Wholesomely sustainable single-family home in Nordic countries

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Written Assignment Report

AF2507 Sustainable Buildings - Concept, Design, Construction and Operation

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Introduction

Coming from a Smart Cities Master program, sustainability and environmental issues are very familiar to us. Innovation in the building sector is key, since buildings and buildings construction sectors are responsible for 36% of the global energy consumption, and for almost 40% of total direct and indirect CO_2 emissions (OECD/IEA, 2017). Moreover, energy demand from this sector is continuously rising.

The focus of this report will be on Nordic countries: these are a hub for innovation, especially in the building sector. Hence, every section of the report is divided in four sub-section, where each Nordic country (Denmark, Sweden, Finland and Norway) is analyzed in detail.

The report is divided into four sections. The first section will concern the analysis of the socio economical context and the building industry in the Nordic country. This will give useful knowledge and background to the reader to achieve a better understanding of the building industry. In the second section an analysis of the existing sustainable single family buildings will be carried out, while in the third section a list of existing sustainable renovation concepts will be reported. Finally, in the fourth section a brief summary of the R&D projects can be found, in order to gain an understanding of what the future building industry will hopefully look like.

The work load has been divided between the two collaborators to the report in equal parts: Hamza explored buildings innovations and projects in Sweden and Norway, while Claudia took care of Denmark and Finland.

Socio-Economical Context and the Building Industry in Nordic countries

Danish buildings

After the oil crisis in 1974, Denmark as a national state acted immediately to push for energy savings. In the period 1975-2000, a 19% reduction in heat consumption was achieved, fact that was mitigated by the 69% growth in energy consumption (Marsh, et al., 2010). Thanks to energy planning, Denmark changed from oil to natural gas and district heating, shifting from more to less carbon intensive technologies (Marsh, et al., 2010). From 2002, the initiative shifted from Denmark to the EU, that through many directives, such as Directive No 2010/31/EU and No 2009/28/EC (the former regarding energy performance of buildings, the latter demanding energy plans for renewables and initiatives of developing sustainable skills in the building sector), tightened the demands on energy consumption (Koch, et al., 2010).

	2010	2011	2012	2013	2014	2015	2016	2017
Detached houses								
Started (1938 -)	4 982	4 569	3 770	3 884	3 951	4 724	5 256	5 034
Completed (1917 -)	4 670	4 987	4 287	4 043	4 235	4 354	5 077	5 392
Under construction (1982 -)	5 569	5 151	4 634	4 475	4 191	4 561	4 740	4 382

Figure 1 - Residential Construction in Denmark, Detached house (StatBank Denmark, 2017)

	2010	2011	2012	2013	2014	2015	2016	2017
Residence all the year roundm total	156	146	125	129	134	140	134	126
Farm houses	266	260	253	259	249	254	247	251
Detached houses	207	203	205	203	200	204	206	205
Terraced, linked or semi-detached houses	116	112	109	110	114	115	116	114
Multi-dwelling houses	106	94	87	94	96	98	98	94

Figure 2 - Average floor area in new-constructed dwellings by use and time (StatBank Denmark, 2017)

The pictures above show the building activity in Denmark during the past seven years. It can be seen that the building construction sector has been growing in the past two years, especially in the field of detached houses.

Swedish Building Sector

The building service sector in Sweden accounted for 39% (146 TWh) of the total energy use, which was 375 TWh by 2015 (SEA, 2016a). Like most of the Nordic countries Sweden decided to reduce its dependence on oil after the major oil crises in the 1970s. The Swedish government introduced more strict regulations for thermal insulation, heat recovery and air tightness (Boverket 2010- Boverket 2016). Quite interestingly the energy use by the Swedish energy sector has reduced by the start of the century, the building heating demands were mostly met by oil pre-dominantly before the 2000s as can be seen in figure 3. District heating and electricity has replaced the oil demand in the building sector by almost 70 % (SEA, 2016a).

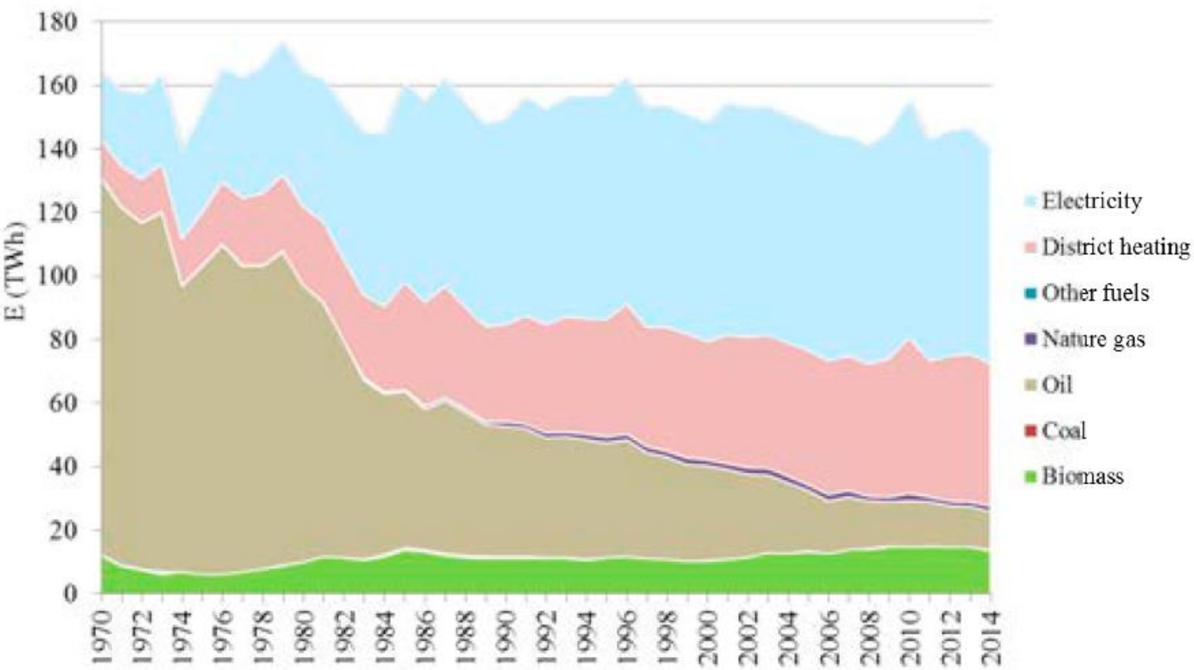

Figure 1 Energy use by the Swedish building and service sector 1970 – 2014 (SEA, 2016a)

Finnish Building Sector

Finland is leader in energy efficiency due to many initiatives (such as the ‘Long-term strategy for mobilizing investment in the renovation of buildings’, and the ‘ERA17 Action Plan – For an Energy-Smart Built Environment 2017’) in the built environment. Despite Finland being a global leader in clean-tech, eco-innovation, research and sustainable construction, due to low external demand and weak economic context, building and construction sector is limited. (Hardiman, 2018).

