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The Integrated Renovation Process Experiences and Future Developments Needed

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1 Introduction: The Integrated Renovation Process

The Integrated Renovation Process (IRP) is a user customized methodology based on judiciously selected constructivist and interactive multi-criteria decision making methods (Galiotto, Heiselberg, & Knudstrup, 2014 (expected)). The IRP supports, informs and reassures building owners to decide on a sustainable renovation of their building while getting the corresponding associated benefits and therefore a building more adapted to user's needs and behaviours. The IRP also helps the building experts to be more structured for the quantitative analyses and the generation of the renovation scenarios so they get more time for the cost optimization and the qualitative analysis of the users' needs and behaviours.

In order to reach a fossil free energy building stock within an acceptable time frame, it is primordial that researchers, politicians and the building industry work hand in hand. Indeed, in order to overcome the financial barriers to energy renovation and bring a new type of building experts in the building renovation sector, cost optimization tools for building renovation have been and can be developed but new legislation and politico-economic supports are still much needed. We present in this report a new contribution from the research and industry sides and results reached with the newly developed methodology, but without a significant contribution from the politico-economic and legislation sides (Figure 1). The experiences met during application of the Integrated Renovation Process are described and developments still needed in the future are introduced.

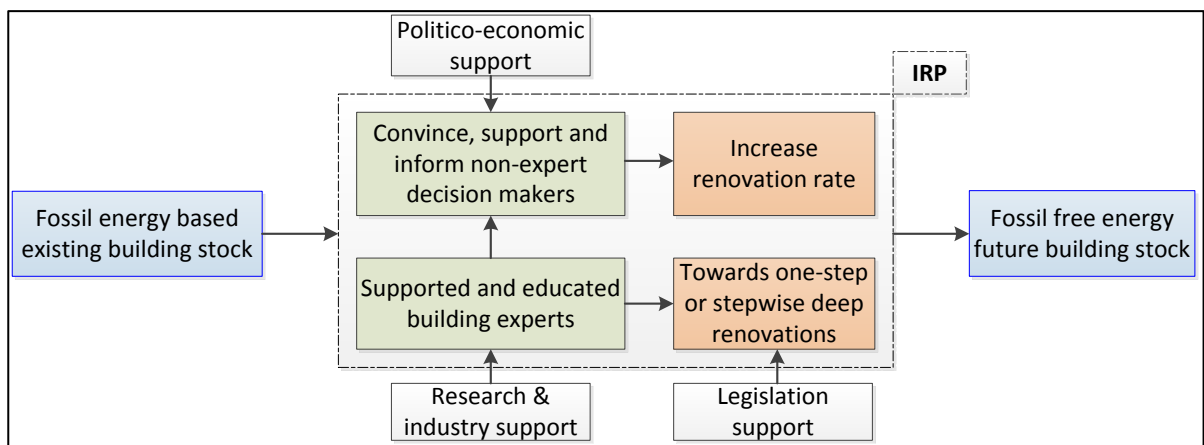


Figure 1: Needed contributions in order to reach a fossil free energy building stock

2 Experiences

The first application of the IRP has been done in collaboration with two single-family home owners. Communication and interaction tools have therefore been adapted for a specific use with non-expert decision makers who live in the house that they own. We have consequently called the methodology IRP4homes in this case.

2.1 Methods and tools

2.1.1 Interaction between the building expert and the homeowners

- Analysis of the homeowners' needs, wishes and behaviours

Questionnaire to the homeowners

The analysis of the homeowners' profile is a close interaction between the homeowners and the building expert. The analysis consists of a questionnaire in two parts answered by the homeowners followed by a discussion. The first part of the questionnaire consisted of a first set of multiple-choice questions dealing with indoor environment, immaterial values and economics. The second part of the questionnaire was a discussion supported by visuals such as pictures, drawings, and plans.

Even if some questions of the questionnaire could have been better formulated, it was very well accepted by the homeowners.

Selection of quality and performance criteria

The selection of the quality and performance criteria and sub-criteria were done in two steps: there was firstly an automatic selection thanks to rules set in connection to the answers received from the questionnaire. Indeed, answers to those questions allowed finding out the levels of sensitivity for the homeowners who were also the building occupants to specific matters such as comfort, health and other satisfaction matters or disturbances. The second step consisted in a manual selection or removal of pre-selected criteria or sub-criteria after interaction on the basis of visual supports and discussions with the homeowners. The consistency of the criteria structure was verified for compliance with Hermione method requirements.

These two parts of the process was quite effective even if it was a bit time consuming. Here is what the building expert suggested at the final interview in order to make the process more time-effective:

"I don't know about an automatic pre-selection and I think it is like the last question, maybe as a visual aid, like a web page or something for the picture regarding the immaterial values and you can add the questionnaire as well, so you have more self-studies directly made by the homeowners themselves instead of having the building expert come out and present it."

- Multi-criteria analysis of the house in the existing conditions undertaken with the help of the homeowners

Selecting the most favourable renovation according to the homeowners' preferences and behaviours is quite a complex problem. Not such because a model of the problem is difficult to set up or solve but more because of the myriad objective and more particularly subjective parameters influencing the result. Furthermore, the problem can have contradictory objectives as often seen in most multi-disciplinary fields. Multi-criteria decision making allows handling this complexity. A multi-criteria analysis consisted in evaluating a set of quality and/or performance criteria using a common homogeneous scale which all together defined how to reach the objectives of a specific problem. The objectives are set on the bases of the decision makers' preferences. Eventually, all the evaluations are aggregated into a synthesis. The strength of the method is that only a simple evaluation scale tool is used all along the process. Even if the attributes are diverse according to the evaluations, the same scale structure is used no matter if the attributes are quantitative or qualitative (Figure 2). Attributes will vary according to; firstly, whether the evaluator is a building expert decision maker (Figure 3 and Figure 4) or a building non expert decision maker (Figure 5 and Figure 6), secondly, whether the evaluation is qualitative (Figure 3 and Figure 5) or quantitative (Figure 4 and Figure 6).

