have choosen to do so. A combination of the two appears to be a believable explanation.

With these variations in mind, the analysis of the results should pay particular attention to potential tendencies caused by or enhanced by a majority of men and/or respondents above 60 years. If this occurs, it is crucial for the validity of the results that it is highlighted in the presentation of findings.



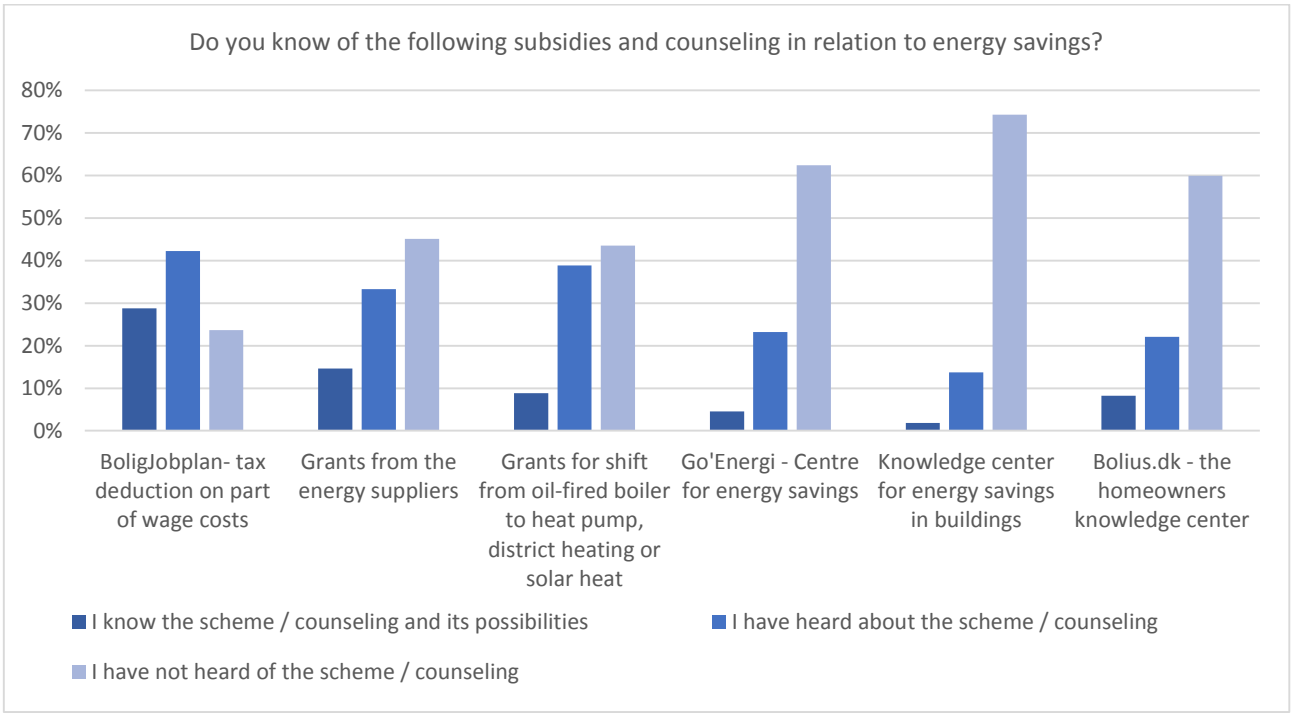
ill.2. The respondents distributed according to age and the statictical data from Statistics Denmark of the age distribution of occupants in Danish single-family houses erected between 1960 and 1979. [7]

The geographic spread of the respondents is between 23% and 27% in the four areas and according to the statistical data the distribution of single family houses in the four areas is between 32% and 19% [8]. The statistical data is collected for the four cities, but including the suburbs of Copenhagen, the surrounding areas where single-family neighborhoods are often found have not necessarily been included in the percentages. The spread of the respondents is naturally within a limited margin since an equal amount of questionnaires were sent out in each region. This is therefore not perceived as damaging the results, even though it differs from the statistics.

3.4. KNOWLEDGE OF POSSIBLE SUBSIDIES AND COUNSELING

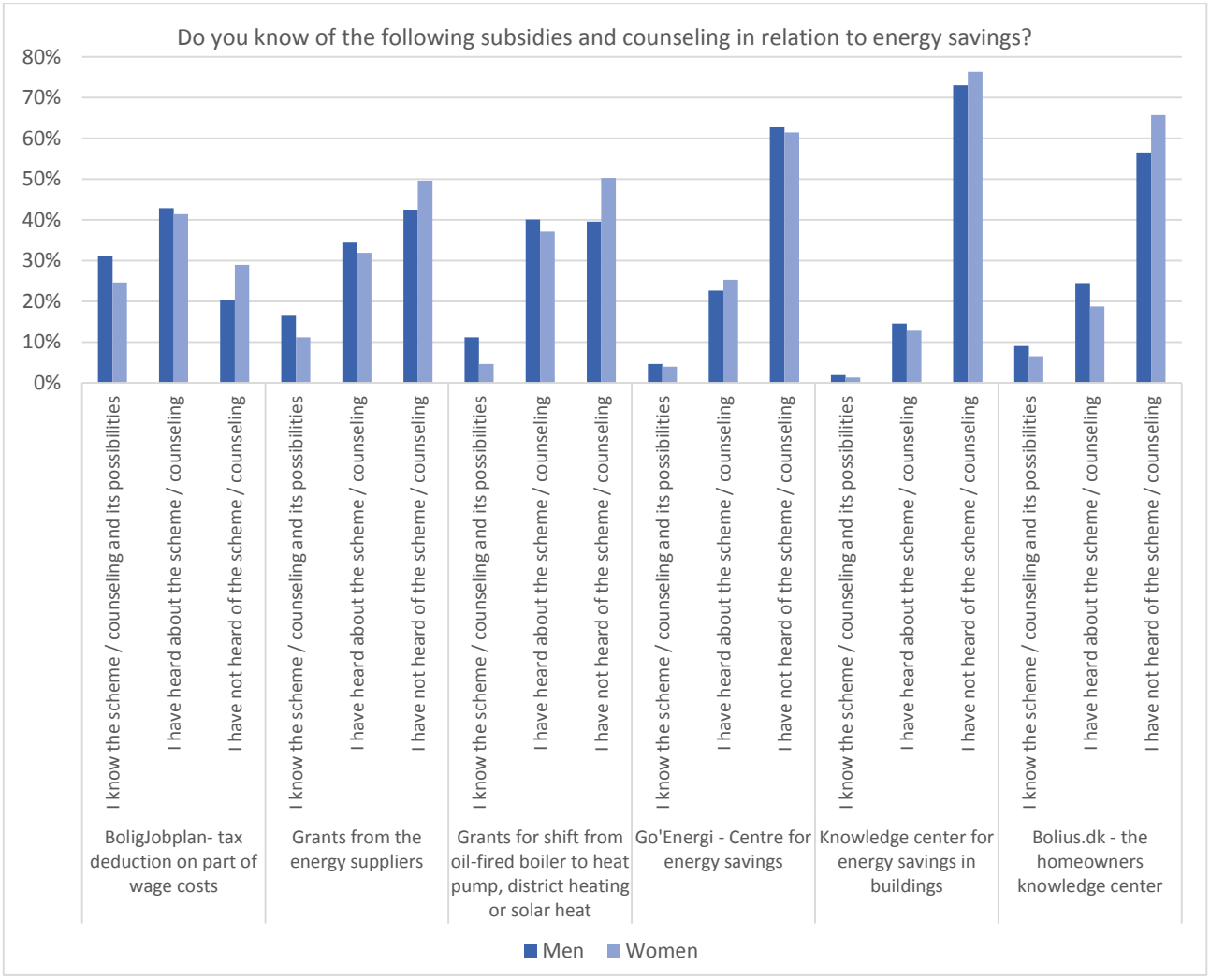
The knowledge of opportunities for subsidies and for counseling is examined to define the current level of knowledge and if more awareness has to be generated about the offers. Not all respondents have answered this question, but the presented results are calculated on the basis on the total respondent group (883 respondents) and in the following paragraphs based on the number of each demographic subdivision (table 1). The average homeowner has to a large extent heard about the possible grants, however not much knowledge about the specific possibilities is present (ill.3). The three listed counseling opportunities are neither known nor heard of by the majority of the respondents. Indicating that the homeowners are more

aware of the potential grants than of the counseling. This is however not surprising since the economy is a crucial factor for the owners in relation to energy savings [9].



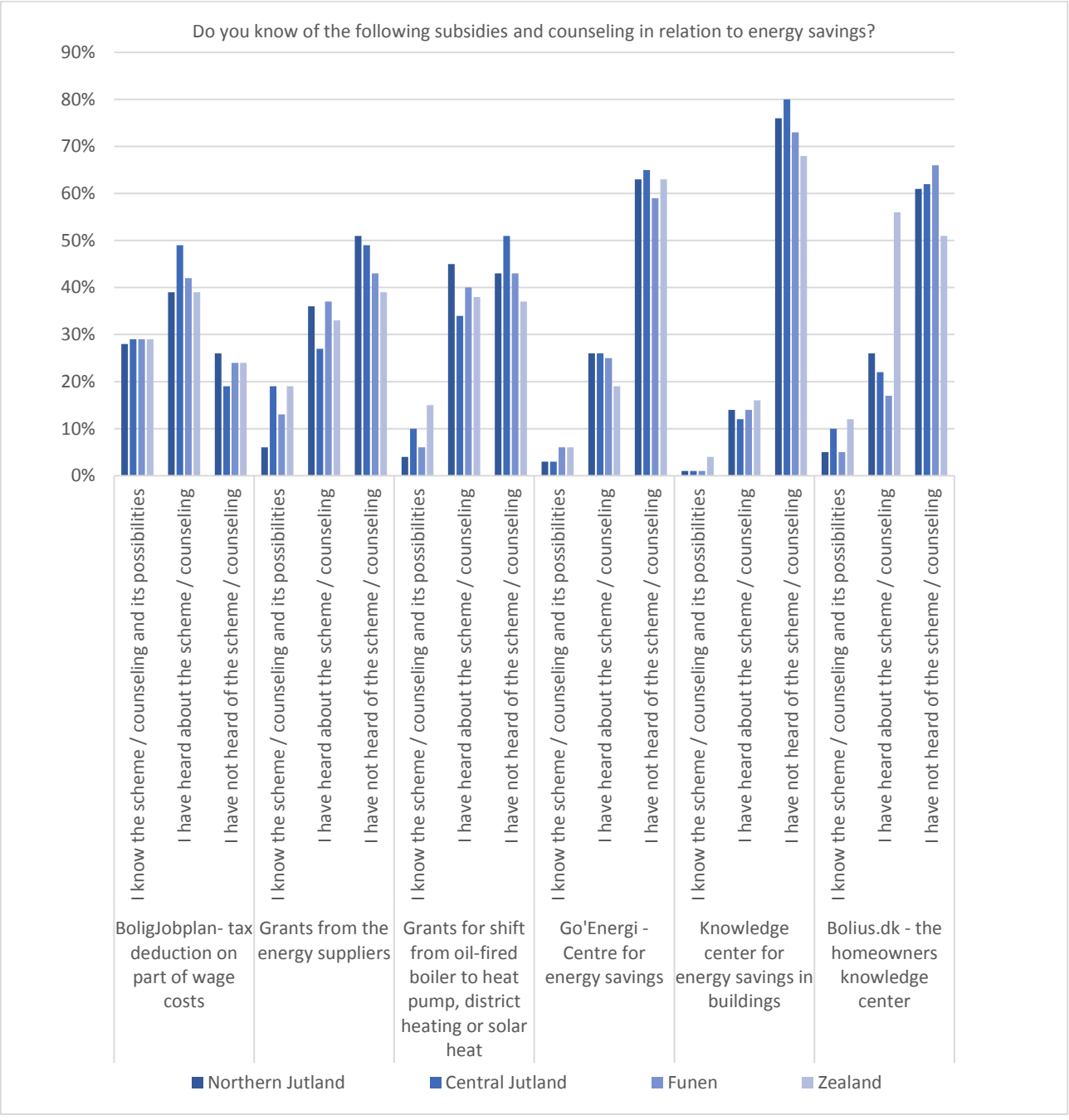
Ill.3. The average level of knowledge about possible subsidies and counseling.

The knowledge of the potential subsidies and counseling is close to alike for women and men, but the men have in general a higher knowledge about the offers and the possibilities here in (ill.4). The differences are however not significant enough to conclude that this is the case.



