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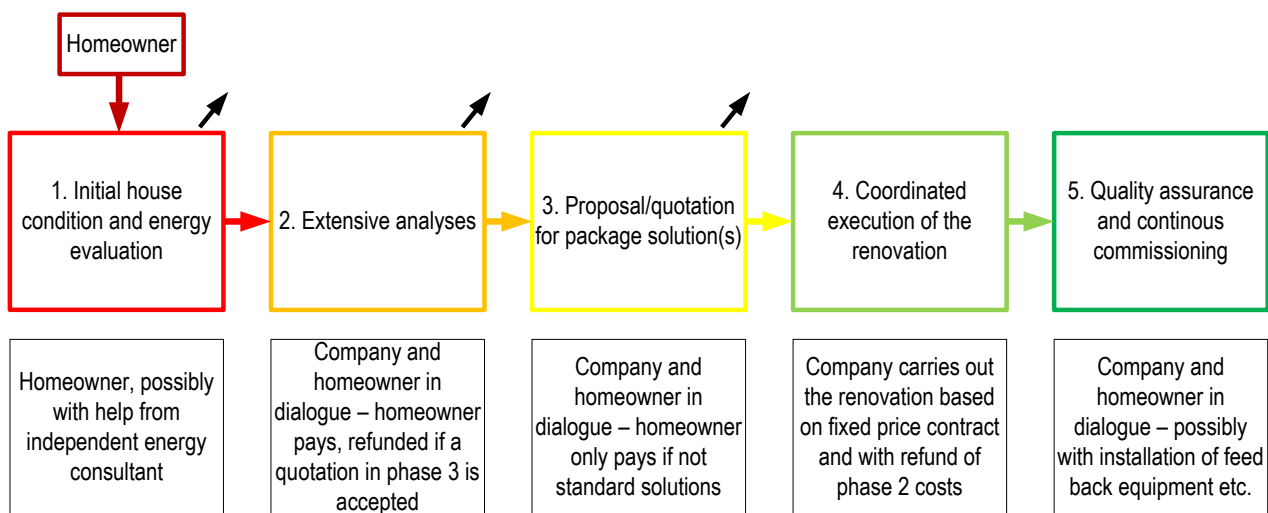
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Extended abstract

There is a need for far-reaching energy efficiency improvements in connection with renovation if existing single-family houses in the Nordic countries are to have competitive power compared to new buildings on the future housing market. If the market is able to explain this to the homeowners there is an open market with undreamt-of possibilities. Good technical solutions exist but need to be combined based on the full range of (standard) solutions in order to reach the low primary energy level of new houses.

A one-stop-shop in the form of a full-service concept could be seen as a possibility to make it easy for the homeowner to realize far-reaching energy savings, provided that the building sector offers the solutions. Such one-stop-shops in the form of full-service providers of energy efficient renovation of single-family house are missing in the Nordic countries, although this service is vital to open up the market. The purpose of such shops, which may be a cheap internet shop, is to help homeowners with design and decision making process in connection with renovation of their house. The one-point-of-contact service provider may be a company/team of consultants and contractors. They can help to bring about a complete sustainable renovation solution including quotation for the work, financing and management of the contract work.

As part of the Nordic research project 'SuccesFamilies' with the purpose to change the business environment in order to speed up the implementation of sustainable renovation of single-family houses –a sustainable renovation concept suitable for different categories of single-family houses with regard to type and age has been proposed in this article. The sustainable renovation concept includes an ideal full-service concept and technical renovation solutions targeted to different types of single-family houses. The ideal full-service concept consists of 5 phases, going from initial evaluation of the house, to extensive analyses, proposal for package solutions, coordinated execution and operation and management of the house after renovation.