Figure 3 - Granted building permits and building starts, mil. m3, moving annual total (Statistics Finland, 2018)

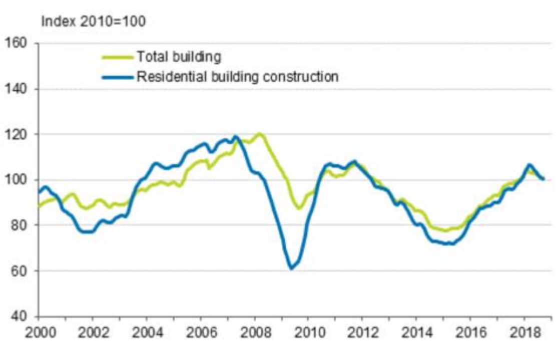

Figure 4 – Volume index of new buildings, 2010=100, trend (Statistics Finland, 2018)

The figures above prove that the construction building hasn’t been growing in the past years. The volume of building permits granted in July to September 2018 fell by 25,4% from the previous year, and the constant-price value or the volume of ongoing building production increased by 1.9 per cent year-on-year. Moreover, the number of residential building starts was 9.0 per cent lower than one year ago (Statistics Finland, 2018).

Norway Building Sector

Norway has a good influx of revenue based on oil and gas exports, that in combination with being an active welfare state makes an average Norwegian a wealthy home owner (Risholt, 2013). The building industry in Norway has shown quite an interest in energy efficient buildings especially “passive housing”, a study by (Nikamp, 2017) shows the number of articles written in the media which reflects public interests, according to which the passive house keyword peaked in 2011-2013 by 160 articles per year.

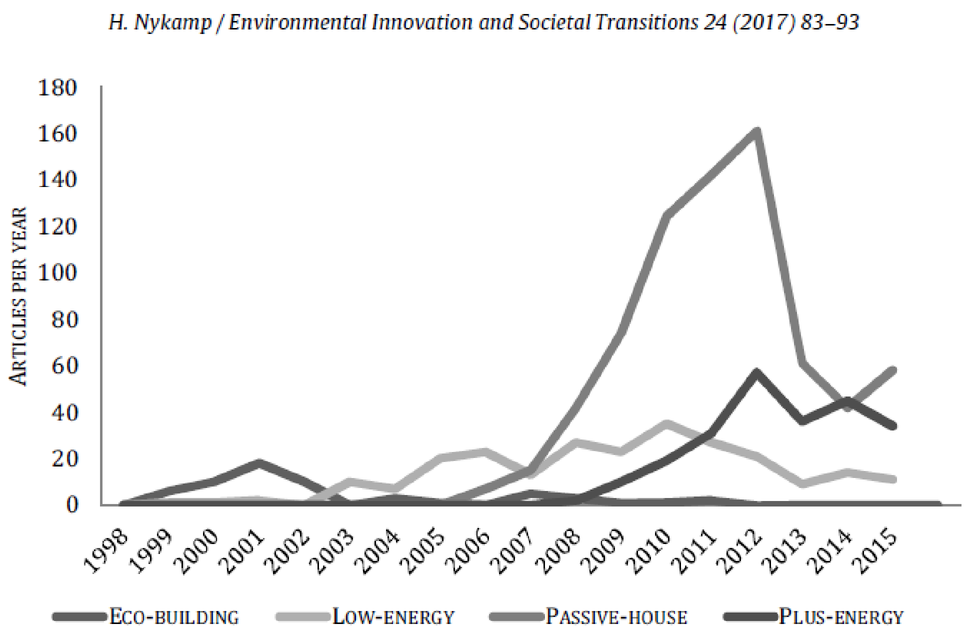

Figure 2 - Media attention to green buildings Soruce (Nikamp, 2017)

Existing Sustainable Single-Family Building Concepts

Denmark

Since early 1990, starting in Germany, the passive house business started to grow. This is the reason why the standard for passive houses comes from the Passive House Institute (PHI), in Darmstadt (Table 1 - Passive House Criteria). But the interest for passive houses has been relevant in Denmark from around 2000, when engineers and contractors started to follow the German development. In 2005 the consultancy Ellehauge and Kildemoes[1] obtained funding for the EU-project "Promotion of European Passive Houses" and since then the consultancy promoted different sustainable solutions (Koch, et al., 2010), ranging from low energy houses, to energy renovation and to development projects (Ekolab, 2012).

Table 1 - Passive House Criteria (Passive House Institute, 2016)

			Criteria[1]			Alternative Criteria[2]
Heating						
Heating demand	[kWh/(m^2a)]	≤	15			-
Heating load[3]	[W/m^2]	≤	-			10
Cooling						
Cooling + dehumidification demand	[kWh/(m^2a)]	≤	15 + dehumidification contribution[4]			variable limit value[5]
Cooling load[6]	[W/m^2]	≤	-			10
Airtightness						
Pressurization test result n_{50}	[1/h]	≤	0.6			
Renewable Primary Energy (PER)[7]			Classic	Plus	Premium	
PER demand[8]	[kWh/(m^2a)]	≤	60	45	30	±15 kWh/(m^2a) deviation from criteria...
Renewable energy generation[9] (with reference to projected building footprint)	[kWh/(m^2a)]	≥	-	60	120	...with compensation of the above deviation by different amount of generation

Komfort Husene

Saint-Gobain Isover[2] initiated a project which builds on international experience on passive houses concepts. Involving a large number of stakeholders, the project's aims at spreading knowledge about passive heating into single-family houses. The requirements is both no heating system and optimal indoor climate. Through this project, 10 different house concepts have been designed[3], operating as a learning process and inspiring future construction and the energy policy

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[1] The company Ellehauge & Kildemoes on January 1, 2012 changed its name to Ekolab (Ekolab, 2012).

[2] Saint-Gobain Sweden AB ISOVER is a Swedish manufacturer of glass wool insulation (ISOVER,2018)

[3] The passive house concepts can be found on the ISOVER website (ISOVER, 2009).

database (Build Up, 2009). By the end of 2008, eight of the ten planned passive houses were inaugurated by the Minister of climate, while two didn't gain the title of Passive Houses (Koch, et al., 2010).

