Gina Ringnes

Marinevold Hageby Energy Efficiency Renovation

Analysis-based Recommendations to Reach EU's Energy Goals by 2035

Master's thesis in Sustainable Architecture
Supervisor: Pasi Aalto
Co-supervisor: Beatrice Stolz
June 2024

Master's thesis

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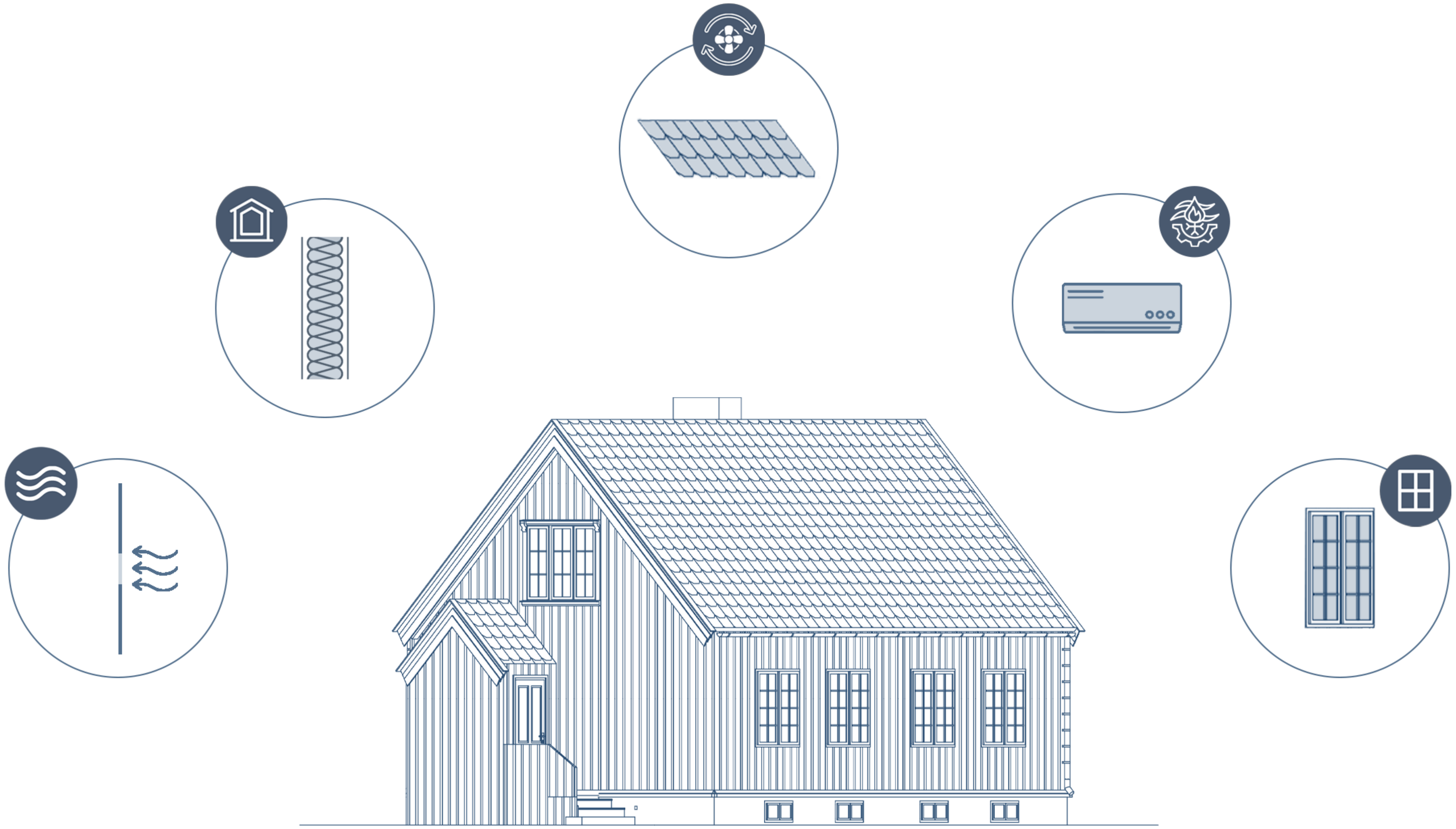
MARINEVOLD HAGEBY ENERGY EFFICIENCY RENOVATION

ANALYSIS-BASED RECOMMENDATIONS TO REACH EU'S ENERGY GOALS BY 2035



Master's thesis in Sustainable Architecture
Student: Gina Ringnes
Supervisor: Pasi Aalto
Co-supervisor: Beatrice Stolz

Norwegian University of Science and Technology
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June 2024

ABSTRACT

This thesis aims to enhance the energy efficiency of residential buildings in Marinevold Hageby, Trondheim, Norway. Improving the energy performance of buildings is essential for reaching the EU's energy efficiency goals, which will result in lower energy bills and lower greenhouse gas emissions. The main research question explores the most effective renovation measures for improving energy efficiency in these houses and how these can be integrated into a development plan for the houses aiming at achieving the EU's energy efficiency goals by 2035. The methodologies employed include SIMIEN energy programming, thermal imaging, Building Information Modeling (BIM), and site analysis to assess local climate conditions, building regulations, and historical context. The study also reviews existing literature and reference projects to identify the best practices in energy-efficient building renovations.

The research findings indicate that renovation measures including adding insulation, air tightening, and adding renewable energy sources like solar panels are good strategies to reduce the energy use of the buildings in Marinevold Hageby. However, the measures need to be done in a way that preserves the historical value of the house. The simulations show that doing these measures will reduce the energy use of the house by 63,35% from 2024 to 2035. Further, the executed measures will update the energy grade from a yellow F to a yellow B. Despite challenges like high retrofit costs and the need to preserve historical building features, the research underscores the importance of targeted renovations and community energy initiatives. The thesis concludes that these measures not only reduce energy bills and greenhouse gas emissions but also enhance indoor environmental quality. Future research should expand simulations to additional houses and explore community energy solutions. Additionally, the recommended measures are presented with the simulation results, and in a user-friendly pamphlet format serving as a practical guide for the homeowners.

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01 INTRODUCTION

INTRODUCTION

Renovating buildings to be more energy efficient is important for reducing both environmental impact and energy costs (Walnum et al, 2021). This thesis focuses on Marinevold Hageby, a residential area in Trondheim, Norway, where buildings were constructed between 1918 and 1920. Originally designed as temporary emergency housing, these houses have remained standing and are now a mix of privately owned and municipally rented properties (Marinevold, n.d.).

Old buildings, like those in Marinevold Hageby, can have a big potential for energy efficiency improvements. They consist of the largest portion of the building stock and are often less energy-efficient compared to modern constructions. In Norway, buildings account for 40% of the total energy consumption. Improving energy efficiency in these existing buildings is therefore an effective way to reach energy and climate targets (SINTEF, n.d.).

The European Union has set targets to reduce the average primary energy use of residential buildings by 16% by 2030 and 20-22% by 2035 (European Commission, 2023). This thesis aligns with these targets and aims to develop a plan for enhancing the energy efficiency of the houses in Marinevold Hageby by 2035. The research involves using SIMIEN energy programming, thermal imaging, and Building Information Modeling (BIM). It also includes a review of existing literature and reference projects to understand the best practices in energy-efficient building renovations. Site analysis is also conducted to assess the local climate, building regulations, and historical context.

The results will be presented in two formats: First by presenting the results of the simulations and analyses, and then with a user-friendly pamphlet for the homeowners and the community. The goal is to provide practical recommendations that not only reduce energy consumption but also ensure that the historical and cultural values of the buildings are preserved because the buildings are protected. Overall, the objective is to provide recommendations for renovation measures that will contribute to an improved future for both the homeowners and the environment.

RESEARCH QUESTION

What are the most effective renovation measures for improving energy efficiency in the residential buildings in Marinevold Hageby, and how can these be integrated into a development plan for the houses, aimed at achieving EU's energy efficiency goals by 2035?

Furthermore, how can this plan be effectively communicated to homeowners and residents through a user-friendly pamphlet format?

GOAL AND SCOPE

GOAL

The goal is to develop a plan and measures for the houses in Marinevold Hageby until 2035. The measures will be presented in 2 versions. Where one shows the simulations and analyses done to explore the best solutions, and the other as a pamphlet with simplified explanations that can be used as a user guide for the homeowners.

SCOPE

The scope of this thesis is limited to residential buildings within the Marinevold Hageby community in Trondheim, with a focus on achieving the EU's energy efficiency goals by 2035. The research aims to provide recommendations and strategies for improving energy efficiency while enhancing the quality of life for residents.

METHODS

SITE ANALYSIS

The site analysis is done to get a better understanding of the site and the area. It involves analysis of the site's climate conditions, including solar orientation and wind. As well as reviewing local regulations and history related to listing of the buildings, and the history of the area and buildings. There is also done research on previous energy markings on the houses. Understanding these factors will help identify opportunities for passive solar design and natural ventilation to minimize energy consumption for heating, cooling, and lighting.

RESEARCH AND REFERENCE PROJECTS:

The method involves reading about energy efficiency and researching the new European rules for more energy-efficient buildings. As well as researching past projects and relevant literature that provides insights for optimizing energy efficiency in Marinevold Hageby. The process involves an examination of literature, reports, and case studies showcasing successful implementations of energy efficiency measures in similar contexts. Analyzing successful initiatives and works can draw upon strategies to inform the approach of this project.

BIM (Building Information Modeling):

The Building Information Model (BIM) is a tool for visualizing and analyzing the house and representing the house's geometry, and materials. The model of one of the residential homes in Marinevold Hageby is made using the ArchiCAD software.
Information for the model is taken from the original building drawings, that were obtained through communication with Trondheim municipality. These drawings, dating back to October 1919 and crafted by Sverre Pedersen, provide foundational data for the BIM. However, it's important to note that due to their hand-drawn quality, they may lack the level of detail found in modern digital architectural drawings. Nevertheless, the BIM remains important in assessing energy-saving measures, and for collecting information for the simulation and evaluation of potential solutions aimed at reducing energy consumption.

THERMAL CAMERA:

Thermal imaging technology allows for the identification of areas within buildings where heat is being lost. Employing thermal cameras can pinpoint locations in Marinevold Hageby's buildings that require improvements in insulation or heating systems, enabling targeted energy-saving efforts.
In this study, a Fluke thermal camera was used to gather data on the condition of the houses. A sample house in Harald Hardrådes gt. 35 in Marinevold Hageby were photographed. The house is owned by a family of 4. Subsequently, the images were analyzed using the Fluke Connect software to assess the different temperatures and potential air leakage in the pictures.

SIMIEN ENERGY:

The SIMIEN Energy Program serves as a computational platform designed for comprehensive analysis of energy usage in buildings. In this study, the SIMIEN program was utilized to extract energy data from houses in Marinevold Hageby. Three analysis scenarios were conducted: one involving the original house dating back to 1919, the other reflecting the standard of a house in 2024, and the last testing measures to make the house more energy efficient by 2035. To ensure consistency, the same sample house in Marinevold Hageby was selected for the simulations, ensuring uniformity in the input information, including direction and surrounding heights. The data utilized in these simulations were collected from various sources, including research findings, Building Information Modeling, and data obtained through thermal imaging. The sample house is the same one used in the other analyses in Harald Hardrådes gt. 35. However, it's important to acknowledge certain limitations and constraints inherent in the SIMIEN analyses. Access to resources was restricted in both the 1919 and 2024 analyses. This was particularly evident in the case of the 1919 house, where the primary resource was the original plan drawings. In instances where direct information was lacking, assumptions were made based on comparable buildings from the same period. These limitations may influence the outcomes of the SIMIEN analysis and require assessment when interpreting the results.

SITE ANALYSIS

RESEARCH AND REFERENCE PROJECTS

BIM MODEL

THERMAL CAMERA

SIMIEN

METHODS

Renovating for a more energy-efficient building requires using various methods that complement each other. Each approach offers insight into different aspects of the building and its surrounding environment. As well as integrating a more complete understanding of the energy usage and potential improvements of the house.

The site analysis contributes to an understanding of the house's local environment and historical context. By analyzing climate conditions, solar orientation, and local regulations, can opportunities for renovation strategies be identified. However, site analysis can not provide complete details about the house's current energy inefficiencies.

Researching relevant literature and reference projects allows to learn from past experiences and practices. Studying similar projects and successful strategies might provide useful insights into effective energy-saving strategies. The research can give a better understanding of which renovation strategies are most suitable for Marinevold Hageby, but it may lack the specificity of the details needed for the house. Building Information Modeling provides a virtual representation of the building's geometry and materials. Creating a BIM helps to give the right input for the Simien energy analysis. However, the lack of information on the building's construction and materials can give inaccurate results. Thermal imaging helps in detecting areas of heat loss within the building. A thermal camera can be used to identify specific places that require insulation improvements or to detect air leaks. The method provides information on existing energy inefficiencies, but it does not capture the full picture of the building's energy usage by itself. Simien Energy analyses involve using simulations to analyze energy usage in buildings. Inputting data from site analysis, BIM, and thermal imaging, allows simulating different scenarios and evaluating their energy performance.

Combining these methods will help to gain a holistic understanding of the house and its energy usage. Site analysis provides the context, research informs the decisions, BIM visualizes and provides the necessary information, thermal imaging identifies existing inefficiencies, and Simien Energy validates the recommendations. The integrated approach ensures that the recommendations for a more energy-efficient house are well-informed and tailored to the specific needs of the house and its occupants in Marinevold Hageby. Not considering all these aspects, can risk missing important opportunities for energy savings and may not achieve the desired outcomes. Therefore, it is essential to utilize all these methods together to ensure the best results with the intention to create a more sustainable and energy-efficient house.

02 BACKGROUND

This chapter will present the two backgrounds for the thesis: the EU Commission directive and the Circular City project. These have determined the choices made during the work of the theses. In particular, the aim of the EU Commission has shaped the various methods and measures for energy efficiency in buildings. The background is also built on the belief that the EU Commission directive will become more relevant in society forward and the future.

EUROPEAN COMMISSION

"EACH MEMBER STATE WILL ADOPT ITS OWN NATIONAL TRAJECTORY TO REDUCE THE AVERAGE PRIMARY ENERGY USE OF RESIDENTIAL BUILDINGS BY 16% BY 2030 AND 20-22% BY 2035, ALLOWING FOR SUFFICIENT FLEXIBILITY TO TAKE INTO ACCOUNT NATIONAL CIRCUMSTANCES. MEMBER STATES ARE FREE TO CHOOSE WHICH BUILDINGS TO TARGET AND WHICH MEASURES TO TAKE."

(European Commission, 2023)

"THE NATIONAL MEASURES WILL HAVE TO ENSURE THAT AT LEAST 55% OF THE DECREASE OF THE AVERAGE PRIMARY ENERGY USE IS ACHIEVED THROUGH THE RENOVATION OF THE WORST-PERFORMING BUILDINGS."

(European Commission, 2023)

The Energy Performance of Buildings Directive (EPBD) is the European Union's main legislative instrument aimed at promoting the improvement of energy efficiency in buildings across the EU member states. The first EPBD was adopted in 2012 and required member states to strengthen building regulations and introduce energy performance certification for buildings. They also developed a set of measures to help the EU members meet its 20% energy efficiency target by 2020.
In 2018, the directive was republished, together with the amending regulation on Energy Efficiency, which updated the policy framework for 2030 and further. It proposed a binding energy efficiency target for a decrease in final energy consumption of at least 32.5% by 2030, following on from the existing 20% target for 2020 (European Commission, n.d.a).

The newest updated directive was effective from October 10, 2023, and is the background of the thesis. The newest revision to the EU Commission's political agreement on rules to boost the energy performance of buildings across the EU is to reduce the average primary energy use of residential buildings by 16% by 2030 and 20-22% by 2035.
The purpose of the directive is to increase the pace of rehabilitation of the building stock in the EU in order to reduce greenhouse gas emissions and energy consumption by 2035, as well as to make the building stock climate-neutral by 2050. The member states are free to choose which buildings to direct the measures towards and which measures to implement, but the national measures must ensure that at least 55% of the reduction of the average primary energy consumption is achieved through the renovation of the worst-performing buildings (European Commission, 2023).

CIRCULAR CITY

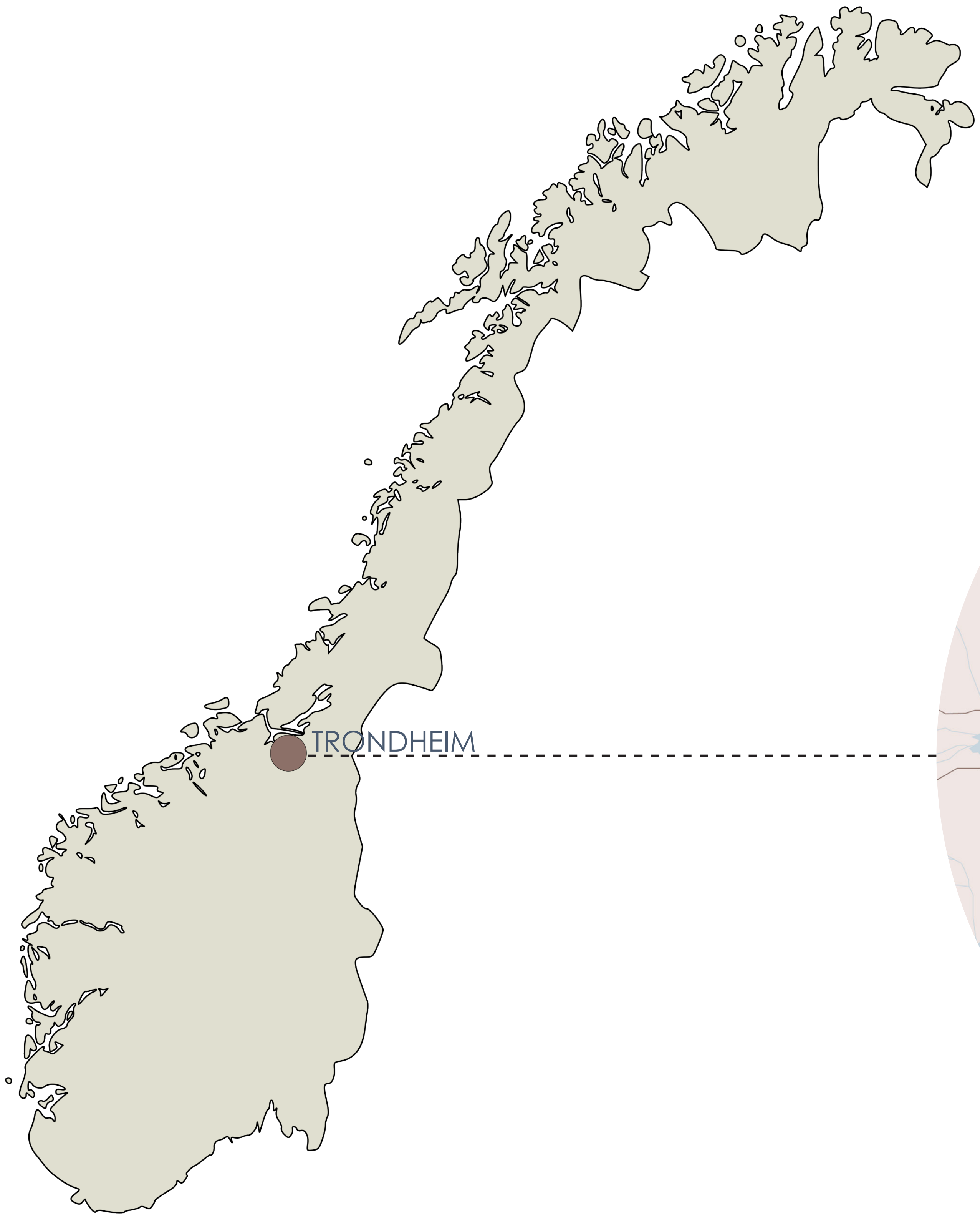
The master thesis is part of the Circular City project at NTNU with the coordinator Pasi Aalto.
The Circular City project is an interdisciplinary collaboration that focuses on understanding existing buildings in Trondheim and their potential as a resource for a future circular economy. The initiative attempts to achieve a circular, low-carbon building mass (NTNU, n.d.).

A low-carbon building is a building that has been designed, constructed, and operated to minimize its carbon footprint and greenhouse gas emissions. The buildings prioritize energy efficiency by reducing heating and cooling demands. Low-carbon buildings should also integrate renewable energy sources like solar panels and geothermal systems to generate on-site renewable energy. The materials should be low-embodied carbon materials or recycled materials (Kalaiselvam & Parameshwaran, 2013).

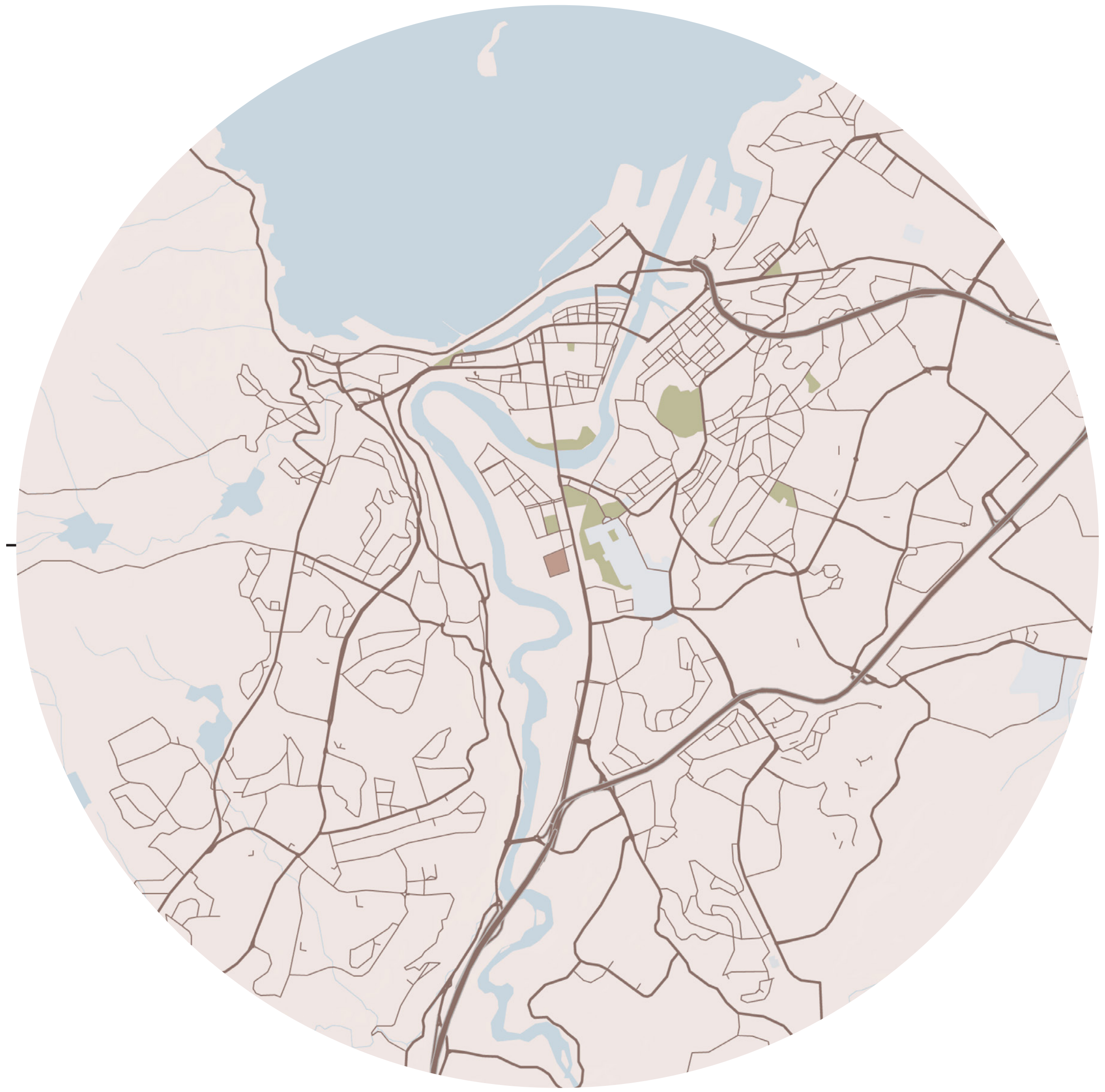
03 SITE ANALYSIS

This chapter includes an examination of the local climate and building conditions in Marinevold Hageby to assess the local climate, building regulations, and historical context. These analyses have a role in understanding the unique challenges and opportunities for energy efficiency improvements in the houses and the neighborhood.

SITE ANALYSIS TRONDHEIM



Marinevold Hageby is located in Trondheim Norway. Trondheim is a city and a municipality in Trøndelag. The city consists of 214 565 inhabitants (2024), and most of the people live close to the city center (Rosvold, 2024).



MARINEVOLD HAGEBY

Marinevold Hageby comprises 35 identical two-family houses and one four-family home. The houses are situated on the streets of Harald Hardrådes gate, Abels gate, Udbyes gate, and Magnus den Godes gate. The main road in the area is called "Midtergata", with houses on this road having addresses on either Abels gate or Magnus den Godes gate (Marinevold, n.d.).

LAND USE

The two-family houses are located in an attractive and central residential area in Øya/ Elgeseter in Trondheim. The property is within walking distance of St. Olavs Hospital, NTNU Gløshaugen campus, and Lerkendal Stadium, as well as shopping possibilities, restaurants, and services in the city center.

Public transportation in Øya includes buses, trains, and airport buses.

The property is also close to recreational areas such as green spaces, Festningen, or the Nidelva River, providing recreational opportunities year-round. Other attractions and cultural offerings include Nidaros Cathedral and Lerkendal Stadium near the residential area.

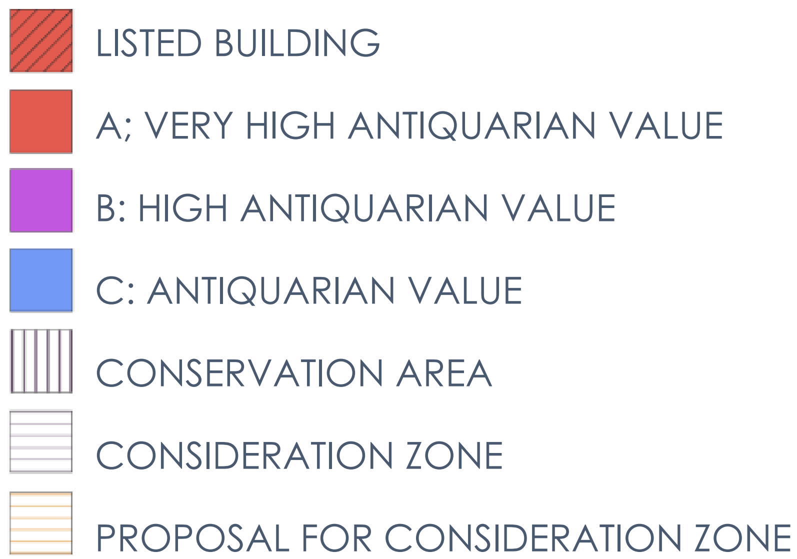
- SITE
- GLØSHAUGEN
- ST. OLAVS HOSPITAL
- GRAVEYARD
- GREEN AREAS
- LERKENDAL STADION
- FESTNINGEN
- NIDAROSDOMEN
- ROADS
- NIDELVEN

ANTIQUARIAN VALUE

Map of antiquarian value (Trondheim kommune, 2024).

The area is protected, and the houses are classified as antiquarian value class C, which means the roofs, facades, windows, doors, material use, and colors are protected. If residents want to make changes, such as adding a veranda door or building an extension, they must apply to the Building Development Office in the municipality (Trondheim kommune, 2024).

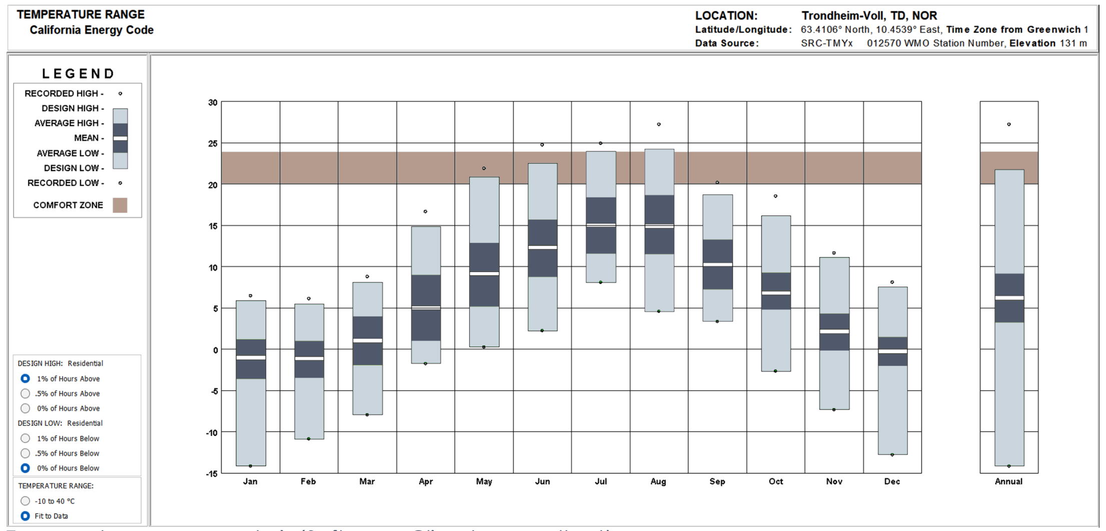
The houses in Marinevold Hageby have remained nearly identical due to this protection. When preserving a building's cultural and historical values, as in Marinevold, it's important to keep interventions as small as possible.



CLIMATE

TEMPERATURE RANGE

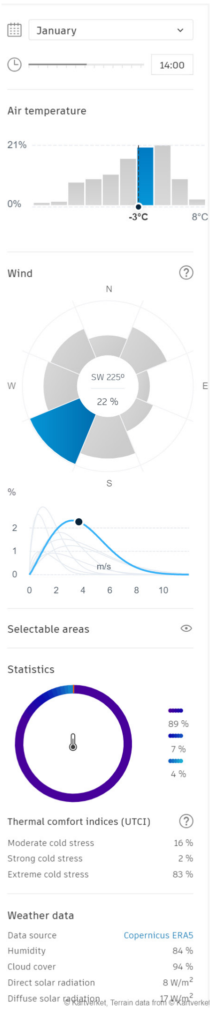
Trondheim experiences a climate characterized by mild summers and cool winters. The average annual temperature in Trondheim ranges from a mean of approximately 0°C in winter to 15°C in summer. The mean annual temperature is approximately 7°C.