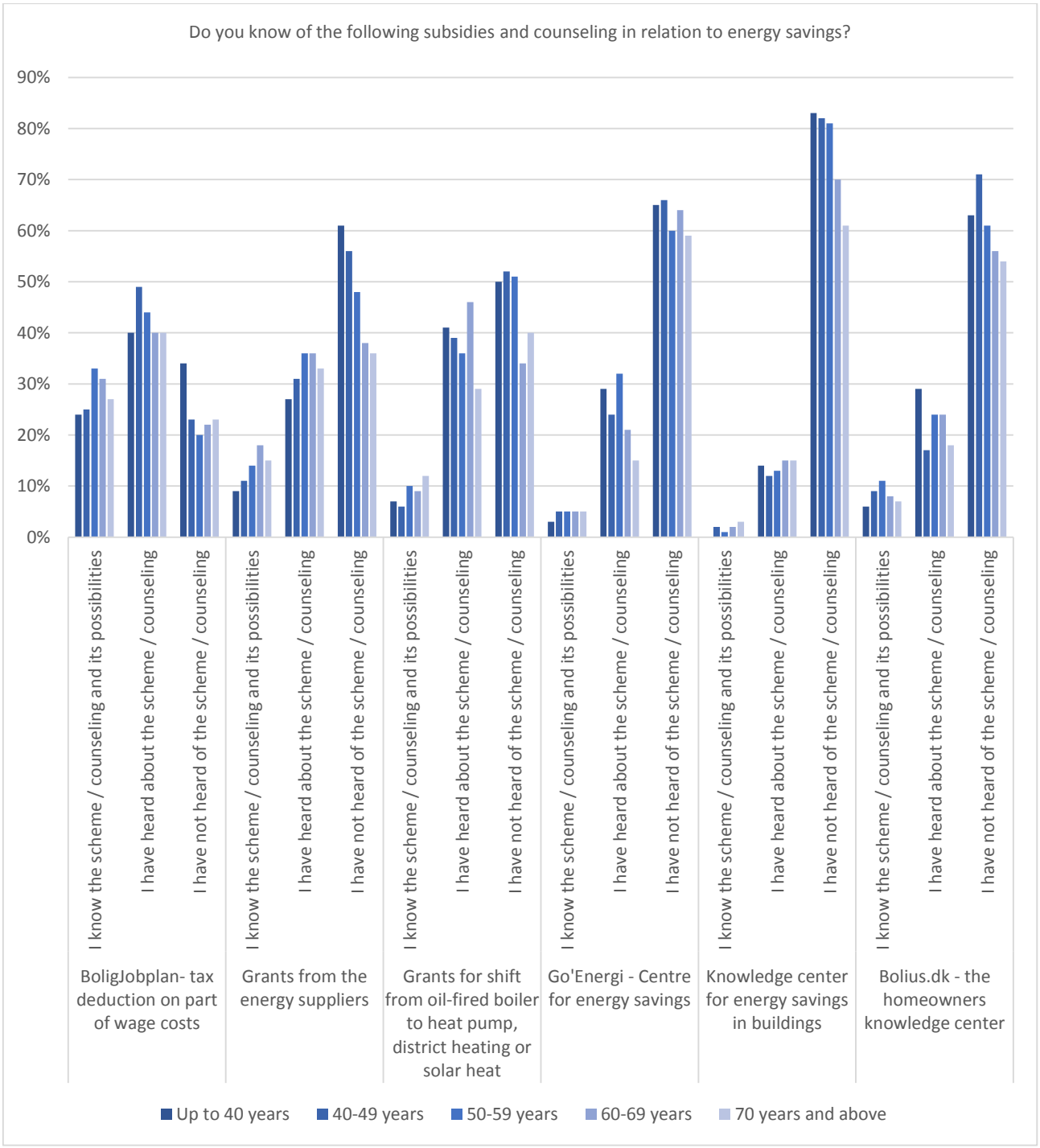
Ill.4. The difference between the women and the men in the respondent group when it comes to their knowledge about subsidies and counseling.

The geographic spread of the respondents has noteworthy influence on the knowledge (ill.5). The homeowners from Zealand have in general a higher level of knowledge about both subsidies and counseling than the remaining three locations. Those from Central Jutland have in some cases more knowledge than those from Northern Jutland and Funen, but this is not a consistent tendency.



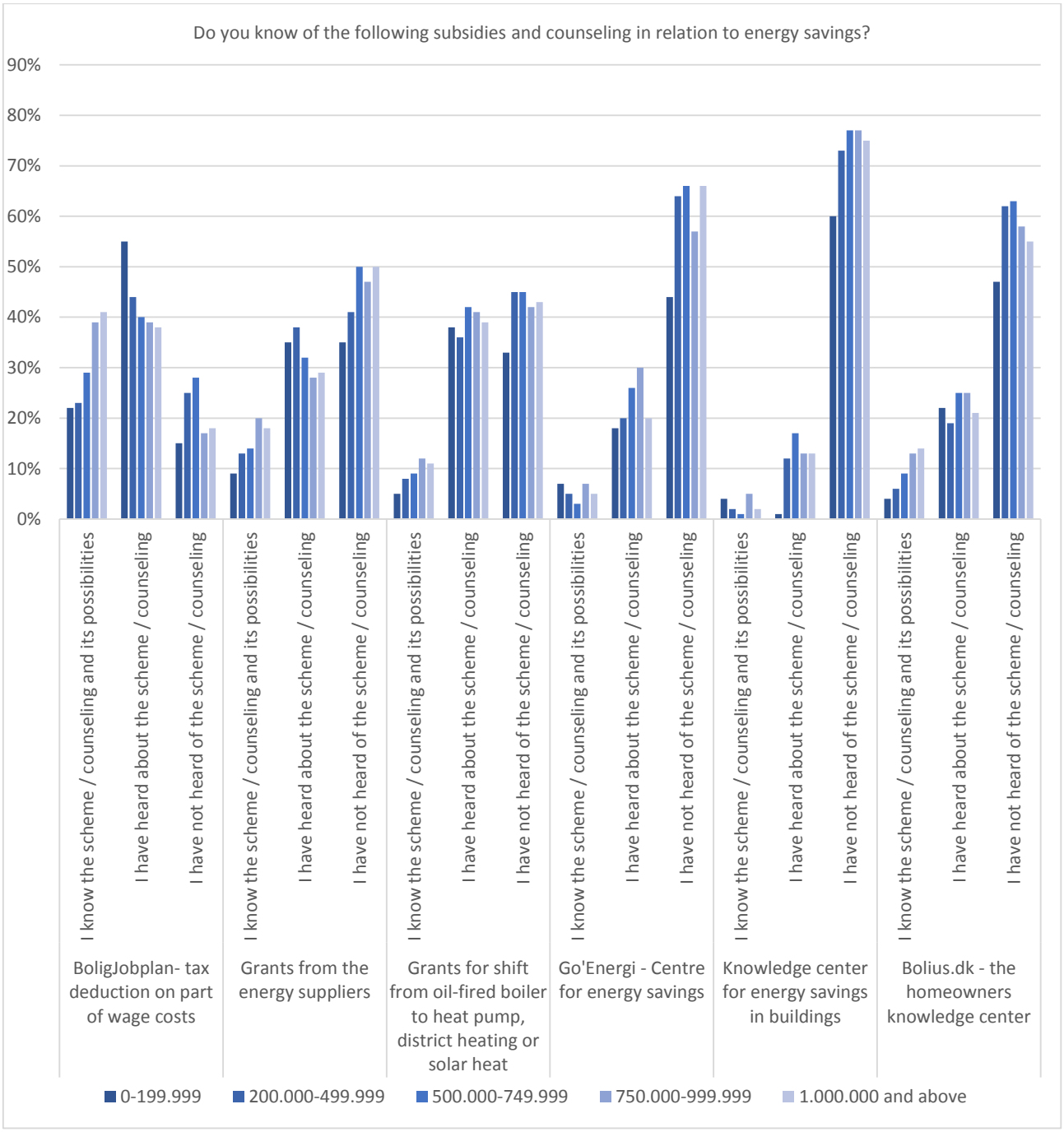
Ill.5. The level of knowledge about subsidies and counseling in the four regions.

The age of the homeowners has some impact on the knowledge of the opportunities. There is a tendency that the younger the homeowner, the higher the percentage that have not heard about the presented subsidies and counseling (ill.6). At the same time the younger the respondent, the lower the percentage that have knowledge about the possibilities within the subsidies and counseling. The group which has heard about the offers, but has no particular knowledge about the opportunities, varies depending on the scheme and counseling and no clear tendencies are seen here.



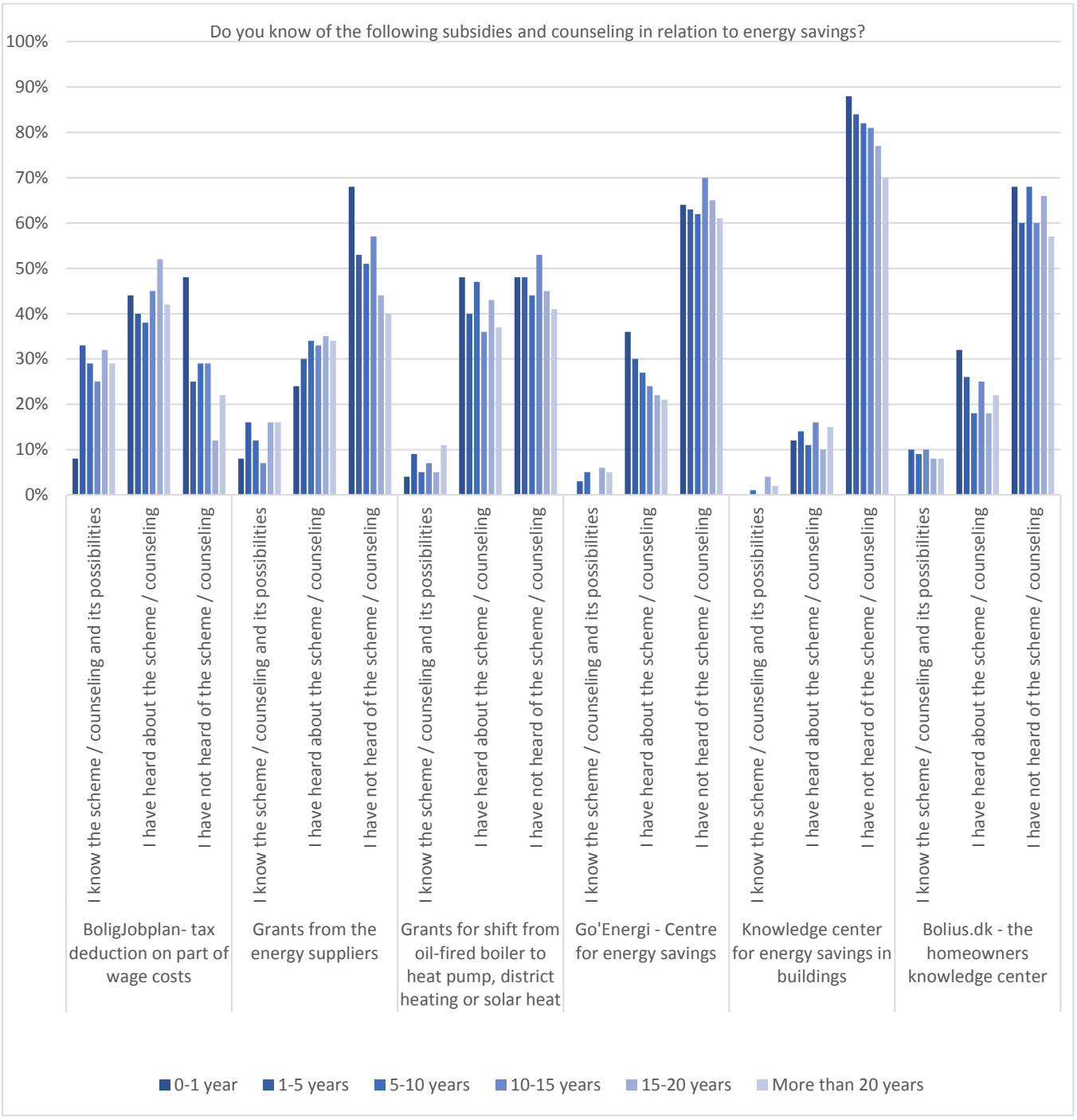
Ill.6. The knowledge level about potential subsidies and counseling among the five age groups.

