Different ways to develop green housing

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Summary

The Finnish Government has established a target of cutting down on environmental emissions by at least 80% from the 1990 levels by 2050 with the main focus on housing, properties and transport. Fragmented real estate and construction cluster is facing challenges to align processes across the whole value chain of designing, producing and maintaining buildings. Additionally the old guidelines for the design and construction are not valid due to the changes in requirements for the energy efficiency. This paper presents a combination of variety of methods used in a case study, which aimed to develop green housing concept as a product, production and customer interface.

Very low energy houses use less than 50 % of the energy used in typical buildings and such energy efficient buildings can be achieved in cold climate by carefully designing buildings as a whole. However, the acceptability of very low energy houses depends largely on the economic sustainability of these constructions and to this extent, it requires methods and concepts that differ from the one used in central Europe, e.g. in Germany. Additionally, the development of a very low-energy house market is hindered by a lack of awareness and a lack of very low-energy house products which are mainly only demonstration projects.

A very low-energy house (passive house) has the following features:

- a very well insulated building envelope
- no thermal bridges, i.e. no cold corners or surfaces indoors
- controlled ventilation with > 75% yearly heat recovery efficiency
- airtight construction, air tightness n50< 0.6 1/h
- a limited total primary energy demand

When setting specific energy efficiency targets like passive house or energy efficiency classification A, it should be considered what kind of energy saving investments are the most profitable to choose. The choice order of energy saving investments may vary depending on who is exploring the choice process. Certain initial data is needed to make the systematic analysis of possible energy saving choices. The needed data include the price of the heating energy, the energy saving amount achieved by the measure, and the economical lifetime of the measure. The building costs caused by the energy saving measure must be divided into two sections. The first section includes

the costs directly caused by the improvement of the structure. The other section consists on the additional costs that are caused when the improved structure is attached to the interrelated structures. The third criterion that is used for the examinations is investment costs / annual energy savings.

In the context of green housing the user journey mapping was constructed to be adequate to analyze the resident´s experience of energy efficient apartment. The experience of living in a sustainable house is composed of several independent actions. These actions require from the resident knowledge that cannot be assumed to be possessed spontaneously. The user journey map discusses the residential life as a journey with different action points which forms dimensions that are arrival to home, spending time at home and leaving home. The user journey map can analyze these action points and study what happens in one specific point from the perspective of the residents. Observations and walkthroughs in apartments indicate that not all the solutions were designed from the perspective of daily use.

Developing the design around the user journeys provides confidence that the investigated solution will cater to the typical users' needs. The map of the existing user journey provides a clear view on how easy or difficult it is for a typical user to reach their goal. The ideal journey can often prove to be difficult to implement, with business objectives and technical/design limitations impacting the ability to produce a quick journey, therefore, it is important to create the ideal journeys with a multidisciplinary team to ensure all angles are covered. Balancing user goals and business goals is very important to ensure both are taken care of without impacting each other.

User journeys are very useful to speed up the planning of a new project by highlighting the current issues and produce an ideal picture from a typical user's perspective early in the process. To a customer in the residential life it is indifferent who is providing the services he needs and is ready to consume. From his perspective the everyday life is a journey, were different action points merge as a flow of experiences. On this journey the key criterions are the usability of the technical solution supporting sustainability and the residents' level of knowledge. A well managed supply chain of services can enhance the sustainable behaviour of use.

Three different methods of developing green housing provide a holistic picture. The energy efficiency can be approached from the technical, financial or behavioral perspective. The technical approach provides verified guidelines and the simulations can develop a thorough set of reliable data of analyzed system concepts. However the weakness is that full scale validation requires the long term follow up research is needed. The calculations are providing guidelines, but the approach is very sensitive for economical and financial perspectives. The quality of data is weak because the information about cost components is many times unverified and it can only be estimated. However the pilot cases can provide important data. The challenge is to provide iterative processes where the technical elements and financial elements are investigated in a cycles of development. Next to the technical and economical factors the individual factor can be approach e.g. with the methods of service design. User journey approach provides a possibility to test the technical solutions as a part of users' daily life and it can identify the critical touch points which either facilitate or hinder the energy efficient use of the technical solution. The weakness is typical challenge in qualitative approach: how can these findings be generalized.