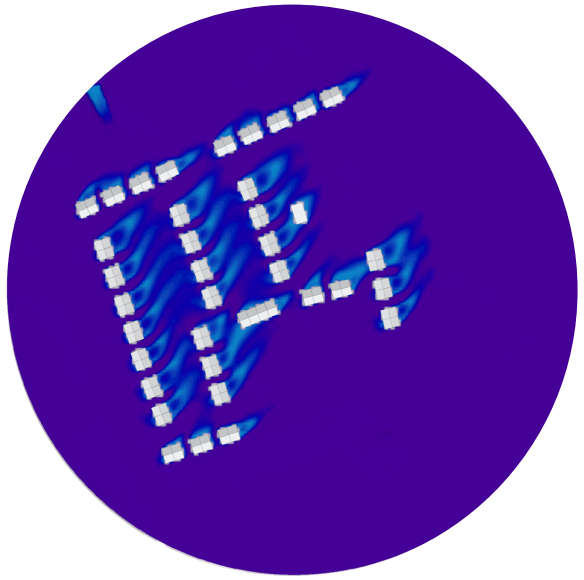
Temperature range analysis (Software: Climate consultant)

MICROCLIMATE

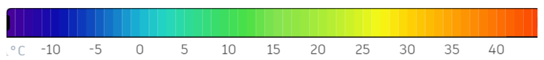
The microclimate analysis is used to assess the linkages between the outdoor environment and thermal comfort. The results is a combination between humidity, radiation, and wind.



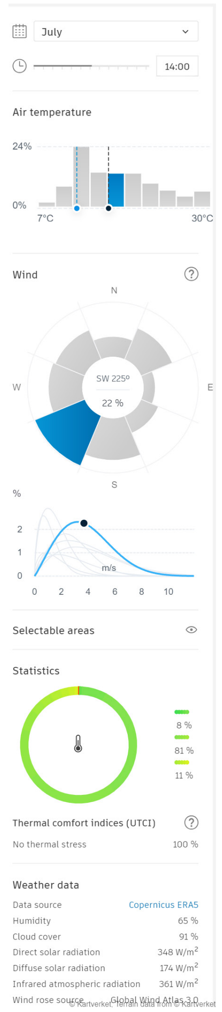
MICROCLIMATE JANUARY



Microclimate analysis (Software: Autodesk Forma)

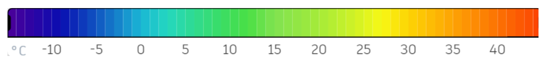


The results show that the temperature is below -10°C 89% of the month, between -10°C to -5°C 7% of the month, and -5°C to 0°C 4% of the month. These results indicate that the month could have thermal stress because of the cold temperatures, varying from moderate to extreme cold stress.



MICROCLIMATE JULY

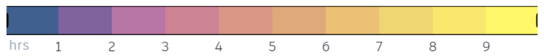
Microclimate analysis (Software: Autodesk Forma)



The summer microclimate analysis shows no thermal stress. The month has 10°C to 15°C 8% of the month, 15°C to 20°C 81% of the month and 20°C to 25°C 11% of the month.

SUN HOURS JANUARY 15.

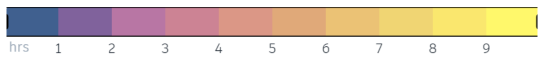
Sun hour analysis (Software: Autodesk Forma)



The analysis results show the number of sun hours on the building. The results from January 15 show a low amount of sun hours during the day, ranging between 0 and 5,5 hours.

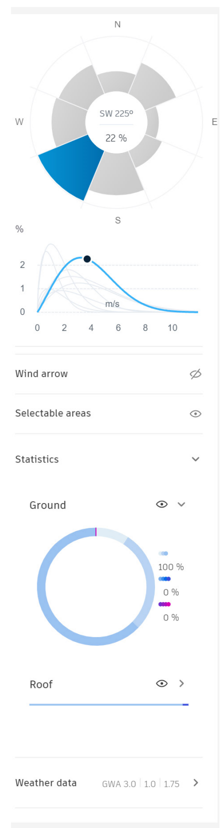
SUN HOURS JULY 15.

Sun hour analysis (Software: Autodesk Forma)

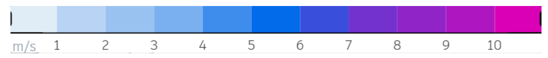


The results from July 15 show a lot more sun hours during the day because the days are a lot longer in the summer than in the winter. The amount of sun hours ranges between 10,9 to 18,6 hours.

WIND DIRECTION

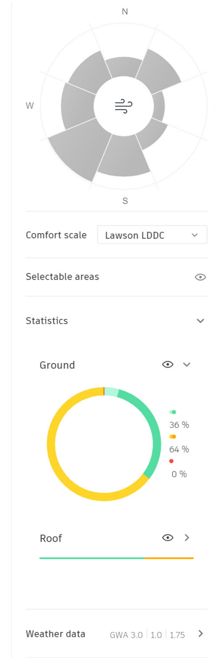


Wind direction analysis (Software: Autodesk Forma)

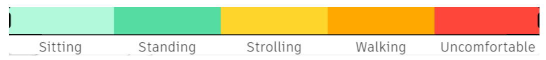


The wind rose displays the probability of wind coming from a certain direction. The highest percentage of wind is coming from the southwest with 22% of the total wind.

WIND COMFORT



Wind comfort analysis (Software: Autodesk Forma)



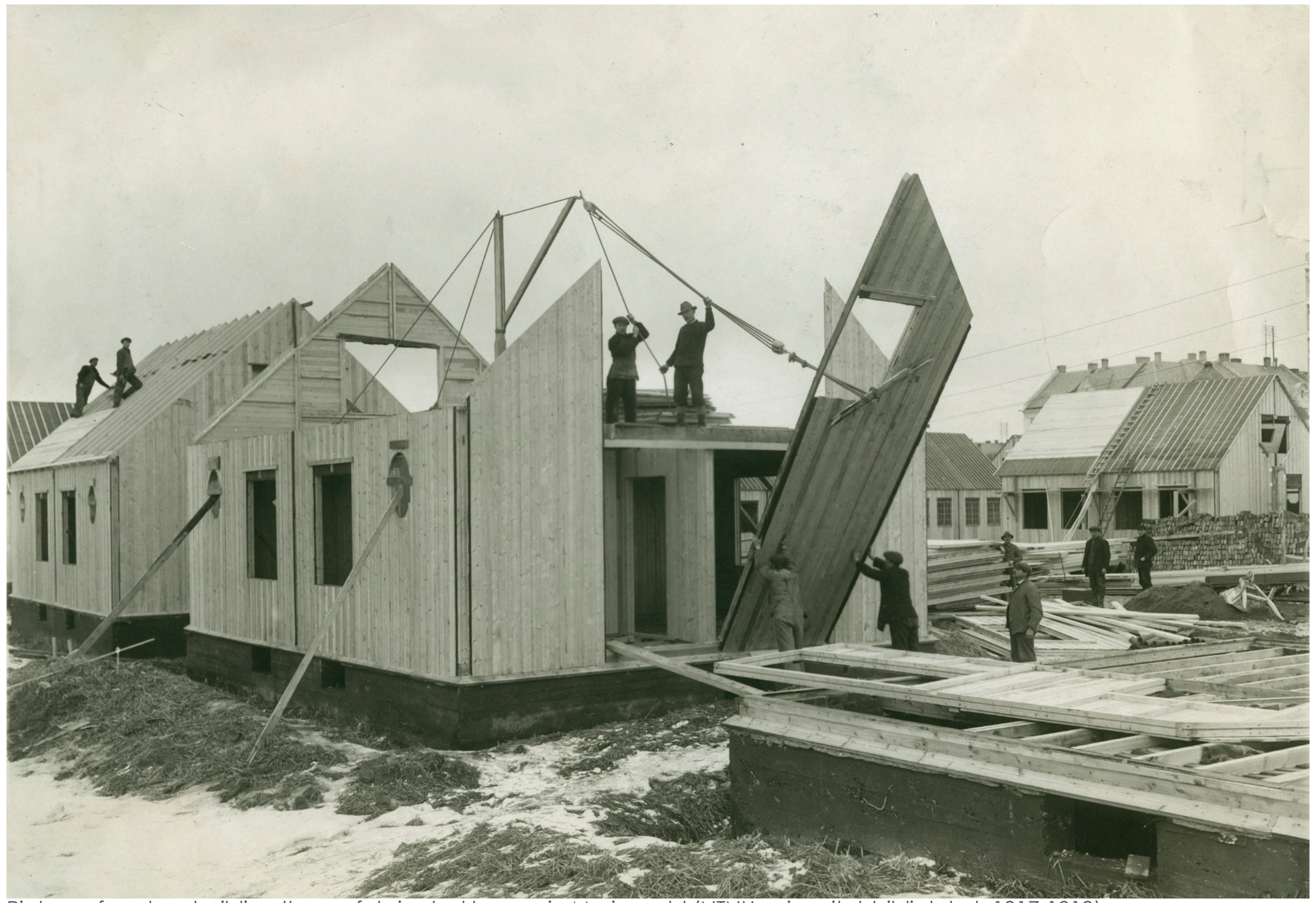
The color scale shows the level of comfort for different levels of activity over longer periods. The comfort scale used in the analysis is the Lawson LDDC scale. The results show that strolling is comfortable 64,5% of the time over longer periods, standing is comfortable 31,1% of the time over longer periods, and sitting is comfortable 4,4% of the time over longer periods. The wind comfort is 0% uncomfortable.

MARINEVOLD HAGEBY HISTORY

Most of the houses in Marinevold Hageby are privately owned, while some are owned by the municipality and rented out. The houses were built between 1918 and 1920 and were originally intended as temporary emergency housing but have remained standing. The architect, Sverre Pedersen, designed the houses using prefabricated modules, which were innovative at the time. The prefabricated modules were produced by "Kommunenes Træsentral" (Kulturminnesøk, n.d.). The area is also known as "Skitbyen," a name that originated because many of the early residents worked for the municipality's sanitation agency as toilet cleaners. The area at Marinevold is a unique and comprehensive example of residential construction during World War 1. The area is of national interest both based on its history and based on the architecture represented in the area (Marinevold, n.d.).

The area is now housing a variety of populations that have lived there for longer and shorter time. they are now a well-functioning social community. One of the reasons for this is "Huset", which is a shared social house with an associated shared garden. They also have a garden team that was established to manage parts of the common area around the house (Marinevold, n.d.). The common house and the garden are not protected like the rest of the houses (Trondheim kommune, 2024).

Picture of Trondheim (NTNU universitetsbiblioteket, 1917-1919).


Picture of workers building the prefabricated houses in Marinevold (NTNU universitetsbiblioteket, 1917-1919).

MARINEVOLD HAGEBY HISTORY

The houses are vertically divided semi-detached houses built with 2 floors above the basement. The building was originally built as an uninsulated element construction of wood. The exterior cladding is made of wooden panels and the roofing is made of roof tiles. The apartments consisted of a living room, kitchen, and entrance hall on the 1st floor, a large bedroom on the 2nd floor, and a basement with a WC (Marinevold, n.d.).

The houses in Marinevold are similar to other houses built in the same period. They started to use machine-planned panels for construction, which provided more stability. Wind resistance was improved because the frame was covered with cardboard as insulation. Prefabricated houses with ready-made wall elements like the ones in Marinevold started appearing on the market. The foundation wall was often built of plastered concrete stone. The windows were often parted in two, while the top floor often had a lower window (Varsomt, n.d.).

Picture of Marinevold Hageby (NTNU universitetsbiblioteket, 1917-1919).

Picture of Marinevold Hageby (NTNU universitetsbiblioteket, 1917-1919).

04 RESEARCH AND REFERENCE PROJECTS

Existing literature will be researched for potential recommendations, measures, and practices for energy efficiency in residential buildings. The chapter also includes studies on similar energy-efficiency upgrading projects and energy community initiatives.

ENERGY EFFICIENCY

ENERGY EFFICIENCY

Buildings account for over 40% of EU energy consumption. Most of the consumption comes from heating, cooling, and domestic hot water. In addition, buildings are also responsible for 36% of energy-related greenhouse gas emissions. Currently, over 35% of the EU's buildings are over 50 years old, with nearly 75% being energy inefficient. At the same time, the average annual energy renovation rate is only around 1% (European Commission, 2023). Worldwide attention to energy usage and carbon emissions has grown over the last few decades, resulting in a variety of regulations aimed at ensuring a more sustainable future. Given that most economies have set the aim of being carbon neutral, the building industry must apply more strict energy-saving measures for both new and existing buildings (Yang & Chen, 2022).

Energy efficiency is the use of less energy to do the same work or get the same result. Energy-efficient houses and buildings require less energy to heat, cool, and operate appliances and equipment (U.S. Department of Energy, n.d.a).
An energy-efficient building is designed and constructed to minimize energy consumption and maximize the use of renewable energy sources, aiming to reduce environmental impact and associated costs while ensuring a comfortable indoor environment. By minimizing energy waste and maximizing savings, efficient buildings lower energy bills and decrease reliance on other energy sources, therefore reducing greenhouse gas emissions. Energy efficiency benefits include cost savings and improved indoor comfort through optimized heating and air conditioning systems (Pacheco et al., 2012).
Another reason that energy efficiency is cost-effective is that homeowners can receive support from Enova. They encourage homeowners who wish to make a difference by making smart climate decisions and implementing energy and climate measures (Enova, n.d.a). Energy-efficient renovation is therefore a good investment for the future both for the individual homeowner and for reducing energy use in order to reach the EU Commission's goals.

ENERGY LABEL

Energy labeling is mandatory for residences and buildings larger than 50 square meters. Beginning July 1, 2010, all houses and commercial buildings sold or rented out had to get an energy certificate. The energy label consists of an energy rating and a heating rating. The energy grade goes from A to G and is based on calculated delivered energy. The heating grade is given with a five-part color rating from red to green and ranks the house according to which heating system is installed.
The energy rating is the result of calculated energy delivered to the house during normal use. The calculation is determined in the standard NS 3031 (Førland-Larsen. Et al., 2011).

The scale is designed so that buildings that are constructed according to the minimum requirements in TEK-07 and do not use solar energy or a heat pump for heating, will normally achieve the grade C. To get the grade B the building must have approximately 25% better energy standard than with grade C, which often in practice means the installation of a heat pump or solar energy for heating and/or better insulation and windows than the requirements in the building regulations. To achieve energy grade A, which equates to around 50% less supplied energy than grade C, actions must often be done on the building body, technological facilities, and energy supply. Most existing buildings will receive grades between D and G (Førland-Larsen et al., 2011).

ENERGY EFFICIENCY

INDOOR AIR QUALITY

Indoor air quality is important to consider in energy-efficient buildings as it directly impacts occupant health, productivity, and the overall indoor environment quality. Poor indoor air quality may cause symptoms such as headaches or disturb the occupant's ability to concentrate. In contrast, good indoor air quality creates a healthy and comfortable indoor environment, which improves occupant well-being and productivity (REHVA. n.d.).

These side effects of poor indoor climate are a lot of times talked about in commercial buildings but are likely as important in residential buildings because we use and work more from home (EDIAQI, n.d.).

Ventilation is the primary link between indoor air quality and energy use in buildings. Increasing ventilation improves indoor air quality but can also increase energy consumption for heating and cooling. On the other hand, lowering ventilation to conserve energy could lead to poor indoor air quality if indoor pollutants are not effectively managed. (EDIAQI, n.d.).

A balanced strategy is required to achieve acceptable indoor air quality while also increasing energy efficiency. Many measures can improve indoor air quality and save energy, including higher envelope airtightness, and various ventilation and air cleaning strategies. The challenge is to use the correct balance of ventilation and air cleaning technologies to satisfy indoor air quality targets while still being energy efficient (EDIAQI, n.d.).

However, ventilation is more complicated in older protected buildings because natural ventilation often is the only ventilation source. Installation of balanced mechanical ventilation systems in older houses is expensive and can lead to extensive visual and physical intervention in the building that is not cohesive with the antiquarian value. It is therefore, in the same way as other buildings, important to have a holistic view and find a good balance between indoor climate and energy efficiency. If mechanical ventilation is not achievable, aeration can be used as an alternative. Aeration should be done in short bursts at regular intervals so that the air gets replaced quickly (SINTEF, 2004).

COSTS OF ENERGY EFFICIENCY

Energy efficiency in buildings can provide large cost savings over time. Energy-efficient buildings use less energy for heating and cooling, which reduces energy costs over the life of the building. The saved costs can exceed the purchase and installation costs of energy-efficient measures over time (Ministry of Oil and Energy, 2023). The saving period for the expenses related to energy measures is usually over periods of between 1-10 years. Energy-efficient buildings also often have a higher market value and attractiveness, which can increase the property's value in connection with a sale (UngEnergi, 2024).

Financial support for energy measures can be provided by Enova. They promote innovation and the development of new climate and energy solutions (Ministry of Oil and Energy, 2023).

Installing renewable solutions such as solar panels usually costs between 100,000kr and 300,000kr including installation. Enova can provide up to 32,500kr in total in support of the initiative (Enova. n.d.c). Additional insulation costs on average 2,000kr-4,000kr per square meter of wall surface. It is often not the insulation itself that is expensive, but the work around it and changing other materials in the wall. It may therefore be worthwhile to re-insulate in combination with other upgrades in the house (Byggstart, 2024)

Energy poverty refers to situations where households cannot afford to maintain satisfactory heating levels in the home due to low incomes and poor energy efficiency. Energy efficiency in housing is therefore an important measure to reduce energy poverty. In the least developed countries, are energy poverty linked to low access to energy and general poverty. In Europe, energy poverty means having cold homes in the winter and uncomfortably hot homes in the summer. One can be energy-poor even if you live above the poverty level. Energy poverty is therefore not only affected by income but also by living conditions such as housing type, quality of housing, climate, and season (Winther et al, 2022).

ENERGY EFFICIENCY MEASURES

Saving energy and preserving cultural heritage in buildings are essential environmental policy goals. At the same time, is it important to keep buildings and their architectural value as best as possible. Environmental targets of keeping the architectural value and upgrading the effectiveness may contrast with each other. With proper planning, heritage-worthy houses can be built denser and warmer while maintaining their distinctive character. Certain efficiency methods have a higher impact on the building than others. Each house is different in its technical, architectural, and functional aspects, requiring an individual assessment. Protected buildings can give restrictions to efficient renovation solutions. It is therefore important to look at what can be achieved without physical measures on the building façade, in addition to solutions that fit most in with the current architecture (SINTEF, 2004).

There are three different important aspects of energy-efficient renovation. These aspects should be used in a holistic assessment when choosing renovation strategies for the building.The three aspects consist of what is easiest to implement, what is most preserving for the building, and what is cheapest (SINTEF, 2004). Keeping a balance between these assessments will give the best solution for the building. Some solutions save energy by improving the building envelope these are called passive design strategies, while others are installation strategies that increase energy efficiency and are called active strategies (Fathi, 2023). Following are some measure solutions that can be implemented for the houses in Marinevold Hageby.

INSULATION

Many residences built during the same time as Marinevold Hageby lacked ideal insulation or had inadequate insulation levels (Lund, 2016). Inadequate insulation causes heat loss, increases energy use for heating, and reduces overall energy efficiency.

In Trondheim's climate, heating is a significant energy expense during the long winter months, while cooling may be less of a concern. Therefore, initiatives for enhancing insulation and limiting heat loss in buildings are important to reduce energy consumption and expenses. The house can be difficult to heat effectively without using significant amounts of electricity, gas, or wood because the heat escapes through poorly insulated ceilings, floors, and walls. A properly insulated house heats fast and maintains heat, resulting in energy savings. This is reflected in lower energy costs (Natural Insulation NZ, n.d.).

When insulating, can insulation be added on the inside or the exterior facade of the house. Both approaches have their advantages and disadvantages. External re-insulation eliminates draft concerns with floors by creating a consistent wind barrier across the entire wall surface. The approach typically involves replacing the original exterior cladding and building elements, resulting in a different appearance. Internal insulation can be used to preserve a well-kept exterior. Inside insulation allows for individual room insulation, focusing on areas that require it the most (SINTEF, 2004).

AIR LEAKAGE

Air leakage happens when outside air enters a house and conditioned air escapes uncontrollably through cracks and gaps. Insufficient construction methods and a lack of air sealing measures are common causes of air leakage in older homes. Air leaks cause heat loss, drafts, and increased energy use for heating and cooling (U.S. Department of Energy, n.d.b). Drafts are a common cause of thermal comfort complaints in buildings, as they increase the need for heating (SINTEF, 2004).

It is recommended to minimize air leakage and use controlled ventilation as needed. Simple sealing methods involve using caulk or weatherstrips to seal doors and windows that leak air. In addition, where plumbing, ducting, or electrical wiring comes through walls, floors, and ceilings can also be sealed using caulk (U.S. Department of Energy, n.d.b).
However, the house should not be too tight. Tightening the house might lead to a poor indoor climate and higher demands for mechanical ventilation. The primary goal is to eliminate major air leaks that cause obvious and unpleasant drafts (SINTEF, 2004).

WINDOWS

Heat gain and loss through windows account for 25% to 30% of residential heating and cooling energy consumption. Energy-saving windows, often with double or triple layers of glass and low-emissivity coating, reduce heat loss and provide better insulation. There are also other options than chancing older inefficient windows. These options are controlling and sealing air leakages, as mentioned earlier, or adding energy-efficient window coverings (U.S. Department of Energy, n.d.c).

Changing the windows to modern produced ones, may not always be the best for lowering material use, and keeping the original architecture of the house. It is therefore recommended to map the condition of the windows using a thermal camera. With this method, one can record whether the problem is with the glass itself or air leakages around the windows Improving the insulating capacity of windows without replacing them is therefore the ideal solution for listed buildings (SINTEF, 2004).

The windows are important architectural elements of the facade in older buildings. The windows are often placed and designed to fit into the facade composition. Windows were initially simple, with small panes in Norway because of the production method of glassblowing (SINTEF, 2004). The windows in Marinevold Hageby were originally small panes like this, but they were replaced in the 1970s with windows with the same look as today. Windbreaks and roof windows were later additions to some of the houses (Marinevold, n.d.).

HEATING AND COOLING

Space heating and cooling are some of the major energy costs in a house. Historically, wood-burning fireplaces were used to heat homes. This was also the case with the houses in Marinevold Hageby. After about 1900, electric heaters became more common. Heating with a fireplace or an electric oven are both common heating methods today (SINTEF, 2004). The most beneficial long-term approach is to improve the building structure of the house to minimize the heating and cooling needs. However, heating demands may still exist depending on the climate, so heat pumps are a good and efficient option. Heat pumps are divided into three types: air source, water source, and ground source. Each of these pumps heats the house by extracting heat from the air, water, or ground using a heat exchanger. (Milne & Reardon, 2020). An air-to-air heat pump is the most common and consists of two tubes that connect the outside and interior. The interior unit distributes heat throughout the building. The outside area should be installed shielded from rain and to minimize disruption to the surrounding environment and facade (SINTEF, 2004).

Currently, there is no considerable cooling demand in Norway, but, as global warming continues, summer temperatures will rise, increasing demand for space cooling in Norway (Norsk Industri, 2022). Most older homes feature natural ventilation. The basis of this type of ventilation is that warm air rises since it is lighter than cold air and exits through pipes or ducts, and fresh cold air escapes into the house through leaks in the walls and other openings. A balanced mechanical ventilation system can be difficult to achieve in older protected houses because the outer structure must be very tight. Installation of this system is expensive and will also lead to visual and physical intervention in the building (SINTEF, 2004). Careful investigations should therefore be carried out as to whether there is a need for major intervention or not.

RENEWABLE ENERGY

Renewable energy sources, such as solar panels or geothermal energy, can be used to create a more energy-efficient building. These methods can be combined to help lessen reliance on conventional energy sources. Renewable energy sources have the potential to help homeowners save money on their energy bills over time. While the initial investment may be larger, renewable energy sources like solar panels or geothermal heat provide electricity on their own once installed. They can also bring energy independence to homeowners. Residents who generate their own electricity are less exposed to fluctuating energy prices. This improves energy security and provides a dependable power supply for residential buildings (Moriarty & Honnery, 2011).

Houses with enough space outside can use geothermal heating by digging heat absorption pipes into the ground. The pipes must be laid deeper than 1-2m and require good soil conditions (SINTEF, 2004). Geothermal heat pumps increase efficiency by transporting heat between the house and the ground. They offer minimal running costs because they use generally stable ground temperatures (U.S. Department of Energy, n.d.b).
Another renewable energy solution is solar panels. Solar panels are an effective renewable energy source because it is a cost-effective solution in the long term. This is because they have low operating costs once installed, and maintenance requirements are minimal. It is also becoming a more accessible solution as more models and suppliers are coming to the market.
Solar energy has a lower impact on ecosystems than other nonrenewable energy alternatives since the natural balance is maintained for the benefit of living creatures (Kannan & Vakeesan, 2016).

REFERENCE PROJECTS

MYHRERENGA BORETTSLAG PASSIVE HOUSE RENOVATION


Picture of Myhrenga boretslag (SINTEF, 2010).

The renovation project Myhrerenga boretslag in Skedsmokorset outside Oslo is an example of existing buildings that have been rehabilitated as passive houses to reduce energy consumption and environmental impact. The seven blocks from 1968-1970 underwent a renovation to reduce the total energy requirement from 275-300 kWh/m² to 80 kWh/m² per year and cut the heating requirement by 80-90% to approximately 25 kWh/m² per year (Passivhaus Institute, 2010).

The project carried out measures such as adding insulation of external walls, floor and roof, new passive house windows, balanced ventilation system with heat recovery, reduction of cold bridges and air leaks, new energy center with solar heating and heat pumps, and new simplified heating system with individual energy measurement. The measures led to an energy saving of 70-75% being calculated compared to before renovation. Although the costs were higher than a traditional renovation, the energy savings would cover the additional costs over time. The project also received financial support from Enova and a loan from Husbanken (Sintef, 2010).

INSTALLING INTERNAL WINDOWS INSTEAD OF REPLACING THEM


Pictures of the renovated windows (Fjeldheim, 2011).

Ola H Fjeldheim owns a farm from 1899 which he maintains with a particular focus on preserving cultural heritage. The house had original single-glazed windows. These led to a lot of air leakage and therefore made the house cold. He wanted to improve the windows, but at the same time keep the same look on the facade. The solution was therefore to have some new internal windows specially made with insulating glass. The windows are a whole frame that is fixed into the original frame. The inner window can also be taken out in the summer to make it easily adapted to the different climates and temperatures throughout the year. Measurements of u-value indicate that the new windows now have a value of approximately 1.0 and are therefore in as good condition as many newer windows. He has also made calculations that show that he saved money on this solution because he received support from Kulturminnefondet. He also saved environmental emissions by not using as many new materials (Fjeldheim, 2011).

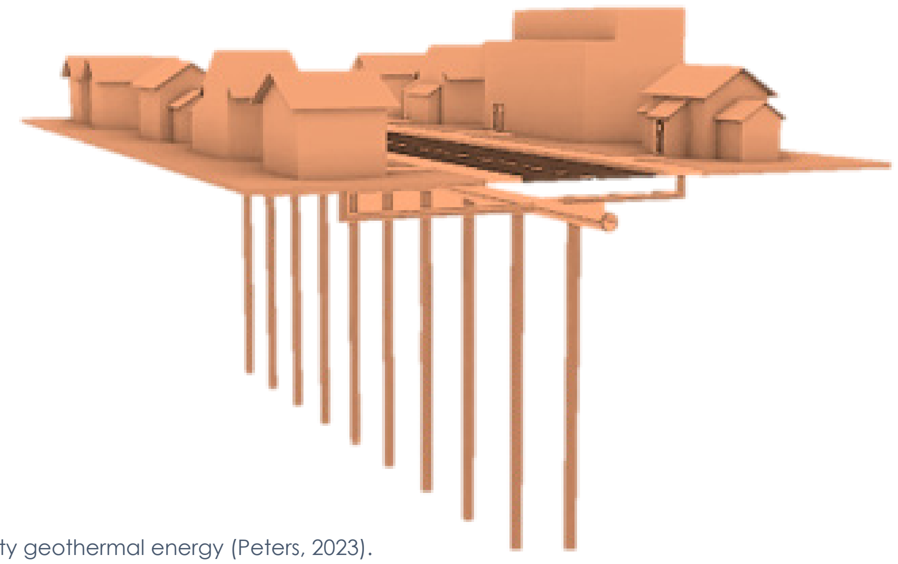
REFERENCE PROJECTS

COMMUNITY SOLAR

Picture of community solar energy (Watkins, 2020).

Community Solar is a company in America that provides solar energy to communities and neighborhoods. They install solar panels in a centralized location in the community. The option is favorable for areas where it's not possible to install solar panels directly on the houses.
The solar panel community helps to support renewable energy while saving on the monthly electric bill. It works by giving each participant a portion of a shared solar garden in the area that will produce renewable energy for them to use. The energy from the solar panels also works in the same way as rooftop solar panels if it produces more than is needed. The company gives the owner credits for the extra energy that can be used in parts of the year when the panels don't produce enough energy (Watkins, 2020).

COMMUNITY GEOTHERMAL HEAT



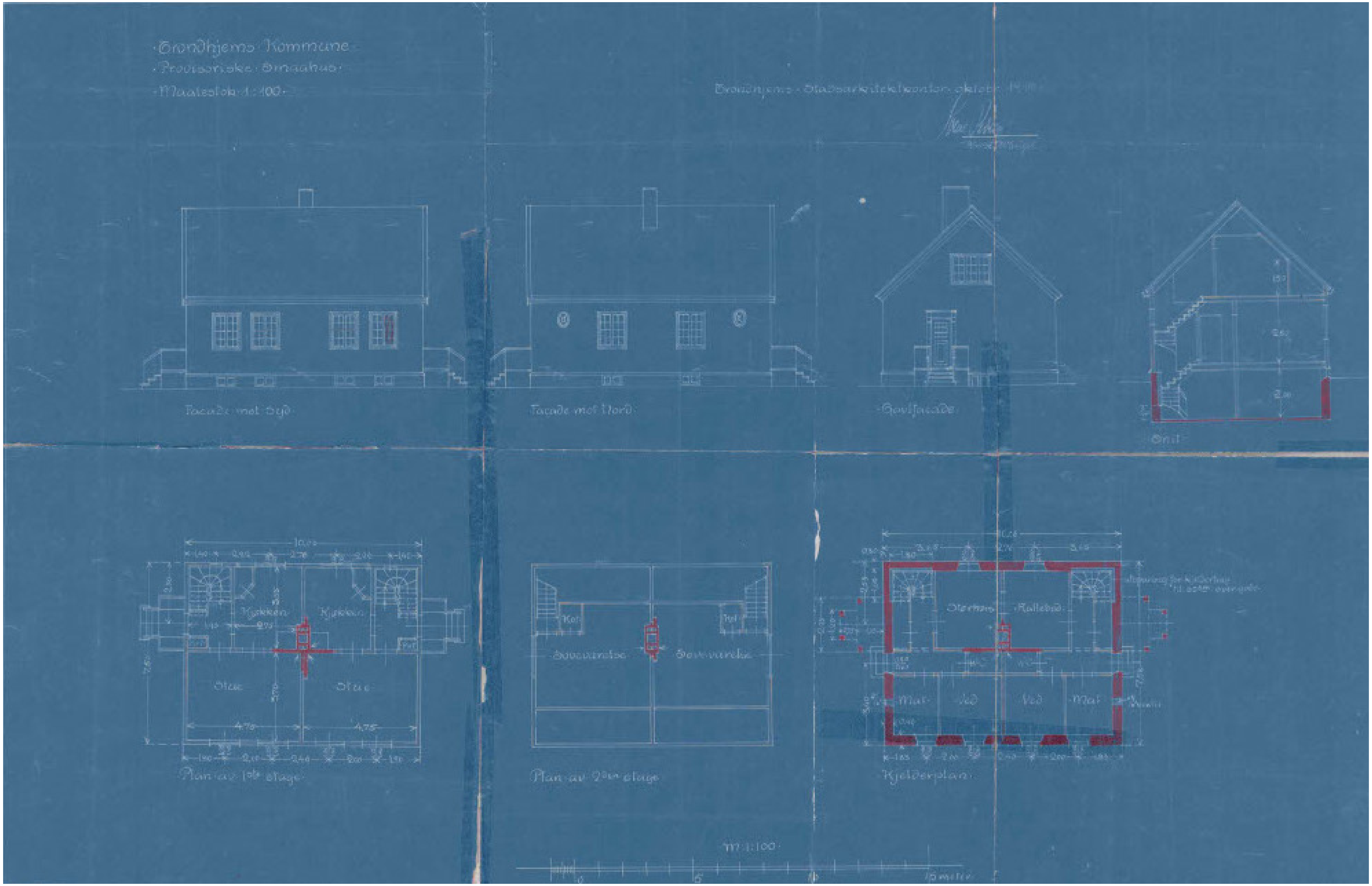
Picture of community geothermal energy (Peters, 2023).

