KEEPING OLD BUILDINGS GREEN WITH RELEVANT TECHNOLOGY

A CASE STUDY OF UNESCO WORLD HERITAGE CENTER, NÆRØYFJORDOMRÅDET

HALLDÓR ÞRASTARSON

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Keeping old buildings green with relevant technology

A case study of UNESCO World Heritage Center, Nærøyfjordområdet

Master thesis in Climate Change Management

Author: Halldór Þrastarson	Author sign. Halldór Þrastarson
Thesis submitted: Spring 2021	Open/confidential thesis Open
Main Supervisor: Marte Lange Vik Co-supervisors: Anders-Johan Almås	
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This thesis is a part of the master's program in Climate Change Management (Planlegging for klimaendringer) at the Department of Environmental Sciences, Faculty of Engineering and Science at the Western Norway University of Applied Sciences. The author(s) is responsible for the methods used, the results that are presented and the conclusions in the thesis.

Preface

I would like to thank the supervisors that help develop this thesis, Anders-Johan Almås and Marte Lange Vik, for valuable help. Then I would like to thank Gøran Johansen, the project leader of the UNESCO World Heritage Center in Aurland, for offering this case, and also for valuable input and help with the thesis. Then I would like to thank MAD Architects for providing the drawings of the concept building on CAD format and for valuable input on the case. Finally I would like to thank family and friends for moral support and feedback on the thesis before hand in.

Abstract

Today the building sector accounts for around 40% of all energy used and emits around 30% of global Green House Gas (GHG) emissions. Buildings play a large role in peoples lives as we spend around 90% of our lives inside buildings. In light of these facts it is important that comfort inside buildings is kept up to standards while still reducing energy usage in buildings. This can be done by implementing Building Management Systems (BMS) to control Heating Ventilation and Air Conditioning (HVAC) systems in buildings. This study will look into the case of refurbishing a building in Aurland in Western Norway. The end goal of the project is to build a UNESCO World Heritage Center. The aim of the study is to recommend technical solutions for the building that will balance energy needs, CO2 emissions and costs. This aim can be split up into two main goals, that is finding a control method for the BMS and HVAC and then choosing the type of energy source used for the HVAC system. Three systems were studied, Air Source Heat Pump (ASHP), Water-Thermal Energy Production System (WEPS) and a conventional Electric boiler. Then several control methods were researched. The methodological part can be mainly split up to three parts. Simien was used to model the building and calculating its energy needs and efficiency. One Click LCA was used to perform a Life Cycle Assessment on the solutions and costs were estimated based on similar studies. Results showed that WEPS had the best performance based on energy usage and CO2 emissions followed shortly by the ASHP, The electrical boiler had by far the worst performance. However the electric boiler was by far the cheapest solution followed by ASHP and the the WEPS was the most expensive solution. The WEPS system was recommended for the project owner based on performance and practical pros and cons. The recommended control method for the BMS was based on research. Model Predictive Control (MPC) was the method that was chosen for this project. MPC outperforms all other control methods in most cases. MPC can reduce energy use from 15-20%.

Samandrag på Norsk

I dag står byggesektoren for rundt 40% av all energibruk og rundt 30% av de globale klimagassutslippene. Bygninger spiller en stor rolle i folks liv da ve tilbringer rundt 90 % av liven våre inne i bygninger. I lys av dette, er det viktig at komforten i bygninger er god, samtidig som den reduserer energiforbruket i bygninger. Dette kan gjøres ved å implementere bygningsstyringssystemer (BMS) for å kontrollere varme, ventilasjon og klimaanlegg (HVAC) i bygninger. Denne studien vil se på at case for renovering av en bygning i Aurland på vestlandet. Målet med prosjektet er å bygge et UNESCOs verdensarvssenter. Målet med studien er å anbefale tekniske løsninger for bygningen som skal balansere energibehov, CO2-utslipp og kostnader. Dette målet kan deles opp i to hovedmål, det er å finne en kontrollmetode for BMS og HVAC og deretter velge hvilken type energikilde som brukes til HVAC systemet. Tre systemer ble studert, luft-til-luft varmepumpe (ASHP), fjordvarme (WEPS) og en konvensjonell varmtvannsbereder. Deretter ble det undersøkt flere kontrollmetoder. Den metodiske delen kan i hovedsak deles opp til tre deler. Simien ble brukt til å modellere bygningen og beregne energibehov og effektivitet. One Click LCA ble brukt til å utføre en livssyklusvurdering av løsningene og kostnadene ble estimert basert på lignende studier. Resultatene viste at WEPS hadde den beste ytelsen basert på energiforbruk og CO2-utslipp, tett fulgt av ASHP. Varmtvannsberederen hadde den dårligste ytelsen. Varmtvannsberederen var imidlertid den billigste løsningen etterfulgt av ASHP, og WEPS var den dyreste løsningen. WEPS-systemet ble anbefalt for prosjekteieren basert på ytelse og praktiske fordeler og ulemper. Anbefalinger for kontrollmetode for BMS ble gjort på bakgrunn av annen forskning. Model Predictive Control (MPC) var metoden som ble valgt for dette prosjektet. MPC overgår alle andre kontrollmetoder i de fleste tilfeller. MPC kan redusere energiforbruket fra 15-20%.

List of Abbreviations

- ANN - Adaptive Neural Network
- ASHP - Air Source Heat Pump
- BAS - Building Automation System
- BCS - Building Control System
- BMS - Building Management System
- CO2 - Carbon Dioxide
- DHW - Domestic Hot Water
- FL - Fuzzy Logic
- GHG - Green House Gas
- GSPID - Gain Scheduling PID (See below)
- HVAC - Heating Ventilation and Air Conditioning System
- HSC - Holte Smart Calc
- IPCC - Intergovernmental Panel on Climate Change
- LCA - Life Cycle Assessment
- MBC - Model Based Control
- MPC - Model Predictive Control
- OC - Optimal Control
- O&M - Operation and Maintenance
- P, PI, PID - Proportional-Integral-Derivative
- RBC - Rule Based Control
- RC - Robust Control
- TPSC - Two Parameter Switching Control

- UNESCO - United nations Educational, Scientific and Cultural Organization
- WEPS - Water-Thermal Energy Production System

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1 Introduction

Climate change is a threat that the whole world is facing and has been growing over the last decades. According to the Intergovernmental Panel on Climate Change (IPCC) the world will undergo irreversible changes such as increasing temperature, raising sea level and more frequent storms, if humans continue to emit greenhouse gasses in the current rate. In fact they need to significantly reduce their emissions in order to maintain the current climate[16]. Since this problem was drawn into the spotlight a spark has been ignited to develop methods to reduce emissions in all sectors.

The building sector plays a big role in green house gas (GHG) emissions. In fact research shows that globally buildings use around 40% of all energy and emit 30% of global GHG in the world. In light of this fact it is obvious that this sector needs attention.[17] Authorities are setting new policies to reduce emissions. The International Energy Agency (IEA) states that 48% of emissions reduction goals for 2030 can be reached through energy efficiency [18].

Today buildings play a large role in society, people spend around 90% of their lives inside buildings. Therefore it is important that the indoor climate is up to standard and that comfort level is sufficient. Indoor air pollution is one of the greatest environmental threats to public health according to the World Health Organisation in 2016 [19]. It can also have an effect on peoples productivity and even reduce it from 10-15%. So it is not only a health issue but also an economical issue.[20]

New technologies to increase energy efficiency in buildings have emerged, for example Building Management Systems (BMS) and Heating, Ventilation and Air Conditioning (HVAC) systems. These systems aim to reduce energy consumption of the building while maintaining sufficient comfort levels and air quality in the building [21].

Lately HVAC systems have started to become a more common sight in modern buildings, not to long ago these systems were thought to be a luxurious feature in buildings. Today they are used in most buildings and they also use the most energy of the end users in buildings. The end users are split into 3 main groups, space conditioning, Domestic Hot Water (DHW) and lighting and appliances. HVAC goes under the group of space conditioning. Studies show that space conditioning uses significantly more energy than the other two groups. [12] Comparison from different areas is shown in table 1. So it is important to not only use more energy efficient solutions it is also important that the energy source is renewable.

End uses in the residential sector(%)	Spain	EU	USA	UK
Space conditioning	42	68	53	62
Domestic Hot Water (DHW)	26	14	17	22
Lighting and appliances	32	18	30	16

Table 1: Energy use by end users in the residential sector.[12]

When thinking about a buildings emissions it is not enough to look into energy usage, the whole life cycle of the building must be taken into account. This accounts for all materials used to build the building and how far they travel, amount of energy and energy source needed to produce each component and so on. So when a building is to be demolished it is important to see if it will be beneficial to refurbish the building instead, considering a life cycle perspective. It is obvious that emissions can be saved by refurbishing the building and therefore save emissions and costs.

This thesis will look into the process of remodelling of a case in Aurland, Norway. The goal is to refurbish an old building that is already standing there and turn it into a UNESCO World Heritage Center. Their goal is to make a sustainable building that uses renewable energy sources and high tech and low tech solutions to raise the buildings energy efficiency and lower its GHG emissions and costs while holding up standards for indoor climate. [3]

The study is run simultaneously with two other studies. The first project is focusing on different materials for the building envelope, that is walls, windows, doors, roof and slab on ground. And the second study is focusing on various combination of renewable energy technologies consisting of heat pumps, solar thermal collectors and solar panels. The results from these three studies will be merged to present a final solution to the project owner. This will be more discussed in chapter 8

1.1 Aim and scope

This study aims to find a solution that will optimize the buildings energy usage by using relevant technology while minimizing GHG emissions and cost.

How can the energy usage of the UNESCO World Heritage Center be optimized, while also considering GHG emissions and costs? a) What control method for BMS and HVAC should be implemented to maximize energy savings? b) What energy source for the HVAC system has the best performance?

Several control methods will be considered and three relevant energy sources for the HVAC system will be studied. The methodological part can be split up to three parts, that is energy efficiency simulation of the building in a program called SIMIEN, Life Cycle Assessment in a program called One Click LCA and finally the financial aspect will be estimated in a program called HOLTE Smart Calc. Then results from these three methods will be gathered and a comparison will be made between different solutions in order to pick the best one suited for this case.

1.1.1 Limitations

The main limitation of this study is that the case it focuses on is not yet fully designed. MAD architects have made a concept of the building as it will be refurbished. This introduces big errors, as the plans will most likely change over time of detailed design. In light of this detailed quantity of piping, electric cables is not available and therefore will not be included in the Life Cycle Assessment. Only the energy production system and pieces associated with them. The calculations in this study will only be based on the concept from MAD architects so they will not represent the final building. However the results can serve as a good base for decisions in the design phase of the building. This study will not focus on energy savings in the end users DHW and lighting and appliances. This relies to much on users behavior and is hard to predict, instead the focus will be put on space conditioning.

1.2 Structure of thesis

This thesis is structured in a classic IMRaD structure. That is Introduction, Methods, Results and Discussion. After the introduction the case is introduced in chapter 2. Chapter 3 introduces relevant theory on BMS and control methods for HVAC systems. Then three different energy sources for HVAC systems are introduced. Chapter 4 includes all methods that were used in this thesis, that is Simien, One Click LCA and cost estimations. Later on limitations concerning the methods are described. Results are reported in chapter 5, first results from each method are shown, then later on the main results from each method are grouped together. In chapter 6 the results are discussed and the decision on the recommended solution is chosen. Chapter 7 concludes the whole study and displays the main results. Then finally chapter 8 shows the results from the three projects and they are briefly compared.

2 The UNESCO World Heritage Center

Aurlandsvangen is a small town located in Arlandsfjorden (Nærøyfjorden) which is a part of Sognefjorden in western Norway, marked with a red dot on figure 1. It is a part of a bigger municipality called Aurland and it consists of around 1700 inhabitants. In 2005 the neighbouring fjord, Nærøyfjorden together with Geirangerfjorden further north were registered as a UNESCO World Heritage Sites. In the fjord the mountains reach up around 1400m above sea level and the water depth reaches 500m. It displays extraordinary landscape and is a big tourist attraction [22]. In 2013 a project was started between the Nærøyfjorden World Heritage Park and Aurland Cooling and Fruit warehouse (in addition to Aurland Nature Workshop). The goal was to develop a World Heritage Center in Aurland linked to the UNESCO values. The project was dropped due to many reasons. Since then the Nærøyfjorden World Heritage Park has put in effort to find a suitable place for a World Heritage center and in 2019 the two parties signed an agreement on developing the center in Aurland. So the ultimate goal of the project is to develop a UNESO World Heritage Center in Aurland based on existing building. The building that was chosen is the Cooling and Fruit warehouse at Odden in Aurlandsvangen. [3]

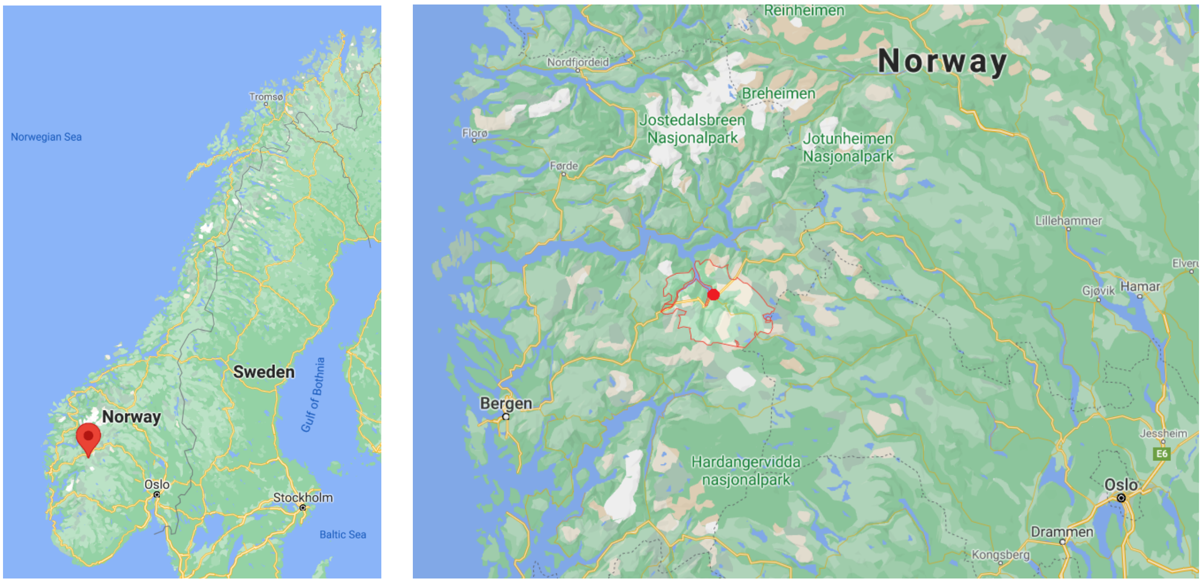

Figure 1: Map of the area. Aurlandsvangen is marked with a a red dot, and Aurland the municipality is marked with a red line on the right figure. [1]

Unesco is the United Nations Educational, Scientific and Cultural Organization. Their goals and values are made around building peace through international education, science and culture. [23] The SDG's are a big importance since UNESCO helped to develop them in 2015 and therefore the project will contribute to some of them. Especially number 12, Responsible consumption and production, since they will be refurbishing the old building instead of building a new one. They plan to use green and innovative technologies to supply energy such as fjord heating, solar heating and natural ventilation as well as utilising high technology and low-tech solutions to create a sustainable building. They plan on targeting the following SDG's shown on figure 2. [3]

It is regarded that this thesis will contribute to the SDG's number 7, 9 and 11. Number 7 stands for, Ensure access to affordable, reliable, sustainable and modern energy for all. Number 9 stands for, Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation. Then 11 stands for, Make cities and human settlements inclusive, safe, resilient and sustainable. [22] How this study relates to these goals will be more elaborated on in section 6.

Figure 2: The SDG's that the project aims to contribute to. [2]

The idea is to build a multi functioning building serving as Fjordportalen or a fjord portal. It was decided to use the old Cooling and Fruit warehouse at the harbour in Aurlandsvangen. The building and the area around it has great potential for development. The municipality will be on board and contribute with different projects such as parking around the area and hiking and biking roads in the area. Since the 1950's there has been cooperation between the local farmers and the Aurland municipality to help the circular economy of the area and it is of great concern that activity conducted in the center will connect its work to the UNESCO World Heritage Center values. The UNESCO World Heritage Center will host diverse activities, such as area for local farmers to sell and exhibit their end product, tourists can stop by when arriving by the ferry for the cafe, shopping, info or visiting exhibitions, halls for exhibitions and events as well as office space. [3]

The existing building was built in 1950, and has served many purposes throughout the years. Since most of the building is not isolated and is in poor condition there is not a lot of work going on there. There is a small office space where the project leader has an office and a store in the basement selling farmers necessities. On the first floor is a small workshop used to fix up different things and the rest of the building is used as some sort of a warehouse for local products such as tourist merchandise and souvenirs. In the attic there is nothing as the roof has no insulation but holds most of the water out. The building as it stands now and the concept building are shown in figure 3.

Figure 3: The building as it stands today compared with the concept that MAD architekt have made. [3]

The building is located at a point called Odden at the harbor in Aurlandsvangen. Overview of the area is shown in figure 4 [3]. In 2018 Multiconsult did a report evaluating the building and if it would be feasible to renovate it. They concluded that it would be possible to reach the Norwegian building regulation, TEK 17 (see more chapter 3) but the building needs serious renovation. That includes a new roof, ground floor, insulation of exterior walls, windows and doors, outer screen and a new Heating, Ventilation and Air Conditioning (HVAC) system. [3]

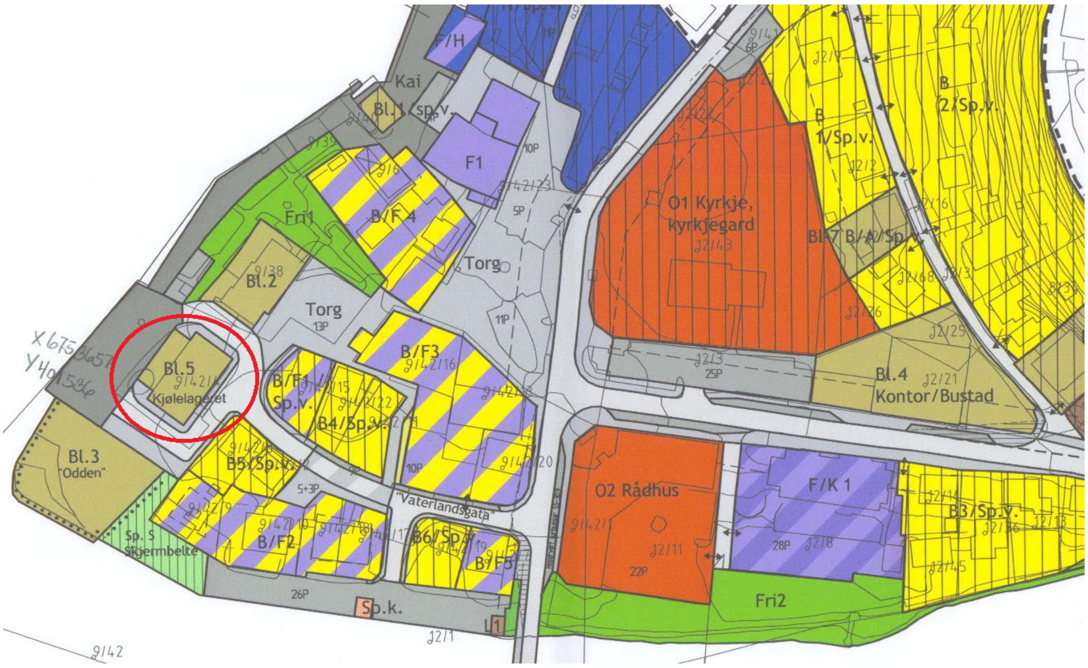

Figure 4: Overview of the area, Cooling and Fruit warehouse is located inside the red circle. [3]

For the concept of the new building that was designed by MAD architects all the areas will have a new purpose. The plan is to extend the area of the building by adding a glass wall. This offers many possibilities, it enables to add an elevator shaft and the glass outer wall offers openings so the area will be integrated with the surrounding space. [3]

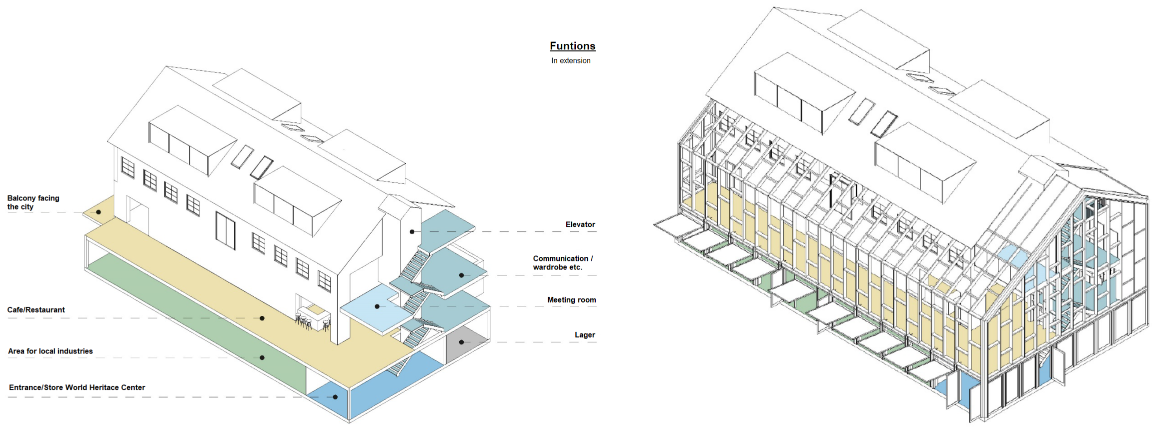

Figure 5: Functions of concept building. [3]

The ground floor, shown in figure 6, will host general areas such as toilets, storage and technical rooms, then the rest of the space is dedicated to sales of local products, there is also storage space for the partner and for now they are as listed: SAKTE, Aurland Bondelag, Sognalarm, Lærdal Grønt and Sogn Jord- og Hagebruksskule. [3]

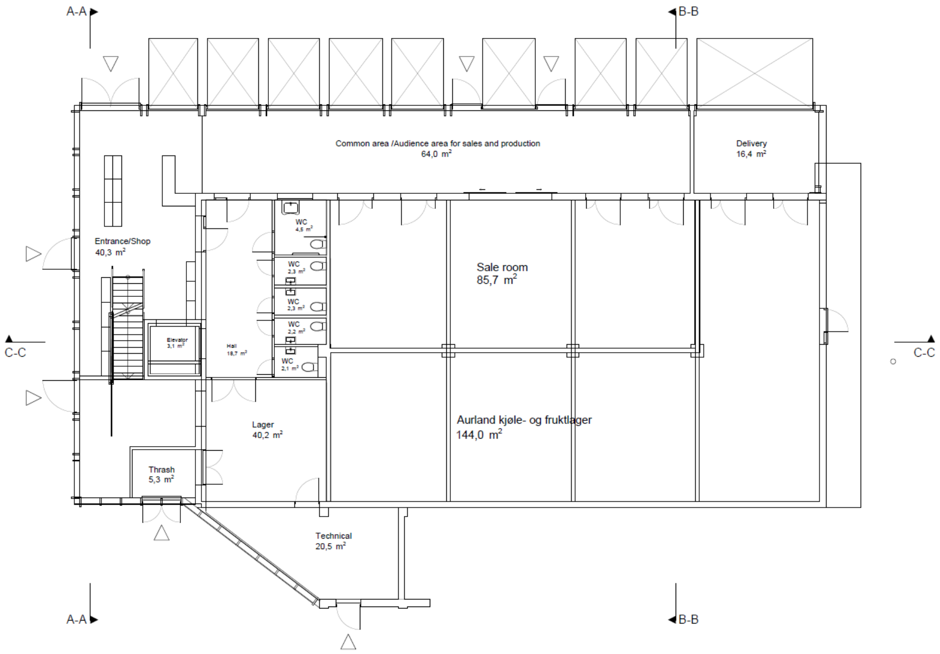

Figure 6: Drawing of the basement of the concept from MAD architects. [3]

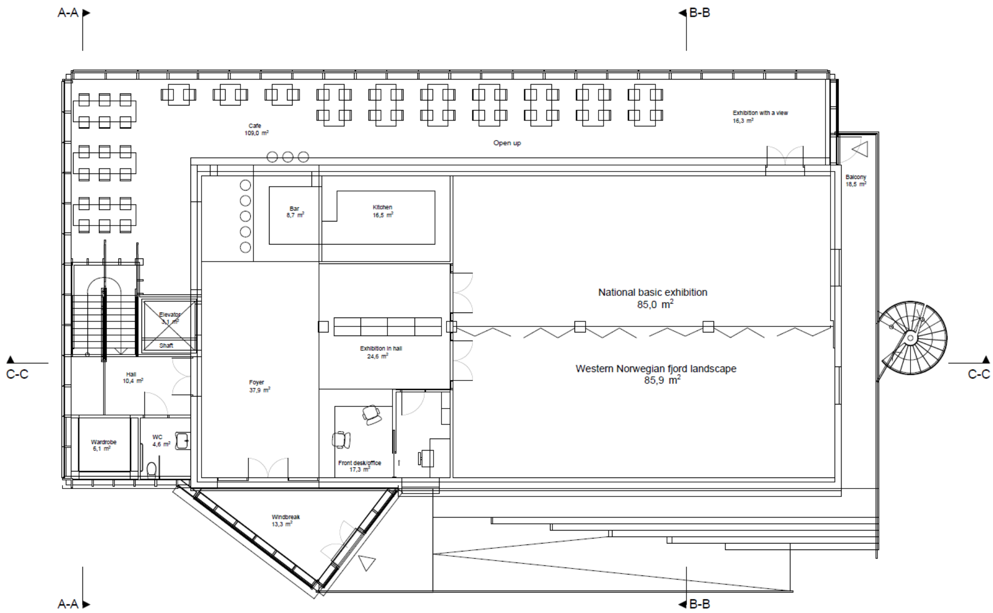

Figure 7: Drawing of floor 1 of the concept from MAD architects. [3]

The main entrance is onto the first floor, shown in figure 7, this entrance is towards the city center. On the first floor the cafe and seating area will be found as well as a service center and the first part of the exhibition area. The exhibition will be connected to the concept of the heritage center, where the goal is that all the municipalities(Lærdal, Voss and Vik, along with Aurland) that are connected to this project get a space in the center to exhibit a part of their region. [3]

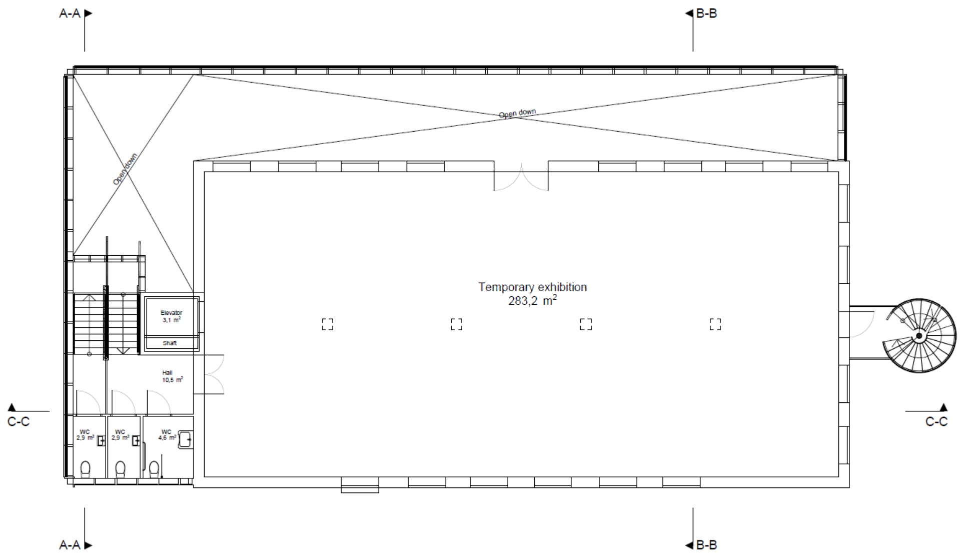

Figure 8: Drawing of floor 2 of the concept from MAD architects. [3]

The second floor, shown in figure 8, will also serve as an exhibition area but since the area is very large it has great possibilities to serve for different purposes, such are conferences, workshops or events/parties. [3]

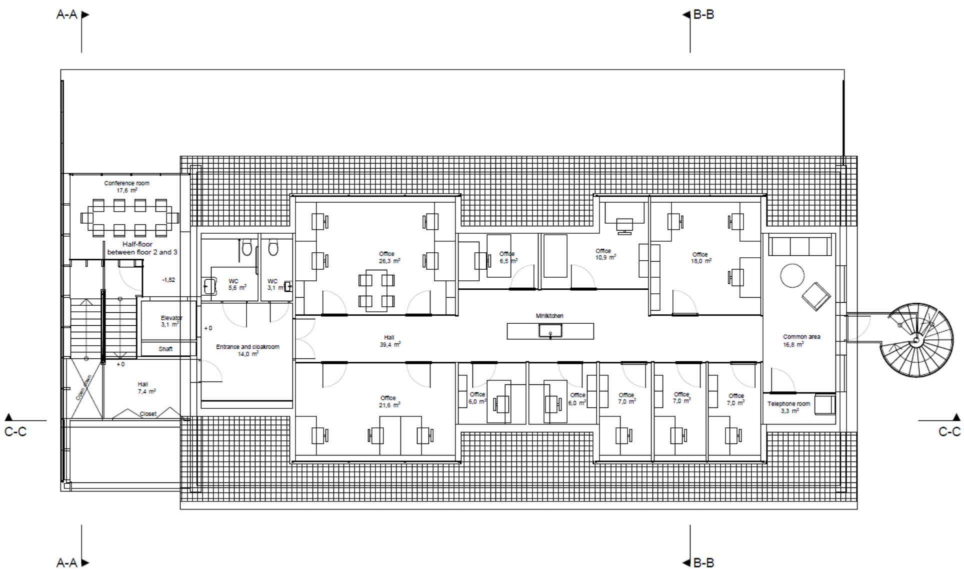

Figure 9: Drawing of floor 3 of the concept from MAD architects. [3]

The attic, shown in figure 9, will serve as an office space. Since it is a requirement of the heritage center to have administrative office space for the connected organisations. That includes The States Nature Supervision, Protected area manager and Aurland Mountain Guides. The area has a common lunch area and some more office spaces for rent. In the glass side of the building will also be a meeting room between 2nd and 3rd floor. [3]

3 Theory

The aim of this study is to look into solutions to optimize the building energy use by using relevant technology while minimizing GHG emissions and costs. The next sections will introduce theory that is relevant for this study. To begin Building Management Systems (BMS) will be introduced, how they are built up and different control methods available for Heating, Ventilation and Air Conditioning (HVAC) systems. Then three energy sources for HVAC systems are introduced, Air Source Heat Pump (ASHP), Water-Thermal Energy Production System (WEPS) and the conventional Electric Boiler.

Since most buildings today are sealed of from the outdoor climate it is important that the indoor climate is up to standard and has sufficient comfort level. Two solutions that can deal with this are using a HVAC system or integrating natural ventilation in the building structure. There is a way to use both these concepts automatically but that requires the use of a BMS. There are different methods to control HVAC systems and they all have their pros and cons, but integrating the HVAC control into a BMS helps the system to have better control of the building and with this system it is also possible to use natural ventilation by opening and closing windows automatically. Using the technology also offers great advantages in fighting climate change. A BMS optimizes the buildings energy use so saving energy and GHG emissions respectively. [5]

The Norwegian regulations on technical requirements for construction work, also referred to as TEK17 is a regulation that sets minimum requirements for all construction work in Norway in order for the building to be legally built. TEK17 is a thorough guide that explains all aspect of how to build a building in Norway. TEK17 also has strict requirements for indoor climate and health as well as energy efficiency. In this study TEK17 is used in order to see if the solutions proposed for the UNESCO World Heritage Center will qualify. [24]

3.1 Building management system(BMS)

BMS's are used to, as the name implies, to manage buildings. They are also know as Building Control System (BCS) or Building Automation System (BAS). The system controls the indoor climate of the building by manipulating lighting, HVAC and more. The main goal of a BMS is to keep the comfort level inside the building up to standard while optimizing the building energy usage. These two goals are contradicting each other, keeping high comfort level requires more energy use, so the BMS is used to solve this problem. This is done by monitoring the building with sensors and data gathering. These systems can also monitor and use efficiently renewable energy produced on site such as solar or wind. [25]

There are three factors used to measure indoor comfort. These are described as follows:

- **Visual comfort** - is the amount of light inside a room, it is measured in LUX and is controlled with blindfolds on windows and the lighting system. [21]
- **Thermal comfort** - is usually measured in temperature and the HVAC system is used to heat or cool the air in the building. [21]
- **Air quality** - is measured in CO2 concentration and the ventilation part of the HVAC system is used to control this. Natural ventilation can also be used here and a BMS has an option to control window openings so this is also a viable solution. [21]

There are different control methods in BMS's they range from simple forward flow control to complex learning and modelling systems. Figure 10 shows a simplified schematic figure of a BMS and its control layers. The BMS is the main controller and then more controllers are spread out through the system. The BMS is more of an overview controller that brings together all the systems, gathers data and has overall control.[4]

These systems have two types of variables, input variables and output variables. Input variables are things that effect the systems, know as manipulated inputs that are set by operators or the system and the disturbances, they can not be controlled. Then output variables are controlled by the system. [4]

Table 2: Common input and output variables for BMS. [4][13]

Common input variables for BMS	Common output variables for BMS
Set points for comfort levels (Manipulated input)	Heating, ventilation and air conditioning system (HVAC)
	Domestic Hot Water (DHW)
Occupancy of building (Disturbance)	Lighting system control Shading system control
Outside weather (Disturbance)	Window openings Energy conservation and storage
Fluctuating energy price (Disturbance)	On site energy production Monitoring and data gathering
	Communication and security system management

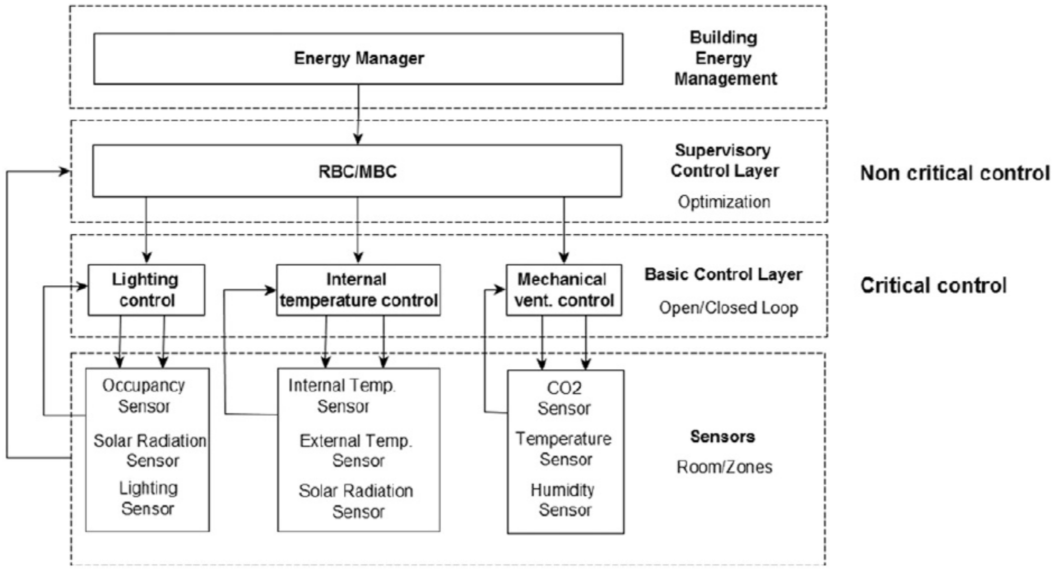

Figure 10: A schematic diagram of a BMS and devices connected to it. Rule Based Control (RBC) and Model Based Control (MBC) are two different ways for higher level control. [4]

Then the control method can be roughly categorized into two main strategies.

