Comparing energy efficiency and renovating costs on family residences built 1950-2013

Mikaela Kallionalusta

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Abstract:

Through my research I set out to discover whether or not renovating an older home to modern energy efficiency standards is possible and / or a financially viable option versus buying a new home. I analyzed data from three different houses to compare costs and benefits for each case. For the older houses I chose one in Lahti that was built in 1954 and another in Pornainen, built in 1980. For the baseline standard of current building codes, a house in Porvoo that was constructed in 2013 was used. The undesirability in the housing market of older homes, inspired me to learn what, if anything, could be done to improve their usefulness and value thus reducing the number of unwanted buildings. Simulations showed that one of the most effective means of achieving this goal were making homes more energy efficient. Adding insulation, updating the existing heating system, renewing windows, doors, and roof, as well as, adding mechanical ventilation all had a positive impact. Furthermore, renovating and updating major items could increase the house's useable lifespan by decades, provided the structure is sound. The floorplans and houses were created using IDA ICE. Two simulations, one before and one after, were made on each of the older houses. Another was created from the house built in 2013 to use as a comparison. The first simulations used U-values that were valid at the time of construction and the second simulation with U-values that conform to current standards. In the second simulation, mechanical ventilation with a heat exchanger was added along with the heating system upgraded to geothermal. Further research involved information on the housing situation in Finland, including statistical costs analysis of available lots as well as prices of homes sold in the selected locations. Renovation costs were calculated and compared to the costs of building a new home. These comparisons resulted in concluding that renovating a house in Finland is more cost effective than new construction. Savings of over 46% were possible by renovating instead of building, but a more conservative number of 18% was used to safely cover any unforeseen costs due to unexpected repair needs . The IDA ICE simulations showed that energy efficiency was increased significantly by lowering the energy consumption due to heating by more than 45 %. The results also indicated a reduction in overall energy consumption, bringing both older houses' energy certificate class value up to the C level. The findings of this research will allow home buyers, sellers, and current owners realize that up-cycling an older house by renovating is a cost effective and viable option to buying or building a new construction.

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Sammandrag:

Genom min forskning bestämde jag mig för att upptäcka huruvida det är möjligt att renovera äldre byggnader till moderna energieffektivitetsstandarder och / eller ett ekonomiskt genomförbart alternativ jämfört med att bygga ett nytt hem. I arbetet analyserades data på tre olika hus för att jämföra kostnader och fördelar. För de äldre husen valde jag ett i Lahtis som byggdes 1954 och ett hus i Borgnäs, byggd 1980. För baslinjestandarden för nuvarande byggbestämmelser användes ett hus i Borgå, byggd 2013. Dåliga rykten på äldre byggnader i bostadsmarknaden inspirerade mig att lära mig vad som skulle kunna göras för att förbättra deras användbarhet och värde, och därmed minska antalet oönskade byggnader. Simuleringar visade att ett av de mest effektiva sätten att uppnå detta mål var att göra bostäder mer energieffektiva. Att lägga till isolering, uppdatera värmesystem, förnya fönster, dörrar och tak samt att lägga till mekanisk ventilation har alla haft en positiv inverkan. Vidare kan renovering och uppdatering öka husets användbara livslängd genom årtionden, förutsatt att strukturen är sund. Husen skapades med IDA ICE, var två simuleringar, en före och en efter, gjordes på var och en av de äldre husen. En skapades på 2013 huset för att användas som jämförelse. De första simuleringarna användes U-värden som gällde vid konstruktionstidpunkten och den andra simuleringen med U-värden som överensstämmer med gällande standarder. I den andra simuleringen tillsattes mekanisk ventilation med en värmeväxlare tillsammans med ett nytt värmesystem som uppgraderades till geotermisk. Ytterligare forskning involverade information om bostadsläget i Finland, inklusive statistisk kostnadsanalys av tillgängliga delar samt priser på bostäder som säljs på de utvalda platserna. Renoveringskostnaderna beräknades och jämfördes med kostnaderna för att bygga ett nytt hem. Dessa jämförelser resulterade i att renovering av ett hus i Finland är mer kostnadseffektivt än nybyggnation. Besparingar up till 46% var möjliga genom renovering istället för byggnad, men ett mer konservativt värde på 15% användes för att säkert täcka eventuella oförutsedda kostnader på grund av oväntade reparationsbehov. IDA ICE-simuleringarna visade att energieffektiviteten ökade signifikant genom att sänka energiförbrukningen på grund av uppvärmning med mer än 45%. Resultaten indikerar också en minskning av den totala energiförbrukningen, vilket innebär att båda äldre husens E-tal nådde C-nivån.

Resultaten av denna forskning kommer att göra det möjligt för hemköpare, säljare och nuvarande ägare att inse att renovering av ett äldre hus är ett genomförbart alternativ.

Nyckelord:	Energieffektivitet, E-tal, kostnadseffektivitet, renovering, koldioxidavtryck
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TERMINOLOGY

a	Year
A_{net}	Net Area
ARA	Asumisen rahoitus- ja kehittämiskeskus
brm^2	Gross area in square meters
dm^3	Cubic decimeter (liter)
E-value	Total energy consumption weighted by energy source factors, per heated net area
K	Kelvin
kWh	Kilo watt hour
LED	Light -emitting diode
m^2	Square meters
nZEB	Nearly zero-energy building
PRRK	Pientalorakentamisen kehittämiskeskus
R-Value	Thermal resistance
U-Value	Thermal transmittance
YM	Ympäristö Ministeriö

FOREWORD

While studying at Arcada University of Applied Sciences in Helsinki my eyes opened to the importance of energy efficiency in buildings and I developed an interest in good insulation and healthy homes. Experiences from living in the United States in very inefficient buildings, from coast to coast, and what I studied gave me an idea and made me interested in the renovation side of construction.

Special thanks go to my husband and extended family who have supported me throughout my studies and with writing of this thesis.

I would also like to thank Mikael Paronen for giving me purpose for the studies and Kim Skön for pushing me to work on my math skills.

27.4.2019 Pornainen

Mikaela Kallionalusta

1 INTRODUCTION

While wanting to relocate from Helsinki to the countryside in search of more space and more affordable living, it became clear that there exists a glut of older homes.

The motivation for this thesis came with wanting to understand why older homes were undesirable and more importantly, what if anything, could be done about them. The listed purchase prices of older homes varied, but in general seemed to present good value for money so the assumption was that at least one main reason for their undesirability was related to their inherent lack of modernity. The question then became whether it is better and more cost effective to renovate an existing older home to modern standards or purchase a lot and build a new home from scratch.

Renovating an existing older home's style and appearance to match that of a new home seemed an uneven and ultimately pointless exercise. The focus, therefore, would be on renovating an existing older home to bring its energy efficiency, ventilation, and quality up to the standard of a modern home, meeting all relevant building codes.

A baseline for energy efficiency was established using a modern home built in 2013 and compared to IDA ICE simulated renovations of two specific examples of existing older homes, one built in 1954 and the other on 1980. Using IDA ICE (Equa) as a tool for energy and heat load simulations, before and after renovations. By changing the materials used and adding more insulation for better U-values should be able to analyze the profitability and possibility of achieving an energy efficient home.

The research involved utilizing quantitative methods as well as cost calculators and statistical data on existing homes to determine the cost effectiveness of renovating existing versus building new.
The aim is to enlighten new home buyers to broaden their search criteria and consider older homes as well.

2 STATISTICS ON BUILDINGS IN FINLAND

According to the Finnish statistics center (Statistics Finland), there were a little over 1,5 million buildings at the end of 2017, these do not include summer cabins, agricultural or outbuildings. Of all residential buildings 60 percent of them were built after 1970, 57 percent of those single family and 67 percent of apartment buildings.

In 2017 the number of buildings increased by 11 000 compared to year before. Buildings built after 1990 has increased a total of 31 percent, and older buildings built before 1921, consists of about 5 percent of the total building stock in Finland.

Two thirds (66 percent) of all buildings in Finland are single story. Approximately 3,6 million (67 percent) Finns live in one- or two-story buildings. Almost 1,3 million Finns live in at least 4 story apartment buildings.

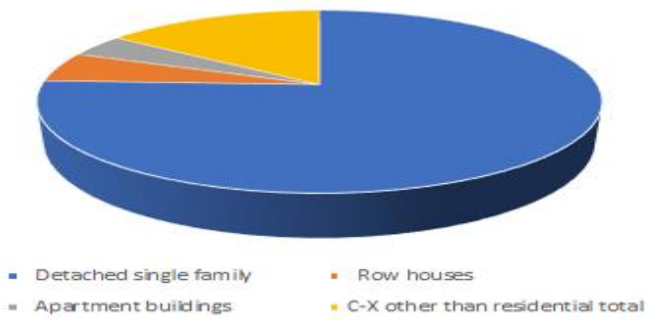


Figure 1. Pie chart showing the magnitude of single family detached homes in Finland

Table 1 below, listing the intended use of building, total amount and percentage of all buildings, compiled by the Finnish statistics center at the end of 2017.

Table 1. The total by number for each of the building types by use

Buildings based on intended use 31.12.2017	**Number of buildings Σ**	**Percentage of all buildings %**
ALL BUILDINGS	**1,523,196**	**100.0**
A. Residential buildings total	**1,294,426**	**85.0**
Detached single family	1,152,489	75.7
Row houses	81,293	5.3
Apartment buildings	60,644	4.0
C-X other than residential total	**228,770**	**15.0**
C Commercial buildings	43,868	2.9
D Office buildings	10,834	0.7
E Transport buildings	57,760	3.8
F Healthcare buildings	9,077	0.6
G Assembly buildings	14,510	1.0
H Educational buildings	8,987	0.6
J Industrial buildings	45,870	3.0
K Warehouse buildings	32,408	2.1
X Other buildings	5,456	0.4

Table 2 below, showing the total number of buildings built in the different time periods, listed on the left, separated by the type of buildings limited to residential applications.

The homes used in this thesis are included in the time periods top, middle and bottom rows.

Table 2. Statistics on the different residential building types built in each decade after 1940 (Stat Fin PX Web database)

FINLAND	Number of buildings built by type and year		
	Detached houses	Row houses	Apartment buildings
1940 – 1959	240,231	1,081	6,757
1960 – 1969	112,991	3,190	8,649
1970 – 1979	152,471	14,320	12,600
1980 – 1989	184,690	28,838	9,114
1990 – 1999	116,091	15,810	8,154
2000 – 2009	129,131	10,452	5,588
2010 - 2017	75,890	6,069	4,880

3 ENERGY EFFICIENCY IN GENERAL

Because of Finland's geographical location, the energy consumptions are quite high, and this energy usage accounts to more than one third of all greenhouse gas emissions caused by buildings and construction (Ympäristö).
The Ministry of the Environment sets all of the building codes to standardize building construction to create energy efficient, safe and sound structures. The codes include but are not limited to planning and supervision, fire safety, energy efficiency, health (indoor air) and soundproofing. (Ympäristöministeriö, Codes).

To reduce energy consumption there are many ways approach it, here are a few examples:

- adding insulation in a home to lower cooling and heating costs
- changing light bulbs to LED lighting
- reducing hot water usage by taking shorter showers
- installing north facing skylight windows for natural light

3.1 Renewable Energy

To reduce carbon dioxide emissions, renewable energy ought to be used in the construction of new buildings. Geothermal for example is fairly easily integrated to new construction and with good planning also to renovations. Renewable energy sources, like wind and solar can also be utilized to produce electricity.

The sun delivers most of the so-called free heat. With direct radiation, the cardinal direction of a building's windows can offer heat to a building or with solar collectors heat domestic water. Reversely you can see an example of an indirect or passive solar design, in figure 3. It demonstrates that a south facing window has different effect in the summer months versus the winter months, and the overhang of the roof plays a big part in that.

