Versatile environmental test facility

Eirik J. Svortevik
Joakim Axelsen
Ole Kristian Døsvik

Bachelor’s thesis in Energy Technology
Bergen, Norway 2020

Høgskulen på Vestlandet

Versatile environmental test facility

Eirik Svortevik
Ole Kristian Døsvik
Joakim Axelsen

Figure 1, Ilustration from Revit

Department of Mechanical- and Marine Engineering
Western Norway University of Applied Sciences
NO-5063 Bergen, Norway

IMM 2020-M81

Høgskulen på Vestlandet
Fakultet for Ingeniør- og Naturvitskap
Institutt for maskin- og marinfag
Inndalsveien 28
NO-5063 Bergen, Norge

Norsk tittel:	Multifunksjonelt klimahus
Author(s), student number:	Eirik J. Svortevik, 572001 Ole Kristian Døsvik, 571994 Joakim Axelsen, 571990
Study program:	Energy technology
Date:	May 2020
Report number:	IMM 2020-M81
Supervisor at HHVL:	Richard J. Grant, Professor at HVL
Assigned by:	HVL
Contact person:	Richard J. Grant
Antall filer levert digitalt:	1

Preface

This thesis completes a Bachelor of Science degree, written at the Department of Mechanical and Marine Engineering at Western University of Applied Scienes (WNUAS). The thesis completes a degree at the study programme: *Energy Technology.* The assignment was given by Richard J. Grant in cooperation with WNUAS, Ricard J. Grant also operate as internal academic supervisor and leader on the project.

The purpose of this thesis is to design a cooling and heating system to the environmental facility. Reaching temperatures within the interval [-20 $°C$, +50 $°C$], with "off the shelf" technical components.

An invitation was sent to GK regarding professional advice and feedback on the thesis. We highly appreciate our external supervisors Caroline Mjeldheim and Geir Bruun for all the help and support during the thesis.

We want to say thank you to Odd Olav Fosso (F-Tech) and Ole Døsvik (Multiconsult) for all the technical help with the systems.

Thank you to the whole team, including Anne Sofie H. Bjelland, Morten Kristoffersen, Joar Jellestad, Andreas Skogvang, Hans-Christian Norveel and Richard J. Grant. Espacially a huge thanks to Richard J. Grant for all the advices, close collaboration and feecback during the thesis.

Abstract

Western Norway University of applied science wants to build an environmental chamber. In this thesis, the technical installations and system drawing is designed. The main purpose of the building is to provide a facility with a possibility to change the temperature and humidity.

In addition to the environmental chamber, the building will include a locker room, hallway, and control room. The control room permits monitoring the athletes in their training, and the ability to measure desirable parameters.

The building is designed to feature the same characteristics as the environment at Kronstad, where a train station has been an important term because of the old train workstation at Kronstad. Further, a collaboration with building students has been necessary in case of modelling the building, where the result has been a 3D model. Different sites have been discussed with Statsbygg, supervisors, and the building students.

The thesis contains a suggestion about how to cool, heat and change humidity in an environmental chamber to accommodate given requirements from the sport institute. In addition to athelets the environmental chamber can be used to medical research, for instance asthema research, and also product testing. The product testing can include treadmills and other training equipment that the atheletes are using, but can be any product that is required to operate in extreme conditions. It can also allow the interface between devices and humans to be evaluated, such as using/dismatling/assembiling product in extreme conditions. This could include taking something appart at one set of conditions and putting back together at another. Also, pshycological evaluation in extreme conditions may be an interesting use of the environmental chamber. One system is designed to cool, heat and change humiditiy in the chamber by using air instead of components inside the chamber. This leads to a system for cooling, heating and change of humidity, that is more space efficient.

An item list of the estimated expenditure for the technical installations has been provided, to indicate approximately price. The components in the budget/component list consist of “of the shelf” products.

Sammendrag

Høgskulen på Vestlandet ønsker å bygge et multifunksjonelt klimahus. I denne oppgaven er tekniske installasjoner og systemtegninger utformet. Hovedformålet med bygningen er å endre temperatur og fuktighet etter ønske.

I tillegg til et klimarom vil bygningen bestå av garderobe, gang og kontrollrom. Fra kontrollrommet overvåkes aktivitet i klimarommet. Målinger blir også utførtt her.

Bygningen er designet med inspirasjon fra historie og arkitektur på Kronstad, hvor tog har vært en viktig inspirasjon i designprosessen grunnet det gamle togverkstedet på Kronstad. Et tett samarbeid med bygningsstudentene har vært nødvendig for å utforme en 3D-modell av bygningen. Ulike tomter har blitt diskutert med Statsbygg, veiledere og bygningsstudentene før egnet tomt ble valgt.

Oppgaven inneholder et forslag til hvordan man kan kjøle, varme og endre fuktighet i et klimarom for å imøtekomme gitte krav fra Institutt for idrett, kosthald og naturfag. I tillegg til idrettsutøvere kan klimarommet brukes til medisinsk forskning, for eksempel astmaforskning, men også produkttesting. Dette kan være ethvert produkt som skal operere under ekstreme forhold. Klimarommet kan også brukes til å evaluere hvordan samspillet mellom ulike produkter og mennesker fungerer, dette kan for eksempel være å bruke, demontere og/eller montere produkt under ekstreme forhold. Dette kan inkludere å demontere et produkt ved en temperatur og sette det sammen ved andre forhold. Psykologiske aspekter kan også være interssant under ekstreme forhold, dette kan for eksempel forsvaret dra nytte av.

Et felles system er designet for å kjøle, varme og endre fuktighet i klimarommet ved å bruke tilluft istedenfor komponenter inne i klimarommet. Dette fører til at systemet for kjøling, oppvarming og endring av fuktighet gir økt bruksareal i klimarommet.

Det er laget en komponentliste som inkluderer et estimert budsjett for tekniske installasjoner. Ingen av de valgte komponentene er spesialdesignet.

Table of contents

Nomenclature

$\dot{Q}$	=	Heating demand [kW]
L	=	Airflow [m^3/s]
ρ	=	Density [kg/m^3]
ΔH	=	Difference in enthalpy[kJ/kg]
q	=	Waterflow [l/s]
H_2O	=	Water
A	=	Personal load [m^3/h]
B	=	Material load [m^3/h]
COP	=	Power factor
GWP	=	A measurment of the effect that the various greenhouse gases
PPM	=	Parts Per Million CO_2
T.	=	Temperature. Dry (°C)
Twet	=	Temperature. Wet (°C)
Tdew	=	Dewpoint temperature (°C)
X	=	Absolute humidity (kg/kg)
RF	=	Relative humidity (%)
h	=	Enthalpy (Kj/Kg)
ρ	=	Pressure (mbar)
IE	=	Electric boiler
IK	=	Heat pump
JP	=	Pump
JV	=	Fan
KA	=	Motorized control unit for damper
LK	=	cooling battery
LR	=	Frequency converter
LV	=	Heat battery
LX	=	Heat recovery
MF	=	Filter
ML	=	Separator for micro bubbles
MR	=	Drain grate
NT	=	Expansion tank
NU	=	Accumulator
OE	=	Energy meter
RD	=	Differential pressure transducer
RI	=	Thermometer

RP	=	pressure sensor
RQ	=	Manometer
RT	=	Temperature sensor
RY	=	Smoke detector
SB	=	Motorized control valve
SG	=	Backlash valve
SM	=	Manual shut-off valve
SR	=	Regulating dampers
SV	=	Throttle valve
XM	=	Motor
..400	=	In
..500	=	Out

[1]

1. Introduction

1.1 Background

Western Norway University of applied science has decided to apply regarding making an environmental chamber. Althought the original motivation behind this assessment is the desire to create a facility for atheletes to train at the highest level; it was soon realised that such a facility is accseible to many other branches of research and testing. This could encompass medical research for healing and asthema, but also physiological and phsycological assessment. Testing devices on a human scale would also be possible: not just functionalility of the products, but also how humans interact with them. In the environmental chamber, the temperature and humidity will be changed to meet what is desirable. The environmental chamber can also be used for product testing research. These products can be everything from car batteries to equipment the army use.

The significant purpose of this environmental chamber is that athletes can perform exercises in different conditions. Some studies argue that acclimatization in warm-hot weather lower heart rate, lower core temperature and gives a higher sweat rate during training sessions. This study concludes that heat acclimatization is a biological adaptation that reduces physiological strain. To get the best results from the acclimatization for high performing athletes, a study describes four important phases to follow:

1. Start early
2. Mimic the competition
3. Climate and exercise tasks, ensure adequate heat stress and recovery
4. Drink and eat adequately

[2]

The environmental chamber will operate in the specter of temperatures between minus 20 to plus $50°C$. Environments to replicate tropical, hot and cold deserts. For instance, Qatar, where the world cup in football is to take place. The climate in Doha, is reckoned as a desert and through the year the temperature varies from 12,8-41,5 ℃ and it is to assume that 12,8 $°C$ is the coldest temperature at night. Qatar’s humidity varies from 41-71% and it hardly ever rain. [3] In contrast, the climate in Singapore, for example, replicate more a tropical rainforest. Temperatures here are more constant over the year, between $23{,}3°C$ and $31{,}7\ °C$, with humidity as high as 82,8-86,7%. [4] The chamber is taking the temperature down to – $20°C$, and this will be to simulate a cold environment, where for example cross country ski athletes will benefit. A study that looks at physical training in rats that were exposed to a low temperature over a longer period of time, shows that the resting metabolic rate in the cold-exposed groups of rats was higher. The rats which were cold-acclimated could double their heat production without detectable shivering after 4-6 weeks. The study also explained that a relationship between physical fitness and the ability to resist cold has been demonstrated in humans although with somewhat conflicting results. On the other hand, a connection between physical fitness and tolerance to cold climate has never been verified in animals at the time this study was made. Since this study discovered a link between metabolic rate and temperature in small mammals, this may replicate to a human being. [5]

The task of designing such a facility require different types of skill sets. Three areas of study, or disciplines were appointed to complete this assignment, which is: sport science, energy students, and building students. Because of this, close cooperation between all specializations is key. Energy students and building students must be on the same page with every decision that is being made. Regular meetings with especially the building engineers are important. [6]

It exists different environmental chambers today, research can be done to a certain point. Lack of information on the area results in confidentiality from the groups and institutes that have valid information and knowledge. First and foremost, information regarding training facilities designed in Norway. Even though Norway is relatively new to this kind of project and facilities, one attempt has been conducted by Olympiatoppen. It is a possibility that other actors have built a similar facility. With the information accessible, a temporary conclusion is that Olympiatoppen possesses the only training chamber in Norway. [7] Olympic committee (NIF) and Norwegian sports federation, have the highest authority inside sports in Norway. Olympiatoppen is the leading division of the group NIF. They have the responsibility and necessary authority to create facilities that bring out the best performance from an individual. [8] Creating the best athletes, rely on tremendous training facilitis and equipment. To keep up with the rest of the world, a training chamber was designed and constructed, named: *Polarrommet.* [9]

Countries around the world are increasing their production and use of environmental chambers. The big difference between Norway and abroad, originates from rules and regulations. One popular method is to make a separate chamber, like a module that can provide the conditions required. Customers then reach out to the suppliers and place an order for a product that is installed inside existing buildings. Most of these chamber modules can change pressure and oxygen levels as well as temperature and humidity. Altitude chambers are not allowed in Norway, which makes these modules illegal. Even though rules today make it illegal in Norway, it may change shortly. To give a perspective on what this module looks like, *Figure 2* illustrates one example. [10] [11]

Figure 2, Illustrates a module [12]

1.2 Aim

- *To design the climatic systems required for a versatile environmental test chamber on a human scale that will simulate a range of environmental conditions of temperature and humidity*

Reaching this aim will fulfil one aspect of the total project. There are other disciplines which will focus on other aspects; working towars a common goal.