When the respondents are divided according to the yearly household income, two tendencies occur (ill.7). In general the higher the income, the higher knowledge of the offers and their possibilities and the higher percentages of respondents have not heard about the scheme and counseling. This means that the high-income groups consist of both a high level of respondents with knowledge and a high level of respondents with no knowledge about the offers. No clear indications are seen in the amount of respondents who have heard about the scheme and counseling, but do not know about the possibilities.



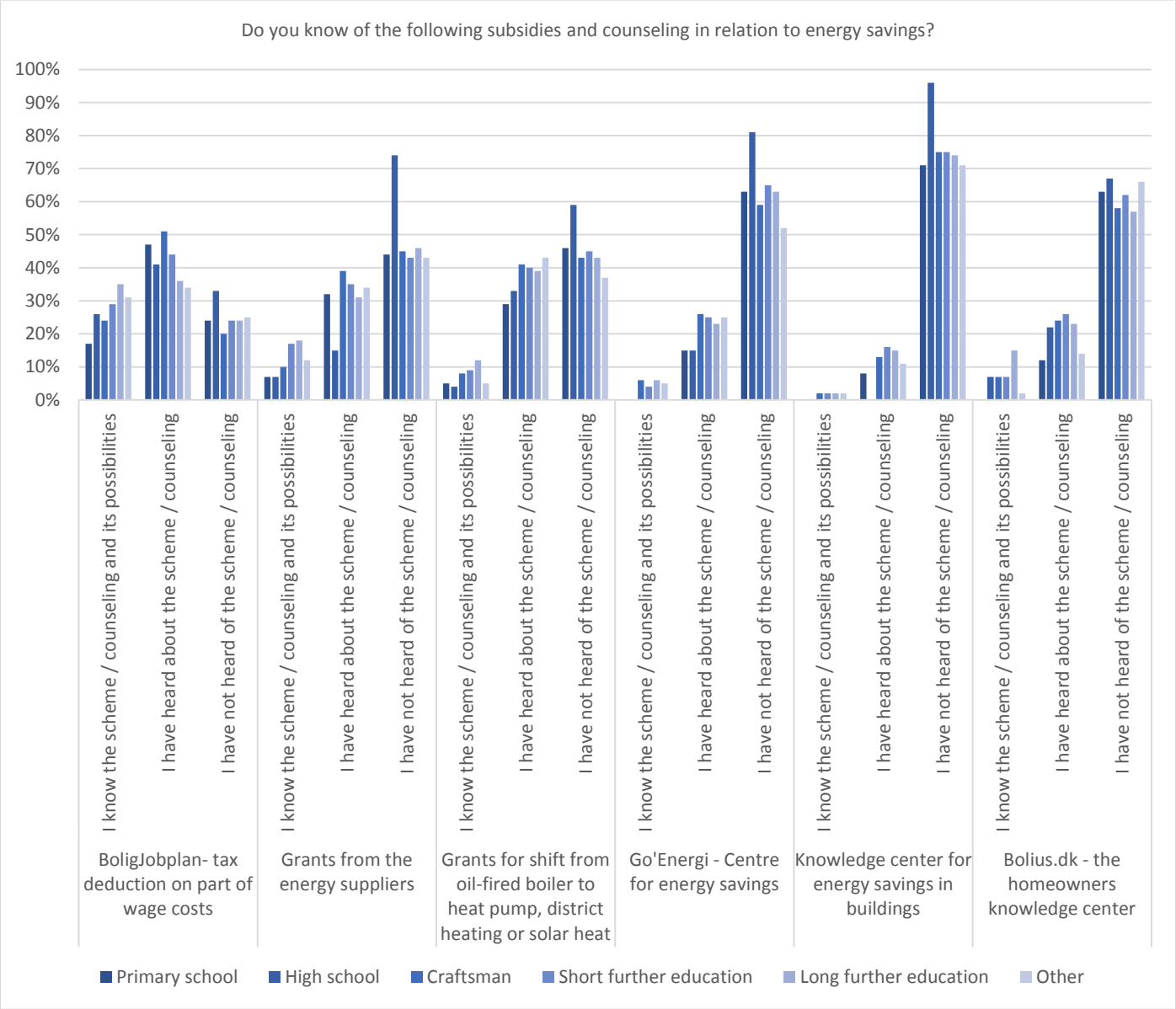
Ill.7. How the income of the respondents affect their knowledge about potential subsidies and counseling.

In general the longer the homeowners have lived in the house the lower amount of them have never heard about the grants and the counseling (ill.8). The knowledge about both the counseling and the potential grants is not significantly influenced by the time the respondents have lived in the current house, however indications are seen, that the homeowners who have lived in the house for less than one year have low knowledge about the possibilities of the presented offers.



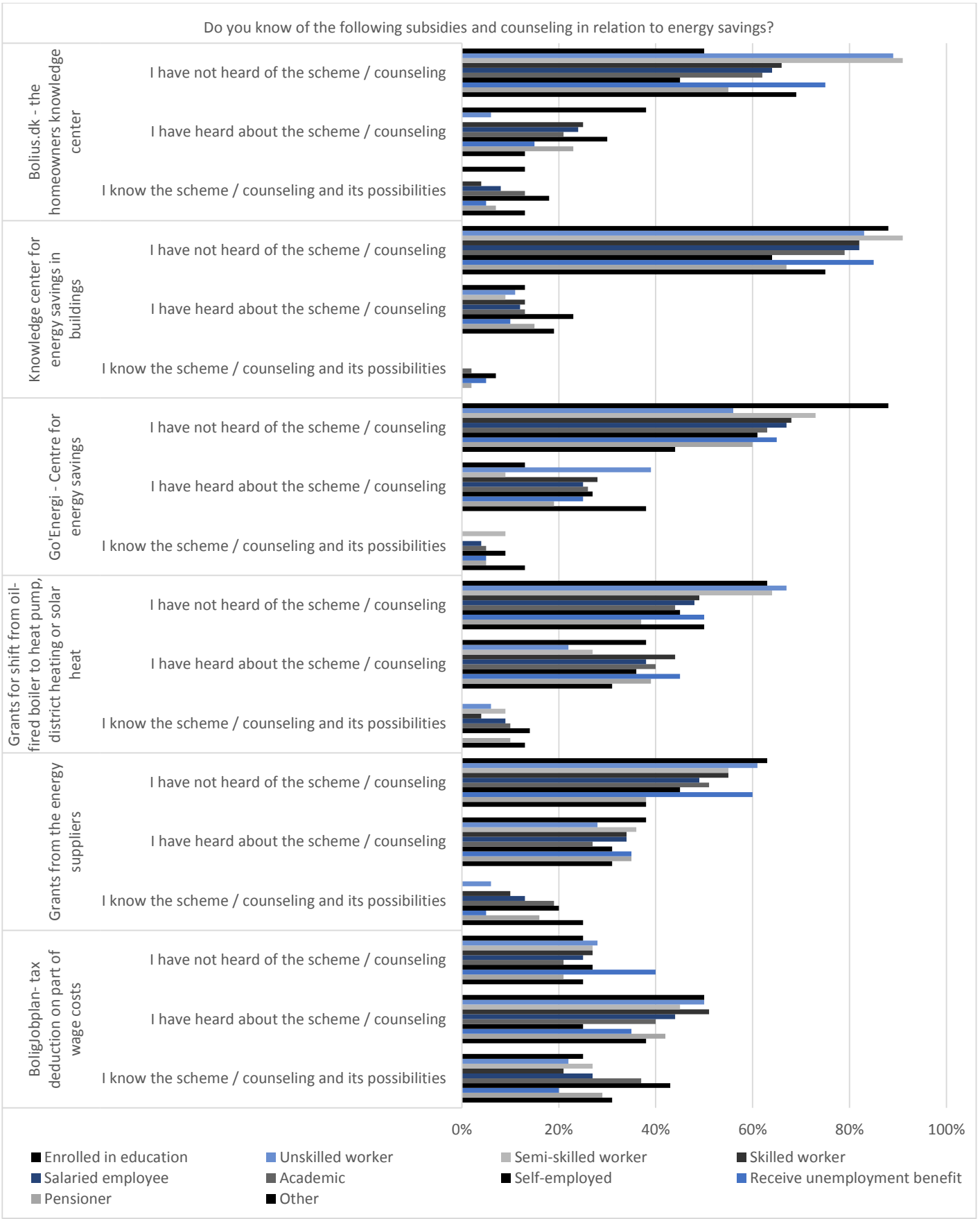
Ill.8. The level of knowledge about possible subsidies and counseling according to the time the respondents have lived in their house.

Two tendencies appear; Among the respondents with high school education, a higher percentage than in all other education groups have not heard about the presented offers and second, the longer the education the higher knowledge about the schemes and the opportunities within (ill.9). The knowledge about the counseling is more evenly distributed without clear trends pictured.



Ill.9. The effect of the respondents' education on the knowledge level.

Finally the division according to the current occupation is analyzed (ill.10). Here there is not a significant tendency reflected in all the presented offers, but there are indications that those employed at academic positions or are self-employed have a higher knowledge about the schemes and counseling and the possibilities herein. The results further indicate that between those enrolled in education, unskilled and semi-skilled workers and pensioners a higher percentage has not heard about the offers than what is the case in the other occupation groups.



Ill.10. The respondents' current occupation and its effect on the knowledge about subsidies and counseling opportunities.

3.5. PREVIOUS RENOVATION OF THE HOUSE

It is further examined if the respondents within the past five years have considered or conducted renovation of their house and if the reason for this has been energy savings. This is done to create an overview of the current situation in the houses and to see which areas the homeowners have already renovated and which are considered for the future.

From the numbers it is clear that some homeowners think about conducting energy saving initiatives and some have already done this. More than half of the respondents (54%) have changed windows in their house within the past five years, which is the largest percentage of the listed potential tasks. Furthermore, an extra 20% considered doing the same. Re-insulation of the attic is performed by 30% of the respondents and considered by an additional 22%, and the third most completed initiative, change of roof coverings, is conducted by 17% (table 2). The remaining tasks are considered or performed by up to 17% of the respondents, but in most cases fewer than that. What is also proven from this, is that it is not the extensive renovation initiatives which have been carried out or considered, but instead the relatively easy tasks and also those where the economics, in relation to investment versus energy savings, is reasonable or where the materials due to age need a replacement.

Renovation initiative	Considered	Conducted	The reason for consideration/ conduction was energy savings
Change windows	20%	54%	74%
Change the size of windows	5%	10%	71%
Change position of windows	3%	5%	77%
Place more windows	3%	6%	68%
Install skylights	5%	6%	62%
Insulate cavity wall	12%	6%	90%
Insulate attic	22%	30%	84%
Insulate façade outside	5%	3%	85%
Interior insulation	3%	6%	77%
Plastering the façade	6%	4%	69%
Change façade cladding	4%	6%	79%
Change roof coverings	14%	17%	71%
Make an extension to the house	6%	6%	64%
Exploit attic for housing	2%	1%	69%
Install solar cells and/or collector	17%	1%	89%
Install geothermal	3%	0%	75%
Other	2%	7%	73%

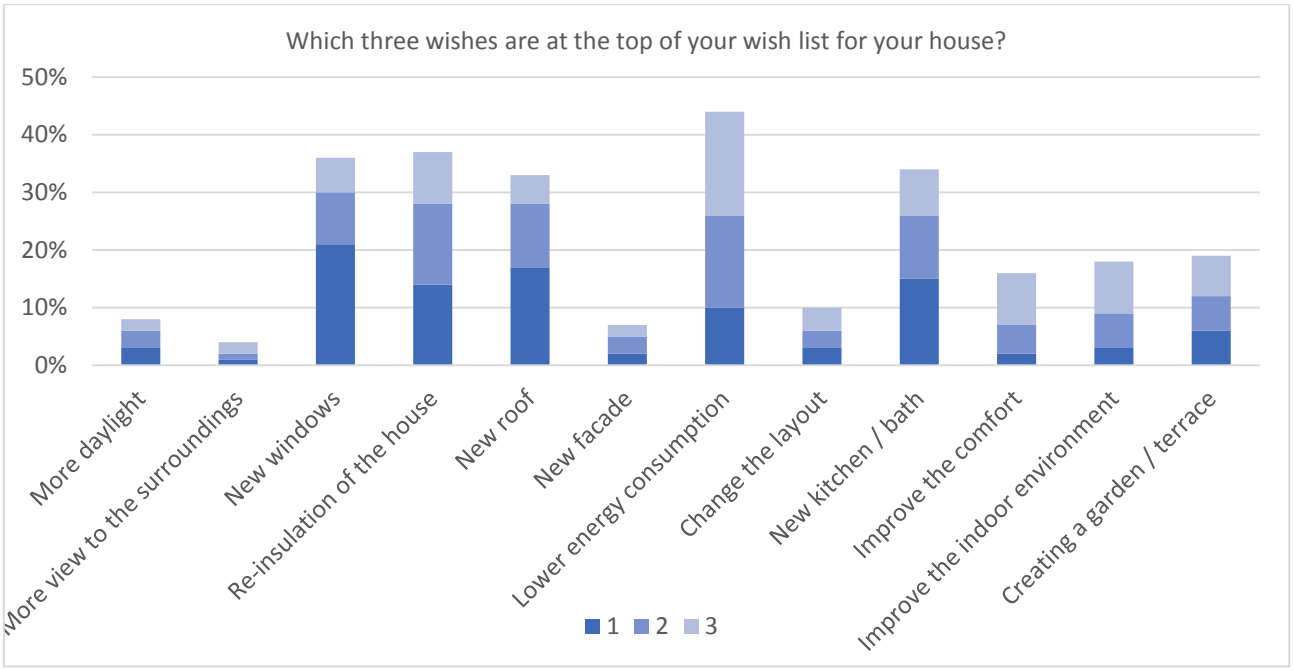
Table 2. The percentages of the respondents who have respectively considered or conducted 17 different renovation initiatives within the last five years and if the reason(s) was energy savings.