- Feedforward (or open loop)
- Feedback (or closed loop)

Open loop controllers take information from the reference, for example a light switch, and processes it in a preset way to generate the input for the system, then the system generates the output. Simple configuration of this process is demonstrated in figure 11. Example of open loop control is a lighting system. Some one presses a light switch and the controller tells the lighting system to turn on the light associated with that switch. [4]

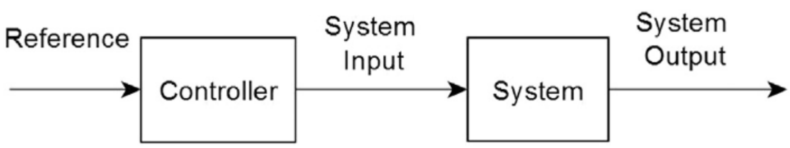

Figure 11: A schematic diagram of a open loop system. [4]

Closed loop controllers work essentially the same way but the output is measured, this is called error, then the controller works to correct the error, this process is demonstrated in figure 12. Example of a closed loop control is temperature control in a HVAC system. Preferred temperature is set by the programmer, then the system tries to produce it and then the output temperature is measured and compared with the preferred input. Then the system can make adjustments to its output to better reached the desired output. [4]

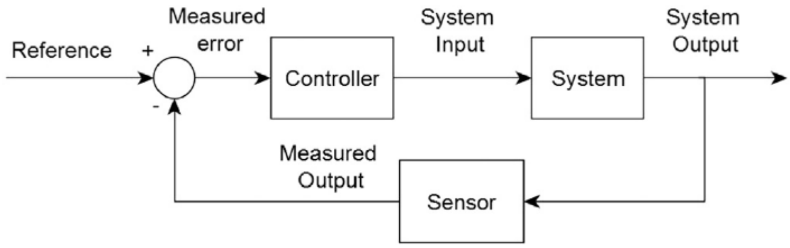

Figure 12: A schematic diagram of a closed loop system. [4]

Open loop or closed loop control refers to low level controlling, that is that control of a single function within the bigger system. When looking at high level control there are other factors to be looked at. Rule Based Control(RBC) is a system that makes decisions based on preset rules. That is "if initial conditions" are met then "action" will be taken. For example if a sensor senses a certain temperature then the system takes action to cool or heat the room. This is considered to be a direct way of control. Today RBC systems are well researched and can be implemented with good results, however they are fully dependent on the rules that are set for them and choices made by the programmers. So they can be easily affected by human error. [4]

Model Based Control (MBC) is a totally different approach. The strategies are considered indirect logic. In these systems the building behaviour is modeled and the next state is calculated based on the model. These systems don´t need this high amount of sensors. This method is much more complex compared to RBC, mostly because of the effort needed to calculate the model. [4]

3.2 Heating Ventilation and Air Conditioning (HVAC) control methods

Research shows that HVAC systems use up to 50% of a buildings energy [5]. Therefore it is obvious that this area needs good optimization. There have been developed many different control methods for HVAC systems. They can be split up to five main groups, shown in figure 13. A brief introduction to the system is described below.

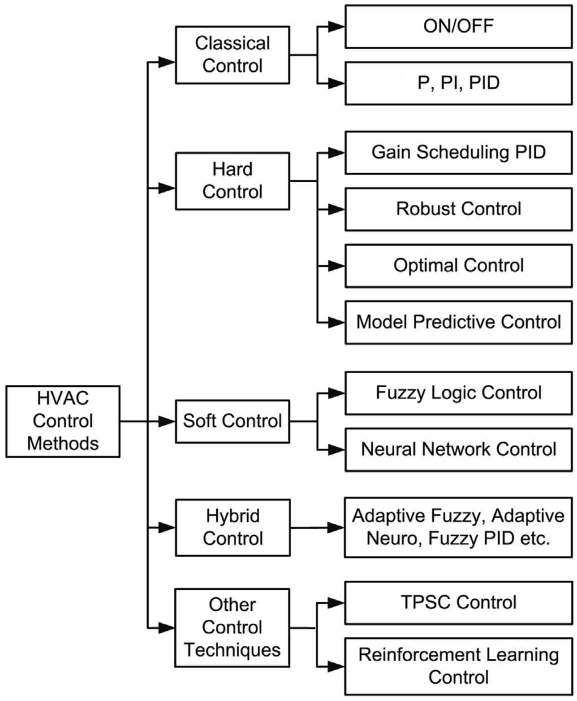

Figure 13: Different control methods for HVAC systems. Modified figure from [5].

- **Classical Control** - are the most basic and easy to implement methods, ON/OFF uses preset values to change states, when temperature reaches a set goal the heating turns of, and then turns on again when it is to cold again. Proportional(P), Proportional-Integral (PI) and Proportional-Integral-Derivative (PID) controllers use error dynamics to regulate the variable by parameters that are preset by the programmer. These methods are widely used but they don't show very good results on energy saving since they use a lot of extra energy due to big volume rooms and time delay. [5] Figure 14 shows how P, PI and PID controllers respond to change in input over time. PID has the least swing in output and is quick to regulate towards the desired output.

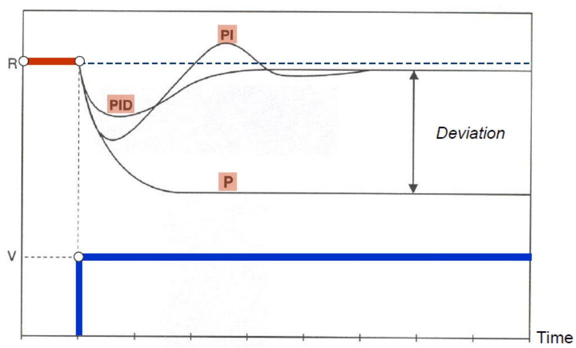

Figure 14: V is a change in input or a disturbance and R shows how P, PI and PID controllers respond over time.[6]

- **Hard Control** - are more complex, there are five types, Gain Scheduling PID (GSPID), Robust control (RC), Optimal control (OC) and Model Predictive Control (MPC). In GSPID multiple linear systems are combined into one nonlinear system. For example uses 2 PID controllers with different gain schedule to control different states of a system. RC is designed to work well for a system that has changes in parameters and disturbances that change over time. For OC, the programmer sets up a cost function and the algorithm tries to solve the function for each given state in order to minimize the cost of running the system. MPC seems to be one of the most promising control techniques, it uses a model to predict the future state of the system and has the ability to deal with external disturbances by including for example weather forecast in the model. Hard control methods are well established and show good results. However they require much more computational power than classical control.[5]

- **Soft Control** - Are relatively new techniques, they became available at the emergence of digital controllers. Fuzzy logic (FL) are based on if-then-else statements, they are often used as supervisory controllers over multiple PID controllers but can also be used as local lower level controllers. Adaptive Neural Network (ANN) control is trained on data from the system and fits a mathematical model to the data. The algorithm is set up in black box configuration so the model does not need to understand the physical attributes of the system, it simply needs the input-output data. [5]

- **Hybrid Control** - Merge together hard and soft control methods, for example uses soft control ANN at higher level and hard control at lower level. Fuzzi-PID uses FL to auto tune several PID controllers. This allows the system to gain advantages from both sides, however this also draws in disadvantages from both types. Soft techniques require big sets of data and hard control can be difficult to design and tune. [5]

- **Other Control Techniques** - Two Parameter Switching Control (TPSC) is a sort of an improvement to the ON/OFF technique. ON/OFF uses on sensor to measure output and acts on that feedback. TPSC uses two sensors at different locations to improve the feedback. For example a water floor radiant system has one temperature sensor in the slab and one in the room, so the system can reduce temperature oscillations in the room. Reinforcement-learning controller learns from previous decisions using machine learning. This method provides acceptable energy savings but does not reach the level of MPC. This is a model free method and improves its saving as the system learns. However this takes to long time. [5]

3.3 Heat pumps

A heat pump is a device that can generate thermal energy from renewable energy sources. They are used to transfer thermal energy from its source and into a heating system to heat up buildings, such as HVAC systems. The main energy sources for heat pumps are ambient air, seawater, groundwater, bedrock, ground(soil), waste heat. [26] Figure 15 shows the working cycle of a heat pump. The system is a closed loop and inside there is a working fluid, there are many different fluids that can be used but the all have similar properties, good thermal conductivity and chemical stability. Most commonly used fluids are HFC, HFO, ammonia, hydrocarbons(e.g. propane) and Carbon Dioxide(CO2). Some working fluids that were used before have now been banned due to high ozone depletion potential or global warming potential (greenhouse gas), such as CFC and HCFC gases. In order to transfer thermal energy from the heat source to the heat supply the working fluid is forced into different states and can thereby be used to amplify thermal energy. [27] A heat pump consists of 4 main components: Evaporator, Compressor, Condenser and Expansion valve.

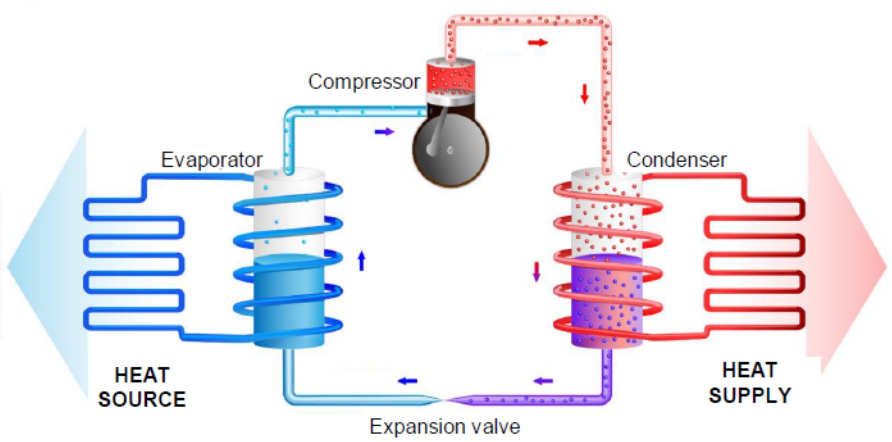

Figure 15: A schematic diagram of a heat pump and how its process works. [7]

The working cycle of a heat pump is described in the following 4 steps. [7]

- **First step - Evaporator** - Working fluid is at low enough pressure so it is colder than the heat source. Heat is transferred from heat source to working fluid due to temperature difference and the heat source gets cooler. As the working fluid gets warmer it evaporates into gas and goes towards the compressor.
- **Second step - Compressor** - The compressor is driven by an electrical motor. It compresses the gas which raises its temperature. The compressor also maintains the low pressure in the evaporator. The compressor releases super heated gas into the condenser.

- **Third step - Condenser** - At this stage the working fluid is at high pressure and the temperature is higher than the heat supply. Thermal energy is transferred to the heating system (water,air) due to temperature difference. As the temperature of the working fluid(gas) drops it starts to condenses into liquid.

- **Forth step - Expansion valve** - The liquid coming from the condenser is at high pressure and high temperature, the expansion valve reduces the pressure and therefore the temperature drops. At the other side of the expansion valve the working fluid will be a mixture of liquid and vapor. Then the low temperature working fluid enters the evaporator end the cycle repeats itself.

A modern heat pump can also be run in cooling mode. Then the cycle is reversed and the heat source is used as a heat sink. [7]

3.4 Air Source Heat Pump (ASHP)

An air source heat pump uses air as an energy source, as the name implies. These heat pumps use ambient air, either from outside or for example exhaust from buildings. These systems use fans to deliver air to the evaporator so the heat pump can run its process. The downside of using air as a heat source is that the air temperature must be relatively stable and the heat pump efficiency is decreased for each degree when temperature goes lower than 5°C. A schematic figure showing the ASHP cycle is shown in figure 16. Following on the decreased efficiency with lower temperature is that when outside air temperature goes below 5°C frost starts to accumulate on the evaporator. To deal with this additional defrosting methods must be applied that require additional energy or resource usage. Example methods for this are hot gas defrosting or using heat from the heating system. Both these methods decrease the system efficiency. [8]

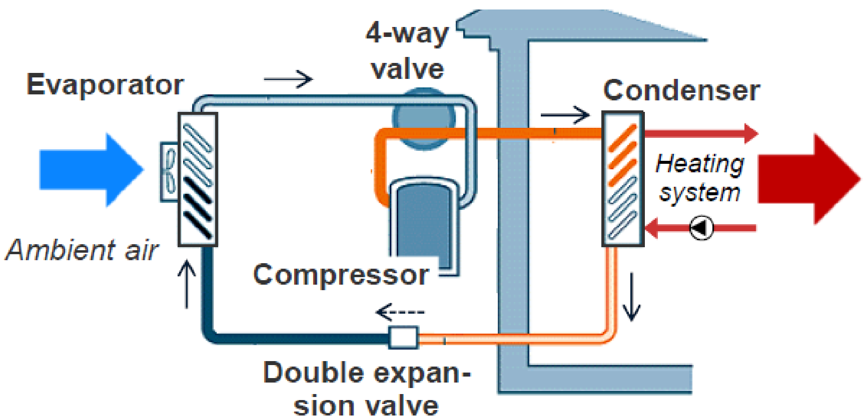

Figure 16: A schematic diagram of a ASHP system and how its process works. [8]

3.5 Water-thermal Energy Production System (WEPS)

WEPS also known as water-water heat pump uses seawater to generate energy for heating and cooling of buildings. This system is already in use in Norway and shows good results, for example in Sogndal, Eid and Drammen. The fjords in Norway are very deep and the water in them is stable and therefore the water temperature at depth stays relatively stable. The water at 50m depth stays around 8-12°C all year. Water at this temperature can be used to extract thermal energy used for heating. So a pipe is laid down into the ocean, connecting to a small shelter house at shore. The system pumps up seawater into a heat exchange unit that transfers heat into a closed fresh water loop. This is done to minimise seawater usage in the system since it can cause corrosion and problems with algae. Having a closed water loop system causes the water to flow with almost no energy since the force of gravity helps pumping the water. The only energy needed is to overcome the force of friction. This allows the system to run with very low energy usage. From here the freshwater is pumped to a distribution station that is closer to the customers. A schematic diagram of this process is shown in figure 17. This is a figure from the system used in Sogndal. [9]

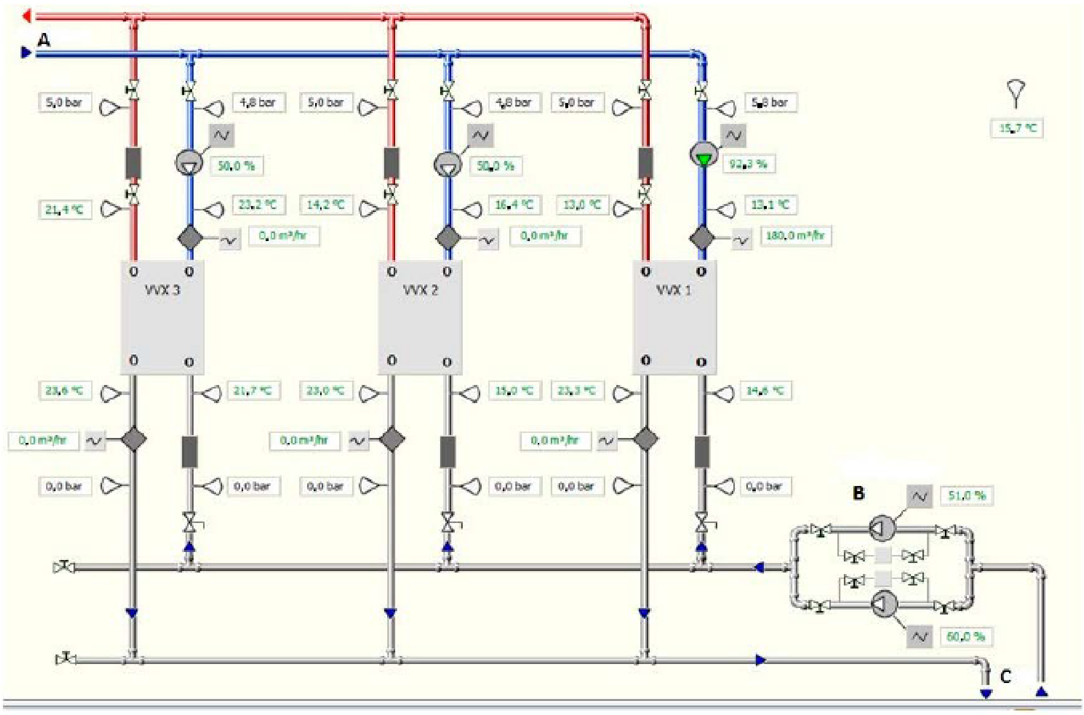

Figure 17: A schematic diagram of the first heat exchange where thermal energy from sea water is transferred to fresh water from the WEPS system in Sogndal. The system was built by Sognekraft AS in 2014. The grey pipes contain seawater that is being pumped up from the ocean, WX1-3 are heat exchange units, red pipes are warm water transferred to distribution the station and the blue pipes are cold water coming from the customers. [9]

There are different versions of this system. In the system in Eid, each customer has its own heat pump and then warm water is pumped straight from the distribution station to the customers but in Sogndal the heat pumps are located in the distribution center and hot water (71°C) is then pumped to the customers. Experience shows that a system with a heat center is more cost efficient. Customers can use either water-water heating equipment, such as radiators or floor loop heating, or water-air to distribute heat with an air conditioning system. Figure 18 shows a schematic diagram of the heat center in Sogndal.[9]

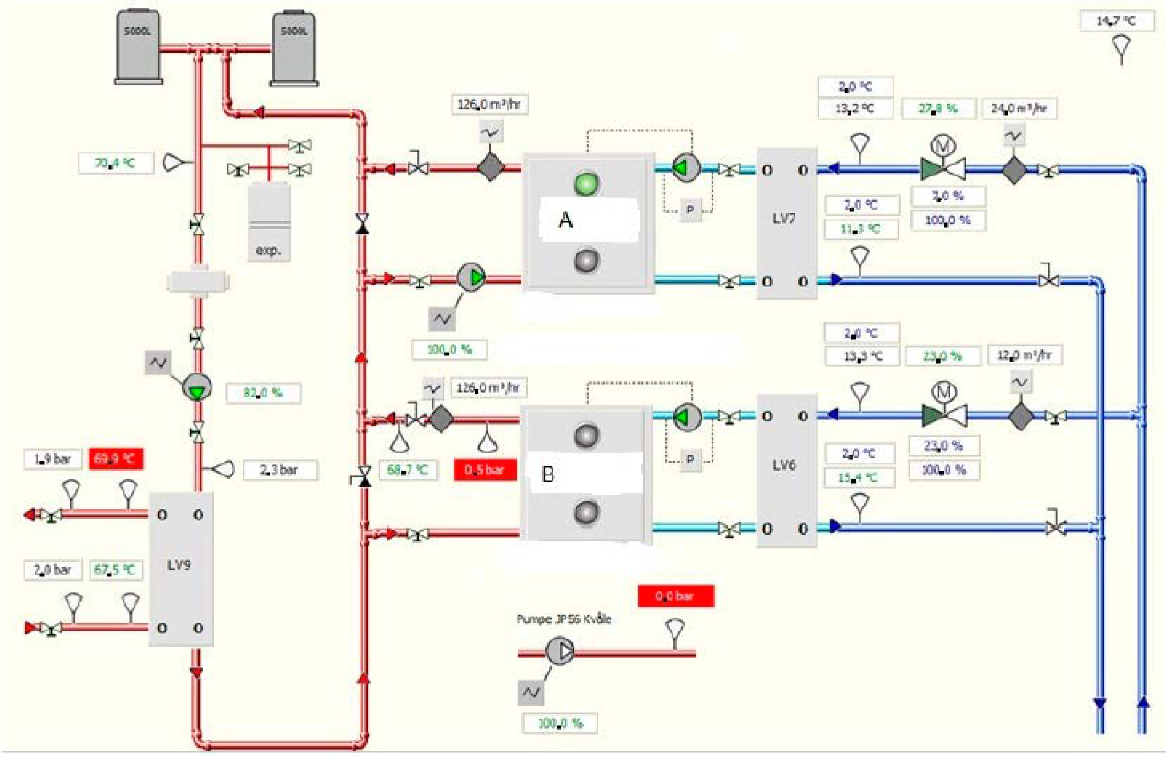

Figure 18: Technical diagram of the heat center in the WEPS system in Sogndal. The system was built by Sognekraft AS in 2014. Blue pipes are water (6-8°C) coming from the sea water station, heat exchanging unit transfers the heat to the next closed loop system (light blue pipes). Then that water goes through the heat pump where the water is heated to about 71°C and then delivered to the customers. [9]

Due to low temperature of the water from the sea water heat exchange unit to the heat pump (6-8°C) there is no need for insulated pipes, since the pipes are dug at least 100cm into the ground the surrounding soil temperature stays relatively stable and heat loss in the water can be neglected. This saves investment cost. The system in Sogndal requires insulated pipes from the heat center to the customers since the water is already heated there. This will result in higher costs but in the other system each customer has to buy its own heat pump and experience shows that not all customers have the knowledge to run and maintain heat pumps so in the end this will be more expensive. Figure 19 shows a explanatory figure of a WEPS system. [9]

This system can also be used in cooling mode, then the cycle is reversed and the water in the fjord is used as a heat sink where heat from the buildings is released. [9]

This system shows outstanding performance and has shown that customers can save from 30-50% of energy used for heating compared to general electric heating using hydro energy. However the investment cost is significantly higher, but investment cost per Wh decreases as the system grows. But as mentioned before there are ways to cut down on investment such as using uninsulated pipes, also it will save a lot if construction is done in parallel with other roadwork, so pipes can be laid in trenches with sever, cables or water source pipes. [9]

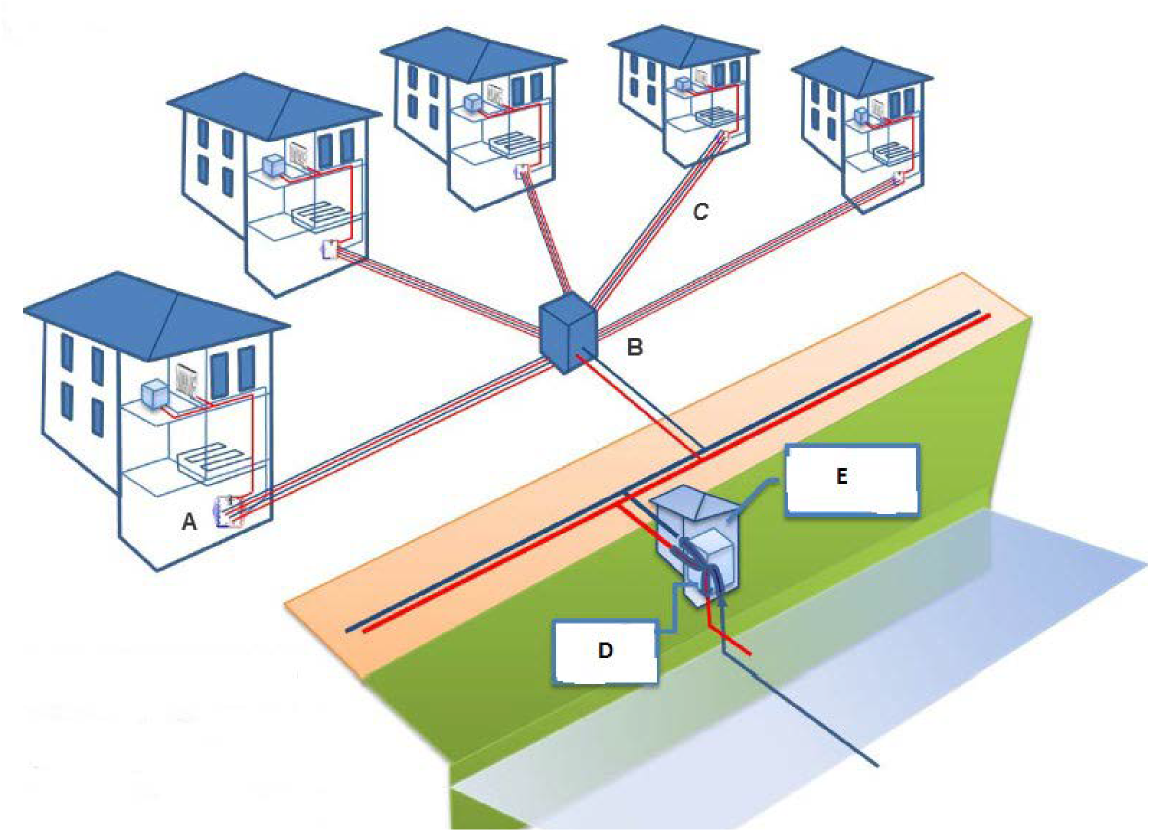

Figure 19: A schematic diagram of the WEPS system. (E) is the building where sea water is pumped into and (D) is the heat exchange unit from sea to fresh water. (B) is the heat pump center, (B) pipes transferring hot water to customer, (A) each customer has a heat exchange unit and a power meter. [9]

3.6 Electric Boiler

A conventional electric boiler is a system that uses electricity to heat water for domestic use. These systems come in various sizes and can be small enough to hang on a wall. A simplified version of system consist of an insulated water tank, two heating elements, two thermostats and pipes pumping water in and out of the tank. This setup is shown in figure 20. Cold water is pumped into the bottom of the tank. The lower heating element starts heating the water, hot water rises up in the tank and gets heated to the desired temperature. Then hot water is pumped to the end users, radiators, showers etc. The thermostats regulate the heating elements to make sure the boiler works in an efficient way. [28]

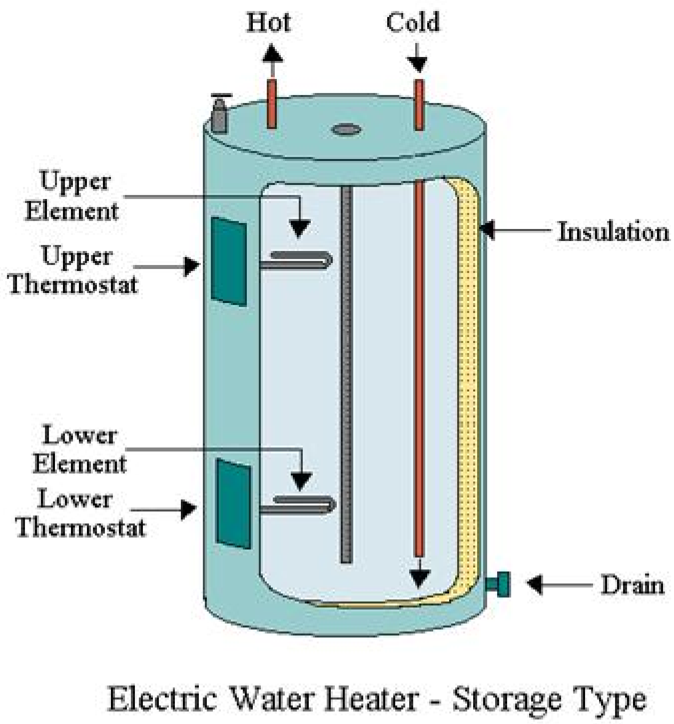

Figure 20: A schematic diagram of an Electric Boiler.[10]

4 Methodology

When a building is to be renovated many things can go wrong. Old buildings sometimes don't meet new standards and when mixing together the old with the new things will not always go as planned. There for it is important to do the preparation work properly. In this project several methods were used to ensure that the remodeling of the building will be as cost efficient as possible while still minimising the GHG emitted during the remodeling and operation time of the building. This study will perform a literature review to look into different solutions to increase the building energy efficiency which will in return lower its emissions. Then the building will be modeled in Simien to see if it meets the current building standard in Norway, TEK17 [29]. Different solutions will also be modeled to see their energy efficiency. Simien is frequently used in the Norwegian market since it is designed to give results based on Norwegian building standards [30]. Life cycle assessment will find out how much GHG these solutions actually emit throughout their whole life cycle. Then the costs connected to each solution will be estimated. Results from these three methods will then be used to compare the solutions and conclude on the best solutions for this case. These methods were chosen because one of the supervisors recommended them.

Decision was made to further look into three solutions for energy source for HVAC systems. These are already described in the theory chapter. Solutions that were chosen are Electrical boiler, ASHP and the WEPS system. These solutions were chosen based on interest from project owner, accessibility on site and solutions already used in the region. The process of the methods is shown in figure 21.

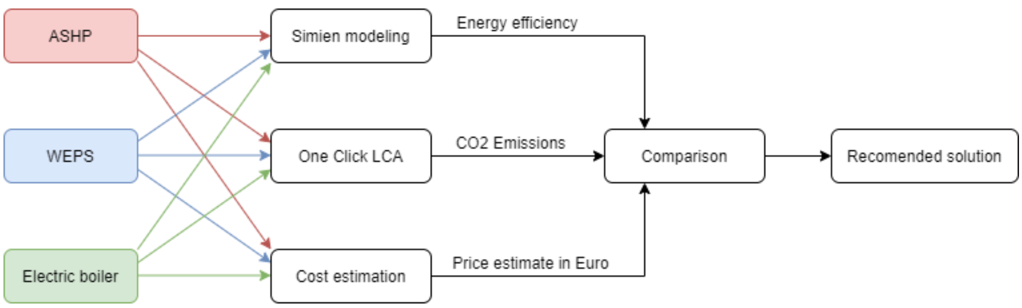

Figure 21: Flow diagram describing the methods.

For the BMS the goal was to look at different control methods that are described in section 3.2 and implement them into Simien modeling and One Click LCA. Then use these programs to calculate potential energy and CO2 emission savings for the building when implementing a BMS in the building. There were some drawbacks when this work started and is reflected on in section 4.4.

This study was conducted in parallel with two other studies on the same case. The first study was looking at different building materials for the building envelope, that is, walls, windows, doors, roof and slab on ground and how they affect energy efficiency and CO2 emissions and costs. Then the second study was looking into various combinations of renewable energy technologies consisting of heat pumps, solar thermal collectors and solar panels and like the others will look at energy efficiency, CO2 emissions and costs. Then later on the three studies will combine to make a complete recommendation to offer to the building owners. This is further discussed in chapter 8.

In the beginning of the thesis period the students went on a field trip to Aurland to examine the building. Gøran Johansen who is the project leader of the UNESCO World Heritage Center hosted the excursion and made sure all aspects of the building were inspected. This excursion helped to get familiar with the building and also to meet and speak with Gøran and hear his ambitions with the project. In the same trip there was also held a meeting with MAD architects and they presented their work and explained what they want to achieve with the concept model that is presented in the preliminary project. [3]

4.1 Simien modeling

This part of the project was conducted in cooperation with the two other projects working on the same case. In the beginning a decision was made to make three models of the building in Simien, one for the existing building as it stands today, one for a TEK 17 version of the existing building where assumptions are made so the building passes for the TEK17 standard and then one for the concept that the architects have made. Then later on this project would try and improve the model for the concept by adding on solutions that will improve its energy efficiency, this task would help with decision on the final solution.

When the modeling work started it quickly became clear that it would be nearly impossible to make a model of the existing building since it is in a really bad condition and figuring out values for thermal transmittance for doors windows etc. would be a near impossible task. Also after reflecting on the purpose of this model it was concluded that it would be unnecessary, in light of this the decision was made to skip this model. Reasoning was it gives no valuable results for the end result.

The existing building was set up in Simien with the assumptions that all values qualified for the TEK17 standard. Multiconsult already did a similar model and some input values needed for the model were taken from their report. After the model succeeded in qualifying for the TEK17 standard the goal was to see how much this model could be improved by the concept building and after implementing technical solutions. Later in the conclusion was made that this info would also be useless since the building will not be refurbished to a building that would qualify for TEK17 as it stands today. The concept building from MAD architects is the end goal so this information is irrelevant. Later on after working on the concept building it became clear that the different systems that will be proposed in this study wont have any effect on the energy efficiency of the building envelope but only on energy usage by these systems and other end users of the building.

4.1.1 Concept building

The model was set up according to concept drawings from MAD architects and given that solutions for isolation, walls and such would qualify for the TEK 17 standard. Multiconsult already made a Construction technical assessments and energy calculations report for the project. This report provided necessary values that were not available either from the TEK17 standard or from the drawings. Due to lack of information some values had to be assumed. The thermal transmittance (U-value) of the big glass wall and the roof is a problem, so the building would not qualify for the TEK17 standard. This report will not focus on this part, rather it will try and increase the building energy efficiency by implementing technical solutions. When the model was complete and sufficient energy efficiency was reached a evaluation report was generated that shows energy usage split up by end users as well as U-values for each building part and if they qualify for TEK17. This report can be seen in appendix B. All input values for the model are shown in appendix A.