1.3 Objectives

- Design a HVAC system.

- Find a solution for the humidification system

- Cost analysis and component list for technical installations.

1.4 Limitations

Building physics:

This overall conception of the project requires the consideration of many aspects including the building physics. In line with the *Aim*, this is beyond the work and the remit of this thesis, which will focus on the heating and ventilation systems (HVAC)

PLS:

The thesis also excludes the theory and the practical use of the PLS (the automatics) surrounding the HVAC system. PLS encompasses everything from the steering device, computers and all the electronic equipment to make this functional. Programming and installation of this, require expertise in areas that none of the given groups possess.

Individual people:

When it comes to how much fluid which is acstracted from the test subject, is in this study sett to 1,5l/h. The variation in size and the climat itself are factors which are changing the amount of fluid which is abstracted from the human boddy. [13]

1.5 Assumptions

1.5.1 SIMIEN

SIMIEN presents simulation from the three following rooms: hallway, locker room, and control room. When simulating a construction in SIMIEN assumptions most be made. The building that is simulated is given by the building student 06.04.2020. Bachelor project of the building students (HVL, May 2020): *Digitale tvillinger i byggebransjen*

Energy supply:

When simulating energy supply in SIMIEN, there are several different standard options. Under simulations, an assumption about the best value has been made.

Zones:

During the simulations, the building is divided into different zones. The first zone is the control room, and the locker room and hallway are the other. Because the locker room and hallway are regarded as one room, the simulation data will be inaccurate.

Facades, windows, floor, internal walls, and roof:
All data which is used to simulate is taken from the bachelor project *digitale tvillinger i byggebransjen (*06.04.2020)

1.5.2 *Byggteknisk forskrift* (TEK 17)

U-values from TEK 17 are used in calculations. [14]

2. Background information

2.1 Law, Regulation and guidelines

It is a few laws, building regulations, and guidelines that need to be followed. Plan –and building law is the Norwegian law that needs to be followed. This law has the purpose to decide how Norway´s areas should be used and regulated and applies for all activities and businesses linked to real estate [14]. TEK 17 is the regulation that supports the law. To support the regulation, it is guidelines for the regulation. One guideline is NS 3031 and concerns buildings´ energy performance. This guideline was formally pulled back by Standard Norge in 2018, but it will be used until a new guideline is ready. [14] The guideline contains airflow demand, temperature demand, CO_2 level requirement in rooms, and more. In addition to law, regulations and guidelines it exists reccomendations that Direktoratet for Byggekvalitet (DiBK) recomands to use. This is called Byggforskserien and can be used to design everything from swimming halls to freezing room. Byggforskserien fulfil every requirement in the regulation (TEK) and other regulations. [15]

2.1.1 SIMIEN

SIMIEN is a dynamic building simulation tool, which is based on the guideline NS 3031. SIMIEN can supply the user with seven simulation configurations; heating demand calculation, cooling demand calculation, annual building performance simulation, evaluation according to the Norwegian building regulations (TEK), energy labeling calculation, evaluation according to the Norwegian passive house or low energy requirement (NS3700/NS3701) and profitability calculation. [16] SIMIEN also take consideration of the location, which means it will calculate after dimensioning outdoor temperature (DUT) and n50. DUT is used for the winter simulation and n50 is used for the summer simulation. DUT is the lowest average temperature for three days which is measured in the *normal period* that is from 1960-1990. N50 is the temperature exceeded over 50 hours a year, in Bergen this temperature is 24 $°C$ [17]. The *normal period*, which is the period the numbers are taken from changes every 30 years. From 2021 a new period will start, which goes from 1990-2020.

2.1.2 Passive and active measures

One of the first steps after determining the localization, shape, and orientation of the building, is to analyze passive measures that can be done to reduce the building`s energy use. Examples of such measures are U-values, sunblind, daylight, and area efficiency. Active measures have a shorter lifetime than passive measures. Examples of active measures are solar panels, HVAC systems, and energy-saving equipment. [18]

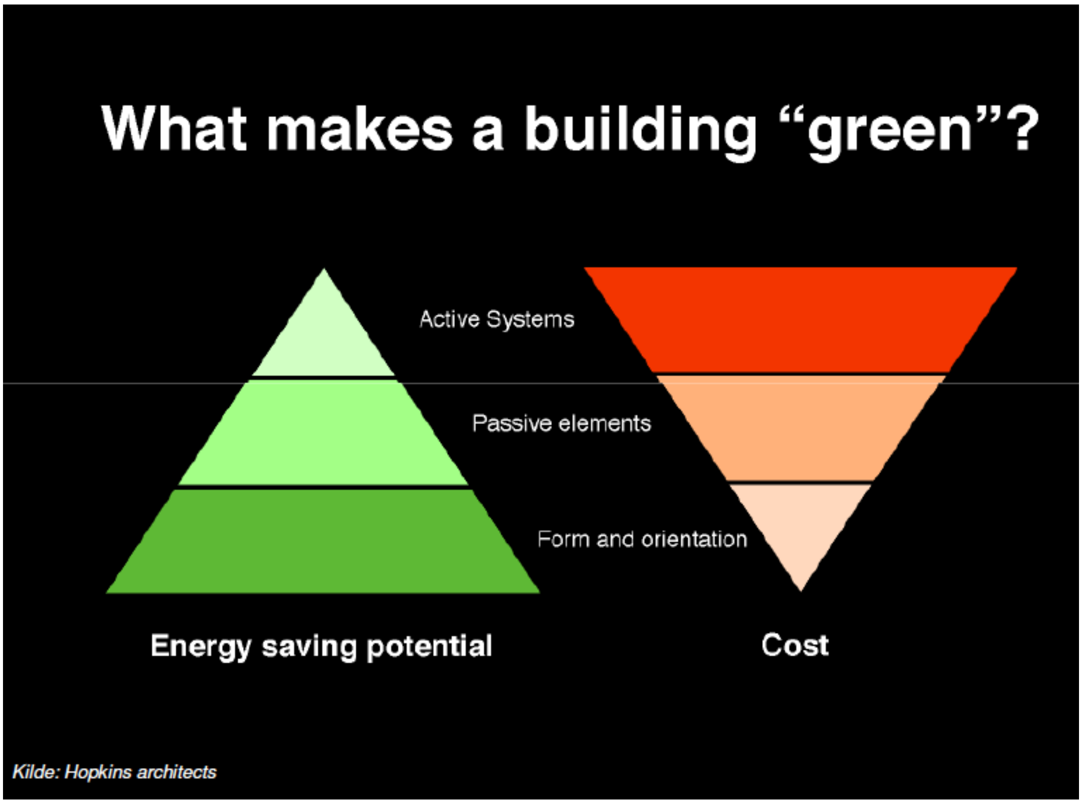


Figure 3, llustrates potential and cost [19]

2.2 HVAC system

2.2.1 H-X diagram

Richard Mollier developed the H-X diagram, which also is called *Mollier diagram*.
Mollier diagram represents a graphical function between different aspects of air, and moist level in the air. With the possibility to calculate and exemplify changes in moist air caused by cooling, heating, humidification, and dehumidification straight from the diagram. Most commonly used in the design and projecting ventilation systems, compressors, refrigerant systems.
The diagram depends on the correlation between six key measurements, which is: [20]

- Temperature. Dry = t. (°C)
- Temperature. Wet. = twet (°C)
- Dewpoint temperature = tdew (°C)
- Absolute humidity = x (kg/kg)
- Relative humidity = RF (%)

- Enthalpy = h (Kj/Kg)
- Pressure. = ρ (mbar)

First an explanation structure-wise on the diagram, and which lines and axes the measurements affect. Not every diagram is similar; it is possible to have small amendments between *Mollier diagrams*. *Figure 4* have the temperature on the y-axis. The y-axis gives dry and wet temperatures, as well as dewpoint. Dewpoint temperature express at which temperature moist occurs. For example, if you have any temperature inside a house below 100%, there will not occur moisture or water on the windows. The curved lines with symbol j indicate relative humidity. Oblique lines from the upside and downwards give enthalpy. A line between the x-axis and lowest humidity line shows the pressure. With a unit of pascal or bar. The last measurement is the x-axis. The x-axis indicates how much H_2O the air possesses, in gram per kilogram.
Figure 4 shows how the mollier diagram can be utilized.

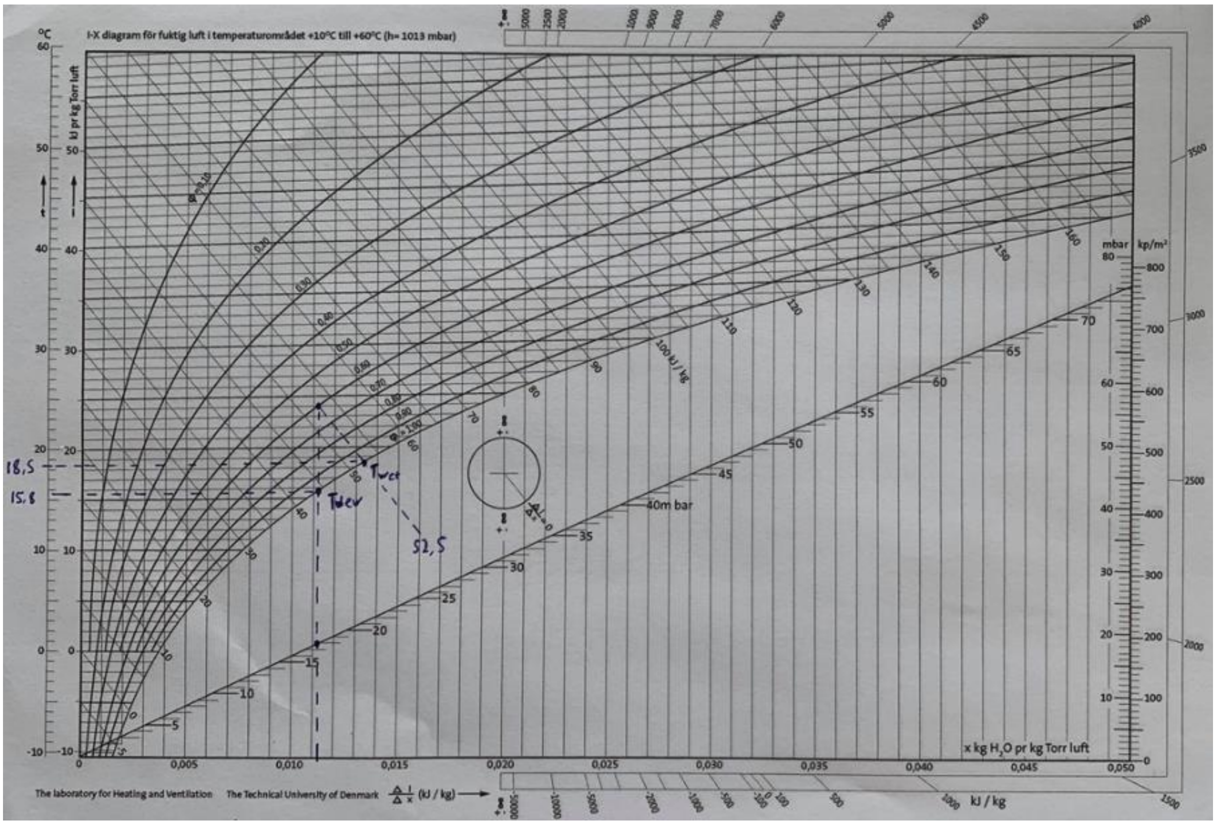


Figure 4, Mollier diagram [21]

Figure 4 shows the diagram with an example to illustrate the function. If the given values are 24 °C and 60% relative humidity, other measurements can be calculated. By following an oblique line downwards, the enthalpy line will be reached and get the number 52.5 kJ/kg. This point also indicates the wet temperature, which is 18.5 °C. Drawing a line straight down to the 100% relative humidity line gives the dewpoint temperature. In this example, that is 15.8 °C. The last measurements are how much water the air possesses. With a line to the bottom of the figure, it is possible to find this number. This state right above 0.011 kg/kg water in the air.