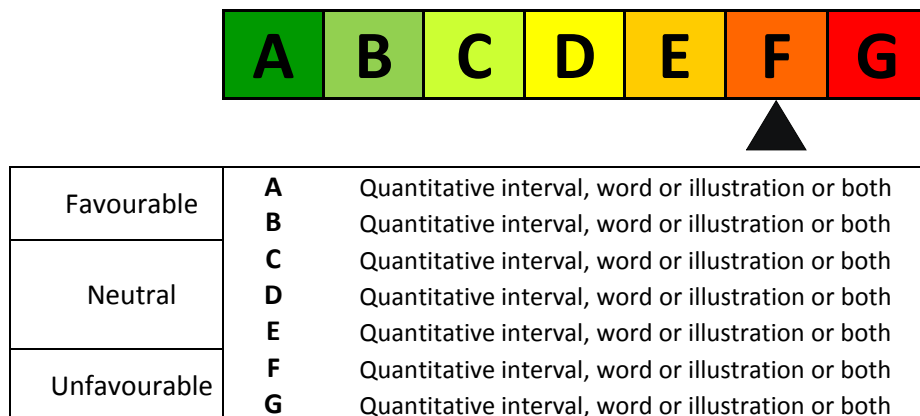


Figure 2: Common scale structure with 7 coloured letter items

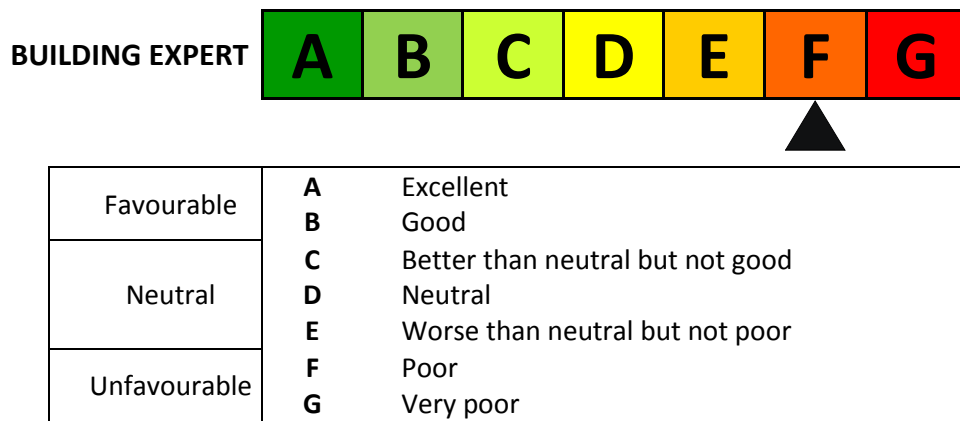


Figure 3: Qualitative building expert evaluation scale

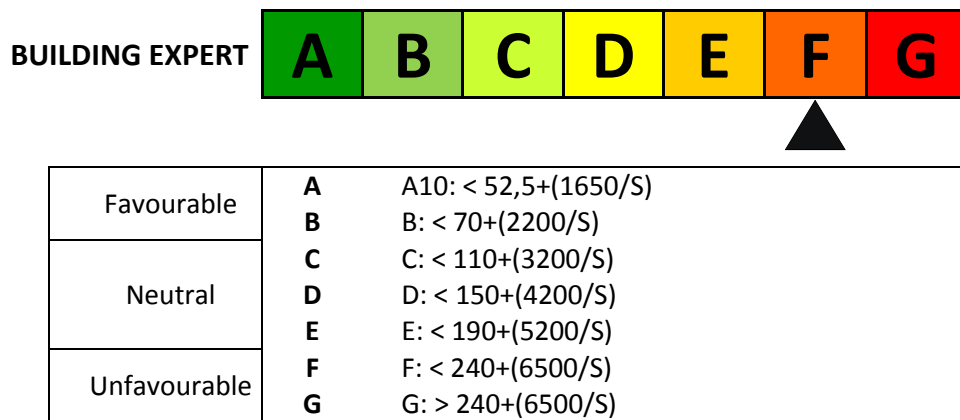


Figure 4: Quantitative building expert evaluation scale

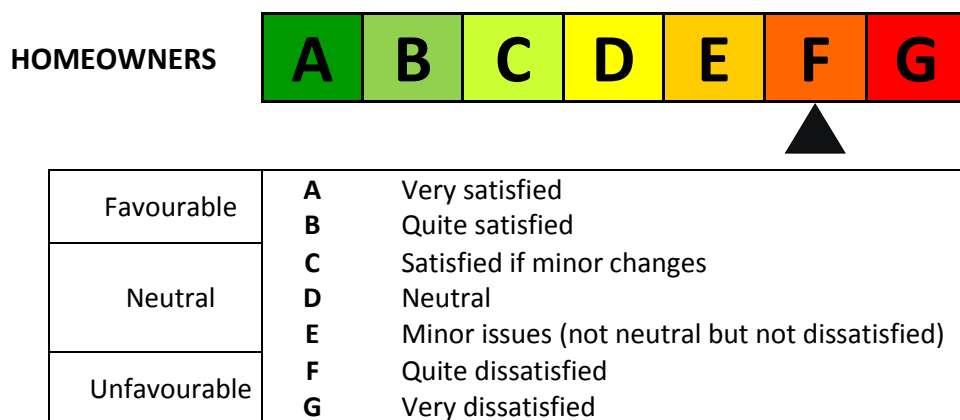


Figure 5: Qualitative building non-expert (homeowners) evaluation scale

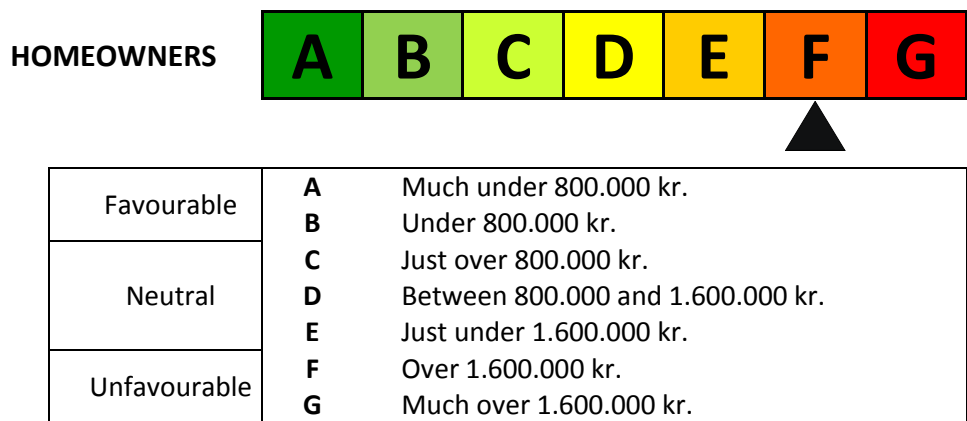


Figure 6: Quantitative building non-expert (homeowners) evaluation scale

Concerning the evaluations done for the house in the existing conditions, most supports used were found directly in the house through visual inspections, look at some building components with the homeowners, analysis of situations in the house, photographs of the house, or also thermal infrared images of the studied house.