The model was run three times with a different energy source for the HVAC system in each run. The WEPS system in Eid can cover 90% of energy used for heating and cooling so the same was assumed in this case [9]. The same numbers were used for ASHP. Then 10% would come from electrical heating. Then for the electric boiler 100% of energy used for heating and cooling comes from electricity. The model generates a report that shows how the building performs on an annual scale. Full reports can be seen in appendices C, D and E

4.2 Life cycle assessment in One click LCA

Life cycle assessment (LCA) is a comparative analysis tool used to evaluate the environmental hazards and recourse consumption associated with the product, throughout its whole life cycle. So for a building or a building part, this would mean materials and energy used to manufacture all components, transportation to the building site. Energy and materials used to assembly and the construction. Energy used for running the building and then finally energy used for demolishing the building or replacing building part.[31]

This report will use a program called One Click LCA. The life cycle will be assessed for ASHP, Electrical Boiler and the WEPS system. Since the building has not been designed in detail the assessment will only count for the energy system itself. So no piping or equipment other than the energy generating system inside the building will be accounted for. This method assumes that the heating or cooling distribution system inside the building will be the same for all the cases so it will make no difference for the LCA.

One Click LCA has a database of solutions that can be assessed in their program. After searching through all relevant databases the best fitting solutions were chosen. Values used for the assessment are given in table 3 and reasoning for choosing these values below.

The name of the chosen products in One Click LCA are following:

- **ASHP** - Heat pump, air/water, 319 kg/unit (MINISTERE DE L'ENVIRONNEMENT, DE L'ENERGIE ET DE LA MER - MINISTERE DU LOGEMENT ET DE L´HABITAT DURABLE)

- **WEPS** - Electric heat pump (water-water), 70 kW

- **Electric boiler** - Electric boiler, per 1kW / unit - beta

For the WEPS system the pipe that will be laid into the sea is not included in this product so additional 32mm pipe was included. Estimated size of the pipe is given from the pipe used in Eid which was 60cm in diameter [9]. That system is significantly larger so this system should not need the same pipe size. It is estimated that the pipe would need to be at least 70 meters long to reach 50m depth. More accurate data on the seabed and detailed design on the system would be needed for accurate length of the pipe. According to a data sheet on PVC pipes the weight of a 30cm diameter pipe is 21,962 kg/m so total weight if the pipe will be 1537,34kg [32]. The pipes are transported the same distance and their service life is considered the same as the building life cycle so it is 50 years (further description later in this chapter).

The product that was chosen is called:

- Pipework for electric heat pump (brine-water, geothermal collector), 70 kW

	ASHP	WEPS	Electric boiler
Power factor of product (kW)	60	70	60
Tansport of product (km)	2000	2000	2000
Service life of product (years)	22	20	15
Annual energy consumption of building (kWh)	161588	155631	235340
Gross internal floor area (m2)	497	497	497
Calculation period (years)	50	50	50

Table 3: Imput values for the LCA in One CLick LCA

Power factor of product was chosen from results from Simien. The annual simulation presents a graph that shows the highest peak load of the system shown in figure 22. By adding together the peak load from heating system (red line) and heating batteries (green line) the highest load need is found. Load from cooling coils (blue line) does not need to be added to this power factor since heating and cooling will not be done simultaneously. The final number chosen was 5kw higher than the peak load from the graph indicated to make sure the device would never have to work at 100% capacity.

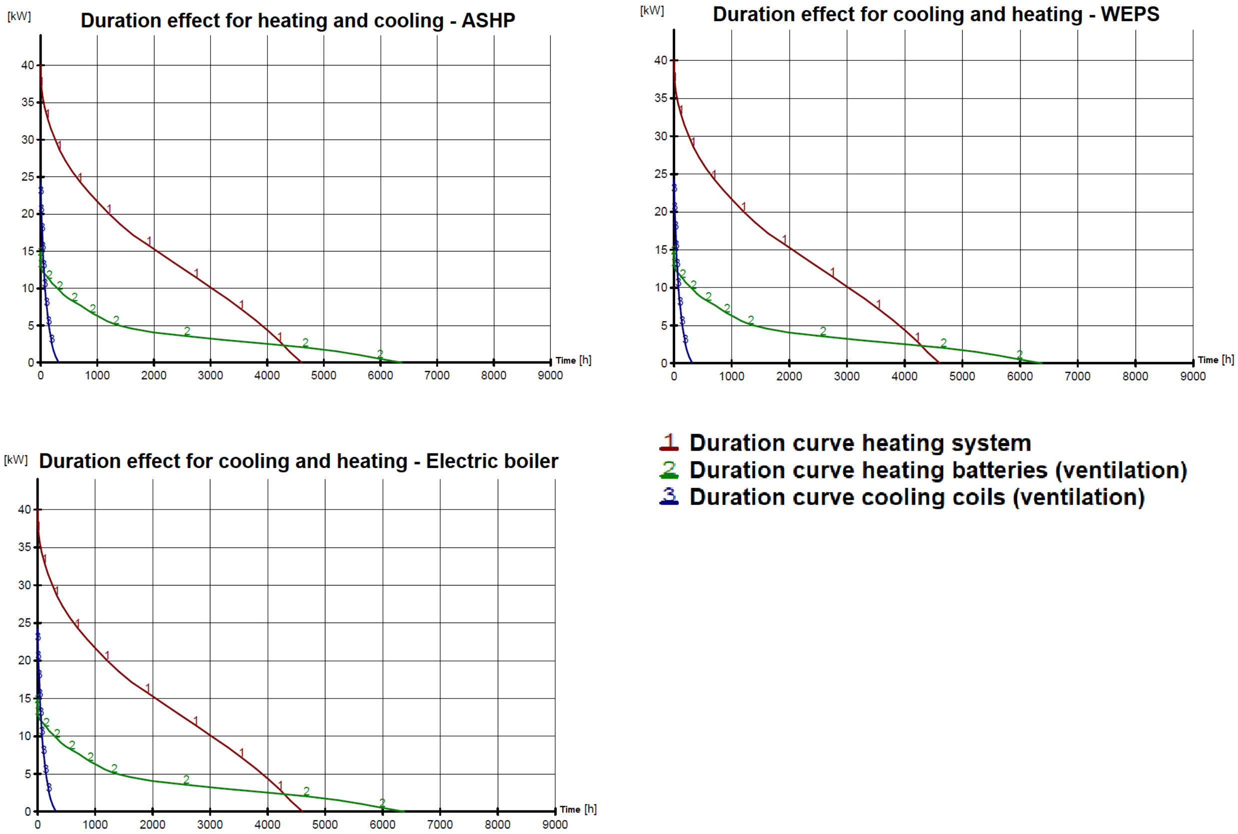

Figure 22: Power factors for the systems.

The actual products for the systems have not been decided on, so it was assumed that they would come from somewhere in central Europe and be delivered by a large delivery truck with 9ton capacity and a 100% fill rate. Directions from google maps show that this could be ca. 2000km drive.

Service life of product was given in the description of the product for the ASHP and WEPS but there was no information on the Electric boiler. However similar products in the LCA program all had a service life of 15 years in their description so that was the chosen number for this calculation.

Annual energy consumption is calculated in Simien and gross internal floor area is calculated from the drawings from MAD architects.

Based on a literature review on LCA of buildings [31], the most commonly used calculation period is 50 years, therefore 50 years was chosen for the calculation of this LCA.

4.3 Cost estimation

A study from Sweden that focuses on costs of different strategies for heating was used to give a reasonable cost estimate [14]. This study has price tables displaying k€/kW, so these prices are easily transferred to the size of systems needed for the UNESCO World Heritage Center. They also state annual operation and maintenance(O&M) costs as % of invest cost. Since this study was conducted in Sweden in 2017 it is likely that these values can represent Norwegian values today, at least for comparative purposes. Table 4 shows given parameters for prices they used for modeling.

Table 4: Costs presented in the Swedish study for a large heat pump, WEPS and Electric boiler. [14]

Technology (Heat capacity)	Parameter	Unit	Value
Heat pump	Specific investment cost	k€/kW_{heat}	0.49-1.1
(0.5MW-10MW)	Total O&M cost	% of inv. cost/year	0.7
Heat pump - Brine - water	Specific investment cost	k€/kW_{heat}	1.77-4
(5kW-300kW)	Total O&M cost	% of inv. cost/year	2-22.6
Electric boiler	Specific investment cost	k€/kW_{heat}	0.7-0.8
(5kW-400kW)	Total O&M cost	% of inv. cost/year	1.6-15

The study in Sweden did not have prices specified for small ASHP systems. However another study that was conducted in Italy has an estimation for ASHP [15]. They are modeling the cost for of heat pump systems in residential buildings in three different locations in Italy for a building of $1050m^2$. Results from this study will be used to try and estimate costs for ASHP in comparison with price given in the Swedish study for large heat pump and water-brine systems.

These results are modeled for a smaller building, so in order to get more accurate results 20% will be added to the investment cost and 50% to the O&M. These numbers were based on experience that investment cost does not go up linearly but O&M cost does. The UNESCO World Heritage Center is $1517m^2$. These are estimations and therefore can not be taken literally. The numbers from the Italian study are shown in table 5. The scaled number of from the Italian study on the WEPS system fit with the numbers from the Swedish study, although investment cost is on the lower side of the scale and O&M is somewhere in the middle, but that makes sense since the scale in the Swedish study ranges from 5kW to 300kW. Therefore the scaled number for ASHP will be used as a cost reference in the UNESCO World Heritage Center case. The scale for WEPS and the electric boiler is considered linear and the final price will be based on the power factor used for these systems.

Table 5: Costs presented in the Italian study for ASHP and WEPS.[15]

Technology	Investment cost[k€]	O&M[k€]	Scaled investment cost[k€]	Scaled O&M[k€]
WEPS	120	30	144	45
ASHP	75	15	90	22.5

4.4 Limitations

When the work started with Simien and One Click LCA it became clear that these programs do not offer any inputs for different control methods for BMS and HVAC. In light of this the recommended control method will be based on literature. This will be further discussed in section 6.

Further limitation with the WEPS system is that in both Simien and One Click LCA it is not available to choose between the two different methods descried in section 3.5. That is the one with a heat center and the one that has a heat pump at each end user. The only option is a heat pump (brine-water), no more specifications on the system. One other thing that introduces bias with the One Click LCA is that inputs are user generated and probably were designed for another project. It is not a possibility to detail the input according to this project. However these results are estimations that aim to recommend the best product rather then giving exact results for the final building.

Then later the intention was to use Holte Smart Calc (HSC) to estimate costs associated with each solution. HSC is based on a Norwegian database that is included in the program. Unfortunately this database mostly focuses on the building envelope, walls, insulation, windows doors, roof etc. Technical solutions are limited. For instance only one 5kW heat pump is available in the database. After contacting support from HSC and receiving the information that this program is not utilised for technical solutions it was decided to skip using HSC. Instead cost estimations will be derived from other studies on similar cases. This method will introduce some errors but hopefully give a reasonable price range for each solution.

5 Results

The results from Simien modeling , LCA and cost estimates are reported in the next sub chapters. These results aim to give a good understanding on how the chosen systems will perform in order to make a recommendation for the project owner. These are only numerical results from the programs, later in chapter 6 more factors such as practical pros and cons will be discussed in order the make the best recommendation.

5.1 Simien

When evaluation for the building was run in Simien the report shows that the building will not meet the minimum requirements for thermal transmittance (U-value) for the outer walls and roof. This is shown in table 7. This is due to insufficient information on big glass walls. These have not yet been designed in detail and therefore the correct values were not available. U-value calculations are not a part of this study and have no effect on it and therefore no more focus will be put on these results. All requirements concerning energy needs are met with all solutions. ASHP,WEPS and the Electric boiler are all energy efficient enough to pass for the TEK 17 standard. The results in table 6 show energy needed for the building based on the building envelope that was set up i Simien. These results show that the building will meet the requirements set in TEK17 concerning energy usage.

Table 6: Calculated energy needs for the building from the evaluation report in Simien.

Energy framework (Total net energy needs)	
Description	Value[kWh/m^2]
1a Calculated energy need for space heating	56.6
1b Calculated energy need for ventilation heating	14
2 Calculated energy need for warm water (tap water)	10
3a Calculated energy need for fans	1.1
3b Calculated energy need for pumps	1.2
4 Calculated energy need for lighting	23
5 Calculated energy need for technical equipment	2.9
6a Calculated energy need for space cooling	0
6b Calculated energy need for ventilation cooling	6.6
Calculated total energy need for building	130
Regulatory net energy requirements (TEK17)	130

Table 7: Values from Simien evaluation report. Requirements are from the TEK17 standard.

Minimum requirements for thermal transmittance (U-value)		
Description	Value	Requirement
U-value outer walls $[W/m^2K]$	0.49	0.22
U-value roof $[W/m^2K]$	0.34	0.18
U-value floor against ground and above $[W/m^2K]$	0.12	0.18
U-value windows and doors $[W/m^2K]$	0.8	1.2
Leakage number (Air tightness at 50Pa pressure difference) [Air exchanges per hour]	0.8	1.5

The main results gathered from the three reports and are used for this study are presented in table 8. Full reports can be seen in appendices C, D and E.

Table 8: Main results gathered from Simien for the three different systems.

Variable	ASHP	WEPS	Electric boiler
Annual delivered energy	161588 kWh	155631 kWh	235340 kWh
Power factor	60kW	70kW	60kW
Annual CO2 emissions	13,8 kg/m²	13,3 kg/m²	20,2 kg/m²

Figure 23 shows monthly energy use split up by end users. Space heating is dominant in winter months, almost 50% in December and January, and only a small amount of cooling is needed during the late summer. This supports the decision of the power factor for the thermal energy generating systems in the methods.

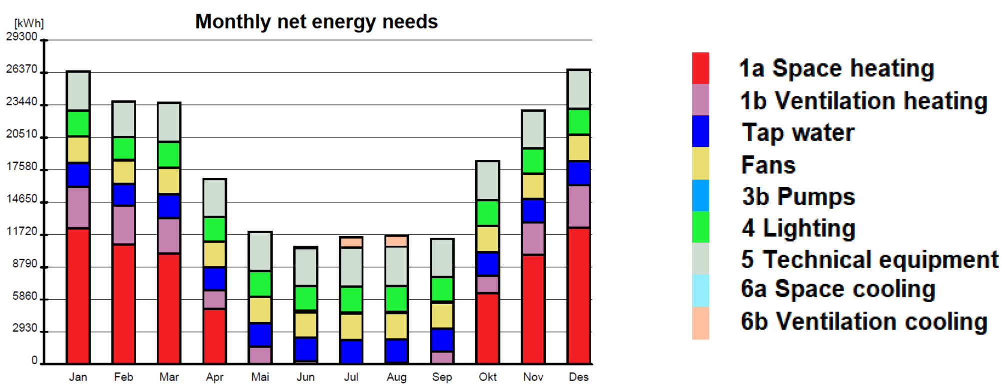

Figure 23: Monthly net energy need split up by end user. See more in Appendices C,D and E

5.2 One Click LCA

Results from One Click LCA show that the WEPS system will emit the least amount of CO2. This is manly due to that it uses the least amount of energy. Table 9 shows CO2 emissions divided up into categories. The main source of CO2 emissions comes from energy use. Transportation and deconstruction can almost be neglected. This can be seen in figure 24. This figure is generated from One Click LCA and there it is clear that transport and destruction don't have any impact in the bigger picture.

Table 9: CO2 emissions from each solutions divided up into categories over the whole life time of 50 years.

Result category (kgCO2)	ASHP	WEPS	Electric boiler
Construction materials (kgCO2)	8.35 E^3	4.89 E^3	1.63 E^3
Tarnsport to site (kgCO2)	5.92 E^1	3.95 E^2	1.42 E^2
Maintenance and material replacement (kgCO2)	1.67 E^4	1.86 E^3	4.91 E^3
Energy use (kgCO2)	2.51 E^5	2.42 E^5	3.66 E^5
Deconstruction (kgCO2)	4.32	6.25	5.95
Total (kgCO2)	2.76 E^5	2.49 E^5	3.72 E^5

Table 10: Percentages representing categories on pie charts in figure 24

Variable	ASHP	WEPS	Electric boiler
Materials	3.0%	2.0%	0.4%
Transportation	0.0%	0.2%	0.0%
Maintenance and replacement	6.0%	0.7%	1.3%
Energy	90.9%	97.1%	98.2%
End of life	0.0%	0.0%	0.0%

Simien results display annual CO2/m^2 emissions connected to each solution. When compared to the results from One Click LCA there is a notable difference. This is reported in table 11 and will be further discussed in chapter 6.

Table 11: Comparison between annual CO2 emissions from Simien and One Click LCA.

	ASHP	WEPS	Electric boiler
Simien (kgCO2/m2/year	13.8	13.3	20.2
LCA (kgCo2/m2/year)	11.11	10.02	14.98

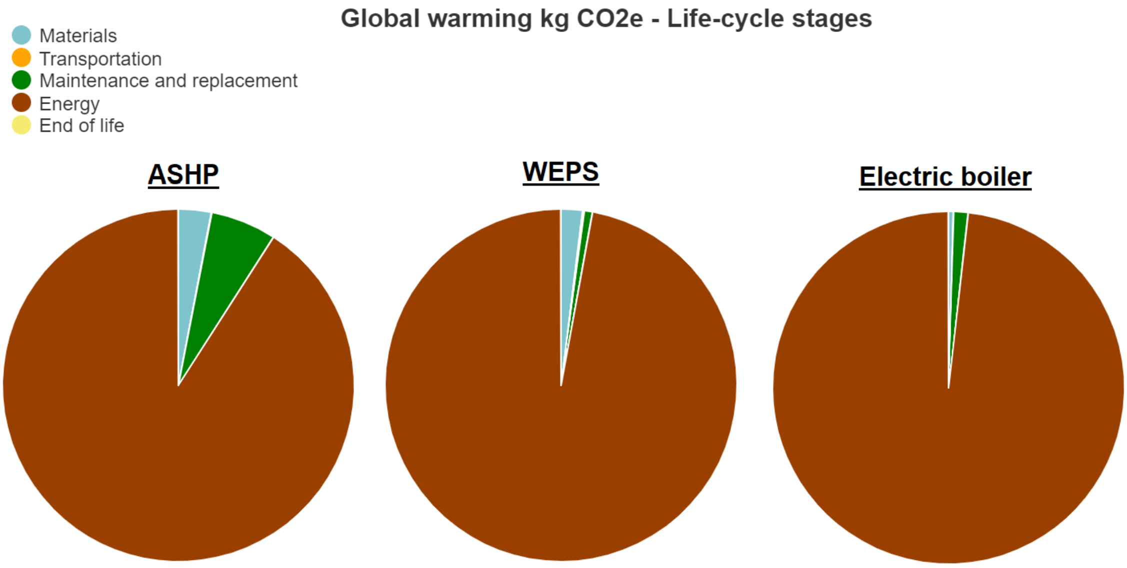

Figure 24: Pie chart displaying CO2 emissions associated with the ASHP system. - Global warming CO2 life cycle stages.

5.3 Costs and final results

Table 12 shows the energy consumption, CO2 emissions and cost of each system that have been examined in this report. The WEPS shows the best performance based on these simulations but will also have the highest price for investment. ASHP follows shortly after but is a much cheaper solution. The electric boiler uses much more energy and therefore also has higher CO2 emissions.

For the WEPS system investment cost was calculated to be 2.26k€/kW_{heat} and O&M 6.53 % of inv. cost/year. For the electric boiler the investment cost was calculated to be 0.7139k€/kW_{heat} and O&M 3.46% of inv. cost/year. This was calculated by linear scale from table 4. However when comparing the O&M costs from the Swedish study and the Italian it is seen that it is significantly higher in the Italian study. Since the plan was to use the scaled O&M costs from the Italian study for the ASHP system, this results that it will be 22.5k€/year. This is double the O&M cost for the WEPS system using the Swedish scale. The scaled O&M cost for the WEPS system is 45k€/year when it is only 10.3k€/year when using the scale from the Swedish study. In order to get a more accurate O&M costs for ASHP system the ratio between the unscaled O&M costs in the Italian study will be applied to the O&M cost for the WEPS system in the Swedish study. This results in O&M cost being 50% lower for the ASHP system.

Table 12: Main results gathered from the three evaluations conducted in this study.

Variable	ASHP	WEPS	Electric boiler
Delivered electric energy(kWh)	161588	155631	235240
GHG emissions (tCO2)	276	249	372
Investment cost (k€)	90	158	43
Operation and maintenance cost(k€/year)	5.15	10.3	1.5

6 Discussion

In a project like this where the goal is to make a recommendation for the best performing HVAC system for a building it is not enough to look at the numbers that have been calculated in this report. The practical pros and cons for each system must also be taken into account. In this chapter these factors will be brought up and discussed then the final decision will be made based on energy usage, CO2 emissions, cost and then practical pros and cons. Then later on the pros and cons of control strategies will be discussed and evaluated. Then the benefits of having such a control method will be added on to the chosen system to show how it will effect the results already calculated before.

6.1 Energy source for HVAC

When looking at the results for the ASHP it could be considered the best solution. It is barely outperformed by the WEPS system in energy usage and CO2 emissions. However it is a much cheaper solution. But there is one crucial factor limiting the usage of an ASHP. These heat pumps have the best performance at a stable outdoor air temperature of 7°C or higher. The heating capacity of the system decreases with decreased temperature. Another factor is that fans used to deliver air to the evaporator generates noise. For such a large system this might cause a decent amount of noise pollution around the building and therefore disturb the peaceful environment at the UNESCO World Heritage Center. [8]

Figure 25 show that temperature is below or around 4°C for 9 months of the past year. This indicates that a ASHP system would have limited heat production capacity for 75% of the year. And would need to use additional methods to deal with frost accumulation. However the system would work well in the summer time, but during that time there is little to no need for heating. The ASHP can contribute a bit for SDG number 7, affordable clean energy and number 9, industry, innovation and infrastructure. The ASHP uses a sustainable energy source and reduces energy usage but offers no help to the community so it could not be considered that it offers much to the third SDG that was chosen, 11, sustainable cities and communities, other then bettering the UNESCO World Heritage Center.

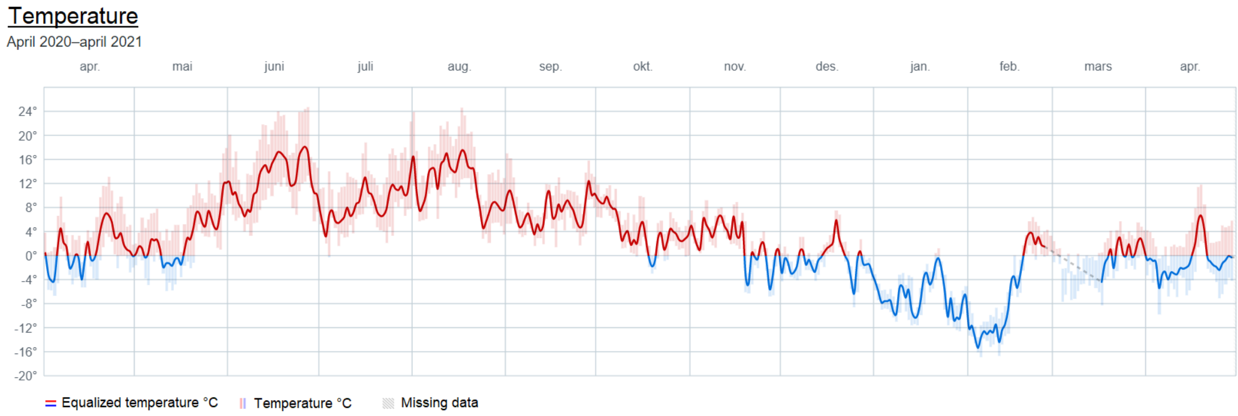

Figure 25: Temperature in Aurland for the past year. [11]

The WEPS system has the best results concerning energy use and CO2 emissions. But unlike the ASHP system, WEPS is significantly more expensive. The system described in the study conducted on a WEPS system in Eid [9] is a much larger system and is used to supply thermal energy to a much higher number of buildings and the generation capacity is measured in GWh and therefore the system is much more expensive. In that study it is stated that costs per Wh decrease as the system grows and a big part of the costs comes from construction concerning pipe network since buildings that used the system are distributed around the city. They managed to lower investment costs by coordinating the constructions with other road work, that is for electric and fiber cables, domestic water and sewage. The costs used for the WEPS system in Aurland have the range from 5-300kW so it indicates that a smaller system can be made. The UNESCO World Heritage Center is located on the harbor so it could be a possibility to bring the intake pipe for seawater straight into the building. This would mean that a separate intake house would not be needed and digging for pipes would be minimized. However this would mean that the system could only be used by the UNESCO World Heritage Center. It could be a great benefit not only for the UNESCO World Heritage Center but also for the Aurland municipality if a bigger system would be implemented and then more buildings in the municipality could benefit from using WEPS. This would however require the municipality and other investors in Aurland to join into that project. This could be a great start towards using less energy while still using green energy sources in the Municipality and contributing work to all the SDG's described in chapter 2. However this decision is out of the scope of this study so a small WEPS system will be considered from now on. The small system would have a less impact for the SDG's that were chosen.

The electric boiler has the worst performance concerning energy usage and CO2 emissions. However it far outperforms concerning investment cost as well as O&M. One of the perks for an electric boiler is that it requires no additional energy source so there is no additional work needed outside of installation the boiler. The system only uses electricity and since the building still needs to be connected to the grid then there is no additional work needed. Only thing that could be added is that the intake cable for the building might have to be a bit bigger. This additional work is minimal. Even though this system seems to be the cheapest one future energy price and climate policies must be taken into account. That is if carbon tax will be increased. This could greatly reduce the cost efficiency of the electric boiler in the long run since this system has the highest CO2 emissions. These factors are out of the scope of this study but are taken into account with the final decision. So a quick saving in investment cost could quickly turn into a bad investment if a high carbon tax would be implemented in Norway. This solution has little to no input for the SDG's that this project puts focus on, this technology only serves the UNESCO World Heritage Center and offers no help to the community.

When all factors are considered, energy efficiency, CO2 emissions, costs and practical benefits, the WEPS system is considered the best system for this case. The system is quiet and can be made nearly invisible (pipes can be dug underground) and therefore contribute to no visual pollution in the area. Since the building is supposed to represent the UNESCO values and serve as a station for visitors arriving with the ferry this would be a great success in keeping the surrounding area free of disturbance, both visual and noise. WEPS has already proven to be successful in Norway and users report reducing energy used for heating from 30-50% compared with using electricity from hydroelectric energy[9]. This fits with the results from Simien where WEPS uses ca. 32% less energy for the whole building.

When the results from One Click LCA and Simien are compared there is a notable difference in CO2/m^2 emissions. This was shown in table 11. This uncertainty is due to different inputs for the programs. There is no option on specifications in the input in Simien. The choice is made between energy sources and output, that is air or water. Then also the temperature of the output. Then for One Click LCA the inputs are found from a database the is user generated. So users can make there own inputs based on there case. So the inputs that were chosen here will possibly not perfectly represent the system to be used in the UNESCO World Heritage Center and also they will most likely not be the same for each program. However the results are the same, that is what system has the best output so this strengthens the choice for the WEPS system.

6.2 Control method

In order for a building to reduce its emissions and energy usage a good solution is to implement a BMS to control the building. These systems are used to control HVAC systems, domestic water, lighting and more. In order for the building to be efficient all these factors must work together, this holds hands with how complex the BMS will be. When looking at the systems already described in this thesis and fitting them with the UNESCO World Heritage Center some have better usability for this case. Table 13 shows a brief pros and cons evaluation that helps with eliminating methods that do not fit the case.

In recent years many studies have been conducted on MPC. This control method shows outstanding results and in most cases outperforms all other control methods also concerning comfort levels. [4, 5, 13] At least in simulation and modeling studies. Not as many real life studies have been conducted and it is hard to generalize this for real life buildings since every building is a unique case. A big study that reviewed a large amount of studies found that implementing MPC to a BMS of a building will save approximately around 15-20% energy. [4] A further advantage that the MPC brings is how easy it can adapt to changes. For example fluctuations in energy price. As well as the ability to include weather forecast to adapt to changes in climate that might happen due to climate change. [33] Then the system can also learn from data that is gathered as the system is used and then further improve its ability to optimize the buildings operations. [4]

Three main critiques were noted that can effect the MPC performance. First one is that the accuracy of the model needs to be good in order for the model to work as it should. Secondly, in order to be able to calculate the model in real time there is a need for large computational power, this is very expensive. Then lastly there is the fact that no case is the same, that is geometry of building, weather, occupancy pattern, end use etc. Therefore the MPC algorithm must be customized for each building. This causes the development of standardized controllers to be slow which translates to controllers being expensive. [4]

MPC is a relatively new technology. In the 90's some started experimenting with it in the processes industry. Now this is the most widespread and considered the best control method in the process industry. In order to bring MPC more into commercial, residential and educational buildings more experiments must be done. It is hard to find the right investors to take part in this since often buildings already have invested in other control methods and therefore don´t want to drop that work that would then be considered sunken costs. [4]

When looking at the UNESCO World Heritage Center it is considered as a good case where MPC could be tested. Currently there is no HVAC or BMS in the building and since owners showed interest in optimistic and energy efficient solutions, then the MPC would be a perfect solution to test there. This could help lift up the technology standard in the Western part of Norway and contribute valuable knowledge to the growing MPC database. MPC would contribute greatly towards SDG number 9 and as noted before help lift up the technological standard in Western Norway and thereby also contribute to SDG number 11. Contribution to SDG number 7 would be limited but still offer some input since MPC would decrease the buildings energy usage. In light of this it would then be recommended to try and implement a MPC system in the UNESCO World Heritage Center. There is however no way to securely state how the system will affect the building since like stated before every building behaves in a unique way.

Table 13: Pros and cons for each control method considered for the UNESCO World Heritage Center. [5]

Control method	Pros	Cons	Fits for the project
ON/OFF	Simple control method Can be a part of a bigger system	Not usable as a higher level controller	No
P,PI,PID	Simple control method Can be a part of a bigger system	Not usable as a higher level controller	No
Gain Scheduling PID	More complex then ON/OFF or PID Can be a part of a bigger system	Not usable as a higher level controller	No
Robust Control	System is acts well on changes in parameters.	Not needed for this case. Does not reach the same energy savings as MPC	No
Optimal Control	System solves a cost function to minimize costs running the system	Does not reach the same savings a MPC	Yes
Model Predictive Control	Uses a model to predict future states Has very good energy saving potential	Very complex system New technology, not distributed widely	Yes
FUZZY Logic Control	This is a RBC method, can be used as higher level control.	Does not reach the same savings a MPC	Yes
Neural Network Control	Works well when the system has learned from data	Needs previous data to be able to work	No
Adaptive FL, ANN, PID	Systems use advantages from soft and hard techniques.	Systems also inherit disadvantages from soft and hard techniques	Yes
TPSC Control	Better version of ON/OFF	Not usable as a higher level controller	No
Reinforcement Learning Control	System uses machine learning to improve.	Takes a long time for the system to become relevant as learning takes place.	No

7 Conclusions

In order to give an idea on how to make the UNESCO World heritage center as energy efficient as possible, while still minimizing CO2 emissions and costs concerning technical systems for the building it was decided to compare different control methods for the Building Management System (BMS) and the Heating, Ventilation and Air Conditioning (HVAC) system. The second aim was to evaluate different energy sources for the HVAC system. The original plan was to use three different programs, Simien to calculate energy usage, One Click LCA to calculate CO2 emissions and then Holte Smart Calc to calculate the cost estimations of each solution.

Decision was made to evaluate three different energy sources for the HVAC systems. These are listed as follows, an Air Source Heat Pump (ASHP), Water thermal Energy Production System (WEPS) and then a conventional Electric Boiler. Simien was used to model the building and calculate energy efficiency and energy usage of each solution. One Click LCA was used co calculate the carbon foot print of each solution over the whole lifetime of the building. Then the intention was to use Holte Smart Calc to calculate the cost estimates. After testing Holte Smart Calc and consulting with their support team it was concluded that this program would not fit for this project. Instead existing literature was used to make estimations on costs. When the work in the programs started it was clear that these programs were not designed to include control methods or BMS. Therefore the results gathered on the control method were purely based on literature research.

Results from Simien and One Click LCA were coordinated, they both show that the WEPS system has the best performance, followed closely by the ASHP and then last comes the Electric Boiler. This is mainly due to the energy use of the Electric Boiler which is around 30% higher than the other systems. Based on the results from One Click LCA then the main source of CO2 emissions was the energy usage.

By using the cost evaluation method of two similar studies cost estimations for each solution were calculated. The Electric boiler proved to be the cheapest solution followed by the ASHP and the WEPS was by far the most expensive solution.

After gathering the results and considering practical pros and cons for each solution, the decision was made to recommend the WEPS system. The ASHP is a bad choice since the weather fluctuates to much and temperatures drop to low for the system to hold up top efficiency. The Electric boiler is threatened by future energy prices and policies concerning carbon tax and therefore it could end up costing much more then the results in this study show.

After looking at different control methods results showed that the Model Predictive Control (MPC) method seems to be the most promising technique. MPC uses a model to predict future states of the system and in order reducing energy usage and CO2 emissions respectfully. This method has in most cases proved to outperform all other control methods and research shows that MPC can save around 15-20% energy compared to reference controllers. MPC has the ability to deal with external disturbances and can easily adapt to changes in input. This means that the system can easily adapt to future climate changes. The MPC is however an expensive control method since it is rather new. Due to the fact that all buildings are unique and therefore it is hard to generalize the problem solving for the MPC controllers. This causes the price for such controllers to be high. It is however recommended that the UNESCO World Heritage Center would serve as a test for MCP in order to help generate real data for MPC controllers and further develop research on these controllers. This could help raise the technology level of Western Norway.

8 The Full Concept Recommendation

This thesis has been conducted in connection to a larger project, which includes three master's theses. In this chapter, the conclusions from the three theses are presented, in desire to create a complete concept recommendation. Advice for implementation into the project will also be discussed. This chapter has been written in collaboration with Berit Johanne Skogvang and Sylvi Brækken.