2.2.2 Waterbased low -and high temperature heating systems

Typical energy sources for low-temperature systems are heat pumps and solar collectors. With a low-temperature system the water temperature will be around 40-45 $°C$. A high-temperature heat system comprises near –and district heating systems, bio boiler, pellet stoves, and boiler that runs on fossil fuels. The water temperature those systems operate with is typically around 65 $°C$ or higher. [22]

2.2.3 Heat exchanger

A heat exchanger is defined in general terms, as a component that transfers heat between fluids. Therefor some devices can be built differently, depending on which medium it is customized against. The core foundations of the system will replicate each other, even if the medium is solid, liquid, or gas. The system is used in both heat and cooling processes. A heat exchanger is relatable in many aspects of engineering design problems. [23]

Transfer of heat, by the consecutive three fundamentals processes:

- Radiation
- Conduction
- Convection

Convection radiation, gases, and liquids.
System designed to transfere gases and liquids utilizes radiation and convection. Conduction has a worthier role in solid parts. Radiation is exceptional in cases where a complete vacuum is required, which is a big advantage from the other methods. The base of heat transfer strains from mass, momentum, and energy conservation. [24]

Heat exchangers mainly have two flow arrangements, parallel flow, and counterflow. A system that utilizes parallel flow, are sending both fluids in the same direction. Both fluids travel in the same direction and use the same inlet source. In the case of the counterflow, the system uses and different methods. The hot and cold fluid does not have the same inlet and outlet positions and is traveling in the opposite direction. One solution is not better than the other, it depends on how other factors around the heat exchanger. Figure 2 gives a view of four different methods with counter and parallel flow. [24]

HVAC system typically uses two different versions of heat transfer. Air-to-liquid or liquid-to-air are the two most common coils. Crossflow arrangement is preferred when HVAC system is designed, a technique where the medium flow across each other. The liquid side often utilizes water, water-glycol solution, or a type of refrigerant. This depends on the temperature the system must reach. Over 90 °C and a refrigerant or water-glycol solution are vital. If plane water is used, it will change phase to steam. [25]

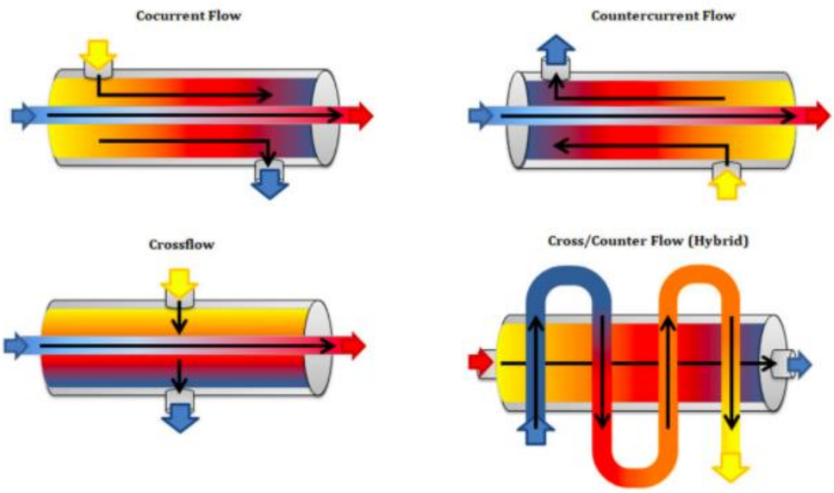


Figure 5, Four diffrent flow variants

2.2.4 Heating battery

Consist of copper, with gratings often made of aluminum. The gratings made of aluminum have the purpose of increasing the heating surface. The battery is feed with hot fluid, often water that has a temperature between 60-80 °C. [26]

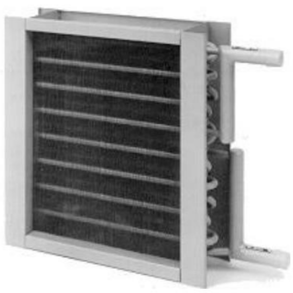


Figure 6, Heat battery [27]

2.2.5 Cooling battery

Consist of copper with gratings, often made of aluminum. The gratings or lamellae made of aluminum have the purpose of increasing the heating surface. The fluid inserted into the copper tubes is usually between 7/12 $°C$. [28]

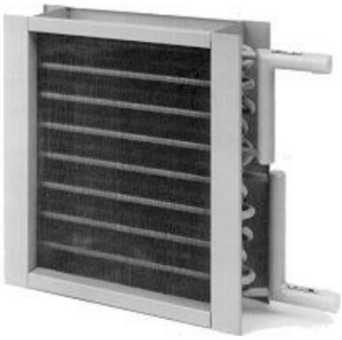


Figure 7, Cooling battery [27]

2.2.6 Dehumidification and humidification

Humidity is measured in absolute humidity. Absolute humidity is expressed as gram moisture per kilogram air. [29] While relative humidity is expressed in percent. [30] Humidification is a process where the air is loaded with moisture. When the humidity is increased, both relative and absolute humidity will increase. Decreasing humidity is a process where moisture is extracted from the air. This will make the air dryer and decrease both the relative humidity and absolute humidity. To remove the moisture from the air, it is possible to carry out directly in the room, but it is also possible with newly supplied air.

2.2.7 Absorption dehumidifier

Absorption dehumidifier exists in a turning wheel with a honeycomb structure. The fresh air passes through the wheel, and the water will bound to the wheel. The surface of the wheel is coated with silicia gel, which will increase the surface area of the wheel. Silicia will attract water molecules. [31] On the other side of the wheel, it is another air stream that is heated up, in this part the air stream will collect the moisture from the wheel. [32]

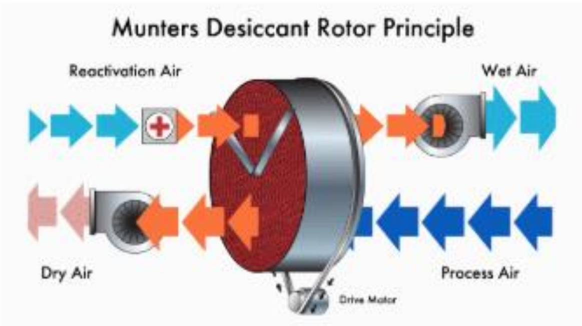


Figure 8, Illustrates dehumidifier [32]

2.2.8 Displacement ventilation and stirring ventilation

The two different ventilation principles are displacement ventilation and stirring ventilation. Displacement ventilation adds the fresh air with slow speed from the floor or a low point at the wall. With this ventilation system the room temperature is often 1-2 $°C$ lower than the room temperature. Another word for this ventilation principle is diffuser ventilation. Stirring ventilation adds the fresh air with higher speed from valves in the roof or high on the wall. The fresh air mixes with the air in the room. The reason for adding the air with higher speed than with displacement ventilation is to get the fresh air down to the human occupants in the room.
[33]

2.2.9 Ducts

Energy efficiency in ventilation ducts has become more and more important over the last years. Experts in the field, claim that higher standards within the ducts system can increase energy efficiency greatly. Some of the main issues are factors like leakage of air, pressure drop, reliability, and low installation- and operating costs. [34]
To give a perspective on how well the pipes are isolated, or how much air is released, there are four tightness classes. The four classes are A, B, C, and D. Class D is the best score a system can get, and class A is the worst with most air leaks. The system today often receives a B or A, showing that there is room for improvement. With isolation on the ducts and tightness, there are also fire regulations. New rules are made to prevent the ducts system to increase an eventual fire. Therefore, the choice of isolation materials is very important. [34]
Preventing pressure drop and correct airspeed is extremely important. These two factors play a huge part in energy efficiency. The low-pressure drop results in less energy used by the fan. Pressure drop has some guidelines on which values a system should have. [35]

- Below 1 Pa/m → Ok.
- Between 1-2 Pa/m → Works.
- Above 2 Pa/m → Not good.

This picture illustrates how it is possible to measure pressure drop with given values. For example, if a system is built with a diameter of 125 mm, and the air travel speed of 3 m/s, the pressure drop will be 1,1 Pa/m. [35]

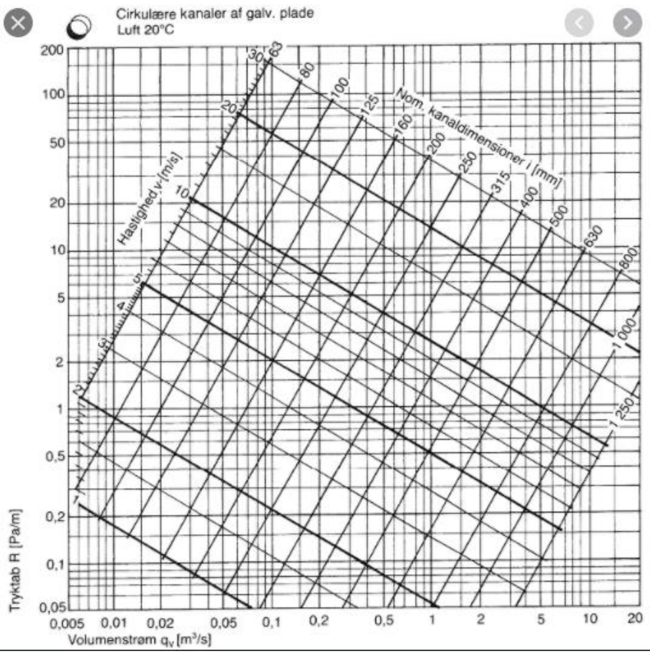


Figure 9, Pressure table

Another factor that influences pressure drop, are the °C on the angles. With every corner, turn or angel, a bend is required. The most common bends are 30° bend, 45° bend and 90° bend. Out of these three options, 45- and 90° bends are most commonly used. But, using a 90° bend have a significant impact on pressure drop. Research and studies on airflow, therefore suggest to rather use two 45 ° bend. If it is manageable to select two 45° bends instead of a 90° bend, the system will operate with less pressure drop. [35]

Figure 10, Duct system [36]

2.2.10 Valves

If the building or any room utilizes underfloor heating, precautions need to be reflected on. A system that uses hot water for heating, for instance, underfloor heating or radiators, demands a regulation device. A valve is designed to have control over the pressure and flow of the fluid that travels through the system. Valves have a crucial responsibility to ensure the pipes of the system, and not exceed its capacity or to high pressure. Generally, the design of a valve is very restricted. It is given a very specific function and works excellent at just that. The most common way valves are used to control fluid, is by the following ways: [37]

- Shutdown its flow
- Regulate its flow
- Inside regulation
- Presetting its flow
- Measuremeant of the flow
- Mixture its flow
- Distribute its flow

With underfloor heating, it is normal to experience a few challenges, where the correct use of a valve is crucial. Shunt valve, safety valve, and regulating valve are the most common valves to control the water circulating. The task these valves have is very important. Measuring pressure, controlling the quantity of the flow, and shutting down if it recognizes any errors in the system. One challenge with underfloor heating is the inlet temperature. In several scenarios, inlet temperature to underfloor heating is lower than inlet temperature to for example radiators. If the system only operates with underfloor heating, this problem disappears. [38] [37]

Figure 11, Example of a shunt valve [39]

2.2.11 Dampers

A damper is a device to control airflow through ducts. Demand-controlled dampers are important in large and complicated duct systems. Dampers make it possible to command certain areas when airflow through the system. If there are many smaller channels attached to the main pipe, the necessity to provide the same air to every channel is rare. Three most used dampers control systems are VAV (Variable Air Volum), CAV (Constant Air Volume) and DCV (Demand Air Volume). [40]

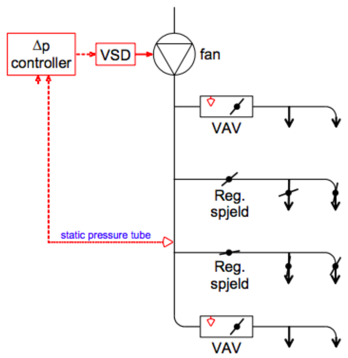


Figure 12, System drawing of dmpers [41]

CAV is the less advanced system, a type of ventilation steering which implies adapted requirements and relatively identical airflow overall. This gives the system a constant airflow. A clock or sort of timetable is often controlling when and how much air running through the system. A switch can be used but represent a very simple form of regulating and steering. Therefore, this suit, for example, a grocery store, with a clear schedule. Given time on and off.