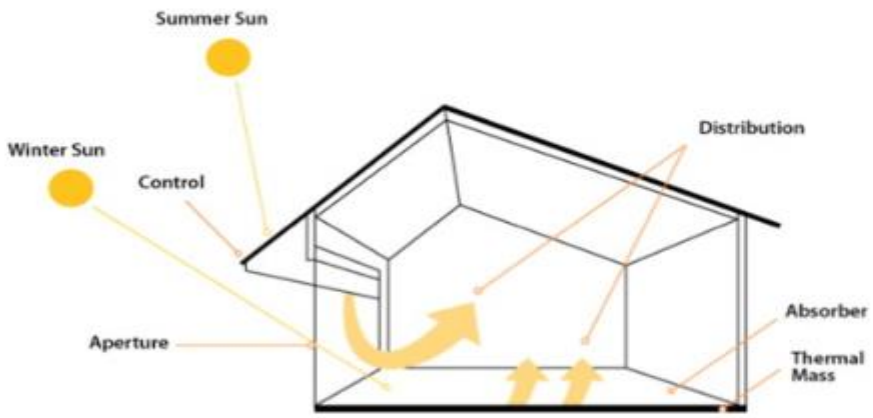


Figure 2. Example of solar design to gain heat in winter and keep cooler in summer (Science direct, Passive solar)

3.2 Indoor climate

A well-ventilated home is a healthy home, but as indoor climate goes it comprises of the temperature, humidity and carbon dioxide level to reach a level of comfort. Indoor climate is not necessarily noticed when it is in good order, but when it does not work it can be unhealthy for the people living in the home. Poor indoor climate is what is often associated with older homes due to the lack of proper ventilation systems that can cause: stuffy air and smells, high carbon dioxide content and hot or cold indoor temperatures.

The building code for indoor climate and ventilation (Edilex, 1009/2017) states all of the ventilation regulations are mainly for new construction but affects also major renovations planned, for instance, increasing the gross floor area of a building. The decree does not however apply to vacation homes or agricultural buildings.

Main design rules for good indoor climate:
- The outdoor air flow needs to be a minimum of 0.35 $(dm^3/s)/m^2$ for a space that may not need additional airflow from time to time, but a dwelling units outdoor air flow shall be designed to a minimum of 18 dm^3/s.
- The design temperature should stay around 21°C in heating season, it may fluctuate between 20°C and 25°C during heating and 20°C and 27°C outside the heating season.
- Carbon dioxide level shall not exceed 800 ppm above the concentration in outdoor air.

3.3 Energy Certificate

Certificates are used as a tool by licensed professionals, only, for improvement suggestions and comparing energy efficiency on existing buildings that are being sold or rented. It is a requirement in all new construction as well.

The certificates energy efficiency class is based on the calculated energy consumption. They are valid until replaced by a newer version, but for a maximum of 10 years (Ympäristö, Energiatodistus)

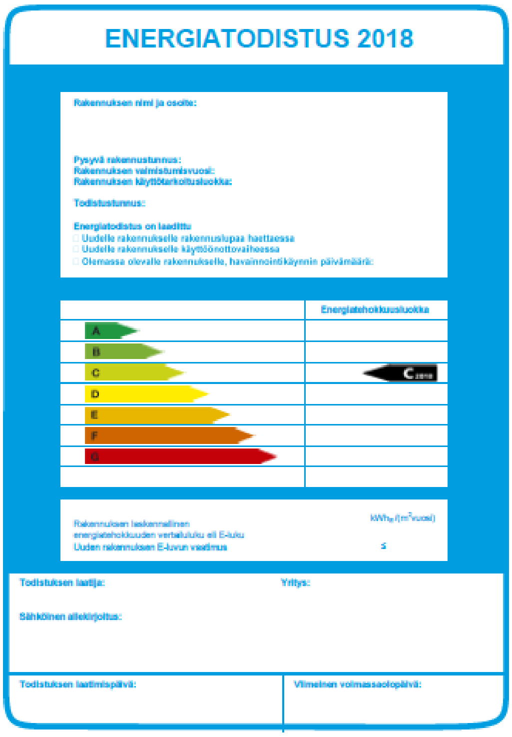


Figure 3. Energy certificate (Motiva)

3.3.1 When are the certificates required and not required

Essentially all buildings that are subject to building codes needs a certificate. Owner of the building is liable for acquiring the certificate.

- All detached single-family houses, and apartment buildings built after 1980
- New construction needs to have an estimated energy consumption certificate when applying for the building permit. This is then replaced before building hand over, in case the information is incomplete and needed clarification.

- Existing buildings being sold or rented.

Few examples of when the certificate is not required:

- If a buildings floor area is less than 50m2
- Recreational home not being used for income purpose
- Industrial buildings or workshops

3.3.2 Energy Efficiency Classes

E-value reading, or the energy certificate value, refers to the total energy consumption per square meter per year. E-value is calculated using the delivered energy total (kWh) for the year divided by the heated net area (m^2) [kWh/m^2a]

All delivered energy used, is considered in the calculations (heating, lighting, domestic hot water, ventilation). There are factors for the different forms of energy which are used to calculate the E-value, so the way the building is heated is important, see table 3.

However, it is important to consider the total energy consumption instead of just the E-value.

As an example; you can have a house heated with firewood with an E-value class of A, but to heat it will be more expensive than an electric heated house with an E-value class of D. Hence it is preferable to look at the energy summary of the energy certificate for the "true energy consumption", which tells the actual yearly energy consumption.

Table 3. Energy factors valid from 1.1.2018

Energy Factors	2018→	2013-2017
Electricity	1.2	1.7
District Heating	0.5	0.7
District Cooling	0.28	0.4
Fossil fuels	1	1
Renewables	0.5	0.5

3.3.3 How to calculate the energy class value based on the building area

Energy certificate class values are calculated using the buildings heated net area (A_{net}): for small residential buildings that are between 50-150 m^2; use the first table of figures, and the second table is for larger buildings of 150-600 m^2. (YM 1048/2017, page 22)

Table 4. Energy efficiency classes for 50-150m^2 buildings above, and 150-600m^2 below

50 m^2 ≤ A_{netto} ≤ 150 m^2, A_{netto} on rakennuksen lämmitetty nettoala

Energiatehokkuusluokka	E-luku (kWh$_E$/(m^{2}vuosi))	
A		E-luku ≤ 110 - 0,2×A_{netto}
B	110 - 0,2×A_{netto} <	E-luku ≤ 215 - 0,6×A_{netto}
C	215 - 0,6×A_{netto} <	E-luku ≤ 252 - 0,6×A_{netto}
D	252 - 0,6×A_{netto} <	E-luku ≤ 332 - 0,6×A_{netto}
E	332 - 0,6×A_{netto} <	E-luku ≤ 462 - 0,6×A_{netto}
F	462 - 0,6×A_{netto} <	E-luku ≤ 532 - 0,6×A_{netto}
G	532 - 0,6×A_{netto} <	E-luku

150 m^2 < A_{netto} ≤ 600 m^2, A_{netto} on rakennuksen lämmitetty nettoala

Energiatehokkuusluokka	E-luku (kWh$_E$/(m^{2}vuosi))	
A		E-luku ≤ 83 - 0,02×A_{netto}
B	83 - 0,02×A_{netto} <	E-luku ≤ 131 - 0,04×A_{netto}
C	131 - 0,04×A_{netto} <	E-luku ≤ 173 - 0,07×A_{netto}
D	173 - 0,07×A_{netto} <	E-luku ≤ 253 - 0,07×A_{netto}
E	253 - 0,07×A_{netto} <	E-luku ≤ 383 - 0,07×A_{netto}
F	383 - 0,07×A_{netto} <	E-luku ≤ 453 - 0,07×A_{netto}
G	453 - 0,07×A_{netto} <	E-luku

After you have made the calculation to figure out your E-value, refer to page 35 for the energy readings, Energy certificate class values (A-G) are calculated by figuring out the upper and lower limits with the net area (A_{net}) of the house by referring to the above tables. Explained below.

For example, a house with net area of 130m^2 and E-value of 172 kWh/m^2 has the Energy certificate class value of C based on the below calculation example:

B = lower limit 110 – 0,2 x 130 = **84** < upper limit 215 – 0,6 x 130 = **137**

The B value upper limit is the same as C values lower limit.

C = lower limit **137** < upper limit 252 – 0.6 x 130 = **174**

(E-value of 172 kWh/m^2 is between 137 and 174, as shown calculated above.)

3.4 U-value

Thermal transmittance, U-value, is used to measure a building materials effectiveness in keeping the heat from transmitting from inside the house to the outside. The lower the value, the better the material works as an insulator.

U-values can be calculated by adding all the material layers thermals resistances, R-values [m^2/KW] + the inside [Ri] and outside surfaces [Ro].

U = $1/\Sigma R + Ri + Ro$ [W/m^2K]

3.5 R-value

Thermal resistance, R-value, of the materials can be calculated by dividing the thickness [L]of the material layer [m] by thermal conductivity [W/mK] of the material. The higher number gives greater resistance, meaning better insulating properties.

R = L/λ [m^2K/W]

3.6 Heating sources

According to building development center for residences (PRKK-Pientalorakentamisen Kehittämiskeskus, which provides advice and training for construction and building contractors) over 50 percent of new home construction uses geothermal as their main heating source, 15 percent extracting air heat pumps and 9 percent electric heat.

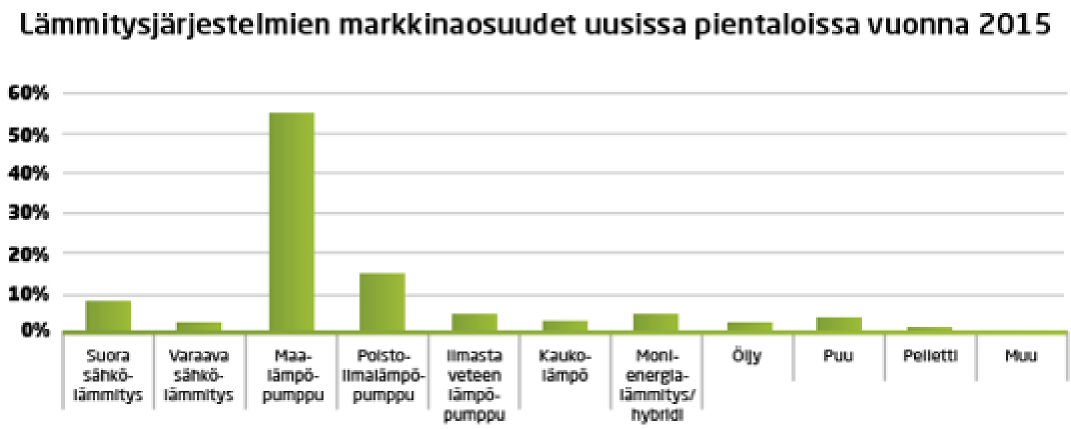


Figure 4. Market shares of heating systems, new construction detached homes in 2015, source PRKK

Listed below are the five most common heat sources selected in new home construction and their investment- and energy costs. These estimated costs were published 12.6.2017 (Lämpöykkönen).

3.6.1 Electric heating

Commonly used in residential construction because of how easy and fast it is to implement. Getting a building permit approved using only electric heating might be problematic, with the tight regulations on energy efficiency. Often it is then paired with heat air pumps as a second source for more efficient heating.

The investment cost for electric heating is approximately 58 €/m^2. Unit price for electricity runs about 10-12 cents/kWh. Pairing with a heat air pump, lowers the energy cost to 7-8 cents/kWh.

3.6.2 District heating

District heat distributes heat generated in a centralized location through a network of insulated pipes. It is a popular heating source in urban areas, and if location allows it can be used in new construction as well. Negative sides for district heat are that, along with renewable energy sources some energy companies still use fossil fuels to produce the energy. The other downside is, residents are locked in to the fluctuating cost for district heating.

District heat investment cost, including hydronic floor heating, is around 79 €/m^2. Depending on the location the unit price for district heat is around 5-13 cents/kWh.

3.6.3 Geothermal

Geothermal energy is the heat stored in the earth. Because it uses renewable energy and that it is cost effective, geothermal is the most popular of all heating systems in new construction of residential properties. Initial investment costs are high but the energy saving potential is the highest compared to other heat pumps, and the system can also be used for cooling a house.

The investment cost for geothermal have reduced with the houses built with better energy efficiency. Cost for new construction is around 117 €/m^2, which includes the hydronic floor heating. Energy cost is 3-4 cents/kWh which is about 70 percent less than electric heating.

3.6.4 Extracting air heat pump

Also called Exhaust air heat pump; extracts the exhaust air from the ventilation system and transfers the heat to the incoming air, domestic water or to the hydronic heating system. Takes care of ventilation and aids in the heating as well. It works best in low energy or passive energy houses where the volume is large compared to the heating power needed. It will not work as sole source of heating and should have a supporting heating source like wood burning or electric heating during the coldest months. (Motiva)

Investment costs comes to around 79 €/m^2 and it includes hydronic floor heating. Energy cost is around 35 percent less than electric heating at 6-8 cents/kWh.

3.6.5 Air-to-water heat pump

Air to water heat pumps utilizes the air from outside to provide heat inside and hot domestic water. Popularity for the air to water heat pump has increased in the last few years, because it is an environmentally friendly option, when geothermal is not suitable for the site. It can also be used in renovations as an energy efficient support to the existing heating source (like oil).