The willingness to renovate and the reasons for doing it can be many. For the tasks listed in the above table, the reason for conducting the job or considering it has in many cases, between 62% and 90%, been energy savings. Between 71% and 84% of the three most conducted initiatives are carried out to obtain energy savings.

3.6. WISH LIST FOR THE HOUSE

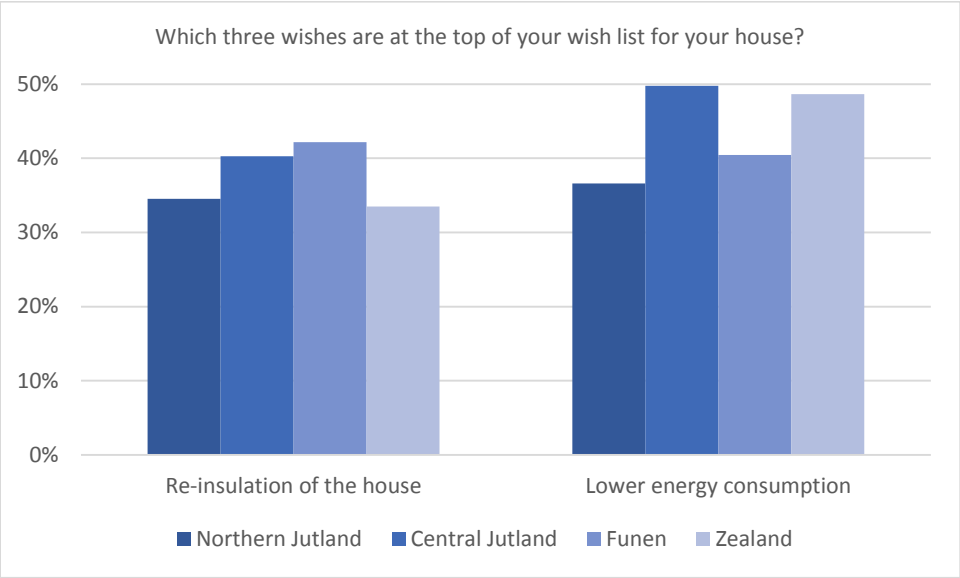
Twelve potential wishes were presented to the homeowners and they were asked to state which three of them were at the top of the personal wish list and which was at the bottom. This serves to identify aspects that might increase the motivation for energy renovation if they are part of the gain and which aspects the homeowners do not put much value in and can therefore presumably not be extra motivating. Five of the aspects stood out among the others as those the average homeowner wanted the most in/at his own house (ill.11). The five aspects are; Lower energy consumption, re-insulation of the house, new windows, new kitchen/bath and finally a new roof. Four of these can be natural consequences of energy renovations even

at a limited extent and if it is a very extensive renovation the final aspect (new kitchen/bath) can even be included, however without energy savings as result. This indicates that if one of these five aspects can be included in a renovation the homeowners will presumably be more motivated to conduct it. On the other hand is it not expected that a new garden/terrace, a new façade and more view to the surroundings can increase the motivation, since these aspects are the least desired by respectively 17%, 11% and 10% of the respondents.



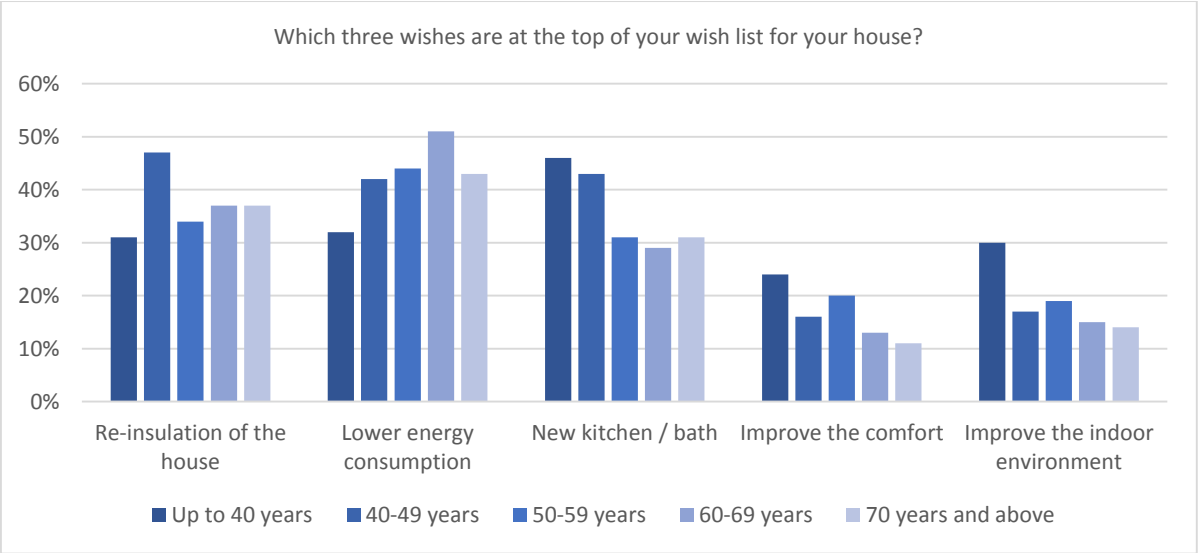
Ill.11. The average homeowners top three wishes for his house.

The gender have limited influence on the wishes, and most of them are evaluated according to the average results. In one case there is though a clear difference between women and men; 48% of the men have "lower energy consumption" in their top three wishes whereas the number for women is 37% (ill.12). The location of the house also has only little impact. The largest differences are seen in the evaluation of the wish "re-insulation of the house" where the homeowners from central Jutland and Funen desire this more than the respondents in the other regions and in "lower energy consumption" where those from central Jutland and Zealand have a higher percentage who have this among the top three wishes than what is the case for northern Jutland and Funen.



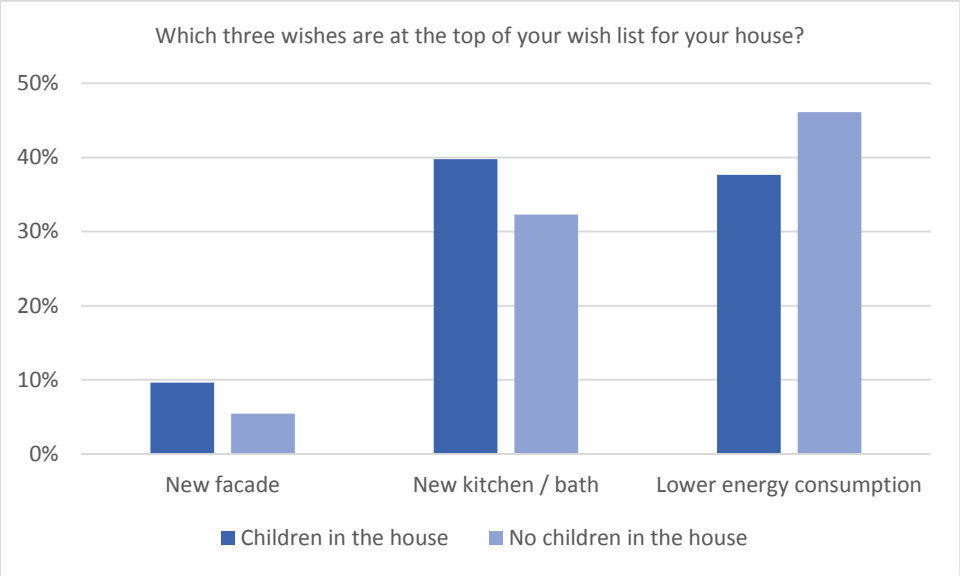
Ill.12. The columns represent the percentages in each group who have marked the wish as number one, two or three at the wish list.

The age of the respondents does, on the other hand, have a large impact on the results (ill. 13). The first clear trend is that the older the homeowner is, the more does he wish for a lower energy consumption and a re-insulation of his house. The second tendency is that the younger the homeowner, the more he wishes for a new kitchen/bath and improvements in both comfort and indoor environment.



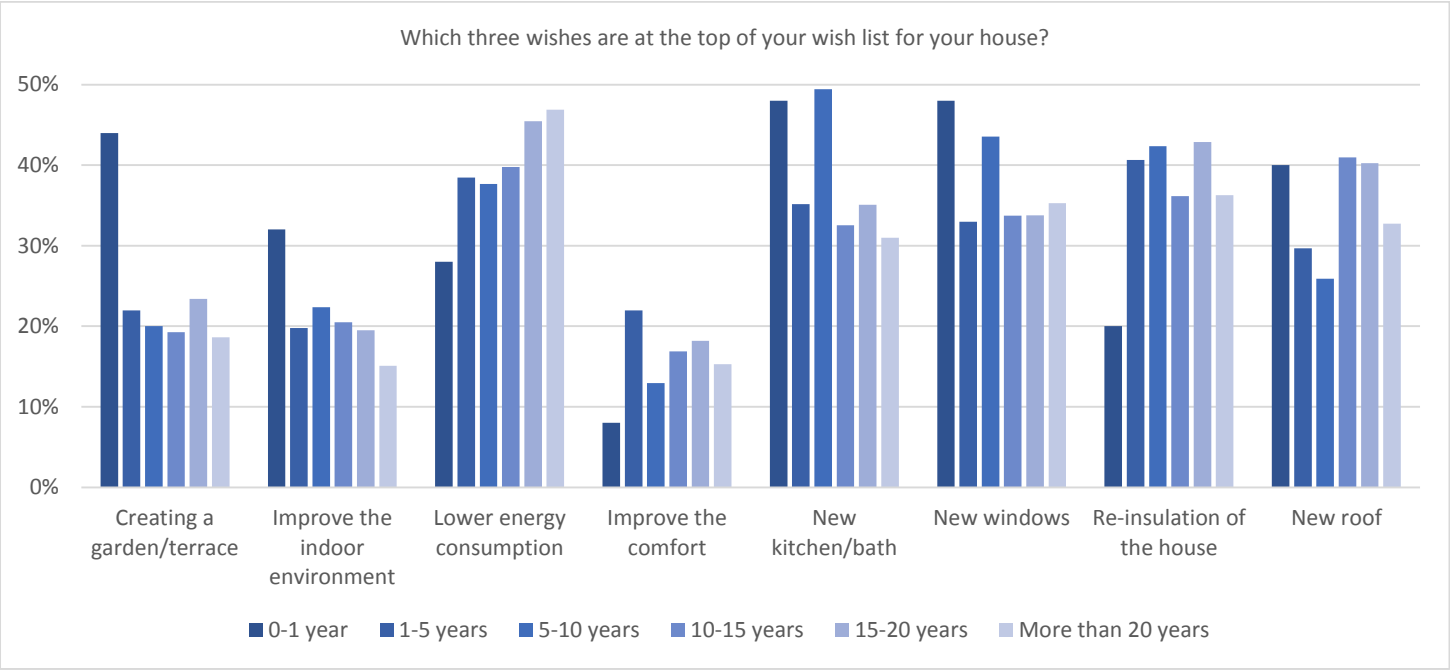
Ill.13. The differences in the top three wishes according to the age of the homeowners.