Factors that lead to the use of CAV: [42]

- Evenly needed ventilation
- The same amount of people, small changes
- A slight variation of heat release

Figure 13, Airflow demand at given time [43]

VAV is the more advanced method and suits HVAC systems with a great variety of airflow. VAV depends on a room with a specified and customized demand for air provided. The energy consumption most commonly stays the same, because the inlet temperature on the air is the same, but airflow varies. Or the air quality often changes or needs to change. Office buildings are an example of where VAV is preferred because it can variate and adapt the airflow with a time schedule. The dampers are programmed to deliver a given calculated airflow to a specific time. Three factors in case of utilizing VAV: [42]

- Unknown demand for ventilation
- Big variation of use, how many people are present
- Variations in load, which release different heat measures

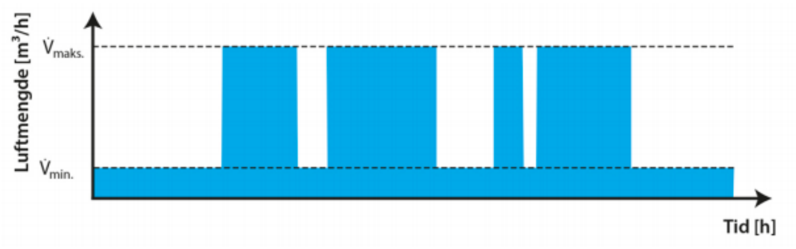


Figure 14, Airflow demand at given time [43]

DCV systems are similar to VAV. But where VAV has given calculations for space, DCV regulates the ventilation and airflow automatically with data and information from the given space. Because it is demand-controlled, sensors are assembled and give feedback and results about air quality. This feedback has direct contact with the dampers.

Therefore, the main difference between DCV and VAV, is that DCV use sensors. There are two types of sensors. DCV-IR, which is a presence detector, and measures the number of people. DCV-CO2

detects how much CO2 is released. When the level of CO2 increases over a certain point, the dampers are getting feedback. [44]
1000 ppm is a normative value, which system use as a maximum setting. The ventilation ensures that CO2 values are below this value. [45]
Using both solutions, have increased the last years. Buildings where some rooms are equipped with sensors and other regulates on the clock. [44]

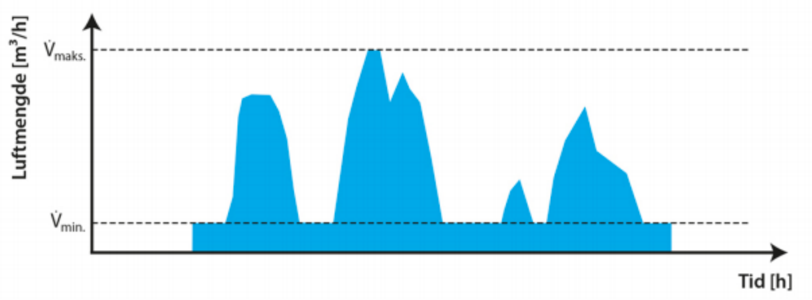


Figure 15, Airflow demand at given time [43]

2.2.12 Air Duct Silencer

Almost every HVAC duct system is equipped with air duct silencer. Air duct silencer is an engineered designed device that incorporates noise handling in the duct system. This device has become critical to ventilation in everything from private residences to huge commercial buildings equivalent to hospitals, office buildings and hotels.
[46] [47]

There are three different types of silencers, rectangular, circular, and oval. Rectangular and circular are the most common types used in ventilation settings. The preferable solution depends on the airflow and how large dimensions the ducts are. With large systems and high airflow, rectangular fits likely best. Circular delivers the best results with circumstances of normal or smaller systems.
[48]

Circular duct silencers are built with absorption materials inside the steel/aluminum pipe. The sound absorption material is called micro-perforated panel (MPP), It is installed inside and as tight as possible to the circular wall pipe, it works excellent on acoustic absorption. This is a thin plate made by many different materials, with sub-millimeter sized borehole inside. Something called acoustic bullet is often placed in the middle, with the purpose to cancel sound and noises from airflow. Both acoustic bullet and absorption material are relatively easy to conduct service on. [49]

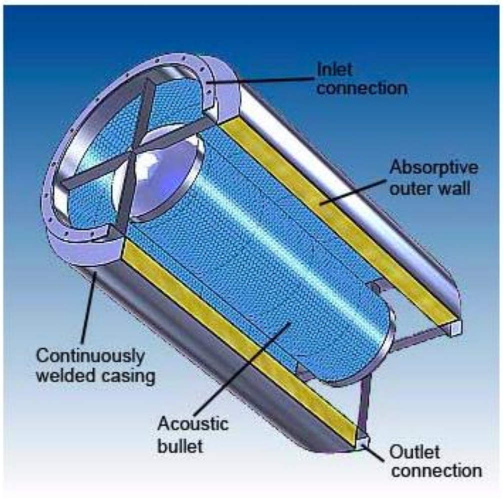


Figure 16, Circular duct silencer [50]

Rectangular duct silencers use a different solution to silence the noise. The answer is to silence the noise with baffles in the middle. The bigger dimension and pipes, the more baffles are possible to place in the device. The baffle can evaluate and change the angle to the best possible position in case of noise-canceling and aerodynamic. The baffles are often made of fiberglass or a steel combination but depend on airflow. High airflow requires strong materials for instance steel. Fiberglass suits lower airflow better. Micro-perforated panel (MPP) is also attached to the inside wall to rectangular silencers, to absorb most noise possible. [51] [52]

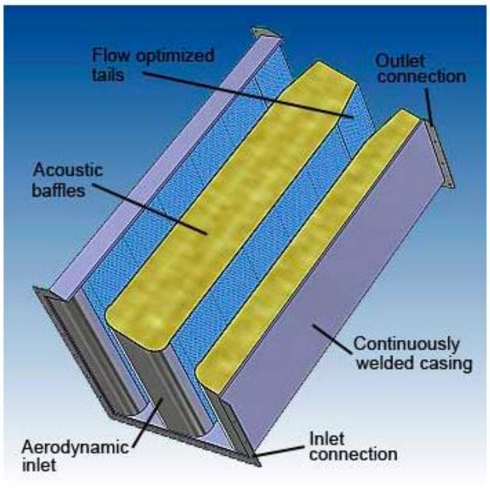


Figure 17, Rectangular duct silencer [53]

HVAC systems are dependent on devices like rectangular and circular silencers, to follow rules and guidelines in case of sound level. TEK 17 and Norwegian standards have strict regulation with acceptable noise from building technology. NS 8175 examines different sound classes from A to D, where D is the lowest ranking and A the greatest. [54]

TEK 17 refers to standard NS 8175 with sound level from technical devices. [55]

Labor inspectorate have defined noise, and levels that are dangerous to human ears. Everything above 80 decibels is described as damaging noise. If the noise extends above 130 decibels, they advise hearing protection. [56] Therefore, it's important that for instance, HVAC systems do not break this guideline.

2.2.13 Compressor

To constitute fluid to boil or evaporate, heat, energy, and low-pressure are needed to make fluid will boil at the desired temperature. There will not be an evaporation prosses in the container if the vapor is not removed and the low-pressure is maintained. The low pressure in the container is maintained when the compressor is removing the vapour. The prosses is still under low pressure as the compressor is removing the vapour such as the fluid still can vaporate.
The vapour entering the inlet side of the compressor, continuing through the inlet valves to the upper side of the piston and becomes compressed. The vapour/gas gets a bigger density and higher temperature. The pressure valves in the compressor operate as a valve that stops the high temperature, high-pressure vapour/gas to flow back to the low-pressure side. [57]

Figure 18, Compressor

2.2.14 Refrigerant

According to an international agreement in the refrigerant industry the letter R is given as designation for every refrigerant. The following number is the chemical composition of fluorine, carbon, hydrogen, chlorine, or bromine atoms. The 400 series consists of two or more substances. When one of these refrigerants in the 400 series evaporates or condenses each substance in the refrigerant reacts independently. That is why the evaporate- and the condense temperature will change in the refrigeration process. [58]

A mix of halocarbon of different types azeotrope refrigerants are numbered from 500 to 506, their specialty is to operate as a one-component substance. [58]
Natural refrigerant is one group, and some of the particles are methane 50, ethane 170, and propane 290. Natural refrigerants are a well-known engineering art, which originates all the way back to the 1700s. The method is well established in the subject area with good thermodynamic qualities. [59]
R717 ammonia and R744 are both carbon dioxide and inorganic refrigerants. Inorganic refrigerant is listed between the following chemical composition numbers: 702 - 764. [58]
Safety classification is a well-known topic, their seam to be some different opinions from different places in the industry. There is however a table that describes some refrigerants by flammability and toxicity.