This heating system, just like geothermal and district heat uses hydronics, preferably floor heating. The cost runs about 96 €/m^2 including hydronic floor heating system. Unit price 5-6 cents/kWh saves in energy costs around 40-60 percent compared to electric heating.

Table 5 shows a summary of the investment costs by each of the energy sources mentioned above and compares the energy cost savings of each to electric heating cost.

Table 5. Energy source investment and energy, costs published 12.6.2017 by Lämpöykkönen.

Costs	Energy sources				
	Electric hea-ting	District hea-ting	Geothermal	Extracting Air heat pump	Air-to-water heat pump
Investment cost per m² [€]	58	79	117	79	96
Energy cost Cent/kWh	10-12	5-13	3-4	6-8	5-6
Savings compared to Electric heat		-20%- 55%	70%	35%	50%

4 CARBON FOOTPRINT OF CONSTRUCTION

Carbon footprint is defined as the carbon dioxide (CO_2) emissions resulting from material manufacturing and maintenance over a review period of 100 years (SYKE).

In 2017, Finland's Ministry of the Environment commissioned a "Road Map" to reduce the carbon footprint of construction, construction materials, and to promote climate objectives in both the Finnish real estate and construction sectors (Bionova).

The new low carbon limits will eventually apply to all buildings, however, the legislative guidance has been planned to affect new construction first. This is intended to target the "carbon peak" produced by new buildings and the construction materials used. Therefore, demolition of existing buildings should be avoided from the low carbon standpoint. Historic buildings are also not exempt and should, for example, seek to reduce their carbon footprint by improving energy efficiency.

4.1 Road map

When commissioning the "Road Map", the Ministry of the Environment stipulated that the calculating and reporting of the carbon footprint resulting from materials and energy used, would initially be voluntary. Then incentives would be offered to the private sector for compliance. Eventually, the calculations would become mandatory and by 2025 the model would change to setting limit values for all buildings. The ”Road Map” is structured accordingly and shows the phasing, guidance, and preparation for the future regulation of the private sector, plus the development of the level of competence. See figure 5 below for the detailed “Road Map”.

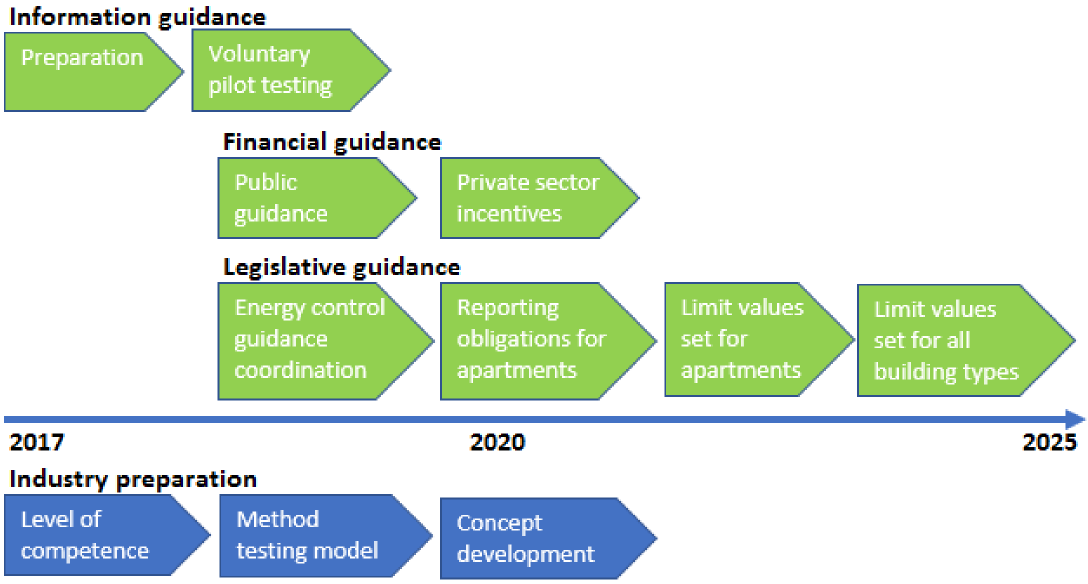


Figure 5. Road map demonstrating the different phases of the guidances, and the industry preparation.

Implementation of the “Road Map” will require development of applicable expertise in both real estate and construction. Additional environmental information on building materials will also be necessary.

4.2 Building life-cycle emissions

Producing the materials required for construction, including concrete, timber, plastic, glass, etcetera, all result in a carbon footprint. Transporting those materials to site also adds to the carbon footprint. Once built and in use the building’s carbon footprint continues to be increased though the site operations. Maintaining and repairing the building as well as the energy and water usage also add to the carbon footprint. Finally, the demolition and disposal of left-over materials is the last addition to the building’s carbon footprint.

Buildings using fossil fuels are most affected, and the carbon footprint is even higher in the actual production and transport of the fossil fuels. Energy demand can be covered by utilizing purchased renewable energy or self-produced renewable energy.

Below is an example chart for a few ARA-properties (ARA- Asumisen rahoitus- ja kehittämiskeskus / Housing Finance and Development Center) demonstrating the carbon footprint lifecycle development trend of buildings as energy efficiency improves. It illustrates how, with the improvement of energy efficiency, the share for material emissions increases.

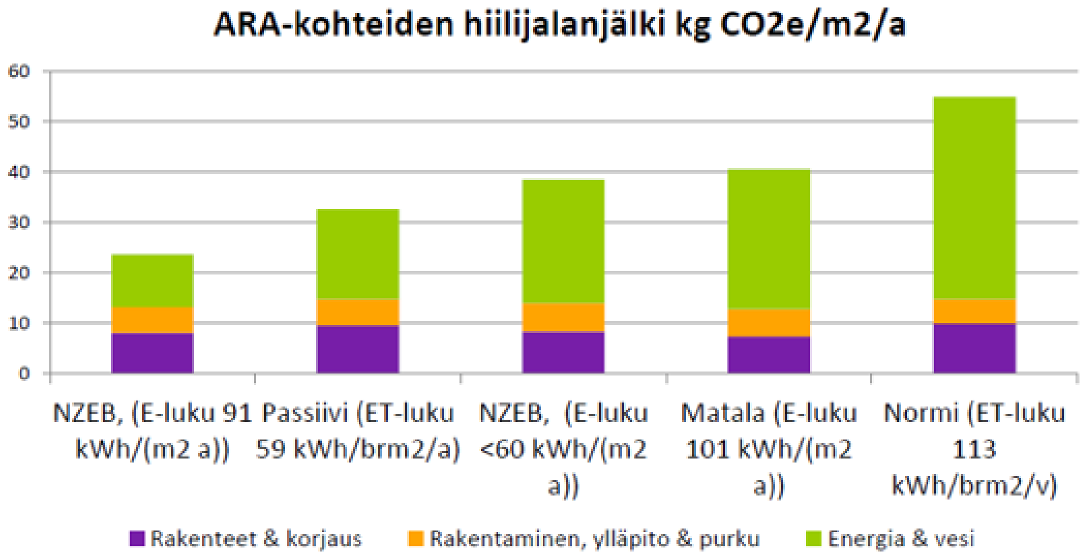


Figure 6. Development trend present as energy efficiency improves (Bionova)

Purple - structures and repair **Orange** - construction, maintenance and demolition **Green** - energy and water

The energy consumption from above chart includes: heating, cooling, ventilation, hot water, lighting and automation. In addition to a building's own emissions, they are also responsible for the emissions from the construction, maintenance and transport of urban infrastructure and road networks needed to serve them. These are controlled, for example, by zoning and excise taxes. The low-emission target above is close to the future E-value limit.

Presently, operating energy generates most of the carbon emissions. By improving energy efficiency and increasing the use of renewable energy, along with developing the energy system, advancements will be made in striving for a lower carbon footprint. Reducing emissions from the energy system will also reduce emissions of energy-intensive materials. With becoming more energy efficient, the need for materials and building technology increases and emissions from materials manufacturing and lifecycle maintenance, repairs and replacements increases also in relation.

5 HOUSES USED IN THE COMPARISON

Two houses are compared for the renovation costs to house number three which is built to the current standards for buildings. Building code U-values used for these comparisons were valid prior to 1969 for house number one, 1978-1985 for house number two and 2010-present for house number three, which will be the baseline for the current regulations. See below for U-value table. (YM 1048/2017, page 9)

Below in table 6, are the U-values valid at the time of construction for each of the buildings for each of the construction parts. After the U-values are descriptions of each of the three homes, IDA ICE drawings with the cardinal directions on bottom right followed by floorplans also drawn in IDA ICE

Table 6. U-values for the three periods in comparison in this thesis

Construction part U-values	pre 1969	1978 - 1985	2010 - present
Exterior walls	0,81	0,35	0,17
External slab (earth)	0,47	0,4	0,16
External slab (crawl space	0,47	0,4	0,17
Roof	0,47	0,22	0,09
Door	2,2	1,4	1
Windows	2,8	2,1	1

5.1 House one, 1954 Lahti

A typical detached house built after the Second World War for the families of soldiers who fought in the battlefront (Rintamamiestalo). Consists of two bedrooms, toilet and partially heated closet on the second floor, open living room, kitchen on first floor and sauna, bathroom, toilet and utility room. Dimensions mentioned below, are inside measurements in meters.

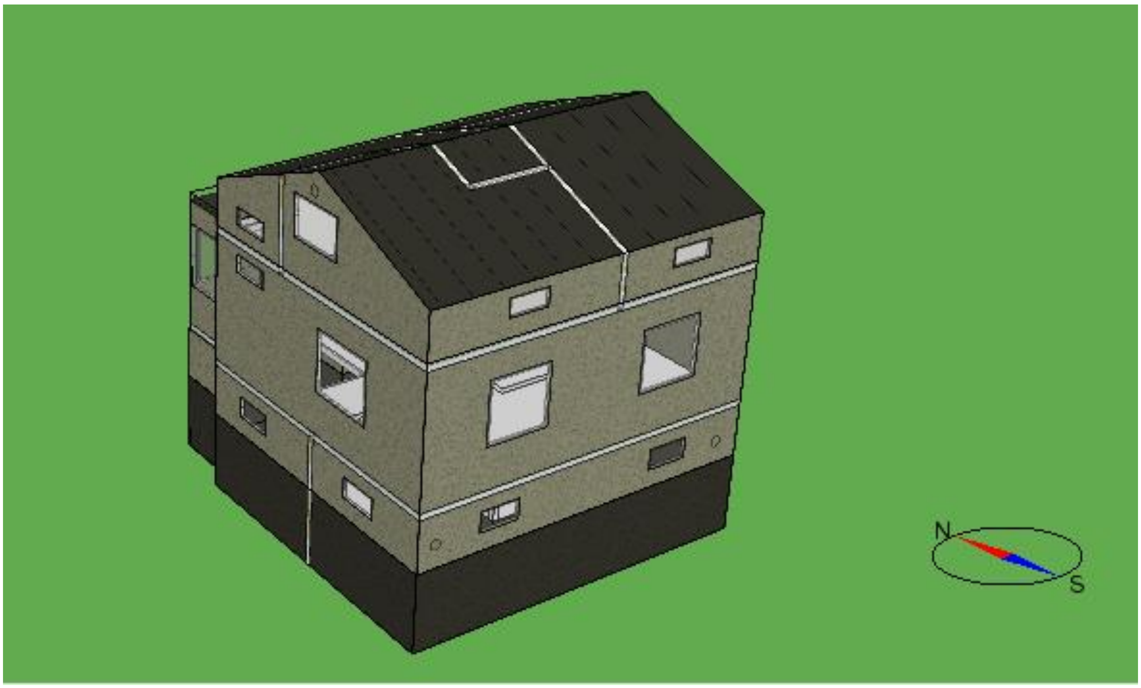
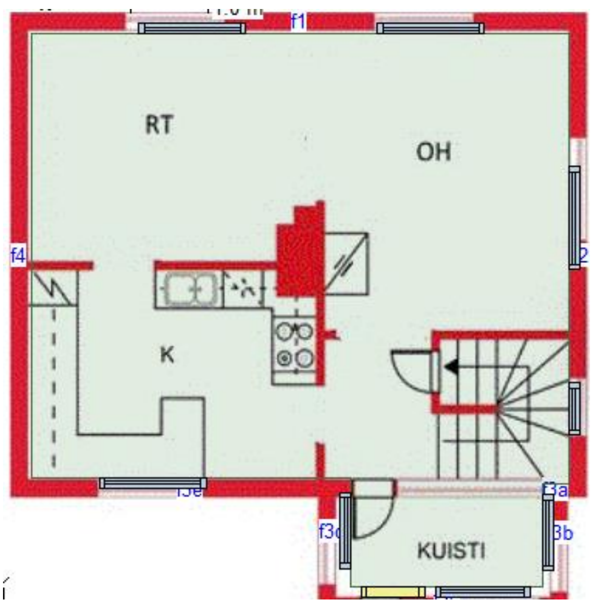