The applied methods indicate that the iterative processes are more important than linear processes when developing green housing. The estimation is that the change towards change in processes of green housing from design, construction and use is more challenging than the solutions in energy efficient products. One can state the energy saving potential can be developed with respect to traditional business logic of construction business. The overall goal should be the energy efficient products and the other options should be excluded: in design, construction and use of buildings.

Keywords: green housing, methods, desing principles, calculation, user journey

1. Introduction

The challenge of decarbonizing the Finnish society is a challenge, which is met by adopting the target of reducing energy use to only 20 percent of 1990 levels by 2050. Finland is a country where two-thirds of the greenhouse gas emissions originate from burning fossil fuels and peat in energy production. This energy is needed to provide the large amounts currently needed for domestic use in winter, and to supply an extensive energy intensive industrial. To meet the target, Finland will have to drastically reduce emissions from buildings, do the same for land transport and generate the energy it does require without using fossil fuels. Four alternative scenarios or pathways to the 80 percent reduction target are laid out in the Foresight report on long-term climate and energy policy, adopted by the Finnish government in October 2009. [1]

The certain features are similar in all four scenarios:

- shifting to a zero-emission energy system
- zero-emission passenger road traffic system (electric cars and investment in tram and rail)
- 50 percent cut in the energy intensity of the economy
- improving buildings: new regulations and investment to retrofit current stock to reduce building energy use by at least 60 percent by 2050
- phasing out fossil fuels and peat as power plants are decommissioned
- continuing to increase renewable energy to at least 60 percent by 2050
- cutting car emissions to 20–30g of carbon dioxide per km (currently 130–150). [1]

The calculated energy saving impact of the measures, where regulations for new building and renovation building end up to savings of 4.9 TWh. This sets its requirements in construction of variety of building segments. Green Building is known as green construction or sustainable building, and is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from location of sites to design, construction, operation, maintenance, renovation, and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability, and comfort. Although new technologies are constantly being developed to complement current practices in creating greener structures, the common objective is that green buildings are designed to reduce the overall impact of the built environment on human health and the natural environment efficiently by using energy, water, and other resources. [2]

Fragmented real estate and construction cluster is facing challenges to align processes across the whole value chain of designing, producing and maintaining buildings. Additionally the old guidelines for the design and construction are not valid due to the changes in requirements for the energy efficiency.

This paper presents a combination of variety of methods used a case study, which aimed to develop green housing concept as a product, production and customer interface. The methods used were calculations about energy economical solutions, design principles for relevant building solutions an technology and user journeys mapping of the user experiences.

2. Green housing

2.1 Very low-energy houses

Very low energy houses use less than 50 % of the energy used in typical buildings and such energy efficient buildings can be achieved in cold climate by carefully designing buildings as a whole. However, the acceptability of very low energy houses depends largely on the economic sustainability of these constructions and to this extent, it requires methods and concepts that differ from the one used in central Europe, e.g. in Germany. Additionally, the development of a very low-energy house market is hindered by a lack of awareness and a lack of very low-energy house products which are mainly only demonstration projects.

The principals, also called as “early adapters” have a key role in the very low-energy house building process, in either demanding for a very low-energy house or agreeing with a very low-energy house concept suggested by the architect. It is important that the very low-energy house building owners are aware of how to operate the building, because the occupants’ behaviour influences the final energy consumption. Negative user experiences would cause a drawback for the market penetration. Information and instructions are essential to make the very low-energy house concept successful with regard to its energy saving potential.

The architects, structural engineers and HVAC designers must be thoroughly familiar with the very low-energy house concept to be able to design a very low-energy house. Especially the air quality and indoor climate issues are crucial, because they are important marketing instruments of the very low-energy house concept.

The building contractors and workers must be familiar with the accuracy that is required for building very low-energy houses: air tightness, careful application of insulation, etc. Very low-energy houses form a huge potential market for the building industry and the building product industry. In many EU countries the suitable components are yet not sufficiently available.

An increased demand and import of suitable products stimulate product development. New local products stimulate the demand of the components. IEE NorthPass-project (Promotion of the Very low-energy house Concept to the North European Building Market) aims at overcoming barriers on the very low-energy house markets in cold climate, such as the lack of well-defined concepts adapted to the severe climate conditions, awareness of very low-energy houses, lack of products on the market and customer attitudes.