Higher flammability	A3: Hydrocarbons	B3: No refrigerants
Flammable	A2:R152a, R1132a, R465A & others	B2: Some blends
Lower Flammability	A2L: Most HFO's & R32	B2L: Ammonia
No flame propagation	A1: CFC, HCFC, most HFC's & some HFO	B1: R123
	Lower toxicity	Higher toxicity

Table 1, Flammability of refrigerents [59]

According to an article written by the European Commission published in 2007, the *Montreal Protocol* signed in 1987 is considered as the most successful environmental protection agreement ever reached. The focus of the protocol was to reduce and phasing out chlorofluorocarbons (CFCs). The prize-winning scientist Paul Crutzen described the ozone layer crises in the 1970-80s as "the worst disaster to hit the global environment". The solution back then was to replace the CFCs with HCFCs. This turned out to be a setback because HCFCs not only destroy the ozone but also contribute to global warming. But on a lower level than CFCs. HCFCs got a huge part in raising economies and were on its way to jeopardizing the recovery of the ozone layer. The solution to the HCFCs was HFCs, this substant does not damage the ozone layer, but contribute significantly to the global warming aspect. In early 1990 the focus on alternatives is huge, but HFCs are playing a bigger part in the global market. The first refrigerant tobe removed was R12, which was used in car air conditioning, and it was replaced by the HFC R134a. Several years after, the R502 was replaced by R404A and in 2010 R22 was phased down and the HFC R410A was intended to be the most secure replacement. [60] Despite all the different efforts from the leading countries and EU the ozone layer above the Antarctic reached its thinnest in 2006, the assessments suggested that the Antarctic ozone will not return to pre-1980s levels until late in the 21st century. [61]

The COP is the power factor that describes how much of the heat effect that is possible to withdraw from the refrigerant rather than the use of electricity.
The COP is an instant value, and it varies with the temperature of the heat source and the temperature the refrigerant will supply to the heating system. [62]

2.2.15 Ammonia

R717 ammonia (NH3), is described in the literature as an elderly type of refrigerant which is still well integrated into the industry. Regardless of R717 long existence, it is still relevant. R717 has a good evaporating ability and except for water, R717 has the highest phase transition energy between fluid and gas. The literature also describes that R717 gives a known COP and a low fil rate per kW installed effect if the design is built correctly. And some may argue that it is the cheapest refrigerant on the market, and has no environmental damage. On the other hand, R717 is toxic and the gas that is mixed with air can be explosive. Usually, the refrigerants are transported in cobber pipes, but if R717 connects with copper the material will corrode. Therefore, the system mostly consists of steel, aluminum, or none corrosion alloy. R717 does not merge with oil and for that reason, the system requires an oil separator which leads the oil back to the compressor. Another problem is that a high-temperature pressure gas comes from the compressor, and this occurs under normal conditions. [58] [59]

2.2.16 Propane

R290, CH3CH2CH3 boils at a temperature minus 42 $°C$, at 1 atm. Often is R290 used as an indirect refrigerant, where the refrigerant that is used in the compressors is holding temperature between minus 30 to plus 7 $°C$. [58] R290 has the same qualities as R22 (CHF2Cl) except for the flammable part of R290. This means that R290 is compatible with the same existing components that used to use R22. R290 also gives a generally better COP value than conventional synthetic working medium, and purely on the thermodynamic aspect, R290 is considered as a good refrigerant. The highly flammable R290 demands that the filling is as low as possible. A system without a sustainable and decent safety system is required to a max refill at 150gram. This rule is debatable if the limit should be raised to 500gram. There is a way to bypass the 150gram limit if the system is parallel connected. Each system in a parallel-connected system is considered as one, but this will influence the installed effect and be more expensive to install. For the system above the fill limit, the technical room must be designed right. On the market today, there is robust engineered room in room modules with low filling amounts. These modules are under a suppressed state and easy to use. [59] The drawback with R290, is the medium's highly flammable ability. According to standard NS-EN 387, the refrigerant is classified as A3. If the gas concentration of R290 is between 2,9-9,5 percent, there's a possibility the gas can ignite and explode. Or if it occurs an open flame, a spark, or the temperature reach 450 $°C$ the outcome of an explosion is possible. There are strict guidelines for use of R290. [58]

2.2.17 Carbon dioxide

R774, also known as CO2 was used as a refrigerant until 1950. R774 has a high condensing pressure compared to other refrigerants. The cooling prosses are occurring in the transcritical area and the refrigerant is working under relatively high-pressure conditions. The system must be designed to work under a given pressure. [58] R774 can be compressed considerably, and therefore cover a small percentage of the volume per Kg. This results in diminutive size on the medium. Compressors and pipes relative to R774 can, therefore, be smaller as a unit. Also, give the option of compressors that operate under a lower installed effect. The high pressure that R774 works at results in a lower temperature decrease, as a result of the pipe friction. This gives the gas a high speed, and that results in smaller pipe sizes and oil returned safely back to the compressor. R774 functions excellently in systems where there is a good distance from the refrigeration unit to the location where the refrigerant is used. The pipes in the system need to be designed so they can handle the given pressure. R774 has strong thermodynamic qualities, and the industry is preferring R774 as a refrigerant in cooling- and freezing facilities, in small and medium plants. (40-300kW). [59]

2.2.18 HFK

HudroFluroCarbones are a commonly used refrigerant classified globally. Some HFCs is R134A, R404A, R410A, R125, and R32. These refrigerants are used in different components, everything from automotive, home air conditioners, and industrial refrigeration. Nowadays different institutions are working with the purpose to reduce the use of HFCs. Since the HFCs have a huge GWP level compered to for example R744. While R744 has a GWP of one, R134a has a level of 1344. [60] Now the change to natural refrigerant or HFO (hydro-fluoro olefines) is about to happen after the amendment to the Montreal protocol called Kigali Amendment. Under this amendment, the use of R404A, R134A, and R410A will not be allowed to be produced after Jan. 1. 2024 and there seems to be a stricter ruleset shortly. [63]

2.2.19 Blend

Blends are HFCs which are bleded with other Refrigernats to give the wanted qualities.

Respective properties of the different low-GWP refrigerants relative to each other						
Refrigerant properties	HFK(1)	Refrigerant with low GWP		Natural		
	HKF	HFO	"Blends"	Ammoniakk	Hydrocarbons(2)	CO_2
GWP-value	××	✓✓	×	✓✓	✓✓	✓✓
Toxicity	✓(3)	×?	×?	××	✓	✓
Flammability	✓	×	×	×	××	✓
Corrosivity	✓	✓	✓	×	✓	✓
Price	×	××	××	✓✓	✓	✓✓
Typical filling quantity	×	××	×	✓✓	✓	×?(4)
Typical construction cost	✓✓	×?	✓?	××	✓	✓
Thermodynamic properties	×	×	××	✓✓	✓?	✓(5)
Knowledge in the industry	✓✓	×	×	✓✓	✓	✓
Multiconsult recommends (2019)	××	××	××	✓✓(6)	✓✓(6)	✓✓(6)
✓✓ = Very low/positive ✓ = Low/positive ×× = Very high/negative × = High/negative ? = Unsure ×/✓? = Indicate (high/low						

Table 2 ,(1) Phasing out started. (2) Primarily propane and iso-butane. (3) Choking gas. (4) Often used in DX-constructions. Low GWP, does not matter. (5) Tanscritical at reletivly low capacitor/gas cooler temperature (31°C). (6) Depends on purpose and conditions. [59]

2.2.20 Condenser

The condenser is a device used to change the state of a medium. With constant pressure, gas and vapor are transformed into a liquid. It is quickly cooled down to saturation temperature, where the liquid travels out of the system. In this state, it is called undercooled liquid. The condenser has a similarity to heat transfers because this device also transfers heat in the operating process. To remove the heat, a coolant is utilized. [64]

The structure of a condenser is made of two different classes. The first method is by using a coolant separated. Vapour circulates through a tube, which is installed with a shell around. Therefore, the coolant and vapor are never in direct contact. The second method is to combine vapor and coolant in one tube, with one single stream. The tubes are often made in conductive metals like copper. Condensers are used in everything from heat pumps to petroleum and chemical industries. [65]

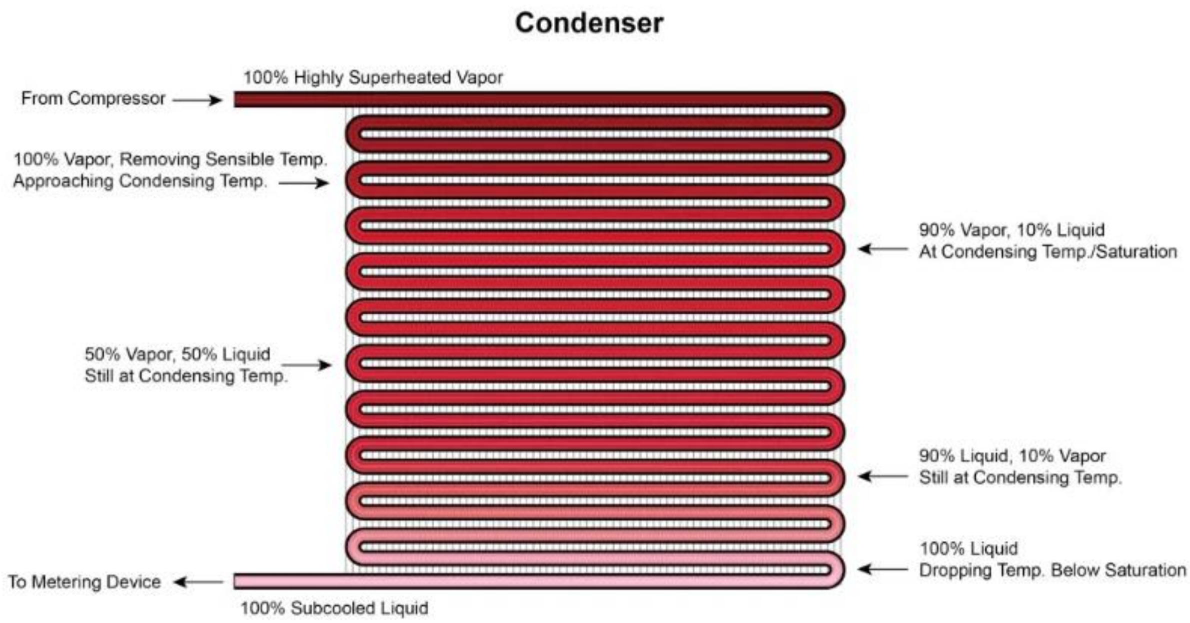


Figure 19, Condenser explained [66]

2.2.21 Air to water heat pump

An air to water heat pump uses heat from outside air or extract air to distribute heat with underfloor heating or radiators. The principle with a heat pump is to use low temperature from surroundings, to increase the temperature to suit the demand. For this to be possible, high-grade energy needs to be supplied. Most commonly electricity. Even though the heat pump utilizes electricity, it is around 50-80% less than conventional heating systems (depending on the air temperature) based only on the use of electricity. Buildings with a waterborne distribution system available, this method is highly preferred.
[67]

Generally, an air to water heat pump exists of four main components:

- *Evaporator*
- *Compressor*

- *Condenser*
- *Expansion valve*

Evaporator operates as a heat exchanger from the chosen source of heat. The working medium in the liquid phase is kept on temperature below the heat source. Refrigerant 404a, 407a, and 410a are commonly used medium. When the outside air arrives with a higher temperature than the existing medium, steam will occur. Most of the liquid then turns to vapour and moves to the compressor with low pressure and temperature. [68]

The *compressor* receives the refrigerant in vapour phase. The compressor increase pressure to such level which the temperature increase. Most of the energy supplied to the compressor is used to increase the level of energy in the vapour. The compressor also has an important task to keeps saturation pressure in the evaporator low, which keeps the saturation temperature in the evaporator lower than the temperature arriving from a heat source (outside air). [68]

Condenser uses the vapour with high pressure and high temperature to warm up the existing medium, for instance, a refrigerant or water with glycol. This medium travels through pipes and reach for example radiators, which release heat. Then the liquid returns and is pushed back in the cycle. [68]

The *Expansion valve* receives the liquid with high pressure and high temperature. The expansion valve adapts the medium from the condenser and maintains differential pressure between the high and low sides. When the temperature and pressure reach is low enough, it is pushed back to the start of the cycle. The process activates yet again. [69]