The idea is to inspire one-stop-shop providers of today and the future to improve their service. Based on analyses of existing full-service concepts the following improvements are suggested:

- Integrated analysis of the energy saving potential and physical conditions
- Extensive analyses such as thermography and blower door test to be able to come up with trustworthy fix price proposals with very limited reservations
- Focus on handling of the homeowners needs and wishes and making it easy to buy renovation services (like in a kitchen studio) and more focus on the non-energy benefits
- Offering of the full range of technical solutions and focus on reducing heating demand before introducing measures to ensure energy efficient energy supply
- Development of tools to quickly put together individual package solutions - based on configuration of standard solutions - and including visualization of the renovation project for the homeowner

Technical energy efficiency measures targeted to different types of single-family houses can be combined into concepts or packages of measures. If such packages should be attractive for the homeowner it is crucial to link energy efficiency measures to the normal renovation measures, in that way reducing the price of implementing the energy efficiency measures. Nordic single-family house owners can generally save about 75% on primary energy use and energy bill by installation of building envelope post-insulation, energy efficient windows, ventilation with heat recovery and an efficient energy supply system. This corresponds to the energy use level of a new house or better. Such renovation will amount to approximately EUR 100,000 and it may be difficult to obtain an economy in balance in the sense that the annual payment on a cheap loan (mortgage refinancing) to finance the renovation is not fully offset by the expected annual energy savings.

Therefore it is also important to address the non-energy benefits of energy efficient renovation, such as better and healthier indoor environment and comfort. Other benefits are improved lifespan of structures, increase in value of the house and less dependence on expected future higher energy prices. With due regard to these important benefits energy efficient renovation should still be attractive for the average homeowner. Better incentives structures, e.g. increased tax on energy and/or subsidy programmes might also speed up the implementation of a complete energy efficient renovation.

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Summary

There is a need for far-reaching energy efficiency improvements in connection with renovation if existing single-family houses in the Nordic countries are to have competitive power compared to new buildings on the future housing market. Good technical solutions exist but need to be combined based on the full range of (standard) solutions in order to reach the low primary energy level of new houses. A one-stop-shop in the form of a full-service concept could be seen as a possibility to make it easy for the homeowner to comply with possible future requirements to realize far-reaching energy savings in connection with extensive renovations, provided that the building sector offers the solutions. Such one-stop-shops in the form of full-service providers of energy efficient renovation of single-family house are missing in the Nordic countries, although this service is vital to open up the market.

As part of the Nordic research project 'SuccesFamilies' with the purpose to change the business environment in order to speed up the implementation of sustainable renovation of single-family houses –a sustainable renovation concept suitable for different categories of single-family houses with regard to type and age has been proposed in this article. The sustainable renovation concept includes an ideal full-service concept and technical renovation solutions targeted to different types of single-family houses.

Keywords: energy efficiency, renovation, single-family houses, one-stop-shop, full-service concept, technical solutions

1. Introduction

Detached single-family houses account for large share of the total number of dwellings in the Nordic countries. With a final energy use for space heating and hot water in the range of 135 to 200 kWh/m², existing single-family houses in the Nordic countries need to be significantly upgraded to be competitive compared to new buildings on the future housing market [1-4].

So far there has been limited attention to address the need for major renovation in existing detached single-family houses. The Nordic single-family house renovation market is dominated by a craftsman based approach with individual solutions, traditional warehouses "do-it-yourself-shops" and some actors marketing single products [5]. In most cases the homeowner is therefore left to himself to compose the right "package" for renovation of his home. In order to ensure the homeowner a sustainable renovation to low primary energy level at a reasonable price, there is a need for a more integrated approach and application of the full range of technical solutions [6].

To speed up the implementation of sustainable renovation of single-family houses there is also a great need for full-service packages including consulting, contract work, follow-up, financing and operation and maintenance. There are few Nordic examples of such service models for renovation of single-family houses which entered the market recently. The success of these concepts is yet to be evaluated. However, most of these service models typically focus on application of only a few of the available technical solutions for renovation and have not been successful in realizing large scale energy efficiency gains [5].

A one-stop-shop in the form of a full-service concept could be seen as a possibility to make it easy for the homeowner to comply with possible future requirements to realize far-reaching energy savings in connection with extensive renovations, provided that the building sector offers the solutions. Homeowners need someone to take care of all relevant steps necessary for the renovation of the house including quotation for the work, financing and management of the contract work. Such one-stop-shops in the form of full-service providers of energy efficient renovation of single-family house are missing in the Nordic countries, although this service is vital to open up the market.