The objectives of NorthPass are 1) to define very-low energy house criteria and concept adapted to the North European countries, 2) to find solutions to remove market barriers for wide market acceptance of those concepts and products, 3) to remove the gap between the demonstration of very low-energy house concept and their broad market penetration and 4) to support the implementation of the EU Commission's strategy and recommendations regarding very low-energy buildings. The project will increase the awareness and market acceptance of very low-energy house in the North European construction market, it will accelerate the identification of suitable solutions adapted to the cold climate environment and it will support the implementation of the EU Commission's recommendations regarding very low-energy buildings.[3]

2.2 Design and dimensioning guidelines of energy efficient buildings

A very low-energy house (passive house) has the following features:

- a very well insulated building envelope
- no thermal bridges, i.e. no cold corners or surfaces indoors
- controlled ventilation with > 75% yearly heat recovery efficiency
- airtight construction, air tightness n50< 0.6 1/h
- a limited total primary energy demand

The properties of the Finnish passive house were defined by VTT in the European research project Promotion of European Passive Houses (PEP) funded by Intelligent Energy Europe program in FP6:

- The total primary energy use for appliances, domestic hot water and space heating and cooling is limited to 130 – 140 kWh/m^2,
- The total energy demand for space heating and cooling is limited to 20 - 30 kWh/m^2 floor area;

The air tightness of the building envelope n_{50} ≤ 0.6 1/h[4]

Thick insulation layers necessitate special attention to be paid to the performance of the structures. Frost protection of foundations, drying capacity of insulated structures, avoidance of thermal bridge effects, and long term performance of the airtight layers need to be considered. The concept development and construction of the first Finnish Passive houses tackled these challenges.

Experiences on ventilation heating systems show that simple heating systems are viable also in the cold climates. The increased heating power demand compared to climates in Central Europe does not reduce the indoor air quality. Room based control enables varying room temperatures according to specific needs of the users.

A passive house for a cold climate requires a high thermal insulation level. A passive house can be built of different building systems, and there is no special material dependence. The importance of thermal mass is also quite low in a cold climate. As the heating season is short, only 4 – 6 months, passive solar heating has also a low importance – there is only few sun shine hours in the midwinter months from November to January.

Passive house design requires accurate knowledge over the properties of building component. The effects of thermal bridges need to be included into the thermal transmittance of the building envelope. Therefore the design bases on more accurate U-value calculations than, e.g., required by the building code. The following indicative properties for thermal insulation of the building envelope help for structural and energy design of the house:

- Wall 0.07 – 0.1 W/m^{2}K
- Floor 0.08 – 0.1 W/m^{2}K
- Roof 0.06 – 0.09 W/m^{2}K
- Window 0.7 – 0.9 W/m^{2}K
- Fixed window 0.6 – 0.8 W/m^{2}K
- Door 0.4 – 0.7 W/m^{2}K

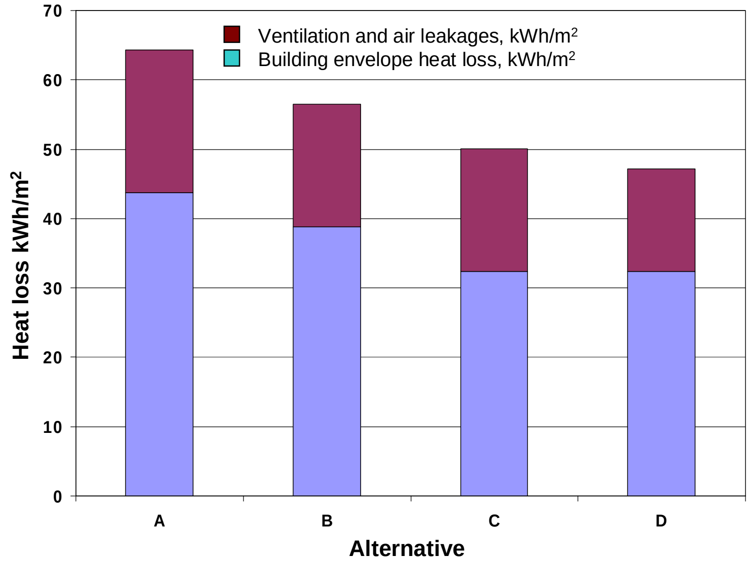
Ground conditions vary in different parts of the country. During a cold winter the ground may freeze down to 1.5 meters in Southern areas, and even down to 2.5 meters in Lapland. These conditions require special attention to foundation system design. Basically, depth of the foundation bed in the ground, heavy foundation insulation, or change of ground mass to non-frosting soil removes the risk. In a typical building the floor heat loss is used for reducing the frost heave risk. As the thermal transmittance of the floor is very low, the heat loss is not applicable any more. Therefore the risk need to be analysed carefully, as the guidelines for foundation design do not cover floor structures with U-values below 0.15 W/m^{2}K.