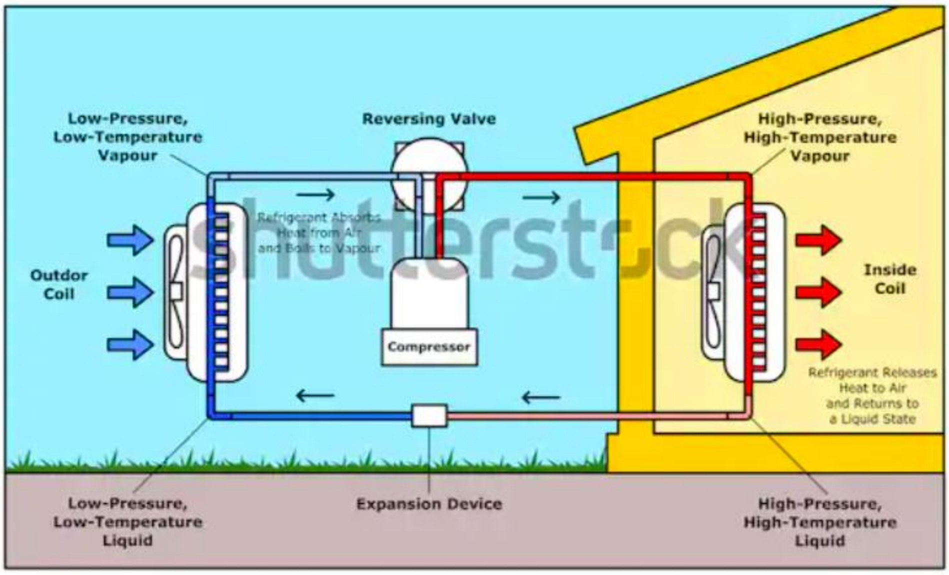


Figure 20, Illustrates the four cycles [70]

To understand the points being made about dimensioning, an explanation of the *duration diagram* is necessary. Y-axes are used to describe efficacy (the ability to produce a desired or intended result) coverage in kilo Watts (kW). X-axis describes a period, in days equivalent to one year. The area under the axis indicates total energy. *Figure 21* illustraets the explanation.
[71]

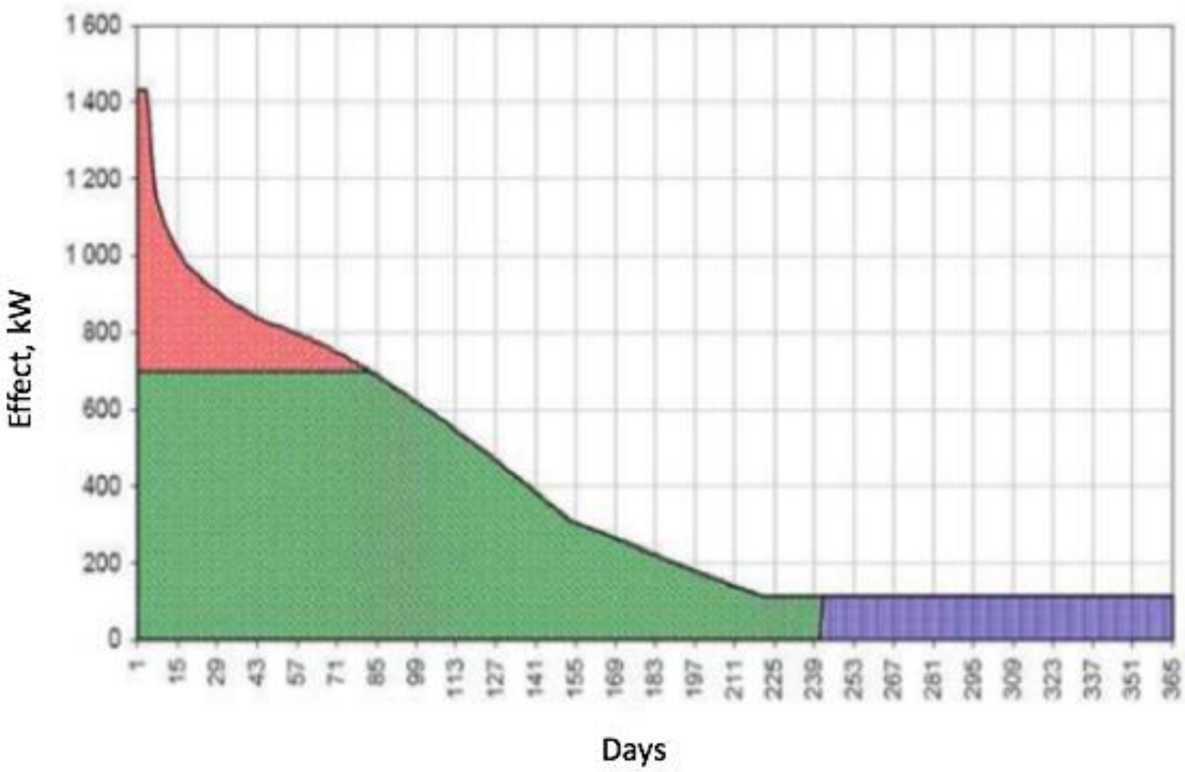


Figure 21, Duration diagram

Dimensioning of a heat pump is important to produce a heating system with maximum effect coverage and ensure that over dimensioning is not an issue. There are a few precautions and guidelines as to why combining a heat pump with another heating device is wise. Arguments to use another unit instead of heat pump, to take care of peak load are as follow:

- A system with a heat pump alone is not regarded as satisfactory, because of operating ability. Establishing a heat pump to operate at 100% power is not energy efficient.
- Attempts to make a heat pump cover 100% efficacy, just increase investments to a ridiculously high amount. Without a guarantee to reach higher efficacity coverage than 60%.
- The temperatures required to delivered from the heat pump are more favorable to its system.

Bacause of this, a heat pump should be dimensioned to cover midle load of the system, with an alternative option to cover peak load. Optimally then, a heat pump is supposed to be installed with intension to cover 40-60 percent of the efficacy demand. This results in 80-90 percent of energy demand dealt with. Remaining efficicay and energy demand are coverd with bio boiler or electric boiler. [71]

One huge positive factor abut air to water heat pump, is the even distribution of heat. If a big number of radiators are lined up, the last few are not providing the same amount of heat. But this is regarded as the best method to distribute heat most evenly. Conditions of mild winters and long summer seasons are preferable to this method. [72]

3. Approach, overall design and calcualtions

3.1 Approach

First step in the project was to consider different sites where it could be expedient to build the environmental facility. This was done in collaboration with building students, supervisors and Statsbygg. After a consideration the building site, shown in *Figure 22*, was chosen at the south end of Kronstad´s property. It was decided to remove the greenhouse, which is standing on the site today. The building was designed in collaboration with building students, where the theme train has played a central role because of the old train workstation at Kronstad. Because of this inspiration, rectangular shaped foundation and curved roof was made. After the building was designed during an itterative process the work with passive and active measures started. In the whole process with the building it was taken into consideration that it is space for all technical installations.

Figure 22, The site

3.1.1 Passive measures

Passive measures are produced in collaboration between building -and energy students. Building students drew the structure in Revit, with advice on the field from energy students. Some aspects that have been taken into account is where to place the windows, shape of the roof, and the division of the room. To reduce the number of cold bridges a rectangular shape is designed. The placement of the window in the environmental chamber is selected to get a view to Mount Ulriken, which can be inspiring for the athletes. Due to the potential for people passing by to look into the chamber, the window can be placed closer to the roof than is usually specified. This is useful if famous athletes are training, and do not want people from outside to stop and star. Because of the solar irradiance, the window will also create natural light in the room. Another solution on the challenge with people stop and star is sunblinding of the window, which also will decrease the cooling demand in the summer because of the solar irradiance. It is not calculated any energy savings from sunblinding of the window. The division of the rooms is done by building students after following current building regulations about universal design.

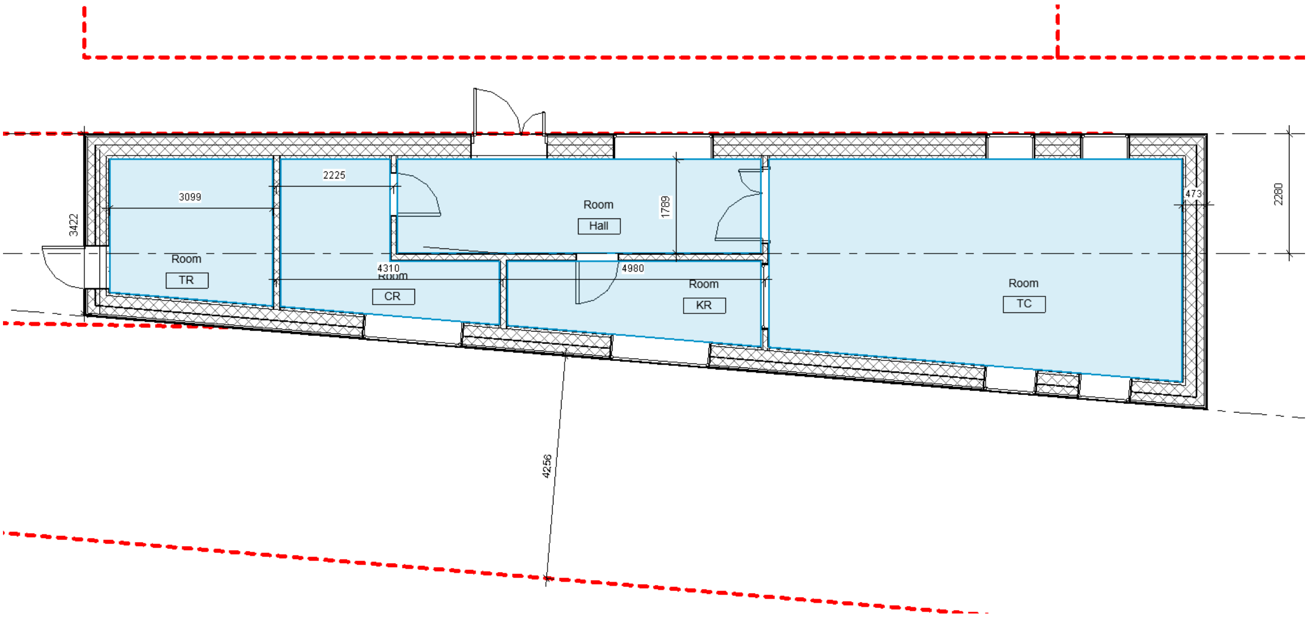


Figure 23, Picture of the room division from Revit, might be minor changes after the picture was captured. Captured 6th of april 2020

3.1.2 Active measures

Solar panels, the HVAC system, PLS (programmable logic control), and energy-saving equipment such as the accumulator tank are active measures the group has thought of. [73] The building will be facilitated for a curved solar film on the roof. This will save electrical energy, especially in the summer. In this thesis, it is not calculated any possible energy savings from the solar film that can be put on the roof.

3.2 Overall design HVAC

The HVAC system will exist of two systems: one adapted to the environmental chamber, and one for the hallway, locker room and control room with belonging air handling unit for the two systems. This is caused because the requirements for the two systems are very different.

3.2.1 Locker room, hallway and control room

The HVAC system in the locker room, hallway, and control room are calculated with A+B from NS 3031. SIMIEN was used to determine the necessary cooling and heating requirement. For the necessary cooling demand, especially in the control room because of the internal loads, an air split unit will be installed, to cool down the air in the room. For more details surrounding the system see section *4.5.2* and 4*.5*.

For the heating system, three radiators are used. The radiators are placed underneath the windows. Necessary effect demand can be found from SIMIEN calculations in the result part. To heat up the water that needs to be used for all waterbaseed equipment an air to water heat pump is used. System drawings of the water based system can be found in the *Results,* section *4.4.1*.

In this system, all the valves are in the ceiling. The locker room is only equipped with outlet air valves, which leads to lower pressure in the given room. Due to the lower pressure, air will move from the hallway into the changing room. This is a common way to design systems and is mainly used for toilets and bath/shower rooms which is an important way to control where the air moves from one room to another. In the control room, an air inlet and outlet unit are specified. The hallway has only an air inlet unit, which anticipates that the air in this room will be exhausted in to the changing room. This ventilation system is a balanced needs-driven ventilation system.