The building expert was quite satisfied with this part of the process:

“Do you think that more visual supports (videos, interactive videos, website, illustration program, etc.) would be needed to support the multi-criteria analysis of the house in the existing conditions undertaken with the help of the homeowners?”

“I don’t think it would be necessary for this part of the process; usually it’s a part that goes on in the homeowners building, so you can walk around and address the various problems in the building as it is.”

- Multi-criteria analysis of the pre-selected renovation scenarios undertaken with the help of the homeowners

The same evaluation scale structure was used for the analysis of the pre-selected renovation scenarios. Concerning the evaluations done for the generated and pre-selected renovation scenarios, most supports used during the evaluations of the house in the existing conditions were also used to compare. In order to show the possible upgrade and improvements, 2D visuals were used by the building expert to support his explanations.

This part of the process worked well but the homeowners took some time to ask all their questions and understand what the building expert meant. Here are the suggestions of the building expert to improve this part of the process:

“I think it shows quite clearly that some of the time spent was used to explain the effects of the scenarios. I think that a 3D model for architects or a simple hand

sketch would be a great help for the homeowners to understand what for instance twenty percent increase in window area would mean to them.”

“Well, if you keep it to a print or also have sketches, it might not save you that much time but maybe if you could maybe build a 3D configurator, you could quite rapidly make a model for the homeowners to work in where they could change for example shapes of windows, for them to work on their own that could save you 30% of the time.”

It seems that the homeowners agreed with the building expert. Here are some citations from the interview given after the process was ended:

“Maybe some of the “drawings, photos and plan” could have been more different in order to make the observer more aware of his or hers aesthetic values when it come to the look of the house.”

2.1.2 Building analyses and generation of renovation scenarios

- Multi-criteria analysis of the house in the existing conditions undertaken by the building expert without the help of the homeowners

Diagnosis of the building

All the analyses of the house in the existing conditions dealing with technical aspects were uniquely treated by the building expert. Thanks to a building inspection, the degradation state and the technical obsolescence of the building components were qualitatively evaluated. The inspection was visual with the use of a few basic measuring instruments plus a thermal infrared camera. The building expert qualitative evaluation scale (Figure 3) was used. The building expert was therefore familiarized with the evaluation scale before supporting the homeowners to evaluate the criteria with the building non-expert scales. Beside the evaluation of each building component, the building expert was indicating the degree of emergency of upgrade of the building component so the stepwise renovation if any could be planned more structurally.

The inspection and the learning process of the building expert went quick and easy. Here is what the building expert said at the interview which ended up the process:

“I found the sheet quite beneficial, it had the general separation of building or construction components and you have the scale to evaluate how far the degradation state and the technical obsolescence were and how to prioritize them so I was quite satisfied with the sheet.”

(See full interview transcript in Appendix 5.1).

Energy performance of the building

The energy performance of the existing building was quantitatively evaluated thanks to the program Be10 (Statens Byggeforskningsinstitut (SBI), 2012) and then confirmed via building simulations in BEopt (National Renewable Energy Laboratory,). The building expert quantitative evaluation scale used (Figure 4) was aligned to the Danish BR10 regulation energy label.

- Generation of possible renovation scenarios

The tool BEopt was used as support for the building expert to generate possible renovation scenarios. This tool can generate and evaluate automatically diverse renovation scenarios towards a zero energy building level and can give the optimized costs corresponding to the each scenario. Yet, at the moment, BEopt has serious limitations. More specifically, the tool is oriented towards the US market (units, regulation based references, cost data base and types of building materials) and does not accept a modification of the geometry of the building envelope within the same optimization study except the window areas in each direction (e.g. scenario including an extension or a demolition of a part of the building). The building expert had therefore to pre-generate scenarios based on the Danish regulation including manually the constraints of possible stepwise renovation (i.e. can we move from scenario 1 to scenario 2 without generating too important additional costs in the process compared to a one-step renovation?). A new project specific costs data base was created, regulation oriented building components were integrated in the tool and an Excel tool was developed to compensate some of its limitations.

All of this together was quite time consuming since it was distributed between two projects only. Here are the suggestions recommended by the building expert at the end of the process:

“Would a tool which would automatically generate possible renovation scenarios and would give for every scenario: an estimation of the total renovation cost (embedded cost data base), the energy performance of the building (i.e. energy label and energy savings) or a tool which would automatically generate possible renovation scenarios and optimize the total renovation cost according the every level of energy performance reached be saving work and time?”

“I think that will help the process greatly, as I said before it’s one of the main time consuming area, so any tool that help speed up the process, if for instance you only have to select a level of energy performance of the building and the corresponding renovation cost follows automatically or the other way around, then you would save a very substantial amount of time.”

“So this is a very important point and the tool which is really needed?”

“Yes, it’s the key tool that needs to be added to this process if we want to make it feasible” “I think that will benefit the process greatly, as it is right now, we first go through the energy performance levels then we go through the costs then we try to optimize the performance at the best cost. It’s basically three workloads that could have been combined into one, I’d say you could save around 75%-80% of the time spent if the program generated automatically, maybe based on price data bases previously done projects.”

“So if I understand well, you said that you spent 6 days out of 9 to work on the building renovation scenarios and quantitative analyses, and saving 80% of the time would mean that out of the 6 days used, you would save most of the time which means that within 1 or 1,5 day, you could work out this part of the process?”

“Yes, surely.”

The homeowners were also demanders of having access to knowledge directly themselves:

“Maybe it would have been good too to have some written documents about the possible renovation measures and corresponding benefits. Internet is OK but it would be good for homeowners to know during the evaluations.”