8.1 Study conducted by Berit

UNESCO World Heritage Center in Aurlandsvangen: Balancing Energy Efficiency, CO2-Emissions and Costs when Remodeling the Building Structure

For the building structure, it is recommended to choose the 400 mm wood fiber concept for the roof, the 300 mm glass wool concept for the wall, new triple pane windows with gas filling, new doors with a u-value of 0.8 W/(m2K) and the 800 mm Glasopor concept for slab on ground. This will result in 11988 kWh saved energy each year compared to the TEK17 concept, an emission of 37.1 tonnes of CO2 eq and a cost of NOK 2,867,581. When considering saved emissions and saved cost from saved energy, this combination of concepts will result in a total cost of 2,560,256 and total emissions of 24.85 tonnes of CO2 eq. These concepts were chosen as a result of the balancing process that was carried out, in an attempt to balance energy efficiency, CO2 emissions and cost.

8.2 Study conducted by Halldór

Keeping Old Buildings Green with Relevant Technology - A Case Study of UNESCO World Heritage Center, Nærøyfjordområdet

The recommended Building Management system (BMS) for the building is Model Predictive Control (MPC). This control method uses a model to predict future states of the building and can therefore reduce energy use by 15-20%. MPC has great potential to act on external disturbances and includes for example weather forecasts in the model and can therefore adapt to future climate change. This method is complicated and expensive but it is believed that this will pay off in the long run.

The Water-Thermal Energy Production System (WEPS) was chosen as an energy source for the Heating Ventilation and Air Conditioning (HVAC) system. This system uses the least amount of energy, has the lowest CO2 emissions of the systems that were researched. However WEPS costs significantly more than the other systems. The practical pros and cons as well as the low energy use and CO2 emissions out value the other systems and therefore this system was chosen.

8.3 Study conducted by Sylvi

Weighing the Importance of Energy Savings, CO2 Emissions and Costs When Implementing Renewable Energy Technologies. Case: Nærøyfjorden UNESCO World Heritage Centre

The recommended combination of energy technologies is a combination with a water-to-water heat pump, flat plate collectors and standard solar panels. This combination gave energy savings of 99 MWh/year, emissions of 254.8 ton of CO2e, an initial cost of 1,178,383 NOK and a net present value of -295,339 NOK.

8.4 Implementation into the project

When implementing these recommendations to the project, it is important to be aware that the recommended WEPS system and the recommended combination of energy technologies does not correlate perfectly. The WEPS system in Halldór's thesis is covering 90% of the energy need, while the water-to-water heat pump in Sylvi's thesis is covering 60%, while the solar thermal collector system is covering 30%. It is therefore not possible to implement all the recommended solutions. Nevertheless, both these recommendations include a water-to-water heat pump, which indicates that these recommendations should be taken into account. With proper control methods for these systems, such as the MPC, the efficiency of the system output can be increased by 15-20%.

All the concepts must be seen in relation to each other, as the energy consumption of the various concepts will impact each other. It is all a part of a bigger system that comprises the whole building, where many factors are working simultaneously. That is, if one recommendation is fully implemented, then that affects the energy consumption of the other recommendations. Thus, when implementing the recommendations it is possible to opt out parts of the recommendations, and still end up with a highly efficient building. Furthermore, more concepts were considered and assessed than what is presented in this recommendation. These are also concepts that are relevant for the building. More information can be found in the respective master theses:

Berit Johanne Skogvang. (2021) UNESCO World Heritage Center in Aurlandsvangen: Balancing Energy Efficiency, CO2-Emissions and Costs when Remodeling the Building Structure

Halldór Þrastarson. (2021) Keeping Old Buildings Green with Relevant Technology - A Case Study of UNESCO World Heritage Center, Nærøyfjordområdet

Sylvi Brækken. (2021) Weighing the Importance of Energy Savings, CO2 Emissions and Costs When Implementing Renewable Energy Technologies. Case: Nærøyfjorden UNESCO World Heritage Centre

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Appendices

A Input values for Simien

Area of walls

Walls:

	NW	NE	SW	SE
Area total	249.96 m²	187.91 m²	188.66 m²	310.53 m²
Area Glass	249.96 m²	32.7 m²	188.66 m²	46.58 m²
Area wall	0 m²	155.21 m²	0 m²	263.95 m²
U-value	0.22	0.22	0.22	0.22
U-value (TEK17)				
Varmelagring i innvendig sjikt	Lettklinker	Lettklinker	Lettklinker	Lettklinker

Floors:

	Basement	1st floor	2nd floor	3rd floor	Total
Volume	1412,3 m³	2633,27 m³	985,5 m³	516,1 m³	5547,17 m³
Area	497.3 m²	491.85 m²	304.1 m²	223.6 m²	1516.85 m²

Roof:

Area total	573.28 m²
Area total Glass	193,5 m²
Area Total Roof	379,78 m²
NW Glass	160 m²
NW Roof	189,89 m²
NW total	**349.89 m²**
SE Glass	33.5 m²
SE Roof	189,89 m²
SE total	**223.39 m²**

Windows & doors:

	Large windows 2.15 m² (150x143)	Small windows 1.47 m² (105x140)	Long window 1,25m² (0,5x2,5)	Door 1 2,3m² (1x2,3)	Door 2 2,5m² (1x2,5)	Door 3 2,1m² (1x2,1)	Door 4 3,32m² (1,2x2,77)	Door 5 3,6m² (1,3x2,77)	Double 1 6,7m² (2,37x2,77)	Double 2 4,3m² (1,56x2,77)
NE	6	2	1	1	1	1				
NW							2		1	
SE	7					1				2
SW								2		

U values walls

Normal wall (mot luft): 0.22 W/(m²K)
Wall against terrain (underground): SE = 0.1826 W/(m²K), NE = 0.2 W/(m²K)
(See table below, depends on "oppfyllingshøyde" (how much of the wall is underground, in m vertically))
Glass: 0.4 W/(m²K) *

471.014 U-verdier. Gulv på grunnen og vegger mot terreng, Tabell 15 a:
https://www-byggforsk-no.galanga.hvl.no/dokument/1536/u-verdier_gulv_paa_grunnen_og_vegger_mot_terreng

		U verdier mot luft → U verdier mot terreng			
Oppfyllingshøyde ↓		**0.15**	**0.2**	**0.25**	**0.22**
	0.5	0.14	0.18	0.23	**0.2**
	1	0.13	0.18	0.22	0.196
	1.5	0.13	0.17	0.21	0.186
	1.67	0.13	0.1666	0.2066	**0.1826**
	2	0.13	0.16	0.2	0.176
	2.5	0.12	0.16	0.19	0.172
	3	0.12	0.15	0.18	0.162

* Selvom man senker emissiviteten til 0,0 kan U-verdien i en tolagsrute aldri bli lavere enn ca. 0,9. For å komme lavere må man gå over til en trelags rute hvor absolutt laveste U-verdi er ca. 0,4. (Glassfakta 2018: https://www.pilkington.com/nb-no/no/produkter/funksjonsglass/energisparing/pilkington-optifloat-clear#brosjyrer)

SW and NW is glass ⇒ **0.4 W/(m²K)**

SE (long wall) - total area: 310.53 m^2, Wall: 263.95 m^2, Glass: 46.58 m^2
17 m of the basement wall is 2.5 m underground, 8.5 m is not underground ⇒ average for the wall (just the wall part) is **1.67** m underground
15.0% glass, 71.5% wall, 13.5% wall underground ⇒
=0.15*0.4+0.715*0.22+0.135*0.1826 = **0.25 W/(m^2K)**

NE (short wall) - total area: 187.91 m^2, Wall: 155.21 m^2, Glass: 32.7 m^2
0.5 m average underground for the wall which is wall
17.40% glass, 79.27% wall, 3.33% wall underground ⇒
=0.174*0.4+0.7927*0.22+0.0333*0.2 = **0.25 W/(m^2K)**

(For glassgård oppvarmet til 15 °C bør U-verdi til glasskonstruksjonene være bedre enn 2,0 W/(m^2K).
527.231 Glassgårder i store bygg. Temperatur- og energiforhold, 34 U-verdi i utvendige fasader. https://www-byggforsk-no.galanga.hvl.no/dokument/421/glassgaarder_i_store_bygg_temperatur_og_energiforhold)

First section shows values for ASHP, second section shows values for WEPS and the last one shows values for electric heater followed by the rest of the values used for the model.

Description ASHP				**Value**	**Unit**	**Reasoning/Reference**
Energy supply	Electricity from the grid	Data for energy source	System efficiency space heating	0.8		Value from SIMIEN
			System efficiency domestic hot water (DHW)	0.98		Value from SIMIEN
			System efficiency heating coils	0.88		Value from SIMIEN
			Coefficient of Performance (COP) space cooling	2.5		Value from SIMIEN
			Coefficient of Performance (COP) cooling coils	2.5		Value from SIMIEN

			CO_2 emissions	130	g/kWh	Value from SIMIEN
			Energy price	0.8	kr/kWh	Value from SIMIEN
		Percentage of energy covered by electricity	Space heating	10	%	Assumed value
			DHW heating	10	%	Assumed value
			Heating coils ventilation	10	%	Assumed value
			Cooling coils ventilation	10	%	Assumed value
			Space cooling	10	%	Assumed value
			Electricity (lighting, equipment, fans and pumps)	100	%	Assumed value
	Heat pumps Air-water 55°C\45°C Heating from ambient air	**Data for energy source**	**System efficiency space heating**	**1.86**		**Value from SIMIEN**
			System efficiency domestic hot water (DHW)	**2.6**		**Value from SIMIEN**
			System efficiency heating coils	**2.67**		**Value from SIMIEN**
			Coefficient of Performance (COP) space cooling	**2.5**		**Value from SIMIEN**
			Coefficient of Performance (COP)	**2.5**		**Value from SIMIEN**

			cooling coils			
			CO_2 emissions	130	g/kWh	Value from SIMIEN
			Energy price	0.8	kr/kWh	Value from SIMIEN
		Percentage of energy covered by electricity	Space heating	90	%	Assumed value
			DHW heating	90	%	Assumed value
			Heating coils ventilation	90	%	Assumed value
			Cooling coils ventilation	90	%	Assumed value
			Space cooling	90	%	Assumed value
			Electricity (lighting, equipment, fans and pumps)	0	%	Assumed value

Description WEPS				**Value**	**Unit**	**Reasoning/Reference**
Energy supply	Electricity from the grid	Data for energy source	System efficiency space heating	0.8		Value from SIMIEN
			System efficiency domestic hot water (DHW)	0.98		Value from SIMIEN
			System efficiency heating coils	0.88		Value from SIMIEN
			Coefficient of Performance (COP)	2.5		Value from SIMIEN

			space cooling			
			Coefficient of Performance (COP) cooling coils	2.5		Value from SIMIEN
			CO_2 emissions	130	g/kWh	Value from SIMIEN
			Energy price	0.8	kr/kWh	Value from SIMIEN
		Percentage of energy covered by electricity	Space heating	10	%	Assumed value
			DHW heating	10	%	Assumed value
			Heating coils ventilation	10	%	Assumed value
			Cooling coils ventilation	10	%	Assumed value
			Space cooling	10	%	Assumed value
			Electricity (lighting, equipment, fans and pumps)	100	%	Assumed value
	Heat pumps brine-water 55°C\45°C Heating from earth,bedrock, water or excess heating	**Data for energy source**	**System efficiency space heating**	**2.28**		**Value from SIMIEN**
			System efficiency domestic hot water (DHW)	**2.6**		**Value from SIMIEN**
			System efficiency heating coils	**2.67**		**Value from SIMIEN**

			Coefficient of Performance (COP) space cooling	**2.5**		**Value from SIMIEN**
			Coefficient of Performance (COP) cooling coils	**2.5**		**Value from SIMIEN**
			CO_2 emissions	130	g/kWh	Value from SIMIEN
			Energy price	0.8	kr/kWh	Value from SIMIEN
		Percentage of energy covered by electricity	Space heating	10	%	Assumed value
			DHW heating	10	%	Assumed value
			Heating coils ventilation	10	%	Assumed value
			Cooling coils ventilation	10	%	Assumed value
			Space cooling	10	%	Assumed value
			Electricity (lighting, equipment, fans and pumps)	100	%	Assumed value

Description Electric boiler				**Value**	**Unit**	**Reasoning/Reference**
Energy supply Electric boiler after 1995	Electricity from the grid	Data for energy source	System efficiency space heating	0.8		Value from SIMIEN
			System efficiency domestic hot water (DHW)	0.98		Value from SIMIEN
			System efficiency heating coils	0.88		Value from SIMIEN
			Coefficient of Performance (COP) space cooling	2.5		Value from SIMIEN
			Coefficient of Performance (COP) cooling coils	2.5		Value from SIMIEN
			CO_2 emissions	130	g/kWh	Value from SIMIEN
			Energy price	0.8	kr/kWh	Value from SIMIEN
		Percentage of energy covered by electricity	Space heating	100	%	Assumed value
			DHW heating	100	%	Assumed value
			Heating coils ventilation	100	%	Assumed value

			Cooling coils ventilation	100	%	Assumed value
			Space cooling	100	%	Assumed value
			Electricity (lighting, equipment, fans and pumps)	100	%	Assumed value
The building	Heated floor area			1516.8	m^2	Measures in drawing
	Heated air volume			5547.2	m^3	Calculated with values and measurements from the drawing
	Infiltration	Leakage number		0.80	1/h	TEK17: § 14-3 (1) a)
		Shielding class		Moderate shielding		Educated assumption
		Facade situation		More than one wind exposed facade		Educated assumption
	Furniture/interior			2	Wh/m^2K	Educated assumption
	Operating days			All days		Educated assumption
	Cold bridge	Normalized cold bridge		0.090	W/m^2K	TEK17: § 14-3 (2)
North-east						
	Total area			187.91	m^2	Calculated from drawing

Outer wall, NE	In data construction	Custom construction	U-value	0.3	W/(m^2K)	TEK17: § 14-3 (1) a) Calculated
		Heat storage in inner layer		13	Wh/(m^2K)	Value from SIMIEN
	Orientation/horizon	Orientation		NE		Drawing
		Horizon		45	Degrees	Drawing
Window, NE: Large	Number of (equal) windows			6		Counted from drawing
	Window size	Width		1,43	m	Measured from drawing
		Height		1,50	m	Measured from drawing
		Frame: height/width		0,05	m	Assume standard value of 15%
	Heat loss properties	Custom total U-value for the window construction		1.2	W/(m^2K)	TEK17: § 14-3 (1) a)
	Heat gain properties	Variable, manually controlled		0.38 0.51		Two layer glass. the inner one is a energy saving glass
Window, NE: Small	Number of (equal) windows			2		Counted from drawing
	Window size	Width		1,40	m	Measured from drawing
		Height		1,05	m	Measured from drawing
		Frame: height/width		0,05	m	Assume standard value of 15%
	Heat loss properties	Custom total U-value for the window construction		1.2	W/(m^2K)	TEK17: § 14-3 (1) a) Multiconsult
	Heat gain properties	Variable, manually controlled		0.38 0.51		Two layer glass. the inner one is

					a energy saving glass
<u>Window, NE: Long</u>	Number of (equal) windows		1		Counted from drawing
	Window size	Width	0.5	m	Measured from drawing
		Height	2.5	m	Measured from drawing
		Frame: height/width	0,05	m	Assume standard value of 15%
	Heat loss properties	Custom total U-value for the window construction	1.2	W/(m^{2}K)	TEK17: § 14-3 (1) a) Multiconsult
	Heat gain properties	Variable, manually controlled	0.38 0.51		Two layer glass. the inner one is a energy saving glass
<u>Door, NE: Door no 1</u>	Number of (equal) doors		1		
	Door size	Width	1	m	Value from drawing
		Height	2.3	m	Value from drawing
		Area	2.3	m^2	
	Heat loss properties	Custom total U-value for the door construction	1.20	W/(m^{2}K)	TEK17: § 14-3 (1) a)
<u>Door, NE: Door no 2</u>	Number of (equal) doors		1		
	Door size	Width	1	m	Value from drawing
		Height	2.5	m	Value from drawing
		Area	2.5	m^2	

	Heat loss properties	Custom total U-value for the door construction		1.20	W/(m²K)	TEK17: § 14-3 (1) a)
Door, NE: Door no 3	Number of (equal) doors			1		
	Door size	Width		1	m	Value from drawing
		Height		2.1	m	Value from drawing
		Area		2.1	m²	
	Heat loss properties	Custom total U-value for the door construction		1.20	W/(m²K)	TEK17: § 14-3 (1) a)
North-west						
Outer wall, NW	Total area			249.96	m²	Calculated from drawing
	In data construction	Custom construc tion	U-value	0.7	W/(m²K)	TEK17: § 14-3 (1) a) Calculated
		Heat storage in inner layer		0.8	Wh/(m²K)	Value from SIMIEN:
	Orientation/horiz on (himmelretning/h orisont)	Orientation		NW		Drawing
		Horizon		315	Degrees	Drawing
Door, NW: Door no 4	Number of (equal) doors			2		
	Door size	Width		1,2	m	Value from drawing
		Height		2,77	m	Assume standard height
		Area		3,32	m²	
	Heat loss properties	Custom total U-value for the door construction		1.2	W/(m²K)	TEK17: § 14-3 (1) a)

<u>Door, NW: Double 1</u>	Number of (equal) doors			1		
	Door size	Width		2,37	m	Value from drawing
		Height		2,77	m	Assume standard height
		Area		6,5	m^2	
	Heat loss properties	Custom total U-value for the door construction		1.2	W/(m^2K)	TEK17: § 14-3 (1) a)
South-east						
<u>Outer wall, SE</u>	Total area			310.53	m^2	Calculated from drawing
	In data construction	Custom construction	U-value	0.29	W/(m^2K)	TEK17: § 14-3 (1) a) Calculated
		Heat storage in inner layer		13	Wh/(m^2K)	Value from SIMIEN: Lettklinker
	Orientation/horizon (himmelretning/horisont)	Orientation		SE		Drawing
		Horizon		135	Degrees	Drawing
<u>Window, SE: Large</u>	Number of (equal) windows			6		Counted from drawing
	Window size	Width		1.43	m	Measured from drawing
		Height		1.50	m	Measured from drawing
		Frame:		0.05	m	
	Heat loss properties	Custom total U-value for the window construction		1.2	W/(m^2K)	TEK17: § 14-3 (1) a) Multiconsult
	Heat gain properties	Variable, manually controlled		0.38 0.55		Two layer glass. The inner one is

						a energy saving glass
Door, SE: Door no 3	Number of (equal) doors			1		
	Door size	Width		1	m	Value from drawing
		Height		2.1	m	Assume standard height
		Area		2.1	m^2	
	Heat loss properties	Custom total U-value for the door construction		1.2	W/(m^2K)	TEK17: § 14-3 (1) a)
Door, SE: Double 2	Number of (equal) doors			2		
	Door size	Width		1.56	m	Value from drawing
		Height		2.77	m	Assume standard height
		Area		4.32		
	Heat loss properties	Custom total U-value for the door construction		1.2	W/(m^2K)	TEK17: § 14-3 (1) a)
South-west						
Outer wall, SW	Total area			188.66	m^2	Calculated from drawing
	In data construction	Custom construction	U-value	0.7	W/(m^2K)	TEK17: § 14-3 (1) a) Calculated
		Heat storage in inner layer		0.8	Wh/(m^2K)	Value from SIMIEN:
	Orientation/horizon (himmelretning/horisont)	Orientation		SW		Drawing
		Horizon		225	Degrees	Drawing
	Number of (equal) doors			2		

Door, SW: Door no 5	Door size	Width		1,3	m	Value from drawing
		Height		2,77	m	Assume standard height
		Area		3.6	m^3	Assume standard value of 20%
	Heat loss properties	Custom total U-value for the door construction		1.20	$W/(m^2K)$	TEK17: § 14-3 (1) a)
Basement	Size	Floor area		497.3	m^2	Measured in drawing
		Outer circumference		96.8	m	Measured in drawing
		Thickness of walls		0.3	m	Measured in drawing
	Construction	U-value		0.18	$W/(m^2K)$	TEK17: § 14-3 (1) a)
		Heat storage in inner layer		63	$Wh/(m^2K)$	Value from SIMIEN: Very heavy construction (concrete > 100 mm)
	Ground/soil conditions	Thermal conductivity		2.00	W/(mK)	Value from SIMIEN: clay/silt
		Heat capacity		556	$Wh/(m^3K)$	Value from SIMIEN: clay/silt
Internal load	Lighting	During operating time	Mean power	3.7	W/m^2	SN-NSPEK 3031:2020, Table A.6
			Heat gain	100	%	SN-NSPEK 3031:2020, Table A.6
		Outside operating time	Mean power	0.4	W/m^2	SN-NSPEK 3031:2020, Table A.6
			Heat gain	100	%	SN-NSPEK 3031:2020, Table A.6

		Operating time		7/52	Days/weeks	Open every day
	Technical equipment	During operating time	Mean power	5.42	W/m^2	SN-NSPEK 3031:2020, Table A.3
			Heat gain	100	%	SN-NSPEK 3031:2020, Table A.3
		Outside operating time	Mean power	0.89	W/m^2	SN-NSPEK 3031:2020, Table A.3
			Heat gain	100	%	SN-NSPEK 3031:2020, Table A.3
		Operating time		7/52	Days/weeks	Open every day
	Tap water	During operating time	Mean power	1.92	W/m^2	SN-NSPEK 3031:2020, Table A.2
			Heat gain	0	%	SN-NSPEK 3031:2020, Table A.2
		Outside operating time	Mean power	0	W/m^2	SN-NSPEK 3031:2020, Table A.2
			Heat gain	0	%	SN-NSPEK 3031:2020, Table A.2
		Operating time		7/52	Days/Weeks	Open every day
	Heat gain people	During working hours		5	W/m^2	SN-NSPEK 3031:2020, Table A.5
		Outside working hours		0	W/m^2	SN-NSPEK 3031:2020, Table A.5
		Operating time		7/52		Open every day
Heating system	Capacity heating system	Maximum power output per m^2		50.0	W/m^2	Value from SIMIEN

		⇒ maximum power output	75.8	kW	Automatically calculated in SIMIEN
		Convective portion of maximum power output	0.5	°C	Value from SIMIEN
	Operating strategy	Set temperature during working hours	21	°C	Value from SIMIEN
		Set temperature outside of working hours	19	°C	Value from SIMIEN
	Operating strategy summer	Set temperature during working hours	19	°C	Value from SIMIEN
		Set temperature outside of working hours	16	°C	Value from SIMIEN
		Summer months	May - September		From SIMIEN
Ventilation	Type		Balanced ventilation		Chosen system
	Air volume	Supply air during operating time	8.15	m^3/hm^2	Chosen value
		Supply air outside operating hours	2.00	m^3/hm^2	Chosen value
		Extract air in operating time	8.15	m^3/hm^2	Chosen value
		Extract air outside operating hours	2.00	m^3/hm^2	Chosen value
	Supply air temperature (constant)		19.0	°C	Chosen value
	Components	SPF-factor	1.50	$kW/m^3/s$	Chosen value
		Heat recovery efficiency	82	%	Chosen value

B Simien evaluation report

SIMIEN
Evaluering Energiregler 2016

Simuleringsnavn: Evaluering
Tid/dato simulering: 21:05 26/5-2021
Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building;

Resultater av evalueringen	
Evaluering av	Beskrivelse
Energiramme	Bygningen tilfredsstiller energirammen ihht. §14-2 (1)
Minstekrav	Bygningen tilfredsstiller ikke minstekravene i §14-3
Luftmengder ventilasjon	Luftmengdene tilfredsstiller minstekrav gitt i NS3031:2014 (tabell A.6)
Energiforsyning	Fossilt brensel benyttes ikke i oppvarmingsanlegget (§14-4)
Samlet evaluering	Bygningen tilfredsstiller ikke byggeforskriftenes energikrav

Energiramme (§14-2 (1), samlet netto energibehov)	
Beskrivelse	Verdi
1a Beregnet energibehov romoppvarming	56,6 kWh/m²
1b Beregnet energibehov ventilasjonsvarme (varmebatterier)	14,0 kWh/m²
2 Beregnet energibehov varmtvann (tappevann)	10,0 kWh/m²
3a Beregnet energibehov vifter	15,7 kWh/m²
3b Beregnet energibehov pumper	1,1 kWh/m²
4 Beregnet energibehov belysning	23,0 kWh/m²
5 Beregnet energibehov teknisk utstyr	2,9 kWh/m²
6a Beregnet energibehov romkjøling	0,0 kWh/m²
6b Beregnet energibehov ventilasjonskjøling (kjølebatterier)	6,6 kWh/m²
Totalt beregnet energibehov	130,0 kWh/m²
Forskriftskrav netto energibehov	130,0 kWh/m²

Minstekrav (§14-3)		
Beskrivelse	Verdi	Krav
U-verdi yttervegger [W/m²K]	0,49	0,22
U-verdi tak [W/m²K]	0,34	0,18
U-verdi gulv mot grunn og mot det fri [W/m²K]	0,12	0,18
U-verdi glass/vinduer/dører [W/m²K]	1,2	1,2
Lekkasjetall (lufttetthet ved 50 Pa trykkforskjell) [luftvekslinger pr time]	0,8	1,5

SIMIEN; Evaluering Energiregler 2016 Side 1 av 5

Simuleringsnavn: Evaluering
Tid/dato simulering: 21:05 26/5-2021
Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building;

Energiforsyning (§14-4 (1))	
Beskrivelse	Verdi
Bruker fossilt brensel til oppvarming	Nei

Krav til formålsdelte energimålere (§14-2 (6))
Yrkesbygninger skal ha formålsdelte energimålere for oppvarming og tappevann.
Dette er ikke en del av evaluering i SIMIEN og må derfor dokumenteres på annen måte.

Krav til isolering av rør, utstyr og kanaler (§14-3 (2))
Rør, utstyr og kanaler som er knyttet til bygningens varmesystem skal isoleres. Isolasjonstykkelsen skal være økonomisk optimal beregnet etter norsk standard eller en likeverdig europeisk standard.
Dette er ikke en del av evaluering i SIMIEN og må derfor dokumenteres på annen måte.

Krav til energifleksible varmeløsninger (§14-4 (2))
Bygning over 1000 m2 oppvarmet bruksareal skal ha energifleksible varmesystemer og tilrettelegges for bruk av lavtemperatur varmeløsninger.
Dette er ikke en del av evaluering i SIMIEN og må derfor dokumenteres på annen måte.

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Sone: Concept building;

Energibudsjett reelle verdier (§14-2 (5))

Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	66835 kWh	44,1 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	23780 kWh	15,7 kWh/m²
2 Varmtvann (tappevann)	25509 kWh	16,8 kWh/m²
3a Vifter	28100 kWh	18,5 kWh/m²
3b Pumper	640 kWh	0,4 kWh/m²
4 Belysning	27248 kWh	18,0 kWh/m²
5 Teknisk utstyr	41925 kWh	27,6 kWh/m²
6a Romkjøling	0 kWh	0,0 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	2073 kWh	1,4 kWh/m²
Totalt netto energibehov, sum 1-6	216111 kWh	142,5 kWh/m²

Levert energi til bygningen (beregnet)

Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	111656 kWh	73,6 kWh/m²
1b El. til varmepumpesystem	43975 kWh	29,0 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	0 kWh	0,0 kWh/m²
6. Annen energikilde	0 kWh	0,0 kWh/m²
7. Solstrøm til egenbruk	-0 kWh	-0,0 kWh/m²
Totalt levert energi, sum 1-7	155631 kWh	102,6 kWh/m²
Solstrøm til eksport	-0 kWh	-0,0 kWh/m²
Netto levert energi	155631 kWh	102,6 kWh/m²

Simuleringsnavn: Evaluering
Tid/dato simulering: 21:05 26/5-2021
Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building;

Dokumentasjon av sentrale inndata (1)

Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	869	
Areal tak [m²]:	473	
Areal gulv [m²]:	497	
Areal vinduer og ytterdører [m²]:	120	
Oppvarmet bruksareal (BRA) [m²]:	1517	
Oppvarmet luftvolum [m³]:	5547	
U-verdi yttervegger [W/m²K]	0,49	
U-verdi tak [W/m²K]	0,34	
U-verdi gulv [W/m²K]	0,12	
U-verdi vinduer og ytterdører [W/m²K]	1,20	
Areal vinduer og dører delt på bruksareal [%]	7,9	
Normalisert kuldebroverdi [W/m²K]:	0,09	
Normalisert varmekapasitet [Wh/m²K]	70	
Lekkasjetall (n50) [1/h]:	0,80	
Temperaturvirkningsgr. varmegjenvinner [%]:	82	

Dokumentasjon av sentrale inndata (2)

Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	81,9	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,50	
Luftmengde i driftstiden [m³/hm²]	8,12	
Luftmengde utenfor driftstiden [m³/hm²]	2,00	
Systemvirkningsgrad oppvarmingsanlegg:	2,00	
Installert effekt romoppv. og varmebatt. [W/m²]:	80	
Settpunkttemperatur for romoppvarming [°C]	19,9	
Systemeffektfaktor kjøling:	2,50	
Settpunkttemperatur for romkjøling [°C]	22,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	30	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	11,0	

Simuleringsnavn: Evaluering
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Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
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Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building;

Dokumentasjon av sentrale inndata (3)

Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	24,0	
Driftstid ventilasjon (timer)	11,0	
Driftstid belysning (timer)	11,0	
Driftstid utstyr (timer)	11,0	
Oppholdstid personer (timer)	11,0	
Effektbehov belysning i driftstiden [W/m²]	8,00	
Varmetilskudd belysning i driftstiden [W/m²]	8,00	
Effektbehov utstyr i driftstiden [W/m²]	1,00	
Varmetilskudd utstyr i driftstiden [W/m²]	1,00	
Effektbehov varmtvann på driftsdager [W/m²]	1,60	
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	
Varmetilskudd personer i oppholdstiden [W/m²]	3,20	
Total solfaktor for vindu og solskjerming:	0,38	
Gjennomsnittlig karmfaktor vinduer:	0,09	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	1,00/1,00/1,00/1,00	

Inndata bygning

Beskrivelse	Verdi
Bygningskategori	Kulturbygg
Simuleringsansvarlig	Berit, Halldor _Sylvi
Kommentar	Kulturbygg or Konturbygg?