Whether children are living in the house or not has little influence on the wish list. In three cases there are however differences; a larger percentage of the homeowners with children in the house wish for a new façade and a new kitchen/bath than those without children do (ill.14). Instead respondents with no children in the house wish for a lower energy consumption more than those with children. The remaining potential wishes are evaluated like the average results.



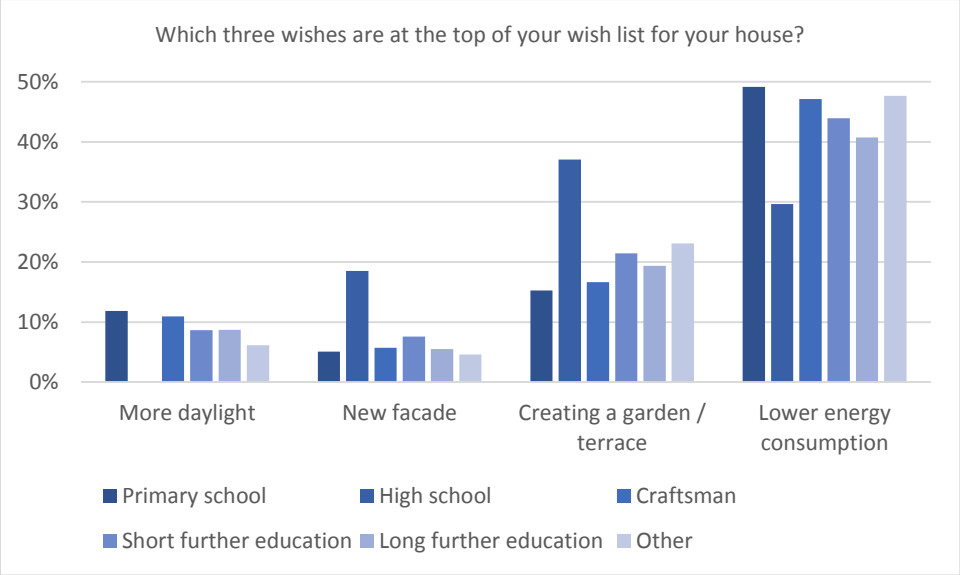
Ill.14. How the presence of children in the house affects the wish for a new façade, a new kitchen/bath and a lower energy consumption.

The number of years the homeowners have lived in their house influences the rank of the wishes and also the amount of respondents who have chosen a specific wish as part of their top three list (ill.15). The respondents who have stayed for less than one year in their house, do not have the same five wishes in the top of the list as the average respondent and those who have lived more than one year in the house. Instead of "lower energy consumption" and "re-insulation of the house" these homeowners wish to "improve the indoor environment" and "create a garden/terrace". Within some of the wishes there are also found differences caused by the demographic parameter. It seems the trend is that the longer one has lived in the house, the more is lower energy consumption and improvements of comfort wanted. Both the homeowners who have lived less than an year in the house and those who have lived there between five and ten years wish for a new kitchen/bath and new windows significantly more than others. When it comes to re-insulation of the house the percentages who wish for this increases intensely after the first year in the house, from 20% to between 36% and 43%. Finally the wish for a new roof is highest among the newest homeowners (0-1 year in the house) and those who have owned the house for more than 15 years.



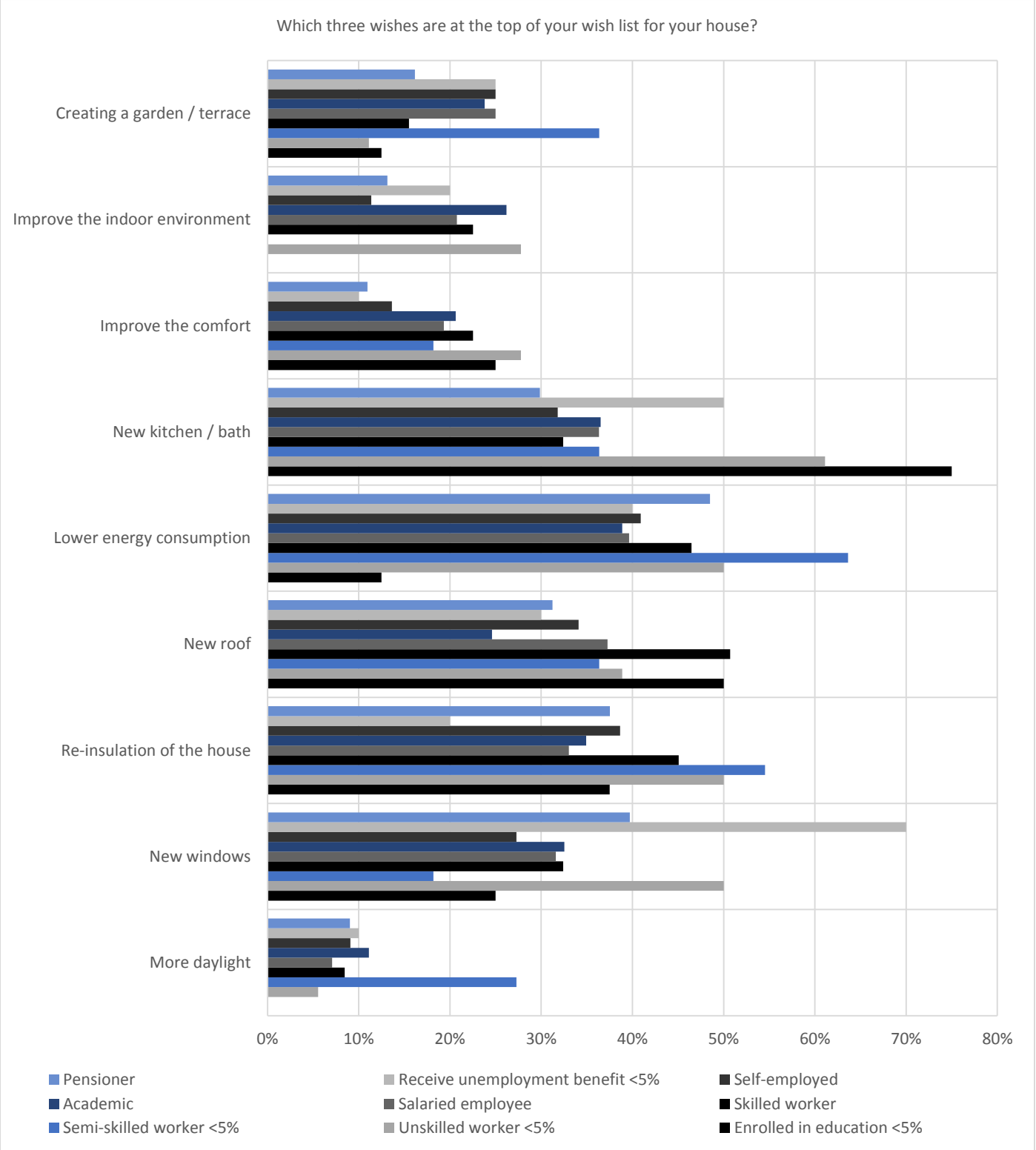
Ill.15. The time the homeowners have lived in their house and how this influences their top three wishes.

One educational group, high school educated, stands out from the others and shows large differences in the percentages of those who put a certain wish in the top three (ill.16). None of the respondents in this group wish for more daylight in their house, instead they want a new façade and a garden/terrace. They also desire a lower energy consumption, much lower than the 5 other groups. The group consisting of high school educated homeowners contains, however, less than 5% of the entire respondent group and therefore these results are not significant, but they can give an indication of a trend.



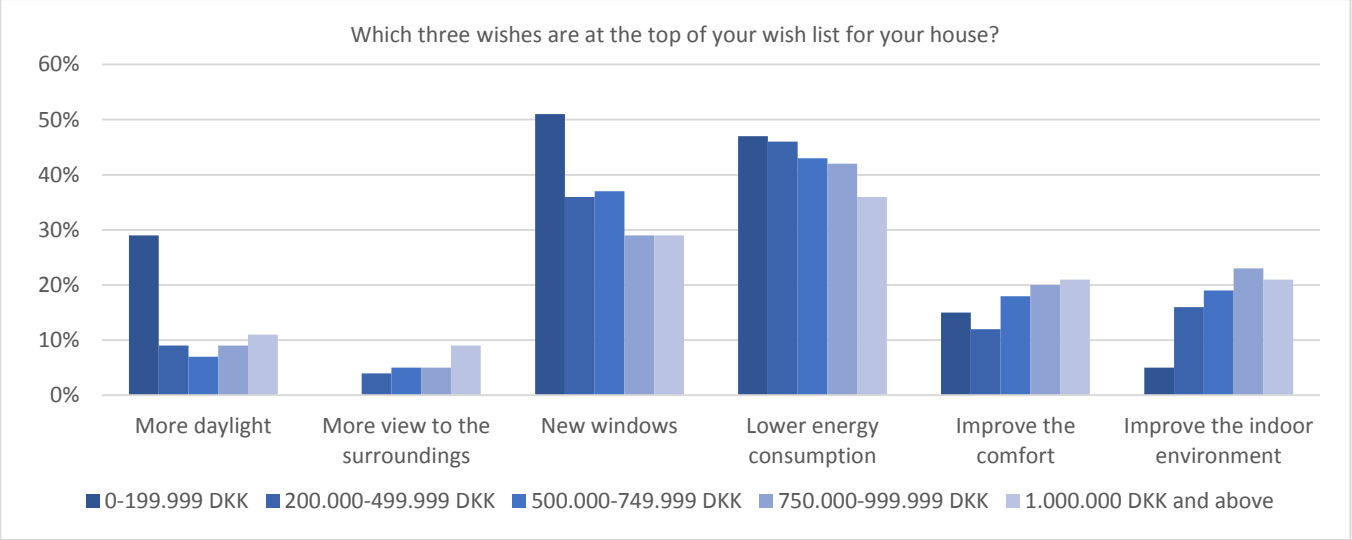
Ill.16. The differences in the top three wishes according to the homeowners last completed education.

The current occupation of the homeowners at first glance seem to have a big impact on the wishes they prefer (ill.17). The groups who separate themselves considerably from the others are though in many cases groups which contain less than 5% of the total respondent group and therefore the results cannot be said to be significant, but as is the case with education, it can only indicate tendencies. These groups are in the illustration marked with "<5%". Those currently enrolled in education have a higher desire for a new roof and new kitchen/bath than the average. The unskilled workers who also desire new windows also wish for a new kitchen to a greater extent than the average respondent. The semi-skilled workers prefer more daylight, lower energy consumption and a new garden/terrace to an extent exceeding the general picture, but no one in this group has "improvement of the indoor environment" in their top three wish list. The only deviation from the average among the skilled workers is their high desire for a new roof, the other wishes are evaluated close to average. The homeowners who receive unemployment benefits wish for new windows and new kitchen/bath more than average, and the percentages who wish for a re-insulation of the house is lower than average. Both the salaried employees, the academic, the self-employed and the pensioners all reflect the average results of top wishes.



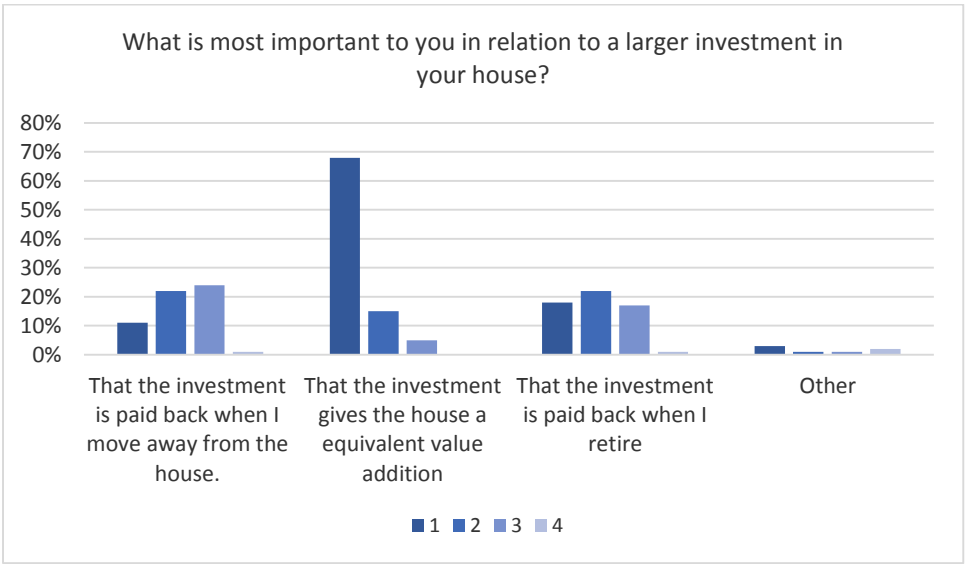
Ill.17. How the current occupation the homeowners affects the top three wishes for the house.