- Pre-selection of possible renovation alternatives

Based on his own knowledge and on the information collected during the previous steps of the process, the building expert chose manually to set three scenarios with a progressive increasing global quality and performance levels from scenario 1 to scenario 3. The tool BEopt was then used to generate automatically alternatives around these 3 levels of global quality (set geometry and set heating area). For each alternative generated, BEopt tool could also automatically predict the energy performance associated to the renovation alternative (as long as the geometry i.e. heated area of the building remained the same). It was then decided to pre-select the alternative associated to each level of global quality with the best energy performance. Unfortunately, because BEopt cost data base could not be used, the total renovation cost associated to these renovation alternatives could not be automatically estimated. Therefore, the independent cost data base built specifically for the case studies was used to estimate the total cost of each renovation alternative.

- Multi-criteria analysis of the pre-selected renovation alternatives undertaken with the help of the homeowners

Diagnosis of the building

All the analyses of the renovation alternatives dealing with technical aspects were again uniquely treated by the building expert. As for the house in the existing conditions, the degradation state and the technical obsolescence of the building components were qualitatively evaluated according to the expert.

Energy performance of the building

The energy performance of the generated renovation alternatives was predicted automatically in BEopt (see the two paragraphs: Generation of possible renovation scenarios - Pre-selection of possible renovation alternatives).

2.1.3 Synthesis, presentation of the results and implementation of the renovation measures

The synthesis consisted of an aggregation in several steps. Firstly quality sub-criteria were synthesized in the decision makers' minds into a criteria evaluation (seven item scale from A to G). Then the criteria were synthesized into a macro-criteria evaluation (e.g. economy evaluation in Figure 7). The result was then given on the bases of a 3 item scale (green: favourable, yellow: neutral or uncertain and red: unfavourable). Finally all macro-criteria were aggregated into a global evaluation representing the favourableness of a renovation scenario (see Figure 8). The global result was also given on the bases of a 3 item scale (green: favourable, yellow: neutral or uncertain and red: unfavourable). Since the global evaluation result was quite diluted, it was important to display beside the global results, the intermediary macro-criteria evaluation results.

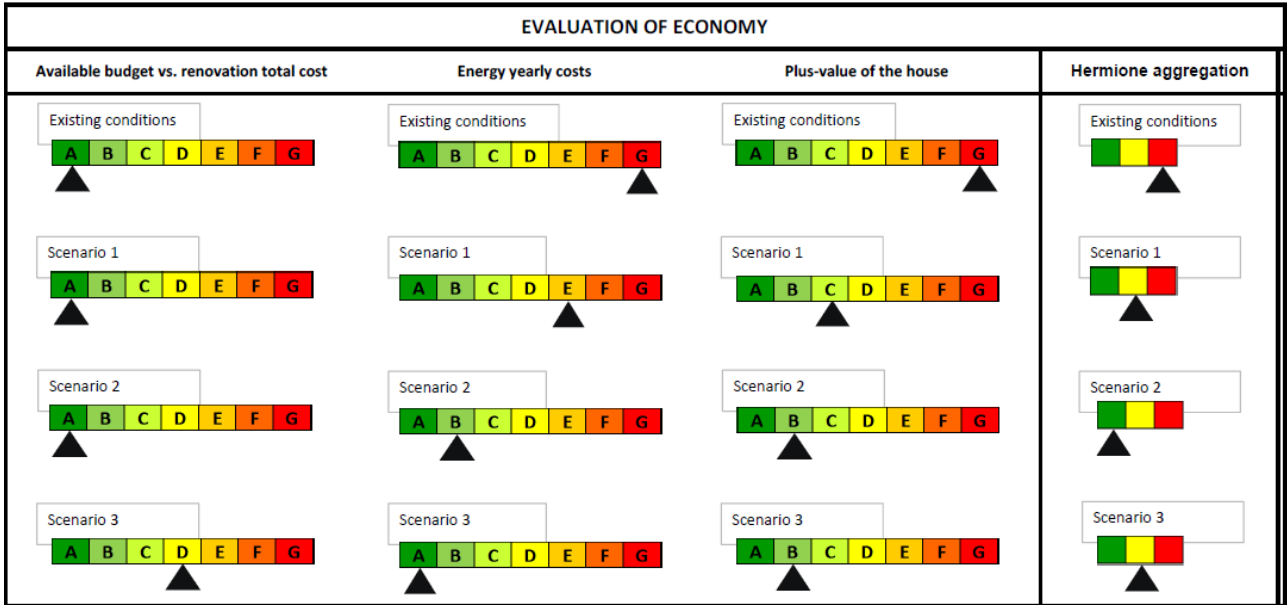


Figure 7: Synthesis of criteria into macro-criteria evaluation for the economy

Existing conditions	Technical aspects		
	Comfort and health		
	Immaterial values		
	Economy		
Scenario 1	Technical aspects		
	Comfort and health		
	Immaterial values		
	Economy		
Scenario 2	Technical aspects		
	Comfort and health		
	Immaterial values		
	Economy		
Scenario 3	Technical aspects		
	Comfort and health		
	Immaterial values		
	Economy		

Figure 8: Aggregation of macro-criteria into a global evaluation

It was experienced that the homeowners were progressively familiarized with the 7 item and 3 item coloured scales, and it therefore came very natural for them to understand the final construction and presentation of the most favourable renovation scenario. This was especially true since they were active actors in building the results. Here is what the building expert said at the interview after the process was concluded:

“Do you think the results should have been presented differently to support the homeowners for the final selection of the most favourable renovation scenario?”

“I think the tool does in the method right now with the right grid and the other scale is quite simple and quite accurate and it gives good general idea of the state of the house before renovation, and how the building will be after scenario one, two and three.”

“So did you find that the homeowners actually understood easily the results through the coloured scale?”

“Yes, it felt quite easy to explain them that green is favourable whereas red is not for earlier parts of the process so by the time we come up with the final result, so they have already understood the concept of the colours.”

Here is what the homeowners said at the interview after that the process was concluded:

“It was a great help to start evaluating the criteria from the first sessions while looking at the pictures. It helped us to understand quite easily the coloured scales all along the process. As far as I remember, we agreed very easily about the evaluations.”

When the homeowners were finally far in deciding on a favourable renovation strategy and had eliminated most of the uncertainties, there were still some questions in suspend such as:

“I was very satisfied with the presentation of the scenarios; however I would like to get more technical details about possibilities of products and the corresponding specifications. I think we need to think ahead of the contractor or of the architect. I like finding solutions before the contractor or architect so I know whether what they suggest is good enough or not.”

“I would like to receive the pictures of for instance the thermal photography. They will prove very valuable if I can show them to the contractor. I have noticed the great problem of insulating the ceiling between the two stores. As this is a renovation and not a new house the challenge of exactly this problem is of essence and the photos would be great.”