Villa Langenkamp

The example for existing sustainable single-family building concepts that is taken into account for Denmark is Villa Langenkamp. The architect of the Villa is Olav Langenkamp, and it is the first certified passive house in Denmark, finished in July 2008 (Langenkamp Architecture, 2008). The gross area of the heated part of the building is of 175m^2, for a total area of 226m^2.

Figure 5 - Villa Langenkamp (Langerkamp Architecture, 2008).

The house has a total energy consumption of 5400kWh per year for heat, hot water and household electricity (Danske Boligarkitekter, 2008). Looking at Denmark Building Regulation of 2010, the energy consumption for new buildings has to be lower than 52.5 kWh/m^2/year (IEA, 2010). Multiplying this value with the heated area of the building, we reach a value of 9030 kWh per year, which is nearly double the actual consumption of the house. This is possible thanks to the materials and the structure of the house: the compact house utilizes the area efficiency through large rooms (Bæredygtigt Byggeri, 2015).

Materials and construction

Many times passive houses are assumed to be less comfortable: many think that living in a passive house means giving up some of the comforts. This house is the proof that this belief is wrong. An interesting story is that the youngest child of the architect, after moving into the new house, became free of asthma. Hence, this passive house ensures both low energy needs and good indoor climate. The low environmental impact is low thanks to the lightweight wooden structure, which is composed of FSC[4] certified wood. The window frames are made in aluminum, which increases the environmental impact but ensures easy maintenance. A passive solar wall of $10m^2$ facing south allows solar gains through a windowed part, which is composed by a red-painted layer of cellulose that redirects the heat into the back wall (the technology is originally from Austria) (Bæredygtigt Byggeri, 2015).

The outer wall has a U value of approx. 0.11 W/m^2K and one total thickness of approx. 520 mm and is made of the following materials (Bæredygtigt Byggeri, 2015):

- 27 mm wood lining
- 25 mm spacing of wood
- 16 mm wood fiber board
- 360 mm glass wool insulation incl. I-beam of wood
- 15 mm OSB board
- 60 mm spacing of wood
- 12.5 mm gypsum board

The house is heated thanks to a geothermal plant and a solar heating system installed on the flat roof, and a ventilation system with heat recovery ensures a better efficiency of the system (Bæredygtigt Byggeri, 2015).

[4] Forest Stewardship Council (FSC) is a global not-for-profit organization that sets the standards for what is a responsibly managed forest, both environmentally and socially. (Forest Stewardship Council, 2018)

Sweden

The first passive house in Sweden was built in 2001, ten years after the first one in Germany. During 2005, the volume of land in planned developments rose, which is positive, but new players established themselves in the market and the competition for attractive land intensified

Sweden is a creative hub for experimentation with passive housing, during 2005 the volume of planned developments of sustainable development rose and new players and projects entered the market. (Skanska, 2005). The following table describes the definition of passive house by Swedish Standards.

Climate zone:		I	II	III
Heat load demand	W/m^2	19	18	17
For non-electric heating systems	kWh/(m^2 year)	63	59	55
For electric heating systems	kWh/(m^2 year)	31	29	27
For combination of different type of energy systems	kWh/(m^2 year)	78	73	68

Figure 3 Swedsh Passive House Criteria Source (Jonas 2010)

Villa Malmborg – Lidköping

The first single-family detached passive house in Sweden was built in Lidköping close to Lake Vänern, by the housing company Vårgårdahus.

Figure 4 Vila Malmorg Source (Janson 2008)

The loadbearing construction of the house is made of highly insulated prefabricated wooden frame walls. It is heated by a small air to air heat exchanger with additional heat from district heating. Domestic hot water is supplied by district heating (Janson, 2008).

Finland

A key role in reaching the goal set in Finland for low-carbon and resource-efficient society is played by bio-economy. Thanks to many renewable natural resources, Finland has the potential to become a pioneer of the bio-economy in the world. The objective of the Finnish Bio-economy Strategy is to generate new economic growth, needed especially in the building industry. One of the initiatives is to enhance usage of wood in construction, which would lead to a more sustainable development and would involve the Finnish forest sector, crucial for the national economy (Kitek Kuzman, et al., 2017).

Both Finland and Sweden have a long tradition of building with wood, because of the enormous resource that is available in Nordic countries. Especially in Finland, knowledge of this age-old building material is preserved and enhanced. New buildings would gain a contemporary twist while keeping an old and traditional look that attracts customers, and are a significant part of the building stock in Finland (Kitek Kuzman, et al., 2017).

Private House EVO

The first case that is mentioned in this report regarding Finland is a wood house made by Honkatalot - Polarlifehaus, a company that manufacture quality custom-made homes (Honkatalot, 2018).

Figure 6 – Interior of the house (Wood Architecture, 2014)

Figure 7 – Exterior of the house (Wood Architecture, 2014)

The house has been designed by the architect Seppo Mäntylä and has been completed in 2014. EVO is a new generation log home[5], where solid wood is used in combination with glass, steel and stone (Honkatalot, 2014).

[5] Log homes are made of wooden logs, and generally are connected to a relaxing atmosphere: the feeling is of uncomplicated, cozy and natural mood. These homes are a good fit for both countryside and city (Rantala, 2017).

This home was designed to have a view of the sea: it has a lower part pushed as far as possible in front of the existing buildings while the higher part is placed such as it doesn't obstruct the view from other houses. (Wood Architecture, 2014).

The company, a part from this house, has an entire collection of green houses, composed by different solutions that would fit different clients. In general, the expert propose a different house depending on location and exposition of the house and on expectations of the client. The collection includes the following models (Polarlifehaus, 2018).

- Fist – the starter model of the green house family, with maximum three bedrooms and a straightforward architecture that ensures more space, light and health for a low budget.
- Glade – a specific model for houses with southern orientation. This has a passive house design with use of only sustainable energy.
- Treetops – a model that ensures view respecting the natural surroundings.
- Barn – a two floor model, with living spaces on the ground floor and bedrooms on the top floor.
- Slant – a luxurious model with sweeping views from every view.
- Leeward – a minimalistic architecture model that offers either protection against harsh climate or maximum privacy in the crowded city environment.
- Escape – an elaborate model for luxurious and healthy living.

From this broad catalogue, it can be seen the true effort of the company to satisfy any need through a wooden technology that wants to spread the conviction that living close to nature will bring both happiness and health (Polarlifehaus, 2018).