C Simien ASHP annual report

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Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 21:49 30/4-2021
Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	66835 kWh	44,1 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	23780 kWh	15,7 kWh/m²
2 Varmtvann (tappevann)	25509 kWh	16,8 kWh/m²
3a Vifter	28100 kWh	18,5 kWh/m²
3b Pumper	640 kWh	0,4 kWh/m²
4 Belysning	27248 kWh	18,0 kWh/m²
5 Teknisk utstyr	41925 kWh	27,6 kWh/m²
6a Romkjøling	0 kWh	0,0 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	2073 kWh	1,4 kWh/m²
Totalt netto energibehov, sum 1-6	216111 kWh	142,5 kWh/m²

Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	111656 kWh	73,6 kWh/m²
1b El. til varmepumpesystem	49932 kWh	32,9 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	0 kWh	0,0 kWh/m²
6. Annen energikilde	0 kWh	0,0 kWh/m²
7. Solstrøm til egenbruk	-0 kWh	-0,0 kWh/m²
Totalt levert energi, sum 1-7	161588 kWh	106,5 kWh/m²
Solstrøm til eksport	-0 kWh	-0,0 kWh/m²
Netto levert energi	161588 kWh	106,5 kWh/m²

SIMIEN; Resultater årssimulering   Side 1 av 28

Simuleringsnavn: Årssimulering
Tid/dato simulering: 21:49 30/4-2021
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Sone: Concept building

Dekning av energibudsjett fordelt på energikilder

Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	4,4 kWh/m²	1,6 kWh/m²	1,7 kWh/m²	0,1 kWh/m²	0,0 kWh/m²	64,6 kWh/m²
Olje	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Gass	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Fjernvarme	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Biobrensel	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Varmepumpe	39,7 kWh/m²	14,1 kWh/m²	15,1 kWh/m²	1,2 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sol	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Annen	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sum	44,1 kWh/m²	15,7 kWh/m²	16,8 kWh/m²	1,4 kWh/m²	0,0 kWh/m²	64,6 kWh/m²

Årlige utslipp av CO_2

Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	14515 kg	9,6 kg/m²
1b El. til varmepumpesystem	6491 kg	4,3 kg/m²
1c El. til solfangersystem	0 kg	0,0 kg/m²
2 Olje	0 kg	0,0 kg/m²
3 Gass	0 kg	0,0 kg/m²
4 Fjernvarme	0 kg	0,0 kg/m²
5 Biobrensel	0 kg	0,0 kg/m²
6. Annen energikilde	0 kg	0,0 kg/m²
7. Solstrøm til egenbruk	-0 kg	-0,0 kg/m²
Totalt utslipp, sum 1-7	21006 kg	13,8 kg/m²
Solstrøm til eksport	-0 kg	-0,0 kg/m²
Netto CO2-utslipp	21006 kg	13,8 kg/m²

Simuleringsnavn: Årssimulering
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Sone: Concept building

Kostnad kjøpt energi

Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	89325 kr	58,9 kr/m²
1b El. til varmepumpesystem	39946 kr	26,3 kr/m²
1c El. til solfangersystem	0 kr	0,0 kr/m²
2 Olje	0 kr	0,0 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	0 kr	0,0 kr/m²
6. Annen energikilde	0 kr	0,0 kr/m²
7. Solstrøm til egenbruk	-0 kr	-0,0 kr/m²
Årlige energikostnader, sum 1-7	129270 kr	85,2 kr/m²
Solstrøm til eksport	0 kr	0,0 kr/m²
Netto energikostnad	129270 kr	85,2 kr/m²

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
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Prosjekt: UNESCO World heritage center in Aurland
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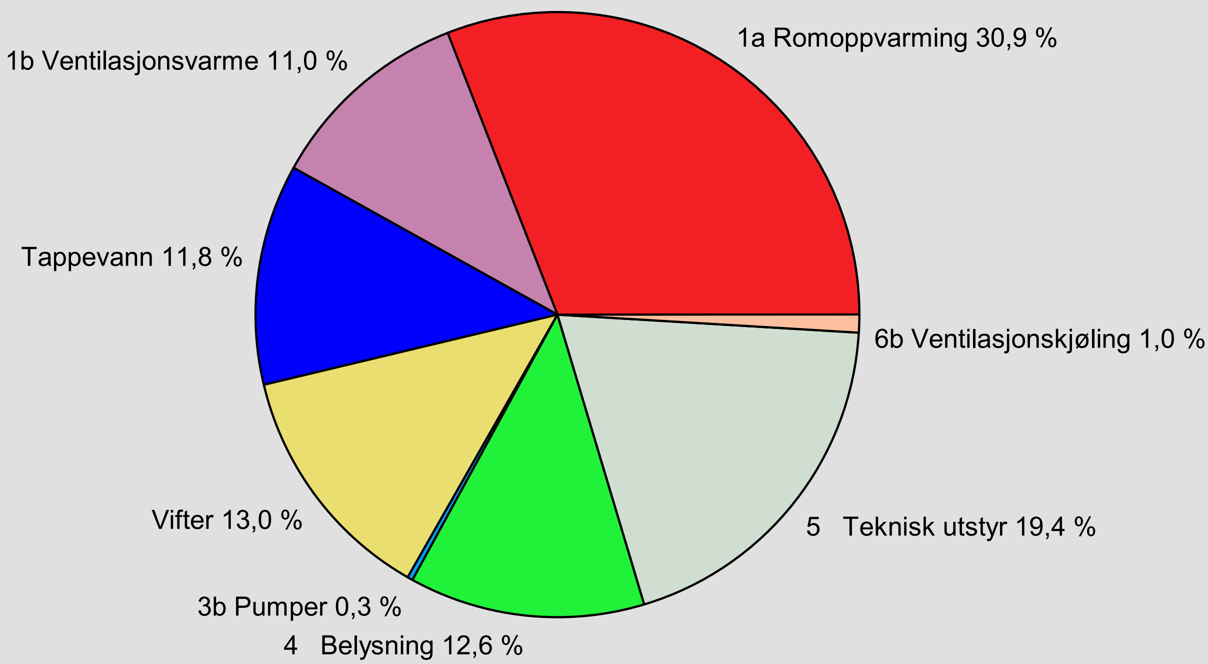
Årlig energibudsjett



1a Romoppvarming	66835 kWh
1b Ventilasjonsvarme (varmebatterier)	23780 kWh
2 Varmtvann (tappevann)	25509 kWh
3a Vifter	28100 kWh
3b Pumper	640 kWh
4 Belysning	27248 kWh
5 Teknisk utstyr	41925 kWh
6a Romkjøling	0 kWh
6b Ventilasjonskjøling (kjølebatterier)	2073 kWh
Totalt netto energibehov, sum 1-6	216111 kWh

Simuleringsnavn: Årssimulering
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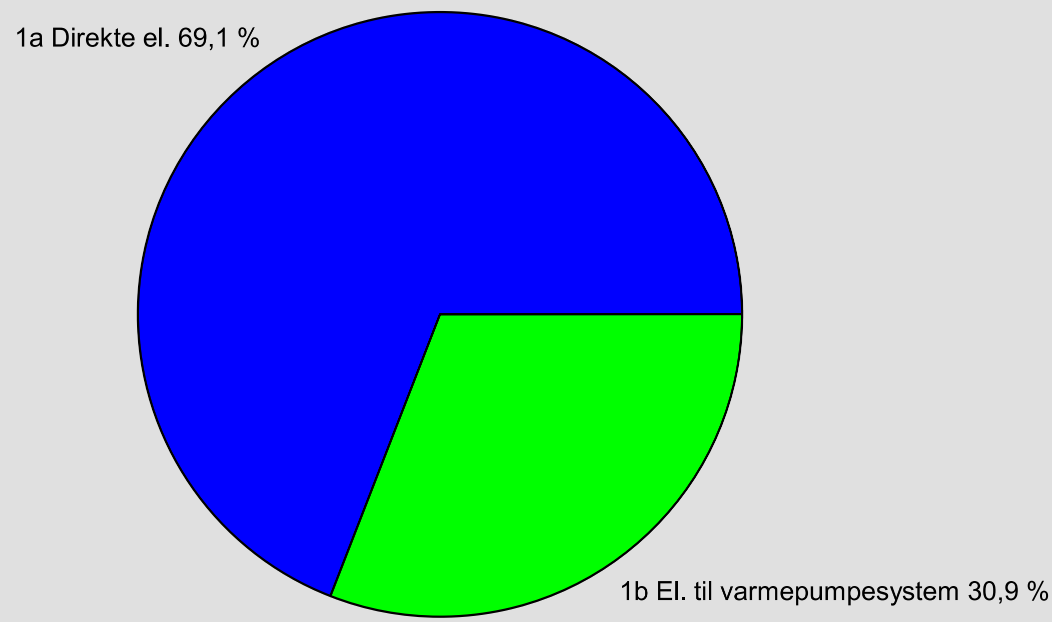
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Levert energi til bygningen (beregnet)



1a Direkte el.	111656 kWh
1b El. til varmepumpesystem	49932 kWh
1c El. til solfangersystem	0 kWh
2 Olje	0 kWh
3 Gass	0 kWh
4 Fjernvarme	0 kWh
5 Biobrensel	0 kWh
6. Annen energikilde	0 kWh
Totalt levert energi, sum 1-7	161588 kWh

SIMIEN

Resultater årssimulering

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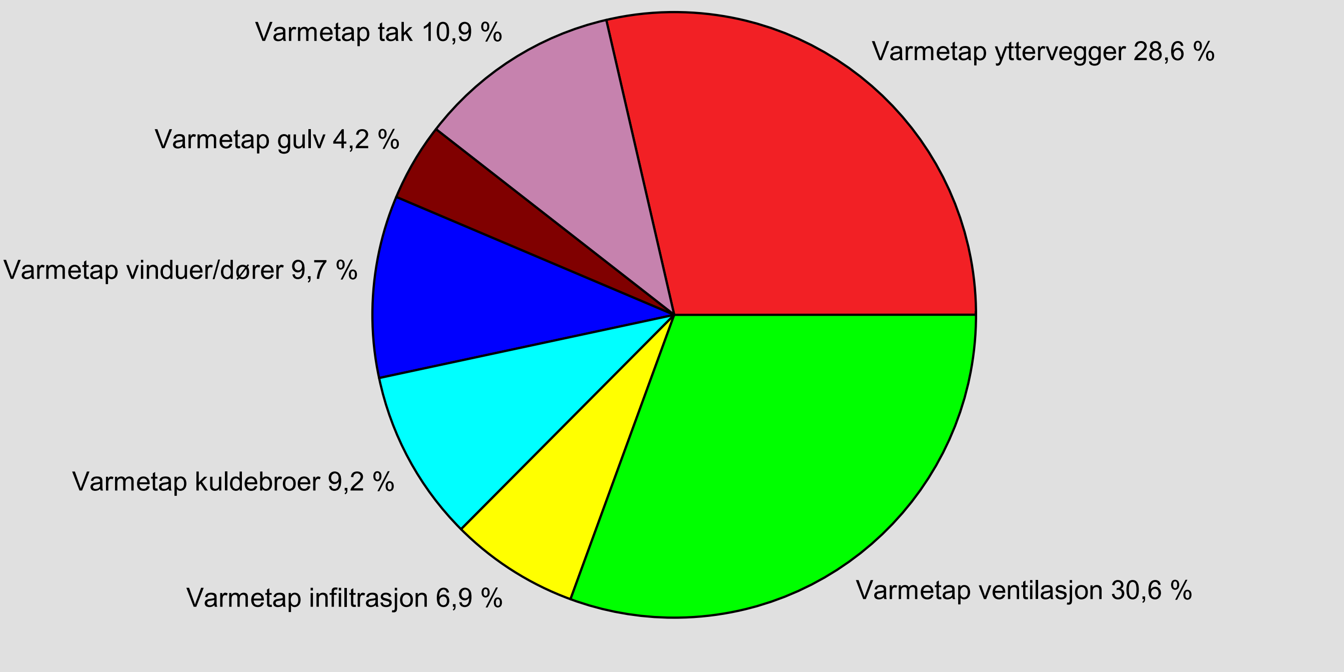
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Varmetapsbudsjett (varmetapstall)



Varmetapstall yttervegger	0,28 W/m²K
Varmetapstall tak	0,11 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,04 W/m²K
Varmetapstall glass/vinduer/dører	0,10 W/m²K
Varmetapstall kuldebroer	0,09 W/m²K
Varmetapstall infiltrasjon	0,07 W/m²K
Varmetapstall ventilasjon	0,30 W/m²K
Totalt varmetapstall	0,98 W/m²K

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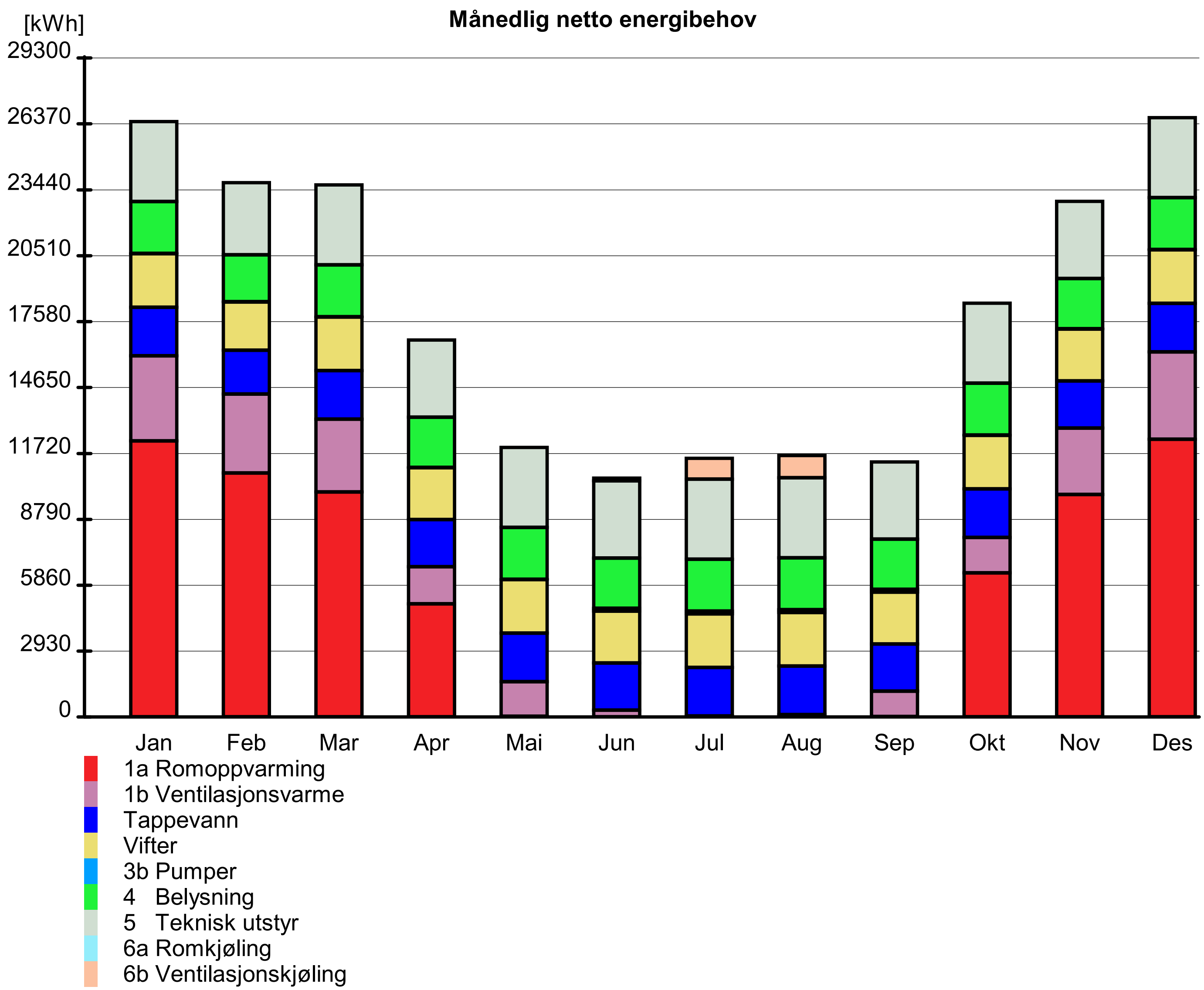
Sone: Concept building



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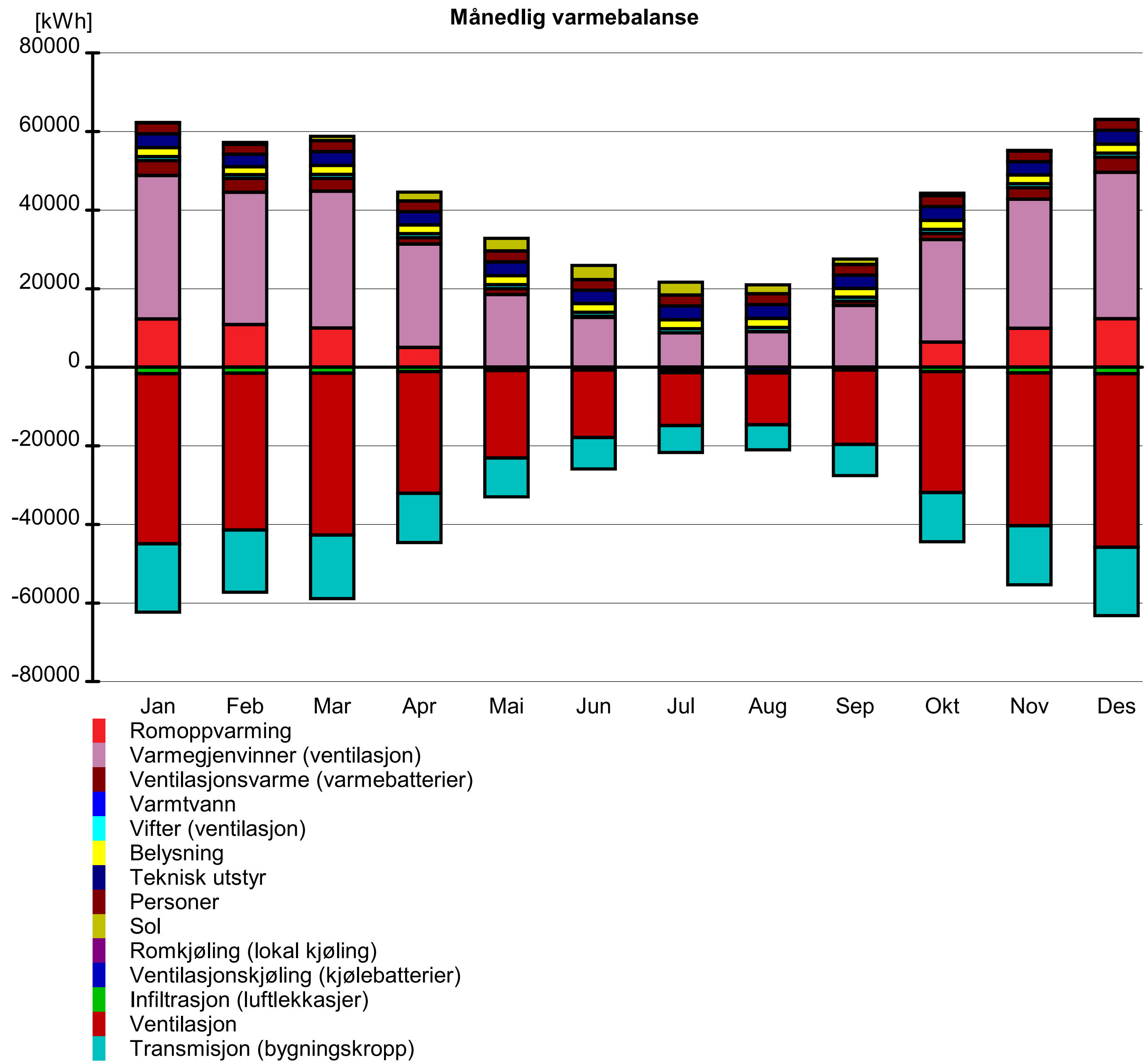

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Månedlige temperaturdata (lufttemperatur)						
Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-2,8 °C	5,5 °C	-14,7 °C	20,0 °C	21,0 °C	19,0 °C
Februar	-3,0 °C	5,9 °C	-14,1 °C	20,0 °C	21,0 °C	19,0 °C
Mars	-1,0 °C	6,1 °C	-10,1 °C	20,0 °C	21,0 °C	19,0 °C
April	3,7 °C	12,5 °C	-4,8 °C	20,1 °C	21,3 °C	19,0 °C
Mai	8,1 °C	18,4 °C	-0,2 °C	19,8 °C	21,9 °C	16,9 °C
Juni	11,5 °C	20,8 °C	4,1 °C	21,0 °C	23,8 °C	18,1 °C
Juli	14,2 °C	24,0 °C	6,0 °C	21,6 °C	24,2 °C	19,2 °C
August	14,1 °C	23,8 °C	4,8 °C	21,2 °C	24,2 °C	18,6 °C
September	9,6 °C	18,7 °C	2,3 °C	19,8 °C	22,5 °C	17,1 °C
Oktober	4,4 °C	12,1 °C	-3,5 °C	20,1 °C	21,0 °C	17,3 °C
November	-0,2 °C	8,6 °C	-9,3 °C	20,0 °C	21,0 °C	19,0 °C
Desember	-2,8 °C	6,6 °C	-12,4 °C	20,0 °C	21,0 °C	19,0 °C

Månedlige temperaturdata (operativ temperatur)						
Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-2,8 °C	5,5 °C	-14,7 °C	19,8 °C	21,0 °C	19,0 °C
Februar	-3,0 °C	5,9 °C	-14,1 °C	19,8 °C	20,9 °C	19,0 °C
Mars	-1,0 °C	6,1 °C	-10,1 °C	19,9 °C	20,9 °C	19,0 °C
April	3,7 °C	12,5 °C	-4,8 °C	20,0 °C	21,2 °C	19,0 °C
Mai	8,1 °C	18,4 °C	-0,2 °C	19,7 °C	21,9 °C	16,9 °C
Juni	11,5 °C	20,8 °C	4,1 °C	21,1 °C	23,6 °C	18,2 °C
Juli	14,2 °C	24,0 °C	6,0 °C	21,7 °C	23,9 °C	19,4 °C
August	14,1 °C	23,8 °C	4,8 °C	21,4 °C	24,0 °C	18,7 °C
September	9,6 °C	18,7 °C	2,3 °C	19,8 °C	22,3 °C	17,2 °C
Oktober	4,4 °C	12,1 °C	-3,5 °C	20,0 °C	21,0 °C	17,4 °C
November	-0,2 °C	8,6 °C	-9,3 °C	19,9 °C	20,9 °C	19,0 °C
Desember	-2,8 °C	6,6 °C	-12,4 °C	19,8 °C	20,9 °C	19,0 °C

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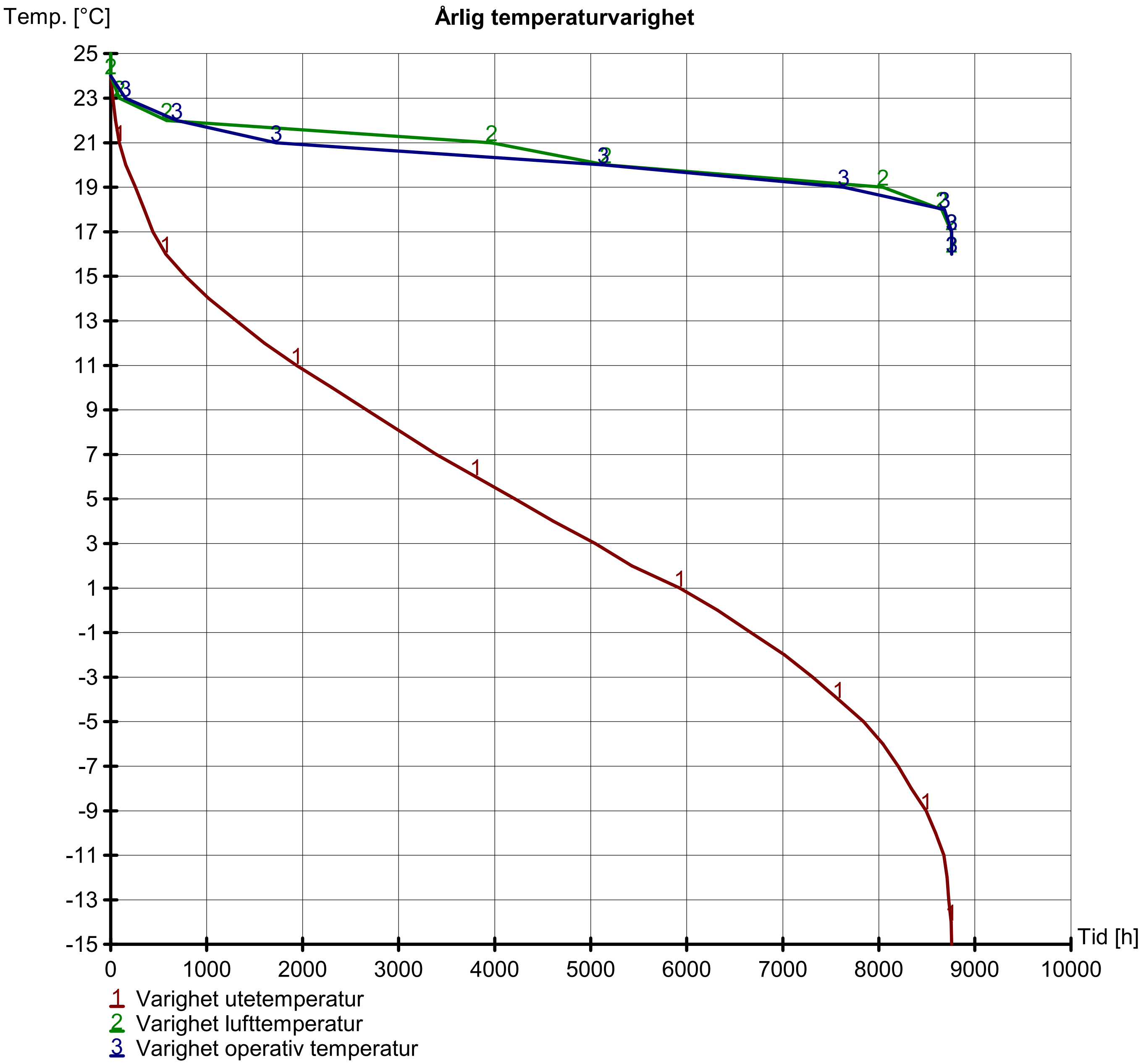

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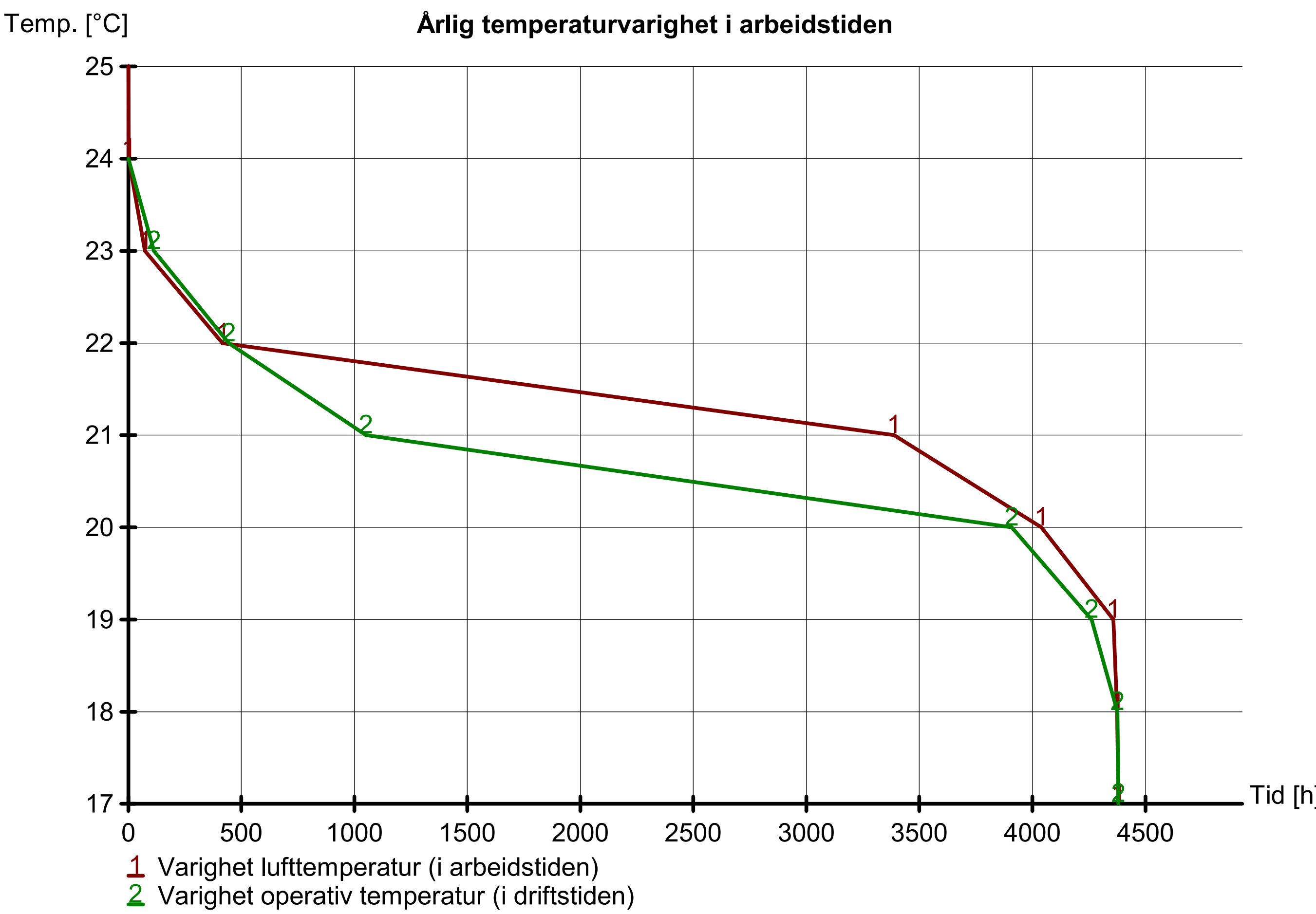

Årlig varighet operativ temperatur i arbeidstiden	
Beskrivelse	Operativ temperatur
Antall timer over 26°C	0

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Resultater årssimulering

Simuleringsnavn: Årssimulering
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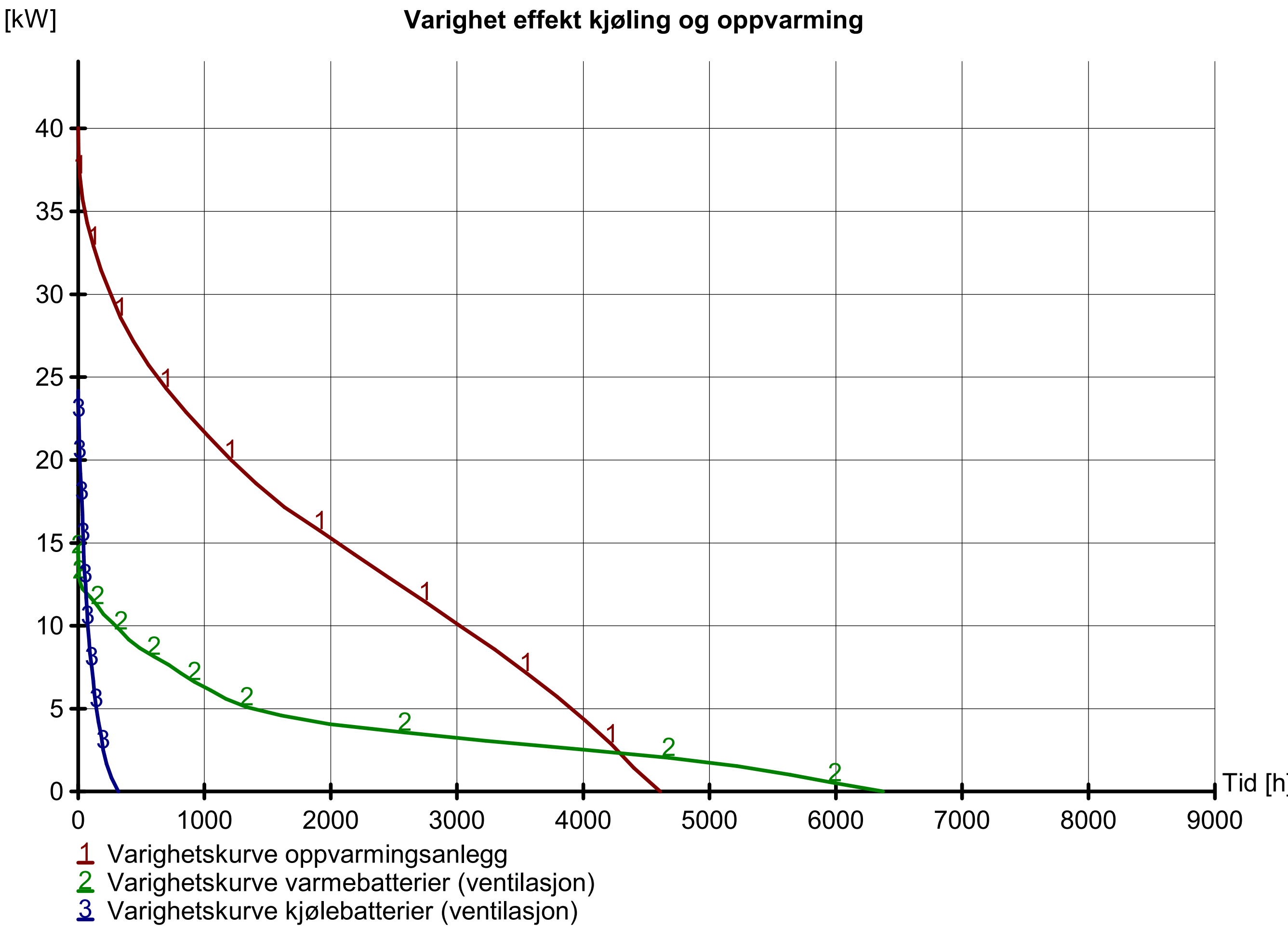

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Resultater årssimulering

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Dekningsgrad effekt/energi oppvarming	
Effekt (dekning)	Dekningsgrad energibruk
49 kW (90 %)	100 %
43 kW (80 %)	100 %
38 kW (70 %)	98 %
32 kW (60 %)	96 %
27 kW (50 %)	91 %
22 kW (40 %)	83 %
16 kW (30 %)	71 %
11 kW (20 %)	54 %
5 kW (10 %)	31 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

Dokumentasjon av sentrale inndata (1)		
Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	869	
Areal tak [m²]:	473	
Areal gulv [m²]:	497	
Areal vinduer og ytterdører [m²]:	120	
Oppvarmet bruksareal (BRA) [m²]:	1517	
Oppvarmet luftvolum [m³]:	5547	
U-verdi yttervegger [W/m²K]	0,49	
U-verdi tak [W/m²K]	0,34	
U-verdi gulv [W/m²K]	0,12	
U-verdi vinduer og ytterdører [W/m²K]	1,20	
Areal vinduer og dører delt på bruksareal [%]	7,9	
Normalisert kuldebroverdi [W/m²K]:	0,09	
Normalisert varmekapasitet [Wh/m²K]	70	
Lekkasjetall (n50) [1/h]:	0,80	
Temperaturvirkningsgr. varmegjenvinner [%]:	82	

Simuleringsnavn: Årssimulering
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Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Dokumentasjon av sentrale inndata (2)

Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	82,0	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,50	
Luftmengde i driftstiden [m³/hm²]	8,09	
Luftmengde utenfor driftstiden [m³/hm²]	2,00	
Systemvirkningsgrad oppvarmingsanlegg:	1,85	
Installert effekt romoppv. og varmebatt. [W/m²]:	80	
Settpunkttemperatur for romoppvarming [°C]	20,0	
Systemeffektfaktor kjøling:	2,50	
Settpunkttemperatur for romkjøling [°C]	0,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	30	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	12,0	

Dokumentasjon av sentrale inndata (3)

Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	0,0	
Driftstid ventilasjon (timer)	12,0	
Driftstid belysning (timer)	12,0	
Driftstid utstyr (timer)	12,0	
Oppholdstid personer (timer)	12,0	
Effektbehov belysning i driftstiden [W/m²]	3,70	
Varmetilskudd belysning i driftstiden [W/m²]	3,70	
Effektbehov utstyr i driftstiden [W/m²]	5,42	
Varmetilskudd utstyr i driftstiden [W/m²]	5,42	
Effektbehov varmtvann på driftsdager [W/m²]	1,92	
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	
Varmetilskudd personer i oppholdstiden [W/m²]	5,00	
Total solfaktor for vindu og solskjerming:	0,38	
Gjennomsnittlig karmfaktor vinduer:	0,09	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	1,00/1,00/1,00/1,00	

Simuleringsnavn: Årssimulering
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Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata bygning	
Beskrivelse	Verdi
Bygningskategori	Kulturbygg
Simuleringsansvarlig	Berit, Halldor _Sylvi
Kommentar	Kulturbygg or Konturbygg?