It would therefore be judicious the extent or connect the developed methodology to a process of translation of the strategies into possible services and products, suggest an automatic follow up or integrate directly professionals in the process. This is however a bit risky since the building expert would be taken away from his status of neutral party in the decision making process. Yet, this neutrality brought some strength into the relation of trust between the building expert and the building non expert decision makers (homeowners).

2.2 Results

Homeowners (building non expert decision makers)

The homeowners have been positive and very satisfied concerning the Integrated Renovation Process. It seems they have been convinced that a major sustainable renovation of their house is what they needed in order to benefit fully from a newly renovated high quality house.

"We are very satisfied with the process and we feel lucky to have been part of it."

"It has been a good process and we got to learn new things. We have learned a lot and will be great advantage when facing the architect and the contractor. We learned about energy, personal values, functionality of the spaces, health, indoor climate, etc. We were aware before but we are even more aware now. We knew we wanted a comfortable house but now we can put words on it. We know now what a high quality home is; it has so opened our eyes."

"It was really a great help. The process made us feel more secured and confident about the choices to make. It also gave us a good overview of the renovation costs and all the benefits. It was really a good thing to put numbers on the benefits and get to know what we get if we do that or that. Also it was good to have numbers to see the consequences of what is possible, such as the energy class modification with the implementation of the renovation actions."

"I am very happy for the support I have received."

"It is now easier to see what we get for our money and how we can save energy and money too."

Building expert (decision making aider)

According to the building expert, the first application of the Integrated Renovation Process on two single-family houses was successful and promising even it was time consuming. Here after are a few extracts from the interview done with the building expert: he gives his conclusions as well as recommendations for the future of the IRP:

"As you mentioned and as you saw earlier, we spent a lot of time on this project and one of the problems was that some tools are missing and also the experience in using the IRP methodology. I think with the right tools and with some more experience in using the method, we could easily match a regular high performance renovation process."

“I think (that with the appropriate tools integrated in the IRP) we could match a regular renovation process (time frame). The main difference between the two, I think, is the quality of the renovation process. With the IRP, I think you end up with a more homeowner specific suggestions, and also you really raise the awareness of the building conditions in the homeowners’ minds, they really influence the process and they are the ones who have to live in the home for the next 20 or 30 years whereas we as building experts or consultants will be moving onto the next project the next week.”

“When we started this process, the homeowners were talking about changing windows, maybe upgrading small parts of their homes, and in both cases, we are actually ending up with a major renovation targeting high performances. This is because they are now really seeking these comfort levels.”

“I’m certain of it (that he has obtained performances he would not have reached with a regular renovation process); homeowners in both case studies did not consider initially a major renovation. They had maybe not the knowledge or were maybe limited in the ideas about renovating.”

“I’ve been very satisfied with it (the application of the IRP), for me personally it has always been very important that my clients or the homeowners I deal with get most value for their money, and with this matter, in the IRP, you really educate the homeowners and provide them with the necessary knowledge to make the right decision regarding their renovation projects.”

“I totally have (been able to motivate homeowners to select a high performance renovation scenario), the homeowners were initially quite hesitant about major renovation, they were not very aware of what the possibilities were and with the final presentation of the scenarios, they went straight for a high performance scenario. I think they wouldn’t have done that if they did not go through the Integrated Renovation Process.”

“I think the method is very good but, as it is now, it lacks more integrated and automatized tools to make it more feasible in practice, one needs to be more time effective as building expert but as a support for homeowners I think it’s already very good.”

3 Future developments needed

a. Need for new tools

In order to make the IRP more effective in terms of time use, cost optimization and transfer and collect of knowledge, new tools are required.

More integrated modules

So far a prototype methodology composed of sub-methods has been developed. It is quite obvious that a friendlier computerized or tool interface connecting the different methods through modules would help both the building expert(s) and the homeowners. It would help to save time and would allow integrating new stakeholders who could have access to tool modules specifically developed for them. Tools and tool interfaces such as EPIQR+ and TOBUS (Flourentzou, Genre, & Roulet, 2001) could be of good inspiration.

Generation of the scenarios

The generation of the renovation scenarios and alternatives has been the most time consuming phase in the process. However, it seems there is a lot of potential in terms of making this phase of the process more time effective and easier of access for the building expert. In both case studies, the tool BEopt (National Renewable Energy Laboratory,) was used but some tool limitations did not allow the building expert to have a fully automatized generation of renovation scenarios. This is due to the following lacks of the tool:

- The building material data base is quite specific to the north American market (even it can be modified)
- The corresponding cost data is specific to the US (even if it can be modified)
- Units used are imperial units only; there is no option for working with the international system.
- The building optimization (cost vs. source energy use) can be run for a specific geometry / floor heating area. Scenarios including a modified building configuration need to be generated apart as a new case.
- The tool considers US regulations only. The Danish or EPBD is not taken into account in the tool. This can be a blockage since some generated scenarios might not comply with the Danish regulation or EPBD requirements if not taken into account prior to the use of the tool.
- The tool allows generating renovation scenarios on the basis of diverse energy performance levels from no saving to zero energy building and the corresponding renovation total costs. However other qualities such as non-degraded building components or systems, non-obsolete building components or systems, indoor environment quality and immaterial values (architectural qualities, etc.) are not taken into account.

The improvement of BEopt based on these comments or the development of a new tool would be a key element of making the IRP more time effective and more user friendly for the building expert.

Interaction between the building expert and the homeowners

There were three different types of interaction between the building expert and the homeowners:

- The first type was an indirect interaction between the parties, the building expert prepared some questions or work to be done by the homeowners. They were then working themselves on it before delivering back their work done to the building expert who was doing the analyses afterwards. This type of interaction was done with or without the building expert being in proximity of the homeowners.

- The second type was a direct interaction between the parties. Some of the work was done in direct collaboration between the building homeowners, either because the building expert needed to collect data about the homeowners or in relation to the house or because the homeowners needed to inform the homeowners before they evaluated a quality theme or before they made a decision.
- The last type of interaction was a predominantly unidirectional interaction where the building expert had to present facts and analysis conclusions to the homeowners.