Figure 7. IDA ICE drawing of house one, 1954

Area	128 m^2 (Floor areas: basement 44 m^2, 1st floor 44 m^2, 2nd floor 40 m^2)
Dimensions	x (6.94 m) y (7.42 m) room height 2.5 m
Roof	Original standing seam metal (top height at 5.85 m)
Floors	1,5 + basement
Year built	1954
Heating	Electric plus fire place
Ventilation	Natural
Heating energy usage	Average over 3 years 21500 kWh/a

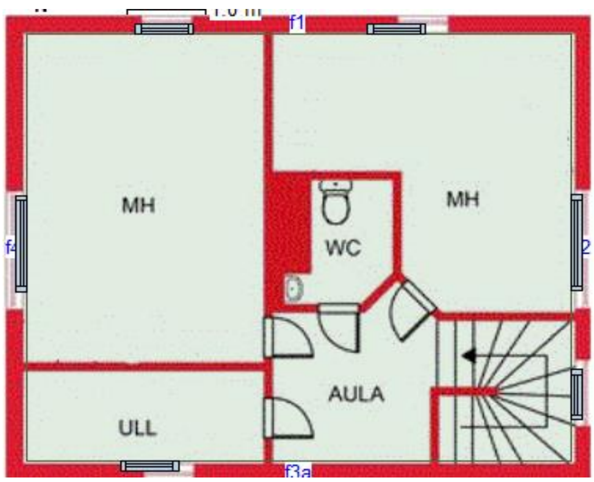
BASEMENT

Bath/sauna, Utility room - Living space, toilet, closet



FIRST FLOOR

Dining area, Living room – Kitchen, Hallway, Foyer



SECOND FLOOR

Bedroom 1, Toilet, Bedroom 2 – Attic storage, Hallway

Figures 8-10. Floor plans drawn in IDA ICE for house number one 1954

5.2 House two, 1980 Pornainen

Typically built brick façade house with wood paneling above windows and a low cast plinth foundation. All rooms are on one floor consisting of two bedrooms, one of them with a loft area, walk in closet/office, bathroom, sauna and utility room, two toilets, open living room and kitchen with high ceiling all the way up to roof, plus partially heated storage and exercise rooms. Dimensions mentioned below, are inside measurements in meters.

Figure 11. IDA ICE drawing of house two, 1980

Area	148 m^2
Dimensions	x (16.5m) y_n (9.4m)/y_s (8.1m) room height 2.5 m / open space 3.9m
Roof	Original tiled roof (top height 4 m)
Floors	1 + loft space
Year built	1980
Heating	Oil heated hydronic radiators, electric, plus fire place
Ventilation	Natural plus a manually operated exhaust fan
Heating energy usage	OIL - Average over 3 years 2000 dm^3/a

Floor plan for house two 1980 – single story with ceiling height up to roof in the living room and bedroom 1.

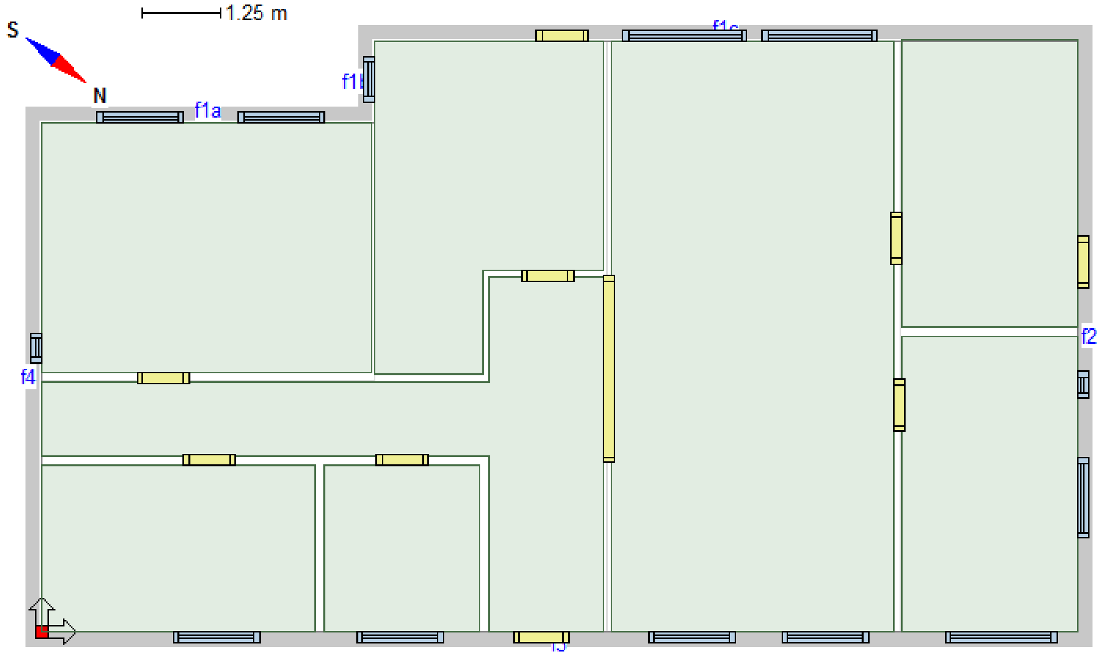


Figure 12. Floor plan drawn in IDA ICE for house number two, 1980

FIRST FLOOR (L-R, Top-Bottom)
Bedroom 1, Bathroom/Sauna, Living room, Storage –
Bedroom 2, Office, Hallway, Living room, Exercise room

5.3 House three, 2013 Porvoo

Newer modern construction two story block house, with a render finish, equipped with a mechanical ventilation system with heat exchanger and using renewable energy for heating. This house has a total of three bed rooms on the second floor and a large open concept living space downstairs. Dimensions, below, are inside measurements in meters.

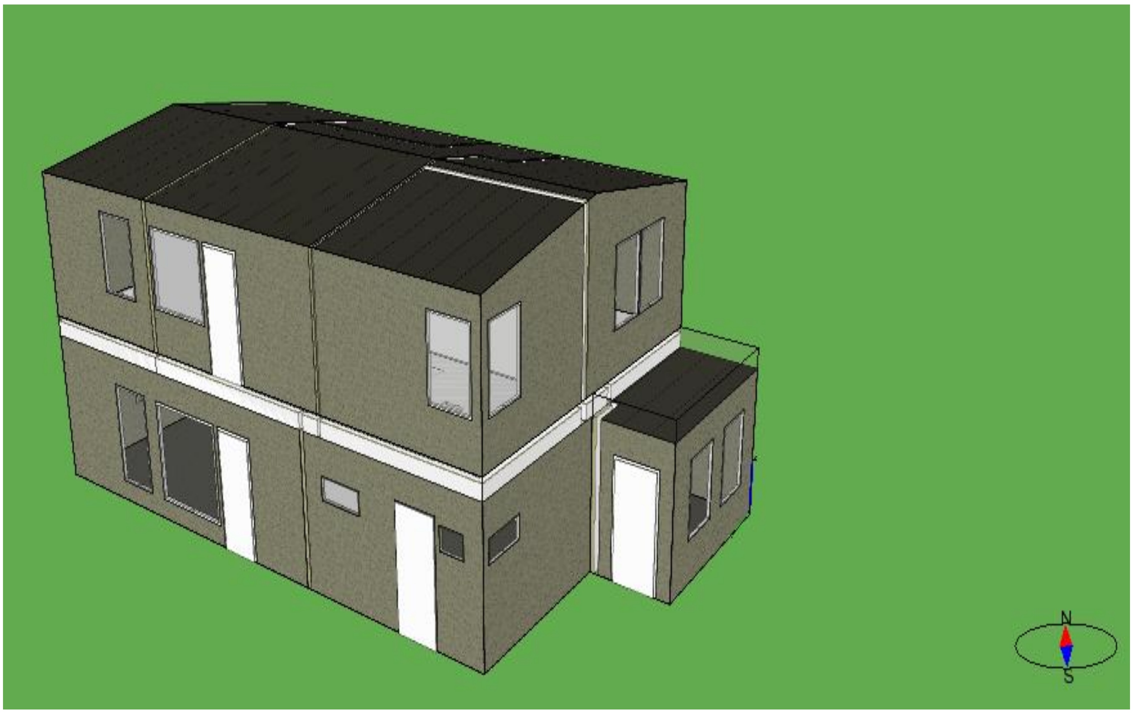


Figure 13. IDA ICE drawing of house number three, 2013

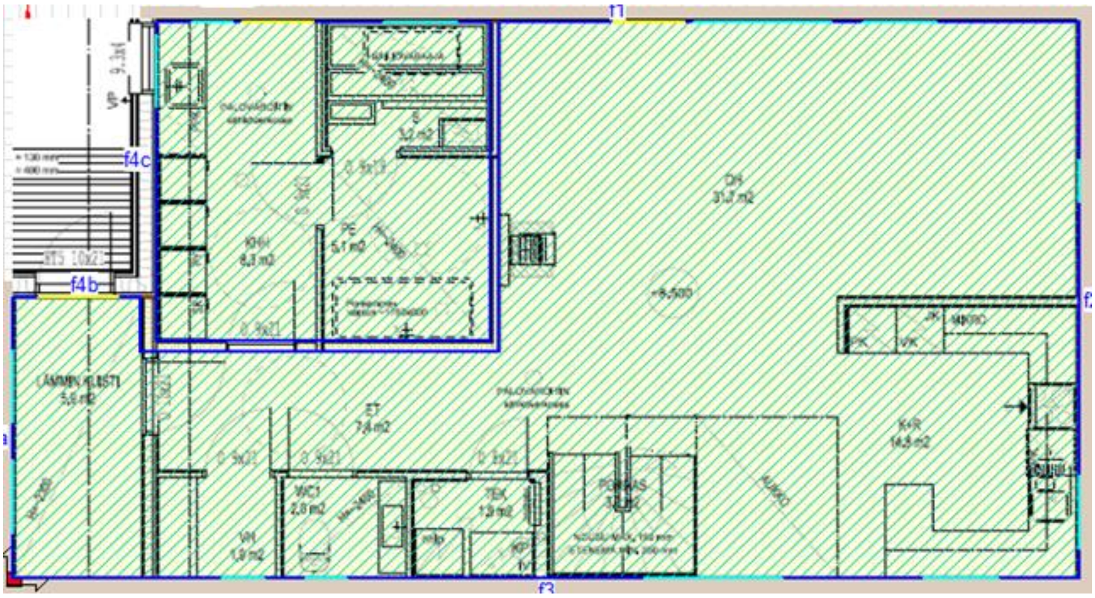
Area	168 m^2 (Floor areas: 1st floor 87 m^2 and 2nd floor 81 m^2)
Dimensions	1st x (13.22 m) y (7.12 m) / 2nd x (11.44 m) y (7.12 m)
Roof	Standing seam metal roof (top height at 6 m)
Floors	2 (room height 2.86 m)
Year built	2013
Heating	Geothermal, hydronic floor heating
Ventilation	Mechanical with heat exchanger
Heating Energy usage	11000 kWh/a, average over 4 years

Floor plans for house number three, 2013 – (Second floor at 2.96 m)

FIRST FLOOR (L-R, Top-Bottom)