A neighborhood in Masechuses is doing a trial project on community geothermal heat. The project features a networked geothermal system underground that will connect to around 40 buildings. The geothermal system will help to heat the connected buildings in a more sustainable way than with existing nonrenewable heating sources.
Most homeowners that use renewable heating sources use air-source heat pumps that pull energy from the outside air to heat the house. However, it is even more efficient with ground source heat pumps because the temperature is constant the whole year. The method can also be cost-effective if a neighborhood could share the expenses of installing the ground source heat pump system (Peters, 2023).

05 BUILDING INFORMATION MODEL

This chapter presents two building information models. The first is based on the original plans which were designed to build the 35 identical houses in Marinevold Hageby. The second is based on Harald Hardrådes gate 35, because it will be used as a sample house later in the simulations. The models are important to get a better understanding of the construction and materials of the houses to use in the simulations. In addition, a material flow is presented showing what materials are used in the houses at different times, and what materials are changed from 1919 to 2024.

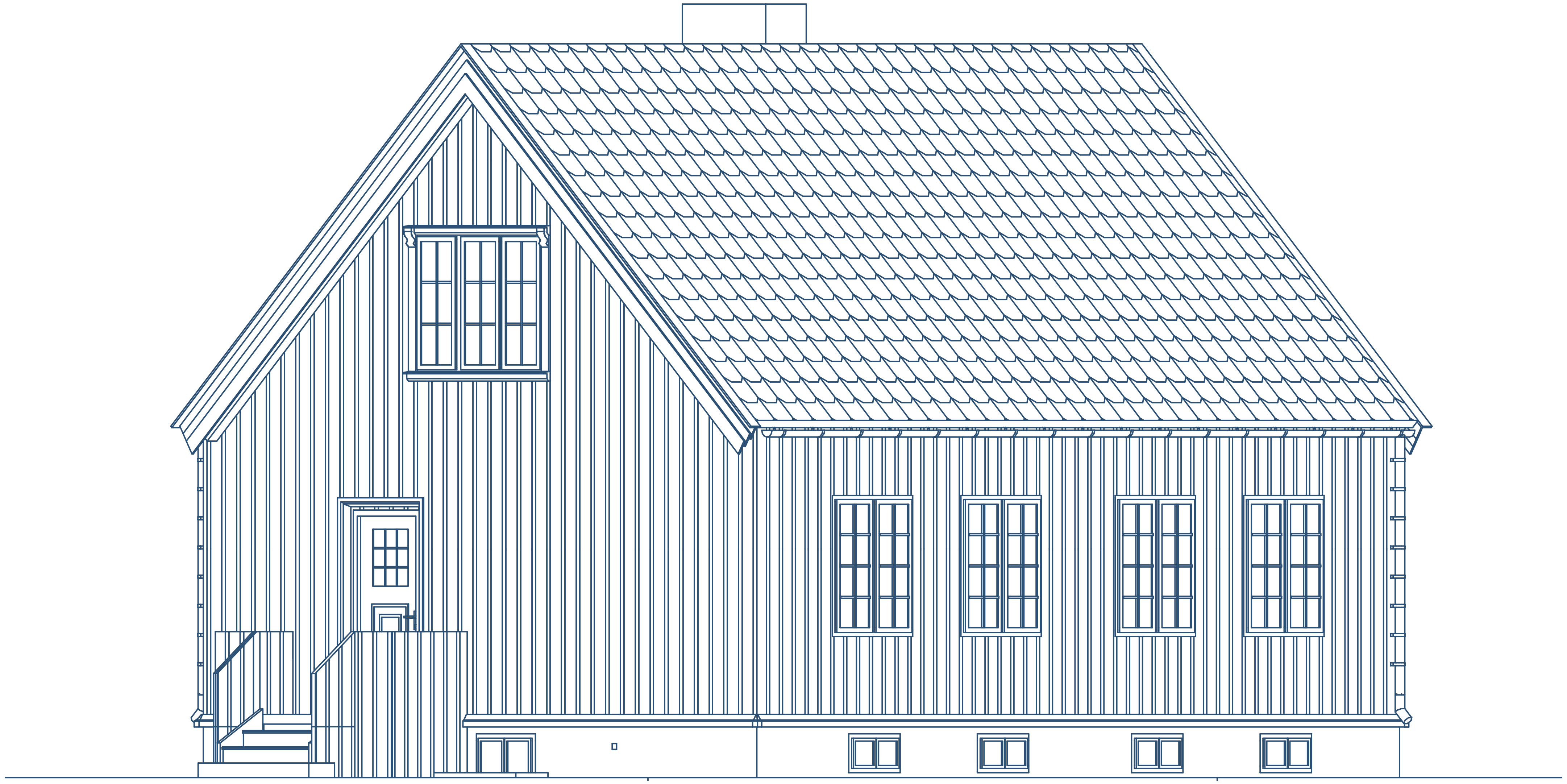
PLANS - ORIGINAL

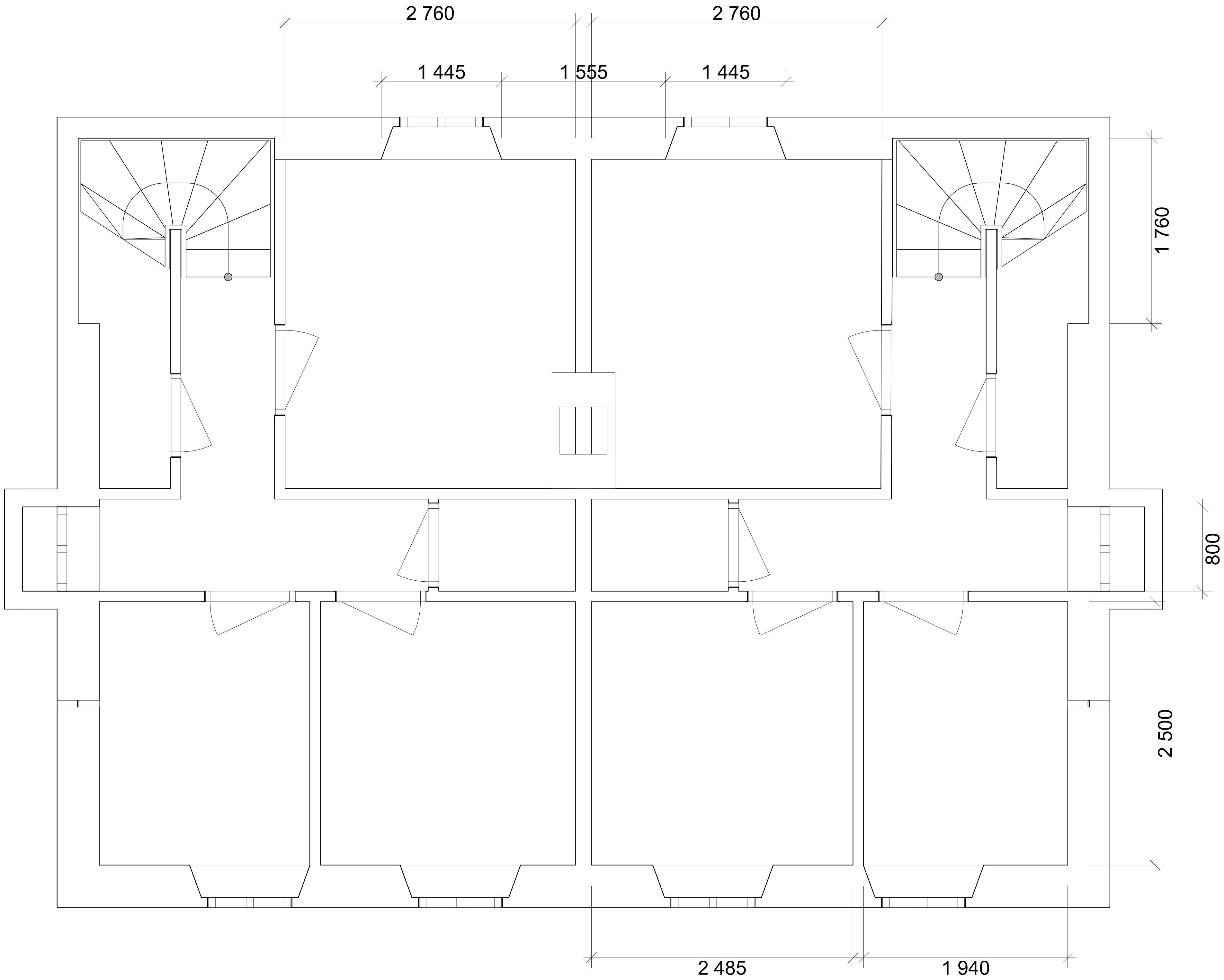


The houses at Marinevold were designed by the architect Sverre Pedersen and consist of 35 identical houses divided into two separate apartments. The original apartments consisted of a living room, a kitchen, an entrance hall on the 1st floor, a large bedroom on the 2nd floor, and a basement with a WC. They were completed in 1918-1920 (Marinevold, n.d.).

The drawings of the original house are collected from Trondheim municipality's archives. The hand-drawn plans and facade drawings contain some measurements but are not as accurate as newer digital drawings. It is therefore important to point out that the drawings and the BIM model are not necessarily completely correct.

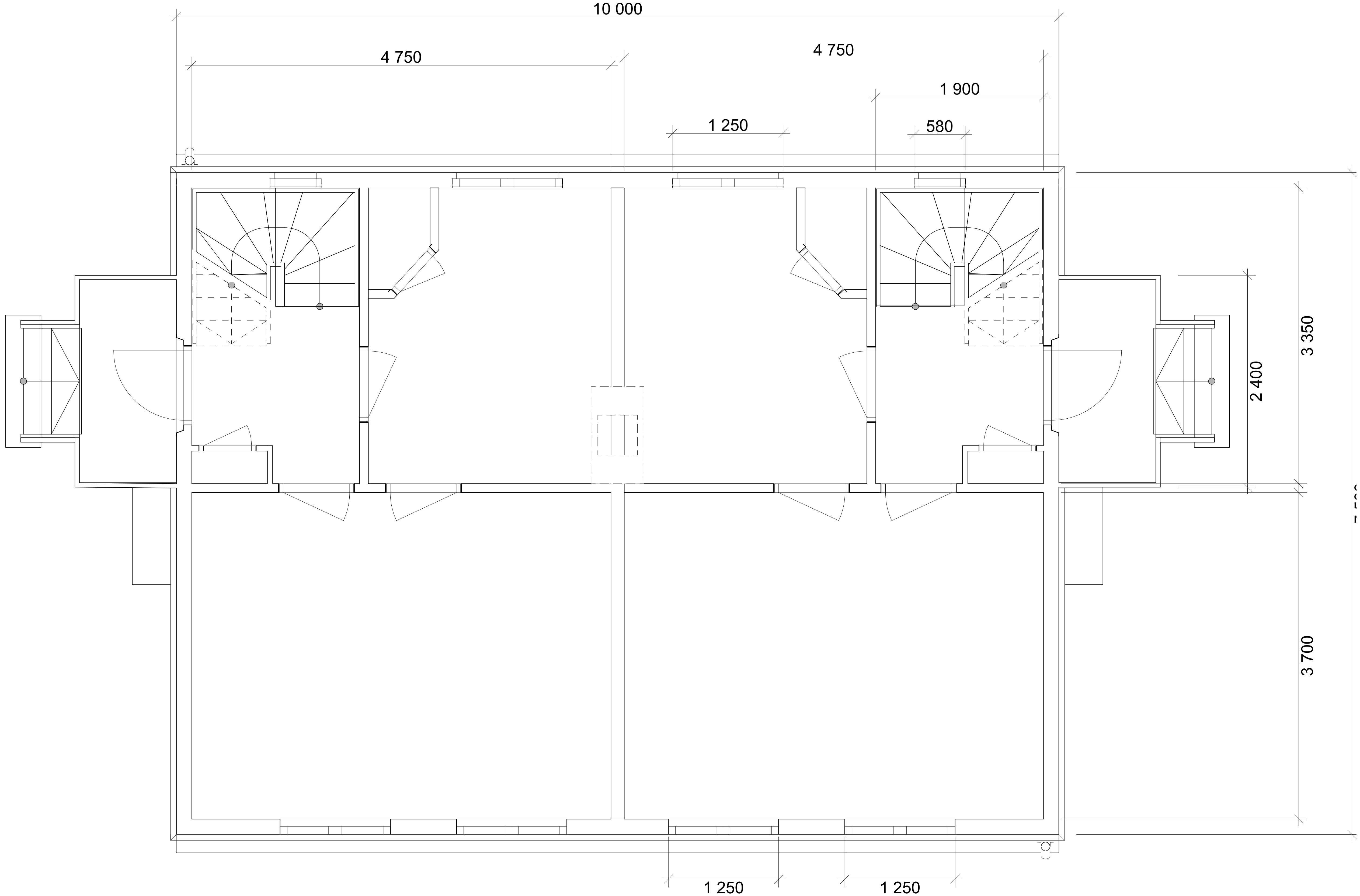
The reconstructed floor plans and model of the house are presented below.

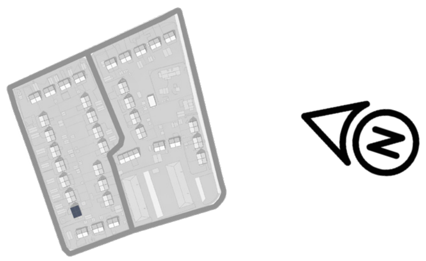




BASEMENT

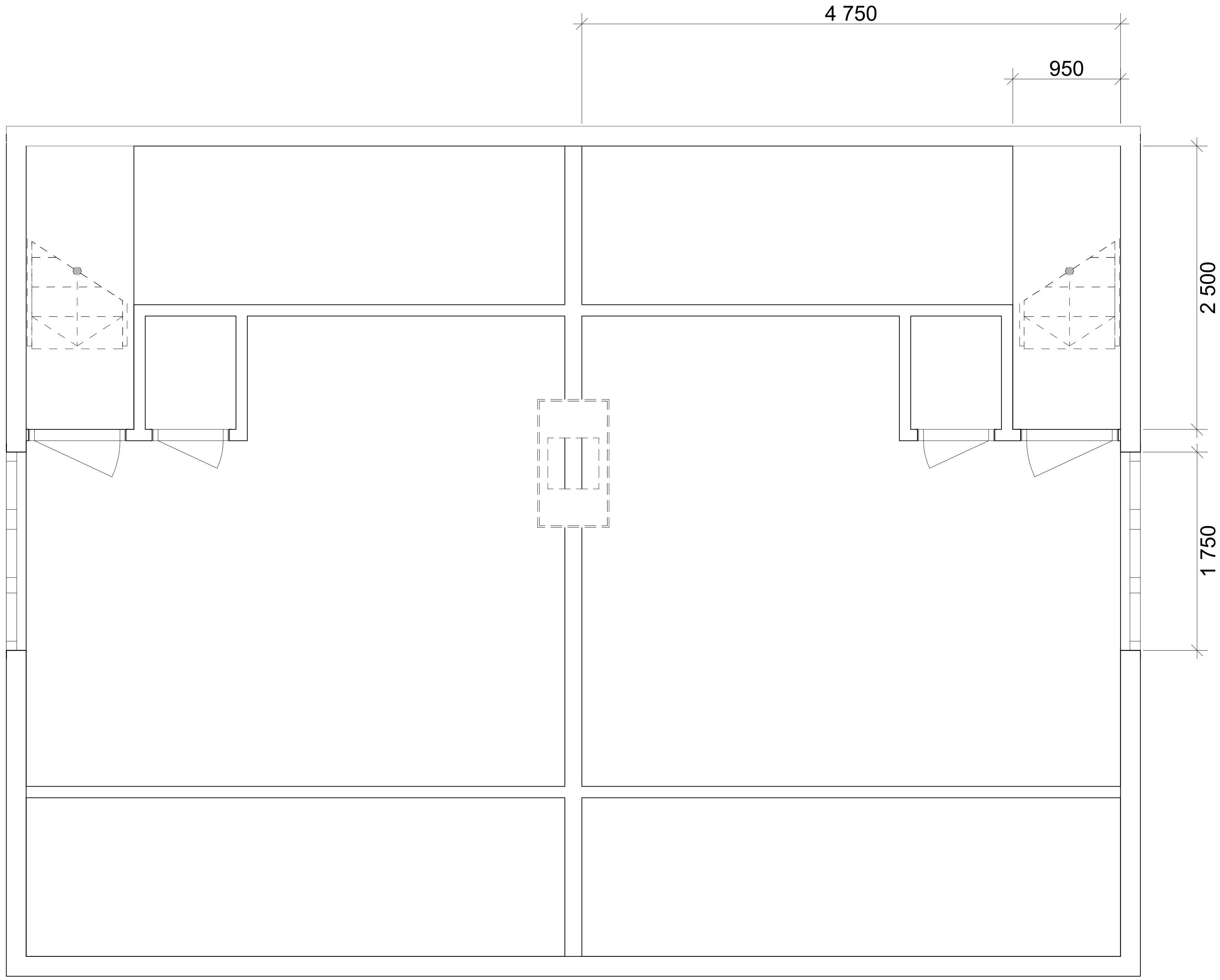
1:50





1ST FLOOR

1:50



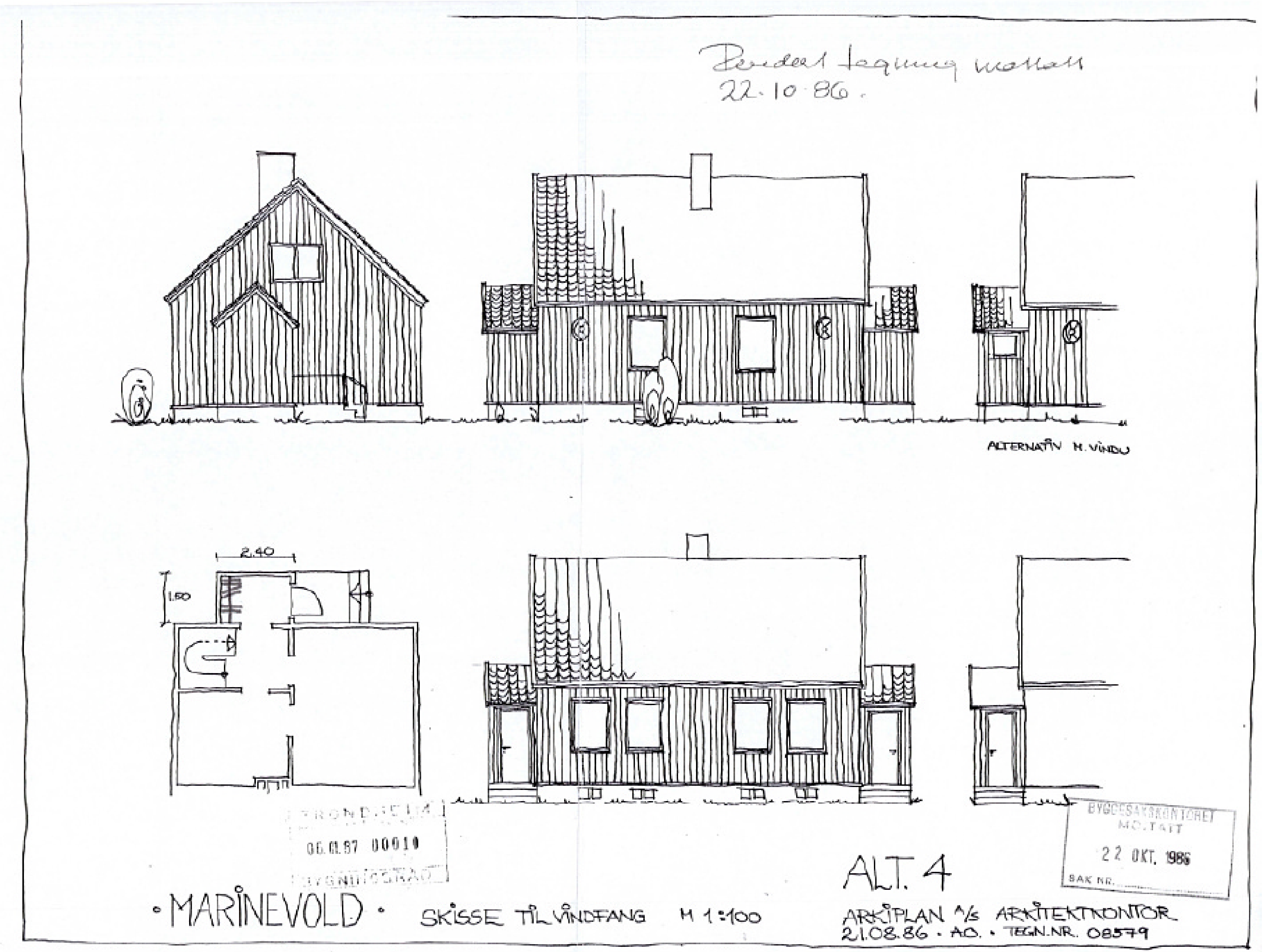
2ND FLOOR

1:50

ROOF

1:50

PLANS - NOW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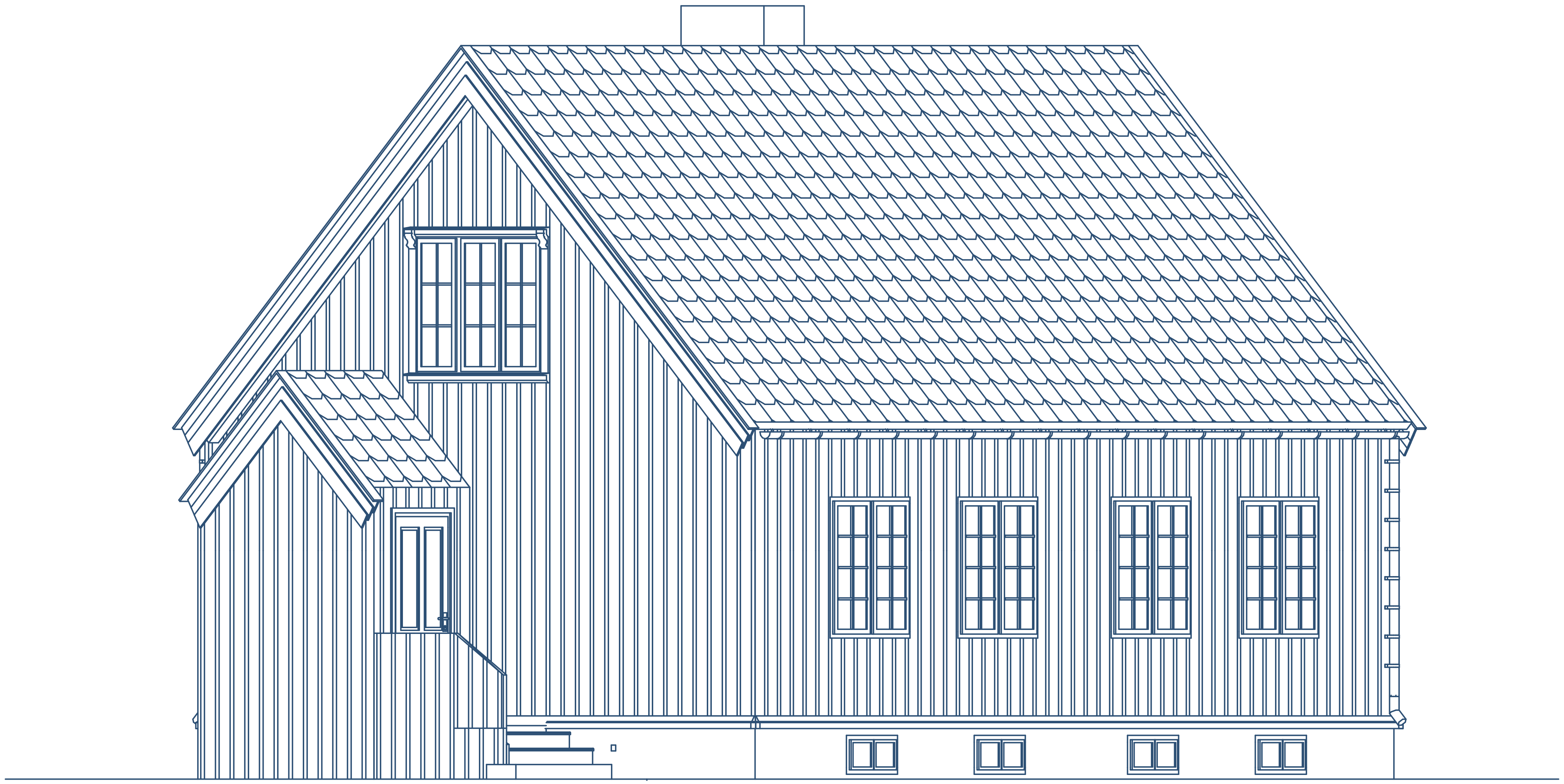
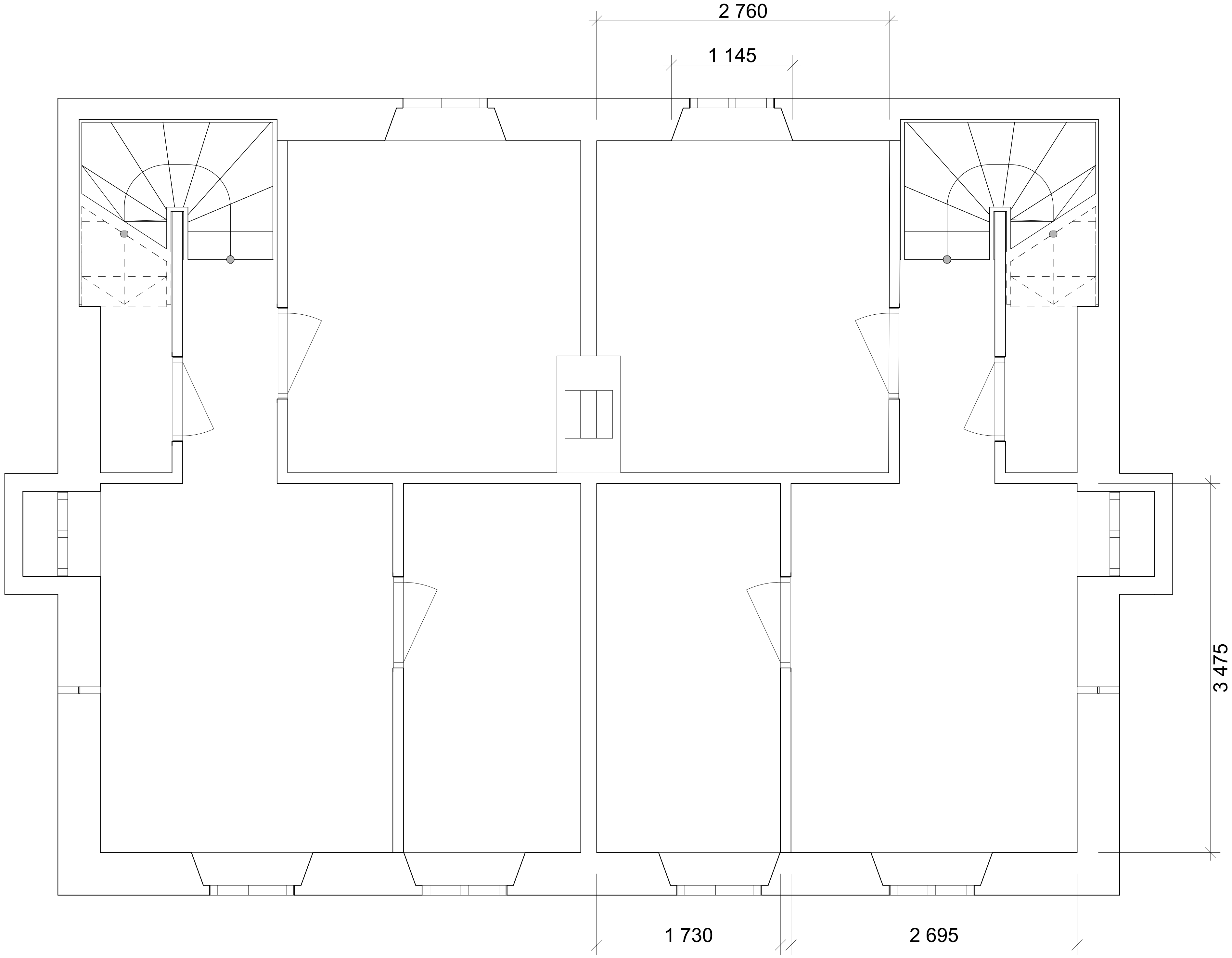
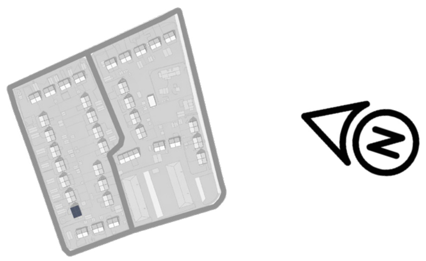
The drawings below show how the house looks today after different renovations have been done. There is some variation in the measures and improvements done in each house. The illustrations are based on Harald Hardrådes gate 35, which will also be used for simulations and thermal camera imagery.

The apartment includes an open living room/kitchen solution on the first floor and two bedrooms on the second floor. The basement has been transformed into a basement living room, a bedroom, and the toilet has been upgraded to a full bathroom. In addition, new entrances were built on all the houses in 1986. The walls have been re-insulated with 50 mm. The windows have also been replaced with 2-layer glass windows that look like the originals. The oval window, which is listed, has not been replaced.