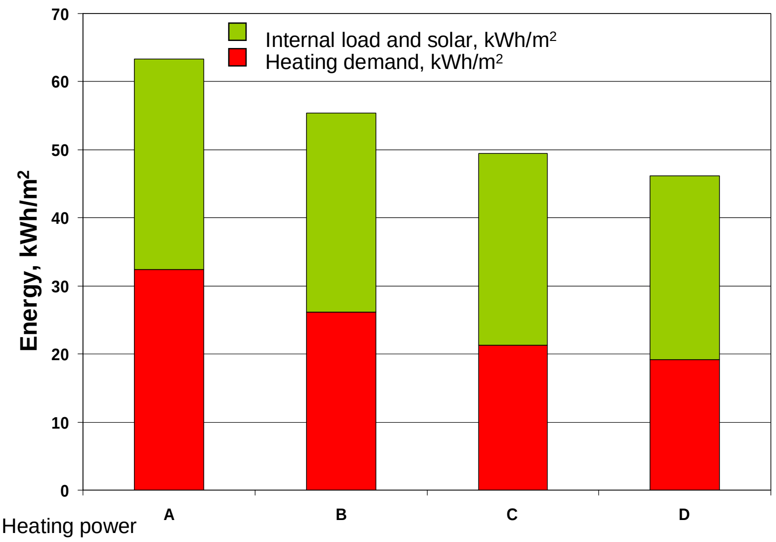
Internal heat loads cover a large part of a passive house's heating demand. Table 1 and Figure 1 show the dependence of the heating demand on the various properties in the climate of Helsinki.

Table 1. Properties for heating energy demand calculations for a passive house in Helsinki

Building envelope					
Component	m^2	a) W/m^{2}K	b) W/m^{2}K	c) W/m^{2}K	d) W/m^{2}K
Wall	343	0.12	0.1	0.09	0.09
Basement wall	110	0.12	0.1	0.08	0.08
Roof	235	0.1	0.07	0.07	0.07
Floor	235	0.15	0.15	0.1	0.1
Window		0.8	0.8	0.7	0.7
- South	6				
- East	8				
- West	30				

- North	6				
Doors	16	0.4	0.4	0.4	0.4
Air tightness					
n_{50} value	1/h	0.6	0.6	0.6	0.6
Ventilation					
Rate	l/s	2 x 76			
Heat recovery	%	70	75	75	80
Spaces					
Gross floor area	2 x 235 m^2 According to external dimensions				
Treated area	2 x 187 m^2 According to internal dimensions				
Gross volume	2 x 844 m^3 According to external dimensions				
Volume	2 x 540 m^3, room height: downstairs 2,6 m, upstairs 3,2 m				





	A	B	C	D
Heating power				
- kW	9	8	7	7
- W/m²	19	17	15	15
Internal loads				
- W/m²	3,1	3,1	3,1	3,1

Figure 1. Passive house's heating demand according to different properties of the house [5]

The risk of freezing of heat recovery unit is a problem connected to cold climate solutions. The energy performance requires an average heat recovery efficiency of more than 75% in the climate of Helsinki at the same time as defrosting is needed. Defrosting by heat or cyclic use of heat recovery for reduces the efficiency of heat recovery. Thus other ways and means should be applied as far as possible.