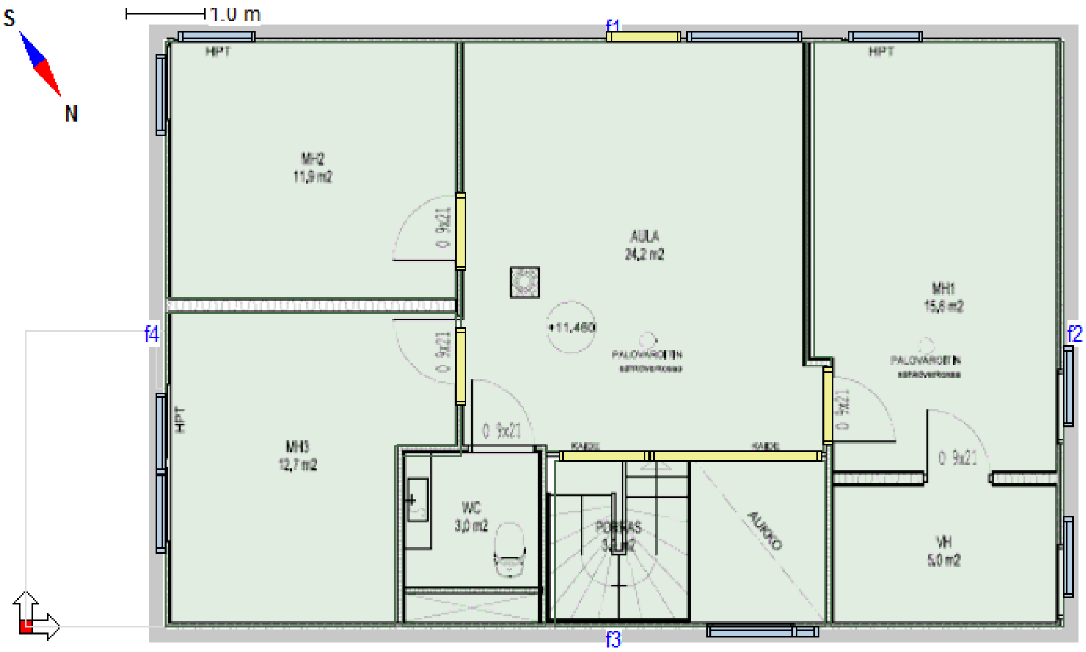
Bathroom/ Sauna/ Utility room, open Living room with hallway and kitchen –

Foyer (partial heat), Hallway, Closet, Toilet, Staircase, Kitchen



SECOND FLOOR (L-R, Top-Bottom)

Bedroom 2, Living space, Bedroom 1 with walk-in-closet – Bedroom 3, Toilet, Staircase



Figures 14-15. Floor plans drawn in IDA ICE for house three, 2013

6 THE SIMULATION WORK

The aim was to keep most of the data the same with the three houses, so the information received is comparable with each other. Main difference with them is obviously going the be the U-values for the building codes that were valid at the time of construction, for the different construction parts in the before-renovation simulations. Important parts which are also considered in the simulations are the air tightness of the building, how the building is the situated on the lot, number of occupants, hot water usage, ventilation or the lack there of, and energy sources used for heating and cooling if applicable.

6.1 IDA Indoor Climate and Energy

IDA ICE is a software for simulating indoor climate and energy in buildings, by EQUA simulation AB in Sweden (Equa). Houses are built using supplied specifications and variables, or they can be imported from a variety of CAD files or IFC models. After creating zones and picking the accurate variables for each zone, adding windows and other necessary building items, simulations can be generated to demonstrate the heating or cooling loads and energy consumption for the whole year.

6.1.1 Variables used in the comparison

To make things more comparable, the same parameter values were used in some of the options, see below for a listing of the common items that were used in both simulations;

- domestic water usage is based on 3 people at 60 liters /person /day
- Attic spaces or storage spaces “Occupant” is always set to “Never present”
- “Lighting” / “Equipment” is scheduled as “Always off”

House three, which is used for new house reference, is using the default values for Finland in building codes used in D3 and C4 2013. (Edilex).

See table 7, below, for the common input variables used in the simulations.

Table 7. Input variables used in the IDA ICE simulations

Domestic Hot water usage	Approximately 66 m^3 / year
Internal gains: Equipment Lighting Occupant	Schedule: House living or lighting Power 75W Power 50W Activity level 1
Infiltration	default
Thermal bridges	Poor (old), Typical (renovated)
Pressure-coefficients	Auto fill
Thermostat setpoints	heat 21°C (partial heat 15°C) / cool 25°C

6.1.2 Output data used in simulations

Below you will find the building defaults used in IDA ICE for the two houses used in this thesis. In tables 8a and 9a; showing all U-values and material thicknesses before and after renovations. The grayed-out rows in the after-renovation column highlights the parts that are not being renovated. Below that in tables 8b and 9b, the construction parts which can be easily renovated (as in exterior walls, roof, doors and windows) are listed.

House one, 1954

Table 8a. Data before and after renovations, 1954

1954 Lahti	**Before**		**After**	
Construction parts	Thickness [m]	U value [W/m²K]	Thickness [m]	U value [W/m²K]
External wall	0.083	0.58	0.233	0.17
External slab	0.32	0.47	0.32	0.47
Internal walls	0.122	1.71	0.122	1.71
Internal walls w insulation	0.112	0.71	0.112	0.71
Internal floors	0.12	0.48	0.12	0.48
Roof	0.11	0.47	0.412	0.09
Windows		2.80		1.00
Doors	0.04	2.19	0.066	1.13
Total		1.17		0.72

House one, 1954 (continued)

Table 8b. Data before and after renovations on changed construction parts, 1954

Exterior wall	Before	After
Wood	0.01 m	0.01 m
Air gap	0.003 m	0.003 m
Gypsum	0.01 m	0.01 m
Insulation	0.05 m	**0.2 m**
Gypsum	0.01 m	0.01 m

Roof	Before	After
Wood	0.022 m	0.022 m
Gypsum	0.01 m	0.01 m
Insulation	0.068 m	**0.368 m**
Gypsum	0.01 m	0.01 m
Metal sheet	0.0001 m	0.0001 m

Doors	
Before	Solid wood core door
After	Wood door with insulation core
Windows	
Before	2-pane glazing (4-12air-4)
After	Pilkington Opti-therm 3-pane glazing (4-15argon-4-12argon-4)

House two, 1980

Table 9a. Data before and after renovations, 1980

1980 Pornainen	Before		After	
Construction parts	Thickness [m]	U value [W/m²K]	Thickness [m]	U value [W/m²K]
External wall	0.272	0.32	0.372	0.17
External slab	0.194	0.40	0.194	0.40
Internal walls	0.122	1.71	0.122	1.71
internal walls w insulation	0.146	0.62	0.146	0.62
Internal floors	0.175	2.39	0.175	2.39
Roof	0.185	0.22	0.425	0.09
Windows		2.10		1
Doors	0.062	1.15	0.066	1
Total		1.11		0.92

House two, 1980

Table 9b. Data before and after renovations on changed construction parts, house two

Exterior wall	Before	After
Brick	0.13 m	0.13 m
Air gap	0.03 m	0.03 m
Insulation	0.2 m	**0.3 m**
Gypsum	0.012 m	0.012 m

Roof	Before	After
Wood	0.022 m	0.022 m
Gypsum	0.013 m	0.013 m
Insulation	0.15 m	**0.39 m**
Metal sheet	0.0001 m	0.0001 m

Doors	
Before	Wood door with 10mm insulation core
After	Wood door with 14 mm insulation core
Windows	
Before	3-pane glazing (4-15air-4-12air-4)
After	Pilkington Opti-therm 3-pane glazing (4-15argon-4-12argon-4)

Actual amounts of insulation probably will differ from what was shown in IDA ICE, the information received from the simulation software was used to come as close as possible to the building regulation U-values. This would allow for a comparable calculation between the three houses as far as energy consumption is concerned.

6.2 IDA ICE Simulation results

In the before-renovation simulations for house number one, building regulation U-values were used from year 1969 and before. House number two used building regulations U-values between years 1978 and 1985, as seen in table 6 on page 21.

In the after-renovations simulations, the 2010-present building regulation U-values were used, as seen in table 8a and 9a on pages 29 and 30 in the “After” column.

As a result, the yearly energy consumption was reduced significantly in both houses by adding insulation in the exterior walls and roof, plus updating windows and exterior doors. For the after renovations simulations, ventilation with heat exchanger was added plus cooling, additionally updated the thermal bridges, Poor-to-Typical and Very Poor-to-Poor. Heating systems were also upgraded to geothermal.

See table 10 below, for the results of the simulations.

Table 10. IDA ICE heating consumption results - before and after renovations

Energy consumption comparison	Houses	
	1954	1980
Heating - original [kWh/a] IDA ICE simulation	22,700	16,500
Heating - renovated [kWh/a] IDA ICE simulation	12,440	8,950
kWh saved	10,260	7,550
kW/m^2 prior to renovation	177	111
kW/m^2 post renovation	97	60
Improvement	-45%	-46%

Only including heating consumption in this comparison, domestic hot water consumption of 3820 kWh/year was the same in all three houses.
See Appendix – I – and – II – for the IDA ICE readings before and after renovations on both houses.

6.2.1 Things noted from simulations

With both houses there were issues with the condensation in the pre-renovations due to lack of ventilation. When adding insulation and making house more energy efficient the need for ventilation increases. Which is why, in the post-renovation's simulations, mechanical ventilation with heat exchanger was added. Both house renovations included upgrading from regular electric radiator heating and oil-heating to geothermal.

Even with added ventilation, the IDA ICE simulations delivered energy sheets show that the building comfort is not ideal, and some thermal dissatisfaction exists.
See Appendices – III, IV and V – for the delivered energy sheets for reference.

6.2.2 Energy readings

Energy consumptions readings are based on the IDA ICE delivered energy values, which includes the total energy consumption (facility lighting, electric cooling, HVAC, electric heating, equipment tenant and domestic hot water). After adding an air handling unit for ventilation and tightening up the thermal bridges with the renovations by adding more insulation, both old houses lowered their energy consumptions by more than 45 percent. Which was enough to get on the acceptable level of the energy certificate class value, see table 11 below for details.

Table 11. Energy readings before and after renovations

Delivered energy	OLD kWh/a	kWh/ m²	E class value	NEW kWh/a	kWh/ m²	E class value
house one 1954	31,615	247	D	22,042	172	C
house two 1980	29,342	198	D	20,343	137	C
house three 2013	-	-		20,432	122	B

In table 12 below shows the difference in energy certificate class values based on the size differences (areas) of the houses, calculation method demonstrated on page 19. Houses one and two are both in the 50-150 m^2 size range and use the first table shown in table 4 and house three belongs to the second of the aforementioned table on page 16, for 150-600 m^2 buildings. The results are listed on the right as new and old values.

Table 12. Energy certificate class values for each of the houses based on the area

E readings			example		
	m²		128		House one
A	84.4				
B	84.4	-		138.1	
C	138.1	-		175.1	New
D	175.1	-		255.1	Old
E	255.1	-		385.1	
F	385.1	-		455.1	
G	455.1				
	m²		148		House two
A	80.4				
B	80.4	-		126.2	
C	126.2	-		163.2	New
D	163.2	-		243.2	Old
E	243.2	-		373.2	
F	373.2	-		443.2	
G	443.2				
	m²		168		House three
A	79.8				
B	79.8		-	124.52	New
C	124.52		-	161.66	
D	161.66		-	241.66	
E	241.66		-	371.66	
F	371.66		-	441.66	
G	441.66				

7 COST COMPARISONS FOR RENOVATION AND NEW CONSTRUCTION

The renovation requirements as per the Ministry of Environment decree (YM '2/17') any building renovations must be technically, functionally, and economically feasible.

- Renovations aimed at improving the energy efficiency performance, for example, must not worsen any of the building's original technical design specifications.

Elements such as the indoor climate, sound proofing, and interior moisture control must, therefore, not be negatively affected by the renovations. Similarly, any renovations should not impair or prevent the original function of the building.

- All renovations to residential buildings should be cost-effective based upon a 30-year reference period. Specific elements, which have a shorter life cycle such as water proof coatings or a geothermal pump, are not included.

Comparing the costs of buying an older home and renovating versus purchasing a building lot and constructing a new home, by using cost calculators as an aid in the pricing. researched the statistics information on homes and building lots, sold in the past year, in the same areas as the homes that are used for comparison in this thesis.

7.1 Renovation cost calculators

The calculator used for the costs on renovations are made with a Finnish company (Suomi Rakentaa) that base their extensive research on home repair / renovations and construction sites. Information received, nationally, from thousands of builders and renovators and their choices each year is combined in the calculator to build up cost estimations for the different repairs. These costs will then be compared to the cost of building a new home. All renovation costs and housebuilding cost estimates in the calculator, are intended for the consumers which means the value added tax is included in the amounts.

The costs in the calculator of building new homes were updated in May of 2019 with a 3 percent increase, the costs for renovations remain unchanged since October 2017.

7.1.1 How it works

One can make different selections for the quality of work, demolition needs, material selection and more. The cost estimates do not account for surprises, but they have added a general cost of 25 percent, of total cost of renovation, which is used for designing, planning, site visits, construction management, possible tools or machinery, cleanup et cetera.