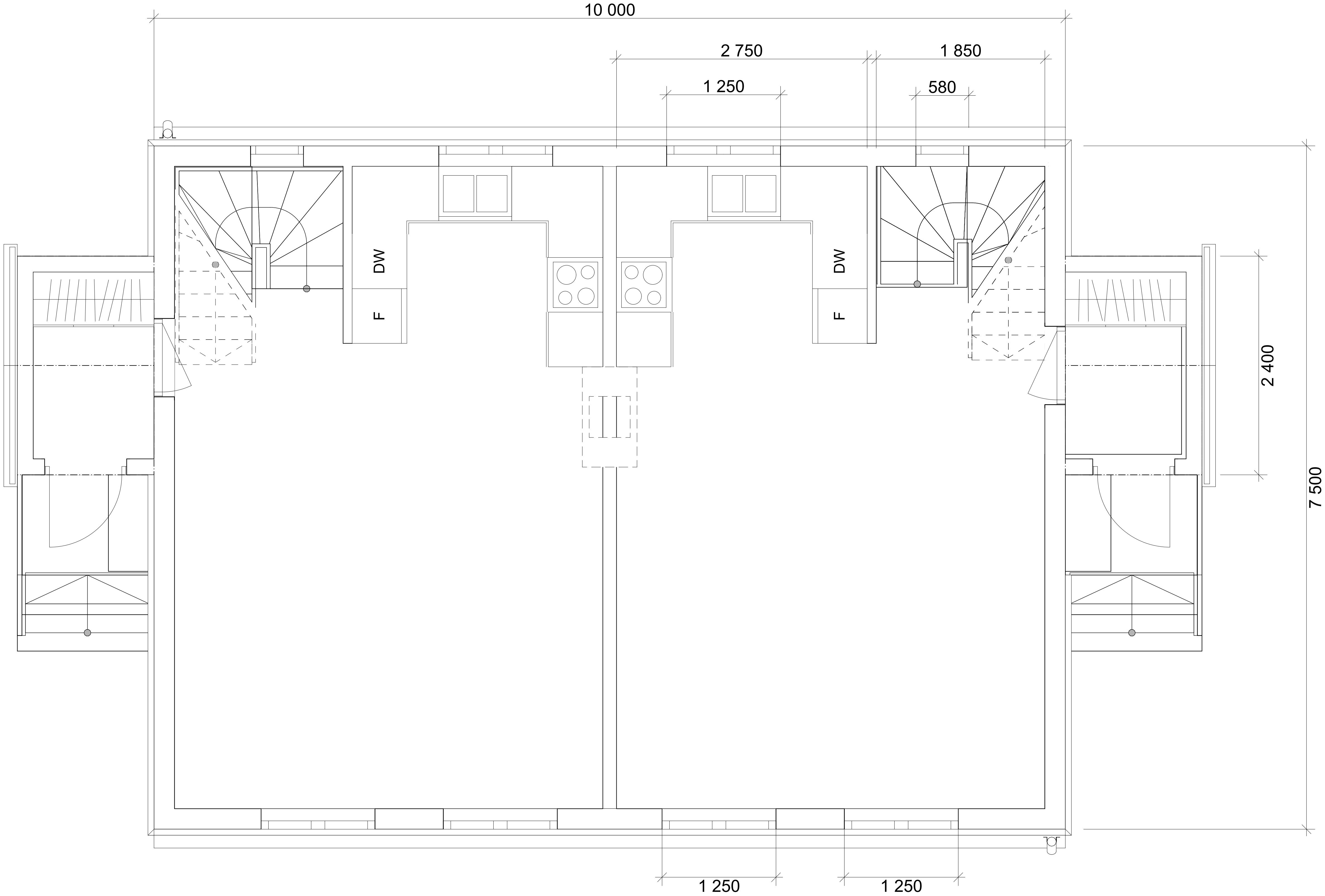






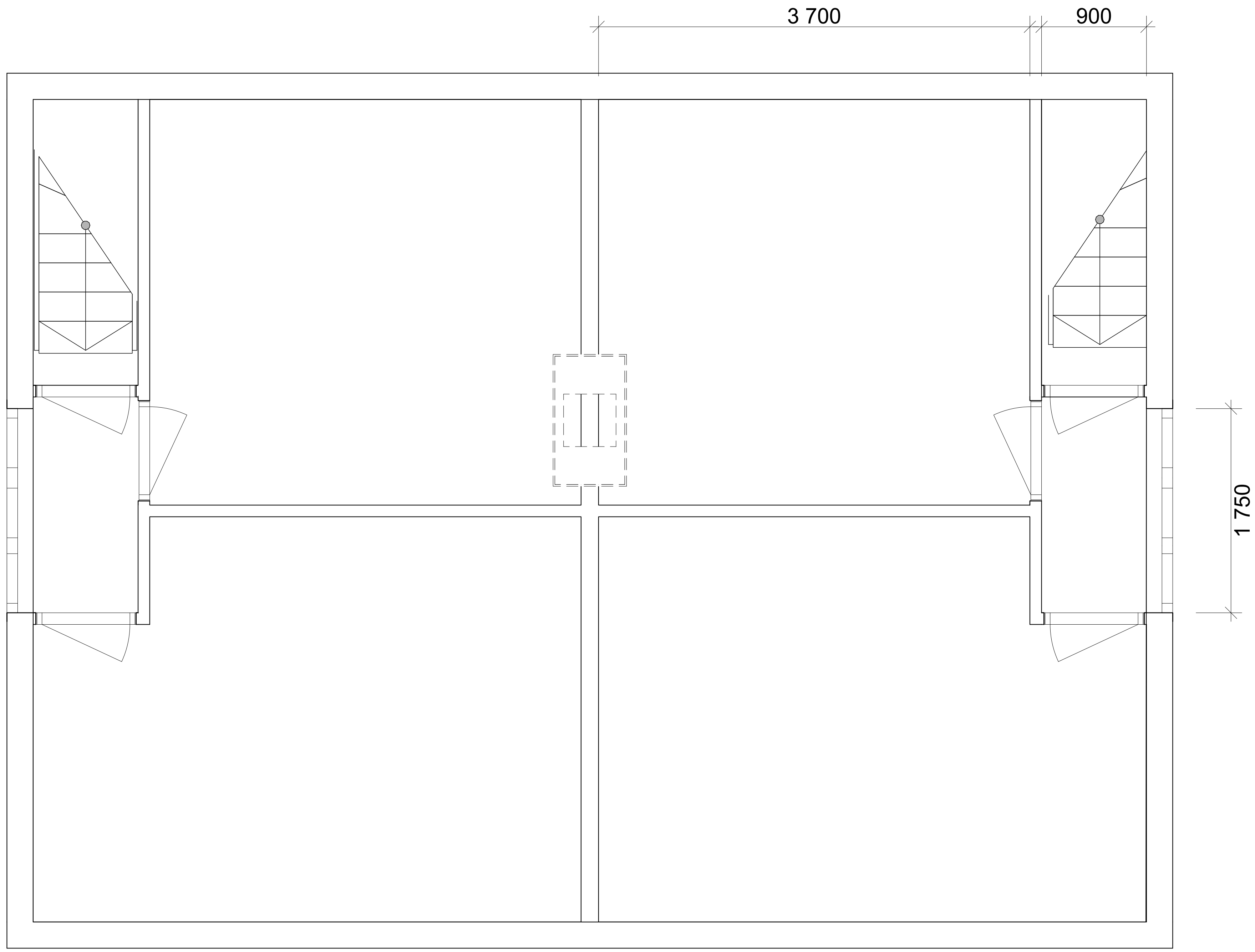
BASEMENT

1:50



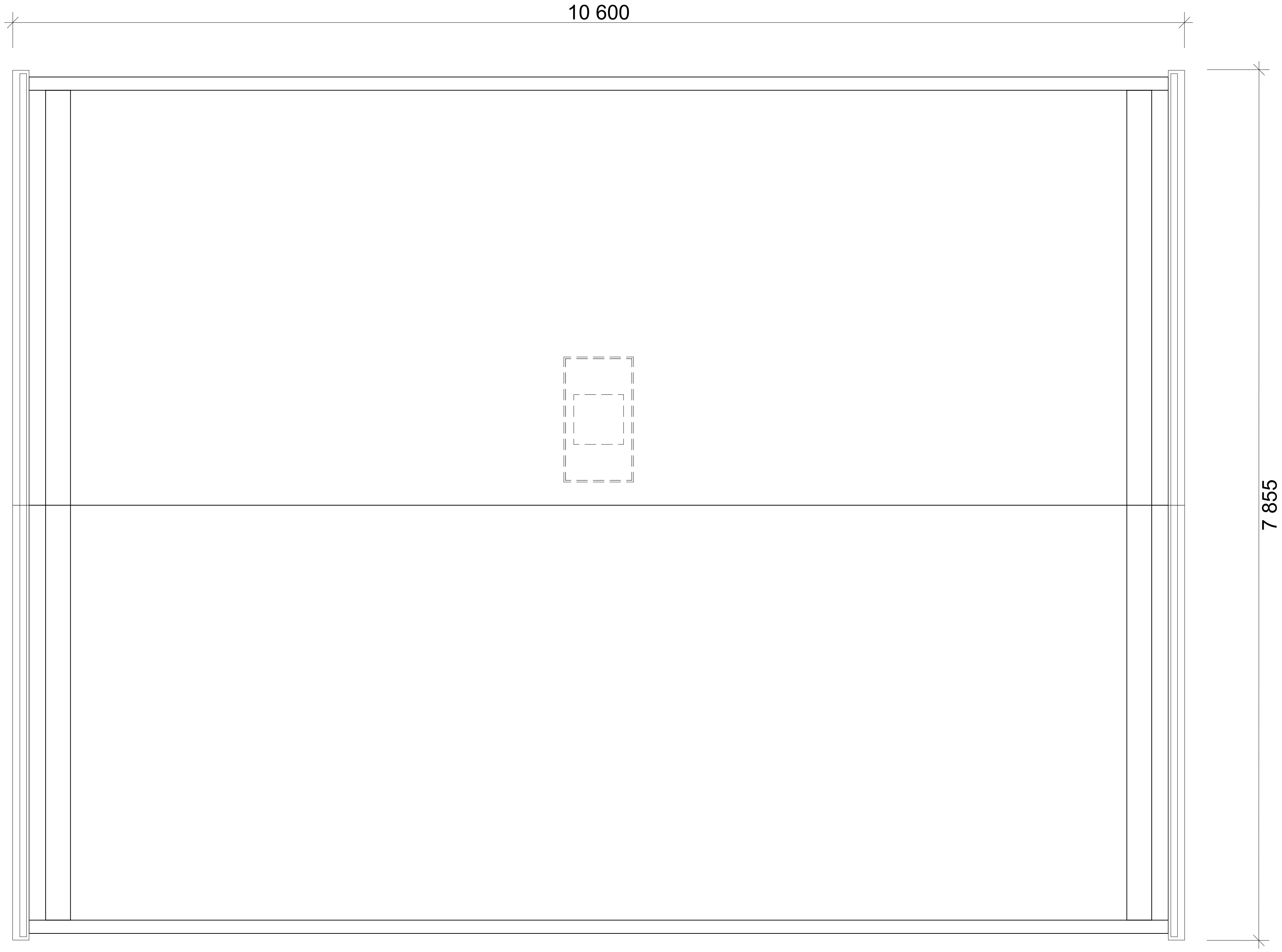
1ST FLOOR

1:50



2ND FLOOR

1:50



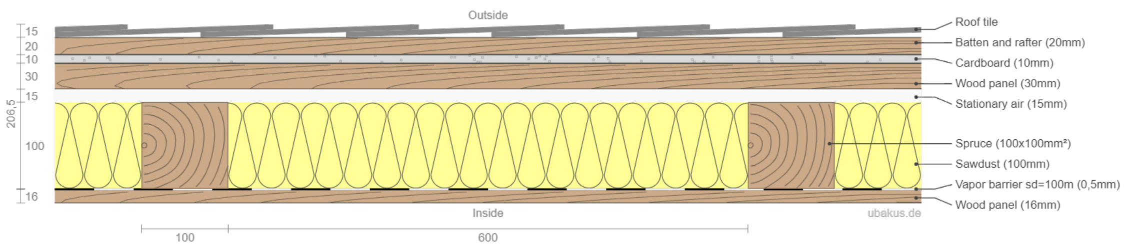
ROOF

1:50

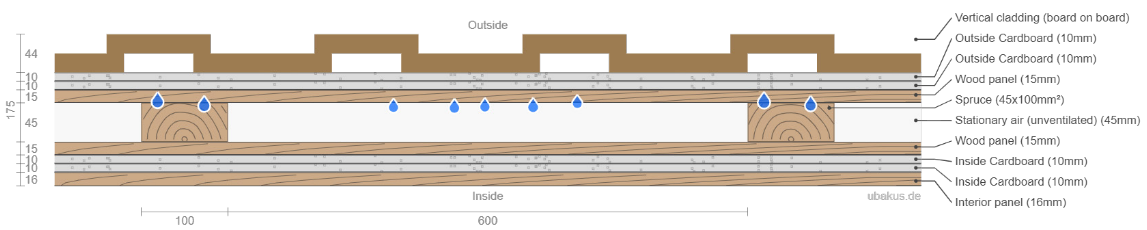
DETAILS

ORIGINAL

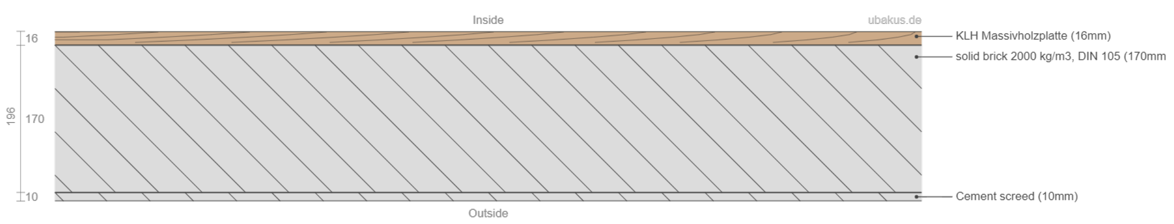
ROOF
U- Value: 0,40 W/(m²K)



WALL
U- Value: 0,80 W/(m²K)

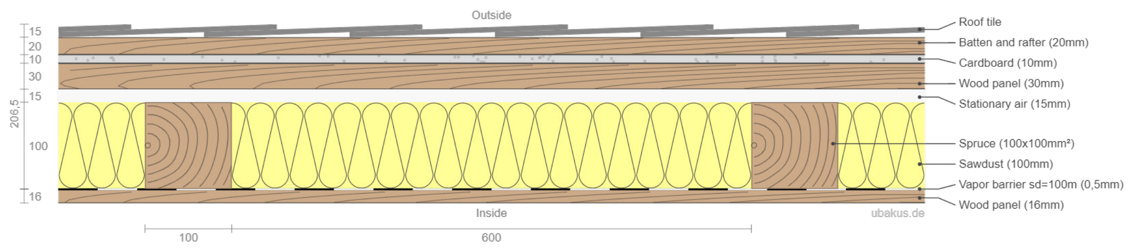


BASEMENT
U- Value: 1,52 W/(m²K)

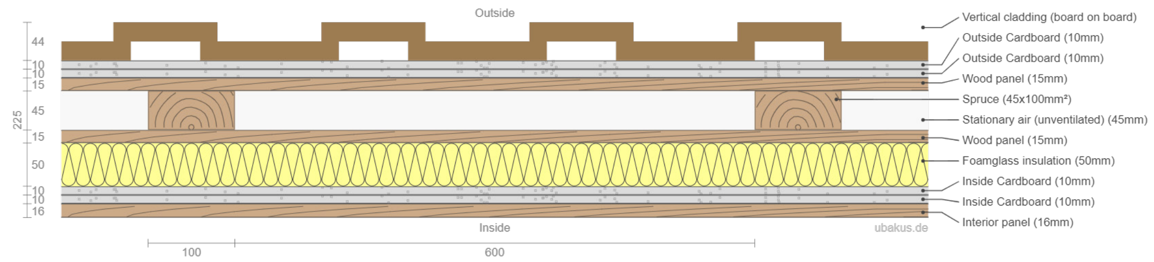


NOW

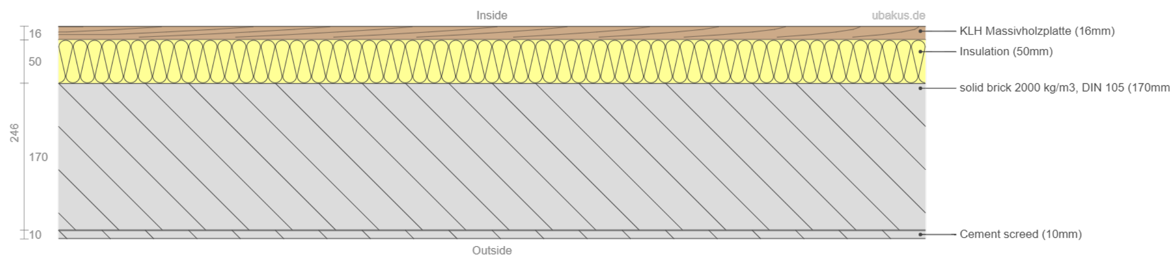
ROOF
U- Value: 0,40 W/(m²K)



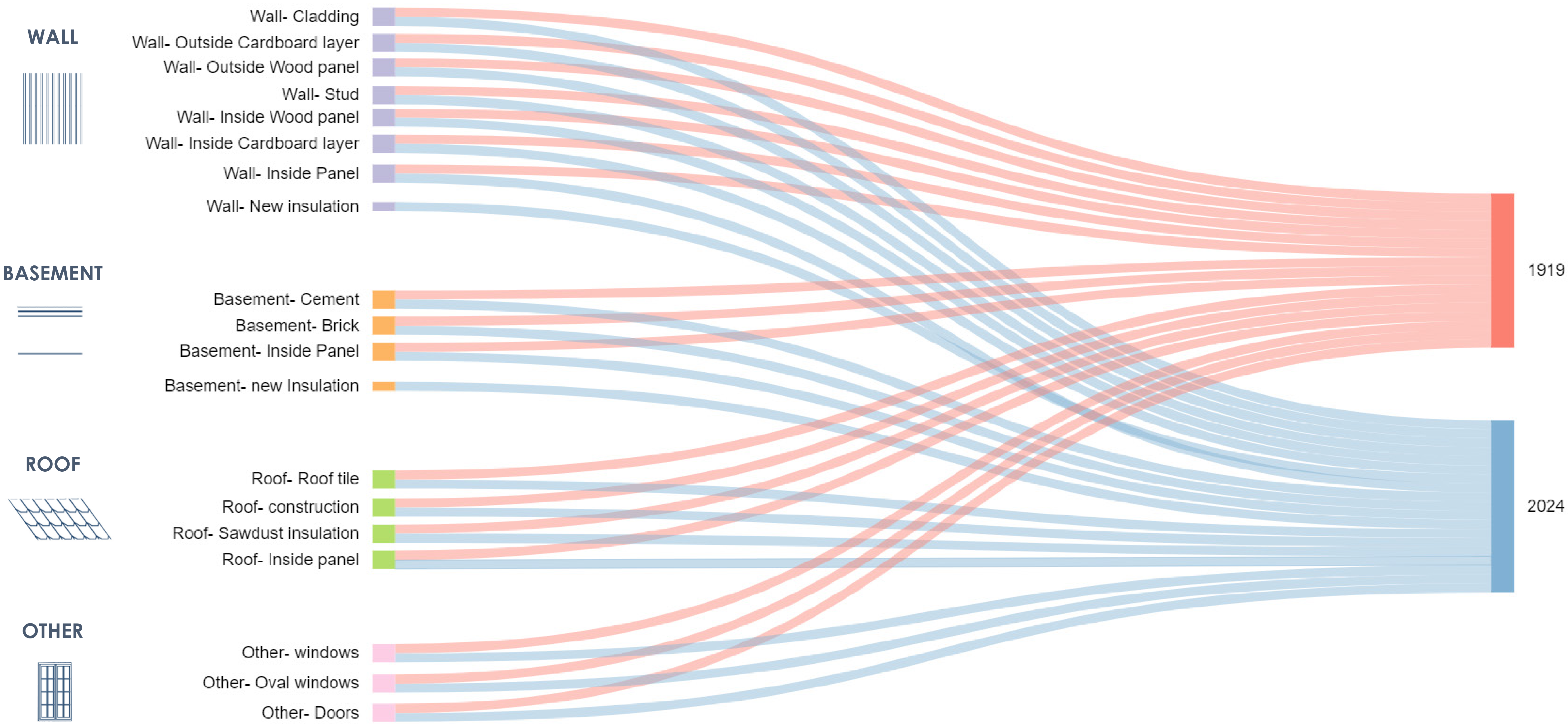
WALL
U- Value: 0,45 W/(m²K)



BASEMENT
U- Value: 0,61 W/(m²K)



MATERIAL FLOW



The material flow diagram illustrates the materials used in the various construction components, including the wall, basement, roof, and others. The red lines represent the materials used in the original 1919 house. The materials with a blue and red line indicate that they were still being used in the house in 2024. The materials added to the house between 1919 and 2024 are represented with a blue line.

06 THERMAL CAMERA

This chapter presents analyses done in Harald Hardrådes gate 35 with a thermal camera. The images taken help to understand the condition of the house and for detecting air leakages and thermal bridges.

THERMAL CAMERA

THERMAL CAMERA PHOTOGRAPHY

Thermal camera photography, also known as thermography, is a technique that uses specialized infrared cameras to detect and visualize the heat patterns and thermal performance of buildings and their components. Thermal cameras can pinpoint areas of excessive heat loss or air infiltration in a building envelope, such as poorly insulated walls, ceilings, or windows.
The pictures can then be used for prioritizing and targeting insulation upgrades or air-sealing measures during renovations. Thermography can also assess the performance of existing insulation materials and reveal any gaps, moisture issues, or defects that compromise their thermal efficiency. This helps determine where additional insulation is needed during renovations. The pictures provide a visual representation of energy loss patterns, allowing the user to monitor the impact of renovation measures on reducing heat loss and improving energy performance. The analyses of thermography are a convenient and cost-effective tool for pre-renovation assessments, especially in protected buildings. The technique is non-invasive and does not require any destructive testing or disassembly of building components (FLIR, n.d.) It could also be used after a renovation project to validate the renovation work. The new images can be used to verify the effectiveness of the energy-efficiency measures implemented, ensuring that the desired performance improvements have been achieved (Hawas & Al-Habaibeh, 2021).

The thermal camera works by detecting and visualizing infrared radiation emitted by all objects based on their temperature. They are equipped with a special lens that focuses infrared radiation onto an infrared sensor array instead of visible light like regular cameras.
The sensor array contains thousands of pixels arranged in a grid. Each pixel reacts to the infrared wavelengths hitting it by converting the infrared radiation into an electronic signal. The electronic signals from the sensor array are then sent to an internal processor. The processor uses algorithms to convert the signals into temperature data and assign different colors or shades to represent different temperature values (FLIR, n.d.)
The processed temperature data is then rendered into a thermal image, with the warmest objects appearing in red/orange and cooler objects in purple/black. This color map visually represents the heat signatures and temperature patterns of the objects or environment (RS, n.d.)

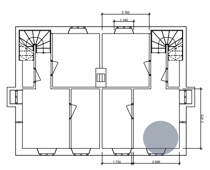
FLUKE CAMERA

The camera used for the analysis is a Fluke Tir32 model. It comes with an extra wide-angle lens to give greater flexibility and to take pictures of larger areas at once.
The camera has batteries that can be recharged and replaced during the examinations if necessary. The menu has three buttons that are used to set the temperature scale and other settings (Fluke, n.d).

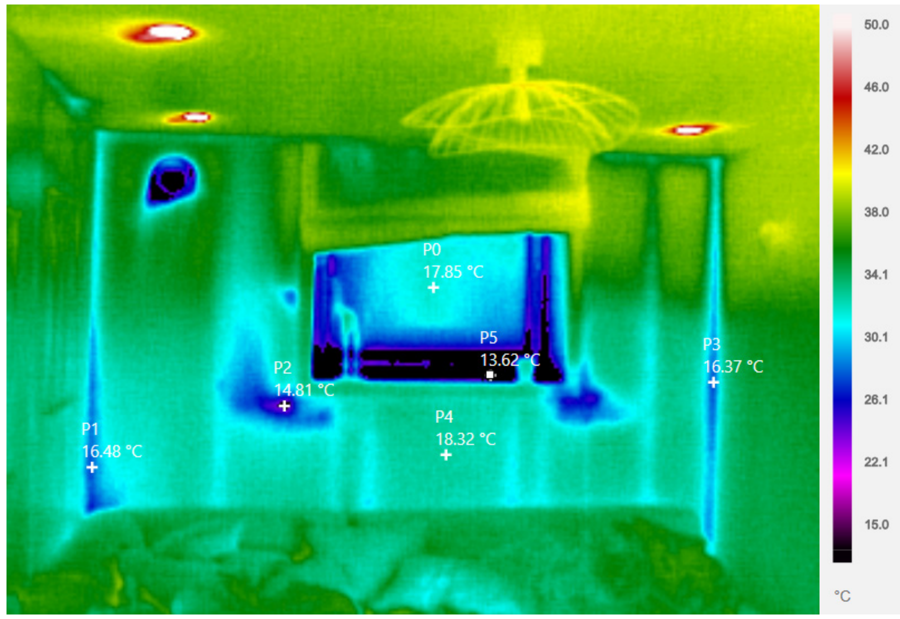
The pictures of Harald Hardrådes gate 35. were taken on the 13. February 2024. The temperatures during that day were average -4,5°C (YR, n.d.).
The pictures were analyzed in Fluke's own analyzing program called Fluke Connect. The program is used by uploading images from the SD card used during the photography. The pictures can then be analyzed individually and further highlight various relevant points in the image. The same settings were set for the images in order to have a comparable material. The color palate was set to high contrast to best see the temperature differences, and the temperature scale was set to 15°C to 50°C.

THERMAL CAMERA RESULTS

PICTURE 1

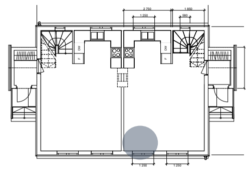


Basement

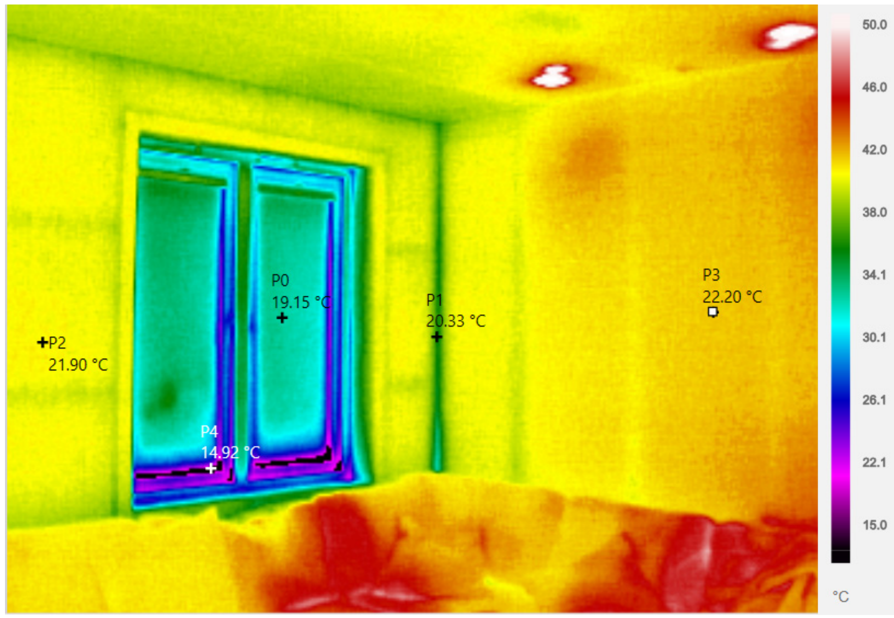


The first picture is of the living room in the basement, facing one of the windows. The wall shows air leakage in the corners. The picture also shows a slightly different temperature on the construction, leading it to show lines on the wall. There is also cooler air entering the building that creates temperature patterns on the wall surface. In the left corner, there is a duct that also leaks cold air. The window has a darker region at the bottom, indicating air leaking around the window frame. The curtain hanging over the upper half of the window appears to stop some of the cold from coming in.

PICTURE 2

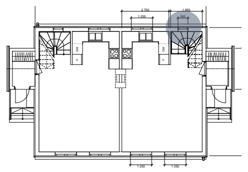


1st floor



The second picture is taken in the living room on the 1st floor, facing the window and the corner. These walls have a higher temperature than the walls in the basement. This is because the owners have reinsulated these walls. There is still some air leakage in the corner, but not as cold as in the first picture. The window has some air leakage around the frame, especially on the bottom.

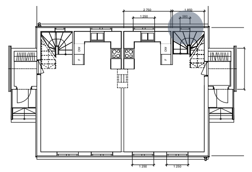
PICTURE 3



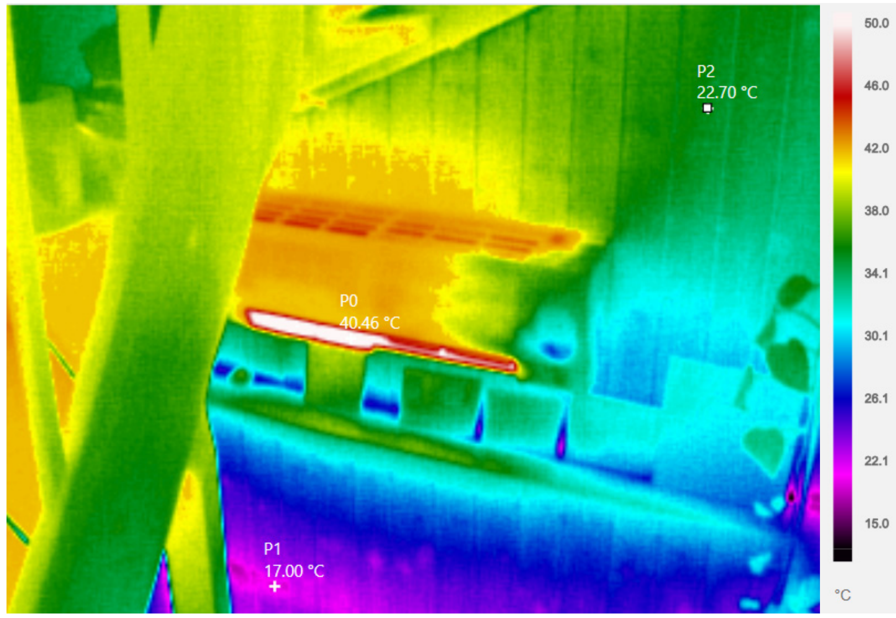
STAIRCASE

The third picture is of the oval window in the staircase. This window is protected and is therefore not allowed to be changed. The glass in the window is original from when the house was built and is a one-layer window. The picture shows that the window is cold because of the thinner glass.