New heating and cooling system design data is needed for utilization of renewable low-temperature heating and high-temperature cooling energy in very-low energy houses. This design data must also ensure the overall thermal comfort of the building user. There is also a need for more accurate human thermal comfort calculation than the commonly used Fanger model.

VTT has developed a new Human Thermal Model (HTM) for predicting thermal behaviour of the human body under both steady-state indoor environment boundary conditions. HTM is a part of the VTT House Building Energy Simulation Environment. By means of HTM the effects of heating and cooling systems on human thermal comfort can be estimated more accurately than before. The results give design data for building service systems in energy-efficient buildings, and they can be used in research and development of building products and building service systems with a user-level approach.

2.3 The systematic of energy saving choices in buildings

When setting specific energy efficiency targets like passive house or energy efficiency classification A, it should be considered what kind of energy saving investments are the most profitable to choose. The choice order of energy saving investments may vary depending on who is exploring the choice process. Construction Company is interested in how it is possible to reach a specific energy efficiency classification as cheap as possible, whereas the choice order may differ when examining the problem from the viewpoint of a house owner or inhabitant.

Certain initial data is needed to make the systematic analysis of possible energy saving choices. The needed data include the price of the heating energy, the energy saving amount achieved by the measure, and the economical lifetime of the measure. The building costs caused by the energy saving measure must be divided into two sections. The first section includes the costs directly caused by the improvement of the structure. The other section consists on the additional costs that are caused when the improved structure is attached to the interrelated structures. For instance, when increasing the thickness of the wall structure also the thickness of the plinth must be increased, the window jamb structures become larger and the surface of the building envelope increases. The costs caused by these actions must be taken into account when examining the additional costs of the energy saving measures.

The examination of energy effective choices should be done by small steps, so that the real economical optimum will not be missed. Table 2 provides an example.

Table 2. Internal rate of return (IRR) on the different increase of insulation thickness of the exterior wall. The price of the heating energy is 10 c/kWh. The choices must be made step by step to get the best results in the choice process.

Improvement	Economi cal life-time (y)	Costs (€)	Energy sav-ings/year (kWh/a)	Annual change in energy costs (€/a)	IRR
The right approach to examine the economic efficiency of increasing the insulation layer of an exterior wall					
Insulation thickness 160-180	50	4 317 €	3307	-331	7,5 %

Insulation thickness 180-200	50	4 791 €	1876	-188	3,0 %
The wrong approach to examine the economic efficiency of increasing the insulation layer of an exterior wall					
Insulation thickness 160-200	50	9 107 €	5183	-518	5,3 %

In the example the basic insulation thickness of exterior wall is 160 mm (mineral wool). When examining how profitable it is to increase the insulation layer from 160 mm to 200, we will get two completely different results by using two different approaches. In the first approach we will examine the increases of insulation level step by step, so that we will at first look at the increase from 160 mm to 180 mm and then further the increase from 180 mm to 200 mm. As it can be noticed when looking at the table 2.4.1, the first insulation increase of 20 mm will have much greater effect on the achieved energy savings than the second increase of 20 mm. In the second approach we will directly increase the insulation level from 160 mm to 200 mm. In this case the investment's internal rate of return is better than in the second step of the first approach. If we use the second approach, it is likely that we will not find the most profitable energy saving measures in the systematic choice process.

In the systematic choice process the selection order of energy saving investments has been determined by three different criteria. These criteria are: the internal rate of return, repayment time within the life cycle and investment costs/annual energy savings. In order to make investment decisions as effective as possible, it is important to understand the strengths and weaknesses of each criterion.

The internal rate of return is the interest rate at which the costs of the investment equals with the benefits of the investment. It is the most "scientific" of the three criteria and it is best alternative to describe the pure economical profitability of the investment. The internal rate of return is a good criterion because it takes the economical lifetime of investment into consideration. The internal rate of return as a criterion causes trouble when its value becomes negative. After that it can no longer be used to determine the economical selection order of different investments.

A repayment time within the lifecycle is a criterion that is the easiest to understand. It explains how many times the investment will pay its investment costs back during its lifecycle. Because of its easy intelligibility the criterion is suited to be used, for example, in a situation, when the intention is to show the profitability of the investments to a potential customer of the house. Because this criterion does not the take the imputed rate of interest into account, it can be considered the best alternative when executing examinations from the environmental viewpoint.