The yearly household income has impact on the top three of the wish list and some tendencies and variations are seen between the five income groups (ill.18). The higher the income the more are view to the surroundings, improvement of the comfort and indoor environment wished for, at the same time, the lower the income the more are new windows and lower energy consumption desired. The respondent group with the lowest income differs from the others in the desire for more daylight, where 29% of this group have this as a top three wish compared to between 7% and 11% for the other four groups.



Ill.18. The influence of the yearly household income before taxes on the three wishes at the top three list.

The above wishes all refer to changes made to the house or the surroundings and clearly some are more wanted than others. When the wishes are carried out and the homeowners make a large investment in their house, it is crucial to them that the investment gives an equivalent value addition (ill.19). 68% of the respondents state this to be the most important factor for them in relation to a larger investment, indicating that the payback time is not important if the house is worth more when the work is done. A division of the respondents according to the demographic parameters does not change this result, they all find the added value most important. A small number of respondents have though other conditions that they find more important than the three presented. These are related to improvement of the wellbeing and needs of the family and to some extent economy.



Ill.19. The most important aspects in relation to a larger investment. The respondents rated the statements with 1 for the most important, 2 for the second most important and so on. Not all respondents expressed their second, third and fourth place.

"Make the house more attractive for my family." [Respondent]

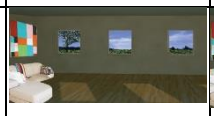
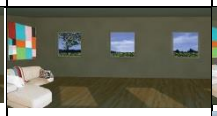
"That I can still afford "*fun", ie* vacation*, camping,* steaks*."* [Respondent]

"That *the* investment is worth it in the short run." [Respondent]

Three examples of what is most important to the homeowners in relation to a large investment. (Edit. translated)

3.7. EVALUATION OF THE CONCEPTS

The homeowners were in the final part of the questionnaire presented to five renovation concepts of different extents (Table 3)(ill.20). The material contained illustrations of the interior and exterior of the house before and after the renovation, a list of benefits and a list of initiatives performed, economic information containing investment size, monthly expense, energy savings and extra payment required per month. The homeowners were asked to evaluate the price of each concept in relation to the benefits and savings, and second to state if they would be interested in conducting a similar renovation at their own house. The first replies are used to examine if there is in fact a limit, from which the respondents no longer find the investment fair despite a number of benefits. The second replies are analyzed in order to define the economic investment limit where the homeowners despite the benefits, and possibly a fair price, do not want to perform a similar renovation themselves. The investment limit is defined as; the price of the concept where 50% or more of a respondent group do not find a similar renovation interesting.

	Original house	**Concept 1**	**Concept 2**	**Concept 3**	**Concept 4**	**Concept 5**
Investment	0 DKK	160,000 DKK	120,000 DKK	310,000 DKK	550,000 DKK	1,300,000 DKK
Illustrations after renovation. Interior and exterior	 	 	 	 	 	 

What has been done		Attic insulation Airtightning of ceiling	New and larger windows Airtightning around windows	New and larger windows Airtightning around windows Attic insulation Airtightning of ceiling Ventilation is installed	New and larger windows Airtightning around windows Re-insulation of the facade The facade is plastered Attic insulation Airtightning of ceiling Ventilation is installed	New and larger windows Airtightning around windows Re-insulation of the facade The facade is plastered New roof Attic insulation Airtightning of ceiling Ventilation is installed
Energy consump-tion kWh/year	22,809	16,324	15,083	7,362	4,806	6,295
Energy savings compared to the original house	0%	30%	35%	70%	80%	70%
Extra net cost per month (investment – energy savings)	0 DKK	291 DKK	56 DKK	380 DKK	1,230 DKK	4,400 DKK

Table 3. Information about the original house and the five presented concepts.

For an investment of approximately 1.300.000 DKK or a monthly expense of 5.400 DKK a traditional single-family house from 1973 can have re-insulated ceiling, facade and foundation, get a new facade cladding, changed and sealed all windows, get a new roof and new ceilings and installed ventilation and heat pump. By doing this an energy saving of about 16.500 kWh/year is achieved, equivalent to 11.900 DKK/Year and at the same time the indoor climate and comfort increases significantly. These savings and the following benefits will cost around 4.400 DKK extra a month when energy savings has been deducted

BENEFITS
- Lower energy consumption.
- Lower heating bills.
- Less economically vulnerable to higher energy prices.
- The house appears as a new building
- The new windows and the plaster facade give the building a more modern expression - both inside and out.

- Comfort and indoor climate are improved significantly.
- No draft from the ceiling, windows and along the floor.
- Windows does not feel cold, and can be used for seating.
- It is possible to furnish in front windows without getting cold seating (downdraft).
- Walls feel warm.

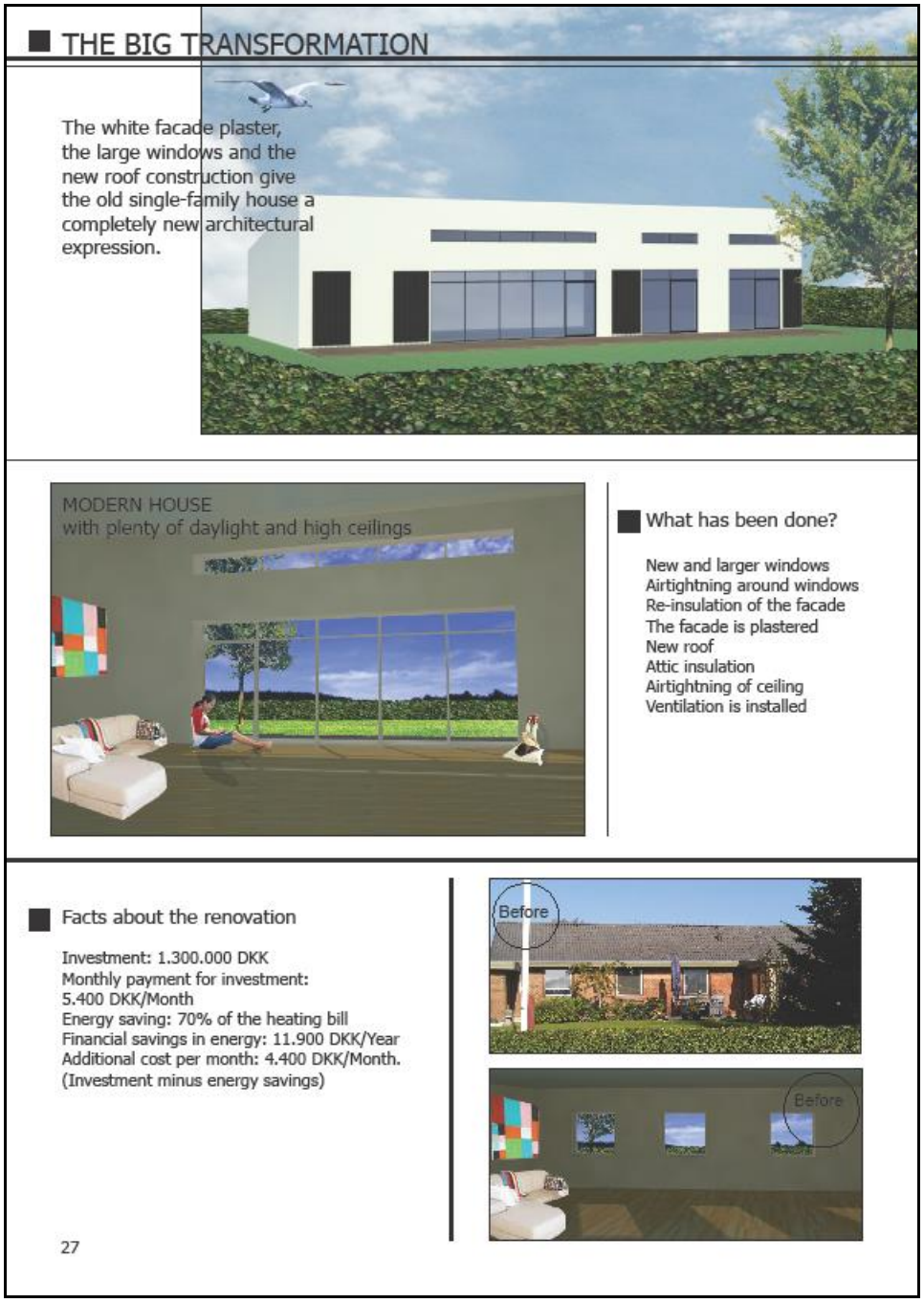
- Rooms in the home can be used in new ways.
- Additional and larger windows provide more daylight in the home.
- The view to the garden increases.
- There will be greater connection between inside and outside.
- New roof construction provides higher to the ceiling.
- Skylights provide additional light to the center of the dwelling.

- Less money and less time is spend on maintenance.
- The ventilation system cleans the outside air from dust, pollen and other allergens, and removes moisture from the house, so that mold and dust mites do not thrive.
- Less dependent on fossil fuels.
- No risk of mold and mildew behind furniture.

18. What do you think about the price of these benefits and savings?
___ It is too expensive
___ It is reasonably priced
___ It seems cheap

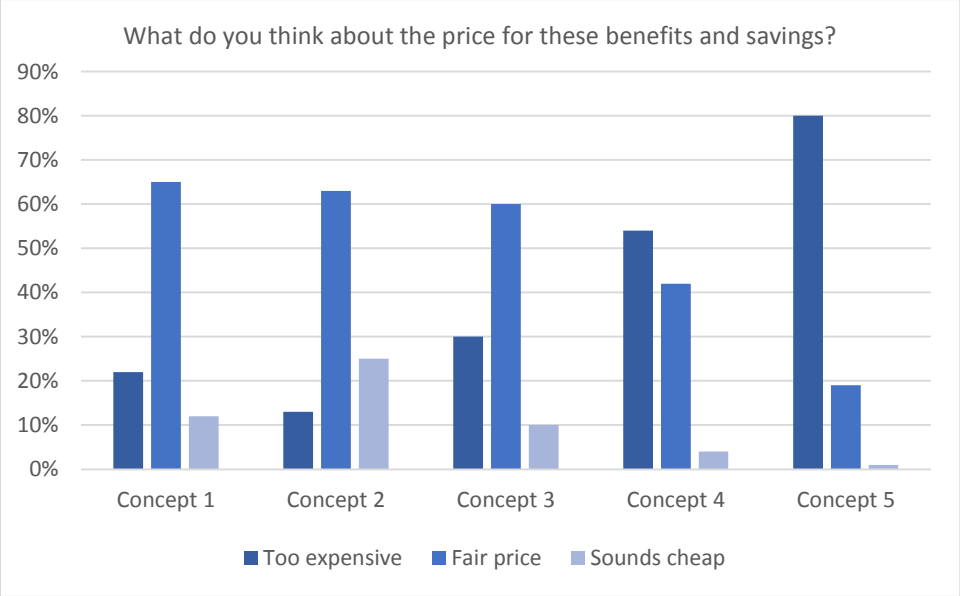
19. Would you be interested in investing 1.300.000 DKK in a similar renovation of your home in order to achieve the aforementioned benefits and savings?
___ It will by no means be of my interest
___ It might be of my interest
___ It is certainly interesting
___ I will do it as soon as possible

Why? Please give reasons for your opinion



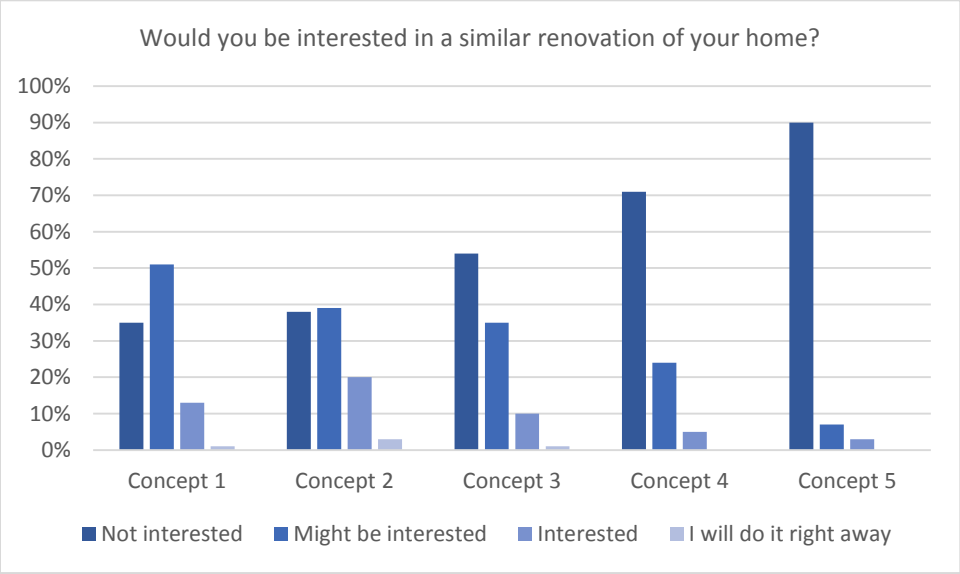
Ill.20. An example of the text and illustrations presented to the respondents for each concept. Here concept 5 is presented.