7.1.2 Used in the comparison

For simplicity's sake the same choices were made for each of the houses in type of renovations or house construction performed. All jobs are 3 (out of 5) stars which would mean you can expect average quality, expense and efficiency, hourly labor cost equaling around 39 euros. Materials used are also of mid-grade in quality and cost.

The main jobs for the renovations which are usually needed in older homes include replacing windows and doors, adding insulation, renewing roof, new heating system, new ventilation and renewing plumbing.
Not all homes need all that work done, but just as a worst-case scenario these renovations were added to the list of possible and conceivable costs.

7.2 Buying used homes

To compare prices of available houses for sale, a statistical site (ARA) was used, where you can input the kind and size of house and location in Finland; which will give you a listing of houses sold in the past year for measure, for your selected location.

7.2.1 Input

Four or more rooms, 100-170 m^2, single family house and for locations Porvoo, Lahti and Pornainen (in the case of Pornainen there were only 4 houses sold, so nearby areas Askola and Mäntsälä were added to the price comparisons), were selected.

7.2.2 Output

Conditions listed are; 'Good', 'Satisfactory' and 'Poor'. Not all houses have the energy rating classification, so the homes with conditions "Satisfactory" and "Good" listings were separated, and then the ones with an energy rating classification and those that did not have one, to get to the average costs per location.
Output shows the Location, Energy rating classification, Condition, Total cost, Cost per square meters, Year built and Square meters.

7.2.3 Results

Out of all results in the selected areas, a chart was made to show the cost for buildings at different efficiency levels based on the energy certificate classification values. The listings without any energy certificate classes, or even conditions, were not considered. Doing so could alter the comparison without knowing the home's actual condition. Appendix – IX – shows all the houses sold categorized by their listed energy certificate values in the selected locations.

Average cost for "ALL", taking all listings into consideration, was 230,500 €. The average cost per square meter was 1830 €/m^2. This is looking at all areas included in the comparison, combining both "Good" with "Satisfactory" conditions. The lowest price house sold for 94,000 €, the highest price was 335,000 € in the selected areas.
In figure 13 the energy certificate classifications were separated into "A-C" and "D-G", the average purchase cost for "A-C" was 285,000 € and the average for "D-G" was 214,000 €.
See the chart below.

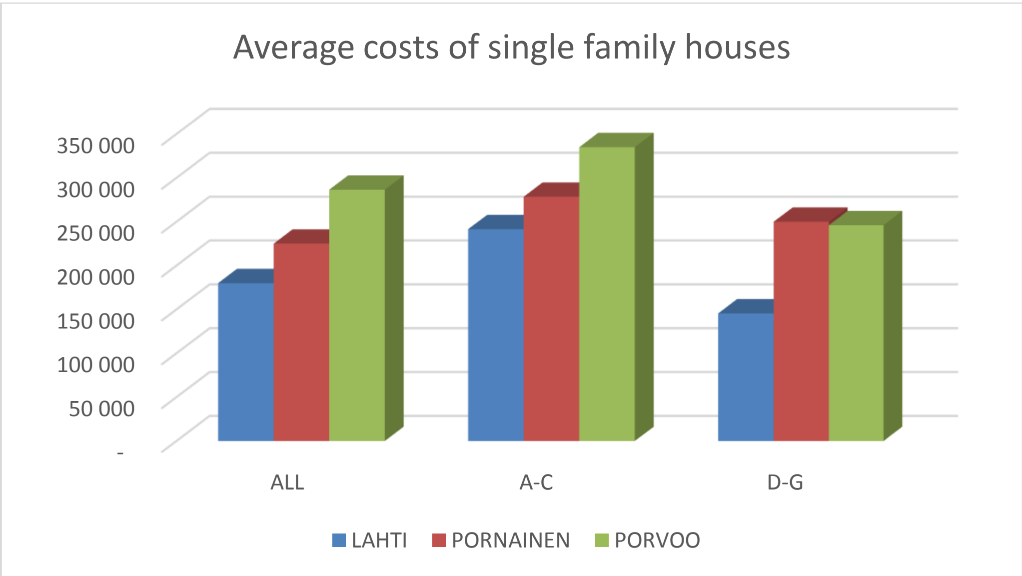


Figure 15. House costs per area for "ALL", and energy certificate classes "A through C" and "D through G"(amounts in Euros)

7.3 Renovation costs on existing building

The other important information is the cost comparisons and profitability between renovations on existing buildings and building new. The renovation costs were estimated using the cost calculators (Suomi Rakentaa), rounding to the nearest 500.

The most important and probably relevant items were added to the list of things to renovate including: roof, domestic water lines, changing the heating system to a more energy efficient one, and adding mechanical ventilation. All renovations were including demolition where needed.

Tables 13 and 14 below shows the renovation and purchase costs of the houses. See the renovations itemized in Appendices – VI – and – VII –.

Two purchase cost averages were made based on the used home prices;

- one by same locations as the comparison homes and only ones without energy ratings and built before the year 1990,
- and the other using all listings average of 230,500 € from Appendix – IX –.

Table 13. Comparison of costs for houses 1 and 2, Renovation+Purchase by location

Amounts in Euros €	**Renovation Cost**	**Renovation Cost / m²**	**Cost of Purchase[1]**	**TOTAL**
House one	82,500	625	114,500	197,000
House two	91,000	616	170,500	261,500

[1] Purchase cost based on average cost for houses without energy certificate class values and older than built 1990 in Lahti and Pornainen.

Table 14. Comparison of costs for houses 1 and 2, Renovation+Purchase all listings average

used in final comparison	**Renovation Cost**	**Renovation Cost / m²**	**Cost of Purchase[2]**	**TOTAL**
House one	82,500	625	230,500	313,000
House two	91,000	616	230,500	321,500

[2] Purchase cost based on average of all listings in all three locations as listed in Appendix – IX –

7.4 Building new home

Using the same site (Suomi Rakentaa) to calculate and approximate cost of house building; list of 20 items included in the build. Continuing with the same three-star quality for the labor and materials as with the renovations cost estimates. In the example, as seen in Appendix – VIII – the cost estimate itemizes all of the 20 items, by labor and material cost. Because an improvement in energy efficiency was important, with the new builds as well as renovations, listed the cost of geothermal in the 5-star version which is a 3 per cent increase to the cost. In general, materials are about 60 percent and labor 40 percent of the total cost.

The cost per square meter for a 3-star build is 2053 €/m^2 and with the geothermal added for heating, the cost is 2113 €/m^2. (updated costs May 2019)

7.4.1 Building lot costs

The fourth quarter of 2018 showed that the prices fell 1.6 percent overall in the whole country, the Helsinki metropolitan area saw 5.5 percent reductions in cost (Statistics Finland lots). Table 14 below shows the whole countries averages by location. For the comparison we will use Southern Finland as the area with median cost of 48 €/m^2.

Table 15. Statistical averages on building lot costs in Finland, 4th quarter 2018

Lot Areas	Median price €/m²	Qty sold
The whole country	26	835
Helsinki Metropolitan area	187	96
Rest of Finland	16	739
Surrounding municipalities[1]	54	73
Areas with: <20000 residents	10	344
20000-100000 residents	23	294
>100000 residents	83	197
Southern Finland	48	387
Western Finland	16	250
Northern Finland	12	126
Eastern Finland	5	72

[1] Hyvinkää, Järvenpää, Kerava, Kirkkonummi, Nurmijärvi, Riihimäki, Sipoo, Tuusula and Vihti

7.4.2 Overall costs

Used the new home build costs with geothermal heating added, from Appendix – VIII –, to come up with the below totals for the build. Then the cost of the lot was added which varied a lot in Finland, chose the area of Southern Finland for the comparison. See below for table 15 using the southern Finland average for building lot prices.

Table 16. New home build with lot total costs (amounts in Euros)

Size	Cost new build[1]	Cost/m2	Lot Cost[2] (S. Finland)	Total
House 128 m^2	270,500	2113	96,000	**366,500**
House 148 m^2	312,500	2113	96,000	**408,500**

[1] New build cost based on Suomi Rakentaa calculators, see Appendix - VIII -, excluding lot purchase price.
[2] Lot cost 48 €/m^2 in Southern Finland, size of lots used in comparison; 2000 m^2

Note: If the actual values from table 14, on page 39, are used the costs would be different. For example; Pornainen, with less than 20,000 residents, new build cost could be as low as 332,500 € and the house in Lahti, with more than 100,000 residents, could be as high as 436,500 €.

7.4.3 Possible savings

Below is a quick calculation of the possible monetary savings for each of the houses when comparing renovations costs to new construction builds. Scenario one uses the average costs from all of the listings and scenario two uses ones from Lahti and Pornainen which do not have energy certificate ratings and are built before 1990.

Table 17. Comparing scenarios for possible savings

Scenario 1 (safe)	House one	House two	Scenario 2	House one	House two
Renovation	313,000	321,500	Renovation	197,000	261,500
new construc-tion	366,500	408,500	new construc-tion	366,500	408,500
Savings %	-15%	-21%	Savings %	-46%	-36%
Average %	-18%		Average %	-41%	
Savings €	- 53,500	- 87,000	Savings €	- 169,500	- 147,000
Average €	-70,250		Average €	-158,250	

8 CONCLUSION AND DISCUSSION

The cold hard data clearly points to the fact that it is possible to cost-effectively purchase and renovate an existing older home compared to having a new home built on a purchased lot. In fact, the research indicates that savings of 15 to 21 percent are possible when comparing the costs of renovating versus building a similarly sized home. Between the two home renovations, savings averaged over 70,000 € compared to building new.
With future legislation on carbon footprint limits on new construction, it might be even more beneficial to renovate an existing building.

While the data is conclusive, there are several other mitigating factors that should be considered before deciding whether or not undertaking a renovation project is the correct choice. For example, not all older existing houses were built with the same level of craftsmanship nor were they all maintained equally. Obviously, they are, therefore, not all in the same condition and some will require much more work than others. Also, not all renovation work is equal, both in terms of cost and complexity. The time required for some renovations is yet another factor to consider.

Clearly then, the successful and cost-effective renovation project begins with an intelligent and informed decision on which house to purchase in the first place. Once the determining factors such as location, size, budget, etcetera are applied to the entire stock of available existing older homes, a like for like comparison can be made. This will narrow down the prospective candidates. A safe assumption would be that all renovation projects to existing older homes will require upgrading their insulation, heating, and ventilation to current standards. It is then reasonable to assume that the same renovation requirements to similarly priced and sized homes will result in similar costs. Thus, a like for like comparison is again possible.
It is at this point that a prospective buyer/ renovator may benefit from some professional counsel. If, for example, one prospective home requires expensive repair to its existing foundation (or other structural elements) and another home in the same price range does not, it is clear which one would be a more sound financial investment. Discovering such hidden damages as well as accurately assessing the costs of correcting them often requires a trained eye.

Other factors that should be considered to determine overall cost effectiveness when comparing which prospective existing older home to renovate, include how the home sits on the land and its overall visual appeal. For example, if one requires more effort than another, but it has a more desirable exposure or beautiful scenic view and will ultimately result in a home that is more enjoyable to live in, then any added cost will have to be considered in such a context. These types of valuations are purely subjective and impossible to represent with the data.

It could further be argued that any value in the process of renovating an existing older home is, in itself, subjective. After all, regardless of the amount of care taken in the planning stage, execution of such projects will undoubtedly involve unforeseen challenges. A smart and prepared renovator will have allowed for such contingencies in their budget, but the added stress and frustration resulting from such situations could affect their opinion of if the project is "worth it" or not.

Finding solutions to the inevitable problems that surface during any renovation project may be enjoyable by one person, while those same problems may cause another person sleepless nights.

It could be viewed as a way to up-cycle an existing building, minimizing the use of natural resources and reduce the number of vacant and decaying buildings in Finland. While another person may simply enjoy the styling of existing older homes. To these people any cost savings of renovating versus building are irrelevant as the act of renovating itself has value.

The opposite is also true. A person who desires a sleek modern home and considers existing older homes to be ugly and the thought of living in one to be offensive, they likely have a different opinion on the value of renovating versus building new.

They would consider the advantages of building a home, such as starting from scratch with no nasty surprises or need to update more valuable than the cost savings of renovating.

This thesis set out to discover whether it is better and more cost effective to renovate an existing older home to modern standards or purchase a lot and build a new home. The research and data prove it is possible to cost effectively renovate an existing older home versus building a new one. The question of which one is better depends on the individual.