The third criterion that is used for the examinations is investment costs / annual energy savings. This criterion describes best the viewpoint of a construction company. The criterion put in order the energy saving measures according to the fact, how much has to be paid for an annual energy saving of one kilowatt-hour. Thus, this investment criterion drives the investor towards cost-effectiveness when considering the investment costs. It is important to notice that this criterion does not take into account the economical lifetime of the measure and the imputed rate of interest. According to this criterion the price of the used heating energy does not affect on the profitability of the investment. These three mentioned factors can be considered as weaknesses of this criterion. This criterion is a good tool when trying to piece together, how the best possible energy efficiency level can be achieved by the lowest possible costs.

Figure 2 presents the economical selection order of energy saving measures in the case project.

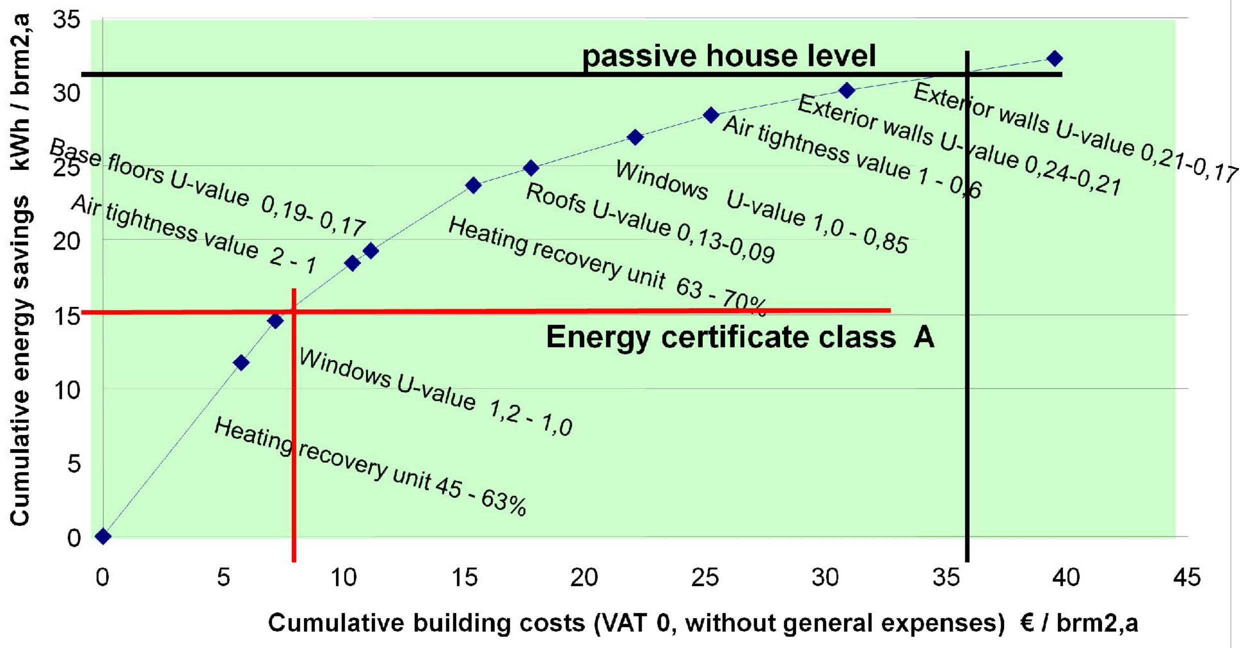


Figure 2. The selection order according to the selection systematics of energy economical choices in the case project when trying to achieve different levels of energy saving targets. The selection criterion used in the figure is investment costs / annual energy savings.

The criterion which is used to create the figure is investment costs/annual energy savings. The Figure indicates, which investments must be chosen, when the goal is to reach energy efficiency classification A or a building that satisfies the heating energy consumption criteria of Finnish passive houses. The X-axis of the figure shows the cumulative building costs of improvements and the Y-axis shows the gain in cumulative energy savings that is achieved with the help of the energy economical choices.