With the first three concepts 60% or more of the homeowners state that they think it is a fair price for the listed benefits and energy savings. The last two concepts are too expensive for more than half of the homeowners despite the gains, 54% of the respondents think the fourth concept with a price of 550.000 DKK is too expensive and 80% think the fifth concept is too expensive with its cost of 1.300.000 DKK (ill.21). The shift between an acceptable price and a price that is too high occurs when the required investment is larger than 310.000 DKK and smaller than 550.000 DKK.



Ill. 21. The homeowners' evaluation of the calculated prices for the five renovation concepts and the benefits within.

When looking at the interest in conducting similar projects at one's own house the picture changes. The point where more than 50% of the homeowners are no longer interested in the investment appears earlier, namely somewhere between a price tag of 160.000 DKK and 310.000 DKK (ill.22). This indicates that even when a project is evaluated as being fair priced in terms of the following gains, the homeowners do not want to invest their own money in a similar project. The investment limit for the average homeowner is thus below the investment needed for concept 3 which is 310.000 DKK.



Ill. 22. How the respondents state their interest in performing a similar renovation.

The interest is clearly affected by the price and not only the extent of the project. The respondents were further asked to back up their interest level with their own words, and when there is no interest, the majority of these comments revolve around the project price and it being too expensive for the homeowner. Other reasons are also present and these are related to; no need for renovation, no trust in the predicted savings, the homeowner being too old for a large project to make (economic) sense and a fear that the architecture will change for the worse.

"*I expect to sell my house within the next 1–3 years and the investment will not be paid back by then.*" [Respondent]

"*Because of my age (65 years) I do not see myself able to invest this amount of money in my house. If I were richer I would* do it as soon as possible." [Respondent]

"I will not spend that much money on these "*improvements".* Attic insulation is okay and replacement of some windows*, but not more than that."* [Respondent]

"It is economically interesting, but the house's original architecture must first and foremost be preserved. Energy *i*mprovements have "*destroyed*" similar houses in the neighborhood. "[Respondent] (Edit. Translated)

For those who have an interest in similar projects the reasons concern increase in sales value and a fair price for the number of gains. Many respondents mention environmental considerations and the possibility of getting a "new house" and new architectural appearance.

"The cost is significantly higher than *the* saving but the quality of the house increases accordingly and the improvement is conceived as a whole." [Respondent]

"The house is future-proofed energy economical and is *architecturally* harmonious/good-looking."

[Respondent] (Edit. Translated)

In the following tables the investment limit is marked as a grey box next to the concept where more than 50% are not interested in conducting a similar project indicating the limit is below the price of the specific concept. "Too expensive" is written next to the concept where more than 50% of the respondents find the price too high compared to the benefits of the concept.

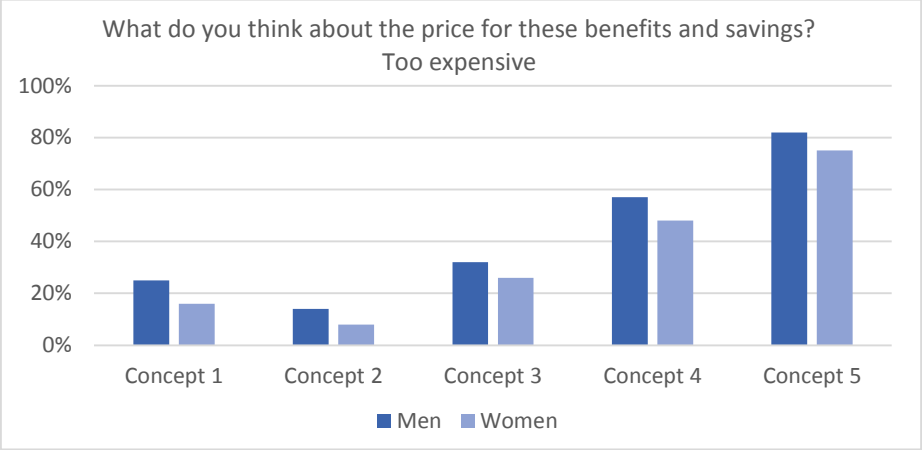
For the average homeowner there is not coherence between a fair price and an interest in a similar project (Table 4). The respondents do not find the prices for fourth and fifth concept reasonable, however the limit for their interest in conducting a similar project is at the third concept.

Investment limit and price evaluation	Average
160.000 DKK (concept 1)	
120.000 DKK (concept 2)	
310.000 DKK (concept 3)	
550.000 (concept 4)	Too expensive
1.300.000 (concept 5)	Too expensive

Table 4. Investment limit and price evaluation of the average respondent.

As seen previously with the evaluation of the wishes the demographic parameters have in some cases a significant influence on the homeowners' thoughts and decisions. When it comes to the evaluation of the concepts this once again applies. Not all subdivisions of the respondents separated themselves from the average results, but if they do, the results are presented in the following chapter.

Between women and men there are differences indicating the tendency that men find the concepts too expensive compared to the benefits and savings to a higher extent than women (ill.23). From this it seems that women are willing to pay more for the renovation benefits. This assumption is supported by the fact that the female investment limit is defined between 310.000 DKK and 550.000 DKK, where for the males it is between 310.000 DKK and 160.000 DKK (table 5).

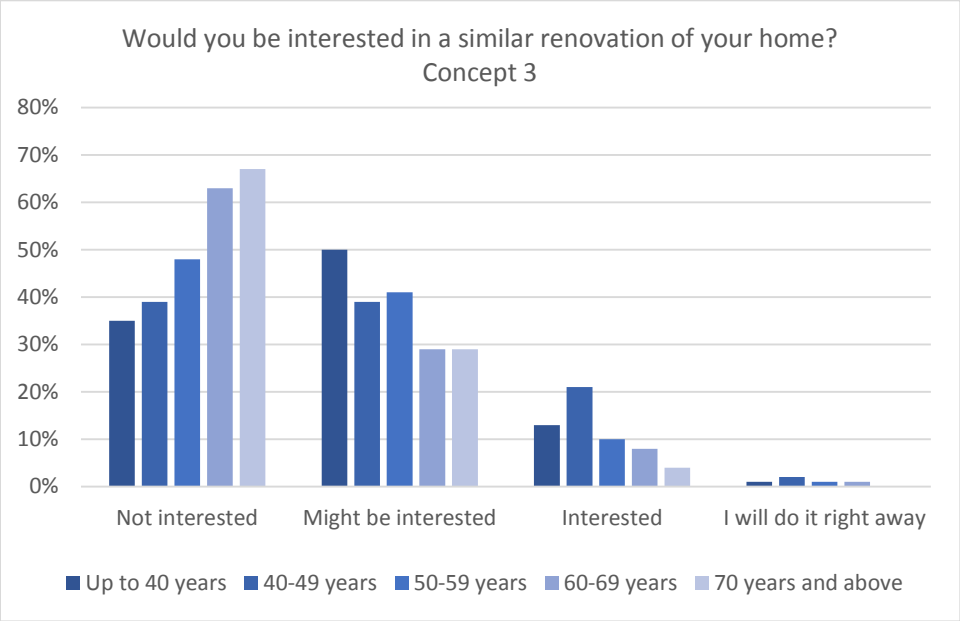


Ill. 23. The influence of gender in relation to when a concept is evaluated as being too expensive.

GENDER Investment limit and price evaluation	Women	Men
160.000 DKK (concept 1)		
120.000 DKK (concept 2)		
310.000 DKK (concept 3) Average limit		
550.000 (concept 4) Average: Too expensive		Too expensive
1.300.000 (concept 5) Average: Too expensive	Too expensive	Too expensive

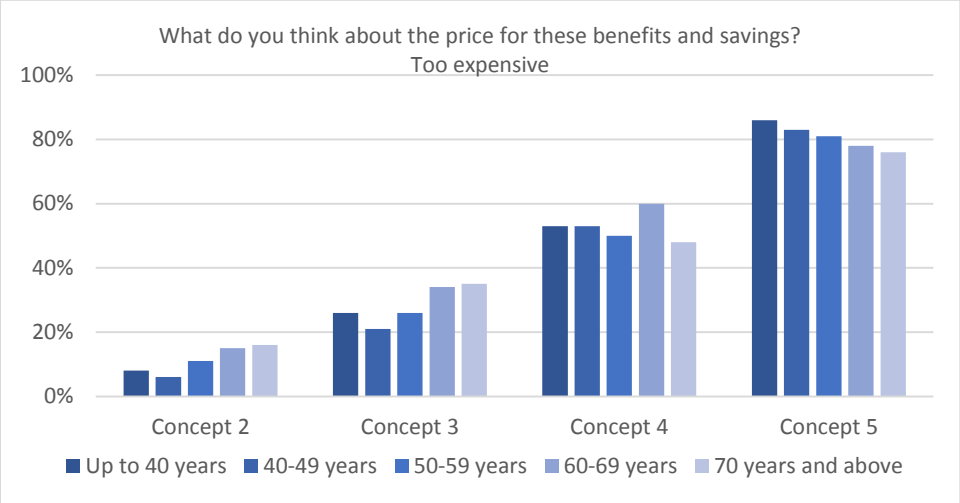
Table 5. The gender differences in evaluation of the concept prices and the desire to conduct a similar renovation.

The general tendencies for the subdivisions according to age is that the older the homeowners are, the more of them have no interest in performing a comparable renovation project, and the opposite is true for the younger respondents (ill.24). The homeowners between the age of 40 and 49 years stand out in concept 1,2 and 3 with significantly higher percentages who find the concepts interesting compared with all other groups. The difference can be caused by the life cycle of these homeowners; their children might be about to move out of the house and consequently the functionality of the house changes, furthermore is this group of homeowners still active in the labor market and can therefore afford the renovation. In the final two concepts this difference is not present, presumably since these are seen as too expensive by these respondents (table 6).



Ill.24. An example on how the age of the respondents influence their interest in conducting renovations as those of the concepts.

The price evaluations are likewise influenced by the homeowners' age. The prices of concept 2 and 3 are assessed as "too expensive" more as the age of the homeowners goes up, and in concept 3 and 4 the case is opposite (ill.25). In concept 1 no tendencies or variations appear. These results clearly show that there can be a difference between what is found to be priced fairly and what is interesting to invest one's own money in. This is the age division obviously an example of, since the oldest of the homeowners finds the fourth concept reasonably priced at 550.000 DKK, but their private investment limit is below the price of concept 1 (160.000 DKK) (table 6).

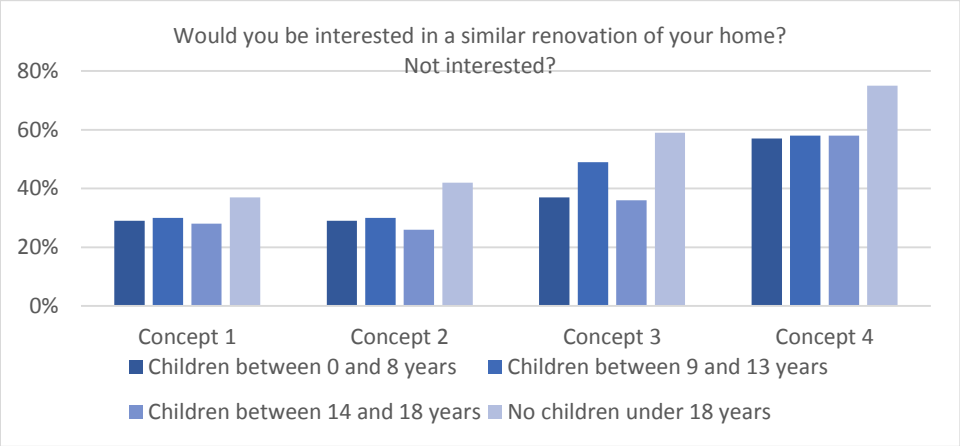


Ill.25. How the homeowners' age affect the assessment of the concept prices.