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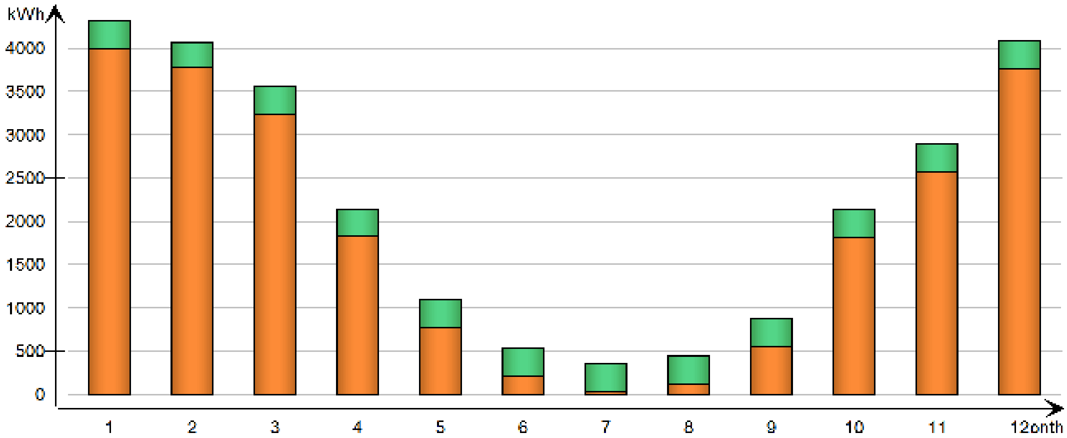
APPENDIX – I – HOUSE ONE 1954 - BEFORE AND AFTER

Used energy

kWh (sensible and latent)

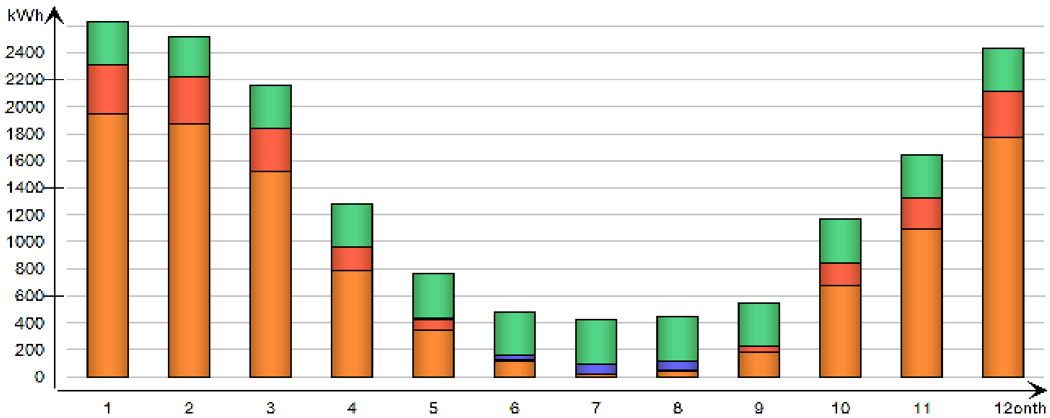
Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
1	4000.0	0.0	0.0	0.0	324.4
2	3780.0	0.0	0.0	0.0	293.0
3	3243.0	0.0	0.0	0.0	324.4
4	1826.0	0.0	0.0	0.0	314.0
5	774.1	0.0	0.0	0.0	324.4
6	219.1	0.0	0.0	0.0	314.0
7	25.1	0.0	0.0	0.0	324.4
8	124.3	0.0	0.0	0.0	324.4
9	556.7	0.0	0.0	0.0	314.0
10	1808.0	0.0	0.0	0.0	324.4
11	2579.0	0.0	0.0	0.0	314.0
12	3759.0	0.0	0.0	0.0	324.4
Total	22694.3	0.0	0.0	0.0	3819.8



Used energy

kWh (sensible and latent)

Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
1	1948.0	0.0	359.1	0.0	324.4
2	1873.0	0.0	351.9	0.0	293.0
3	1516.0	0.0	318.7	0.0	324.4
4	786.1	0.0	177.7	0.0	314.0
5	350.3	0.0	70.0	17.5	324.4
6	114.9	0.0	12.2	41.0	314.0
7	13.6	0.0	0.6	81.6	324.4
8	39.1	0.0	6.5	72.7	324.4
9	181.4	0.0	43.5	4.3	314.0
10	678.6	0.0	165.9	0.0	324.4
11	1092.0	0.0	229.1	0.0	314.0
12	1774.0	0.0	337.2	0.0	324.4
Total	10367.0	0.0	2072.5	217.2	3819.8

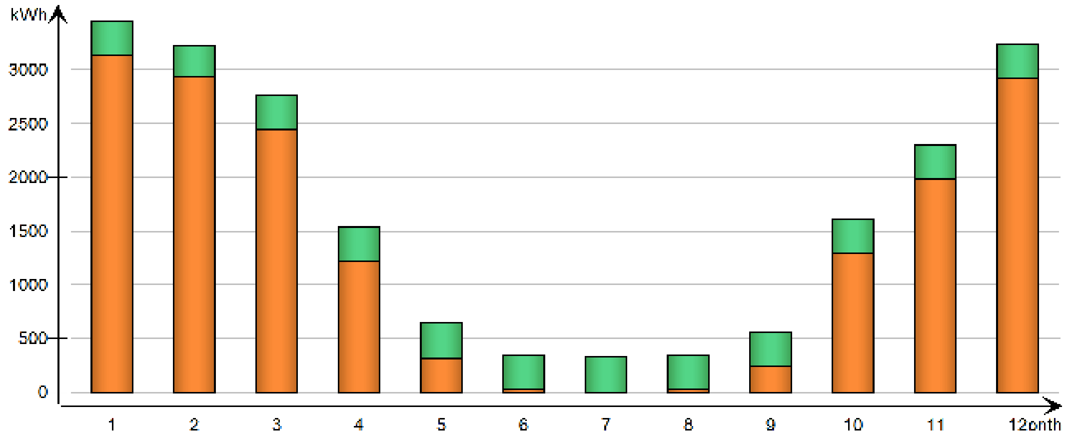


APPENDIX – II – HOUSE TWO 1980 - BEFORE AND AFTER

Used energy

kWh (sensible and latent)

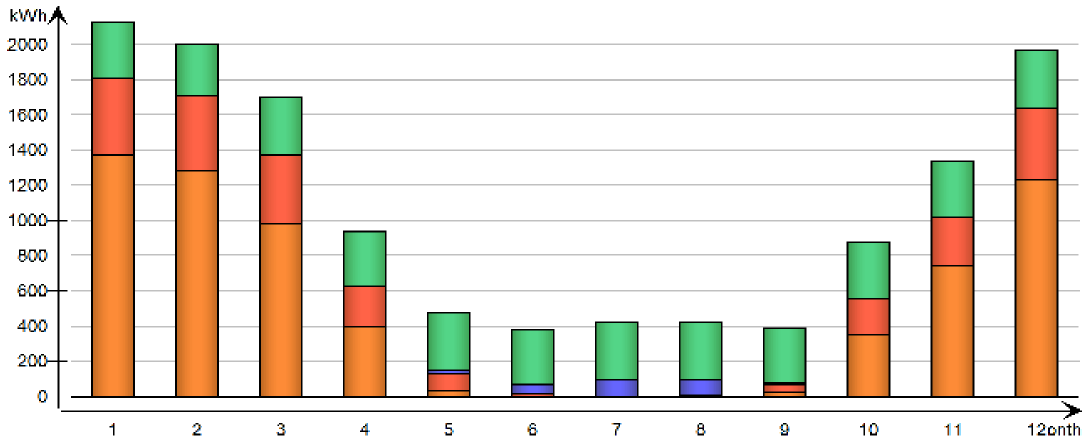
Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
1	3134.0	0.0	0.0	0.0	324.4
2	2936.0	0.0	0.0	0.0	293.0
3	2438.0	0.0	0.0	0.0	324.4
4	1227.0	0.0	0.0	0.0	314.0
5	311.7	0.0	0.0	0.0	324.4
6	27.2	0.0	0.0	0.0	314.0
7	0.0	0.0	0.0	0.0	324.4
8	20.4	0.0	0.0	0.0	324.4
9	242.8	0.0	0.0	0.0	314.0
10	1286.0	0.0	0.0	0.0	324.4
11	1982.0	0.0	0.0	0.0	314.0
12	2917.0	0.0	0.0	0.0	324.4
Total	16522.1	0.0	0.0	0.0	3819.8



Used energy

kWh (sensible and latent)

Month	Zone heating	Zone cooling	AHU heating	AHU cooling	Dom. hot water
1	1369.0	0.0	435.3	0.0	324.4
2	1283.0	0.0	426.9	0.0	293.0
3	981.3	0.0	390.5	0.0	324.4
4	397.3	0.0	229.0	0.0	314.0
5	35.4	0.0	95.2	21.2	324.4
6	0.0	0.0	16.1	49.9	314.0
7	-0.0	0.0	0.3	99.0	324.4
8	-0.0	0.0	6.0	88.2	324.4
9	20.6	0.0	51.5	5.2	314.0
10	347.9	0.0	205.2	0.0	324.4
11	743.3	0.0	277.5	0.0	314.0
12	1229.0	0.0	408.3	0.0	324.4
Total	6406.8	0.0	2541.8	263.5	3819.8



APPENDIX – III – HOUSE TWO 1954 – DELIVERED ENERGY

EQUA SIMULATION TECHNOLOGY GROUP		Delivered Energy Report	
Project		**Building**	
		Model floor area	128.2 m²
Customer		Model volume	280.2 m³
Created by	Mikaela Kallionalusta	Model ground area	44.9 m²
Location	Helsinki-Vantaa_029740 (ASHRAE 2013)	Model envelope area	262.7 m²
Climate file	FIN_HELSINKI-VANTAA_029740(IW2)	Window/Envelope	5.7 %
Case	1954 house vs 2 NEW AHU	Average U-value	0.3491 W/(m² K)
Simulated	29/04/2019 14:15:25	Envelope area per Volume	0.9374 m²/m³

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	25 %
Percentage of hours when operative temperature is above 27°C in average zone	13 %
Percentage of total occupant hours with thermal dissatisfaction	21 %

Delivered Energy Overview

		Purchased energy		Peak demand
		kWh	kWh/m²	kW
	Lighting, facility	1364	10.6	0.37
	Electric cooling	72	0.6	0.35
	HVAC aux	611	4.8	0.07
	Electric heating	16260	126.8	7.82
	Total, Facility electric	18307	142.8	
	Total	18307	142.8	
	Equipment, tenant	3735	29.1	0.56
	Total, Tenant electric	3735	29.1	
	Grand total	22042	172.0	

Month	Facility electric				Tenant electric
	Lighting, facility (kWh)	Electric cooling (kWh)	HVAC aux (kWh)	Electric heating (kWh)	Equipment, tenant (kWh)
1	115.8	0.0	51.5	2632.0	313.5
2	104.5	0.0	46.5	2518.0	286.6
3	115.8	0.0	51.6	2159.0	322.5
4	112.2	0.0	50.0	1278.0	304.6
5	115.9	5.8	52.0	744.8	313.5
6	112.2	13.7	50.6	441.0	313.5
7	116.0	27.2	52.6	338.7	313.5
8	116.0	24.2	52.5	370.0	318.0
9	112.1	1.4	50.4	538.9	309.0
10	115.9	0.0	51.8	1169.0	313.5
11	111.9	0.0	50.0	1635.0	309.0
12	115.8	0.0	51.5	2436.0	318.0
Total	1364.1	72.4	611.2	16260.4	3735.2

Post renovation values

APPENDIX – IV – HOUSE TWO 1980 – DELIVERED ENERGY

EQUA SIMULATION TECHNOLOGY GROUP		Delivered Energy Report	
Project		**Building**	
		Model floor area	224.6 m²
Customer		Model volume	463.6 m³
Created by	Mikaela Kallionalusta	Model ground area	169.1 m²
Location	Helsinki-Vantaa_029740 (ASHRAE 2013)	Model envelope area	523.3 m²
Climate file	FIN_HELSINKI-VANTAA_029740(IW2)	Window/Envelope	3.5 %
Case	1980 house vs 2 w AHU	Average U-value	0.2378 W/(m² K)
Simulated	29/04/2019 13:47:29	Envelope area per Volume	1.129 m²/m³

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	19 %
Percentage of hours when operative temperature is above 27°C in average zone	13 %
Percentage of total occupant hours with thermal dissatisfaction	14 %