From the renewable energy point of view, the roofs can be filled with solar panels and solar collectors. The wood burning fireplaces are modelled with heat exchangers, and the heating system is efficient low temperature floor heating. Moreover, the use of geothermal energy and biomass makes the indoor climate comfortable without the use of fossil fuels (Polarlifehaus, 2018).

Marjala House

The concept of this house was being in harmony with nature, with simple technical solution thus efficient and green. It would be a cheap house for everyone while keeping a good architectural quality and living. It is one example of house largely made of wood products. The coating of the inner surfaces consists in ecological materials from nature (including wall paper, paintings and waxes), while the outer paints are either cooked on site or made of skimmed milk. The energy generation for heating and hot water comes from firewood and sun, through a stove and 10 m^2 of solar heating panels on the roof. A 1’500 liter hot water tank has been installed as heat storage. As peak load solution, a 6kW electric heater provides standby heating at the bottom of the tank. These technical solutions allow energy savings of the order of 50-58% of that of reference houses (Huovila, 2010).

Four-cornered villa by Avanto Architects Ltd

This sustainable rural house built in Virrat, on an island in the middle of a lake, has a floor area of 78m^2, with a sauna of 24m^2. The design and construction of the villa took place between 2008-2010: aim of the house is both to be an expression of sustainability while being modern. Most traditional Finnish houses are electrically heated all year round (avoiding water pipes freezing in winter). This house could instead be a zero emission house, since the there is no running water and electricity is produced by solar energy and heating comes from wood, exclusively from the nearby forest. Natural light follows the inhabitants’ routine from east to west thanks to a perfect orientation. Passive solar energy is used in winter, while the terraces are covered in summer to reduce solar gains. (Floornature Architecture and Surfaces, 2013).

Figure 8 – Left: interior view; right: exterior view (Floornature Architecture and Surfaces, 2013)

Norway

There has been seen a large increase in passive single-family houses in Norway (Anderson, n.d.) Norway. More than 15 passive house projects incorporating more than 1000 apartments are currently in the planning phase. The following table gives an overview of the single passive house projects in Norway.

Building type	Location	Client /Developer	Architect	Energy Engineering	Status
Single family dwelling	Tromsøya, Tromsø	Passivhus Norge AS	Steinsvik Architects	Steinsvik Architects	Completed Dec 2005
7 dwellings in a row house	Storelva, Tromsø	Maurstad-gruppen	Steinsvik Architects	Steinsvik Architects	To be completed April 2007
Single family dwelling	Sørumsand, Akershus	H. Ringstad	Dipl. Ing. Stephan Blohm and Arch. Toril R. Grønvold	Dipl. Ing. Stephan Blohm, and SINTEF	Construction starts April 2007
1 single family dwelling in a row house	Venstøp, Skien	Hansen & Lauritzen AS	T.A. Danielsen, Aplan Viak	SINTEF and Erichsen & Horgen AS	Completed Fall 2006
28 apartments in multi-storey blocks	Fyllingsdalen, Bergen	ByBo AS	ABO Arkitekter	SINTEF	Construction starts summer 2007

Figure 5 Passive House Projects in Norway Source (Anderson, n.d.)

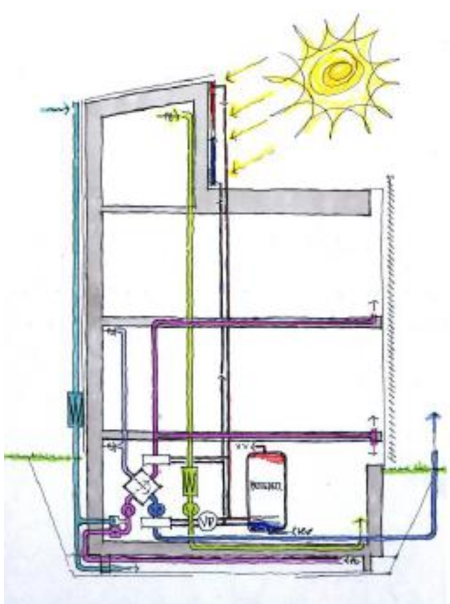


Figure 6 Single family house at Tromsøya, and 7 dwellings at Storelva, Tro Source (Anderson,n.d)

Sustainable Renovation Concepts for Single Family Houses

When it comes to sustainable renovation concepts, the Nordic market is dominated by "do-it-yourself-shops", and only few full service renovation concepts are available but they are not well established (Tommerup, et al., 2010). These shops provide a good temporary solution, but they will probably not lead to a precise and well done renovation of the entire building. To speed up the sustainability process, more options need to be available on the market: it is comprehensible that it is not always possible for a single-house owner to renew the house himself, hence the need of service models. In this way, people can simply leave their house in the hand of the renovator without worrying about going to the shop and doing the work themselves. These services are normally called full service renovation concepts, and should make it easy and secure for the customers to invest in sustainable and low energy renovation. There are a few Nordic examples of such service models, which will be reported in the following pages (Tommerup, et al., 2010).

Denmark

Three concepts for full renovation will be analyzed amongst Denmark market.

Clean Tech – New Energy – Clean Savings (Tommerup, et al., 2010)

Facilitator: Ørsted A/S (former Dong Energy A/S).

Target market**:** Oil-fired old detached single-family houses.

Service: The home owner needs to check the online calculator "test your house", and then can contact the company. Relevant installers will visit the house to determine the optimal solutions and a quote is send to the customer, together with a flexible loan offer. *Impact*. This concept has been introduced in 2009: the project aims at saving measures with a short pay-back time.

Technical Solutions.

"Energy Minus" and "Energy Plus". Uses new windows and easy-to-carry-out insulation measures (such as cavity wall insulation) and renewable solutions for efficient energy supply (such as heat pumps, ground heat or air to water). Consideration on the technical solution:

- Cavity wall insulation. This technology doesn't ensure a uniform and unbroken insulation layer as an external insulation solution. The reduction of the U-value is about 70% (from 1,5 to 0,5 W/m^2K), while using an external insulation would allow a reduction of 90% (reduction to 0,15 W/m^2K).

- Ventilation with heat recovery is not part of the concept.
- Both external insulators and ventilation with heat recovery have great potential for end-use savings and better indoor environment.

Energy saving potential:

The concept has a potential for up to 50% energy savings, which corresponds roughly to the energy standard of a new house build to meet the minimum building requirements.

Climate Construction – A focused effort for energy efficient renovation of exiting residential building (Tommerup, et al., 2010)

Facilitator:

NCC construction DK.

Target market:

Standard housing estates suited for energy renovation (1950-1980).