The final level of energy savings is determined by the heating system and the energy price. At the reject limit of the measures the choice order must be checked by taking the value factors into account. This can be executed, for example, by using “the customer’s willingness to pay” method. This systematic choice process proved to be useful and illustrative for Construction Company when developing green housing in cost-effective way.

2.4 User Journey

The construction sector is putting a considerable effort to reduce the environmental impact of housing. Simultaneously it is important to pay attention to sustainable user behaviour: the residents can multiply or invalidate the benefits of the energy-efficient houses.[6] Service Design methods like user journey mapping can be used in the context of green housing. in order to investigate how user is using the energy efficient appartment. The method can indicate what are the hindrances and enablers of the environmental friendly behaviour and what are the critical touchpoints between the user and technical soltutions during the journey of using the apartment.. The technical solutions of energy-efficient products can be seen in the context of living and users’ reality. The intention is to understand the use of energy efficient house as a journey or a cycle – a series of critical encounters that take place over time and across channels. This is key to integrate the user and the use of technical product. As a method, it enables people to create a rich picture of how service experiences play out in the context of everyday life. [7,8]

User (or customer) journey mapping comes from the corporate sector and market research. It can be used as a form of consultation to improve a service through finding out how people use the service. It provides a map of the interactions and emotions that take place. User journey mapping is the step by step journey that a user takes to reach their goal. The user journey is created to map out the current journey a typical user might take to reach their specific goal, and is then redesigned to form an ‘ideal’ journey. The output is traditionally a flow diagram demonstrating each steps and activity points throughout the entire process. [9,10]

In the context of green housing the user journey mapping was constructed to be adequate to analyze the resident´s experience. The experience of living in a sustainable house is composed of several independent actions. These actions require from the resident knowledge that cannot be assumed to be possessed spontaneously. The user journey map discusses the residential life as a journey with different action points which forms dimensions that are arrival to home, spending time at home and leaving home. The user journey map can analyze these action points and study what happens in one specific point from the perspective of the residents. Observations and walk-throughs in apartments indicate that not all the solutions were designed from the perspective of daily use. [11]

Developing the design around the user journeys provides confidence that the investigated solution will cater to the typical users’ needs. The map of the existing user journey provides a clear view on how easy or difficult it is for a typical user to reach their goal. The ideal journey can often prove to be difficult to implement, with business objectives and technical/design limitations impacting the ability to produce a quick journey, therefore, it is important to create the ideal journeys with a multi-disciplinary team to ensure all angles are covered. Balancing user goals and business goals is very important to ensure both are taken care of without impacting each other.

User journeys are very useful to speed up the planning of a new project by highlighting the current issues and produce an ideal picture from a typical user’s perspective early in the process. To a customer in the residential life it is indifferent who is providing the services he needs and is ready to consume. From his perspective the everyday life is a journey, were different action points merge as a flow of experiences. On this journey the key criterions are the usability of the technical solution supporting sustainability and the residents’ level of knowledge. A well managed supply chain of services can enhance the sustainable behaviour of use.

3. Conclusions

Three different methods of developing green housing are illustrated and together they provide a holistic picture. The energy efficiency can be approached from the technical, financial or behavioral perspective. The technical approach provides verified guidelines and the simulations can develop a thorough set of reliable data of analyzed system concepts. However the weakness is that full scale validation requires the long term follow up research is needed.

The calculations are providing guidelines, but the approach is very sensitive for economical and financial perspectives. The quality of data is weak because the information about cost components is many times unverified and it can only be estimated. However the pilot cases can provide important data. The challenge is to provide iterative processes where the technical elements and financial elements are investigated in a cycles of development.

Next to the technical and economical factors the individual factor can be approach e.g. with the methods of service design. User journey approach provides a possibility to test the technical solutions as a part of users’ daily life and it can identify the critical touch points which either facilitate or hinder the energy efficient use of the technical solution. The weakness is typical challenge in qualitative approach: how can these findings be generalized.

The applied methods indicate that the iterative processes are more important than linear processes when developing green housing. The estimation is that the change towards change in processes of green housing from design, construction and use is more challenging than the solutions in energy efficient products. One can state the energy saving potential can be developed with respect to traditional business logic of construction business. The overall goal should be the energy efficient products and the other options should be excluded: in design, construction and use of buildings.

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