3.2.2 Environmental chamber

Measurements about the environmental chamber are performed in COTES room-calculator. SIMIEN does not accept such low and high temperatures. An important advantage with this room-calculator is the possibility to calculate with internal moisture load. This is an important aspect because when it is used with athletes who breathless and sweating their body will emit moisture in a relatively small room, which increases the humidity level. COTES program makes it possible to calculate the humidity at the inlet air and also the humidity in the room. From COTES room-calculator it is also possible to provide heating and cooling demand. These demands are calculated theoretical and compared to results from COTES room-calculator.
The formula that is used for the cooling demand is:

$$\dot{Q} = L * \rho * \Delta H$$

The formula used for heating demand is:

$$\dot{Q} = L * C_p * \rho * \Delta T$$

A few decisions have been addressed by designing the cooling and heating system. This includes the choice of refrigerant, directly or indirectly cooling, and electric or waterbased systems. For the cooling section 2*.2.16 Propane* is used as an indirectly cooling refrigerant. This refrigerant is cooling down a mix of water and glycerol which is used to cool down the inlet air. For the heating in the room, an **Feil! Fant ikke referansekilden.** will be used to heat up the water in both systems *360 001* and *360 002*. A product list with cost of the products is shown in *Cost analysis and component* list results

An approximately cost analysis is conducted for the technical system, which includes both HVAC systems. The prices are list prices without taxes, discount for ventilation contractors and mounting costs. Prices for the water ducts is not calculated and will need further research.

, section *4.5*.

It is important ascertain where the most expedient place for the air inlet and outlet units in the rooms are. Placement of air inlet- and outlet valves depends on the temperature in the room, and temperature on inlet air.
As explained in section 2.2.8, displacement ventilation adds the fresh air with a few $°C$ lower temperature than the room temperature. This ventilation principle will be used for the cooling part in the environmental chamber. Since the air has a lower speed than stirring ventilation this system might be more comfortable for the athletes compared to a stirring ventilation system. This is especially important for the cooling part because of the low temperatures in the chamber. For the heating part, the room will be heated up by the inlet air. Due to the inlet air temperature, this will be a stirring ventilation principle that means the inlet air has a higher temperature than the room and therefore needs higher speed. For this ventilation principle, is crucial to choose valves that are able to allow inlet air to reach human in the room; so it is not lingering beneath the roof. To be sure that those using the chamber does not feel a draft, a CFD analysis will needs to be made.
The outlet air valves are necessary to get the staled air out of the room. This design is important so that the fresh air is not exhausted. For the heating part in the chamber, the air outlet will be at a low point on the wall, and for the cooling part, it will be at the ceiling in the chamber. This is done because of the vertical temperature gradient, which means it is warmer at the roof compared to the floor. With these choices of the valves and their placement, the risk of exhaust fresh air decreases.

3.3 Calculations

To calculate the airflow that is necessary for both, environmental chamber and the control room the guideline NS 3031 is used together with Byggforskserien. If the cooling demand is larger than

A+B**,** this will be used to determine the right airflow. The calculations for airflow are shown in the result part of the thesis. The airflow demand for a person will increase with the activity level for the person, in Byggforskserien it is paid attention to this.

3.4 Technical installations

Decisions surrounding the use of space and component installation, are done in collaboration with building students. Therefore, it is assured that ducts and valves accommodate the given area. This has been an iterative process and developed after the technical system has changed during the period of study. As for the duct dimension and pressure drops, the system obeys rules and regulations described in theory chaper: *Ducts Section 2.2.9.* Pressure drop will be 1 Pa/m in the main ducts, and 0.5 Pa/m in the secondary ducts. In the duct system it strives for good solutions where the pressure drop is as low as possible because this will make the system more energy efficient. Circular ducts will be used because square ducts make a more ineffective flow pattern and therefore increase energy use. [43]

3.5 Sources of error

- Simien
- Cotes room calculator
- Human error

4. Results

4.1 Results from SIMIEN

The results from the SIMIEN simulation are done to indicate how the indoor environment for changing room, hallway, and control room should be. Given the input data calculated and recovered from TEK17 [14]. These results are not the main part of this thesis, but an addition to get a good picture of the whole building. This simulation is done with input from the building engineers that are modeling the building. For more detailed information on the results and data from the simulation, see *Appendex A.2* and *Appendex A.3.* All figures referred to in this chapter are available in *Appendex A.2.*

4.1.1 Summer

SIMIEN allows the simulation of the solar radiation on the roof. However, the results are approximate compared to reality. Because of the shape of the roof and uncertainty of which sort of panels that the simulation uses, and there may be many uncertainties surrounding this simulation of the solar radiation effect. Even though the results may be subject to large errors, it indicates that solar radiation on the roof can potentially provide anything from 8-10 kW, depending on weather and equipment. See *Figure 33.*

Control room

The temperature indoor is below 23 $°C$ and the CO_2 concentration is below the limit on 1000 PPM described in section *2.2.11*, approximately 767 PPM throughout the day. The other value relative humidity is programmed to linger beneath 65%, which is the maximum percentage before some might argue that the indoor air quality becomes poor.
The internal loads are significant, which requires the cooling system to be able to remove 1733W from the room, so that the temperature becomes comfortable see *Figure 34* - *Figure 39*. A solution is a split unit installed in the ceiling and on the outside wall.

Hallway and locker room

Max temperature in the hallway and locker room is 23 $°C$, the idea in these rooms is supplying air from the hallway and subtracting the air from the locker room. CO_2 concentration is entirely under 1000 PPM at 687 PPM.
The simulation shows that in these rooms the solar radiation is larger, and the cooling will be solved with cold air and no internal cooling. The effect on the cooling battery is not that significant, compared to for the environmental chamber system. *Figure 41* - *Figure 47*.

4.1.2 Winter

Control room

The temperature in this position operates on a comfortable 21 $°C$, and the simulation shows that CO_2 concentration is at 575 PPM. To get a good idea the internal loads are not included in the winter simulation. In the case of this room, they are not utilized. They are not needed for internal heat. The simulation shows that heat from inlet air is enough, but to install an additional radiator is not expensive, given the system already facilitates this equipment. See *Figure 49* - *Figure 55*

Locker room and hallway

The result from the simulation in this area is equal to the control room, except for heat demand. Heat demand is higher, and, therefore radiators are required, and the heating subsidies are higher throughout the day. Temperature is equal, and CO_2 is 469 PPM. See *Figure 60* - *Figure 66*.

4.2 Theoretical calculations

One of the first calculations to consier is airflow. Heat and cooling data are adapted to each room and build on correct airflow. Airflow depends on the area, person load, and materials. The environmental chamber, changing room, control room, and hallway have different values measured on factors mentioned above. Referring to *Appendex A.1* for airflow demands.

4.2.1 Environmental chamber

Airflow:

$$\mathrm{A} + \mathrm{B} = \text{Airflow demand}$$

$$250\frac{m^3}{h * person} * 4person + 2{,}5\frac{m^3}{m^2 * h} * 30m^2 = 1075\frac{m^3}{h}$$

Standard values taken from: *SINTEF Byggforskserien* [74].

Heating effect:

$$\dot{Q} = L * C_p * \rho * \Delta T$$

$$\dot{Q} = 1075\frac{m^3}{h} * \frac{\mathrm{1h}}{3600s} * 1.2\ \frac{\mathrm{kg}}{m^3} * 1\ \frac{\mathrm{kJ}}{kg°C} * (50 - (-12))°C$$

$$\dot{Q} = 22.2kW$$

This is the effect the heating from ventilation will need including heating battery and heat recovery.

Cooling effect:

$$\dot{Q} = L * \rho * \Delta H$$

$$\dot{Q} = 1075\frac{m^3}{h} * \frac{1h}{3600s} * \frac{1.2kg}{m^3} * \frac{(75— (-23))kJ}{kg}$$

$$\dot{Q} = 34.4kW$$

Necessary effect to the cooling battery. Because of the desiccant wheel in the dehumidifier the cooling demand will be higher than the given calculation above. More accurate demand can be found from Cotes room calculator.

4.2.2 Control room

Airflow:

$$\text{A} + \text{B} = \text{Airflow demand}$$

$$L = 26\frac{m^3}{h * person} * 2person + 2{,}5\frac{m^3}{m^2 * h} * 30m^2$$

$$L = 69.5\frac{m^3}{h}$$

Heating effect:

$$\dot{Q} = L * C_p * \rho * \Delta T$$

$$\dot{Q} = 69.5\frac{m^3}{h} * \frac{1\text{h}}{3600s} * 1.2\ \text{kg}/m^3 * 1\ \text{kJ/kg°}C * (25 - (-12))°C$$

$$\dot{Q} = 0.86\ kW$$

This is the effect the heating from ventilation will need including heating battery and heat recovery.

Cooling effect:

$$\dot{Q} = L * \rho * \Delta H$$

$$\dot{Q} = 69.5\frac{m^3}{h} * \frac{1h}{3600s} * \frac{1.2kg}{m^3} * \frac{(25 - 23)kJ}{kg}$$

$$\dot{Q} = 0.05\ kW$$

Necessary effect to the cooling battery. For cooling effect included internal loads see *Figure 34*.

4.2.3 Hallway and locker room

Since the locker room only have air outlet the necessary effect for locker room and hallway is given as one.

Airflow:

$$A + B = Airflow\ demand$$

Hallway: $L = 26 \frac{m^3}{h*person} * 4person + 13.7 \frac{m^3}{m^2h} * 2{,}5m^2$

$$L = 138.25 \frac{m^3}{h}$$

Locker room: $L = 2.5 \frac{m^3}{m^2h} * 8{,}4m^2$

$$L = 21 \frac{m^3}{h}$$

Total: $L = 138.25 \frac{m^3}{h} + 21 \frac{m^3}{h}$

$$L = 159.25 \frac{m^3}{h}$$

Assuming four people are located in hallway and locker room.

Heating effect:

$$\dot{Q} = L * C_p * \rho * \Delta T$$

$$\dot{Q} = 159.25 \frac{m^3}{h} * \frac{1\text{h}}{3600s} * 1.2\ \text{kg}/m^3 * 1\ \text{kJ/kg°}C * (25 - (-12))°C$$

$$\dot{Q} = 0.69\text{kW}$$

This is the effect the heating from ventilation will need including heating battery and heat recovery.

Cooling effect:

$$\dot{Q} = L * \rho * \Delta H$$

$$\dot{Q} = 159.25 \frac{m^3}{h} * \frac{1h}{3600s} * \frac{1.2kg}{m^3} * \frac{(25-23)kJ}{kg}$$

$$\dot{Q} = 0.11\text{kW}$$

Necessary effect to the cooling battery.

4.3 Results from Cotes room calculator

This system illustrates an absorption dehumidifier with including heat and cooling batteries. The bottom airstream at the *Figure 24* shows the inlet air to the environmental chamber and the airstream at the top shows the airstream that is taking out the moisture from the desiccant wheel. At this picture the two cooling batteries are turned off due to the heating part, this is controlled with PLS. This room calculator also shows energy demands from cooling and heating batteries.