Service:

The service is offered by NCC with focus on solutions based on individual needs. The difference of this service compared to the previous one is that with NCC the costumer experiences a thorough examination of the building (blower door test, thermography model, virtual building model): this gives the possibility for the company to give an overview of the possible solutions, that will include not only energy savings, but better comfort, improvements and maintenance. The customer is then presented with the package solution (which includes a financing option).

Impact:

So far, NCC has started an extensive refurbishment of 493 houses in Albertslund (constructed in 1960s). The energy efficiency will arise to the modern standards. The residents have been currently rehoused, and the renovation is scheduled to be completed in September 2019 (News Cision, 2015).

Technical Solutions:

Different solution will be taken into account depending on the need of the house. The category of the solutions are the following:

- Building envelope
- Energy supply
- Active measures
- Electricity consumption
- Behavioral guidance and financing

Energy saving potential:

The energy saving potential depends on actions. For the mentioned project in Albertslund, the efficiency will be taken up to the modern standards.

Passive house renovation – Pilot project in Hjørring, North Jutland (Tommerup, et al., 2010)

Facilitator:

Parvenu ApS (small local construction firm) and Bjerg Arkitektur A/S (architect).

Target market:

Old energy-intensive houses with robust economy and not worthy facades.

Service:

The service is offered by NCC with focus on solutions based on individual needs. The difference of this service compared to the previous one is that with NCC the costumer experiences a thorough examination of the building (blower door test, thermography model, virtual building model): this gives the possibility for the company to give an overview of the possible solutions, that will include not only energy savings, but better comfort, improvements and maintenance. The customer is then presented with the package solution (which includes a financing option).

Impact:

The three villas included in the pilot will be transformed into passive houses with a maximum energy consumption for heating below 15 kWh/m2/year.

Technical Solutions:

The houses will be completely sealed, are insulated outside and inside, equipped with large south-facing windows with three-layer energy glass. Heat recovery ventilation systems will continuously clean and renew the air, as well generating heat for domestic hot water. The use of traditional radiators will be abolished, since the house will be heated through the solar and recovery system. However, on very cold winter days, it is possible to supplement heat from a small geothermal plant. The external renovation will also make the accommodation more spacious (Pressemeddelelse - Pressport, 2009).

Energy saving potential**:**

The factor of renovation is 10, making this service a very low energy renovation concept.

Sweden

Most of the residential buildings in Sweden are over 40 years old and in great need of renovation (Norlén & Andersson, 1993). Many of these buildings also have poor energy performance. The commonproblems with old buildings are high energy use and maintenance cost, inefficient heating and ventilation systems, poor airtightness, draft and cold floors,

As per the new EU-directive EPBD on building energy usage, Government proposed to reduce their energy use by 50 % by 2050 as compared to the energy use in 1995 (SEPA, 2013).

Small scale renovations have traditionally been the market of small and medium sized contractors (SME's) interacting directly with the house owners (SME defined as EU, 2005). Contractors with less than 10 employees represent more than 80% of Swedish construction enterprises measured in number and 31% measured in turnover (SCB 2010). The SMEs with under 250 employees are responsible for a large part of the renovation work in Sweden.

District Heating system Renovation Case-Study (Odensala district)

Primary energy use in buildings can be reduced significantly by shifting from resistor based heating systems to district heating systems, one of the major problems in Sweden is to convince the people for connecting to the district heating systems (Tomerup, 2010).

There are around 700 dwellings in the Odensala district of Central Sweden. A survey in June 2005 showed that 84 % of the residents are not willing to connect to the district heating systems in the coming 4 years even if it meant saving energy. (Tomerup, 2010).

However, within a year a marketing campaign by the company "Jämtkraft's" in collaboration with the municipalities managed to convince 78 % of the homeowners to shift to district heating solutions.

Jamkrafts managed to change the perception by targeted marketing and providing services that included a 2-year guarantee on the installed system, a fixed price per installation, de-installation of the existing solution). The offer also included an option for the homeowners to get a discounted price for connection to Jämtkraft's fibre optic broadband network through which multiple companies provide internet service.

Finland

Four renovation concepts will be analyzed for Finland.

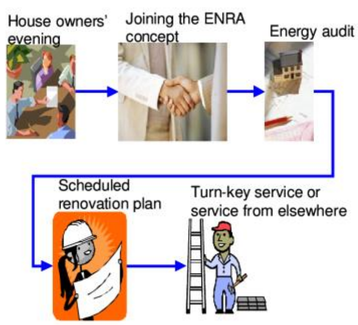
ENRA – Energiatejpllaam remontoinnin ja asumisen ohjelma (Tommerup, et al., 2010)

<u>*Facilitator*</u>. Rustholli Oy (renovation company).

<u>*Target market*</u>:

Single-family houses from 1940-90's (Veteran Houses)

<u>*Service:*</u>



The particularity of this renovation service is its concept, which was developed by a group of companies led by Rustholli renovation company. The philosophy of this service is represented in the following image. Potential clients are invited to participate to an evening event, during which it is explained why sustainability in the building sector is so important, and what could be done from the renovation point of view to contribute to help combat climate change. Also the other benefits of energy renovation are shown. The participants can then decide to join the ENRA concept. If they accept, they will receive an ENRA expert for an energy audit. After estimating the most suitable energy efficiency improvement actions and cost estimation, the ENRA expert will visit the customer to find out individual needs. After this, the customer can choose to accept the turn-key service, that includes a list of pre-chosen alternatives from the material and device producers in the ENRA-group.

<u>*Technical Solutions:*</u>

Since the ENRA-group includes a window and door manufacturer, a ventilation system manufacturer/supplier, an insulation manufacturer, an energy certificate supplier and a heat pump supplier, all the technical solutions are at first chosen from the group itself. This makes it easier to conduct the analysis since a lot of data and reliable solutions are already available from inside the group. The client, though, can always chose to implement different solutions than the one proposed by ENRA-group. The technical solutions include energy efficient windows and doors, ventilation with a heat recovery, internal extra insulation or new insulation and heat pumps.

Energy saving potential:

Since the service is an ad-hoc solution, the energy saving potential highly depends on the case.

Senera energy renovation (Tommerup, et al., 2010)

Facilitator:

SENERA Oy

Target market.

Home owners in southern Finland

Service.

The package offered is advantageous because only one contracting party is involved. It includes a renovation plan, warranty service and user guidance.

Technical Solutions.

The main intervention is replacing the heating system with ground source, air or air-water heat pumps, and the installation of low temperature floor heating system. The company suggests also renovation of the ventilation, windows and insulation in the roof and walls.

Energy saving potential. The company claims that with renovation the heating cost can be reduced up to 80%, but the precise impact depends on the undertaken actions.