Delivered Energy Overview

	Purchased energy		Peak demand
	kWh	kWh/m²	kW
Lighting, facility	1312	5.8	0.36
Electric cooling	88	0.4	0.43
HVAC aux	741	3.3	0.09
Electric heating	12769	56.9	5.78
Total, Facility electric	14910	66.4	
Total	14910	66.4	
Equipment, tenant	5433	24.2	0.81
Total, Tenant electric	5433	24.2	
Grand total	20343	90.6	

Month	Facility electric				Tenant electric
	Lighting, facility (kWh)	Electric cooling (kWh)	HVAC aux (kWh)	Electric heating (kWh)	Equipment, tenant (kWh)
1	111.4	0.0	62.5	2129.0	456.1
2	100.6	0.0	56.4	2003.0	416.8
3	111.6	0.0	62.5	1696.0	468.7
4	107.9	0.0	60.7	940.2	443.1
5	111.6	7.1	63.0	455.0	456.3
6	107.8	16.6	61.4	330.1	455.8
7	111.6	33.0	63.8	324.7	456.3
8	111.7	29.4	63.6	330.5	462.6
9	108.0	1.7	61.1	386.1	449.5
10	111.4	0.0	62.9	877.6	456.2
11	107.4	0.0	60.7	1335.0	449.4
12	111.1	0.0	62.5	1962.0	462.3
Total	1312.1	87.8	741.1	12769.2	5433.1

NOTE: Model floor area is counting attic space as well, real is 148m², see energy readings for actual kWh/m² **Post renovation values**

APPENDIX – V – HOUSE THREE 2013 – DELIVERED ENERGY

Customer		Model volume	444.7 m^3
Created by	Mikaela Kallionalusta	Model ground area	87.9 m^2
Location	Helsinki (Ref 2012)	Model envelope area	374.8 m^2
Climate file	HKi-Vantaa_Ref_2012	Window/Envelope	6.2 %
Case	2013 house vs 3	Average U-value	0.2484 W/(m^2 K)
Simulated	12/02/2019 20:51:26	Envelope area per Volume	0.8427 m^2/m^3

Building Comfort Reference

Percentage of hours when operative temperature is above 27°C in worst zone	4 %
Percentage of hours when operative temperature is above 27°C in average zone	1 %
Percentage of total occupant hours with thermal dissatisfaction	7 %

Delivered Energy Overview

	Purchased energy		Peak demand	Primary energy	
	kWh	kWh/m^2	kW	kWh	kWh/m^2
Valaistus, kiinteistö	1107	6.8	0.13	1882	11.6
Jäähdytys	95	0.6	0.53	162	1.0
LVI sähkö	1545	9.6	0.18	2626	16.2
Sähkölämmitys, kiinteistö	11374	70.3	5.13	19336	119.5
LKV, sähkölämmitys	3820	23.6	0.44	6494	40.1
Total, Facility electric	17941	110.9		30500	188.6
Total	17941	110.9		30500	188.6
Laitteet, asukas	2491	15.4	0.28	4235	26.2
Total, Tenant electric	2491	15.4		4235	26.2
Grand total	20432	126.3		34735	214.7

Month	Facility electric										Tenant electric	
	Valaistus, kiinteistö		Jäähdytys		LVI sähkö		Sähkölämmitys, kiinteistö		LKV, sähkölämmitys		Laitteet, asukas	
	(kWh)	Prim. (kWh)	(kWh)	Prim. (kWh)	(kWh)	Prim. (kWh)	(kWh)	Prim. (kWh)	(kWh)	Prim. (kWh)	(kWh)	Prim. (kWh)
1	94.0	159.9	0.0	0.0	130.6	222.0	2207.0	3751.9	324.4	551.5	211.6	359.7
2	84.9	144.4	0.0	0.0	117.9	200.4	1938.0	3294.6	293.0	498.1	191.1	324.9
3	94.0	159.9	0.0	0.0	130.6	222.0	1732.0	2944.4	324.4	551.5	211.6	359.7
4	91.0	154.7	0.3	0.6	126.8	215.6	777.2	1321.2	314.0	533.8	204.7	348.0
5	94.0	159.9	5.1	8.6	131.4	223.4	112.5	191.3	324.4	551.5	211.6	359.7
6	91.0	154.7	12.9	21.9	127.5	216.8	22.1	37.5	314.0	533.8	204.7	348.0
7	94.0	159.9	37.8	64.2	132.2	224.7	0.1	0.2	324.4	551.5	211.6	359.7
8	94.0	159.9	38.1	64.8	132.1	224.6	2.2	3.8	324.4	551.5	211.6	359.7
9	91.0	154.7	1.0	1.7	127.1	216.1	155.2	263.8	314.0	533.8	204.7	348.0
10	94.0	159.9	0.0	0.0	131.1	222.9	869.9	1478.8	324.4	551.5	211.6	359.7
11	91.0	154.7	0.0	0.0	126.6	215.2	1570.0	2669.0	314.0	533.8	204.7	348.0
12	94.0	159.9	0.0	0.0	130.7	222.2	1988.0	3379.6	324.4	551.5	211.6	359.7
Total	1107.1	1882.1	95.2	161.8	1544.6	2625.8	11374.2	19336.1	3819.8	6493.7	2491.1	4234.9

For comparison, this house is using the IDA ICE default settings of 'FIND32013 -Detached home'.

APPENDIX – VI – COST OF RENOVATIONS (1954 HOUSE)

[1] Window replacement with demolition costs	7 133	
[2] Exterior door replacement with demolition costs	1 936	
[3] Roof replacement with demolition costs	10 919	
[4] Exterior wall renovation with demolition costs	16 017	
[5] Ventilation with heat exchanger addition	9 631	
[6] Geothermal heating with radiator demolition	24 404	
[6*] Air-water heat pump with radiator demolition		12 492
[7] Renew domestic water lines, sewer and demolition	12 512	
Total cost of renovations including major items	**82 552**	***70 640**

Approximate cost of renovations per square meter is 625 €

Renovation cost inclusion explained below:

[1] includes demolition of 12 windows and installation of 5 small and 7 medium windows.

[2] includes demolition of 2 exterior doors, and installation of 2 exterior doors

[3] Demolition of old sheet metal roof. Area of roof used 70 m^2, includes the following; underlay and ventilation lath, Classic standing seam sheet metal roofing, all required fire ladders and roof bridge, fascia boards including gutters and downspouts, sheet metal around chimney and 300 mm of insulation added.

[4] replacing all exterior paneling, area equaling 155 m^2, adding 100 mm insulation and framing, 12mm wind board, and finally new wood paneling.

[5] Cost includes demolition and the addition of ventilation unit with heat exchanger, 10 percent is added to the cost for possible planning, permits and other costs.

[6] Demolition of old radiators and addition of the complete heating system including pump, distribution and drilling. 10 percent is added to the cost for possible planning, permits and other costs.

*if air-water heat pump used instead of geothermal, saving a total of 11 912 of total renovation cost.

[7] Demolition of the domestic water lines and sewer, installation of new water lines and sewer pipes. 25 percent of the total cost is for possible planning, permits and other costs incurred by renovator.

APPENDIX – VII – COST OF RENOVATIONS (1980 HOUSE)

[1] Window replacement with demolition costs	7 007	
[2] Exterior door replacement with demolition costs	1 936	
[3] Roof replacement with demolition costs	28 448	
[4] Exterior wall renovation with demolition costs	5 167	
[5] Ventilation with heat exchanger addition	9 631	
[6] Geothermal heating with oil tank demolition	26 442	
[6*] Air-water heat pump with oil tank demolition		14 530
[7] Renew domestic water lines, sewer and demolition	12 512	
Total cost of renovations including major items	**91 143**	*** 79 231**

Approximate cost of renovations per square meter is 616 €

Renovation cost inclusion explained below:

[1] includes demolition of 10 windows and installation of 8 medium and 2 large windows

[2] includes demolition of 2 exterior doors, and installation of 2 exterior doors

[3] Area of roof used 200 m^2, includes the following; underlay and ventilation lath, Classic standing seam sheet metal roofing, all required fire ladders and roof bridge, fascia boards including gutters and downspouts, sheet metal around chimney and 300 mm of insulation added.

[4] Replacing all exterior paneling (which is located between windows and the triangles above the brick to the roof), area equaling approximately 50 m^2, adding 100 mm insulation and framing, 12mm wind board, and finally new wood paneling.

[5] Cost includes demolition and the addition of ventilation unit with heat exchanger, 10 percent is added to the cost for possible planning, permits and other costs.

[6] Demolition of old oil burner and tank, installation of the complete heating system including pump, distribution and drilling. 10 percent is added to the cost for possible planning, permits and other costs.
*if air-water heat pump used instead of geothermal, saving a total of 11 912 of total renovation cost.

[7] Demolition of the old domestic water and sewer lines, installation of new water lines and sewer lines. 25 percent of the total cost is for possible planning, permits and other costs incurred by renovator.

APPENDIX – VIII – COST OF BUILDING NEW

Using a star quality of 3/5 (same as with renovating)

m^2	€	€/m^2	Heating Geothermal	€/m^2
128	262,733	2053	270,421	2113
148	303,785		312,674	
168	344,837		354,927	

		Materials	Labor	**Total**
1	Construction	11,187	3,891	15,078
2	Planning	-	12,314	12,314
3	Labor management and site purchases	10,214	11,802	22,016
4	Ground and yard construction	14,515	9,664	24,179
5	Foundation (and Base)	11,981	6,016	17,997
6	Exterior and facade	17,920	10,816	28,736
7	Intermediate and top floor structures	10,432	5,210	15,642
8	Roof	6,720	4,634	11,354
9	Exterior doors and windows	10,150	1,702	11,852
10	Interior walls and ceilings	4,723	7,002	11,725
11	Fire place and chimney	4,531	2,982	7,513
12	Interior walls and ceilings	3,968	5,005	8,973
13	Floors	4,864	2,880	7,744
14	fixtures	10,739	2,944	13,683
15	Inner doors, stairs & trim	4,339	2,368	6,707
16	Appliances	4,941	333	5,274
17	Heating (3-star)	7,539	5,274	12,813
18	Plumbing	4,877	5,018	9,895
19	Ventilation	5,414	1,728	7,142
20	Electrical, television, information technology	7,334	4,762	12,096
		156,388	**106,345**	**262,733**
		60%	40%	

Example, building a new 128 m^2 house –

3-star heating includes one of the following:
Woodburning, Oil, air-water heat pump or reserve electric heating.

5-star heating would include: Geothermal instead of the above and adds approximately 3% to the cost

Costs updated May 2019

APPENDIX – IX – USED HOME PRICE COMPARISON

Average cost	E Values	AVG cost 'A'	Avg cost 'B'	Avg cost 'C'	Avg cost 'D'	Avg cost 'E'	F or G	No E value	cost/m²	Years built	Count	Avg m²
Lahti	GOOD with E-value	272,000							2065	2011-2013	2	131
			263,000						2064	1981-2018	8	128
				189,000					1546	1978-1997	2	123
					183,000				1462	1960-1999	5	125
						212,500			1663	1982-2004	4	128
							122,000		1080	1954	1	113
	GOOD without E-value							160,000	1310	1946-1989	20	123
								249,500	1877	1990-2016	14	133
	SATISFACTORY				156,500				1251	1971-1986	4	124
						94,000			783	1975	1	120
							105,000		847	1961	1	124
								123,000	1022	1920-1987	15	121
	POOR							60,000	536	1972	1	112
180,000				241,333			145,500	148,125	1431		78	125
Pornainen/ Askola/ Mäntsälä	GOOD with E-value	316,000							2821	2013	1	112
			241,500						2212	1995-2013	3	109
					253,000				2181	1992-2012	4	117
						247,000			1848	1991-2007	3	133
	GOOD without E-value							210,500	1629	1920-1987	7	132
								227,500	1768	1992-2013	8	129
	SATISFACTORY							135,250	1239	1981-1984	2	124
	NONE							165,000	1222	1984	1	135
225,000				278,750			250,000	184,563	1827		29	125
Porvoo	GOOD with E-value		335,000						2561	2010	1	131
					275,000				2262	1976-2005	3	122
						283,500			2052	1957-2002	3	139
	GOOD without E-value							284,500	2217	1913-1989	11	133
								321,500	2361	1990-2017	10	140
	SATISFACTORY					180,000			1304	1969	1	138
								282,500	2394	1962-1986	5	119
	NONE							182,500	1772	1973-1979	2	103
286,500				335,000			246,167	267,750	2231		36	128

See 6.2.3 for the averages chart figure 13 on page 37

Average of all listings based on the locations from the left-hand column 230,500 €