PICTURE 4



STAIRCASE

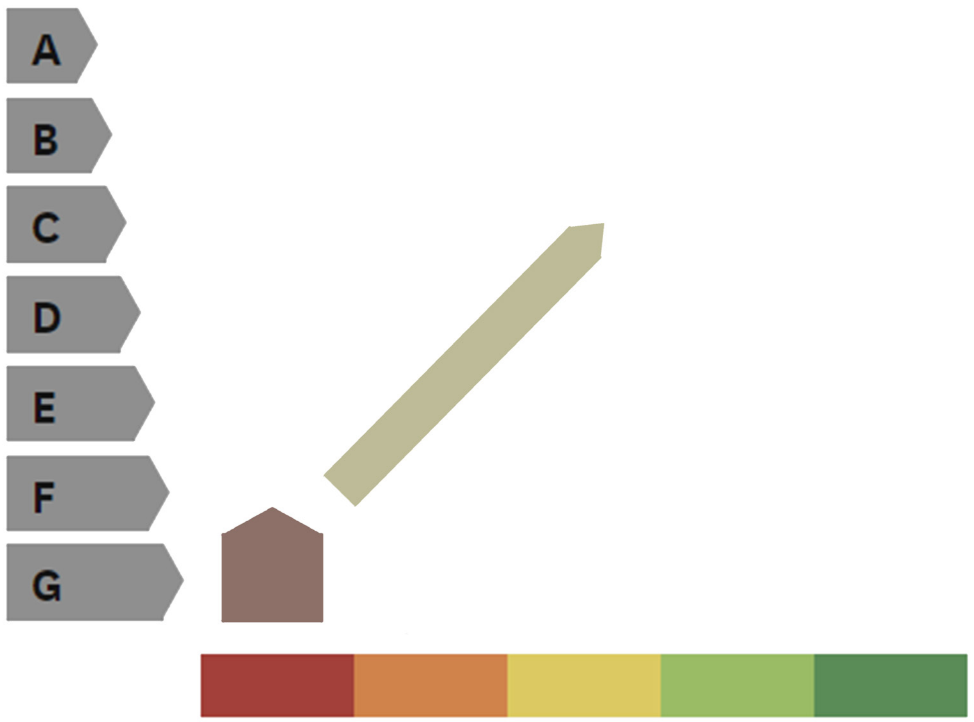


The fourth picture is taken in the staircase leading down to the basement. It shows the air-to-air heat pump. The wall over the heat pump is warmer than the wall under the heat pump. The coldest wall is in the basement and has approximately the same temperature as the rest of the basement wall shown in the first picture.

07 SIMIEN ENERGY ANALYSIS

This chapter presents the simulations done with the SIMIEN energy program on the original house from 1919 and the sample house in 2024. The results are then compared to see the differ-ences and the upgrades that have been done over time.

ENERGY LABEL



The values that determine the energy rating are different for different buildings. The houses in Marinevold Hageby fall within the category of detached houses. The following values apply to the various grades:
A: Lower than or equal to 95 kWh/m2
B: Lower than or equal to 120 kWh/m2
C: Lower than or equal to 145 kWh/m2
D: Lower than or equal to 175 kWh/m2
E: Lower than or equal to 205 kWh/m2
F: Lower than or equal to 250 kWh/m2
G: All higher values

The heating grade is provided in five parts, from red to green, and is calculated using the systems installed for heating and tap water in the house. The best grade is green, which is provided when the house includes systems that allow for the use of a large proportion of energy products other than electricity, oil, or gas, but the use of only fossil fuels and direct usage of electricity receives the red grade.
The proportion of electricity and fossil fuel must be below the following values to achieve the various color gradings:
Dark green: 30%
Light green: 45,5%
Yellow: 65%
Orange: 82,5%
Red: 100%

(Førland-Larsen. Et al., 2011)

ENERGY MARKING ENOVA

Enova offers energy labeling for homes. This is done by the homeowners themselves by logging in and entering information about the home, but they can also get others to do it if desired. The homeowner chooses if they want a simple or detailed evaluation. The simple one only requires that they enter information that is absolutely necessary to create an energy label, such as type of building, year of construction, area of use, and heating method. The detailed one is used if they have made structural changes such as new windows, new insulation, extensions, or similar since the home was new, or if they want the most accurate energy certificate possible (Enova, n.d.b).

In Enova, you can also log in to see the energy markings on almost all buildings in Norway. All the energy labels added to the homes in Marinevold Hageby are marked on the map. The houses that lack an energy label were most likely sold before the requirements for energy labeling came in 2010. The house that is being examined and simulated as an example house (Harald Hardrådes gate 35B, 7030 TRONDHEIM) was last energy labeled on January 31, 2019, and was then given an energy rating of G and a heating rating of orange.
Measures should therefore be proposed that can increase the energy rating and improve the heating rating from the current rating of G-orange for the building to meet the European Commission's energy requirements. The SIMIEN simulations will also check if G is the correct energy grade or not.

SIMIEN

The SIMIEN Energy Program is a simulation tool designed to analyze energy use and indoor climate in buildings. It is utilized to model and predict the performance of the building. SIMIEN allows users to assess the energy consumption of buildings, such as energy calculations, evaluation, and energy labeling.

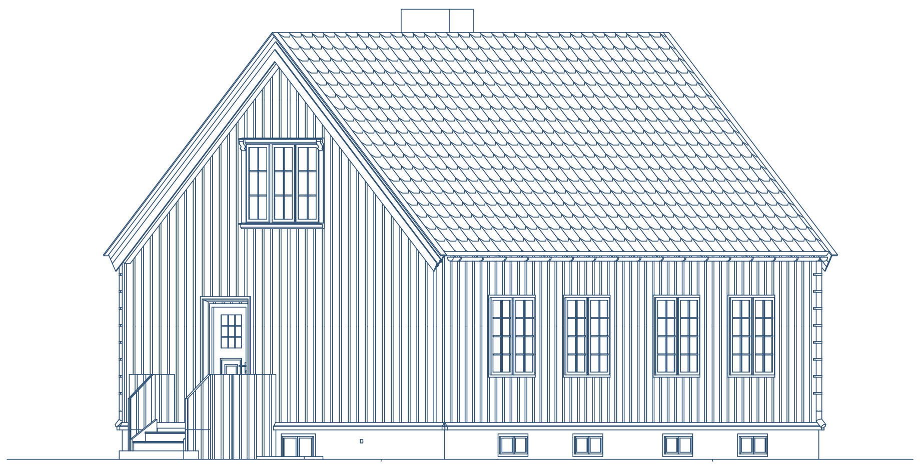
A range of data about the building is needed to make energy calculations. The first thing to do is to start collecting data on general conditions such as location so that the program can collect climate data automatically, as well as the building category so that automatic values that are not specific to the simulated house will be correct in the rest of the simulation. The location is here set to Trondheim with the category residential house.

Furthermore, data for the design of the building must be entered into the program. These values are entered into a zone, in this case, the entire house is entered as one zone and set as a vertically divided house with two apartments. Information about the interior of the house, operating days, and infiltration must also be entered here. The operating days are the whole year and are the same for all the simulations. After this, the various building elements such as the basement, walls, floor, windows, doors, and roof are added. Values must also be entered here for the various building parts such as construction, heat storage in the inner layer, and orientation. It is this information that determines the u-values used in the simulation. There are some preselections, but because the simulations have been carried out on buildings from before the current standard, other u-values have been entered which are calculated in Ubacus. After the building parts have been inserted, technical elements and energy sources must be added. Finally, after entering all the necessary information about the house, is the desired simulations ready to run. The simulations that have been run in this analysis are annual simulations to see how the house operates throughout the year and in the various months, and energy label simulations to get the energy and heating rating.

All the simulations are done on the house at Harald Hardrådes gate 35. This is the same house where the thermal images were taken. It is used as a sample house because it is representative of all the houses in Marinevold Hageby.

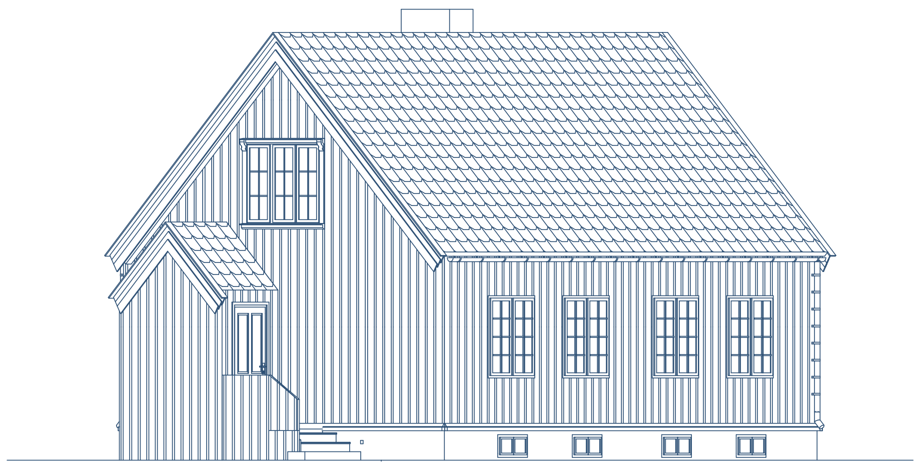
ORIGINAL

In the simulation for the original house from 1919, are the general conditions the same as in the other simulations. The leakage number is set to 4 (N50) [1/h] because this was the requirement in TEK 1997 (Relander, 2008). The only heating source used in the house in 1919 was a fireplace. Natural ventilation was used for ventilation. The U-values in the walls, floor, roof, and basement are simulated in Ubacus and are shown on the facades and floors below. The U-values for the windows are assumed from the building regulations of the 1940s (Enova, 2012).



NOW

Since 1919, 50mm insulation has been installed in the walls and basement of the current house. New modern windows and doors were also installed. U-values are determined using Ubakus and given below. The new entrance area is not simulated because it is unheated. The leakage number has been updated to 2.5 (N50) [1/h]. A heat pump has also been installed to provide heating, as well as hot water, and ventilation. Appliances, lights, and technical equipment have also been included.



ORIGINAL

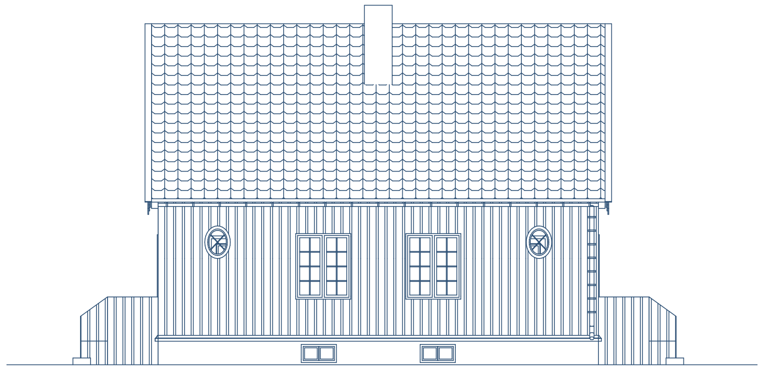
NORTH FACADE

WALL
– Total area incl. windows: 36 m2
– U-value: 0,80 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 335°

WINDOW X1
– Size: height: 1.45m, idth: 1.75m
– U-value: 3,00 W/m2K

DOOR
– Size: 2,50 m2
– U-value: 2,50 W/m2K

EAST FACADE



WALL
– Total area incl. windows: 35 m2
– U-value: 0,80 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 245°

WINDOW X2
– Size: height: 1.45m, idth: 1.25m
– U-value: 3,00 W/m2K

WINDOW OVAL X2
– Size: height: 1.45m, idth: 1.25m
– U-value: 3,00 W/m2K

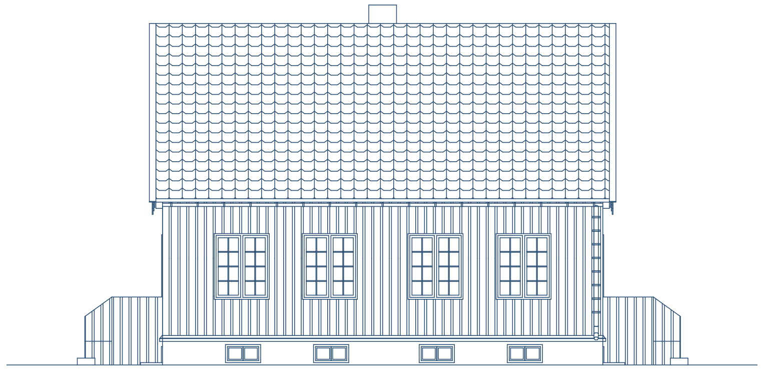
SOUTH FACADE

WALL
– Total area incl. windows: 36 m2
– U-value: 0,80 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 115°

WINDOW X1
– Size: height: 1.45m, idth: 1.75m
– U-value: 3,00 W/m2K

DOOR
– Size: 2,50 m2
– U-value: 2,50 W/m2K

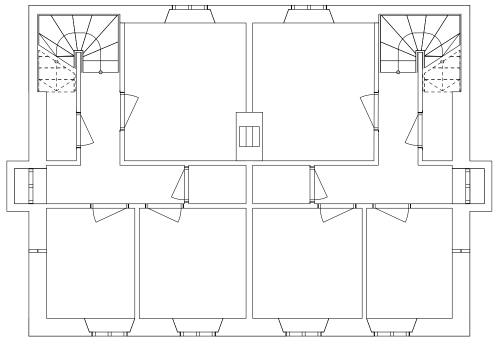
WEST FACADE



WALL
– Total area incl. windows: 35 m2
– U-value: 0,80 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 245°

WINDOWS X4
– Size: height: 0,72m, idth: 0.58m
– U-value: 3,00 W/m2K

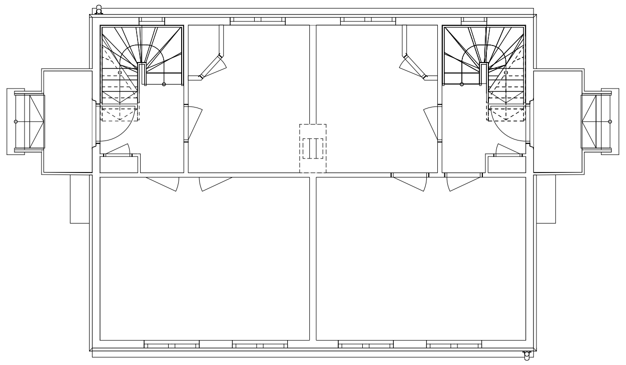
BASEMENT



FlOOR
– Total area incl. windows: 62 m2
– U-value: 1,52 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K

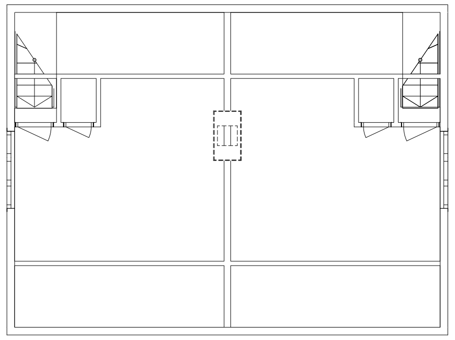
WINDOWS X6
– Size: height: 0.80m, idth: 1.40m
– U-value: 3,00 W/m2K

1ST FLOOR



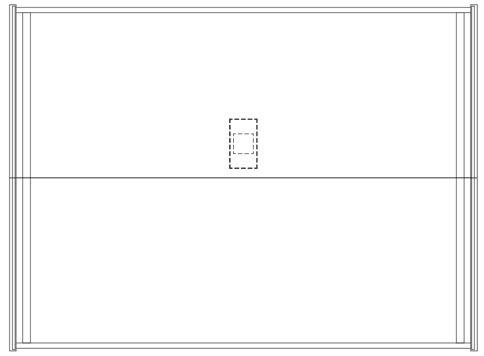
FLOOR
– Total area incl. windows: 69 m2
– U-value: 0,26 W/m2K
– Heat storage inner layer- Heat capacity: 11,20 Wh/m2K

2ND FLOOR



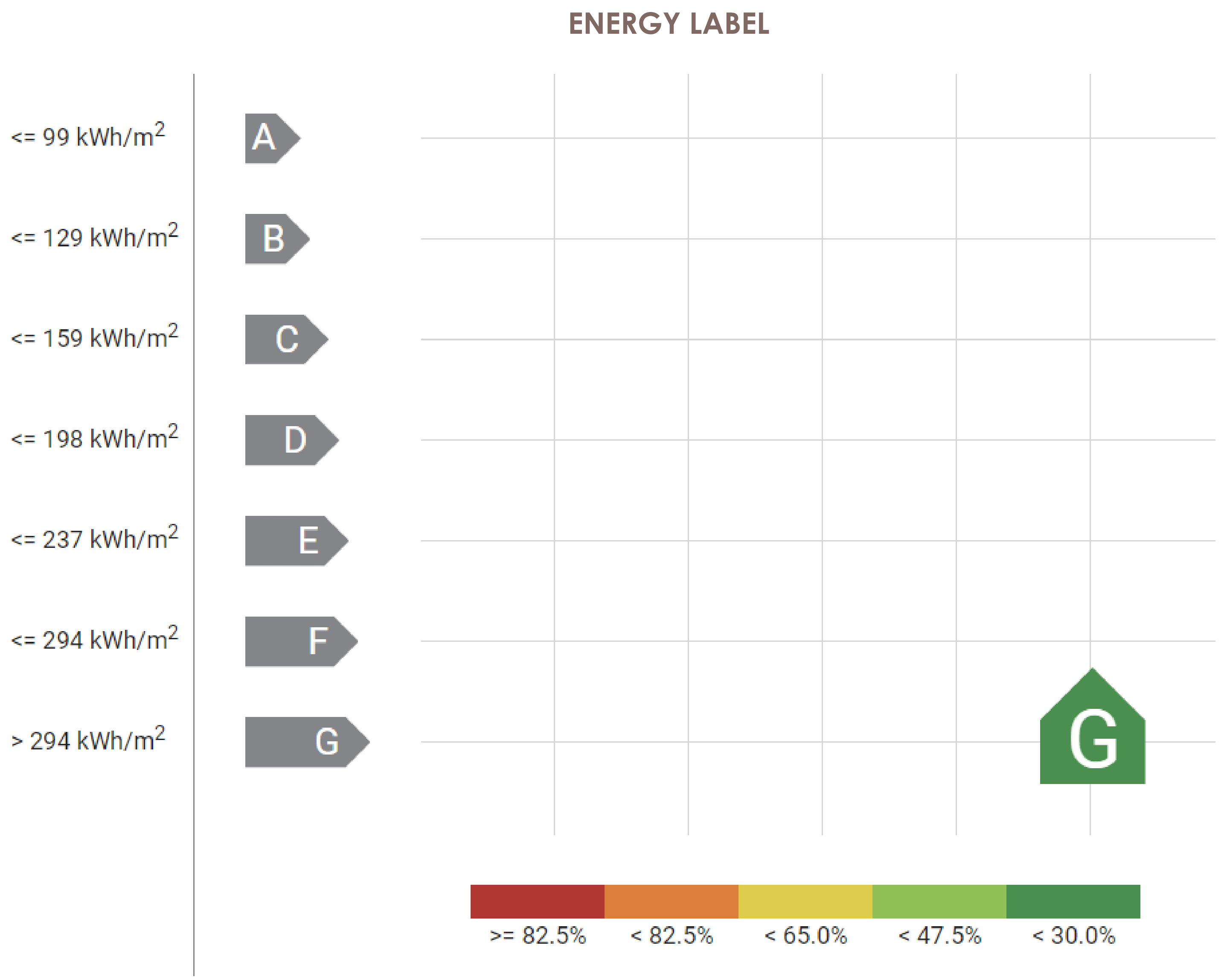
FLOOR
– Total area incl. windows: 69 m2
– U-value: 0,26 W/m2K
– Heat storage inner layer- Heat capacity: 11,20 Wh/m2K

ROOF



ROOF
– Total area incl. windows: 80 m2
– U-value: 0,40 W/m2K
– Heat storage inner layer- Heat capacity: 4,46 Wh/m2K

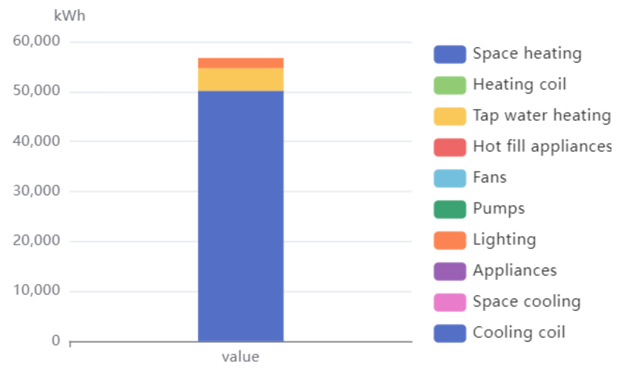
RESULTS ORIGINAL



The simulation gave the result G as the energy mark, with a dark green heating character. It is also significantly below the set point of grade G with the estimated delivered energy with a normalized climate of 361 kWh/m2. The total share of electricity/oil/gas of net heating demand is 14.5%.
The results were expected because the house is of a lower standard than today's requirements for buildings. The character is dark green because the heating source is biofuel (wood).

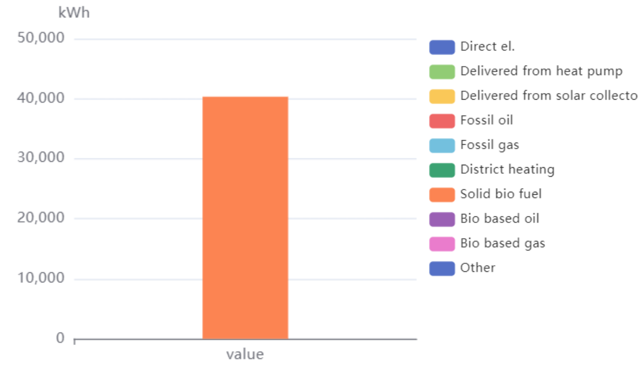
NET ENERGY NEED

The net energy needed is divided into space heating, tap water heating, and lightning. The big-gest net energy need is for space heating, with the need for 50,172.3 kWh of a total of 50,172.3 kWh.

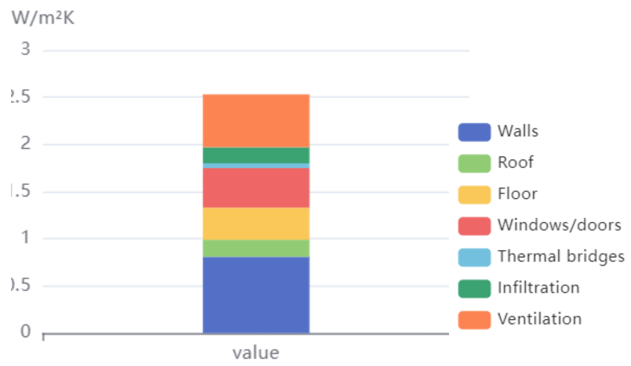


SHARES HEATING

All the heating comes from solid biofuel because the fireplace was the only heat source and used wood for heating. The total is 50,172.3 kWh



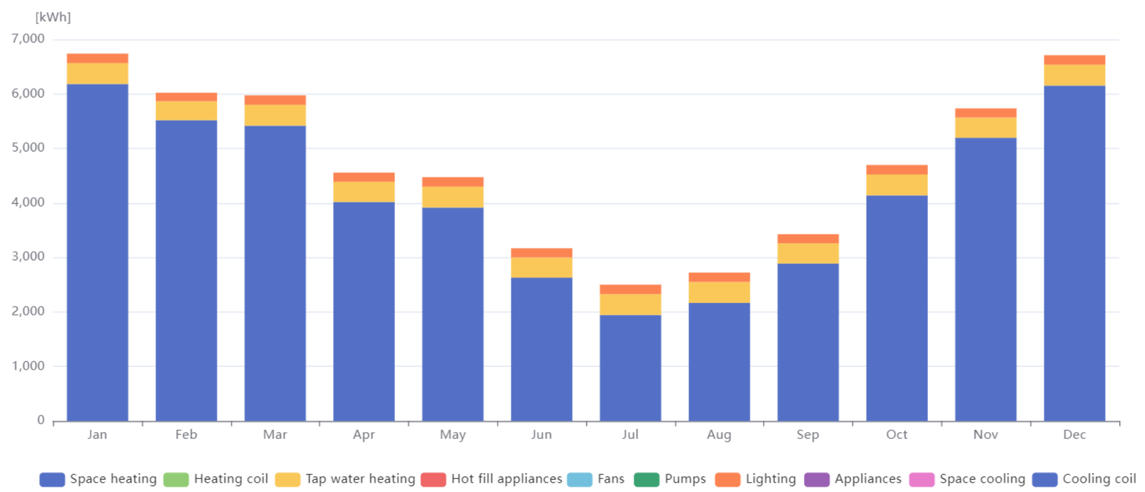
SPECIFIC HEAT LOSSES



The heat loss shows the distribution of heat loss in the building. The walls account for the biggest heat loss of 0.81 W/m²K of a total of 2.53 W/m²K.
There is also heat loss in the roof, floor, window, and ventilation, but also in thermal bridges and infiltration.

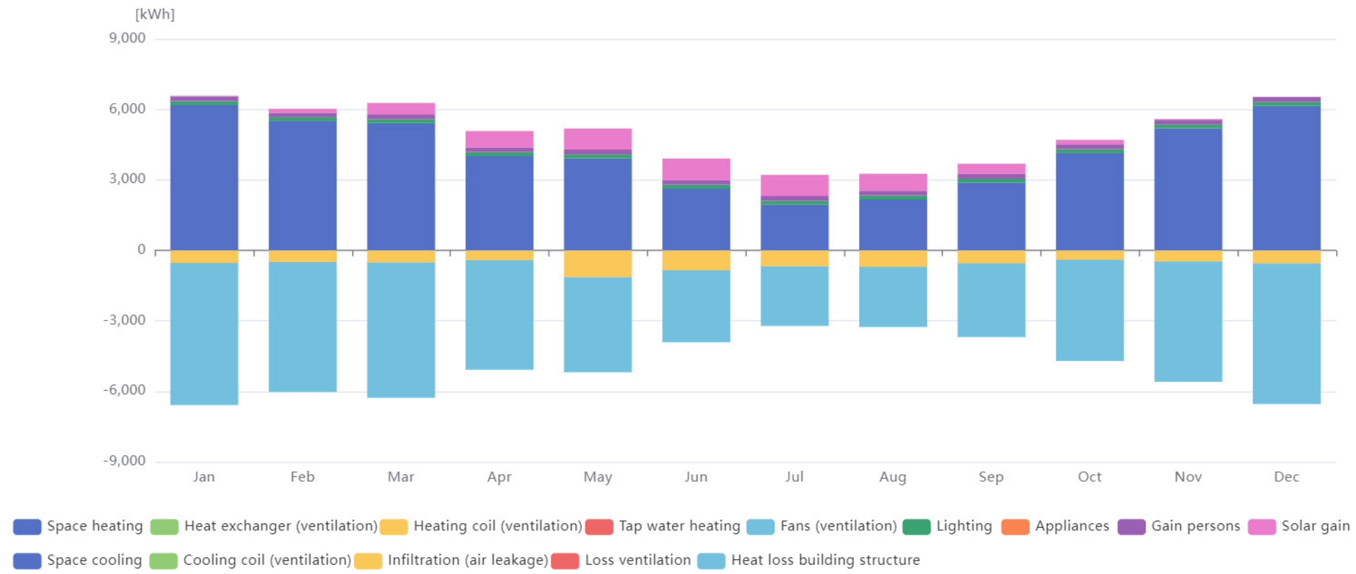
MONTHLY NET ENERGY NEED

The monthly net energy need shows the energy need for each month during the year. There are generally more energy needs in the winter months than in the summer months. The month with the lowest energy need is July and the highest is January.

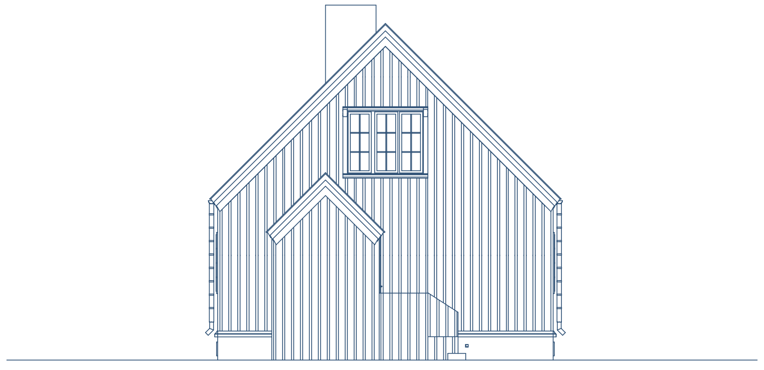


MONTHLY HEAT BALANCE

The heat balance shows the heat gains and losses in the house. The heat losses come from the building structure, as well as from air leakage. The heat gain comes mostly from space heating, but also from lighting, people, and solar gain mostly in the summer months.