As part of the Nordic research project 'SuccesFamilies' with the purpose to change the business environment in order to speed up the implementation of sustainable renovation of single-family houses –a sustainable renovation concept suitable for different categories of single-family houses with regard to type and age has been proposed in this article. The sustainable renovation concept includes an ideal full-service concept in five phases, going from initial evaluation of the house, to extensive analyses, proposal for package solutions, coordinated execution and operation and finally management of the house after renovation and includes technical renovation solutions.

2. Full-service renovation concepts

A full-service or one-stop-shop renovation concept is defined as a documented series of actions that can be repeated and that produces individual renovated single-family houses aiming at fulfilling the defined requirements optimally. The term full-service renovation concept indicates that all relevant steps necessary for the renovation of the house are included [5]. Typically, the requirements are defined by the homeowner and building code, e.g. requirements to heat loss (U-values), energy performance (energy consumption), indoor environment (indoor air quality, thermal comfort and daylight) and architectural quality. As mentioned previous, a full-service or one-stop-shop renovation concept could be seen as a possibility to make it easy for the homeowner to comply with the requirements. The one-stop-shop can help the homeowner with design and decision making process in connection with renovation of the house.

Analysis of existing full-service renovation concepts has shown that they can generally be improved by:

- A more integrated analysis of the energy saving potential, physical conditions and technical solutions using the full range of solutions, i.e. advice to reduce heating demand before introducing measures to ensure energy efficient energy supply.
- Including advanced analyses such as thermography, possibly complemented by U-value measurements [7], a and blower door test that the homeowner can buy and may get refunded if they buy a renovation solution – which enables the company offering full-service renovation to come up with trustworthy fixed price proposals with very limited reservations.
- Better handling of the homeowners needs and wishes.
- Package solutions made up from different standard parts, making it easy to carry out sustainable renovation (like e.g. in a kitchen studio)
- Making the energy efficiency improvements more attractive and cost effective by focusing on the non-energy benefits.
- Developing tools to quickly put together proposals for full-service renovation including drawings and calculations that can visualize the renovation project for the homeowner.

2.1 Full-service renovation – ideal concept

An ideal one-stop-shop concept for preparation and execution of complete package solutions for sustainable renovation of single-family house is suggested. The idea is to inspire one-stop-shop providers of today and the future to improve their service. The concept consists of five phases, going from initial evaluation of the house to extensive analysis, proposal for package solutions for sustainable renovation, detailed planning and execution; and operation and management of the house after renovation, see Fig. 1.

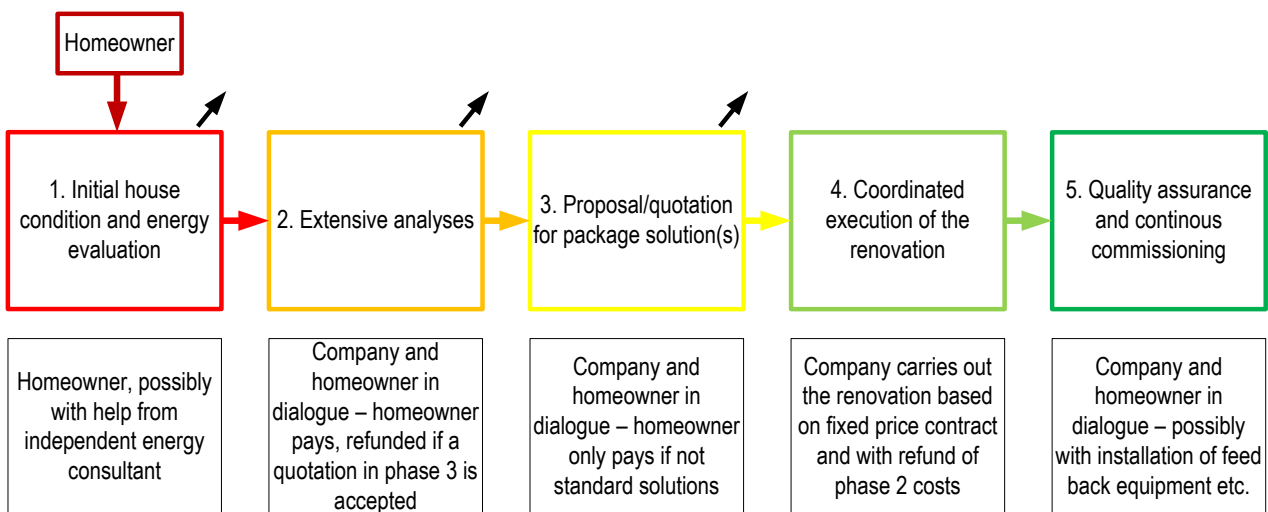


Fig.1. Full-service or one-stop-shop concept.