LLK energy renovation (Tommerup, et al., 2010)

Facilitator.

LLK energy renovation, Suomen KattoCenter Oy renovation company (Suomen KattoCenter Oy, 2018).

Target market.

Old timber houses, veteran houses, wood construction, mineral wool insulated houses from 1960-1970 and cottages.

Service.

Through this service the interest is not only replacing some building components, but also increase the overall energy efficiency of the building components (roof, exterior walls, foundations, floors…), in order to comply to future energy requirements. This is possible through a collaboration with an insulation producer and several building material suppliers. The offer is a full renovation plan, based on the performance of each property and on the living comforts required by the customers.

Technical Solutions.

The main interventions regard windows, insulation improvements, changes in the heating system or ventilation, plumping and sanitary work in kitchen and bathroom.

Energy saving potential.

The energy saving potential depends on the intervention of the case studied.

Targenee energy renovation (Tommerup, et al., 2010)

Facilitator:

TerMater Oy (TerMater Oy, 2014).

Target market:

The company works in the industrial, commercial and agricultural sector. Therefore these renovation services aren't specific for homes.

Service.

The package offers a one contact service: experts will determine a cost estimation of the renovation after a benefit analysis. The offer is a turn-key renovation service based on pre-chosen alternatives. After the renovation the company offers an energy certificate.

Technical Solutions:

The company provides insulation improvements and installation of heat pumps. One of the technical solutions for insulation is the TERMO-builder plate technology, consisting of a plate made of plasterboard combined with polyurethane, which acts as a vapor barrier and insulation material.

Energy saving potential:

The company offers a service that allows up to 70% energy savings.

Norway

Norway spends a hefty budget on improvements and some authors have termed Norway as the "World Champion in home improvement" (Risholt, 2013). More than 6.2 billion euros were spent on upgrading 2.3 million Norwegian households (Statistisk Sentralbyra, 2010).

According to a case study (Risholt, 2013) that involves energy efficient analysis of 102 dwellings and interviewing 11 Norwaigian dwellings for renovation status of single-family homes that were built between 1896-1990 yields interesting results. It was found that "air to air heat pumps" were the most popular choice while renovating a house considering energy efficiency. Almost 60 % of the renovated households did so with the inclusion of air-to-air heat pumps.

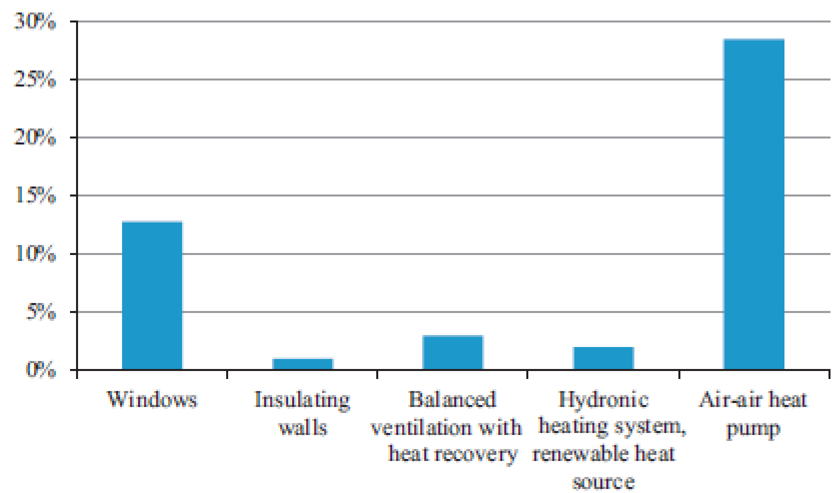


Figure 7 Energy efficiency measures installed Source (Risholt, 2013)

Private homeowners identify the renovation need and decide upon renovation based on their needs, desires and capabilities however like most of the Nordic countries new business models for project managers as energy efficient renovation providers is seem to be increasing. (Tomerup, 2010), one such example in Norway is given below:

Norway-Jadarhus Rehab

The company Jadarhus Rehab designs and renovates new single-family dwellings and smaller apartment buildings. Jadarhus Rehab starts the process with a meeting with the client, in which they study the potential of the house. Based on this, they plan a building process which is similar to the process for a new house.

They describe the following initiatives as the main energy efficiency actions:

- Additional insulation in cold attics
- New windows with lower U-values and reduced draft air leakages
- Tightening of windproof materials and additional insulated layers either inside or outside the outer part of roof (Tomerup, 2010)

R&D in Sustainable Single-Family Building Concepts

With the implementation of stricter laws and regulation and of well improved building codes, new buildings have to be built to use less energy and perhaps even have a net energy production. With the increasing awareness of climate change effects, different certifications of buildings according to the consumption of energy and the carbon footprint have been developed. Two examples are Leadership in Energy and Environmental Design (LEED) from US and the Building Research Establishment Environmental Assessment Method (BREEAM) from the UK (Gurung, 2017).

Denmark

Denmark has always been very active in the sustainable building sector, especially in Research and Development projects. In the following table, a list of different concepts is reported, with connected the year of introduction in Denmark, the number of projects and the connected actors and examples (Koch, et al., 2010).

Table 2 – Sustainable Single Family Building Concepts (Koch, et al., 2010)

Concepts	Year of introduction	Number of projects (in 2010)	Actors	Examples
Passive houses – Darmstad criteria	2008	20		Komforthusene H2 College
Active houses	2009	3	Velux Group	Lystrup, Cph.
Energy Class II	2010	>4 large projects		KPMG, Flintholm City, Court Kolding, Christian Union HQ, Industrien Hus
Energy Class I	2006	9 projects and 7 under construction	Arkitema, KAB, Ramboll, Pihl, Lind og Risør, a.m.o.	Stenløse Syd, Multimediehus, Navitas
DGNB (Deutsche Gesellschaft fur Nachhaltiges Bauen)	2012	2	Green Building Council Denmark, Ramboll, Alborg University	Ramboll HQ, Company house NCC, KPMG Domicil.
LEED (Leadership in Energy and Environmental Design)	2010	>7 large projects	COWI, KPC, Sjælsø	FN-byen, UL Intern, Demko HQ
BREEAM (Building Research Establishment Environmental Assessment Method)	2010	>6 large projects	Grontmij DK	Vestas HQ, Sillebroen shopping center, Grontmij DK

Denmark is a leader in eco-innovation and sustainable construction, with of funding schemes supporting projects of development of eco-efficient technologies and of technologies that guarantee a better energy efficiency. Moreover, energy efficient renovation of buildings is supported by the strategy *Road to energy-efficient buildings in the Denmark of the future* (European Commission , 2018). In the report, a number of challenges within energy storage, transport and integration of energy sectors are acknowledged, and the role of buildings in this context is explored (Mathiesen, et al., 2016).