NORTH FACADE

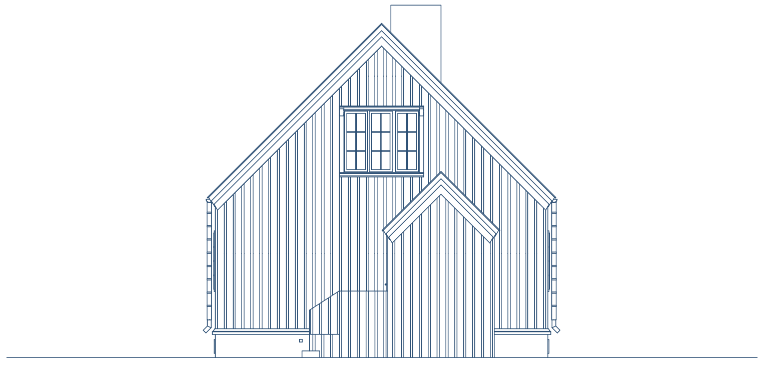


WALL
– Total area incl. windows: 36 m2
– U-value: 0,45 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 335°

WINDOW
– Size: height: 1.45m, idth: 1.75m
– U-value: 1,10 W/m2K

DOOR
– Size: 2,50 m2
– U-value: 1,20 W/m2K

SOUTH FACADE

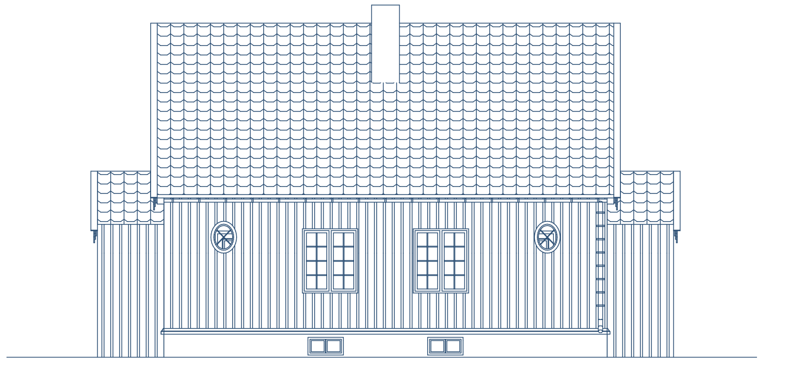


WALL
– Total area incl. windows: 36 m2
– U-value: 0,45 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 115°

WINDOW
– Size: height: 1.45m, idth: 1.75m
– U-value: 1,10 W/m2K

DOOR
– Size: 2,50 m2
– U-value: 1,20 W/m2K

EAST FACADE

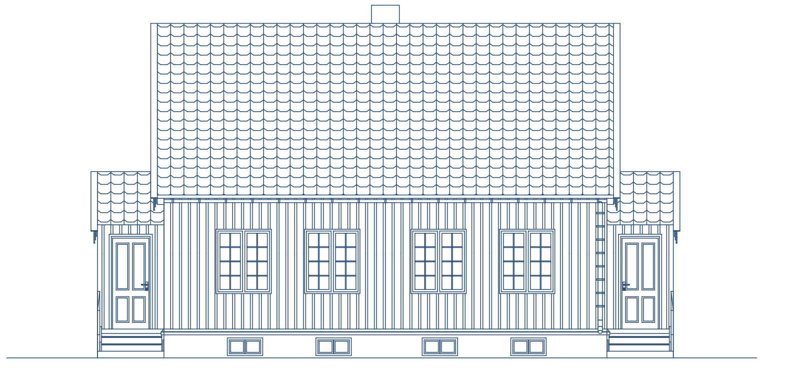


WALL
– Total area incl. windows: 35 m2
– U-value: 0,45 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 245°

WINDOW X2
– Size: height: 1.45m, idth: 1.25m
– U-value: 1,10 W/m2K

WINDOW OVAL X2
– Size: height: 1.45m, idth: 1.25m
– U-value: 3,00 W/m2K

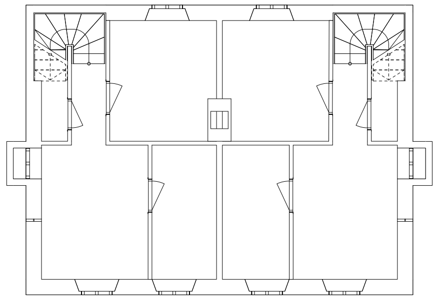
WEST FACADE



WALL
– Total area incl. windows: 35 m2
– U-value: 0,45 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 245°

WINDOWS
– Size: height: 1.45m, idth: 1.25m
– U-value: 1,10 W/m2K

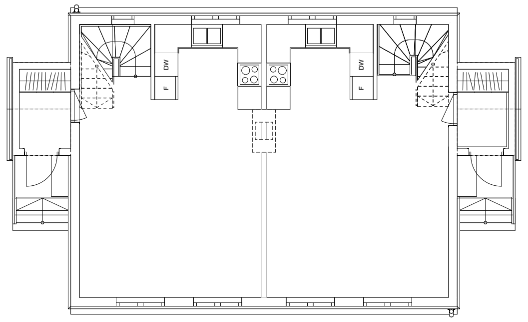
BASEMENT



FlOOR
– Total area incl. windows: 62 m2
– U-value: 0,61 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K

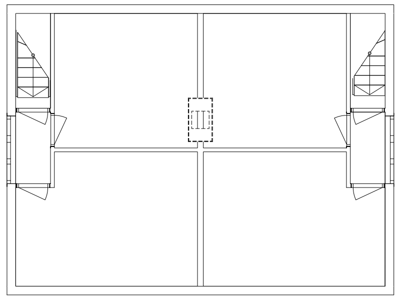
WINDOWS X6
– Size: height: 0.80m, idth: 1.40m
– U-value: 3,00 W/m2K

1ST FLOOR



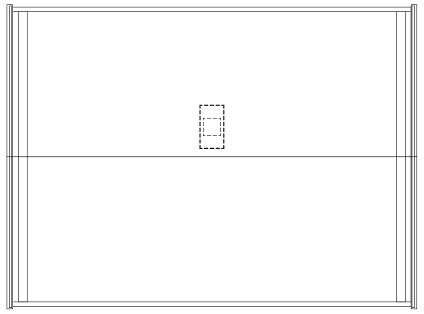
FLOOR
– Total area incl. windows: 69 m2
– U-value: 0,26 W/m2K
– Heat storage inner layer- Heat capacity: 11,20 Wh/m2K

2ND FLOOR

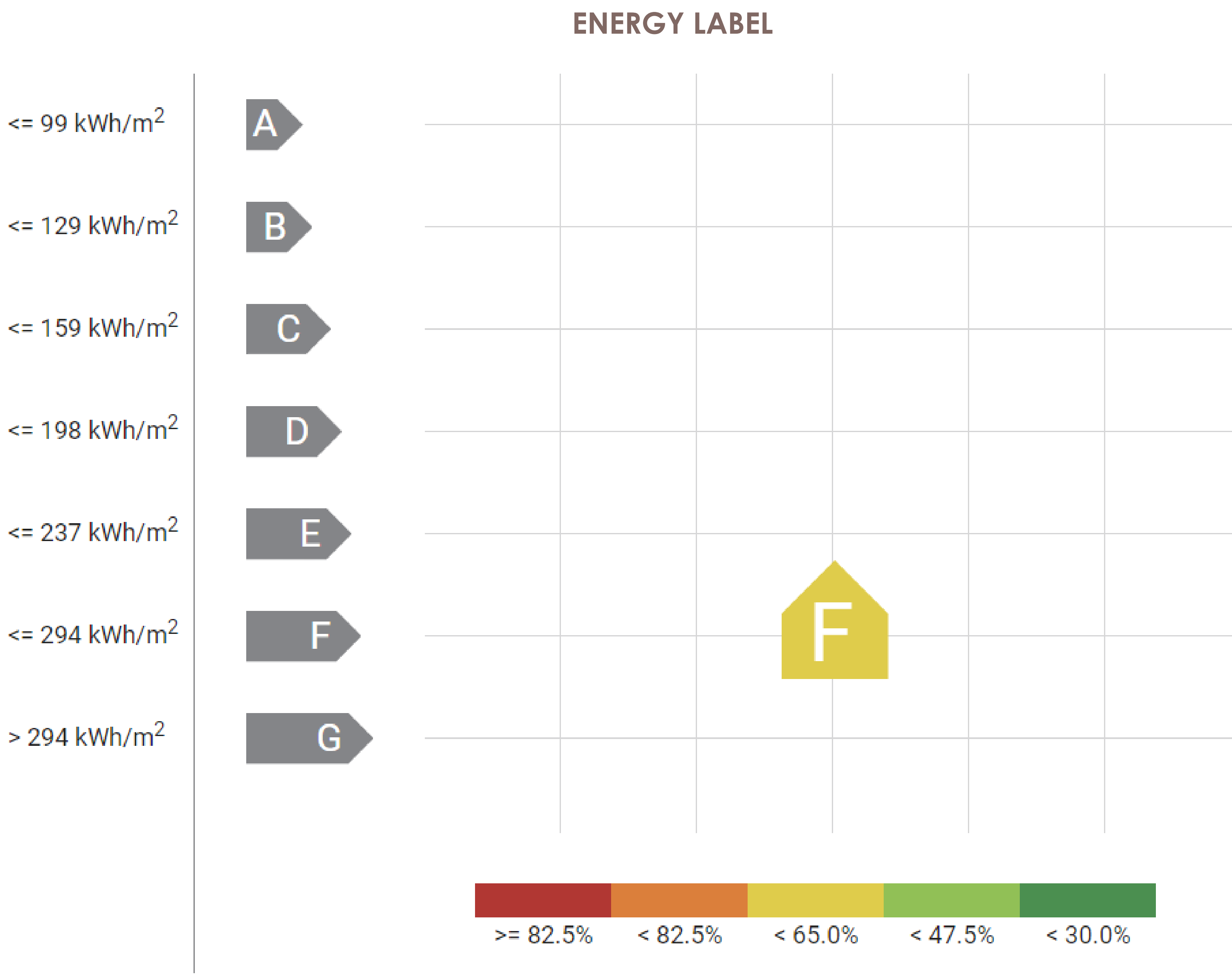


FLOOR
– Total area incl. windows: 69 m2
– U-value: 0,26 W/m2K
– Heat storage inner layer- Heat capacity: 11,20 Wh/m2K

ROOF



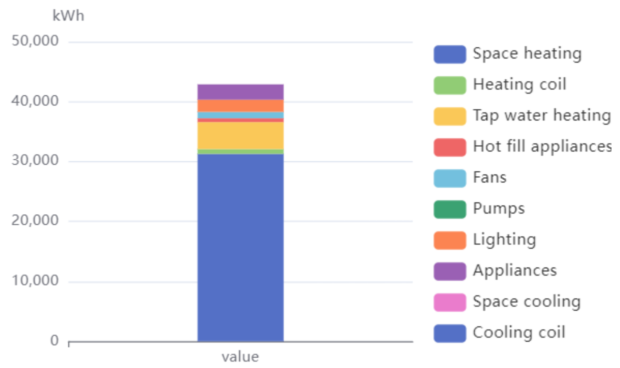
ROOF
– Total area incl. windows: 80 m2
– U-value: 0,40 W/m2K
– Heat storage inner layer- Heat capacity: 4,46 Wh/m2K



The simulation gave the result F as the energy mark, with a yellow heating character. The energy label is therefore better than the simulation done by Enova, which gave the house an energy mark G.
The heat pump causes the color of the label to be yellow because 55.2% of the heating demand is covered by electricity heating. The estimated delivery of energy in normalized climate is 262 kWh/m2.

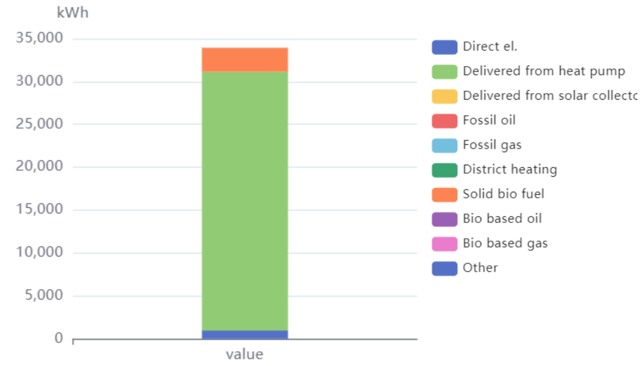
NET ENERGY NEED

The net energy needed is divided into space heating, heating coil, tap water heating, Hot fill appliances, fans, lighting, and appliances. The biggest net energy need is for space heating, with the need for 31,278.8 kWh of a total of 42,873.2 kWh.

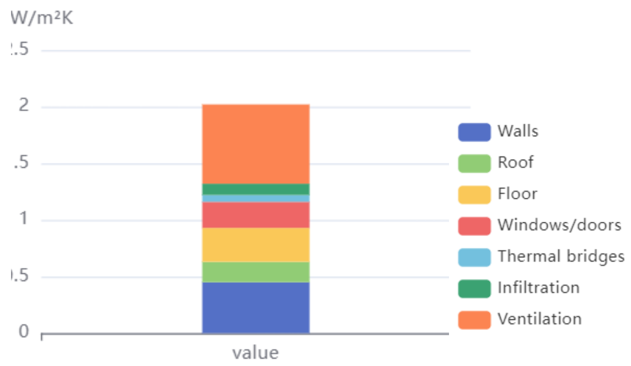


SHARES HEATING

Most of the heat is delivered from the heat pump. The rest is delivered from solid biofuel (fireplace) and some from direct el. The total is 33,934.6 kWh.



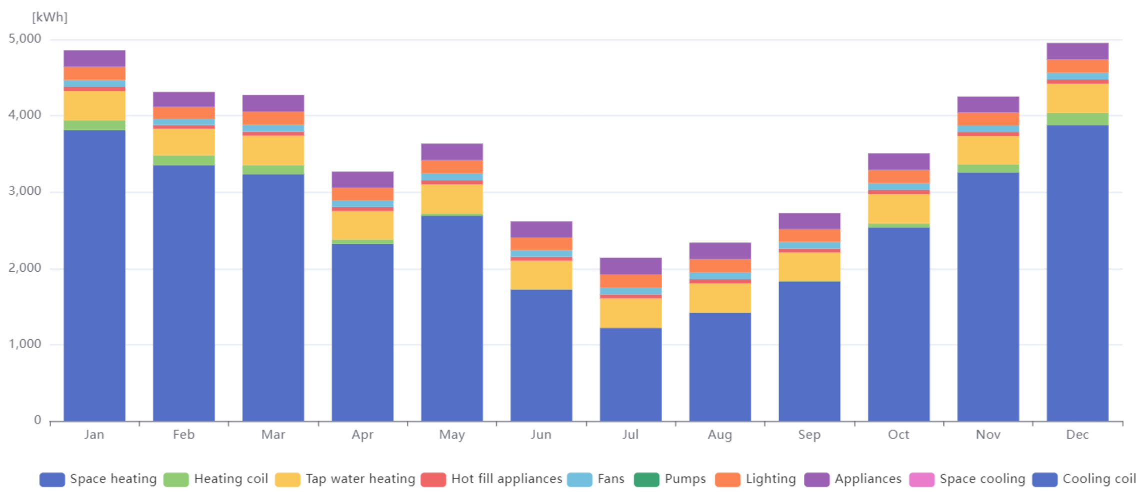
SPECIFIC HEAT LOSSES



The biggest heat loss is in the ventilation with 0.7 W/m²K of a total of 2.02 W/m²K. There is also heat loss in the walls, roof, floor, and window, but also in thermal bridges and infiltration.

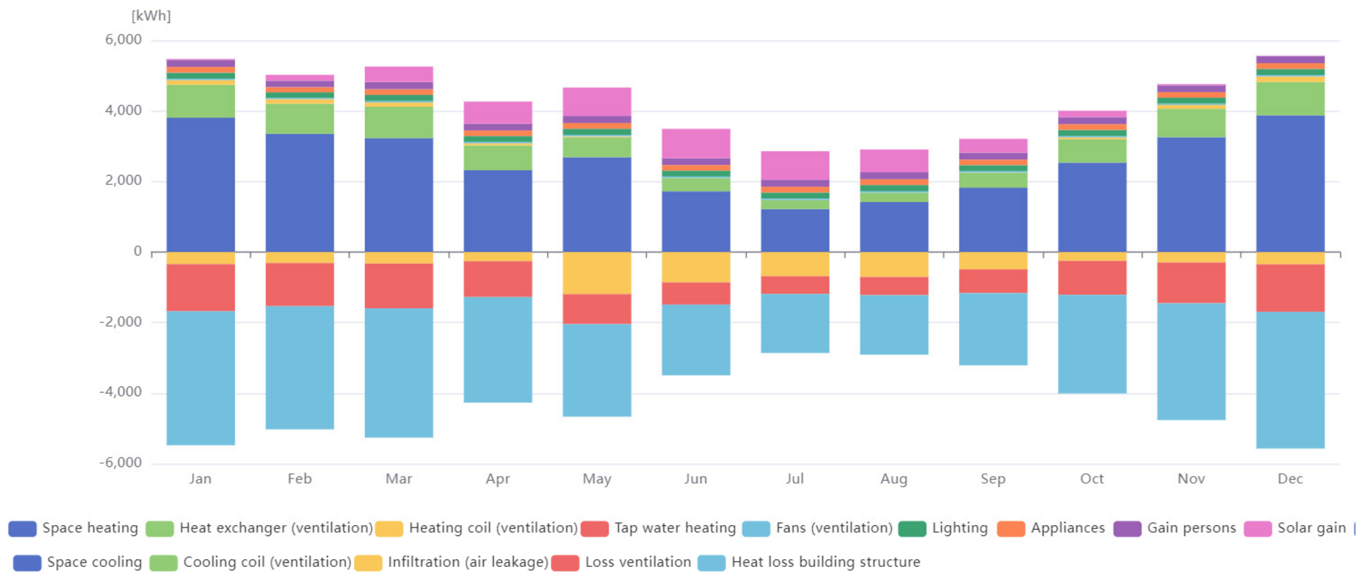
MONTHLY NET ENERGY NEED

The month with the lowest energy need is July and the highest is December, because of the higher demand on the heating coil.



MONTHLY HEAT BALANCE

The heat losses come from the building structure and air leakage, but also from loss through the ventilation system. The heat gain comes mostly from space heating. It also comes from the heat exchanger in the ventilation, people gain, solar gain, appliances, lighting, fans, and from the heating coil in the winter months.



COMPARISON ORIGINAL (1919) VS. NOW (2024)

	ORIGINAL	Both	NOW
Energy label	G- dark green		F- yellow
Estimated delivered energy	361 kWh/m2		262 kWh/m2
Heating demand covered by el./oil/gas	14.5%		55.2%
Net energy needs total	50,172.3 kWh		42,873.2 kWh
Biggest energy needs source		Space heating	
Biggest monthly net energy need	January		December
Lowest monthly net energy need		July	
Shares heating total	50,172.3 kWh		33,934.6 kWh
Highest heat delivery source	Fireplace		Heat pump
Heat loss total	2.53 W/m^2K		2.02 W/m^2K
Biggest heat loss source	Walls		Ventilation

The changes done to the house from 1919 to 2024 have made the energy mark go from G to F.
It has also reduced the energy usage by 27, 42%.

08 ENERGY COMMUNITY

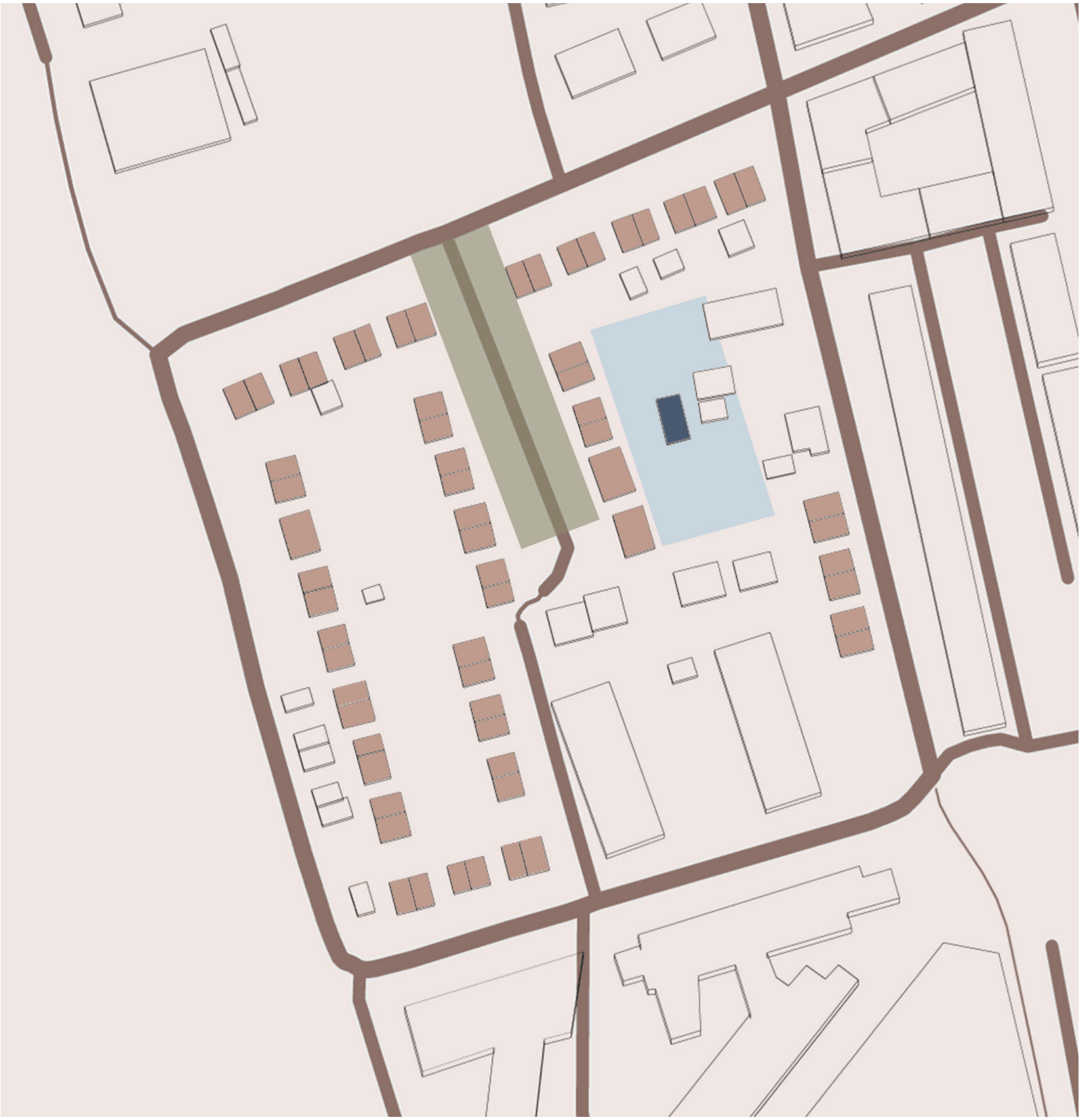
This chapter presents what energy communities are and proposals for how the method can be included in the neighborhood in Marinevold Hageby.

ENERGY COMMUNITY

Energy communities are neighborhoods, communities, or an area of buildings that cooperate to produce, manage, and consume their own renewable energy at a local level. Energy communities aim to increase energy efficiency, reduce energy costs for members, promote sustainable energy production, and enable citizen participation in the transition to more energy-efficient cities (Enel X Corporate, n.d.).

The European Union has introduced specific legislation recognizing "renewable energy communities" and "citizen energy communities" to encourage establishment across member states. They want the member states to adapt in a way that energy communities can participate on an equal level as larger participants. They have also developed a "Support Service for Citizen Led Renovation" which will help communities to develop their energy communities. The service will help the community overcome legal, financial, technical, and information problems. They have already supported 4 pilot projects in Belgium, Portugal, Ireland, and Bulgaria in 2023, and are supporting new projects in 2024 (European Commission, n.d.).

MARINEVOLD HAGEBY AS AN ENERGY COMMUNITY



The community in Marinevold Hageby can install a solar garden like the reference project presented earlier (Watkins, 2020). It could be placed in the community garden and on the roof of the community house marked in blue on the map. There will assumingly not be produced enough energy to cover all the energy needed for the houses, but it could be an opportunity to lower the energy bills.
Another opportunity for Marinevold Hageby is to do a common ground source heat system like the other reference project has done (Peters, 2023). It could be an efficient way to heat the houses in a renewable way. It is also a cost-effective way of heating because the system is commonly installed, and not individually on each plot. A good placement for the system could be in the middle of the Hageby, under the road. The suggested placement is marked on the map in green.

Sandberg et al. (2023) proposes some measures that authorities should explore and consider implementing in the long run in order to save more energy. One of these measures is about opening for neighborhood sharing of electrical energy. The proposal concerns that buildings within an energy location must be able to connect and share energy. Further, must agreements be developed for neighborhood energy sharing, and current regulations be modified to allow for energy storage and consumption at the local level (Sandberg et al, 2023).

09 FUTURE POTENTIAL AND DISCUSSION

This chapter presents simulations of proposals for changes and measures that can be taken to reach the EU energy goals by 2035. The simulations aim to identify and evaluate the most effective renovation measures for enhancing energy efficiency in the sample house. The measures that have been tested are an outcome of the other analyses and research that have been carried out earlier in the project. Lastly is a discussion including discussions on result reliability, challenges and limitations, and future research presented.

FUTURE POTENTIAL

The EU Commission's energy goal is to "reduce the average primary energy use of residential buildings by 16% by 2030 and 20-22% by 2035" (European Commission, 2023). The research, BIM, and thermal camera imaging have helped gain the information needed to simulate the house in its current state (2024). This simulation gave the house the energy grade G. It is necessary to take some measures for the house to reach the energy goal by 2035. The earlier simulations and research can help with finding the weak points in the building, and therefore what measures need to be taken.

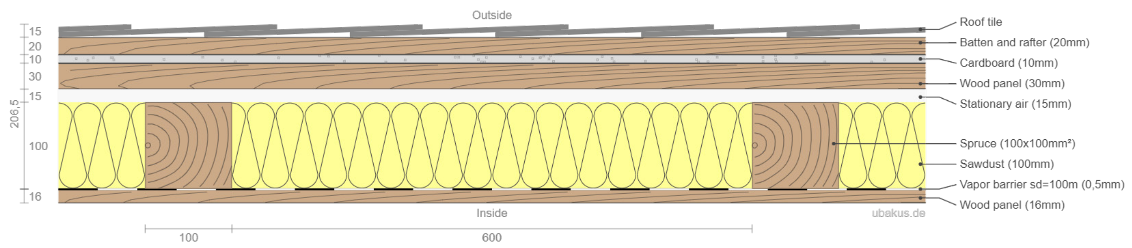
The measures chosen are air tightening, insulating walls and the basement, and adding solar panels as a renewable energy source. The potential of solar energy is tested with a solar analysis simulation in Autodesk Forma. The three measures are first added to the 2024 simulation by themselves to see the isolated effect of each of them. They are then added together to get the final simulation result to see if the measures are enough to reduce the average primary energy use by 20-22% by 2035.

The air tightening measure involves using the pictures from the thermal camera analysis to find and tighten air leakages. The result of the tightening is assumed a reduction in the leakage number from 2.5 (n50) [1/h] to 2.0 (n50) [1/h].

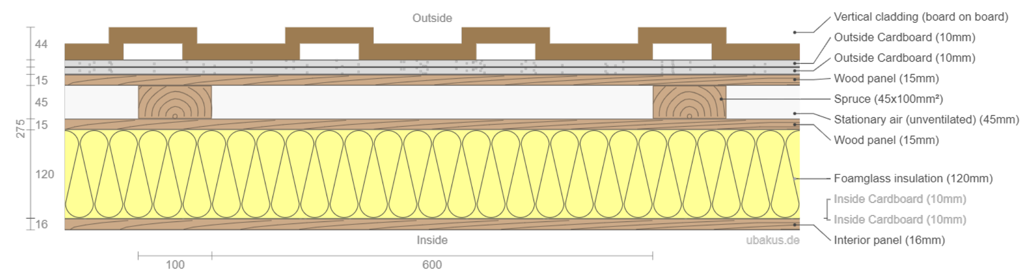
The insulation measure involves adding insulation to the walls and the basement. The walls and basement were insulated sometime between 1919 and 2024 with 50mm, but changing the insulation to 120mm in the walls and 100mm in the basement will give a reduction in u-value from 0,45 W/(m²K) to 0,28 W/(m²K) in the walls and, from 0,61 W/(m²K) to 0,38 W/(m²K) in the basement. The new insulation in the walls and the basement is added on the inside to not change the façade because the building is protected. The roof already has 100mm of insulation. There is therefore no added insulation to the roof in the simulation, but the insulation should be changed if needed when adding the solar panel roof tiles. The new u-values and details are shown in the picture.

The last measure is to add solar panel roof tiles. The roof tiles are chosen because they can get approved on protected buildings, unlike normal panels that are more visible. The panels are added on 30% of the roof.

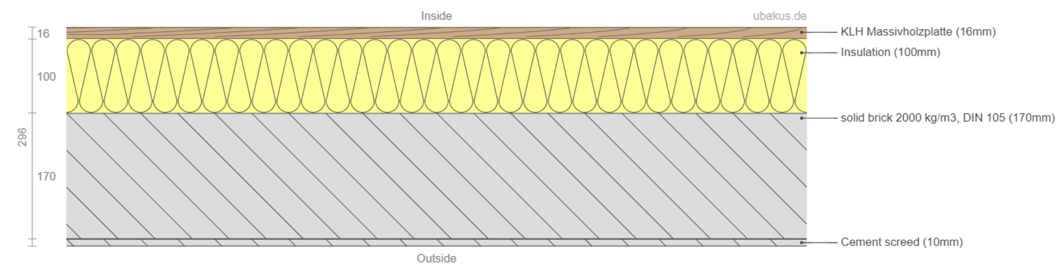
ROOF
U- Value: 0,40 W/(m²K)



WALL
U- Value: 0,28 W/(m²K)



BASEMENT
U- Value: 0,38 W/(m²K)



SOLAR PANEL CALCULATION

Filter building surfaces

Filtered surfaces between 0-75 degrees

Selected surface area	4,194m²

Annual solar energy potential

Total solar energy	3,110,000 kWh
Average solar energy	740 kWh/m²

Solar panel configuration

Surface coverage	30 %
Panel efficiency	20 %

Estimate energy from solar panels

Panel placement area	1,258 m²
Annual electrical output	148,000 kWh

Solar panels are a renewable energy source that produces clean, renewable electricity directly from the sun. By producing its own electricity on-site, the houses are less dependent on the central power grid. Although the investment cost may be high initially, solar panels will over time provide significant energy savings, increase energy security, and reduce greenhouse gas emissions for the building. This makes them a good energy-saving measure to reach the EU Commission's energy goals (Aggarwal, 2014).

The type of solar panel, the amount of light that falls on it, and the temperature influence the panel's output. A panel's output reduces when the amount of light falling on it decreases. Another reason for a reduced output is that the conversion efficiency decreases by approximately 0.38% per °C increase in panel temperature (Melis et al, 2014). The Norwegian colder climate may therefore be good for producing solar energy.

The solar analysis done in Autodesk Forma can give indications of the potential for solar panels in Marinevold Hageby. There are different levels of effectiveness on the different buildings, but there is an average of 740 kWh/m² solar energy. The roof of the common house has a flat roof and gives 838 kWh/m² solar energy according to the analysis.

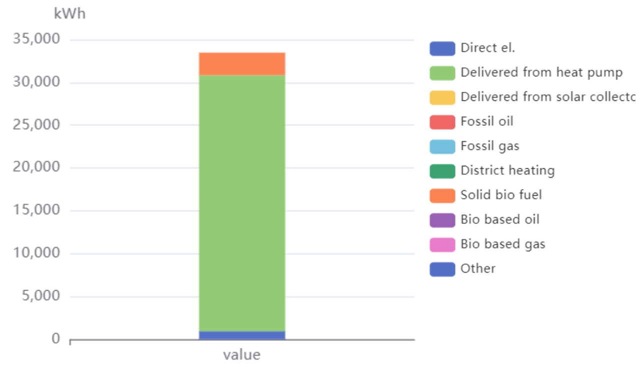
MEASURES FROM 2024 TOWARDS 2035

MEASURE TOWARDS 2035 1:

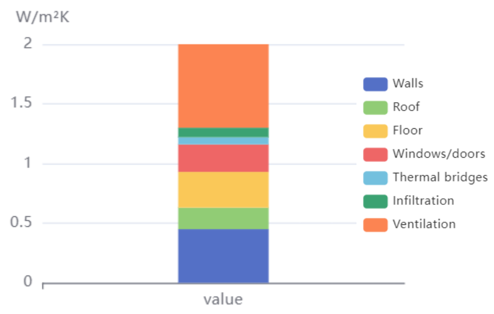
AIR SEALING

Changing the infiltration level to 2.0 (n50) [1/h].