The different phases in the concept are briefly described below.

2.1.1 Initial house condition and energy evaluation (phase 1)

This initial analysis of house condition and energy saving potential should be free of charge and may be carried out by the homeowner using an internet tool / simple model, provided by the one-stop-shop/company offering complete renovation package solutions. Alternatively, the homeowner could ask for help from an independent energy consultant. A basis for the analysis is a possible existing energy label, house condition report, drawings, pictures and other relevant documents.

Information about house type, year of construction, existing building envelope structures (U-values), existing heating and ventilation system and areas is needed. Furthermore, since user behaviour influences energy use, information about indoor environment, i.e. indoor temperature, air change rate, venting habits etc., is required. Based on this information, the analysis provides the homeowner with a guided choice of energy efficiency measures and a rough estimation of possible savings and other measures based on his needs and wishes for improvements of the energy performance and living comfort etc. Furthermore, indoor environment benefits, renovation costs, financing expenses, increase in value of the house etc. are documented. The homeowner also receives documentation/visualisation of the effect of energy and non-energy benefits on the cost of financing the renovation. Besides this, the company provides the homeowner with information about relevant legislation and subsidy possibilities.

2.1.2 Extensive analyses (phase 2)

The initial analysis is followed by more extensive analyses. This service is carried out by the company in dialogue with the homeowner and paid for by the homeowner but refunded if a renovation package solution is bought in phase 3. The extensive analyses also have as purpose to provide the company with knowledge that allows for a safe foundation for providing the homeowner with an economical attractive and fixed price quotation for the renovation work. The extensive analyses could include relevant services such as blower door testing of the building envelope's air tightness, building thermography to reveal thermal bridges and possibly heat loss measurements and estimation of remaining life time of building components.

As an output from phase 2 the company gathers an initial house evaluation report with the results of the analyses that can be used for the homeowner's consideration of future renovation work. The evaluation report includes a clarification of the needed renovation work, needs and wishes for improvement, order of priority and estimated costs. Furthermore, advice on how to improve the energy performance of the house in connection with needed renovation work is stated in the report. Besides this, the evaluation report should include an estimation on the economic implications of normal step-wise renovation, thorough sustainable renovation and demolition of existing house and building of a new house (if relevant). In some cases, a major sustainable renovation is not relevant and therefore the company should offer to make a detailed long term plan for renovation and modernization, which optimizes the economy in relation to the house owner's wishes and needs.

2.1.3 Proposal for package solutions (phase 3)

In this phase proposals for renovation package solutions are put together, including quotation for the work, financing and management of the contract work. The main point is that the typical homeowner needs help in the design and decision making process. As a starting point for this phase, the company organises a meeting with the homeowner to discuss the initial house evaluation report, needs and wishes, technical solutions and available budget. Output from this meeting is used for further analyses of possible technical renovation measures in order to result in trustworthy proposals for sustainable renovation including energy and non-energy benefits, economic profitability, financing, plan for renovation, durability issues and fulfilment of user needs and wishes. Economic profitability and priority of measures can be analysed using e.g. the criterion of cost of conserved energy incl. twofold benefit of energy savings and rehabilitation of the building components physical condition.

The company should be able to carry out this phase within a maximum of 4 hours provided that the right system for configuration of technical standard solutions is in place including simplified but accurate calculation models. If the homeowner wants special solutions that are not standard it may not be free of charge getting quotation for renovation work.

As output from phase 3 the homeowner receives a pre-project folder with fixed priced proposal(s) for optimized package solutions for renovation including visualization/documentation of the effect on energy use and energy bill, household economy (short and long term, including effect of increased value of the house), indoor environment and other durability and maintenance issues.