Inndata klima	
Beskrivelse	Verdi
Klimasted	Sogndal
Breddegrad	61° 9'
Lengdegrad	7° 7'
Tidssone	GMT + 1
Årsmiddeltemperatur	4,7 °C
Midlere solstråling horisontal flate	86 W/m²
Midlere vindhastighet	2,9 m/s

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Inndata energiforsyning

Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,80 Systemvirkningsgrad varmtvann: 0,98 Systemvirkningsgrad varmebatterier: 0,88 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 10,0% Andel oppv, tappevann: 10,0% Andel varmebatteri: 10,0 % Andel kjølebatteri: 10,0 % Andel romkjøling: 10,0 % Andel el, spesifikt: 100,0 %
1b El. til varmepumpesystem	Systemvirkningsgrad romoppv,: 1,86 Systemvirkningsgrad varmtvann: 2,60 Systemvirkningsgrad varmebatterier: 2,67 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 90,0% Andel oppv, tappevann: 90,0% Andel varmebatteri: 90,0 % Andel kjølebatteri: 90,0 % Andel romkjøling: 90,0 % Andel el, spesifikt: 0,0 %

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Inndata ekspertverdier	
Beskrivelse	Verdi
Konvektiv andel varmetilskudd belysning	0,30
Konvektiv andel varmetilsk. teknisk utstyr	0,50
Konvektiv andel varmetilsikudd personer	0,50
Konvektiv andel varmetilsikudd sol	0,50
Konvektiv varmoverføringskoeff. vegger	2,50
Konvektiv varmoverføringskoeff. himling	2,00
Konvektiv varmoverføringskoeff. gulv	3,00
Bypassfaktor kjølebatteri	0,25
Innv. varmemotstand på vinduruter	0,13
Midlere lufthastighet romluft	0,15
Turbulensintensitet romluft	25,00
Avstand fra vindu	0,60
Termisk konduktivitet akk. sjikt [W/m²K]:	20,00

Inndata rom/sone	
Beskrivelse	Verdi
Oppvarmet gulvareal	1516,8 m²
Oppvarmet luftvolum	5547,2 m³
Normalisert kuldebroverdi	0,09 W/(m²K)
Varmekapasitet møbler/interiør	2,0 Wh/m² (Lett møblert rom)
Lekkasjetall (luftskifte v. 50pa)	0,80 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	31
Driftsdager i Februar	28
Driftsdager i Mars	31
Driftsdager i April	30
Driftsdager i Mai	31
Driftsdager i Juni	30
Driftsdager i Juli	31
Driftsdager i August	31
Driftsdager i September	30
Driftsdager i Oktober	31
Driftsdager i November	30
Driftsdager i Desember	31

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Sone: Concept building

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	Wall NE (fasade)
Totalt areal	187,9 m²
Retning (0=Nord, 180=Sør)	45°
Innv. akkumulerende sjikt	Lettklinker Varmekapasitet 13,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,30 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Big (Vindu(er) på Wall NE)
Antall vinduer	6
Høyde vindu(er)	1,50 m
Bredde vindu(er)	1,43 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Small (Vindu(er) på Wall NE)
Antall vinduer	2
Høyde vindu(er)	1,05 m
Bredde vindu(er)	1,40 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

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Sone: Concept building

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Long (Vindu(er) på Wall NE)
Antall vinduer	1
Høyde vindu(er)	2,50 m
Bredde vindu(er)	0,50 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata ytterdør	
Beskrivelse	Verdi
Navn:	Door no1 (ytterdør)
Areal inkl. karm/ramme	2,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør	
Beskrivelse	Verdi
Navn:	Door no2 (ytterdør)
Areal inkl. karm/ramme	2,5 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

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Firma: Undervisningslisens
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Sone: Concept building

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no3 (ytterdør)
Areal inkl. karm/ramme	2,1 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	Wall NW SEA (fasade)
Totalt areal	250,0 m²
Retning (0=Nord, 180=Sør)	315°
Innv. akkumulerende sjikt	Egendefinert Varmekapasitet 0,8 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,70 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Double no1 (ytterdør)
Areal inkl. karm/ramme	6,5 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no4 (ytterdør)
Areal inkl. karm/ramme	3,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

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Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
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Sone: Concept building

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no4 (ytterdør)
Areal inkl. karm/ramme	3,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	Wall SE (fasade)
Totalt areal	310,5 m²
Retning (0=Nord, 180=Sør)	135°
Innv. akkumulerende sjikt	Lettklinker Varmekapasitet 13,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,29 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Big (Vindu(er) på Wall SE)
Antall vinduer	6
Høyde vindu(er)	1,50 m
Bredde vindu(er)	1,43 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

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Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
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Sone: Concept building

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no3 (ytterdør)
Areal inkl. karm/ramme	2,1 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Double no2 (ytterdør)
Areal inkl. karm/ramme	4,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Double no2 (ytterdør)
Areal inkl. karm/ramme	4,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	Wall SW (fasade)
Totalt areal	188,7 m²
Retning (0=Nord, 180=Sør)	225°
Innv. akkumulerende sjikt	Egendefinert Varmekapasitet 0,8 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,70 W/m²K

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Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
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Sone: Concept building

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no5 (ytterdør)
Areal inkl. karm/ramme	3,6 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no5 (ytterdør)
Areal inkl. karm/ramme	3,6 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

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Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata CAV

Beskrivelse	Verdi
Navn:	Ventilation (CAV ventilasjon)
Ventilasjonstype	Balansert ventilasjon
Driftstid	12:00 timer drift pr døgn
Luftmengde	I driftstiden: tilluft = 8.1 m³/hm², avtrekk = 8.1 m³/hm² Utenfor driftstiden: tilluft = 2.0 m³/hm², avtrekk = 2.0 m³/hm² Helg/feridag: tilluft = 3.0 m³/hm², avtrekk = 3.0 m³/hm²
Tilluftstemperatur	Normal: 19.0 °C Fra Mai til August: 19.0 °C
Varmebatteri	Ja Maks. kapasitet: 30 W/m²
Vannbåren distribusjon til varmebatteri	Delta-T: 30.0 °C SPP: 0.5 kW/(l/s)
Kjølebatteri	
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.6 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.82
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	1.50 kW/m³/s
Redusert luftmengde ved lav utemperatur	Utetemperatur lavere enn: -10.0°C Luftmengde: 5.00 m³/hm²

Inndata gulv mot friluft/kryprom/grunn

Beskrivelse	Verdi
Navn:	Basement (gulv)
Oppvarmet gulvareal	497,3 m²
Gulvtype	Gulv på grunn
Utvendig omkrets	96,80 m
Tykkelse grunnmur	0,30 m
Grunnforhold	Egendefinert Varmekapasitet: 556 Wh/m³K Varmeledningsevne: 2,00 W/mK
Ekstra kantisolering	Nei
Innv. akk. sjikt gulv	Egendefinert Varmekapasitet 63,0 Wh/m²K
Gulvkonstruksjon	Egendefinert Uverdi: 0,18 W/m²K

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Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	1st floor (skillekonstruksjon)
Totalt areal	491,9 m²
Konstruksjonstype	Gulv
Innv. akkumulerende sjikt	Meget tung konstruksjon (betong > 100mm) Varmekapasitet 63,0 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	2nd floor (skillekonstruksjon)
Totalt areal	304,1 m²
Konstruksjonstype	Gulv
Innv. akkumulerende sjikt	Meget tung konstruksjon (betong > 100mm) Varmekapasitet 63,0 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	3rd floor (skillekonstruksjon)
Totalt areal	223,6 m²
Konstruksjonstype	Gulv
Innv. akkumulerende sjikt	Meget tung konstruksjon (betong > 100mm) Varmekapasitet 63,0 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

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Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata yttertak

Beskrivelse	Verdi
Navn:	Roof NW (yttertak)
Totalt areal	324,0 m²
Retning (0=Nord, 180=Sør)	315°
Takvinkel	32,2°
Innv. akkumulerende sjikt	Lett himling Varmekapasitet 3,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,39 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Roof window (Vindu(er) på Roof NW)
Antall vinduer	2
Høyde vindu(er)	1,98 m
Bredde vindu(er)	6,62 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata yttertak

Beskrivelse	Verdi
Navn:	Roof SE (yttertak)
Totalt areal	201,0 m²
Retning (0=Nord, 180=Sør)	135°
Takvinkel	32,2°
Innv. akkumulerende sjikt	Lett himling Varmekapasitet 3,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,26 W/m²K

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Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Roof window (Vindu(er) på Roof SE)
Antall vinduer	2
Høyde vindu(er)	1,98 m
Bredde vindu(er)	6,62 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata belysning

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 3,7 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,4 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 3,7 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

Inndata teknisk utstyr (internlast)

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, teknisk utstyr)
Effekt/Varmetilskudd teknisk utstyr	I driftstiden; Effekt: 5,4 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,9 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 5,4 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

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Inndata oppvarming av tappevann

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, tappevann)
Tappevann	Driftsdag; Midlere effekt: 1,9 W/m²; Varmetilskudd: 0 %; Vanndamp: 0,0 g/m² Helg/feriedag: Midlere effekt: 1,9 W/m²; Varmetilskudd: 0 %; ; Vanndamp: 0,0 g/m²

Inndata varmetilskudd personer (internlast)

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 5,0 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 5,0 W/m² Antall arbeidstimer: 12:00

Inndata oppvarming

Beskrivelse	Verdi
Navn:	Warming (oppvarming)
Settpunkttemperatur i driftstid	21,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	50 W/m²
Konvektiv andel oppvarming	0,50
Driftstid	12:00 timer drift pr døgn
Annen drifsstrategi i sommermåneder	Fra Mai til September
Settpunkttemperatur i driftstiden (sommer)	19,0 °C
Settpunttemperatur uten driftstiden (sommer)	16,0 °C
Driftstid sommermåneder	12:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Nei

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Resultater årssimulering

Simuleringsnavn: Årssimulering
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Simuleringsansvarlig: Berit, Halldor & Sylvi
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Sone: Concept building

Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	66835 kWh	44,1 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	23780 kWh	15,7 kWh/m²
2 Varmtvann (tappevann)	25509 kWh	16,8 kWh/m²
3a Vifter	28100 kWh	18,5 kWh/m²
3b Pumper	640 kWh	0,4 kWh/m²
4 Belysning	27248 kWh	18,0 kWh/m²
5 Teknisk utstyr	41925 kWh	27,6 kWh/m²
6a Romkjøling	0 kWh	0,0 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	2073 kWh	1,4 kWh/m²
Totalt netto energibehov, sum 1-6	216111 kWh	142,5 kWh/m²

Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	111656 kWh	73,6 kWh/m²
1b El. til varmepumpesystem	43975 kWh	29,0 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	0 kWh	0,0 kWh/m²
6. Annen energikilde	0 kWh	0,0 kWh/m²
7. Solstrøm til egenbruk	-0 kWh	-0,0 kWh/m²
Totalt levert energi, sum 1-7	155631 kWh	102,6 kWh/m²
Solstrøm til eksport	-0 kWh	-0,0 kWh/m²
Netto levert energi	155631 kWh	102,6 kWh/m²

Simuleringsnavn: Årssimulering
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Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Dekning av energibudsjett fordelt på energikilder

Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	4,4 kWh/m²	1,6 kWh/m²	1,7 kWh/m²	0,1 kWh/m²	0,0 kWh/m²	64,6 kWh/m²
Olje	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Gass	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Fjernvarme	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Biobrensel	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Varmepumpe	39,7 kWh/m²	14,1 kWh/m²	15,1 kWh/m²	1,2 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sol	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Annen	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sum	44,1 kWh/m²	15,7 kWh/m²	16,8 kWh/m²	1,4 kWh/m²	0,0 kWh/m²	64,6 kWh/m²

Årlige utslipp av CO2

Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	14515 kg	9,6 kg/m²
1b El. til varmepumpesystem	5717 kg	3,8 kg/m²
1c El. til solfangersystem	0 kg	0,0 kg/m²
2 Olje	0 kg	0,0 kg/m²
3 Gass	0 kg	0,0 kg/m²
4 Fjernvarme	0 kg	0,0 kg/m²
5 Biobrensel	0 kg	0,0 kg/m²
6. Annen energikilde	0 kg	0,0 kg/m²
7. Solstrøm til egenbruk	-0 kg	-0,0 kg/m²
Totalt utslipp, sum 1-7	20232 kg	13,3 kg/m²
Solstrøm til eksport	-0 kg	-0,0 kg/m²
Netto CO2-utslipp	20232 kg	13,3 kg/m²

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Sone: Concept building

Kostnad kjøpt energi

Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	89325 kr	58,9 kr/m²
1b El. til varmepumpesystem	35180 kr	23,2 kr/m²
1c El. til solfangersystem	0 kr	0,0 kr/m²
2 Olje	0 kr	0,0 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	0 kr	0,0 kr/m²
6. Annen energikilde	0 kr	0,0 kr/m²
7. Solstrøm til egenbruk	-0 kr	-0,0 kr/m²
Årlige energikostnader, sum 1-7	124505 kr	82,1 kr/m²
Solstrøm til eksport	0 kr	0,0 kr/m²
Netto energikostnad	124505 kr	82,1 kr/m²

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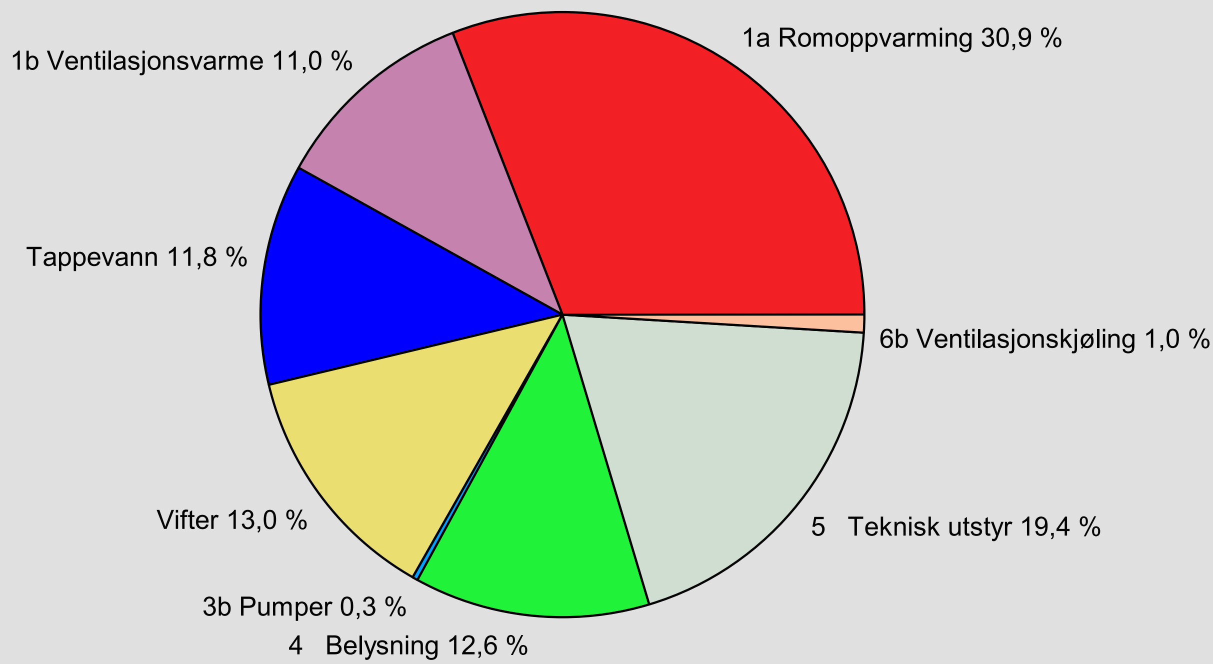
Årlig energibudsjett



1a Romoppvarming	66835 kWh
1b Ventilasjonsvarme (varmebatterier)	23780 kWh
2 Varmtvann (tappevann)	25509 kWh
3a Vifter	28100 kWh
3b Pumper	640 kWh
4 Belysning	27248 kWh
5 Teknisk utstyr	41925 kWh
6a Romkjøling	0 kWh
6b Ventilasjonskjøling (kjølebatterier)	2073 kWh
Totalt netto energibehov, sum 1-6	216111 kWh

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Resultater årssimulering

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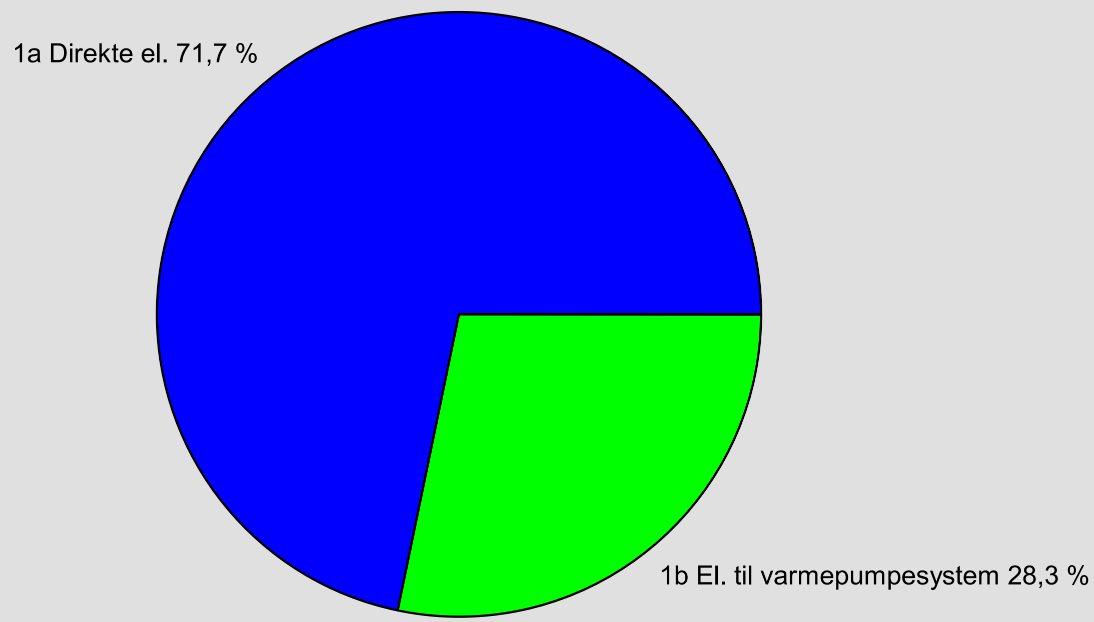
Levert energi til bygningen (beregnet)



1a Direkte el.	111656 kWh
1b El. til varmepumpesystem	43975 kWh
1c El. til solfangersystem	0 kWh
2 Olje	0 kWh
3 Gass	0 kWh
4 Fjernvarme	0 kWh
5 Biobrensel	0 kWh
6. Annen energikilde	0 kWh
Totalt levert energi, sum 1-7	155631 kWh

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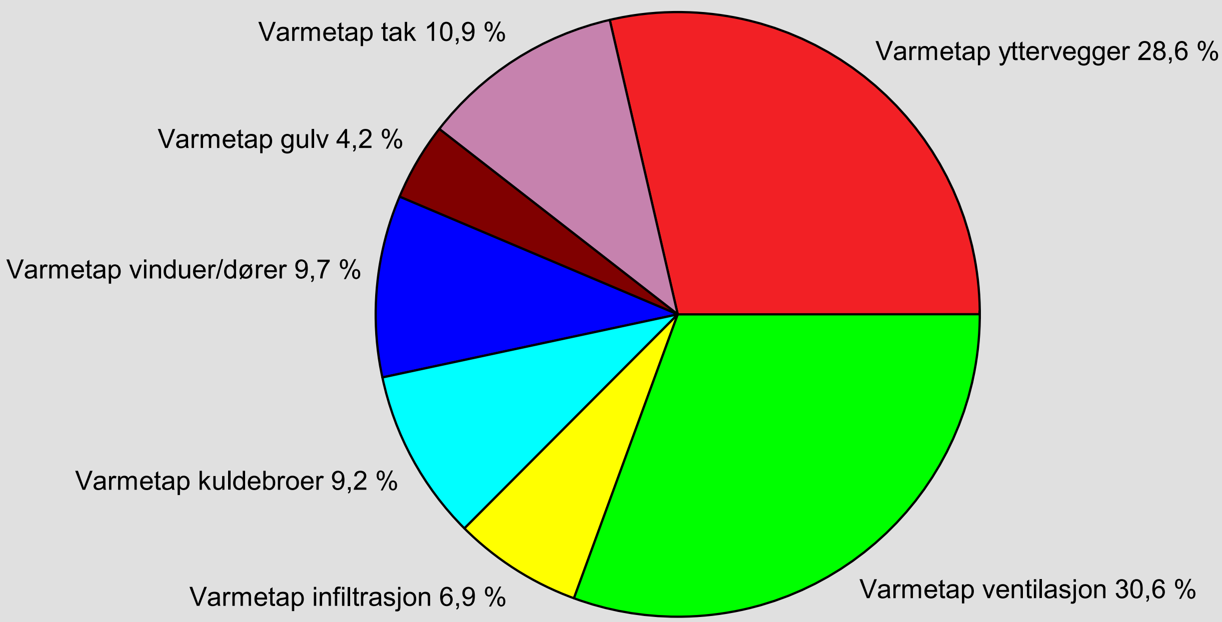
Sone: Concept building

Varmetapsbudsjett (varmetapstall)



Varmetapstall yttervegger	0,28 W/m²K
Varmetapstall tak	0,11 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,04 W/m²K
Varmetapstall glass/vinduer/dører	0,10 W/m²K
Varmetapstall kuldebroer	0,09 W/m²K
Varmetapstall infiltrasjon	0,07 W/m²K
Varmetapstall ventilasjon	0,30 W/m²K
Totalt varmetapstall	0,98 W/m²K

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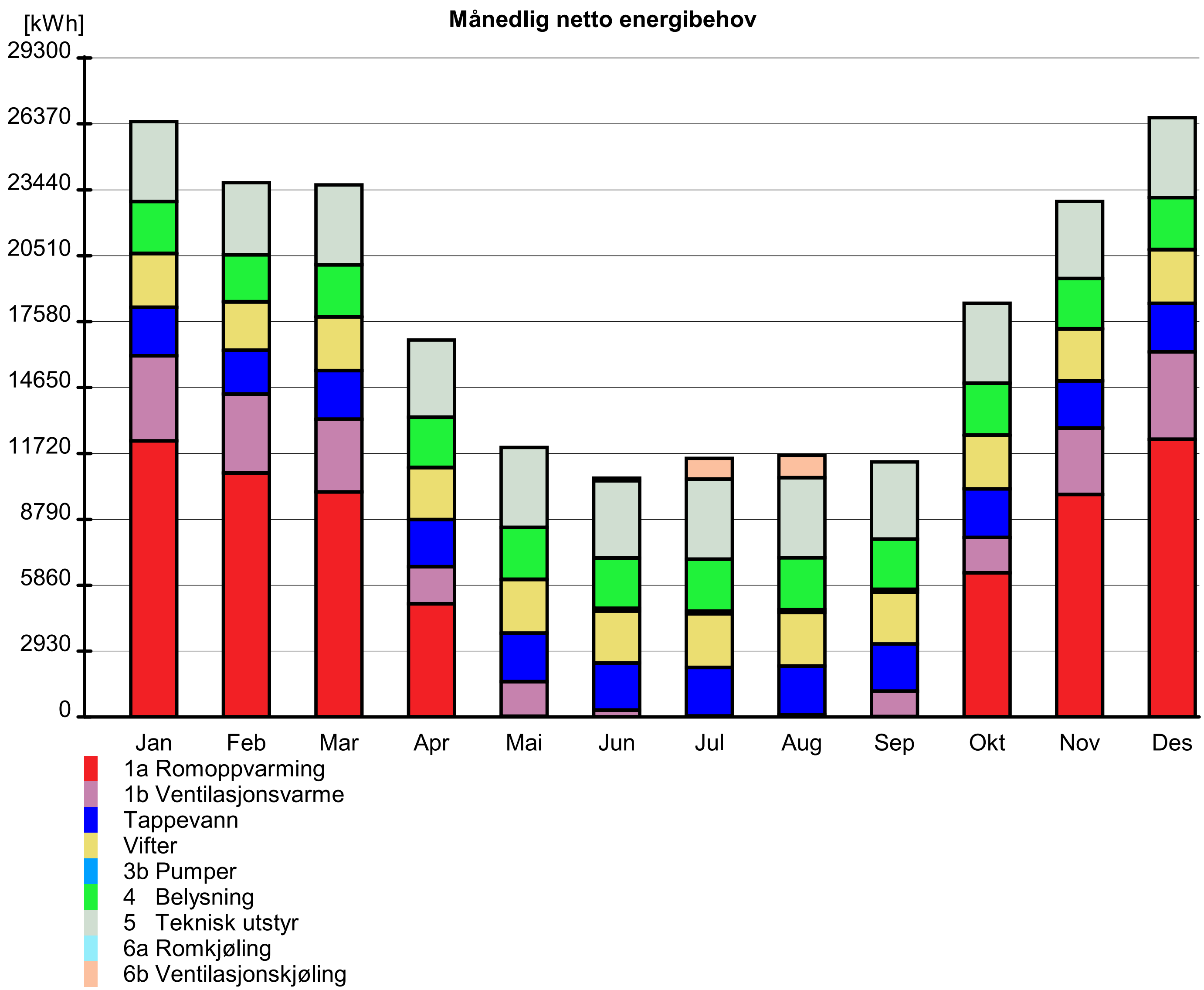

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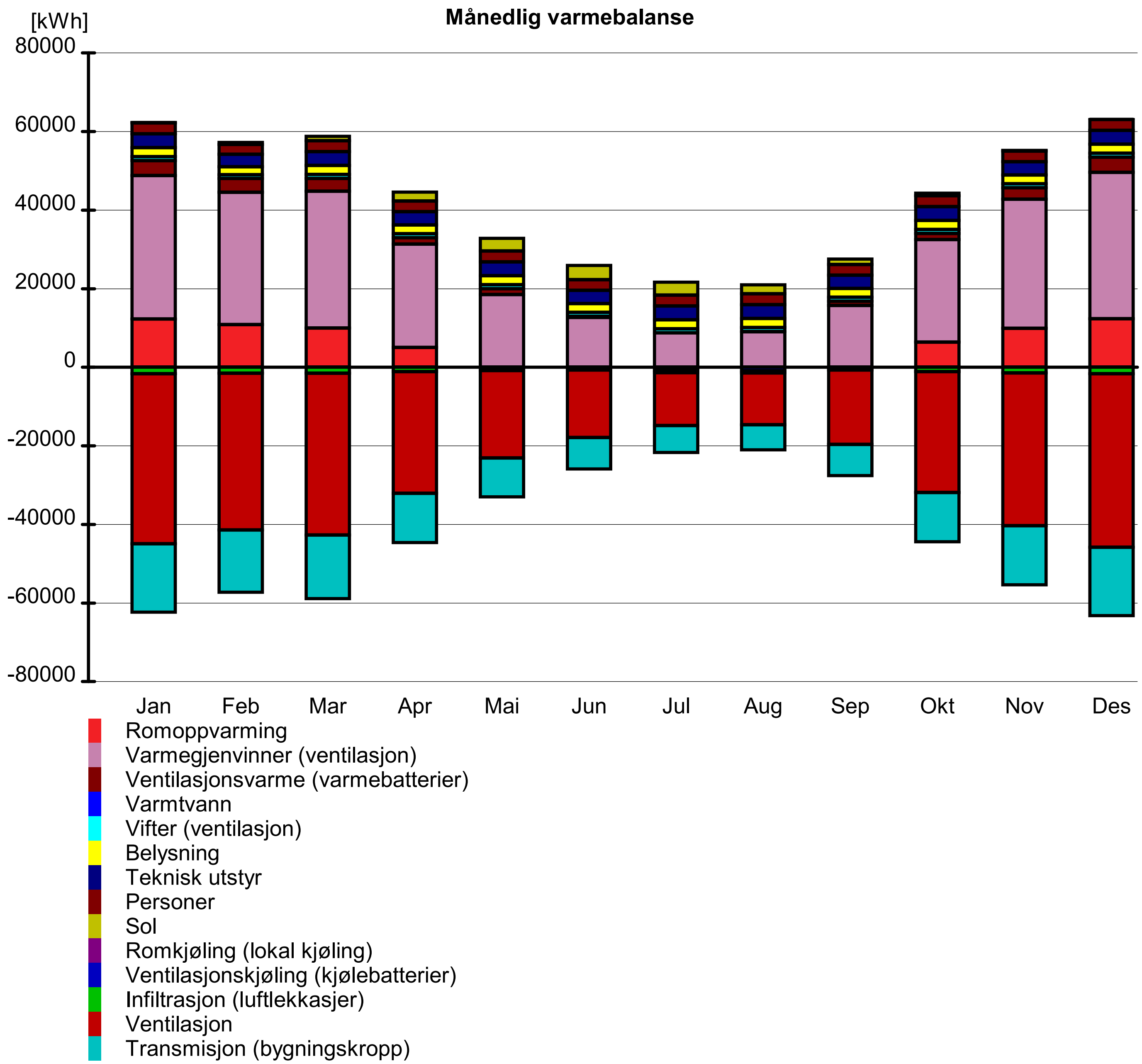

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Månedlige temperaturdata (lufttemperatur)

Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-2,8 °C	5,5 °C	-14,7 °C	20,0 °C	21,0 °C	19,0 °C
Februar	-3,0 °C	5,9 °C	-14,1 °C	20,0 °C	21,0 °C	19,0 °C
Mars	-1,0 °C	6,1 °C	-10,1 °C	20,0 °C	21,0 °C	19,0 °C
April	3,7 °C	12,5 °C	-4,8 °C	20,1 °C	21,3 °C	19,0 °C
Mai	8,1 °C	18,4 °C	-0,2 °C	19,8 °C	21,9 °C	16,9 °C
Juni	11,5 °C	20,8 °C	4,1 °C	21,0 °C	23,8 °C	18,1 °C
Juli	14,2 °C	24,0 °C	6,0 °C	21,6 °C	24,2 °C	19,2 °C
August	14,1 °C	23,8 °C	4,8 °C	21,2 °C	24,2 °C	18,6 °C
September	9,6 °C	18,7 °C	2,3 °C	19,8 °C	22,5 °C	17,1 °C
Oktober	4,4 °C	12,1 °C	-3,5 °C	20,1 °C	21,0 °C	17,3 °C
November	-0,2 °C	8,6 °C	-9,3 °C	20,0 °C	21,0 °C	19,0 °C
Desember	-2,8 °C	6,6 °C	-12,4 °C	20,0 °C	21,0 °C	19,0 °C

Månedlige temperaturdata (operativ temperatur)

Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-2,8 °C	5,5 °C	-14,7 °C	19,8 °C	21,0 °C	19,0 °C
Februar	-3,0 °C	5,9 °C	-14,1 °C	19,8 °C	20,9 °C	19,0 °C
Mars	-1,0 °C	6,1 °C	-10,1 °C	19,9 °C	20,9 °C	19,0 °C
April	3,7 °C	12,5 °C	-4,8 °C	20,0 °C	21,2 °C	19,0 °C
Mai	8,1 °C	18,4 °C	-0,2 °C	19,7 °C	21,9 °C	16,9 °C
Juni	11,5 °C	20,8 °C	4,1 °C	21,1 °C	23,6 °C	18,2 °C
Juli	14,2 °C	24,0 °C	6,0 °C	21,7 °C	23,9 °C	19,4 °C
August	14,1 °C	23,8 °C	4,8 °C	21,4 °C	24,0 °C	18,7 °C
September	9,6 °C	18,7 °C	2,3 °C	19,8 °C	22,3 °C	17,2 °C
Oktober	4,4 °C	12,1 °C	-3,5 °C	20,0 °C	21,0 °C	17,4 °C
November	-0,2 °C	8,6 °C	-9,3 °C	19,9 °C	20,9 °C	19,0 °C
Desember	-2,8 °C	6,6 °C	-12,4 °C	19,8 °C	20,9 °C	19,0 °C

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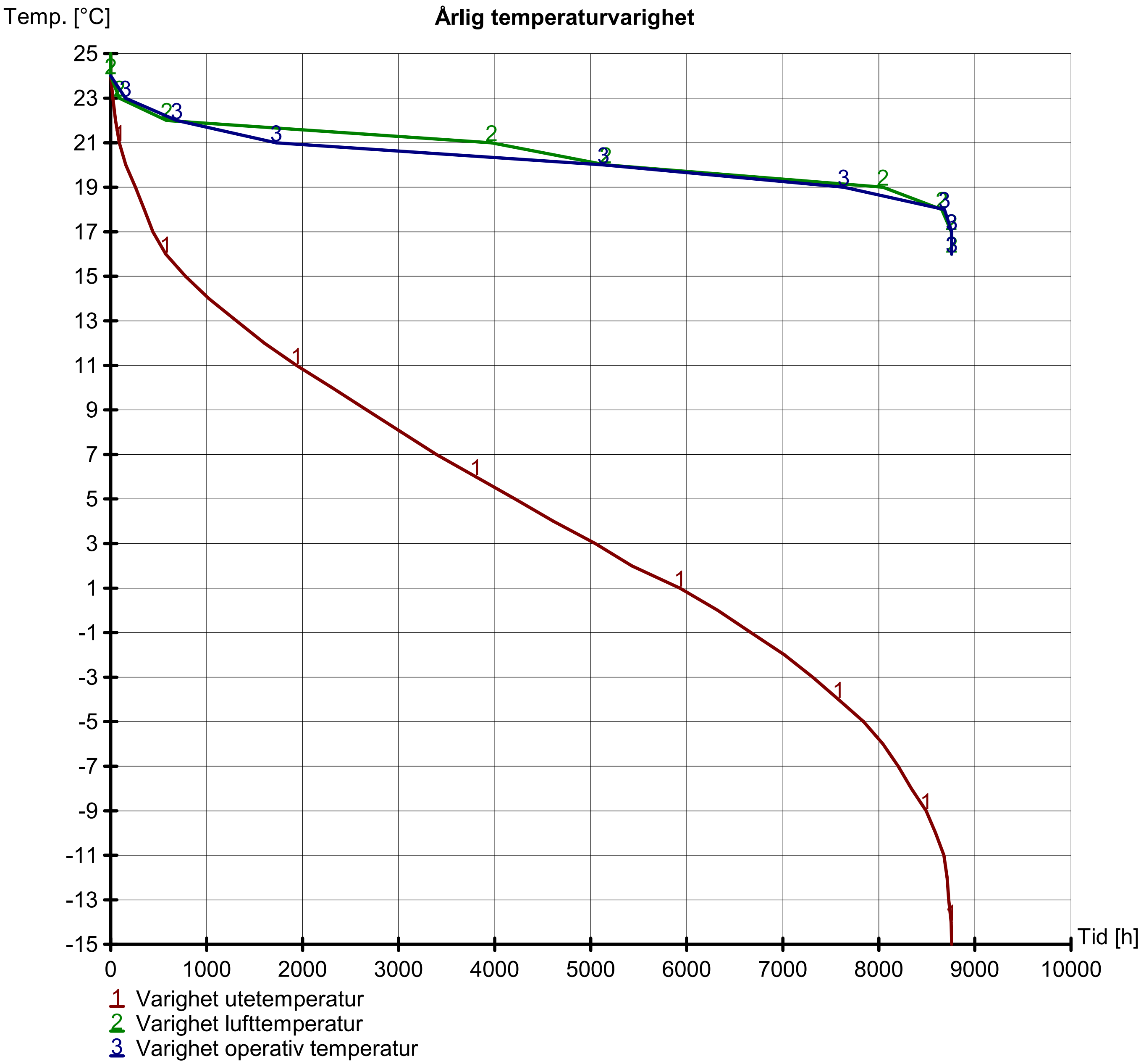