AGE ***Investment limit and price evaluation***	Up to 40 years	40-49 years	50-59 years	60-69 years	70 years and above
160.000 DKK (concept 1)					
120.000 DKK (concept 2)					
310.000 DKK (concept 3) Average limit					
550.000 (concept 4) Average: Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	
1.300.000 (concept 5) Average: Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	Too expensive

Table 6. The impact of respondents' age on the investment limit (marked with grey) and the evaluation of the price.

Whether children under the age of 18 are living in the house does not affect the price evaluation considerably. The limit where more than 50% of a group finds the price too expensive is the same no matter if there are children in the house or not. There is however still a tendency in concept 2 and 3 that a higher percentage of those without children living at home, find the price too expensive than for those with children. The investment limit and interest in a similar renovation are to a greater extent affected. In the first four concepts there is furthermore a trend showing that those with children have a lower level of "no interest" than those who have no children in the house (ill.26). The investment limit of the homeowners with no children is below the price of concept 3 (310.000 DKK) whereas for those with children it is below 550.000 DKK (concept 4).



Ill. 26. The percentages who have no interest in conducting similar renovation project according to the age and present of children in the house.

The replies are further analyzed according to the number of years the homeowners have lived in their current house and the results show that this has a large impact on both the evaluation of the price and the interest in conducting similar projects. The investment limit is lowered as the number of years in the house is increased. The new homeowners have an investment limit below 1.300.000 DKK, which is reduced to 550.000 DKK after the first year and again to 310.000 DKK after 20 years. This indicates that the sooner the homeowners perform energy renovations, the higher can the investment be and thereby the more extensive can the renovation be. Concept 4 is additionally evaluated as being reasonably priced by the homeowners who have lived less than one year in their house, where the five other groups find it too expensive, which further indicates that these homeowners will pay more for the improvements than all others (table 7).

YEARS LIVED IN THE HOUSE Investment limit and price evaluation	0-1 year	1-5 years	5-10 years	10-15 years	15-20 years	More than 20 years
160.000 DKK (concept 1)						
120.000 DKK (concept 2)						
310.000 DKK (concept 3) Average limit						
550.000 (concept 4) Average: Too expensive		Too expensive	Too expensive	Too expensive	Too expensive	Too expensive
1.300.000 (concept 5) Average: Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	Too expensive

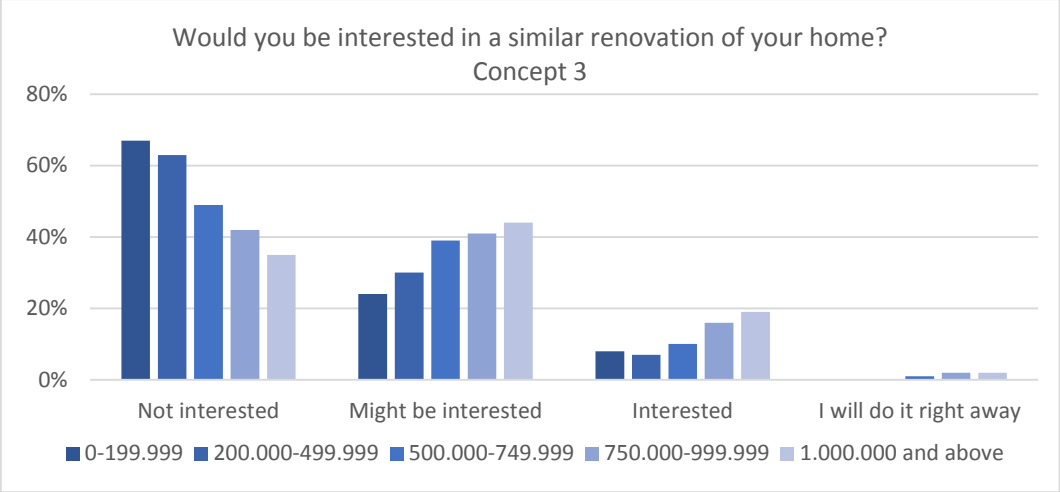
Table 7. The investment limit (marked with grey) and the evaluation of the prices according to the years the respondent has lived in the house.

The location of the house, the respondents' education and their current occupation has no significant effect on the evaluation of the prices, which are assessed according to the average evaluation by all groups. Furthermore, while location and education has no impact on the interest and the investment limit, occupation does (Table 8). Here only semi-skilled workers and the pensioners have the average investment limit of 310.000 DKK. Those enrolled in education have a limit below 1.300.000 DKK and the limit for the six remaining groups are below 550.000 DKK. The homeowners enrolled in education are represented only by 8 persons (1% of the respondent group) and therefore the results are not found significant enough to make conclusions from. This is also why the high investment limit for this homeowner group is not found realistic.

OCCUPATION Investment limit and price evaluation	Enrolled in education <5%	Unskilled worker <5%	Semi-skilled worker <5%	Skilled worker	Salaried employee	Academic	Self-employed	Receive unemployment benefit <5%	Pensioner
160.000 DKK (concept 1)									
120.000 DKK (concept 2)									
310.000 DKK (concept 3) Average limit									
550.000 (concept 4) Average: Too expensive		Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	Too expensive		Too expensive
1.300.000 (concept 5) Average: Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	Too expensive

Table 8. The differences in the evaluation of the concept prices and the desire to perform a similar renovation according to the homeowners' current occupation.

The final demographic parameter to examine is the yearly household income. Two very clear tendencies appear during the analyses; 1. The lower the income, the lower is the interest in comparable renovations (ill.27) and 2. The higher the income, the larger can the investment be before it is found too expensive (table 9). This indicates that the wealthiest groups will pay more to get the same benefits and savings and since they are also willing to invest in the more costly renovations, these homeowners can potentially be motivated to perform deep and extensive renovations.



Ill.27. Interest in performing the renovation project of concept 3 according to the different income groups. An example of the tendency that the higher the income, the higher the interest in performing the renovation.

Despite the investment limit and the limit for a fair price is not at the same level, there is a correlation between the two, when income is the dividing parameter.

INCOME IN DKK/YEAR Investment limit and price evaluation	0-199.999	200.000-499.999	500.000-749.999	750.000-999.999	1.000.000 and above
160.000 DKK (concept 1)					
120.000 DKK (concept 2)					
310.000 DKK (concept 3) Average limit					
550.000 (concept 4) Average: Too expensive	Too expensive	Too expensive	Too expensive		
1.300.000 (concept 5) Average: Too expensive	Too expensive	Too expensive	Too expensive	Too expensive	Too expensive

Table 9. How the investment limit (marked with grey) and the evaluation of the concept prices are influenced by the income of the respondents.

4. SUMMARY

From the results, it is clear that the knowledge about possible subsidies and counseling is not great among the respondents. They neither know about the possibilities to seek information and advice, nor do they know about the schemes from which grants are given in relation to energy savings of different kinds. There is however more knowledge about the economic grants than about the counseling, and some groups know more than others. The homeowners who have lived for less than one year in their current house have little knowledge about their opportunities and the longer the respondents have lived in the same house, the lower the amount that have not heard about the possibilities for grants and/or counseling. Furthermore, a tendency is seen in the age distributed groups; the younger the homeowner, the higher the amount that have not heard about the presented offers and the lower the amount that have knowledge about the possibilities in the scheme and counseling. Finally a trend visualized is that the longer the education and the higher the income, the higher the level of knowledge about the schemes, the counseling and the possibilities. At the same time, the respondents with a high income also have a large percentage who have not heard about the offers compared to the other income groups.

There have been many reflections about energy saving initiatives and many of the initiatives have already been performed. There is however still a high number missing and particularly the depth of the renovation needs to be increased for Denmark to approach the defined objectives. The positive is that the listed tasks are predominantly carried out or considered to save energy, indicating that the homeowners are aware of this benefit.

On the wish list presented to the homeowners, five wishes were selected significantly more than the remaining seven (More daylight, more view to the surroundings, new façade, change the lay-out, improve the comfort, improve the indoor environment, create a garden/terrace). The five are; Lower energy consumption, re-insulation of the house, new windows, new kitchen/bath and finally a new roof. Since these are at the top of the wish list it is expected that, by including these in a potential renovation, the renovation can be found more appealing. Hence the five wishes should be part of a motivation strategy to increase the incentives for energy renovations for the homeowners.

The evaluation of the five concepts provided knowledge about the investment limit for private energy renovations and the limit for how much the homeowners think is acceptable to pay for the potential benefits and savings.

The general picture is that the prices of the first three concepts (160.000 DKK, 120.000 DKK and 310.000DKK) are fair compared to the outcome, but when the needed investment is at 550.000 DKK and above, the majority think it is too expensive despite the benefits.

The investment limit for the private renovations is defined on the basis on the homeowners' interest in performing similar projects as the presented. The average limit is below 310.000 DKK the price of concept 3. However some of the respondents have a higher limit, and naturally some a lower limit. To increase the amount of deep renovations large private investments are needed and the results show that this is most likely to happen;

- Before the homeowners have lived for one year in their house, since the investment limit is lowered as time goes on, and these homeowners have proven willing to pay more than average for the same benefits and savings.
- As long as children under the age of 18 years are living in the house, because the homeowners here have a higher than average interest in conducting similar project, hence a higher investment limit.
- When the homeowners are young as this is where the interesting investment is largest.

- In households with a high yearly income. Both the interest in similar projects and the acceptance of the prices of these show that these homeowners will invest in extensive projects.

The respondents' wishes presented in this report and previously defined motivation factors based on other results from the same questionnaire survey [9,13,14] are therefore expected to generate more motivation in the four above mentioned situations.

5. REFERENCES

1. Regeringen, *Strategi for reduktion af energiforbruget i bygninger (Strategy for reducing of the energy consumption in buildings)*, Version 1, Erhvervs- og Byggestyrelsen, 2009, http://www.ebst.dk/file/43439/reduktion-af-energiforbruget-i-bygninger.pdf

2. EA ENERGY ANALYSES, Risø DTU, Danish Greenhouse Gas Reduction Scenarios for 2020 and 2050, Technical University of Denmark, 2008

3. K.B. Wittchen, *SBi 2009:05: Potentielle energibesparelser i det eksisterende byggeri (SBi 2009: 05: Potential energy savings in the existing buildings)*, Statens Byggeforskningsinstitut, 2009, ISBN 978-87-563-1363-6

4. A. Mortensen, P. Heiselberg, M. Knudstrup, *Barriers for energy renovation of Danish single-family houses and suggested solutions to overcome these*, Finnish Association of Civil Engineers RIL; VTT Technical Research Centre of Finland, 2011

5. A. Bryman, *Social Research Methods*, Oxford university press, 2008; ISBN:978-0-19-920295-9

6. Rambøll, *Random check calculation*, http://www.surveyxact.dk/loesninger > Stikprøveudregner – få det sande billed [15.08.13]

7. Statistic Denmark, *BOL201: Residents by county, use, tenure, ownership, year of construction, age and sex*, http://www.statistikbanken.dk/bol201, [15.08.13]

8. Statistic Denmark, *BOL22: Occupied dwellings by region, type of dwelling, year of construction and installations*, http://www.statistikbanken.dk/bol22, [15.08.13]

9. A. Mortensen, P. Heiselberg, M. Knudstrup, *Economy controls energy retrofits of Danish single-family houses. Comfort, indoor environment and architecture increase the budget*, published in Energy and Buildings, vol. 72, pp. 465–475, April 2014

10. A.K. Larsen, En e*nklere metode (A simpler method)*, Akademisk forlag, 2010, ISBN:978-87-500-4157-3

11. T. Harboe*, Metode og projektskrivning (Methodology and project writing),* Samfundslitteratur, 2010, ISBN:978-87-593-3176-3

12. M.W.Boolsen, *Spørgeskemaundersøgelser (Questionnaire surveys)*, Hans Reitzels Forlag, 2008, ISBN:978-87-412-5143-1

13. A. Mortensen, P. Heiselberg, M. Knudstrup, *Identification of key parameters determining Danish homeowners' willingness and motivation for energy renovations*, 2015, Submitted to International Journal of Sustainable Energy

14. A. Mortensen, P. Heiselberg, M. Knudstrup, *Definition of specific comfort implications, indoor environmental and architectural quality. Evaluated by Danish single-family homeowners*, 2015, Submitted to Indoor and Built Environment

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