2.1.4 Coordinated execution of the renovation work (phase 4)

This phase is carried out based on the homeowner's evaluation of the pre-project proposals for sustainable renovation. If the homeowner chooses to accept any of the proposals, any remaining economic and financing issues are clarified and a contract for renovation work is signed. The contract could include approval of a possible loan and/or governmental subsidy or contract details could be fine-tuned considering the specific situation, e.g. some extra work or/and better products might be included. Signing of the contract could be based on a fixed priced contract work carried out on risk of the facilitator of the full-service package solution or it could be based on energy performance contracting (EPC) utilized and redeveloped to match the single-family house renovation market.

After signing of the contract, drawings and a detailed work description are prepared and the contract work is carried out, managed and quality assured by the company and the affiliated professional group of consultants and contractors. However, as the traditional market for renovation is very much a do-it-yourself-culture, service packages should be flexible to handle a customer wish for contributing to the process of carrying out the work.

2.1.5 Quality assurance and continuous commissioning (phase 5)

After the execution of the sustainable renovation an important phase begins. Quality of the renovation work is inspected, e.g. by a independent certified energy consultant, and heating and ventilation systems are commissioned according to the project, and this not only once but on a continuous basis. Continuous or Life-Cycle Commissioning (LcCx) in connection of existing buildings is usually considered as "a systematic process for assuring that buildings operate, function and are maintained optimally according to owner expectations and user needs." [8]

After visit of the independent energy consultant the homeowner is provided with a follow-up evaluation report. Besides this, the homeowner also receives a user manual including a plan for continuous commissioning of the house (like car service) to make sure that the house functions optimally according to owner expectations and user needs and the peak energy performance is continuously reached. Since user behaviour can have large impact on energy use, it is important to present the homeowner with information on the consequences for energy use and indoor environment if the house is not operated as prescribed.

To check if expected energy savings are fulfilled equipment for measurements and presentation of weather data, energy use, and actual use of the house, e.g. ventilation, indoor temperature and opening of windows is needed. When relevant such system may suggest actions to reduce energy use, e.g. indoor temperature, ventilation rate or hot water use, based on comparison with the assumptions made in the calculation of expected energy use and savings in phase 3 – including estimate of the consequences of the more energy friendly use of the house. A validated model of the house could be the basis for intelligent control of active and passive systems for heating, cooling, ventilation, solar shading etc., based on measurement of actual and forecasted weather data and use of the house. The Danish Energy Saving Trust is offering a new program to homeowners (My E-Home, [9]) that could – with the right equipment - be used for online control of energy use in single-family houses, i.e. to switch on, turn off or adjust the heating and ventilation system etc.

2.2 Full-service concepts for different single-family houses

Nordic single-family houses vary in age, size, architecture, insulation standards etc. Hence, a standard renovation concept might not be applicable to all types of houses. Each renovation project with different framework conditions may need to be evaluated separately. Accordingly, it may be relevant to focus full-service concepts to a certain category of single-family houses.

Analysis of the building stock in the Nordic countries as part of the 'SuccesFamilies' project showed that the typical single-family houses identified to have large primary energy saving potential almost descend from the same time period in each Nordic country. The first segment is houses built in large numbers during the 1960's and 1970's before tightening of the insulation standards in the building codes in the late 1970's due to the oil crisis. The second segment is houses built before 1945 (except for Finland) where a large part of them has been renovated, but energy renovation of those houses today would still account for a large energy saving. The third segment is type houses from the post-war period in Finland, houses that are all individual but built in the same way with the same materials. In Fig. 2, an illustration of some of the type houses can be seen.



Fig. 2 Typical single-family houses in the Nordic countries. From left to right: Danish house built before 1945, Norwegian house built before 1945, Post-war Finish house, Danish house built in 1960/70's.

The renovation process for these different categories of single-family houses may be very similar but the technical solutions are different. For example, many people regard facades of typical Danish single-family houses built before 1945 (so-called master builder houses) as being worth preserving. Facades can be thermally improved by filling the cavity with e.g. granulated mineral wool and by installing new storm windows with energy efficient glazing whereas a facade constructed from wooden framed walls, as can be found in Norwegian single-family houses built before 1945, may be more likely to be renovated along with adding external insulation.

Hence, technical renovation concepts can be defined for these different categories of single-family houses.

3. Technical renovation concepts

A technical renovation concept is defined as a package of solutions targeted to a certain category of house (type and age) [5]. The package of technical solutions carried out during an overall or step wise planned renovation should be a good combination of the full range of technical solutions, especially in order to reach a low primary energy level.