Most of the time used on the project was for interactions of the second type where the building expert and the homeowners were working together. The building expert was pretty satisfied with the types of interactions undertaken in the process. However he suggested at the end of the process that, in order to make the IRP more time effective, he would suggest having more interaction time of the first type and less of the second type. Here follow some selected citations made by the building expert during the interview at the end of the process:

“Together it was a bit time consuming, because the homeowners were very interested in many of the details of the scenarios and it is quite important for them to understand fully what they were gaining with the different scenarios so I think we spent like four or five hours.”

“maybe a visual aid, like a web page or something for the picturing the immaterial values (would allow the building expert to save time) and you can add the questionnaire as well, so you have more self-studies directly made by the homeowners themselves instead of having the building expert come out and present it.”

“I think it shows quite clearly that some of the time spent was used to explain the effects of the scenarios. I think that a 3D model for architects or a simple hand sketch would be a great help for the homeowners to understand what for instance twenty percent increase in window area would mean to them.”

“It was along with the questionnaire and the pictures regarding architecture mobilization that could be something you offered for the homeowners to do themselves and I think it will save out the time spent with the homeowners about 15%.”

“Well, if you keep it to a print or also have sketches, it might not save you that much time but maybe if you could maybe build a 3D configurator, you could quite rapidly make a model for the homeowners to work in where they could change cons, shapes of windows for them to work on their own that could save you 30% of the time.”

“In the IRP, you really educate the homeowners and provide them with the necessary knowledge to make the right decision regarding their renovation projects.”

“I think it’s very effective way to increase the awareness of what is possible when talking renovation and maybe give people a broader view of what’s possible and what can be done.”

The homeowners concluded in the same sense that the expert:

“It would have been great to have more material to read during the process such as explanation about the vocabulary, introduction to the questionnaire, and why not 3D or even 2D pictograms for the evaluations.”

It seems that the balance of selected interactions has been successful since the building expert has been able to collect the data he needed to customize the approach, and the homeowners received the right quality and quantity of information to make the final decision which made them feel right and satisfied about selecting a high performance renovation scenario. However, it will be important in the future to develop tools which would allow homeowners to work more via self-studies so the building expert can save time in the process and homeowners can keep track of the work between the meetings with the building expert. Nevertheless, it is important that an improvement of the time effectiveness for the building expert does not lead to a deterioration of the quality of the information and a decrease of the quantity of information treated during the process or even a loss of the level of trust gained between the building expert and the homeowners.

Follow-up after the selection of the most favourable scenario

The IRP ended with the homeowners selecting a strategy for the coming renovation that they are going to undertake to their house. At the end of the process, they had an idea of budget and got to know what benefits they could expect for this estimated budget. However, some barriers to home renovation can still be met at this stage of the process. Indeed, depending on the qualifications of the building expert, tasks such as the selection of a general contractor or diverse building professionals, definition of specific specifications and selection of the building products and equipment, etc. still need to be done. These tasks may be barriers important enough to stop the homeowners. It would therefore be judicious in the future to combine the IRP with an automatic transition between the selection of the most favourable strategy by the homeowners and the selection of services from professionals, and specific building equipment and products.

b. Need for professionals with multi-disciplinary knowledge

Even if the IRP is simple in its structure, it requires from the building expert multi-disciplinary skills in order to be able to manage successfully the role of IRP building expert.

This level of knowledge needed depends directly on the qualifications of the building expert(s), on the number of building experts included in the process as well as on the type of expert tool(s) used. At the present time, few professionals have this multi-disciplinary knowledge. It is therefore important that the IRP building expert is selected adequately depending of the degree of complexity of the renovation work. For example, an architect professional may be advisable in case of major transformation of the architecture of the building, while a general contractor with the support of the appropriate tool may be able to acquire the knowledge needed to lead the IRP for a renovation with a preserved architecture. No matter the qualifications that building professionals may currently have, it is primordial for the success of the IRP on a large scale to start educating and train all types of building professionals to this type of multi-disciplinary work.

c. Need for financial incentives

During the application of the IRP on two first single-family house case studies, it has been observed that the IRP has led the homeowners to decide on a major renovation leading to a building with high performances. It has also been observed that the main barrier to deep renovation was the level of investment needed. Indeed, the energy performance levels of the houses after renovation, according to the selected strategies, are still far from the energy performance levels required by regulation for new homes in the years to come in Denmark. Yet, it seems that with a financial incentive and an adapted legislation (levels of incentives accorded depending on the level of energy performance reached in the present and possibly in the future), these homeowners could have invested more in reducing the impact on the environment from operating their house, besides still investing in the same levels of individual benefits to high quality home renovation. In that case, they could have got even closer to a nearly zero or even zero energy home.

d. Need for an adapted legislation

During the application of the IRP, alternatives have been generated to comply or exceed the current legislation requirements for existing buildings to be renovated in Denmark. The costs corresponding to these alternatives also were estimated. It seemed quite easy for the building expert to avoid the obligations set by the legislation due to costs being higher than the levels of cost-effectiveness. Furthermore, even the existing legislation in Denmark, require specific levels of performance at the scale of new building elements, it does not require or motivate homeowners and building professionals to target the global energy performance of the building nor to prepare themselves for possible implementation of measures which could bring the building to higher energy performance levels in the future (e.g. a new roof built on an existing house should be able to integrate a future photovoltaic installation without deconstructing or re-investing twice in specific building elements). Such a change in the legislation would allow the government to be more aware concerning which buildings are updatable in the future towards nearly zero or zero energy levels and at what cost. Also, the government could adapt possible incentives to levels of energy performance reached and to the levels possibly reachable in the future.

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5 Appendices

5.1 Interview with Mikkel Frostholt - 30th of January 2014 – Vamdrup (Denmark)

1. Hi Mikkel Frostholt, thank you for accepting our invitation of interview about the Integrated Renovation Process. Could you tell us a few words about yourself so people listening know who you are?

ANSWER: Yes, I'm currently working as a technical consultant at Isover Denmark. I am educated as a carpenter and I previously worked as an architect and as an estimator.

Mikkel, you were the first building expert to apply the Integrated Renovation Process on case studies. Just as a recall: The Integrated Renovation Process (IRP) is a user customized methodology based on constructivist and interactive multi-criteria decision making methods. When applied to a home renovation, the Integrated Renovation Process for Homes (IRP4homes) supports, informs and reassures homeowners to decide on a sustainable renovation of their home while getting the corresponding associated benefits and therefore a home more adapted to their lifestyles. The IRP4homes also helps the building experts to be more effective for the quantitative analyses and the generation of the renovation scenarios so they get more time for the cost optimization and the qualitative analysis of the homeowners' needs, wishes and behaviours.