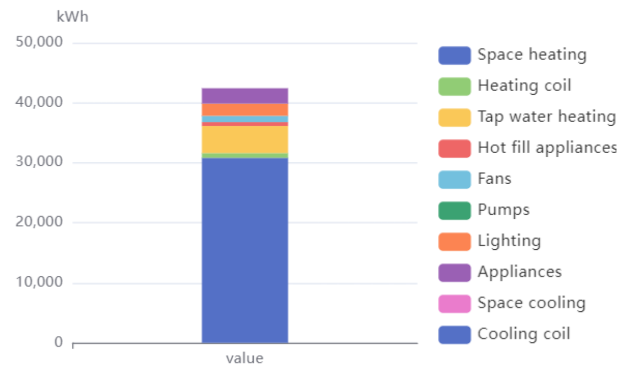
SHARES HEATING



SPECIFIC HEAT LOSSES



NET ENERGY NEED

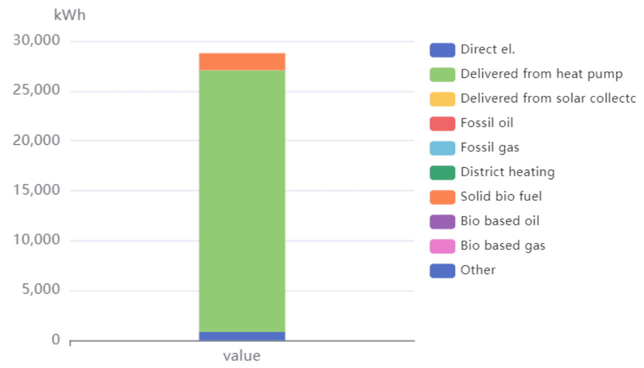


MEASURE TOWARDS 2035 2:

INSULATING

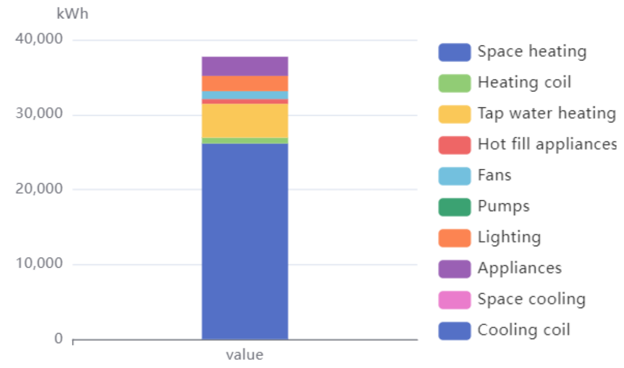
Insulating the basement with 100mm and the walls with 120mm.

SHARES HEATING



SPECIFIC HEAT LOSSES

NET ENERGY NEED

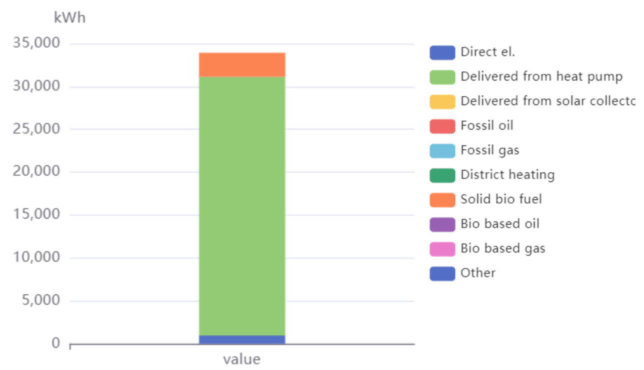


MEASURE TOWARDS 2035 3:

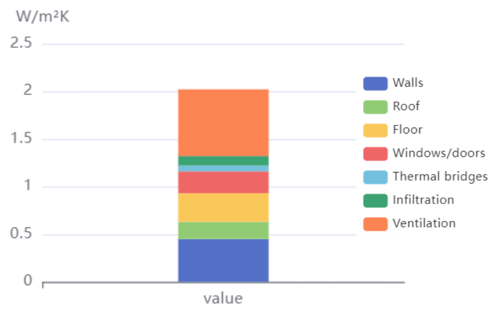
SOLAR PANELS

Adding roof tile solar panels on 30% of the roof

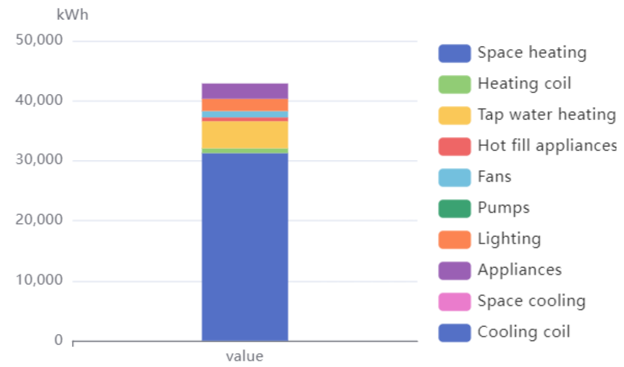
SHARES HEATING



SPECIFIC HEAT LOSSES



NET ENERGY NEED



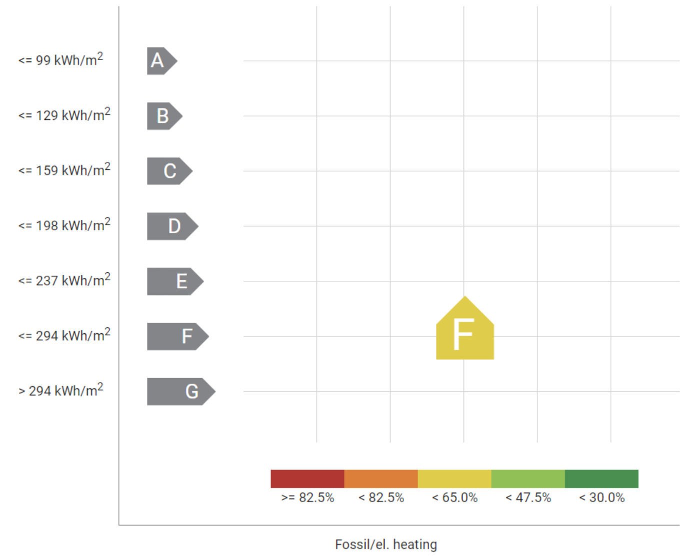
MEASURES FROM 2024 TOWARDS 2035

AIR SEALING

The images taken with the thermal camera can show where there is air leakage and therefore the need for sealing. By sealing some of these points, it can be estimated that the leakage values go from 2.5 (n50) [1/h] to approx. 2.0 (n50) [1/h]. The sealing can be done with sealing strips around windows and by sealing transitions between building parts.

The estimated delivered energy in normalized climate is: 256 kWh/m2 and the total share of electricity/oil/gas of net heating demand is: 55.6 %

2,29%
Reduced energy use from the house's standard today (2024)

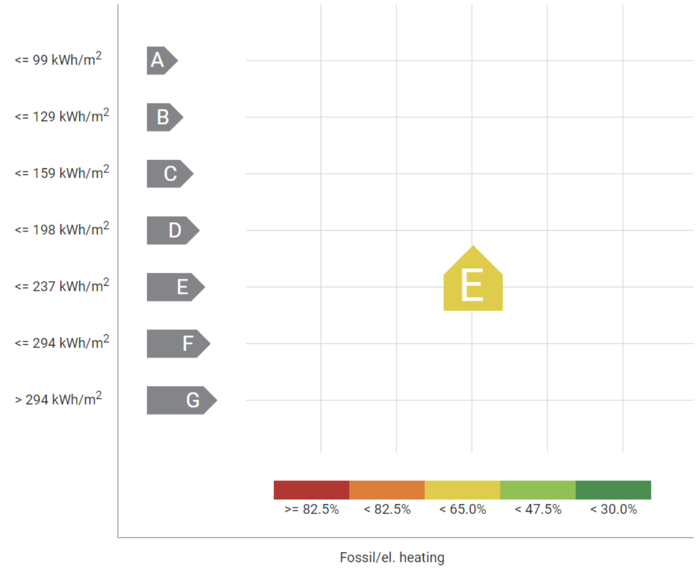


INSULATING

The second measure involves insulating both the walls and the basement to get a better u-value. The new insulation is added on the inside. The walls now have a u-value of 28 W/(m²K) and the basement has a u-value of 38 W/(m²K).
The added insulation makes the specific heat losses lower.

The estimated delivered energy in normalized climate is: 222 kWh/m2 and the total share of electricity/oil/gas of net heating demand is: 58.8 %

15,26%
Reduced energy use from the house's standard today (2024)

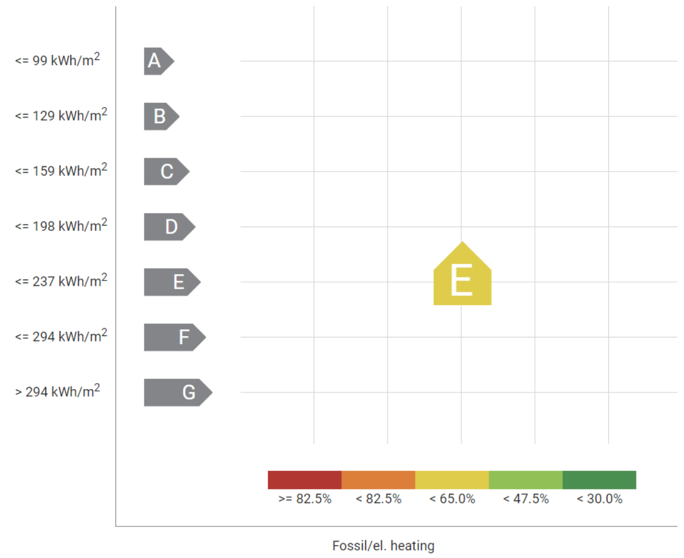


SOLAR PANELS

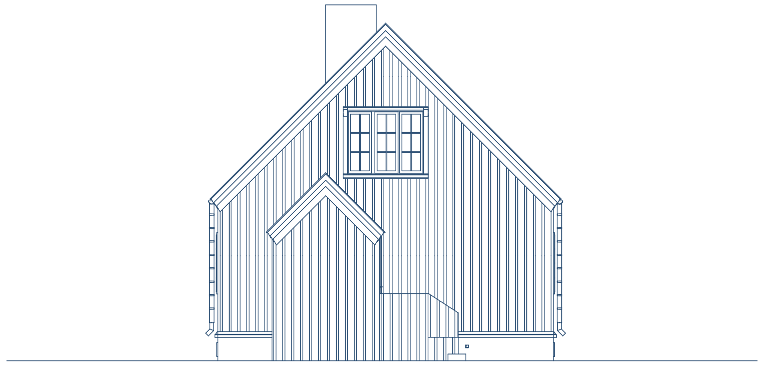
Adding roof tile solar panels will not alone help with lowering the energy demand significantly. There is still high heat loss and energy demand, which needs to be fixed by renovating the building before adding renewable energy sources.

The estimated delivered energy in normalized climate is: 216 kWh/m2 and the total share of electricity/oil/gas of net heating demand is: 55.2 %

17,55%
Reduced energy use from the house's standard today (2024)



NORTH FACADE

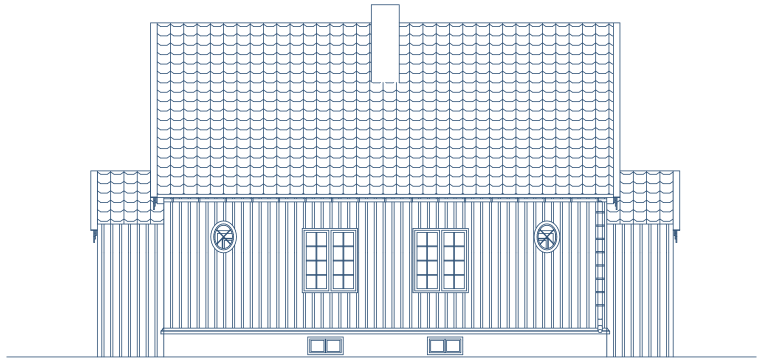


WALL
– Total area incl. windows: 36 m2
– U-value: 0,28 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 335°

WINDOW
– Size: height: 1.45m, idth: 1.75m
– U-value: 1,10 W/m2K

DOOR
– Size: 2,50 m2
– U-value: 1,20 W/m2K

EAST FACADE

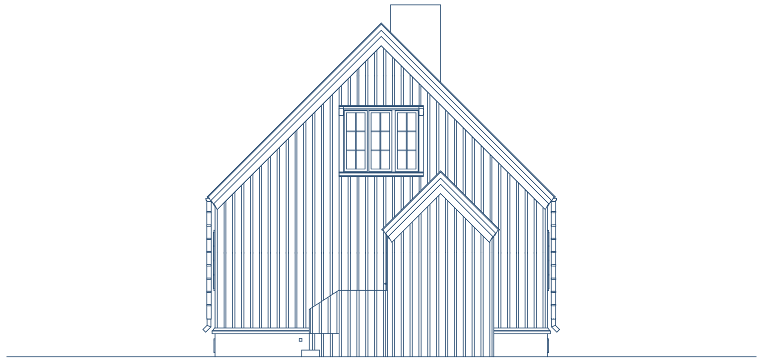


WALL
– Total area incl. windows: 35 m2
– U-value: 0,28 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 245°

WINDOW X2
– Size: height: 1.45m, idth: 1.25m
– U-value: 1,10 W/m2K

WINDOW OVAL X2
– Size: height: 1.45m, idth: 1.25m
– U-value: 3,00 W/m2K

SOUTH FACADE

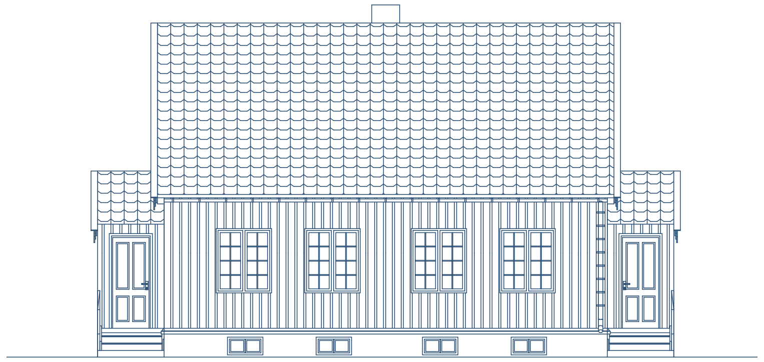


WALL
– Total area incl. windows: 36 m2
– U-value: 0,28 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 115°

WINDOW
– Size: height: 1.45m, idth: 1.75m
– U-value: 1,10 W/m2K

DOOR
– Size: 2,50 m2
– U-value: 1,20 W/m2K

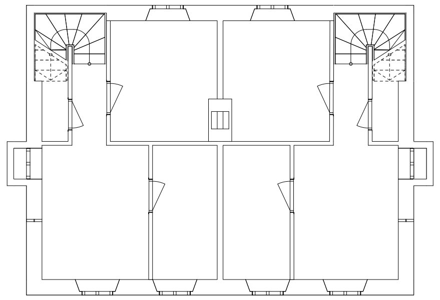
WEST FACADE



WALL
– Total area incl. windows: 35 m2
– U-value: 0,28 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K
– Sky direction: 245°

WINDOWS
– Size: height: 1.45m, idth: 1.25m
– U-value: 1,10 W/m2K

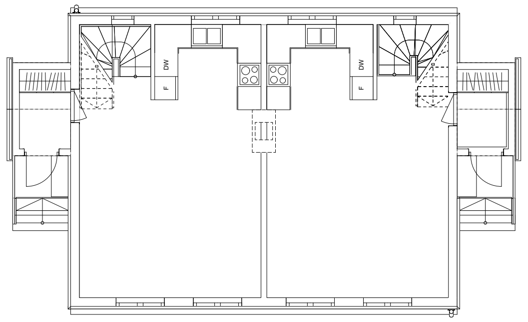
BASEMENT



FlOOR
– Total area incl. windows: 62 m2
– U-value: 0,38 W/m2K
– Heat storage inner layer- Heat capacity: 4,60 Wh/m2K

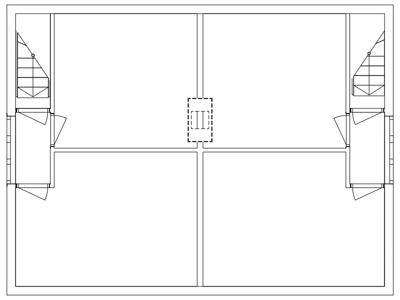
WINDOWS X6
– Size: height: 0.80m, idth: 1.40m
– U-value: 3,00 W/m2K

1ST FLOOR



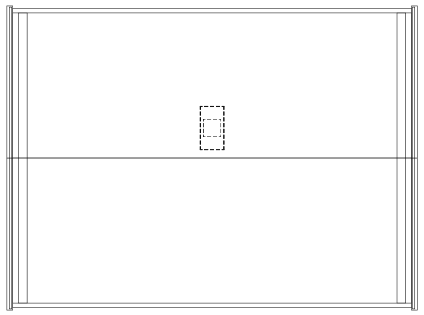
FLOOR
– Total area incl. windows: 69 m2
– U-value: 0,26 W/m2K
– Heat storage inner layer- Heat capacity: 11,20 Wh/m2K

2ND FLOOR

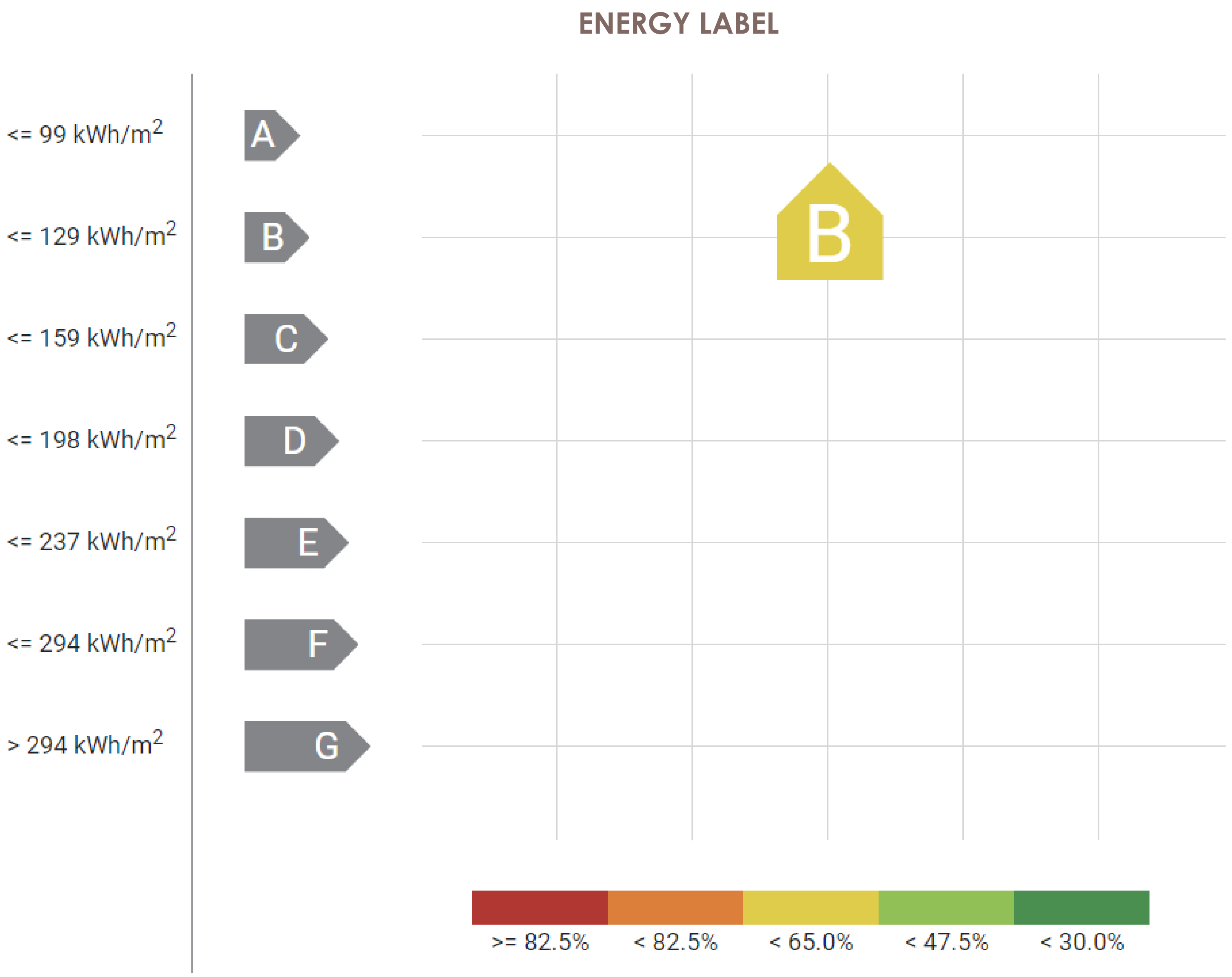


FLOOR
– Total area incl. windows: 69 m2
– U-value: 0,26 W/m2K
– Heat storage inner layer- Heat capacity: 11,20 Wh/m2K

ROOF



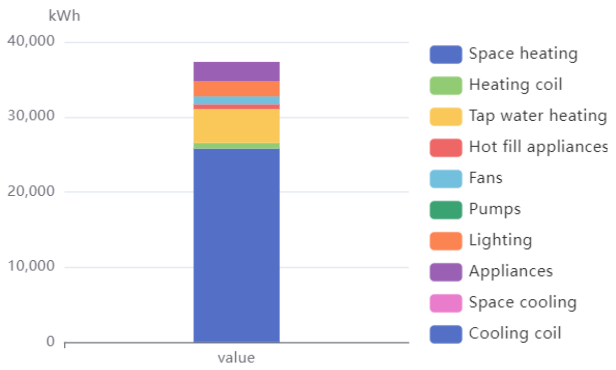
ROOF
– Total area incl. windows: 80 m2
– U-value: 0,40 W/m2K
– Heat storage inner layer- Heat capacity: 4,46 Wh/m2K



The simulation gave the result B as the energy mark, with a yellow heating character. The update in the grade is because of the combination of the measures done to improve the house from 2024 to the future (2035). The measures done are air sealing, insulating, and adding solar panels. As seen above is the measures alone not enough to reach the EU energy goal, but the combination of the renovation measures is enough to give the building a significant energy update. The estimated delivered energy in normalized climate is now 96 kWh/m2 and the total share of electricity/oil/gas of net heating demand is 52.2 %.

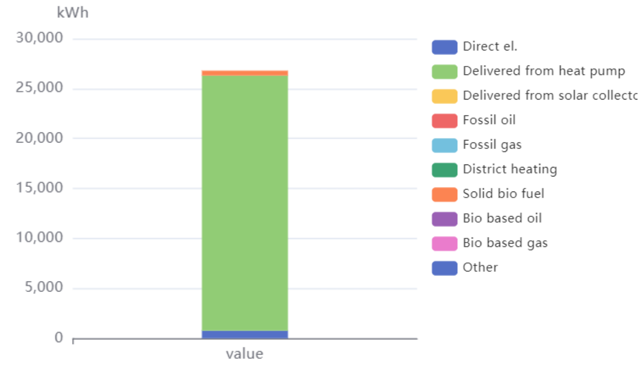
NET ENERGY NEED

The net energy needed is divided into the same categories as the 2024 simulation: space heating, heating coil, tap water heating, hot fill appliances, fans, lighting, and appliances. The biggest net energy need is still for space heating, but now with the need for 25,776.9 kWh instead of 31,278.8 kWh in 2024. The total net energy needed is 37,318.5 kWh, in 2024 was the total 42,873.2 kWh.

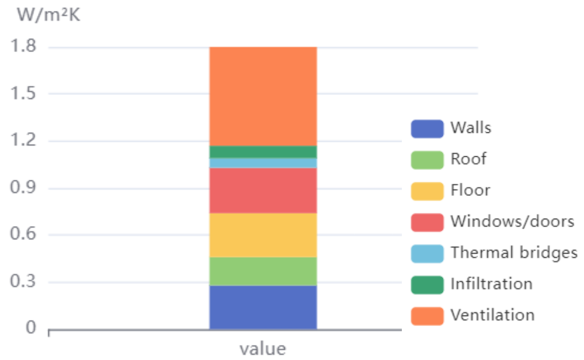


SHARES HEATING

Most of the delivered heat is still from the heat pump. The rest is delivered from solid biofuel (fireplace) and some from direct el. The total is 26,789.9 kWh. It shows that a heat pump still is a good and effective heat source.



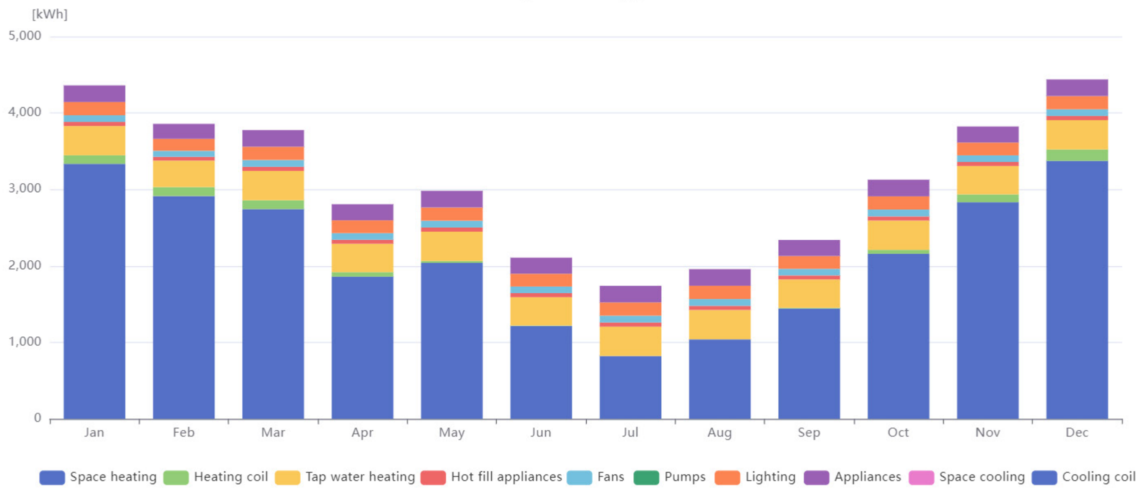
SPECIFIC HEAT LOSSES



The heat losses have gone from a total of 2.02 W/m²K in 2024 to 1.8 W/m²K. The biggest heat loss is still in the ventilation. The heat loss in the walls has gone down from 0.45 W/m²K to 0.28 W/m²K because of the added insulation. The heat loss in the infiltration has gone down from 0.1 W/m²K to 0.08 W/m²K since 2024 because of the measures to fix air leakage in the building. The rest of the heat losses are in the roof, floor, window, and thermal bridges.

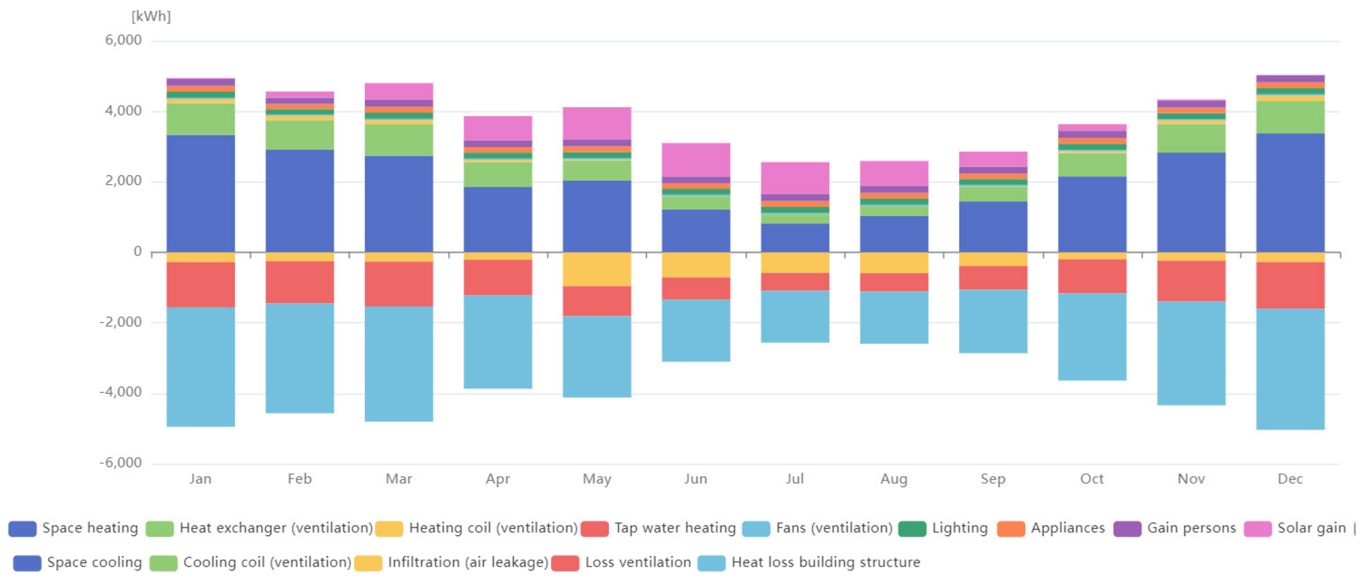
MONTHLY NET ENERGY NEED

Similar to the 2024 simulation, July is the month with the lowest energy need and the highest is December.



MONTHLY HEAT BALANCE

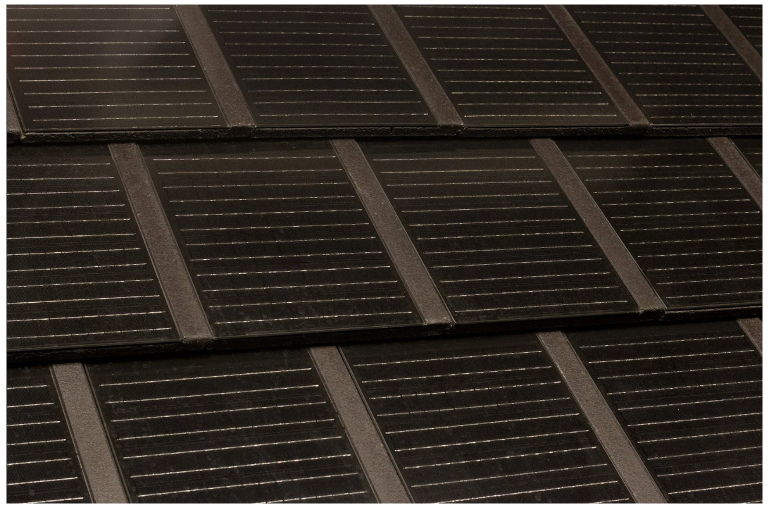
The monthly balance is similar to the 2024 simulation in that the heat losses are coming from the building structure, air leakage, and loss through the ventilation system. The heat gain comes mostly from space heating. It also comes from the heat exchanger in the ventilation, people gain, appliances, lighting, and fans, from the heating coil in the winter months, and from solar gain in the summer months.



SOLAR PANEL ROOF TILES

Solar panel roof tiles are roof tiles with integrated solar cells. It replaces and looks like a normal roof. The advantage is that the solar panel tiles can be installed only where it is effective, and then the rest of the roof tiles can be normal tiles that do not produce energy.
The result is a roof that looks like a normal roof while producing electricity.
A disadvantage with the tiles is that they are more expensive than normal solar panels, but they are also qualified for financial support from Enova (Hammerstad, 2023).

The information for the simulation is collected from the Norwegian producer Skarpnes's solar panel tile called Ovati (Skarpnes, n.d.).
The simulation input is shown in the table.