3.1 Technical renovation solutions

To reach a low primary energy level, different technical solutions such as renovation of roof, facade, changing windows, installation of energy efficient heating systems, and establishing a ventilation system etc., need to be combined. The technical principles are illustrated in Fig. 3 in recommended order of application and an indication of the needed level of energy efficiency of these principles is also included. Focus is on technical solutions relevant for renovation of typical single-family houses in the Nordic countries.

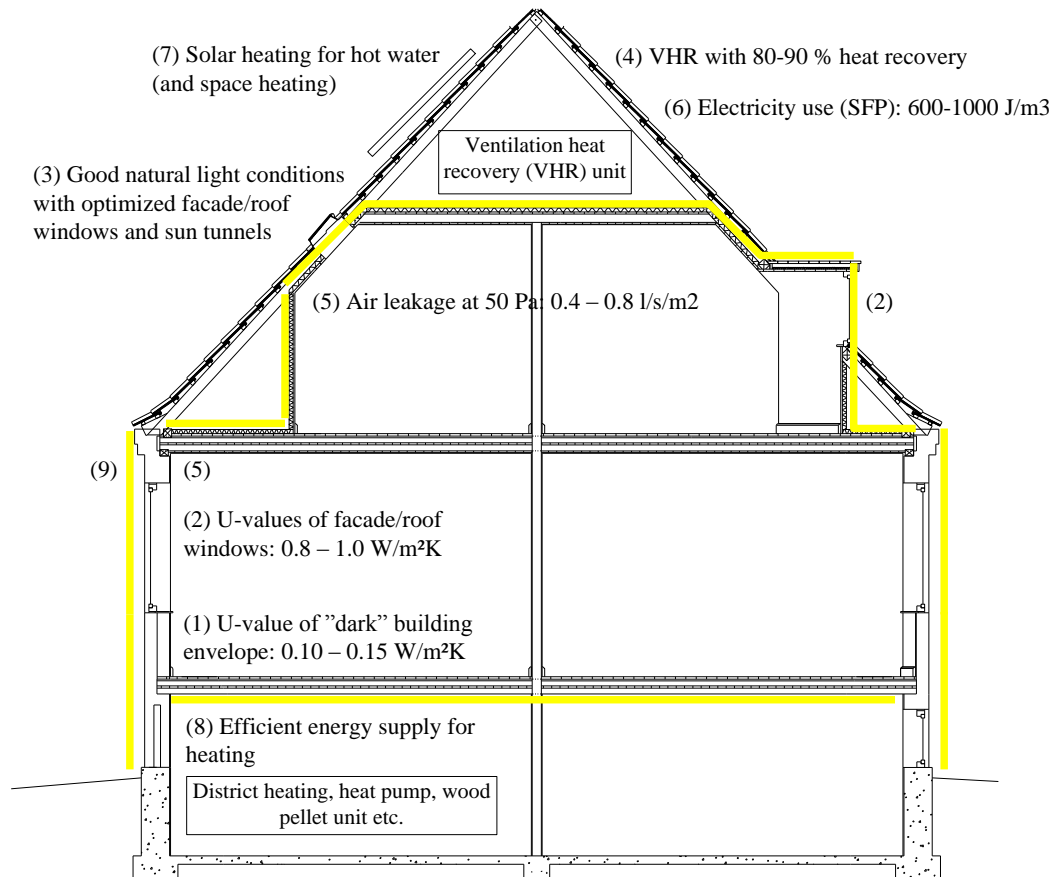


Fig. 3 Technical renovation principles in order of application. (1) Reduced transmission heat losses from opaque building envelope (2) Reduced transmission heat losses, good solar gains and light transmission from the transparent building envelope (3) Optimized utilization of passive solar heat gains (4) Minimized ventilation heat losses (5) Minimized infiltration heat losses (6) Minimized ventilation electricity use (7) Minimized water heating demand (8) Efficient energy supply for heating (9) Mainly passive measures for overheating control.

Besides the technical principles illustrated in Fig. 3, also intelligent control and continuous commissioning and the installation of energy efficient electrical appliances need to be considered.