2. As a building expert, did you feel that the IRP helped you to be more effective in terms of:
 - a. Generation pre-selection of renovation scenarios?
 - b. Quantitative analyses (i.e. evaluation of the renovation costs, energy savings and performance of the building, house plus-value)?

ANSWER: I actually spent quite a lot of time generating the scenarios, including the costs and also the quantitative analyses so as it today it's not a more time effective method but it does provide the tools to reach high performance renovation levels and an interesting way to make to homeowners feel satisfied about the selected renovation work.

3. For each case study, how much time of work did you spend on the following actions:
 - c. The analysis of the questionnaire answers?

ANSWER: I have spent less than two hours.

d. The Analysis of the homeowners' needs, wishes and behaviours (first discussion, interviews and brief visit of the house)?

ANSWER: Well with the discussion, of course it buried a bit. I would say on average three hours.

e. The diagnosis of the building?

ANSWER: I think it was quite simple to follow the given tools from the method so I would say around three hours.

f. The multi-criteria analysis of the house in the existing conditions undertaken with the help of the homeowners?

ANSWER: Again a job done with the homeowners so again there is a bit time consumption, because we needed to sometimes make them aware of the problems in their homes so I would say around three hours.

g. The generation of possible renovation scenarios?

ANSWER: This is really a time consuming part of the process. For these two case studies I spent an average of six days per study.

h. The pre-selection of possible renovation scenarios?

ANSWER: When we first had the generation of scenarios including cost and energy savings, it was quite simple to combine and/or to subtract different measures in the scenarios so maybe two hours.

i. The multi-criteria analysis of the pre-selected renovation scenarios undertaken with the help of the homeowners?

ANSWER: Together it was a bit time consuming, because the homeowners were very interested in many of the details of the scenarios and it is quite important for them to understand fully what they were gaining with the different scenarios so I think we spent like four or five hours.

j. The support of the homeowners for the final selection of the most favourable renovation scenario?

ANSWER: Once we presented the different scenarios to the homeowners in order to understand, they were quite positive regarding the major renovations, so they were quite keen on those. So it was quite easy for them to make decisions, what to pursue further, so then both of them went for major renovations within an hour.

4. In your opinion, what time would take the decision making of selecting a renovation scenario (from first contact until the selection of the renovation measures to implement) in a more regular approach (architect, energy consultant, etc.)?

ANSWER: I think that it would vary greatly with the kind of renovation we are talking about. If it is a standard renovation with new windows, doors maybe with changing the interior walls and roof, I would say maybe one to two days. And if we are talking high performance energy renovation then we're at least talking three to five days.

5. As estimation, as a percentage value, how much extra working time did the application of the IRP4homes represent compared to a more regular approach?

ANSWER: Well compared to the standard renovation, I would say two hundred percent, instead of maybe two, three days we spend eight or nine days in regards to high performance renovation, it is about hundred percent, we spend twice the time. It's what would normally be required.

6. Out of this extra working time, how would you divide it between extra time used on the analysis of the building and quantitative analyses, and extra time used to interact with the homeowners?

ANSWER: We spent more time on both, the homeowners and the building, compare to regular renovation processes. But the main focus here, because many of the generation of high performance suggestions was very time consuming as you're really looking for the optimization of the energy performance in every part of the building, I would say 90% percent of the extra time spent went to the renovation scenarios and the quantitative analyses. Even though we spent quite a bit more time interacting with them and trying to educate them to make better choices, the main part of our extra time was spent on generating high performance scenarios.

7. Mikkel, you said most of the extra time was uses on the generation of the renovation scenarios and on the quantitative analyses so in your opinion, which of the following tools would help you to save time during the application of the IRP?

- a. An automatic analysis of the questionnaire answers?

ANSWER: Yeah, they could save some time but in the whole process of this method is a minor point and I would say you risk losing information if you do this automatically, so it is better to go through the questions one by one.

- b. An automatic pre-selection of quality and performance criteria?

ANSWER: I don't know about an automatic pre-selection and I think it is like the last question, maybe as a visual aid, like a web page or something for the picture regarding the immaterial values and you can add the questionnaire as well, so you have more self-studies directly made by the homeowners themselves instead of having the building expert come out and present it.

So the homeowners could do some work themselves so it would save time to the building expert?

ANSWER: Exactly.

- c. A more formal tool to analyse the homeowners' needs, wishes and behaviours (in IRP, we used a first discussion, interviews and a brief visit of the house)?

ANSWER: I don't think that this would be a good idea, because I think, once we have the first information meeting in person with the homeowners, gives us a general idea of what their answers to the questions mean, and I think it is very important for the process to go and meet them.

- d. Another tool than the degradation / technical obsolescence evaluation sheet for the diagnosis of the building?

ANSWER: I found the sheet quite beneficial, it had the general separation of building or construction components and you have the scale to evaluate how far the degradation state and the technical obsolescence were and how to prioritize them so I was quite satisfied with the sheet.

e. More visual supports (videos, interactive videos, website, illustration program, etc.) to support the multi-criteria analysis of the house in the existing conditions undertaken with the help of the homeowners?

ANSWER: I don't think it would be necessary for this part of the process; usually it's a part that goes on in the homeowners building, so you can walk around and address the various problems in the building as it is.

f. A tool which would automatically generate possible renovation scenarios and would give for every scenario: an estimation of the total renovation cost (embedded cost data base), the energy performance of the building (i.e. energy label and energy savings) or a tool which would automatically generate possible renovation scenarios and optimize the total renovation cost according the every level of energy performance reached?

ANSWER: I think that will help the process greatly, as I said before it's one of the main time consuming area, so any tool that help speed up the process, if for instance you only have to select a level of energy performance of the building and the corresponding renovation cost follows automatically or the other way around, then you would save a very substantial amount of time.

So this is a very important point and the tool which is really needed?

ANSWER: Yes, It's the key tool that needs to be added to this process if we want to make it feasible.

g. More visual supports (videos, interactive videos, website, illustration program, etc.) to support the multi-criteria analysis of the pre-selected renovation scenarios undertaken with the help of the homeowners?

ANSWER: I think it shows quite clearly that some of the time spent was used to explain the effects of the scenarios. I think that a 3D model for architects or a simple hand sketch would be a great help for the homeowners to understand what for instance twenty percent increase in window area would mean to them.

h. A tool which would give the house plus-value more globally and also more accurately?