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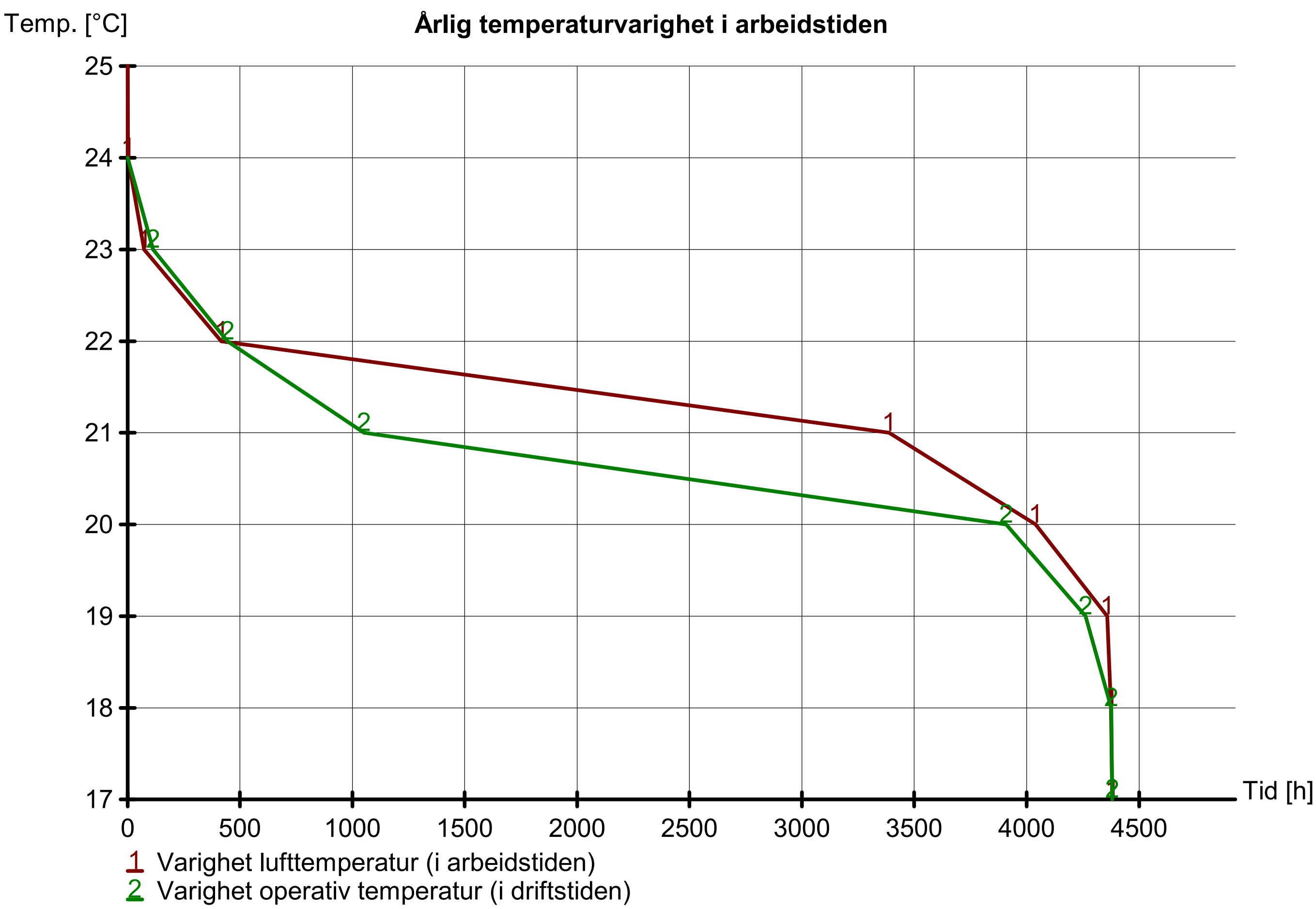

Årlig varighet operativ temperatur i arbeidstiden	
Beskrivelse	Operativ temperatur
Antall timer over 26°C	0

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Resultater årssimulering

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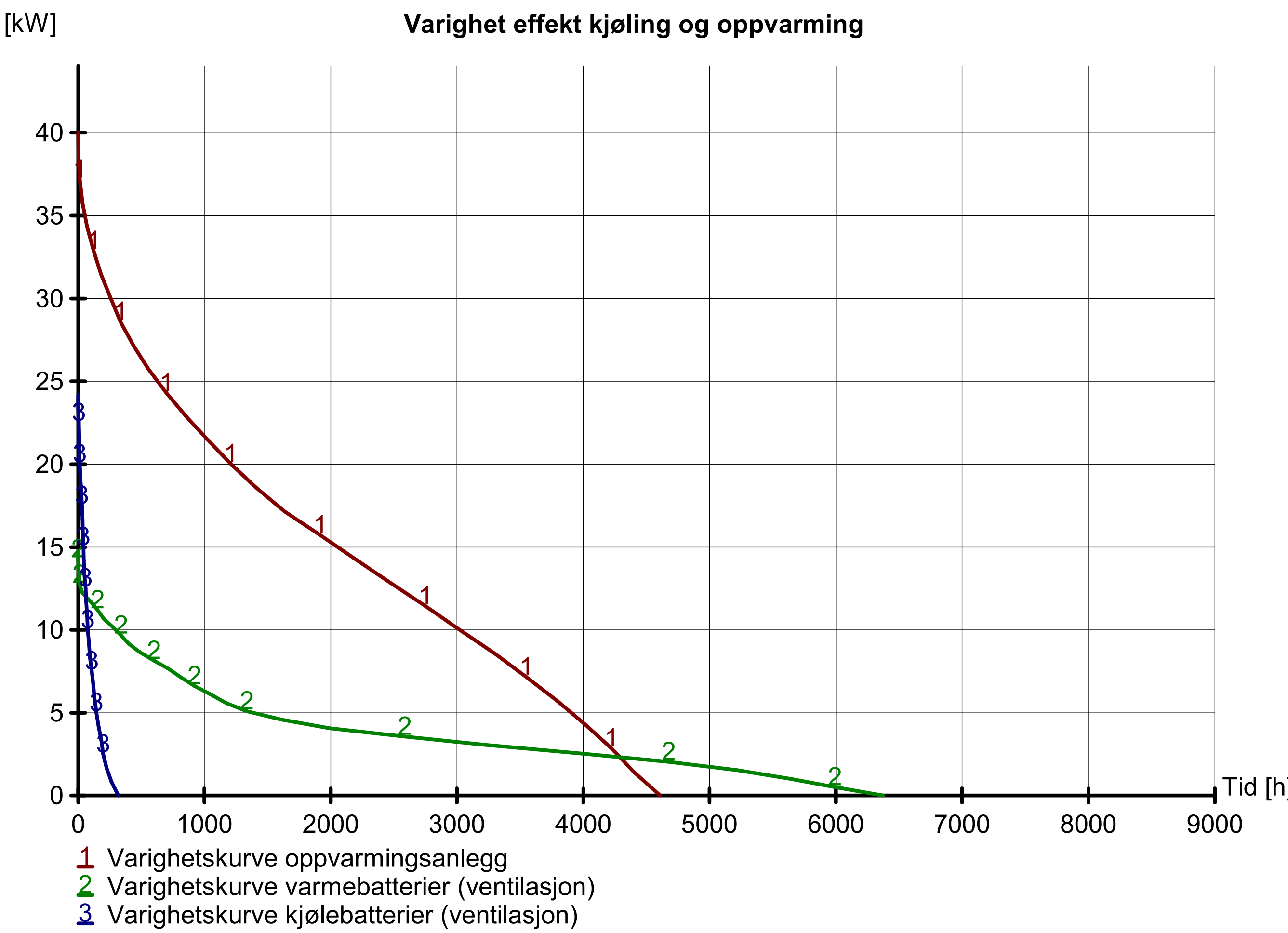

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Dekningsgrad effekt/energi oppvarming

Effekt (dekning)	Dekningsgrad energibruk
49 kW (90 %)	100 %
43 kW (80 %)	100 %
38 kW (70 %)	98 %
32 kW (60 %)	96 %
27 kW (50 %)	91 %
22 kW (40 %)	83 %
16 kW (30 %)	71 %
11 kW (20 %)	54 %
5 kW (10 %)	31 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

Dokumentasjon av sentrale inndata (1)

Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	869	
Areal tak [m²]:	473	
Areal gulv [m²]:	497	
Areal vinduer og ytterdører [m²]:	120	
Oppvarmet bruksareal (BRA) [m²]:	1517	
Oppvarmet luftvolum [m³]:	5547	
U-verdi yttervegger [W/m²K]	0,49	
U-verdi tak [W/m²K]	0,34	
U-verdi gulv [W/m²K]	0,12	
U-verdi vinduer og ytterdører [W/m²K]	1,20	
Areal vinduer og dører delt på bruksareal [%]	7,9	
Normalisert kuldebroverdi [W/m²K]:	0,09	
Normalisert varmekapasitet [Wh/m²K]	70	
Lekkasjetall (n50) [1/h]:	0,80	
Temperaturvirkningsgr. varmegjenvinner [%]:	82	

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Dokumentasjon av sentrale inndata (2)

Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	82,0	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,50	
Luftmengde i driftstiden [m³/hm²]	8,09	
Luftmengde utenfor driftstiden [m³/hm²]	2,00	
Systemvirkningsgrad oppvarmingsanlegg:	2,04	
Installert effekt romoppv. og varmebatt. [W/m²]:	80	
Settpunkttemperatur for romoppvarming [°C]	20,0	
Systemeffektfaktor kjøling:	2,50	
Settpunkttemperatur for romkjøling [°C]	0,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	30	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	12,0	

Dokumentasjon av sentrale inndata (3)

Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	0,0	
Driftstid ventilasjon (timer)	12,0	
Driftstid belysning (timer)	12,0	
Driftstid utstyr (timer)	12,0	
Oppholdstid personer (timer)	12,0	
Effektbehov belysning i driftstiden [W/m²]	3,70	
Varmetilskudd belysning i driftstiden [W/m²]	3,70	
Effektbehov utstyr i driftstiden [W/m²]	5,42	
Varmetilskudd utstyr i driftstiden [W/m²]	5,42	
Effektbehov varmtvann på driftsdager [W/m²]	1,92	
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	
Varmetilskudd personer i oppholdstiden [W/m²]	5,00	
Total solfaktor for vindu og solskjerming:	0,38	
Gjennomsnittlig karmfaktor vinduer:	0,09	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	1,00/1,00/1,00/1,00	

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Sone: Concept building

Inndata bygning	
Beskrivelse	Verdi
Bygningskategori	Kulturbygg
Simuleringsansvarlig	Berit, Halldor _Sylvi
Kommentar	Kulturbygg or Konturbygg?

Inndata klima	
Beskrivelse	Verdi
Klimasted	Sogndal
Breddegrad	61° 9'
Lengdegrad	7° 7'
Tidssone	GMT + 1
Årsmiddeltemperatur	4,7 °C
Midlere solstråling horisontal flate	86 W/m²
Midlere vindhastighet	2,9 m/s

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Inndata energiforsyning

Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,80 Systemvirkningsgrad varmtvann: 0,98 Systemvirkningsgrad varmebatterier: 0,88 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 10,0% Andel oppv, tappevann: 10,0% Andel varmebatteri: 10,0 % Andel kjølebatteri: 10,0 % Andel romkjøling: 10,0 % Andel el, spesifikt: 100,0 %
1b El. til varmepumpesystem	Systemvirkningsgrad romoppv,: 2,28 Systemvirkningsgrad varmtvann: 2,60 Systemvirkningsgrad varmebatterier: 2,67 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 90,0% Andel oppv, tappevann: 90,0% Andel varmebatteri: 90,0 % Andel kjølebatteri: 90,0 % Andel romkjøling: 90,0 % Andel el, spesifikt: 0,0 %

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Inndata ekspertverdier	
Beskrivelse	Verdi
Konvektiv andel varmetilskudd belysning	0,30
Konvektiv andel varmetilsk. teknisk utstyr	0,50
Konvektiv andel varmetilsikudd personer	0,50
Konvektiv andel varmetilsikudd sol	0,50
Konvektiv varmoverføringskoeff. vegger	2,50
Konvektiv varmoverføringskoeff. himling	2,00
Konvektiv varmoverføringskoeff. gulv	3,00
Bypassfaktor kjølebatteri	0,25
Innv. varmemotstand på vinduruter	0,13
Midlere lufthastighet romluft	0,15
Turbulensintensitet romluft	25,00
Avstand fra vindu	0,60
Termisk konduktivitet akk. sjikt [W/m²K]:	20,00

Inndata rom/sone	
Beskrivelse	Verdi
Oppvarmet gulvareal	1516,8 m²
Oppvarmet luftvolum	5547,2 m³
Normalisert kuldebroverdi	0,09 W/(m²K)
Varmekapasitet møbler/interiør	2,0 Wh/m² (Lett møblert rom)
Lekkasjetall (luftskifte v. 50pa)	0,80 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	31
Driftsdager i Februar	28
Driftsdager i Mars	31
Driftsdager i April	30
Driftsdager i Mai	31
Driftsdager i Juni	30
Driftsdager i Juli	31
Driftsdager i August	31
Driftsdager i September	30
Driftsdager i Oktober	31
Driftsdager i November	30
Driftsdager i Desember	31

Simuleringsnavn: Årssimulering
Tid/dato simulering: 21:50 30/4-2021
Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	Wall NE (fasade)
Totalt areal	187,9 m²
Retning (0=Nord, 180=Sør)	45°
Innv. akkumulerende sjikt	Lettklinker Varmekapasitet 13,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,30 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Big (Vindu(er) på Wall NE)
Antall vinduer	6
Høyde vindu(er)	1,50 m
Bredde vindu(er)	1,43 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Small (Vindu(er) på Wall NE)
Antall vinduer	2
Høyde vindu(er)	1,05 m
Bredde vindu(er)	1,40 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
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Sone: Concept building

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Long (Vindu(er) på Wall NE)
Antall vinduer	1
Høyde vindu(er)	2,50 m
Bredde vindu(er)	0,50 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no1 (ytterdør)
Areal inkl. karm/ramme	2,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no2 (ytterdør)
Areal inkl. karm/ramme	2,5 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Simuleringsnavn: Årssimulering
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Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no3 (ytterdør)
Areal inkl. karm/ramme	2,1 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	Wall NW SEA (fasade)
Totalt areal	250,0 m²
Retning (0=Nord, 180=Sør)	315°
Innv. akkumulerende sjikt	Egendefinert Varmekapasitet 0,8 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,70 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Double no1 (ytterdør)
Areal inkl. karm/ramme	6,5 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no4 (ytterdør)
Areal inkl. karm/ramme	3,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Simuleringsnavn: Årssimulering
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Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata ytterdør	
Beskrivelse	Verdi
Navn:	Door no4 (ytterdør)
Areal inkl. karm/ramme	3,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata fasade/yttervegg	
Beskrivelse	Verdi
Navn:	Wall SE (fasade)
Totalt areal	310,5 m²
Retning (0=Nord, 180=Sør)	135°
Innv. akkumulerende sjikt	Lettklinker Varmekapasitet 13,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,29 W/m²K

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Big (Vindu(er) på Wall SE)
Antall vinduer	6
Høyde vindu(er)	1,50 m
Bredde vindu(er)	1,43 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
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Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
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Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no3 (ytterdør)
Areal inkl. karm/ramme	2,1 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Double no2 (ytterdør)
Areal inkl. karm/ramme	4,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Double no2 (ytterdør)
Areal inkl. karm/ramme	4,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	Wall SW (fasade)
Totalt areal	188,7 m²
Retning (0=Nord, 180=Sør)	225°
Innv. akkumulerende sjikt	Egendefinert Varmekapasitet 0,8 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,70 W/m²K

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Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no5 (ytterdør)
Areal inkl. karm/ramme	3,6 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no5 (ytterdør)
Areal inkl. karm/ramme	3,6 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Simuleringsnavn: Årssimulering
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Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata CAV	
Beskrivelse	Verdi
Navn:	Ventilation (CAV ventilasjon)
Ventilasjonstype	Balansert ventilasjon
Driftstid	12:00 timer drift pr døgn
Luftmengde	I driftstiden: tilluft = 8.1 m^3/hm^2, avtrekk = 8.1 m^3/hm^2 Utenfor driftstiden: tilluft = 2.0 m^3/hm^2, avtrekk = 2.0 m^3/hm^2 Helg/feridag: tilluft = 3.0 m^3/hm^2, avtrekk = 3.0 m^3/hm^2
Tilluftstemperatur	Normal: 19.0 °C Fra Mai til August: 19.0 °C
Varmebatteri	Ja Maks. kapasitet: 30 W/m^2
Vannbåren distribusjon til varmebatteri	Delta-T: 30.0 °C SPP: 0.5 kW/(l/s)
Kjølebatteri	
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.6 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.82
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	1.50 $kW/m^3/s$
Redusert luftmengde ved lav utemperatur	Utetemperatur lavere enn: -10.0°C Luftmengde: 5.00 m^3/hm^2

Inndata gulv mot friluft/kryprom/grunn	
Beskrivelse	Verdi
Navn:	Basement (gulv)
Oppvarmet gulvareal	497,3 m^2
Gulvtype	Gulv på grunn
Utvendig omkrets	96,80 m
Tykkelse grunnmur	0,30 m
Grunnforhold	Egendefinert Varmekapasitet: 556 Wh/m^3K Varmeledningsevne: 2,00 W/mK
Ekstra kantisolering	Nei
Innv. akk. sjikt gulv	Egendefinert Varmekapasitet 63,0 Wh/m^2K
Gulvkonstruksjon	Egendefinert Uverdi: 0,18 W/m^2K

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Sone: Concept building

Inndata skillekonstruksjon

Beskrivelse	Verdi
Navn:	1st floor (skillekonstruksjon)
Totalt areal	491,9 m²
Konstruksjonstype	Gulv
Innv. akkumulerende sjikt	Meget tung konstruksjon (betong > 100mm) Varmekapasitet 63,0 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Inndata skillekonstruksjon

Beskrivelse	Verdi
Navn:	2nd floor (skillekonstruksjon)
Totalt areal	304,1 m²
Konstruksjonstype	Gulv
Innv. akkumulerende sjikt	Meget tung konstruksjon (betong > 100mm) Varmekapasitet 63,0 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Inndata skillekonstruksjon

Beskrivelse	Verdi
Navn:	3rd floor (skillekonstruksjon)
Totalt areal	223,6 m²
Konstruksjonstype	Gulv
Innv. akkumulerende sjikt	Meget tung konstruksjon (betong > 100mm) Varmekapasitet 63,0 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Simuleringsnavn: Årssimulering
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Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata yttertak

Beskrivelse	Verdi
Navn:	Roof NW (yttertak)
Totalt areal	324,0 m²
Retning (0=Nord, 180=Sør)	315°
Takvinkel	32,2°
Innv. akkumulerende sjikt	Lett himling Varmekapasitet 3,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,39 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Roof window (Vindu(er) på Roof NW)
Antall vinduer	2
Høyde vindu(er)	1,98 m
Bredde vindu(er)	6,62 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata yttertak

Beskrivelse	Verdi
Navn:	Roof SE (yttertak)
Totalt areal	201,0 m²
Retning (0=Nord, 180=Sør)	135°
Takvinkel	32,2°
Innv. akkumulerende sjikt	Lett himling Varmekapasitet 3,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,26 W/m²K

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Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Roof window (Vindu(er) på Roof SE)
Antall vinduer	2
Høyde vindu(er)	1,98 m
Bredde vindu(er)	6,62 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata belysning

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 3,7 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,4 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 3,7 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

Inndata teknisk utstyr (internlast)

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, teknisk utstyr)
Effekt/Varmetilskudd teknisk utstyr	I driftstiden; Effekt: 5,4 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,9 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 5,4 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

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Inndata oppvarming av tappevann

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, tappevann)
Tappevann	Driftsdag; Midlere effekt: 1,9 W/m²; Varmetilskudd: 0 %; Vanndamp: 0,0 g/m² Helg/feriedag: Midlere effekt: 1,9 W/m²; Varmetilskudd: 0 %; ; Vanndamp: 0,0 g/m²

Inndata varmetilskudd personer (internlast)

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 5,0 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 5,0 W/m² Antall arbeidstimer: 12:00

Inndata oppvarming

Beskrivelse	Verdi
Navn:	Warming (oppvarming)
Settpunkttemperatur i driftstid	21,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	50 W/m²
Konvektiv andel oppvarming	0,50
Driftstid	12:00 timer drift pr døgn
Annen drifsstrategi i sommermåneder	Fra Mai til September
Settpunkttemperatur i driftstiden (sommer)	19,0 °C
Settpunttemperatur uten driftstiden (sommer)	16,0 °C
Driftstid sommermåneder	12:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Nei

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Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 13:44 28/4-2021
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Firma: Undervisningslisens
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Energibudsjett		
Energipost	Energibehov	Spesifikt energibehov
1a Romoppvarming	66835 kWh	44,1 kWh/m²
1b Ventilasjonsvarme (varmebatterier)	23780 kWh	15,7 kWh/m²
2 Varmtvann (tappevann)	25509 kWh	16,8 kWh/m²
3a Vifter	28100 kWh	18,5 kWh/m²
3b Pumper	640 kWh	0,4 kWh/m²
4 Belysning	27248 kWh	18,0 kWh/m²
5 Teknisk utstyr	41925 kWh	27,6 kWh/m²
6a Romkjøling	0 kWh	0,0 kWh/m²
6b Ventilasjonskjøling (kjølebatterier)	2073 kWh	1,4 kWh/m²
Totalt netto energibehov, sum 1-6	216111 kWh	142,5 kWh/m²

Levert energi til bygningen (beregnet)		
Energivare	Levert energi	Spesifikk levert energi
1a Direkte el.	235340 kWh	155,2 kWh/m²
1b El. til varmepumpesystem	0 kWh	0,0 kWh/m²
1c El. til solfangersystem	0 kWh	0,0 kWh/m²
2 Olje	0 kWh	0,0 kWh/m²
3 Gass	0 kWh	0,0 kWh/m²
4 Fjernvarme	0 kWh	0,0 kWh/m²
5 Biobrensel	0 kWh	0,0 kWh/m²
6. Annen energikilde	0 kWh	0,0 kWh/m²
7. Solstrøm til egenbruk	-0 kWh	-0,0 kWh/m²
Totalt levert energi, sum 1-7	235340 kWh	155,2 kWh/m²
Solstrøm til eksport	-0 kWh	-0,0 kWh/m²
Netto levert energi	235340 kWh	155,2 kWh/m²

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Dekning av energibudsjett fordelt på energikilder

Energikilder	Romoppv.	Varmebatterier	Varmtvann	Kjølebatterier	Romkjøling	El. spesifikt
El.	44,1 kWh/m²	15,7 kWh/m²	16,8 kWh/m²	1,4 kWh/m²	0,0 kWh/m²	64,6 kWh/m²
Olje	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Gass	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Fjernvarme	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Biobrensel	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Varmepumpe	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sol	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Annen	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²	0,0 kWh/m²
Sum	44,1 kWh/m²	15,7 kWh/m²	16,8 kWh/m²	1,4 kWh/m²	0,0 kWh/m²	64,6 kWh/m²

Årlige utslipp av CO2

Energivare	Utslipp	Spesifikt utslipp
1a Direkte el.	30594 kg	20,2 kg/m²
1b El. til varmepumpesystem	0 kg	0,0 kg/m²
1c El. til solfangersystem	0 kg	0,0 kg/m²
2 Olje	0 kg	0,0 kg/m²
3 Gass	0 kg	0,0 kg/m²
4 Fjernvarme	0 kg	0,0 kg/m²
5 Biobrensel	0 kg	0,0 kg/m²
6. Annen energikilde	0 kg	0,0 kg/m²
7. Solstrøm til egenbruk	-0 kg	-0,0 kg/m²
Totalt utslipp, sum 1-7	30594 kg	20,2 kg/m²
Solstrøm til eksport	-0 kg	-0,0 kg/m²
Netto CO2-utslipp	30594 kg	20,2 kg/m²

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Resultater årssimulering

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Sone: Concept building

Kostnad kjøpt energi

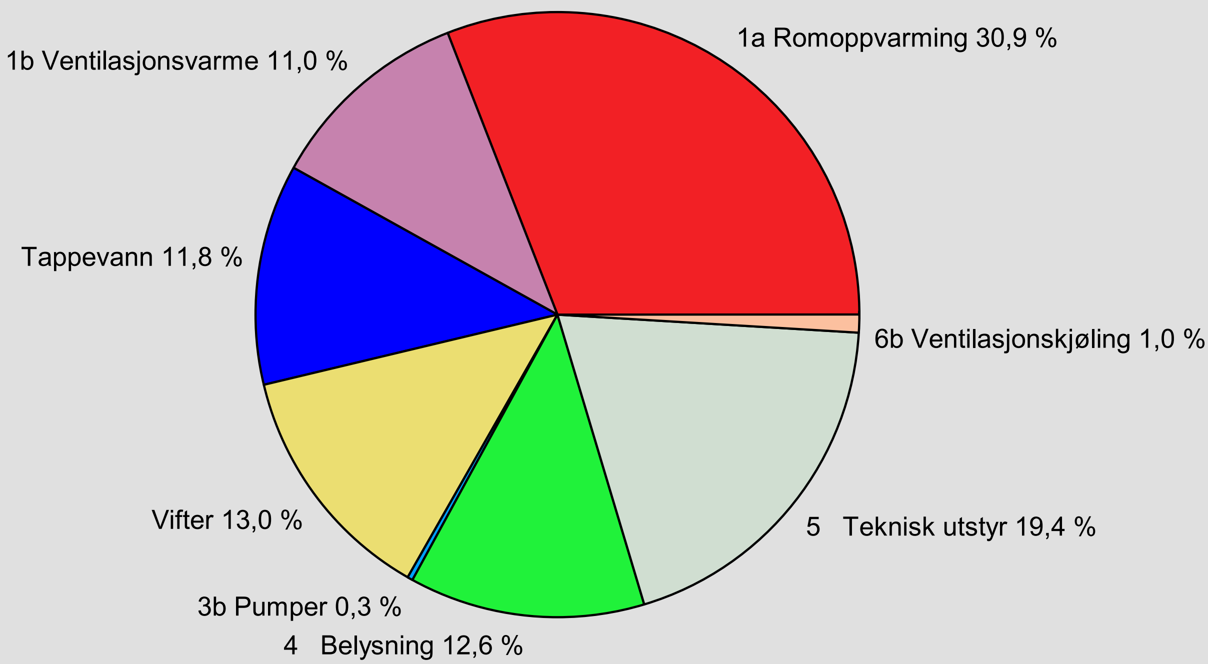
Energivare	Energikostnad	Spesifikk energikostnad
1a Direkte el.	188272 kr	124,1 kr/m²
1b El. til varmepumpesystem	0 kr	0,0 kr/m²
1c El. til solfangersystem	0 kr	0,0 kr/m²
2 Olje	0 kr	0,0 kr/m²
3 Gass	0 kr	0,0 kr/m²
4 Fjernvarme	0 kr	0,0 kr/m²
5 Biobrensel	0 kr	0,0 kr/m²
6. Annen energikilde	0 kr	0,0 kr/m²
7. Solstrøm til egenbruk	-0 kr	-0,0 kr/m²
Årlige energikostnader, sum 1-7	188272 kr	124,1 kr/m²
Solstrøm til eksport	0 kr	0,0 kr/m²
Netto energikostnad	188272 kr	124,1 kr/m²

SIMIEN

Resultater årssimulering

Simuleringsnavn: Årssimulering
Tid/dato simulering: 13:44 28/4-2021
Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Årlig energibudsjett



1a Romoppvarming	66835 kWh
1b Ventilasjonsvarme (varmebatterier)	23780 kWh
2 Varmtvann (tappevann)	25509 kWh
3a Vifter	28100 kWh
3b Pumper	640 kWh
4 Belysning	27248 kWh
5 Teknisk utstyr	41925 kWh
6a Romkjøling	0 kWh
6b Ventilasjonskjøling (kjølebatterier)	2073 kWh
Totalt netto energibehov, sum 1-6	216111 kWh

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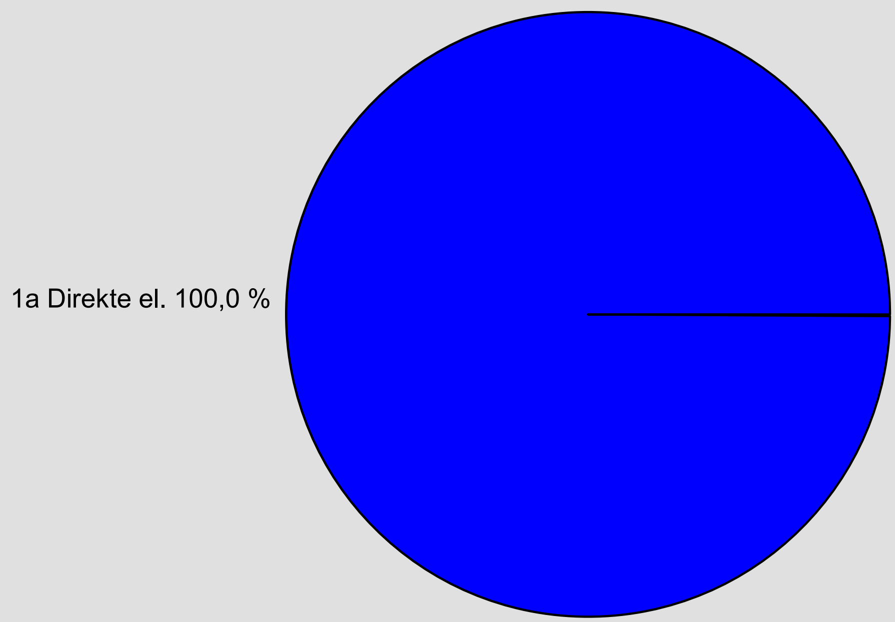
Levert energi til bygningen (beregnet)



1a Direkte el.	235340 kWh
1b El. til varmepumpesystem	0 kWh
1c El. til solfangersystem	0 kWh
2 Olje	0 kWh
3 Gass	0 kWh
4 Fjernvarme	0 kWh
5 Biobrensel	0 kWh
6. Annen energikilde	0 kWh
Totalt levert energi, sum 1-7	235340 kWh

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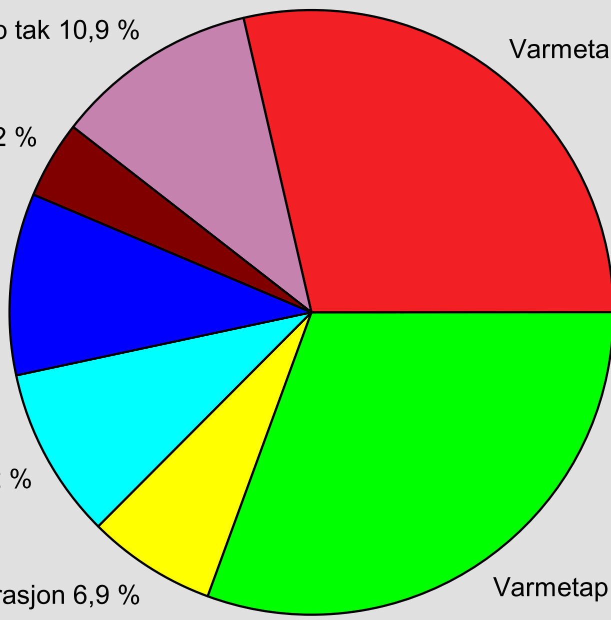
Sone: Concept building

Varmetapsbudsjett (varmetapstall)



Varmetapstall yttervegger	0,28 W/m²K
Varmetapstall tak	0,11 W/m²K
Varmetapstall gulv på grunn/mot det fri	0,04 W/m²K
Varmetapstall glass/vinduer/dører	0,10 W/m²K
Varmetapstall kuldebroer	0,09 W/m²K
Varmetapstall infiltrasjon	0,07 W/m²K
Varmetapstall ventilasjon	0,30 W/m²K
Totalt varmetapstall	0,98 W/m²K

SIMIEN

Resultater årssimulering

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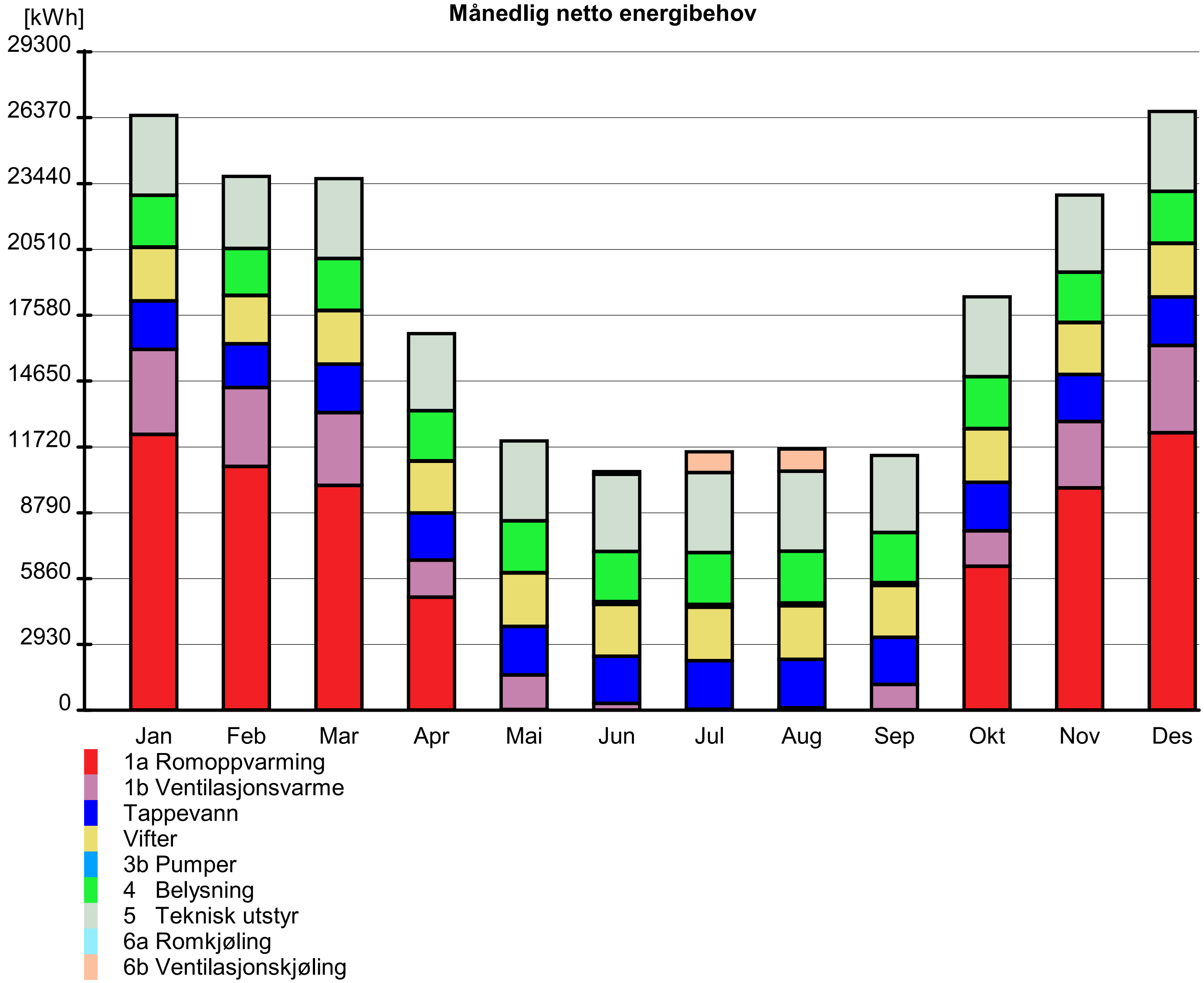
Månedlig netto energibehov