3.2 Packages of technical renovation solutions

Technical renovation solutions/measures can be combined into technical renovation concepts or packages. Such packages have been defined and analysed as part of the SuccesFamilies project, see Table 1. Package #1 "Existing house" is to be regarded as the scenario where renovation may be carried out in the form of e.g. a new roof and/or new exterior wall rainscreen, but no measures to improve energy efficiency are implemented.

Table 1 Packages of technical renovation solutions.

#	Package	Energy efficiency measures	Technical principles
1	Existing house	No energy efficiency measures	Traditional renovation
2	"Easy-to-carry-out" measures	Insulation and sealing of building envelope, windows that allow for utilization of passive solar heat gains and daylight without excess overheating.	Minimized transmission and infiltration heat losses, utilization of passive solar heat gains and daylight etc
3	+Efficient energy supply system	Heat pump, district heating, low temperature system, energy efficient circulation pumps, insulation of heating pipes etc.	Efficient energy supply for heating
4	+ Ambitious measures	Mechanical ventilation system with heat recovery (VHR), solar energy for hot water etc.	Minimized ventilation heat losses and water heating demand
5	+ Extensive measures	Façade insulation that changes the appearance of the house, or measures that are far reaching but allow for a large reduction in the primary energy use	Various

A complete energy efficient renovation of a typical house includes post-insulation and sealing of the buildings envelope - roof/ceiling, façade, windows/doors and foundation and maybe slab on ground - installation of a mechanical ventilation system with high efficiency heat recovery and low electricity use and if not already there, an energy efficient heating system based on district heating, heat pump etc. This package of technical solutions can be carried out during an overall or step wise planned renovation dependent on the condition of the house, the financial possibilities of the homeowner etc.

3.3 Example – Packages of solutions for Danish single-family houses built during the 1960/70's

An example of calculation of packages of technical solutions for energy efficient renovation is given below.



Calculation have been based on analysis of a typical Danish single-family house built in 1972 with a heated floor area of 155 m² and heated by a gas-fired boiler.

The house is one of the many 450.000 Danish typical single-family houses built during the 1960/70's. External walls of these houses are constructed as cavity or framed walls with an insulation thickness of 75-100mm, an outer leaf of 110mm masonry and an inner leaf of 100mm of light-weight concrete or 110mm of masonry. Windows are typically wooden (coupled) windows which need a replacement.

Primary energy use and savings for individual technical renovation measures are stated in Table 2. The installation of a heat pump has not been considered as in future, most Danish single-family are expected to be connected to the district heating network.

Table 2 Primary energy use and savings (kWh/m² per year) for typical individual technical renovation measures.

#	Technical renovation measure	Primary energy	Energy savings
	Existing house from 1972, 155 m ² , gas boiler	246	-
A	External wall insulation, 100-150mm (U = 0.19 W/m ² K)	225	20
B	345 mm insulation in roof (U = 0.10 W/m ² K)	230	16
C	External wall insulation, 200-250 mm (U = 0.13 W/m ² K)	222	24
D	150 mm extra insulation in floor (U = 0.15 W/m ² K)	232	14
E	New energy efficient windows (U = 1.34 W/m ² K)	200	46
F	New low-energy windows (U = 0.80 W/m ² K)	196	49
G	VHR, efficiency: 80%, SFP: 1 kJ/m ³ , infiltration: 0.13 h ⁻¹	231	15
H	VHR, efficiency: 85%, SFP: 0.6 kJ/m ³ , infiltration: 0.13 h ⁻¹	218	27
I	Replacement of existing circulation pump (60W) with smaller energy efficient pump (25W)	240	5
J	Replacement of existing boiler with new condensing boiler	214	32
K	Solar panels for domestic hot water	241	5

3.3.1 Package of solutions

Based on the individual technical renovation measures, the influence of different packages of technical renovation solutions, composed according to the principle in Table 1, has been investigated. In Table 3, the space heating need, primary energy use and savings and overheating hours for each package of solutions are stated.

Table 3 Energy use and savings (kWh/m² per year) and thermal indoor climate for package of solutions.