ANSWER: For some people it would be very important, especially for people who need to go to the bank for great amount of their finances. It will be very important for them to be able to show the bank the new estimated plus-value of their house. It will be the basic fall for the loan they will need to take.

Yes I understand, and this because the estimation of the plus value is only related to the improvement of the energy label of the house?

ANSWER: Yes, the current plus-value we have is related to the energy level, and is not accurate enough.

- i. A tool which would display the results differently to support the homeowners for the final selection of the most favourable renovation scenario?

ANSWER: I think the tool does in the method right now with the right grid and the other scale is quite simple and quite accurate and it gives good general idea of the state of the house before renovation, and how the building will be after scenario one, two and three.

So did you find that the homeowners actually understood easily the results through the coloured scale?

ANSWER: Yeah, it felt quite easy to explain them that green is favourable whereas red is not for earlier parts of the process so by the time we come up with the final result, so they have already understood the concept of the colours.

8. In your opinion, how much working time the use of one of the previous discussed tool or a combination of tools would save?

Compared to the time used for building and quantitative analyses (in %):

- A tool which would automatically generate possible renovation scenarios and would give for every scenario: an estimation of the total renovation cost (embedded cost data base), the energy performance of the building (i.e. energy label and energy savings) or a tool which would automatically generate possible renovation scenarios and optimize the total renovation cost according the every level of energy performance reached.

ANSWER: I think that will benefit the process greatly, as it is right now, we first go through the energy performance levels then we go through the costs then we try to optimize the performance at the best cost. It's basically three workloads that could have been combined into one, I'd say you could save around 75%-80% of the time spent if the program generated automatically, maybe based on price data bases previously done projects.

So if I understand well, you said that you spent 6 days out of 9 to work on the building renovation scenarios and quantitative analyses, and saving 80% of the time would mean that out of the 6 days used, you would save most of the time which means that within 1 or 1,5 day, you could work out this part of the process?

ANSWER: Yes, surely.

- A tool which would give the house plus-value more globally and more accurately.

ANSWER: I don't think we will save that much time, but it will be a great benefit for the process because it's not for all people. In our first case study, it didn't really matter for the homeowners, because they didn't they would sale the house anytime soon, but still it actually matters because some people maybe have to take loans, and to do the renovation, they need to know the plus-value of their house after they renovate because it's a major factor when the bank does estimates if they can get these loans or not.

Compared to the time used to interact with homeowners (in %):

- An automatic pre-selection of quality and performance criteria.

ANSWER: It was along with the questionnaire and the pictures regarding architecture mobilization that could be something you offered for the homeowners to do themselves and I think it will save out the time spent with the homeowners about 15%.

- More visual supports (videos, interactive videos, website, illustration program, etc.) to support the multi-criteria analysis of the pre-selected renovation scenarios undertaken with the help of the homeowners.

ANSWER: Well, if you keep it to a print or also have sketches, it might not save you that much time but maybe if you could maybe build a 3D configurator, you could quite rapidly make a model for the homeowners to work in where they could change cons, shapes of windows for them to work on their own that could save you 30% of the time.

So we add up 15% of time saving from the criteria selector and 30% from the 3D configurator, it would save the building expert pretty much half of the time he spent with the homeowners?

ANSWER: Yes indeed, it would.

9. Mikkel, we just saw together we actually can save some time both in terms of building evaluations and interaction with the homeowners by using the appropriate tools. In your opinion, in the context of the IRP, would this combination of tools allow you to be more time effective than in a more regular renovation approach which would still be targeting high building performances (i.e. energy performance, cost optimization, building plus-value, etc.)?

ANSWER: As you mentioned and as you saw earlier, we spent a lot of time on this project and one of the problems was that some tools are missing and also the experience in using the IRP methodology. I think with the right tools and with some more experience in using the method, we could easily match a regular high performance renovation process.

You mean that in terms of time frame, if you take around 3 to 5 days for a regular renovation approach, you might actually be able to take around the same 3 to 5 days to run the IRP?

ANSWER: Yes, I think we could match a regular renovation process with the IRP. The main difference between the two, I think, is the quality of the renovation process. With the IRP, I think you end up with a more homeowner specific suggestions, and also you really raise the awareness of the building conditions in the homeowners' minds, they really influence the process and they are the ones who have to live in the home for the next 20 or 30 years whereas we as building experts or consultants will be moving onto the next project the next week.

What about the performances of the building that you reached at the end of the process?

ANSWER: When we started this process, the homeowners were talking about changing windows, maybe upgrading small parts of their homes, and in both cases, we are actually ending up with some a major renovation targeting high performances. This is because they are now really seeking these comfort levels.

Do you actually believe that by using the IRP, you have obtained high performances that you would have not reached with a more regular type of renovation process?

ANSWER: I'm certain of it; homeowners in both case studies did not consider initially a major renovation. They had maybe not the knowledge or were maybe limited in the ideas about renovating.

10. So Mikkel, this is going to conclude the interview. I have a couple of short questions left to ask you. Have you been generally satisfied or dissatisfied with the application of the IRP?

ANSWER: I've been very satisfied with it, for me personally it has always been very important that my clients or the homeowners I deal with get most value for their money, and with this matter, in the IRP, you really educate the homeowners and provide them with the necessary knowledge to make the right decision regarding their renovation projects.

11. And in your opinion, can the IRP be an effective way of working in the renovation sector in the future?

ANSWER: I think it's very effective way to increase the awareness of what is possible when talking renovation and maybe give people a broader view of what's possible and what can be done.

12. So have you actually been able to motivate homeowners to select a renovation scenario with higher performances?

ANSWER: I totally have, the homeowners were initially quite hesitant about major renovation, they were not very aware of what the possibilities were and with the final presentation of the scenarios, they went straight for a high performance scenario. I think they wouldn't have done that if they did not go through the Integrated Renovation Process.

13. So you believe that the homeowners were happy and satisfied with the process they have gone through?

ANSWER: I have that impression.

14. What are your suggestions or recommendations for the future of the IRP?

ANSWER: I think the method is very good but, as it is now, it lacks more integrated and automatized tools to make it more feasible in practice, one needs to be more time effective as building expert but as a support for homeowners I think it's already very good.

OK Mikkel, thank you very much for your time.