Changes needed in the system	➢ Extensive integration of renewable electricity, predominantly offshore wind
	➢ Complete phase out of fossil fuels
	➢ Savings in building heating and electricity use
	➢ Savings in industry fuel and electricity use
	➢ Increase in DH from 53 % to 66 % of heat supply, with focus on low temperature district heating
	➢ Massive decrease in individual boilers in households
	➢ Massive increase in individual heat pumps
	➢ Substantial increase in EVs
	➢ Extensive increase in the production of electrofuels for heavy-duty transport and aviation
	➢ Robust and resilient energy system with respect to electricity exchange with neighbouring countries and bioenergy prices

Figure 10 - Changes needed in the energy system from 2015 to 2050 following the IDA Energy Vision (Mathiesen, et al., 2016)

The latest report regarding research is the IDA Energy Vision 2050 (IDA Danish Society of Engineers), which concludes that 100% renewable energy in 2050 is technically possible and economically feasible. The contribution of the building sector is essential for smart energy infrastructures and a 100% renewable Denmark (Mathiesen, et al., 2016).

Sweden

As discussed in the previous sections, Sweden has a lot of ongoing sustainable housing projects like *Stockholm Royal Seaport* and the *Lindas Passive Housing Project.*

One important task is to disseminate relevant research findings to the construction sector and to strengthen co-operation between research and practice.

Following are some research and development projects with nexus of academia and industry that shall shape the future sustainable buildings.

System integration in Kvillebäcken

The aim is to achieve a high concentration of biomass for more efficient production of biogas. A special system stores energy in the district heating network. Public transport is to be further developed by means of passenger boats running on biogas (Bergström, 2011)

Homes for Tomorrow

Homes for Tomorrow at the Chalmers University of Technology – supports future homes in the global era with new technologies, materials and spatial structures that radically reduce resource, material and energy intensity. The Homes for Tomorrow research team is co-operating with Mölndal City in their exploitation of the a former industrial area.

The Water Sensitive Home

According to sustainability.formas.se, the water sensitive home is an idea to give a new way for light and structures to create restorative environments using novel materials and building concepts by providing solution for better acoustic environment, ventilation and daylight indoor lighting. (Bergström, 2011).

Figure 8 New Karolinska Solna University Hospital (with around 98 % green energy) Source (Bergström, 2011)

Finland

Finland is ranked second in the 2016 Eco-innovation index (with a score of 137%, where EU average represents the 100% value). Around 40% of the Finnish public R&D funding goes into the energy and environment sector. The total R&D spending on energy technologies in 2014 was the highest among OECD countries, being nearly 0.12%. The private sector is also an important contributor, accounting for around 70% of total energy R&D expenditure. As stated in the *Action plan for research and innovation policy* (where the vision for 2020 is for a country where citizens and business live in a stable and sustainable environment) eco-innovation, intelligent construction and circular economy are specific priorities for the government (Research and Innovation Policy Council, 2014). These are supported by a series of public bodies that can allocate fundings, such as TEKES (The Finnish Funding Agency for Technology and Innovation), VTT (Technical Research Centre of Finland) and the Academy of Finland (European Commission, 2018).

Green Growth – Towards a Sustainable Future is a program that funds companies with growth potential in the area of energy and material-efficiency, bio-economy and biomaterials, recycling and waste management. Thanks to this project, an innovative method for processing construction waste materials has become reality, that transforms them into re-composite raw materials, aiming to achieve a 100% recycling rate (European Commission, 2018).

VTT coordinates the research project *ecobim*, that aims at building a business model based on life-cycle assessment tools and Building Information Modelling (BIM). In connection with this project, the collaboration forum *BuildingSMART Finland* has been established to spread BIM information and support in implementing BIM-based processes. Granlund Finnish company, a member of *BuildingSMART*, plays an active role in BIM processes and in developing BIM and IFC standards (European Commission, 2018).

SATO Case Study (Gurung, 2017)

SATO is a company that operates responsibly, enabling sustainable urbanization, participating in real estate organizations and development projects that promote sustainability (Sato, 2018). SATO succeeded in saving 22.2 GWh of its total energy consumption, including heating and electricity by 2016, compared to the level of 2014. The target is to reduce it below 40 kWh/m^2 by 2020, with a reduction up to 23% from 2009 level (Gurung, 2017).

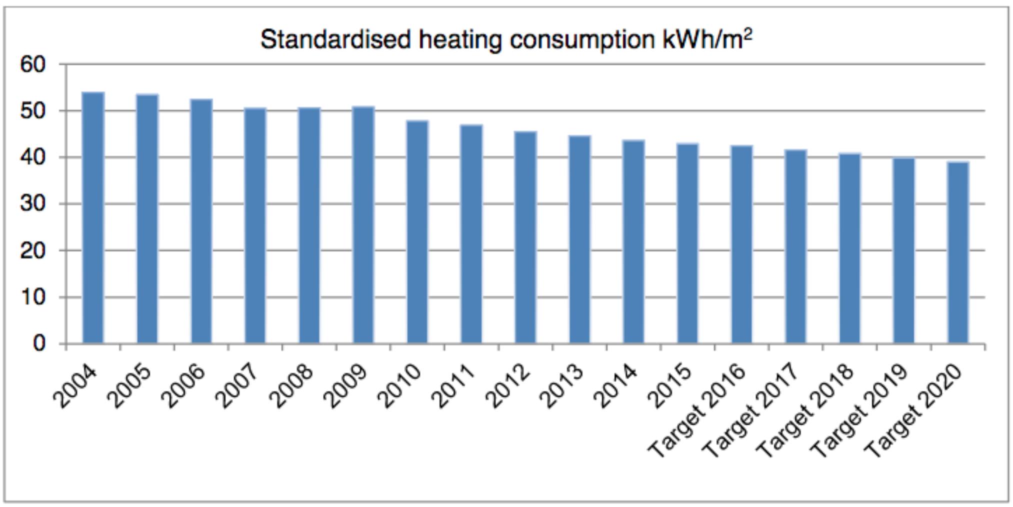


Figure 11 – Standardized heating consumption SATO's buildings; figures and prediction (Gurung, 2017).

As well as heating, also the trend in water consumption is downwards (despite the value between the years 2015-2016). The company aims at reducing the specific water consumption to 343 l/m^2 by the year 2020, a reduction of 20% from the consumption of 2009. To achive such a reduction, water saving methods are applied such as water saving fixtures at home, decreased water pressure in the pipes, fixes of leakages in the buildings.