SIMIEN

Resultater årssimulering

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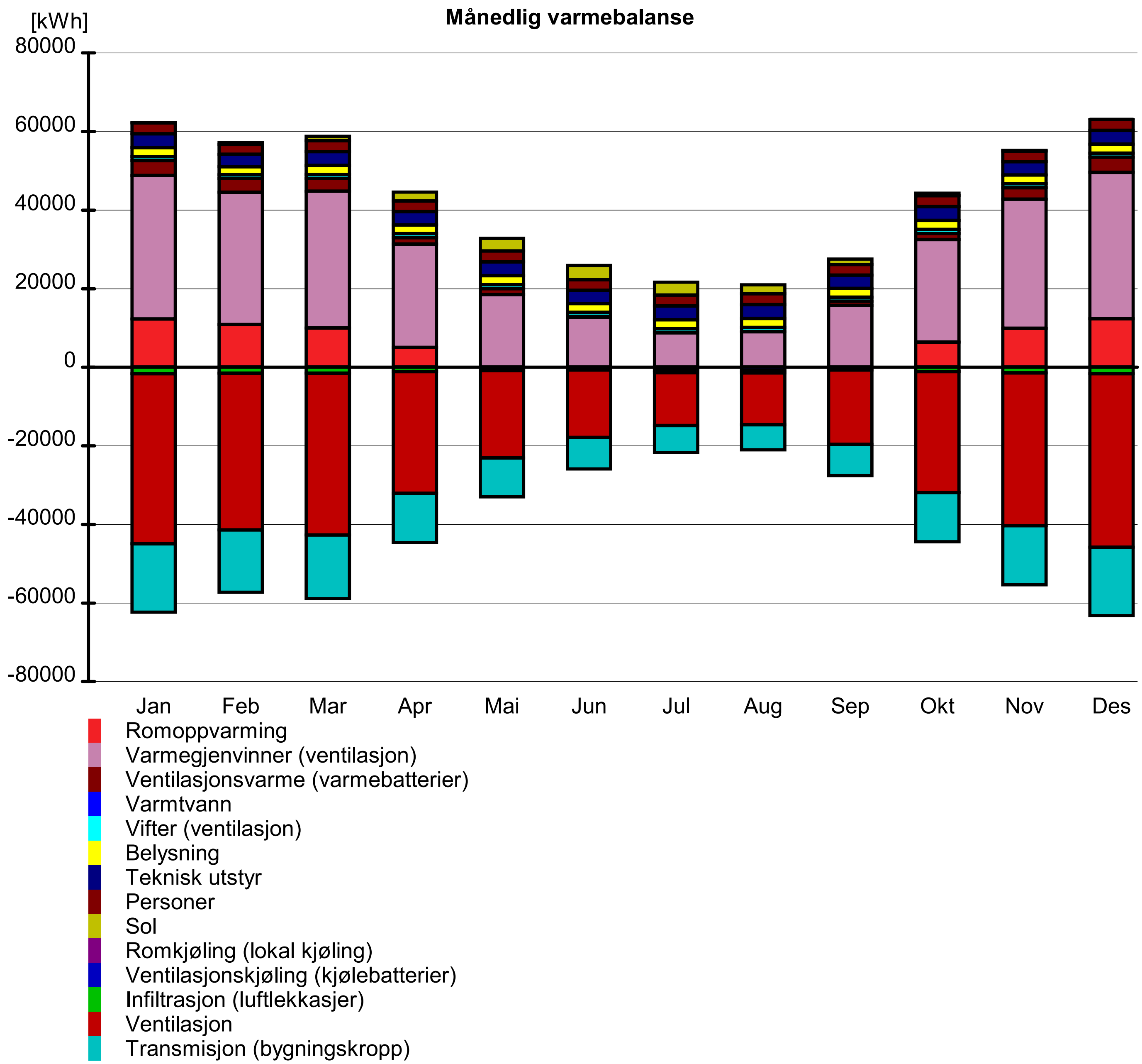

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Månedlige temperaturdata (lufttemperatur)

Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-2,8 °C	5,5 °C	-14,7 °C	20,0 °C	21,0 °C	19,0 °C
Februar	-3,0 °C	5,9 °C	-14,1 °C	20,0 °C	21,0 °C	19,0 °C
Mars	-1,0 °C	6,1 °C	-10,1 °C	20,0 °C	21,0 °C	19,0 °C
April	3,7 °C	12,5 °C	-4,8 °C	20,1 °C	21,3 °C	19,0 °C
Mai	8,1 °C	18,4 °C	-0,2 °C	19,8 °C	21,9 °C	16,9 °C
Juni	11,5 °C	20,8 °C	4,1 °C	21,0 °C	23,8 °C	18,1 °C
Juli	14,2 °C	24,0 °C	6,0 °C	21,6 °C	24,2 °C	19,2 °C
August	14,1 °C	23,8 °C	4,8 °C	21,2 °C	24,2 °C	18,6 °C
September	9,6 °C	18,7 °C	2,3 °C	19,8 °C	22,5 °C	17,1 °C
Oktober	4,4 °C	12,1 °C	-3,5 °C	20,1 °C	21,0 °C	17,3 °C
November	-0,2 °C	8,6 °C	-9,3 °C	20,0 °C	21,0 °C	19,0 °C
Desember	-2,8 °C	6,6 °C	-12,4 °C	20,0 °C	21,0 °C	19,0 °C

Månedlige temperaturdata (operativ temperatur)

Måned	Midlere ute	Maks. ute	Min. ute	Midlere sone	Maks. sone	Min. sone
Januar	-2,8 °C	5,5 °C	-14,7 °C	19,8 °C	21,0 °C	19,0 °C
Februar	-3,0 °C	5,9 °C	-14,1 °C	19,8 °C	20,9 °C	19,0 °C
Mars	-1,0 °C	6,1 °C	-10,1 °C	19,9 °C	20,9 °C	19,0 °C
April	3,7 °C	12,5 °C	-4,8 °C	20,0 °C	21,2 °C	19,0 °C
Mai	8,1 °C	18,4 °C	-0,2 °C	19,7 °C	21,9 °C	16,9 °C
Juni	11,5 °C	20,8 °C	4,1 °C	21,1 °C	23,6 °C	18,2 °C
Juli	14,2 °C	24,0 °C	6,0 °C	21,7 °C	23,9 °C	19,4 °C
August	14,1 °C	23,8 °C	4,8 °C	21,4 °C	24,0 °C	18,7 °C
September	9,6 °C	18,7 °C	2,3 °C	19,8 °C	22,3 °C	17,2 °C
Oktober	4,4 °C	12,1 °C	-3,5 °C	20,0 °C	21,0 °C	17,4 °C
November	-0,2 °C	8,6 °C	-9,3 °C	19,9 °C	20,9 °C	19,0 °C
Desember	-2,8 °C	6,6 °C	-12,4 °C	19,8 °C	20,9 °C	19,0 °C

Simuleringsnavn: Årssimulering
Tid/dato simulering: 13:44 28/4-2021
Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
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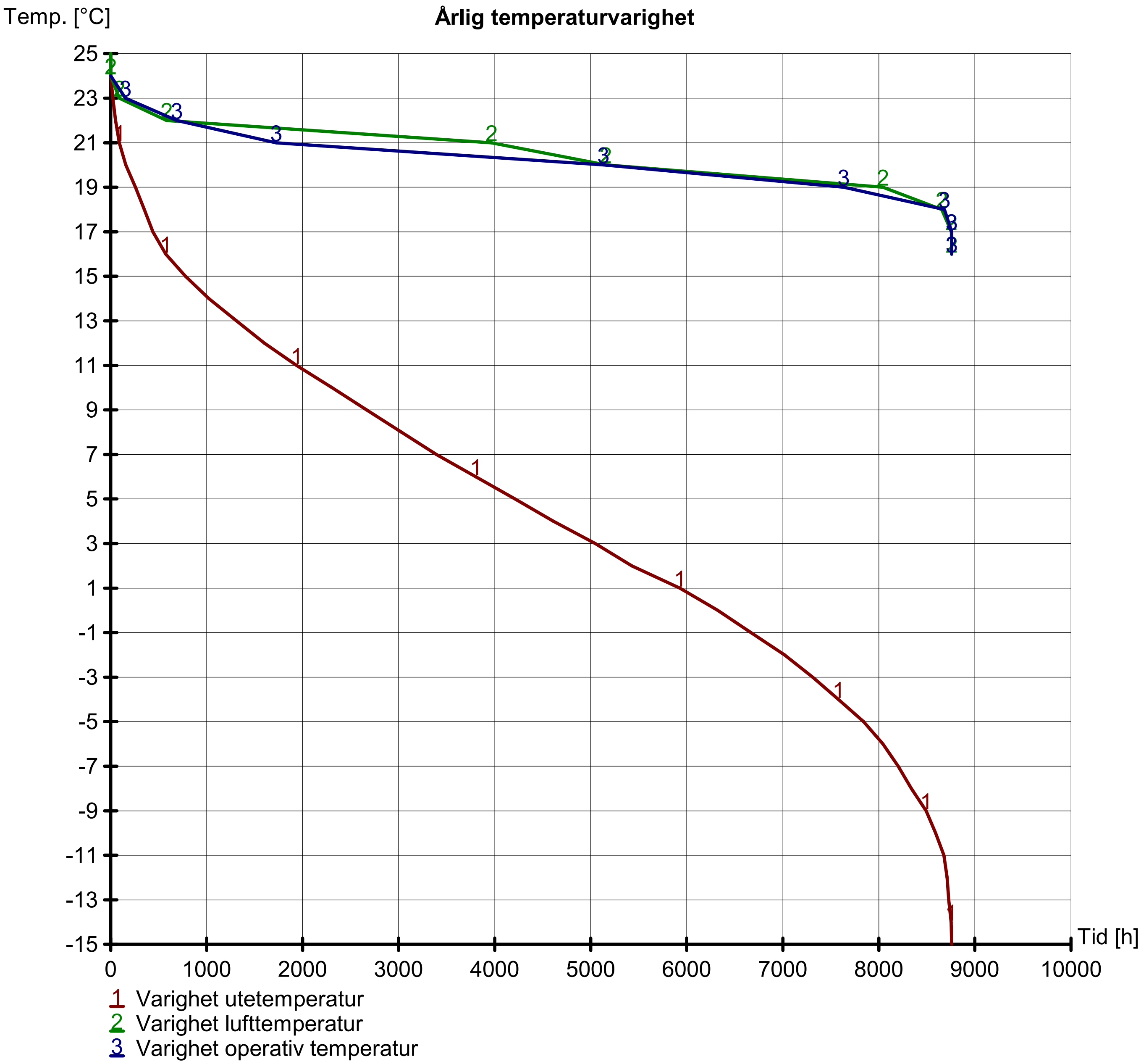
Sone: Concept building



SIMIEN

Resultater årssimulering

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Tid/dato simulering: 13:44 28/4-2021
Programversjon: 6.015
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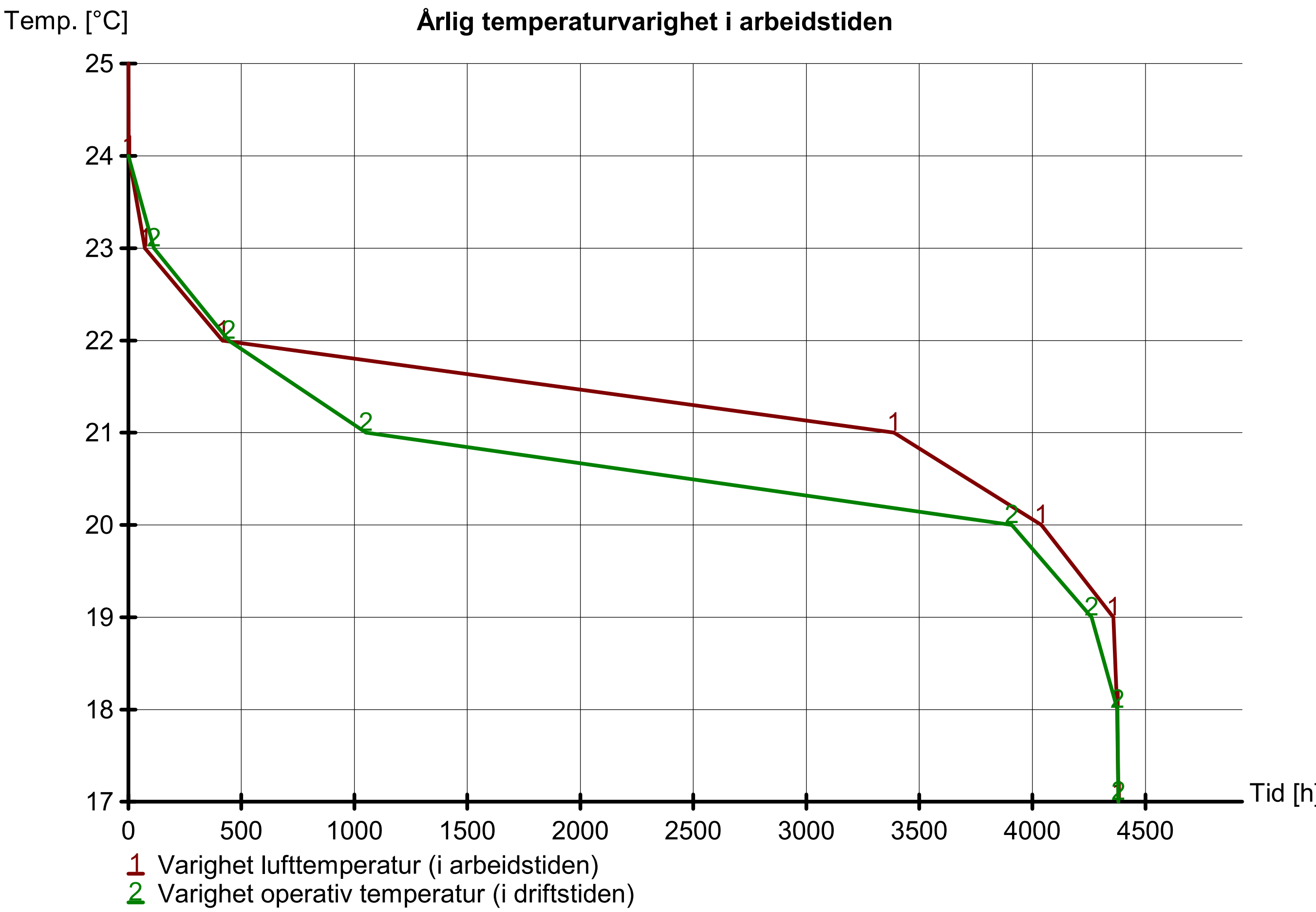

Årlig varighet operativ temperatur i arbeidstiden	
Beskrivelse	Operativ temperatur
Antall timer over 26°C	0

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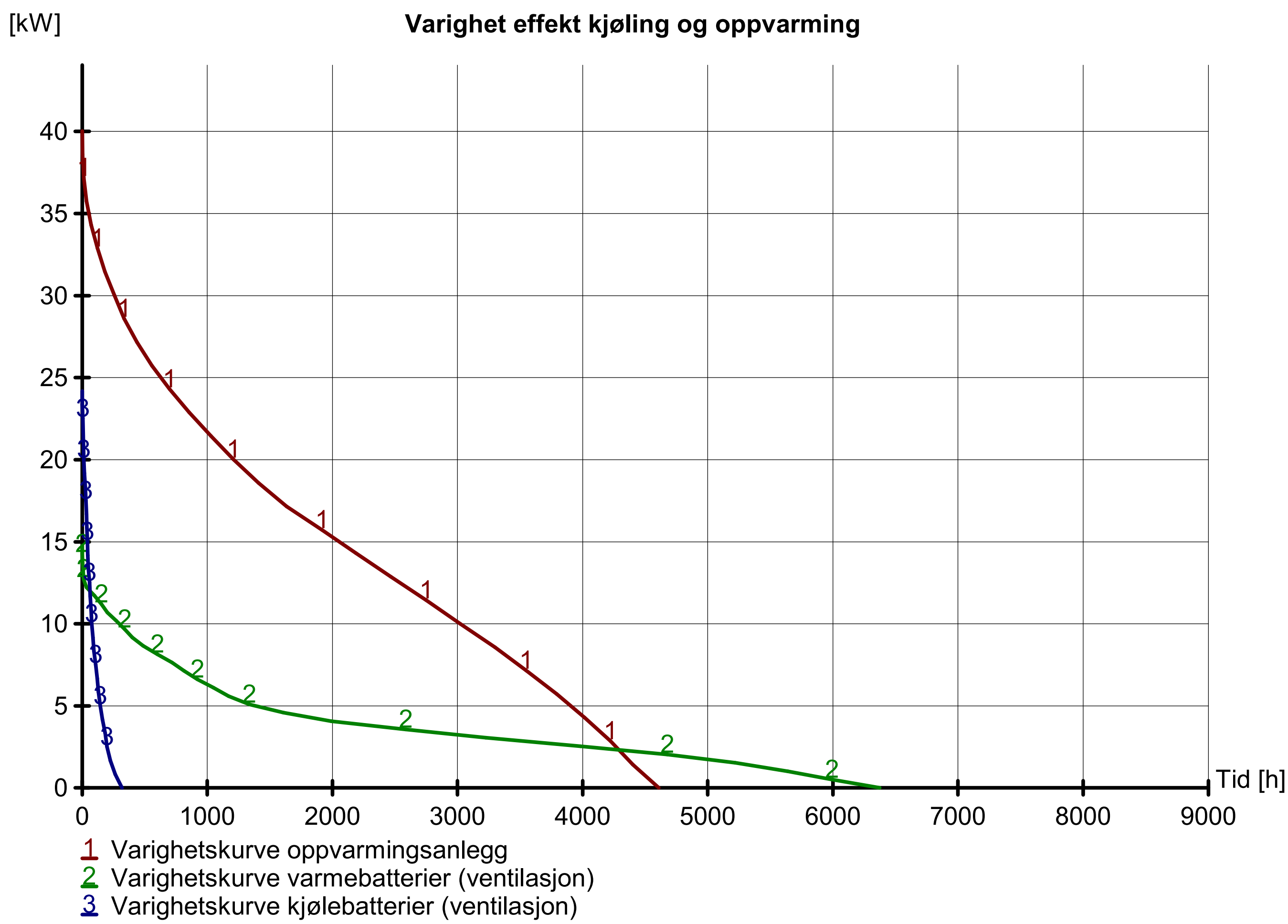

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Dekningsgrad effekt/energi oppvarming	
Effekt (dekning)	Dekningsgrad energibruk
49 kW (90 %)	100 %
43 kW (80 %)	100 %
38 kW (70 %)	98 %
32 kW (60 %)	96 %
27 kW (50 %)	91 %
22 kW (40 %)	83 %
16 kW (30 %)	71 %
11 kW (20 %)	54 %
5 kW (10 %)	31 %
Nødvendig effekt til oppvarming av tappevann er ikke inkludert	-

Dokumentasjon av sentrale inndata (1)		
Beskrivelse	Verdi	Dokumentasjon
Areal yttervegger [m²]:	869	
Areal tak [m²]:	473	
Areal gulv [m²]:	497	
Areal vinduer og ytterdører [m²]:	120	
Oppvarmet bruksareal (BRA) [m²]:	1517	
Oppvarmet luftvolum [m³]:	5547	
U-verdi yttervegger [W/m²K]	0,49	
U-verdi tak [W/m²K]	0,34	
U-verdi gulv [W/m²K]	0,12	
U-verdi vinduer og ytterdører [W/m²K]	1,20	
Areal vinduer og dører delt på bruksareal [%]	7,9	
Normalisert kuldebroverdi [W/m²K]:	0,09	
Normalisert varmekapasitet [Wh/m²K]	70	
Lekkasjetall (n50) [1/h]:	0,80	
Temperaturvirkningsgr. varmegjenvinner [%]:	82	

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Sone: Concept building

Dokumentasjon av sentrale inndata (2)

Beskrivelse	Verdi	Dokumentasjon
Estimert virkningsgrad gjenvinner justert for frostsikring [%]:	82,0	
Spesifikk vifteeffekt (SFP) [kW/m³/s]:	1,50	
Luftmengde i driftstiden [m³/hm²]	8,09	
Luftmengde utenfor driftstiden [m³/hm²]	2,00	
Systemvirkningsgrad oppvarmingsanlegg:	0,85	
Installert effekt romoppv. og varmebatt. [W/m²]:	80	
Settpunkttemperatur for romoppvarming [°C]	20,0	
Systemeffektfaktor kjøling:	2,50	
Settpunkttemperatur for romkjøling [°C]	0,0	
Installert effekt romkjøling og kjølebatt. [W/m²]:	30	
Spesifikk pumpeeffekt romoppvarming [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt romkjøling [kW/(l/s)]:	0,00	
Spesifikk pumpeeffekt varmebatteri [kW/(l/s)]:	0,50	
Spesifikk pumpeeffekt kjølebatteri [kW/(l/s)]:	0,60	
Driftstid oppvarming (timer)	12,0	

Dokumentasjon av sentrale inndata (3)

Beskrivelse	Verdi	Dokumentasjon
Driftstid kjøling (timer)	0,0	
Driftstid ventilasjon (timer)	12,0	
Driftstid belysning (timer)	12,0	
Driftstid utstyr (timer)	12,0	
Oppholdstid personer (timer)	12,0	
Effektbehov belysning i driftstiden [W/m²]	3,70	
Varmetilskudd belysning i driftstiden [W/m²]	3,70	
Effektbehov utstyr i driftstiden [W/m²]	5,42	
Varmetilskudd utstyr i driftstiden [W/m²]	5,42	
Effektbehov varmtvann på driftsdager [W/m²]	1,92	
Varmetilskudd varmtvann i driftstiden [W/m²]	0,00	
Varmetilskudd personer i oppholdstiden [W/m²]	5,00	
Total solfaktor for vindu og solskjerming:	0,38	
Gjennomsnittlig karmfaktor vinduer:	0,09	
Solskjermingsfaktor horisont/utspring (N/Ø/S/V):	1,00/1,00/1,00/1,00	

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Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata bygning	
Beskrivelse	Verdi
Bygningskategori	Kulturbygg
Simuleringsansvarlig	Berit, Halldor _Sylvi
Kommentar	Kulturbygg or Konturbygg?

Inndata klima	
Beskrivelse	Verdi
Klimasted	Sogndal
Breddegrad	61° 9'
Lengdegrad	7° 7'
Tidssone	GMT + 1
Årsmiddeltemperatur	4,7 °C
Midlere solstråling horisontal flate	86 W/m²
Midlere vindhastighet	2,9 m/s

Inndata energiforsyning	
Beskrivelse	Verdi
1a Direkte el.	Systemvirkningsgrad romoppv,: 0,80 Systemvirkningsgrad varmtvann: 0,98 Systemvirkningsgrad varmebatterier: 0,88 Kjølefaktor romkjøling: 2,50 Kjølefaktor kjølebatterier: 2,50 Energipris: 0,80 kr/kWh CO2-utslipp: 130 g/kWh Andel romoppvarming: 100,0% Andel oppv, tappevann: 100,0% Andel varmebatteri: 100,0 % Andel kjølebatteri: 100,0 % Andel romkjøling: 100,0 % Andel el, spesifikt: 100,0 %

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Inndata ekspertverdier	
Beskrivelse	Verdi
Konvektiv andel varmetilskudd belysning	0,30
Konvektiv andel varmetilsk. teknisk utstyr	0,50
Konvektiv andel varmetilsikudd personer	0,50
Konvektiv andel varmetilsikudd sol	0,50
Konvektiv varmoverføringskoeff. vegger	2,50
Konvektiv varmoverføringskoeff. himling	2,00
Konvektiv varmoverføringskoeff. gulv	3,00
Bypassfaktor kjølebatteri	0,25
Innv. varmemotstand på vinduruter	0,13
Midlere lufthastighet romluft	0,15
Turbulensintensitet romluft	25,00
Avstand fra vindu	0,60
Termisk konduktivitet akk. sjikt [W/m²K]:	20,00

Inndata rom/sone	
Beskrivelse	Verdi
Oppvarmet gulvareal	1516,8 m²
Oppvarmet luftvolum	5547,2 m³
Normalisert kuldebroverdi	0,09 W/(m²K)
Varmekapasitet møbler/interiør	2,0 Wh/m² (Lett møblert rom)
Lekkasjetall (luftskifte v. 50pa)	0,80 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	31
Driftsdager i Februar	28
Driftsdager i Mars	31
Driftsdager i April	30
Driftsdager i Mai	31
Driftsdager i Juni	30
Driftsdager i Juli	31
Driftsdager i August	31
Driftsdager i September	30
Driftsdager i Oktober	31
Driftsdager i November	30
Driftsdager i Desember	31

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Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	Wall NE (fasade)
Totalt areal	187,9 m²
Retning (0=Nord, 180=Sør)	45°
Innv. akkumulerende sjikt	Lettklinker Varmekapasitet 13,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,30 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Big (Vindu(er) på Wall NE)
Antall vinduer	6
Høyde vindu(er)	1,50 m
Bredde vindu(er)	1,43 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Small (Vindu(er) på Wall NE)
Antall vinduer	2
Høyde vindu(er)	1,05 m
Bredde vindu(er)	1,40 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

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Inndata vinduselement

Beskrivelse	Verdi
Navn:	Long (Vindu(er) på Wall NE)
Antall vinduer	1
Høyde vindu(er)	2,50 m
Bredde vindu(er)	0,50 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no1 (ytterdør)
Areal inkl. karm/ramme	2,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no2 (ytterdør)
Areal inkl. karm/ramme	2,5 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

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Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no3 (ytterdør)
Areal inkl. karm/ramme	2,1 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	Wall NW SEA (fasade)
Totalt areal	250,0 m²
Retning (0=Nord, 180=Sør)	315°
Innv. akkumulerende sjikt	Egendefinert Varmekapasitet 0,8 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,70 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Double no1 (ytterdør)
Areal inkl. karm/ramme	6,5 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no4 (ytterdør)
Areal inkl. karm/ramme	3,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

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Inndata ytterdør	
Beskrivelse	Verdi
Navn:	Door no4 (ytterdør)
Areal inkl. karm/ramme	3,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata fasade/yttervegg	
Beskrivelse	Verdi
Navn:	Wall SE (fasade)
Totalt areal	310,5 m²
Retning (0=Nord, 180=Sør)	135°
Innv. akkumulerende sjikt	Lettklinker Varmekapasitet 13,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,29 W/m²K

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Big (Vindu(er) på Wall SE)
Antall vinduer	6
Høyde vindu(er)	1,50 m
Bredde vindu(er)	1,43 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Simuleringsnavn: Årssimulering
Tid/dato simulering: 13:44 28/4-2021
Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no3 (ytterdør)
Areal inkl. karm/ramme	2,1 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Double no2 (ytterdør)
Areal inkl. karm/ramme	4,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Double no2 (ytterdør)
Areal inkl. karm/ramme	4,3 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata fasade/yttervegg

Beskrivelse	Verdi
Navn:	Wall SW (fasade)
Totalt areal	188,7 m²
Retning (0=Nord, 180=Sør)	225°
Innv. akkumulerende sjikt	Egendefinert Varmekapasitet 0,8 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,70 W/m²K

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Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no5 (ytterdør)
Areal inkl. karm/ramme	3,6 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

Inndata ytterdør

Beskrivelse	Verdi
Navn:	Door no5 (ytterdør)
Areal inkl. karm/ramme	3,6 m²
Dørtype	Egendefinert Uverdi: 1,20 W/m²K

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Inndata CAV	
Beskrivelse	Verdi
Navn:	Ventilation (CAV ventilasjon)
Ventilasjonstype	Balansert ventilasjon
Driftstid	12:00 timer drift pr døgn
Luftmengde	I driftstiden: tilluft = 8.1 m^3/hm^2, avtrekk = 8.1 m^3/hm^2 Utenfor driftstiden: tilluft = 2.0 m^3/hm^2, avtrekk = 2.0 m^3/hm^2 Helg/feridag: tilluft = 3.0 m^3/hm^2, avtrekk = 3.0 m^3/hm^2
Tilluftstemperatur	Normal: 19.0 °C Fra Mai til August: 19.0 °C
Varmebatteri	Ja Maks. kapasitet: 30 W/m^2
Vannbåren distribusjon til varmebatteri	Delta-T: 30.0 °C SPP: 0.5 kW/(l/s)
Kjølebatteri	
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.6 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.82
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	1.50 $kW/m^3/s$
Redusert luftmengde ved lav utemperatur	Utetemperatur lavere enn: -10.0°C Luftmengde: 5.00 m^3/hm^2

Inndata gulv mot friluft/kryprom/grunn	
Beskrivelse	Verdi
Navn:	Basement (gulv)
Oppvarmet gulvareal	497,3 m^2
Gulvtype	Gulv på grunn
Utvendig omkrets	96,80 m
Tykkelse grunnmur	0,30 m
Grunnforhold	Egendefinert Varmekapasitet: 556 Wh/m^3K Varmeledningsevne: 2,00 W/mK
Ekstra kantisolering	Nei
Innv. akk. sjikt gulv	Egendefinert Varmekapasitet 63,0 Wh/m^2K
Gulvkonstruksjon	Egendefinert Uverdi: 0,18 W/m^2K

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Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	1st floor (skillekonstruksjon)
Totalt areal	491,9 m²
Konstruksjonstype	Gulv
Innv. akkumulerende sjikt	Meget tung konstruksjon (betong > 100mm) Varmekapasitet 63,0 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	2nd floor (skillekonstruksjon)
Totalt areal	304,1 m²
Konstruksjonstype	Gulv
Innv. akkumulerende sjikt	Meget tung konstruksjon (betong > 100mm) Varmekapasitet 63,0 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	3rd floor (skillekonstruksjon)
Totalt areal	223,6 m²
Konstruksjonstype	Gulv
Innv. akkumulerende sjikt	Meget tung konstruksjon (betong > 100mm) Varmekapasitet 63,0 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Simuleringsnavn: Årssimulering
Tid/dato simulering: 13:44 28/4-2021
Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
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Sone: Concept building

Inndata yttertak

Beskrivelse	Verdi
Navn:	Roof NW (yttertak)
Totalt areal	324,0 m²
Retning (0=Nord, 180=Sør)	315°
Takvinkel	32,2°
Innv. akkumulerende sjikt	Lett himling Varmekapasitet 3,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,39 W/m²K

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Roof window (Vindu(er) på Roof NW)
Antall vinduer	2
Høyde vindu(er)	1,98 m
Bredde vindu(er)	6,62 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata yttertak

Beskrivelse	Verdi
Navn:	Roof SE (yttertak)
Totalt areal	201,0 m²
Retning (0=Nord, 180=Sør)	135°
Takvinkel	32,2°
Innv. akkumulerende sjikt	Lett himling Varmekapasitet 3,0 Wh/m²K
Konstruksjon	Egendefinert Uverdi: 0,26 W/m²K

Simuleringsnavn: Årssimulering
Tid/dato simulering: 13:44 28/4-2021
Programversjon: 6.015
Simuleringsansvarlig: Berit, Halldor & Sylvi
Firma: Undervisningslisens
Inndatafil: C:\...\Concept-fixed.smi
Prosjekt: UNESCO World heritage center in Aurland
Sone: Concept building

Inndata vinduselement

Beskrivelse	Verdi
Navn:	Roof window (Vindu(er) på Roof SE)
Antall vinduer	2
Høyde vindu(er)	1,98 m
Bredde vindu(er)	6,62 m
Bredde karm/ramme	0,05 m
Total U-verdi (rute+karm/rammekonstr.)	1,20 W/m²K
Variabel (regulerbar) solskjerming	Innvendige persienner 28 mm lameller, 2-lags rute, 1 energiglass Total solfaktor v, maks, skjerming: 0,38 Total solfaktor v, min, skjerming: 0,51

Inndata belysning

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 3,7 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,4 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 3,7 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

Inndata teknisk utstyr (internlast)

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, teknisk utstyr)
Effekt/Varmetilskudd teknisk utstyr	I driftstiden; Effekt: 5,4 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,9 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 5,4 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 12:00

Simuleringsnavn: Årssimulering
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Inndata oppvarming av tappevann

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, tappevann)
Tappevann	Driftsdag; Midlere effekt: 1,9 W/m²; Varmetilskudd: 0 %; Vanndamp: 0,0 g/m² Helg/feriedag: Midlere effekt: 1,9 W/m²; Varmetilskudd: 0 %; ; Vanndamp: 0,0 g/m²

Inndata varmetilskudd personer (internlast)

Beskrivelse	Verdi
Navn:	Internlaster (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 5,0 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 5,0 W/m² Antall arbeidstimer: 12:00

Inndata oppvarming

Beskrivelse	Verdi
Navn:	Warming (oppvarming)
Settpunkttemperatur i driftstid	21,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	50 W/m²
Konvektiv andel oppvarming	0,50
Driftstid	12:00 timer drift pr døgn
Annen drifsstrategi i sommermåneder	Fra Mai til September
Settpunkttemperatur i driftstiden (sommer)	19,0 °C
Settpunttemperatur uten driftstiden (sommer)	16,0 °C
Driftstid sommermåneder	12:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Nei