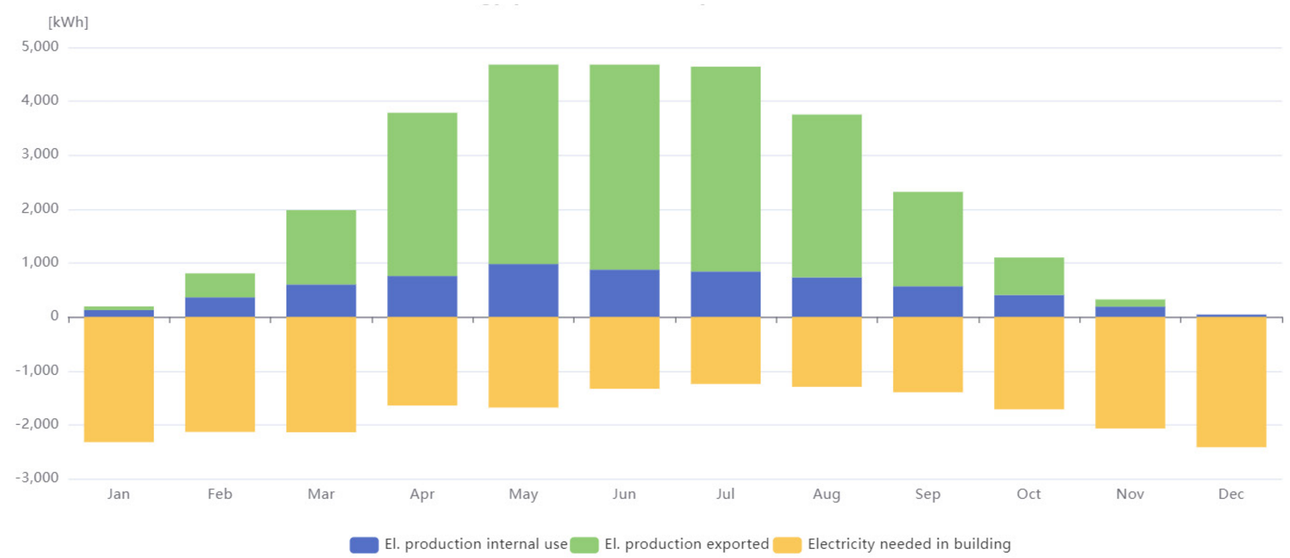



Pictures of solar panel roof tiles (Skarpnes, n.d.).

ENERGY PRODUCTION SOLAR PANELS

Size	0,33m x 0,42m
Weight	5,3kg
Number of panels per 1 m2	9,5
Number of panels	285= 35m2
Orientation	245°
Effect	After 25 years, a minimum of 80% of the stated effect

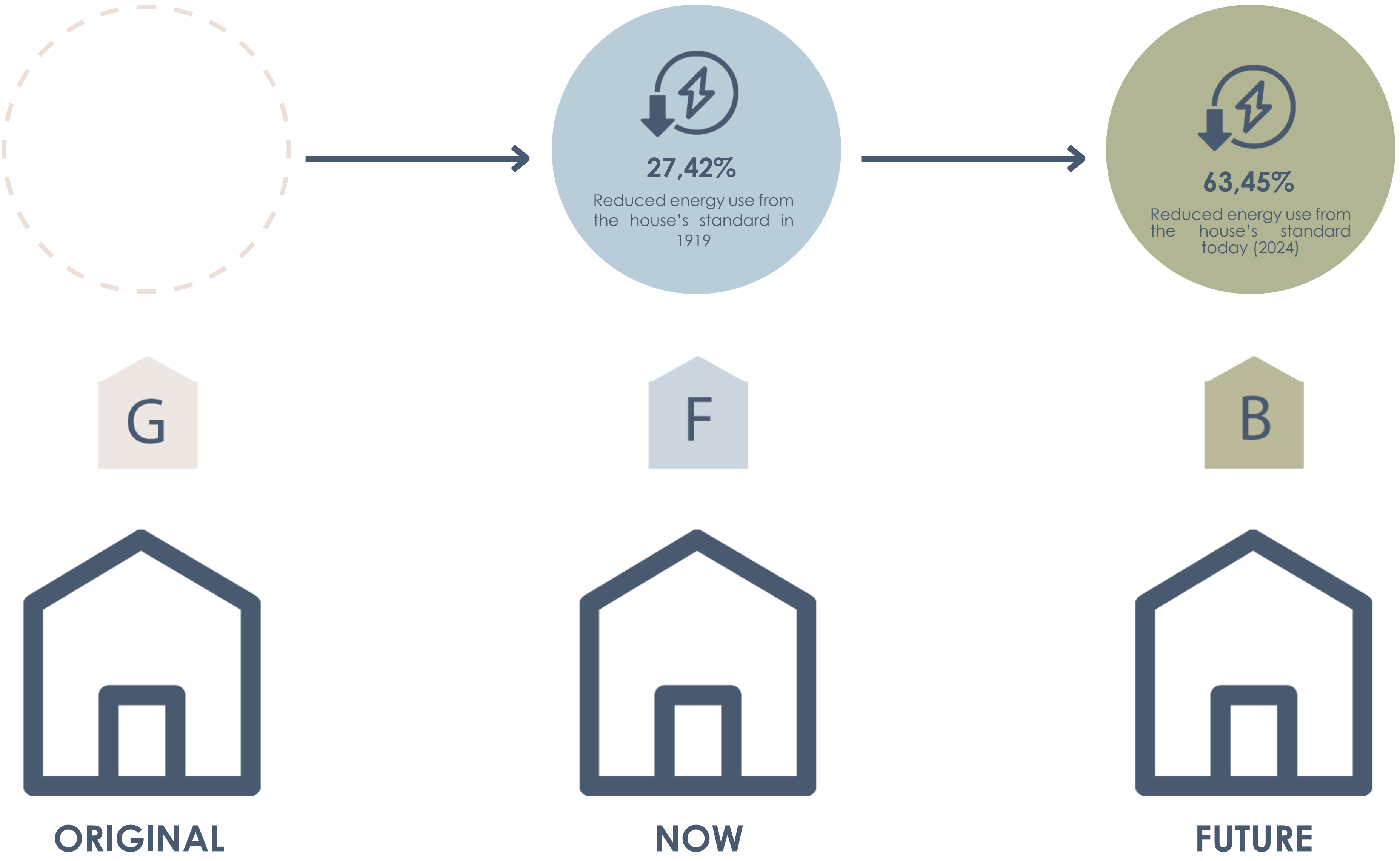
The results from the simulation unsurprisingly show that the peak production is in the middle of summer, while there is less production in the darker winter months. There is also some lower electricity need in the building in the summer months and higher in the winter months. Nevertheless, energy is exported in all months except December, with higher kWh exported in the summer months.



Description	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Sum
Solar panel	195	808	1,981	3,787	4,680	4,680	4,642	3,754	2,319	1,103	325	45	28,318
Total	195	808	1,981	3,787	4,680	4,680	4,642	3,754	2,319	1,103	325	45	28,318
Used	129	364	603	760	983	878	844	735	569	408	193	45	6,510
Exported	67	444	1,378	3,027	3,697	3,801	3,798	3,019	1,750	694	132	0	21,808

The results from the simulation show that doing all the measures will give a reduction of the energy use in the house of 63,35%. The renovation measures suggested for Marinevold Hageby will therefore help with reaching the EU energy efficiency goal of reducing the energy use of residential buildings by 20-22% by 2035 is therefore achieved.

The measures are mostly effective when having all of them done, but they could also be done separately over time in the years towards 2035 to reach the energy goal. The building has also gone from an energy mark F to an energy mark B after doing all the measures.



OTHER MEASURES TO IMPROVE THE ENERGY EFFICIENCY OF THE HOUSES

SWITCH OFF LIGHT AND ELECTRICAL APPLIANCE

Avoid electrical equipment and lights being left on unnecessarily when not in use by turning off lights and unplugging sockets. It is also energy-saving to not leave equipment in standby mode (NHSaves, n.d.).

USE ENERGY-EFFICIENT APPLIANCES

Appliances use energy marking to tell the user how much energy they use. Therefore, the most energy-efficient appliances with higher energy markings should be chosen when buying new ones (Enova, n.d.d).

USE LESS HOT WATER

Hot water is one of the biggest energy sources after space heating. The biggest usage is when taking showers or baths. Shortening or reducing the time of a shower, or not filling the bathtub as regularly can lower energy use (Enova, n.d.d).

USE CURTAINS TO PREVENT AIR LEAKAGE

Curtains could help to prevent cold air from leaking in through air gaps in the windows. It is therefore good to close the curtains during the night to block the cold air out. The curtains should be open during the day to let sunlight in to heat the home (NHSaves, n.d.).

REDUCE THE INTERIOR TEMPERATURE

It is expected to reduce the energy use for space heating by approximately 5% for each degree the indoor temperature is lowered. Lowering the temperature in spaces that are not used as much or used only for parts of the day is therefore a good way to save energy. (Enova, n.d.d).

AIR WITH WINDOWS IN SHORTER PERIODS

Air in shorter periods instead of airing with small gaps during a long period. The shorter airing period shifts out the air fast without cooling down surfaces as much as longer periods will do (Enova, n.d.d).

DISCUSSION

Result reliability

Existing literature shows that having good insulation, sealing air leakages, efficient windows, efficient heating and cooling appliances, and renewable energy sources are good measures to get a more energy-efficient building. These measures were simulated with the SIMIEN energy simulation program on a sample house in Marinevold Hageby to see if they could make the buildings more energy-efficient, in order to achieve the EU's energy efficiency goals by 2035.

The results of the simulation show that the measures will give a reduction of the energy use in the house of 63,35%. The building has also gone from an energy mark F to an energy mark B after doing the measures. This shows that doing these measures will result in contributing to reaching the EU energy efficiency goals of reducing the energy use of residential buildings by 16% by 2030 and 20-22% by 2035.

The results may not be reliable because there is no security that the input in the simulation is correct. The geometry and structure of the house are collected by making the building information model. However, the information to draw these drawings is collected from the original hand-drawn plans that weren't accurate with all the measurements and materials. The lack of information for making the model is collected from other sources that describe similar buildings built at the same time. This information does not necessarily apply to the houses in Marinevold. This can affect the u-values used in the simulation. Even if the input values may not be accurate the simulations still show that the chosen measures will enhance the energy efficiency of the house and improve the energy labeling.

Challenges and Limitations

However, these measures can be expensive to execute, even with support from organizations like Enova. If people are already struggling with energy poverty, will these measures be big investments that may not be realistic for everyone.

However, if the house is going to be renovated, should the extra measures to make the building more energy efficient be done simultaneously. It may not always be necessary to do this before renovating. Extra insulation can for example be added when the walls already are open, or a three-layer window could be chosen if the windows have to be replaced anyway.

The measures may also be difficult to execute because of the antiquarian value of the houses because there are restrictions on how much can be changed. The balance between improving energy efficiency and preserving the historical and cultural values of the buildings should be individually analyzed depending on the state of the different houses. Renovation can cause the original cladding and building details to disappear so that the building changes its appearance. This is not compatible with the protection of the building.

Demolition and replacement of materials are not beneficial from a resource and environmental perspective. The building industry accounts for one of the largest consumptions of raw materials and production of waste. There should therefore be an awareness of keeping the building as intact as possible without changing materials unnecessarily. At the same time, this must be measured against the benefits of making the building more energy efficient and emissions linked to non-renewable energy production. In addition to the fact that the energy need will be bigger if the house is not renovated. In the example house, has it been chosen to add extra insulation even if the building materials are replaced. This is because the insulation gives big gains in terms of energy savings, but in another project, may the choice perhaps have been different depending on the starting point. Solar roof tiles have been chosen instead of traditional solar panels to maintain the house's antiquarian value. These have not been on the market as long as other solar panels and may therefore not be as effective. It is also possible to start with smaller measures such as air sealing or installing a heat pump. These measures do not have the same impact on the building and therefore do not have the same impact from an environmental perspective.

Future Research

The simulation is only done on one of the houses. They were originally built identically but have been renovated slightly differently over the years. Future research should therefore include simulating the other houses as well to compare them and reduce the insecurity of having different results on the houses.

Further, should the approach of community energy be included to see how it could improve the energy efficiency of the houses on a neighborhood scale. This could include calculations on how solar panels on the community house and area could supply the community. Other places like fences or garages could also be considered as placement for the panels. These areas including the community house are not protected, which means normal solar panels can be used instead of solar panel roof tiles. Geothermal heat could also be further researched to see if this method of local renewable energy is achievable in Marinevold Hageby.

10 CONCLUSION

The conclusion chapter presents the final development plan for the houses in Marinevold Hageby, and the final measures to improve the energy efficiency in the houses. Finally, a conclusion is presented which presents and summarizes the results of the thesis.

DEVELOPMENT PLAN

F

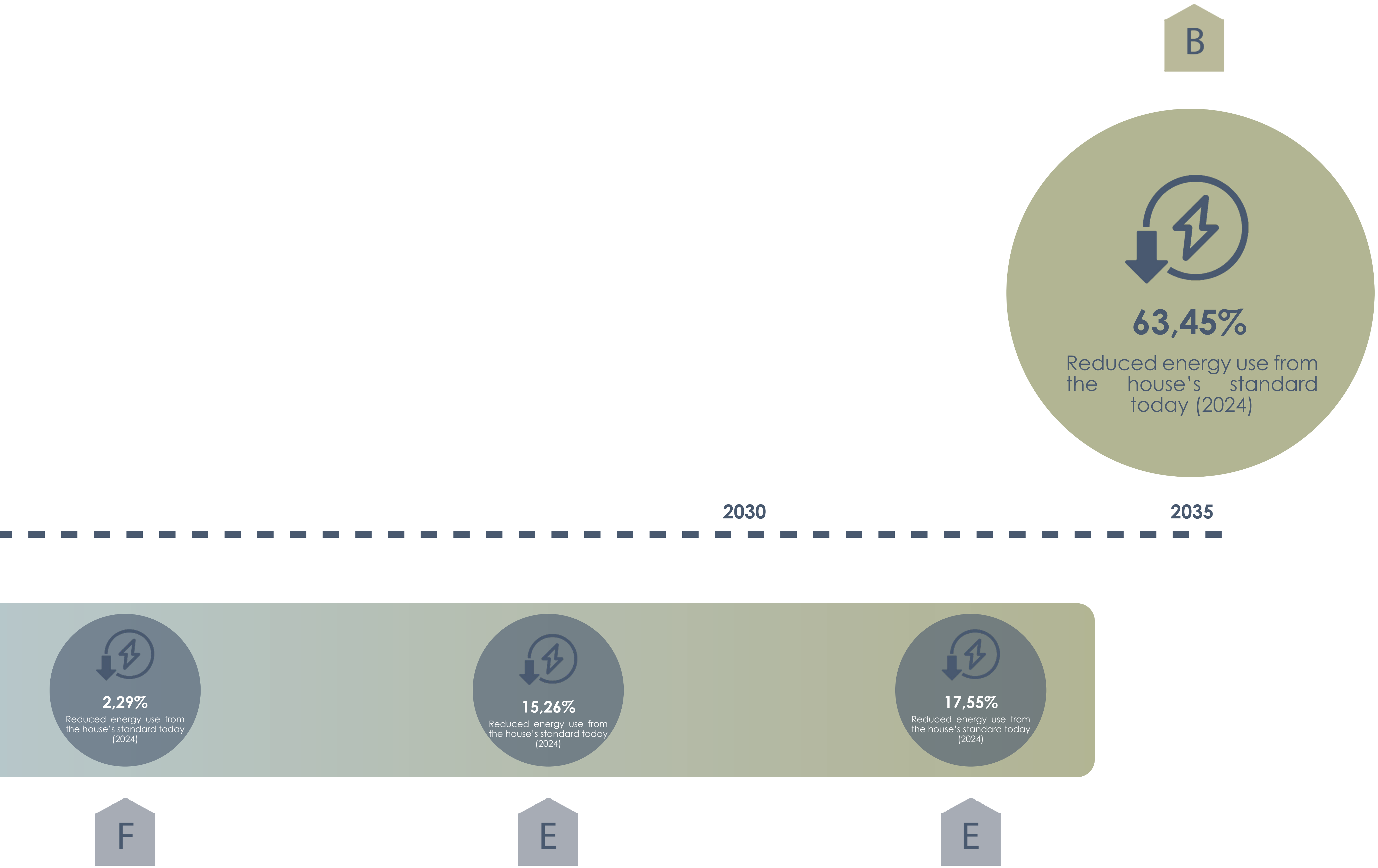
27,42%

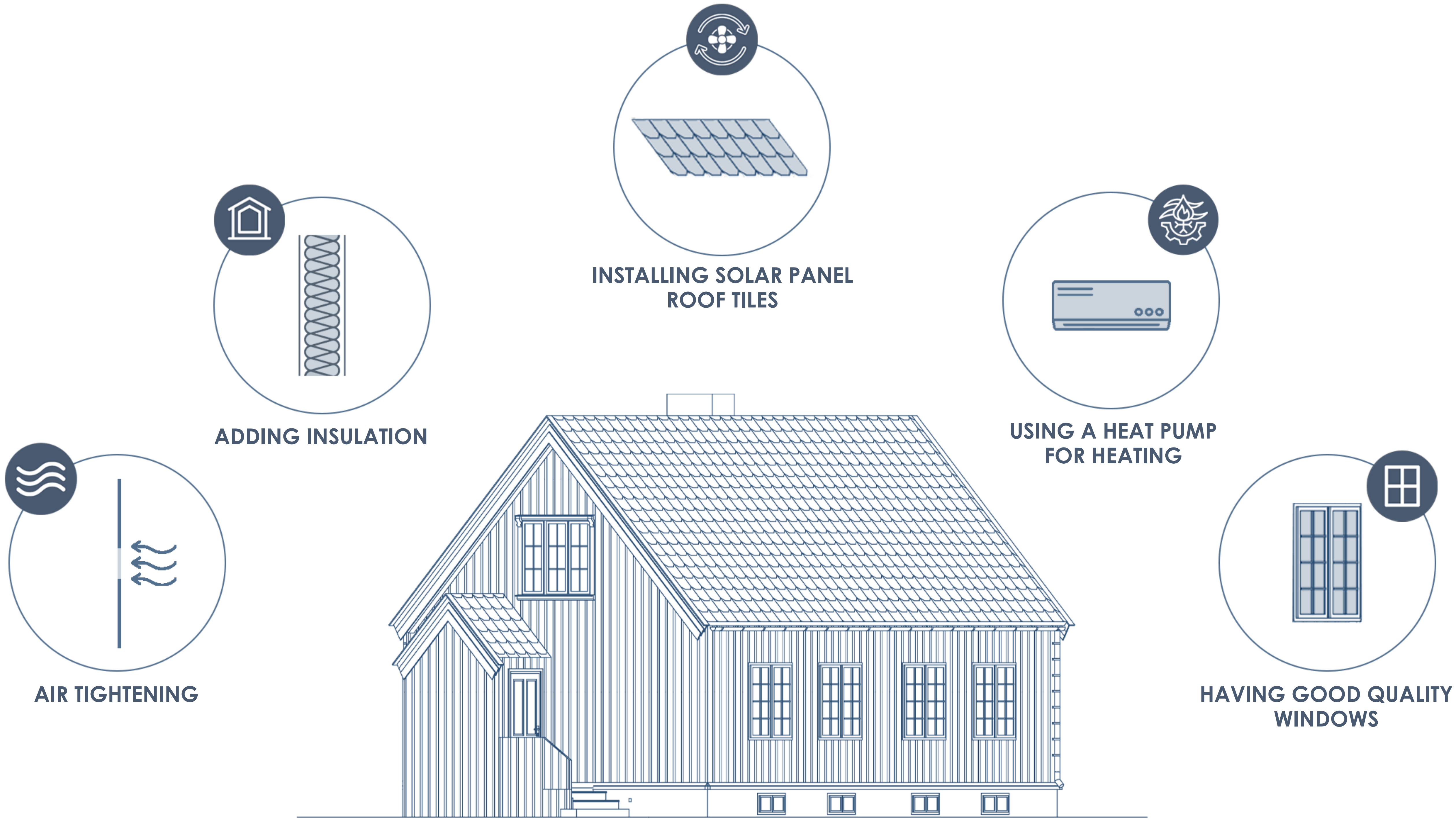
Reduced energy use from the house's standard in 1919

1919

2024

G


B
63,45%
Reduced energy use from the house's standard today (2024)
2030
2035
2,29%
Reduced energy use from the house's standard today (2024)
15,26%
Reduced energy use from the house's standard today (2024)
17,55%
Reduced energy use from the house's standard today (2024)
F
E
E


INSTALLING SOLAR PANEL ROOF TILES
ADDING INSULATION
USING A HEAT PUMP FOR HEATING
AIR TIGHTENING
HAVING GOOD QUALITY WINDOWS

CONCLUSION

This thesis explored the potential for optimizing energy efficiency in the residential buildings of Marinevold Hageby by 2035. The research included methods to obtain information about the neighborhood and the houses and methods for investigating energy efficiency and the potential to improve the houses.

The research investigated the effectiveness of energy-saving measures with the method combination of site analysis, research of relevant literature, Building Information Modeling, thermal imaging, and the SIMIEN energy simulation program. These investigated measures, including improved insulation, air sealing, efficient windows, and the use of renewable energy sources, were shown to significantly reduce energy consumption and improve the buildings' energy labeling.

The findings indicate that implementing these measures could contribute to achieving the EU's energy efficiency goals of reducing the energy use of residential buildings by 20-22% by 2035, with a potential energy use reduction of over 60%, and from an energy mark F to an energy mark B. However, the study also highlighted challenges such as the high costs of renovation, the need to preserve the historical and cultural value of the buildings, and the limitations in the accuracy of data due to the reliance on historical plans and supplementary sources.

Despite these challenges, the research underscores the importance of targeted renovations and community energy initiatives in enhancing energy efficiency. The integration of energy-efficient strategies not only reduces energy bills and greenhouse gas emissions but also contributes to the overall improvement of indoor environmental quality and comfort.

Future research should focus on simulating additional houses in the area and exploring community energy solutions, including solar and geothermal energy. These efforts would provide a more comprehensive understanding of the potential for energy efficiency improvements on a neighborhood scale.

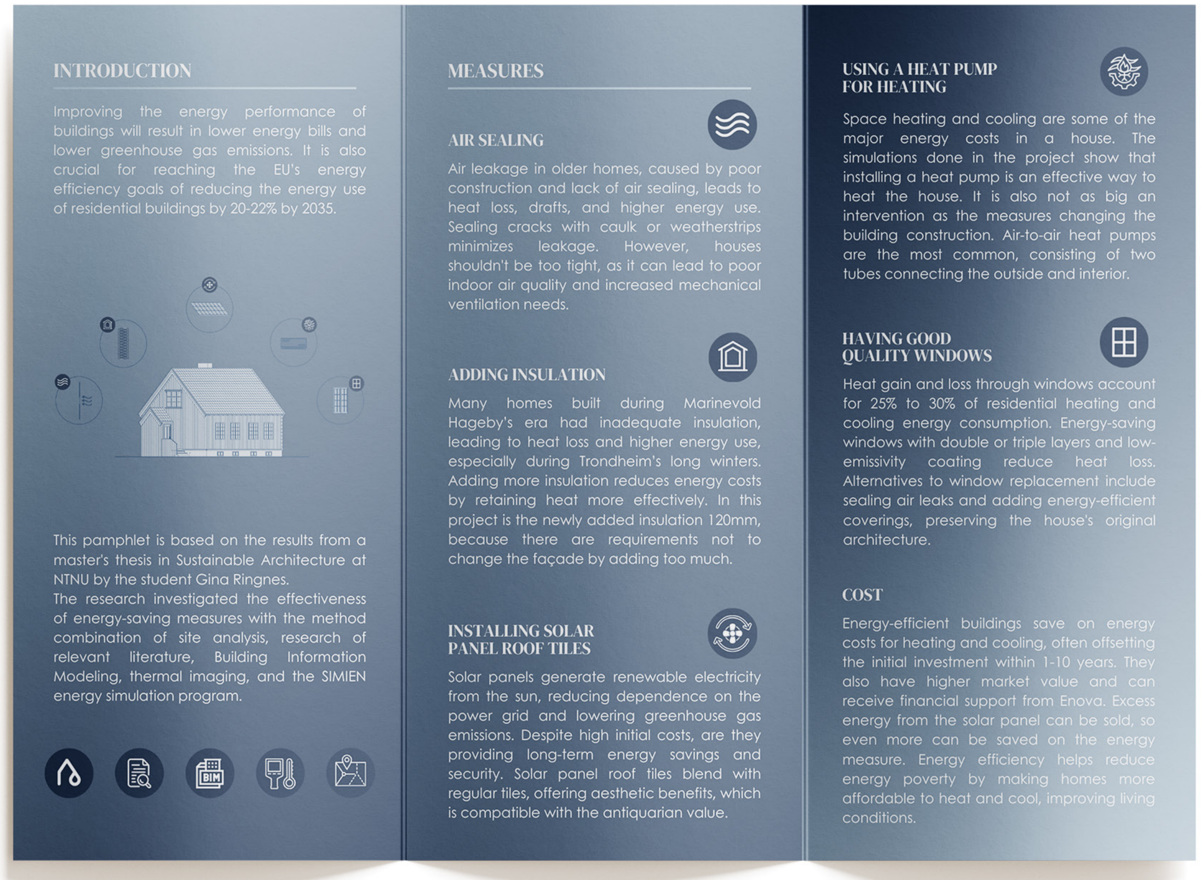
In conclusion, this thesis provides insights and recommendations for improving the energy efficiency of older residential buildings with antiquarian value, emphasizing that renovations are an investment into a better and more efficient future. By adopting these measures, the residents of Marinevold Hageby can contribute to a more sustainable and energy-efficient community, aligning with broader environmental and energy efficiency goals.

11 PAMPHLET

This chapter presents the pamphlet designed to give a short description of the results and measures to the homeowners in Marinevold Hageby. The pamphlet will be given to the board of Marinevold Hageby and the family in the sample house as a thank-you for providing information and for doing analyses in their home.

The goal of the pamphlets is to summarize the recommended measures and benefits without overwhelming the reader with too much information. The pamphlet includes simple illustrations and information on the measures and the result of simulating them. It also includes simple energy-saving measures and community energy suggestions. It can easily be distributed and can handed out or mailed directly to homeowners, ensuring that everyone receives the recommendations. Homeowners can quickly refer back to the pamphlet for specific recommendations or tips, making it a practical guide for implementing energy efficiency measures. Ideally, the pamphlet will help and inspire homeowners to choose energy-efficient solutions in the future or for the next time they renovate. It can also inspire and inform about solutions such as solar panel roof tiles and that Enova can support these and other measures.


SMALLER ENERGY-SAVING MEASURES
Reduce the interior temperature by 1-2 degrees
Use curtains to prevent air leakage during the night
Air with windows in shorter periods to not get cool surfaces
Switch off lights and electrical appliances when it's not used
Use less hot water when showering
Use energy-efficient appliances with high energy markings
ENERGY COMMUNITY
Community energy solutions like solar panels on the common house and area, and geothermal energy under the middle road could be good and innovative solutions for the neighborhood.
63,45%
Reduced energy use from the house's standard today (2024)
The results were shown to significantly reduce energy consumption and improve the buildings' energy labeling by executing methods such as improved insulation, air sealing, efficient windows, and the use of renewable energy sources. The goal of the project was reached with a potential energy use reduction of over 60% and with getting the building from an energy mark F to an energy mark B by 2035.
F
B
1919
2024
MARINEVOLD HAGEBY ENERGY EFFICIENCY RENOVATION
A user guide for homeowners and the neighborhood in Marinevold Hageby
Master's thesis in Sustainable Architecture
Student: Gina Ringnes
Supervisor: Pasi Aalto
Co-supervisor: Beatrice Stolz
Norwegian University of Science and Technology
Faculty of Architecture and Design
Department of Architecture and Technology
June 2024


INTRODUCTION
Improving the energy performance of buildings will result in lower energy bills and lower greenhouse gas emissions. It is also crucial for reaching the EU's energy efficiency goals of reducing the energy use of residential buildings by 20-22% by 2035.
This pamphlet is based on the results from a master's thesis in Sustainable Architecture at NTNU by the student Gina Ringnes.
The research investigated the effectiveness of energy-saving measures with the method combination of site analysis, research of relevant literature, Building Information Modeling, thermal imaging, and the SIMIEN energy simulation program.
BIM
MEASURES
AIR SEALING
Air leakage in older homes, caused by poor construction and lack of air sealing, leads to heat loss, drafts, and higher energy use. Sealing cracks with caulk or weatherstrips minimizes leakage. However, houses shouldn't be too tight, as it can lead to poor indoor air quality and increased mechanical ventilation needs.
ADDING INSULATION
Many homes built during Marinevold Hageby's era had inadequate insulation, leading to heat loss and higher energy use, especially during Trondheim's long winters. Adding more insulation reduces energy costs by retaining heat more effectively. In this project is the newly added insulation 120mm, because there are requirements not to change the façade by adding too much.
INSTALLING SOLAR PANEL ROOF TILES
Solar panels generate renewable electricity from the sun, reducing dependence on the power grid and lowering greenhouse gas emissions. Despite high initial costs, are they providing long-term energy savings and security. Solar panel roof tiles blend with regular tiles, offering aesthetic benefits, which is compatible with the antiquarian value.
USING A HEAT PUMP FOR HEATING
Space heating and cooling are some of the major energy costs in a house. The simulations done in the project show that installing a heat pump is an effective way to heat the house. It is also not as big an intervention as the measures changing the building construction. Air-to-air heat pumps are the most common, consisting of two tubes connecting the outside and interior.
HAVING GOOD QUALITY WINDOWS
Heat gain and loss through windows account for 25% to 30% of residential heating and cooling energy consumption. Energy-saving windows with double or triple layers and low-emissivity coating reduce heat loss. Alternatives to window replacement include sealing air leaks and adding energy-efficient coverings, preserving the house's original architecture.
COST
Energy-efficient buildings save on energy costs for heating and cooling, often offsetting the initial investment within 1-10 years. They also have higher market value and can receive financial support from Enova. Excess energy from the solar panel can be sold, so even more can be saved on the energy measure. Energy efficiency helps reduce energy poverty by making homes more affordable to heat and cool, improving living conditions.

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F → **B**

1919 **2024**

MARINEVOLD HAGEBY ENERGY EFFICIENCY RENOVATION

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Master's thesis in Sustainable Architecture
Student: Gina Ringnes
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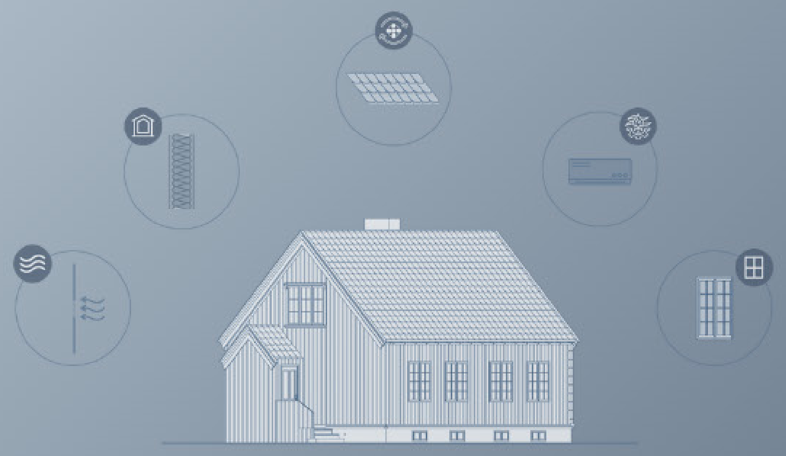

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PROGRAMS

ArchiCAD

Autodesk Forma

Climate consultant

Fluke Connect

InDesign

Photoshop

SIMIEN

Ubakus

NTNU

Norwegian University of
Science and Technology