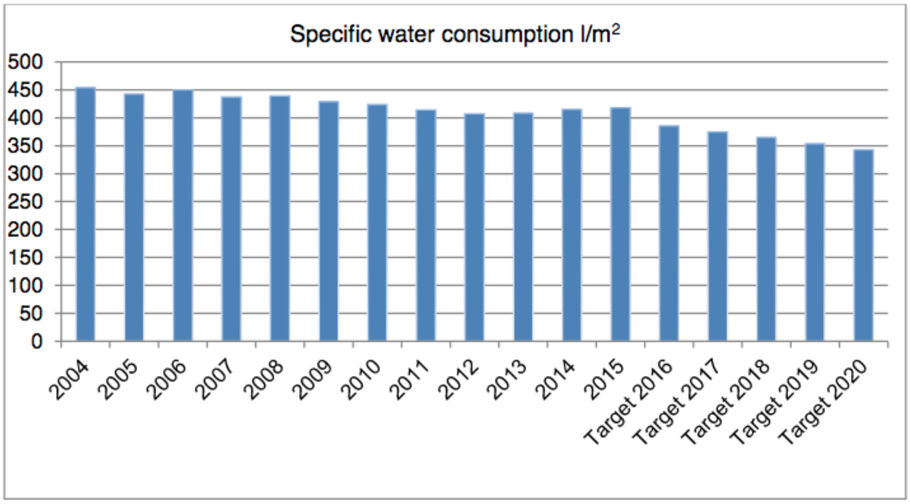


Figure 12 – Specific water consumption SATO's buildings; figures and predictions (Gurung, 2017).

To save energy, it's crucial to have residents full commitment and engagement. A water saving competition was organized by SATO for its residents in Lahti, Finland: the participants, within three months, reduced around 20% of their water consumption without compromising their living comfort (Gurung, 2017).

Norway

While in Norway regulations and policy play an important role in sustainbale building sectors, there are some very attractive research projects that might be the face of the future smart cities of Norway.

In Drøbak, a possibly greenest school in the world exists. On top its solar panels face sun at 33 degrees and energy wells beneath extract geothermal energy. (Hurst, 2018)

Norway is on its course to produce that much energy, that accounts for all the lifetime energy, the design is changing from form follows function to form follows environment.

Figure 9 Powerhouse Montenssori Source (Powerhouse)

The example such as above demonstrates the path Norway has set on that is mainly to move more towards form follows environment in all building sectors.

References

Bæredygtigt Byggeri, 2015. *Villa Langenkamp,* u.o.: u.n.

Build Up, 2009. *KOMFORT HUSENE - Comfort houses.* [Online] Available at: http://www.buildup.eu/en/practices/cases/komfort-husene-comfort-houses

Danske Boligarkitekter, 2008. *Villa Langenkamp.* [Online] Available at: https://www.danskeboligarkitekter.dk/find-projekt/projekt/vis/villa-langenkamp/

Ekolab, 2012. *Ellehauge & Kildemoes har skiftet navn til Ekolab.* [Online] Available at: https://ekolab.dk/2012/03/21/vi-skifter-navn-fra-elle-kilde-til-ekolab/

Forest Stewardship Council, 2018. *What is FSC.* [Online] Available at: https://ic.fsc.org/en/what-is-fsc

Hardiman, S., 2018. Insight into Construction in Finland by the European Construction Sector Observatory. *Construction 21 International,* 23 Apr .

IEA, 2010. *Denmark, Building Regulations 2010.* [Online] Available at: https://www.iea.org/beep/denmark/codes/building-regulations-2010.html

ISOVER, 2009. *Komfort Husene - De 10 Huse.* [Online] Available at: https://www.isover.dk/komfort-husene-de-10-husehttps://www.isover.dk/komfort-husene-de-10-huse

ISOVER, 2018. *ISOVER in english.* [Online] Available at: https://www.isover.se/isover-english

Koch, C., Buser, M. & Construction Management Chalmers, 2010. *Multiple dynamics of sustainable housing concepts in Denmark - on the role of passive houses,* u.o.: Chalmers Publication Library.

Langenkamp Architecture, 2008. *langenkamp.dk architects.* [Online] Available at: http://www.langenkamp.dk/

Langerkamp Architecture, 2008. *Projects.* [Online] Available at: http://www.langenkamp.dk/Projects/?nav=p&pid=4&imgid=127&page=0

Marsh, J., Larsen, V. & Kragh, M., 2010. *Housing and energy in Denmark: past, present and future challenges.* u.o.:Building Research and Information.

News Cision, 2015. *NCC secures order for refurbishment of housing units in Denmark for SEK 610 million.* [Online]
Available at: http://news.cision.com/ncc/r/ncc-secures-order-for-refurbishment-of-housing-units-in-denmark-for-sek-610-million,c9887696

OECD/IEA, 2017. *Buildings.* [Online]
Available at: https://www.iea.org/buildings/

Passive House Institute, 2016. *Criteria for the Passive House, EnerPHit and PHI Low Energy Building Standard,* Darmstad: Passive House Institute.

Pressemeddelelse - Pressport, 2009. *Fra energisultent typehus til villa i passivhusstandard.* [Online]
Available at: https://www.pressport.com/dk/byggerietspressebureau/pressreleases/fra-energisultent-typehus-til-villa-i-passivhusstandard-7633

ResearchGate, 2010. *The ENRA concept.* [Online]
Available at: https://www.researchgate.net/figure/The-ENRA-concept_fig1_46406079

StatBank Denmark, 2017. *Statistics Denmark.* [Online]
Available at: http://www.statbank.dk/statbank5a/default.asp?w=1920

Statistics Finland, 2018. *Clearly fewer building permits were granted than one year ago.* [Online]
Available at: https://www.stat.fi/til/ras/2018/09/ras_2018_09_2018-11-27_tie_001_en.html

Suomen KattoCenter Oy, 2018. *Home.* [Online]
Available at: https://www.kattocenter.fi/?gclid=Cj0KCQiAuf7fBRD7ARIsACqb8w6WXd36TFwwK_xqjqNJ9saN8QAB96-4h-PO9IRXPhUt58J2msWXdWcaAlXDEALw_wcB

TerMater Oy, 2014. *Home.* [Online]
Available at: https://www.termater.fi/

Tommerup, H. o.a., 2010. *Existing Sustainable Renovation Concepts,* Copenhagen: Nordic Innovation Centre.