#	Package of solutions	Energy use			Overheating hours, class II >26°C		
		Space heating	Primary energy	Primary energy savings	Venting 1.5 h ⁻¹ (Ref)	Venting 3.0 h ⁻¹	External shading
1	Existing house	160	246	-	217	110	58
2	A+B+E	81	154	38%	397	155	104
3	A+B+E+H+I+J	55	104	58%	363	148	90
4	A+B+E+H+I+J +K	55	100	59%	363	148	90
5	B+C+D+F+ H+I+J +K	35	66	73%	270	93	68

Table 3 shows that in order to reach a low primary energy level comparable to new Danish buildings today [10], a complete energy efficient renovation with installation of building envelope post-insulation, energy efficient windows, ventilation with heat recovery and an efficient energy supply system is needed. A side effect of insulation measures may be some overheating, which can effectively be avoided by external movable solar shadings and/or to some extent by higher venting rate by use of e.g. automatically controlled windows. A ventilation system with heat recovery will also contribute to a good thermal comfort by draught-free supply of fresh air and make sure of an excellent air quality.

In general, calculation of packages of energy efficient renovation solutions targeting the three segments of houses showed that primary energy use and heating bill could be reduced with up to about 75% or a factor 4 corresponding to the level of a new house or better. The potential is particularly high for houses with electric heating where installation of a heat pump and water-based heat supply system will reduce primary energy use and heating cost with about 70%. Besides efficient energy supply systems, VHR systems are important in order to reach a low primary energy level and a good indoor environment after renovation of single-family houses. VHR systems can give substantial final energy reduction, but the primary energy benefit depends strongly on the type of heat supply system, the amount of electricity used for VHR and the air tightness of the house. It is important to consider the interaction between heat supply system and VHR systems to reduce primary energy use [11].

The investment needed to reach a low primary energy level and a good indoor environment after renovation has been calculated to be in the range of EUR 100,000. With this investment cost, it is generally difficult to obtain an economy in balance in the sense that the annual payment on a cheap loan, e.g. mortgage refinancing, to finance the investment is not fully offset by the expected annual energy savings. In other words, if packages of technical energy efficiency measures should be attractive for the homeowner it is crucial to link energy efficiency measures to the normal renovation measures, in that way reducing the price of implementing the energy efficiency measures. Furthermore, it is also important to address the non-energy benefits of energy efficient renovation, such as better and healthier indoor environment and comfort. Other benefits are improved lifespan of structures, increase in value of the house and less dependence on expected future higher energy prices.

4. Conclusion

There is a need for far-reaching energy efficiency improvements in connection with renovation if existing single-family houses in the Nordic countries are to have competitive power compared to new buildings on the future housing market. If the market is able to explain this to the homeowners there is an open market with undreamt-of possibilities. Good technical solutions exist but need to be combined based on the full range of (standard) solutions in order to reach the low primary energy level of new houses. A one-stop-shop in the form of a full-service concept could be seen as a possibility to make it easy for the homeowner to realize far-reaching energy savings, provided that the building sector offers the solutions. Such one-stop-shops in the form of full-service providers of energy efficient renovation of single-family house are missing in the Nordic countries, although this service is vital to open up the market. The purpose of such shops, which may be a cheap internet shop, is to help homeowners with design and decision making process in connection with renovation of their house. The one-point-of-contact service provider may be a company/team of consultants and contractors. They can help to bring about a complete renovation solution including quotation for the work, financing and management of the contract work.

An ideal full-service concept in five phases has been proposed, going from initial evaluation of the house, to extensive analyses, proposal for package solutions, coordinated execution and operation and finally management of the house after renovation and different package solutions of technical energy efficiency measures targeted to different types of single-family houses have been investigated. Analyses show that typical single-family houses can be renovated to the level of energy performance required for new houses today or in some cases renovated to low-energy level. Nordic single-family house owners can generally save about 75% on primary energy use and energy bill by installation of building envelope post-insulation, energy efficient windows, ventilation with heat recovery and an efficient energy supply system. The finances of such a complete energy efficient renovation are, however, not fully offset by the expected annual energy savings. But with due regard to all the non-energy benefits, such as better and healthier indoor environment and comfort, increase in value of the house and less dependence on expected future higher energy prices, a complete energy efficient renovation could still be attractive for the average homeowner. Better incentives structures, e.g. increased tax on energy, low interest loans and/or subsidy programmes might also speed up the implementation of a complete energy efficient renovation.

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