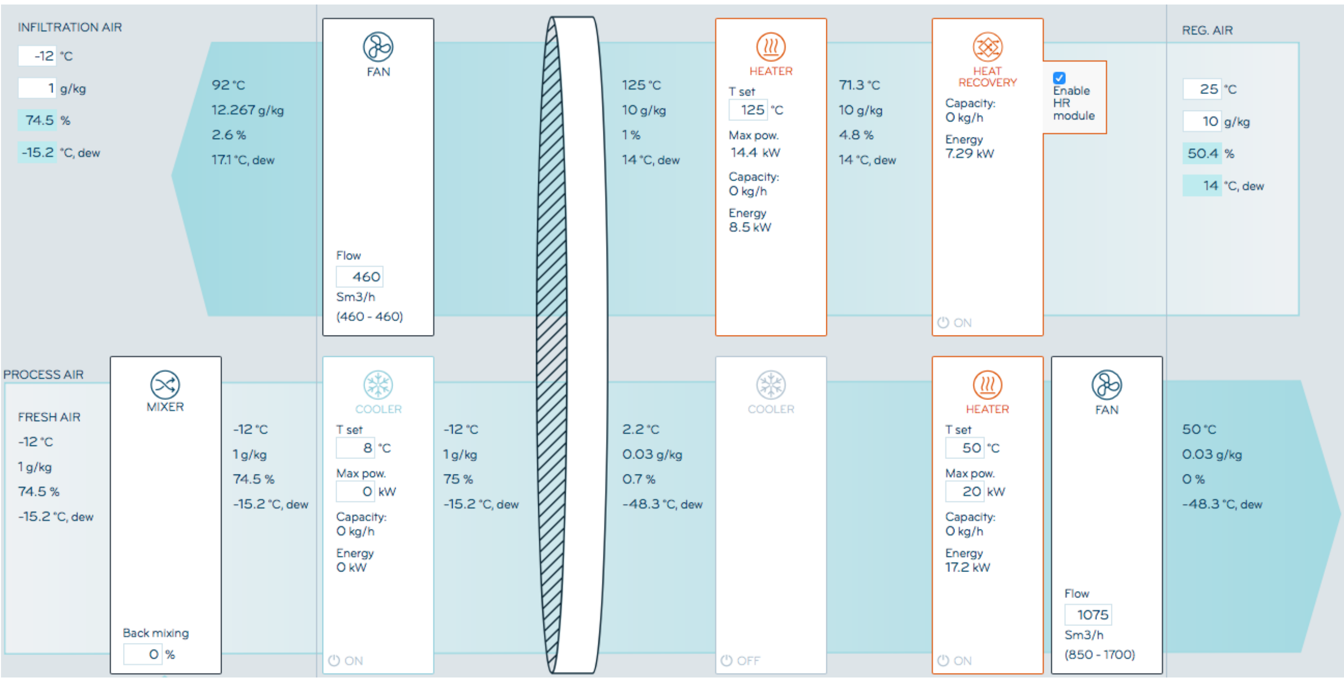


Figure 24, Shows heating part from Cotes room calculator

Figure 25 explains the input data with room dimensions and moisture load. The internal moisture load is chosen in collaboration with, the supervisor for the sports students, Morten Kristoffersen. This number is based on a moisture release, and four athletes in the room at the same time.

$$2kg/h * person * 4\, person = 8kg/h$$

With this internal moisture load, the room will have a relative humidity at 8,1 % which will be the lowest the system manages without increasing the capacity of the system. To get lower humidity then 8,1%, the airflow needs to increase or have a dehumidifier.

In addition to this system, it is possible to humidify the dry inlet air and control the relative humidity. According to the HX diagram shown at figure the relative humidity will be 98%, with a humidifier that has an airstream output at 85 kg/h and 50 $°C$ inlet temperature. This means that the humidifier needs to deliver approximately 85 kg/h to deliver up to 98% in RH. To control this, a PLS system is necessary. This can control the relative humidity from 8-98%. It is important to emphasize that this is the limit when the internal load is 8 kg/h. If this number is lower the possibility to get it even dryer in the room occurs.

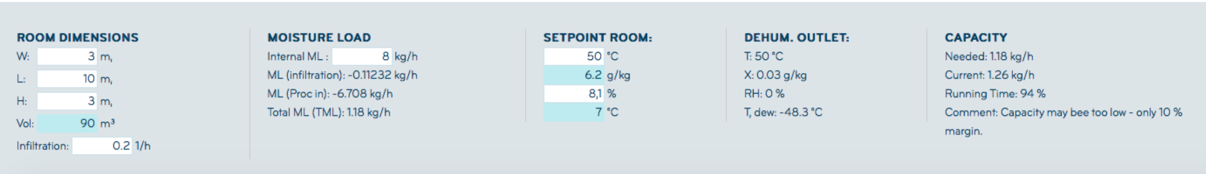


Figure 25, Illustrates moisture load

The *Figure 26* illustrates the cooling part. For the cooling system, the air will be cooled down to 8 $°C$, and then be dehumidified by the desiccant wheel. By decreasing the humidity, the original dew point will change, which leads to a possibility to cool the inlet air further down. The inlet air will be cooled down to -23 $°C$ by the second cooling battery. According to the HX diagram, the relative humidity will be high and absolute humidity low at low temperatures. This means that regulation will not be possible of the humidity for the cooling part since the variation of absolute humidity is low.

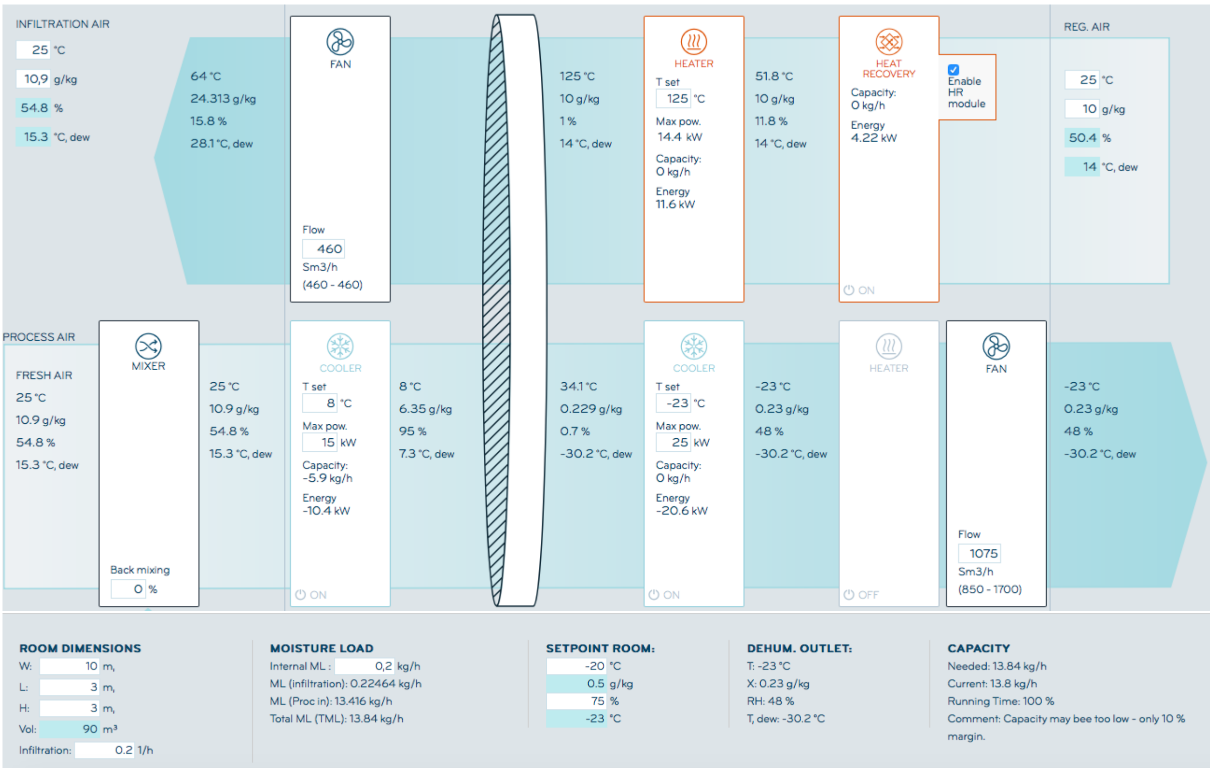


Figure 26, Shows cooling part from Cotes room calculator

4.4 System drawings

Figure 27, *Figure 30* and *Figure 31* are proposals of how the water and air systems can be designed. All componensts are coded so that it is easy for the SD system to diagnose and maintenance becomes easier.

The total water flow is calculated with formula:

[75]

$$q_{Tot} = q_{m\ 360\ 001} + q_{m\ 360\ 002} + q_{m\ radiator} = 0{,}268 l/s$$

$$q_{m\ 360\ 001} = \frac{20\ 000\ J/s}{1000 kg/m^3 \times 4184 J/(kg \times K) \times (50-30)K} \times 1000 l/m^3 = 0{,}24 l/s$$

The other waterflows were calculated in the same matter as the one from system 360 001

$$q_{m360\ 002} = 5{,}975 \times 10^{-3} l/s$$

$$q_{m\ radiator} = 0{,}023 l/s$$

The temperature of the water into the heat battery that heats opp the air to the environmental chamber may be to low to heat up to the desired temperature.

4.4.1 320 001

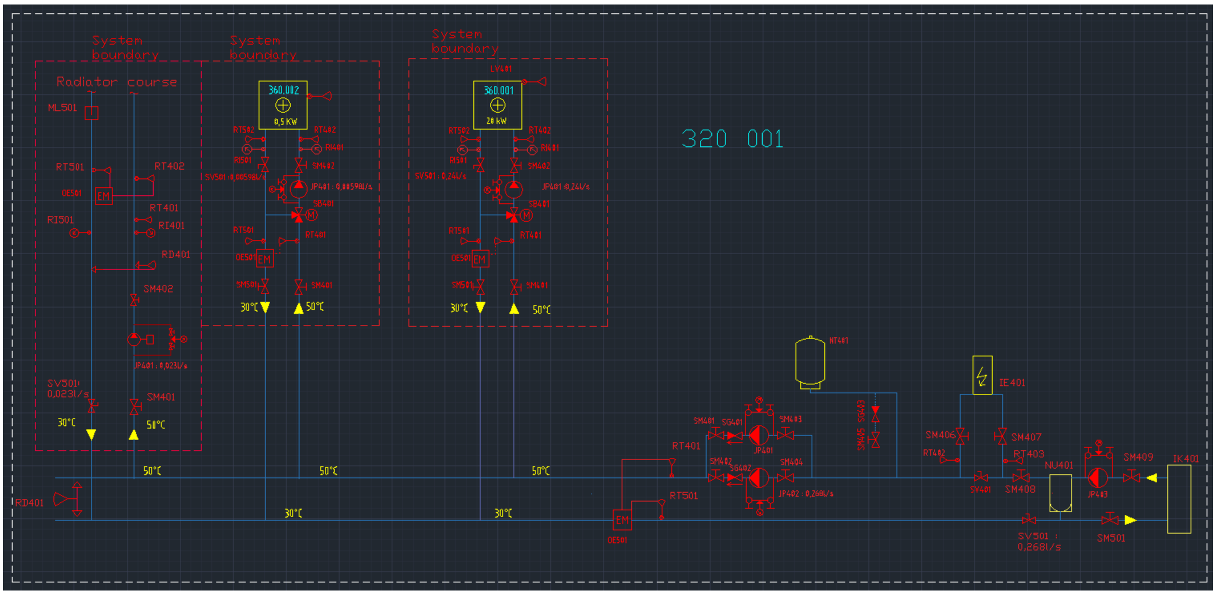


Figure 27, Watersystem

System 320 001 shows the water flowing to the different heat contributors all through the building. The idea is to use as little space as possible to the most affordable price. In conversations with different people with much experience and expertise, the solution regarding not deliver to hot water to the heat pump *Figure 28* was regarded as the best and cheapest way of action.

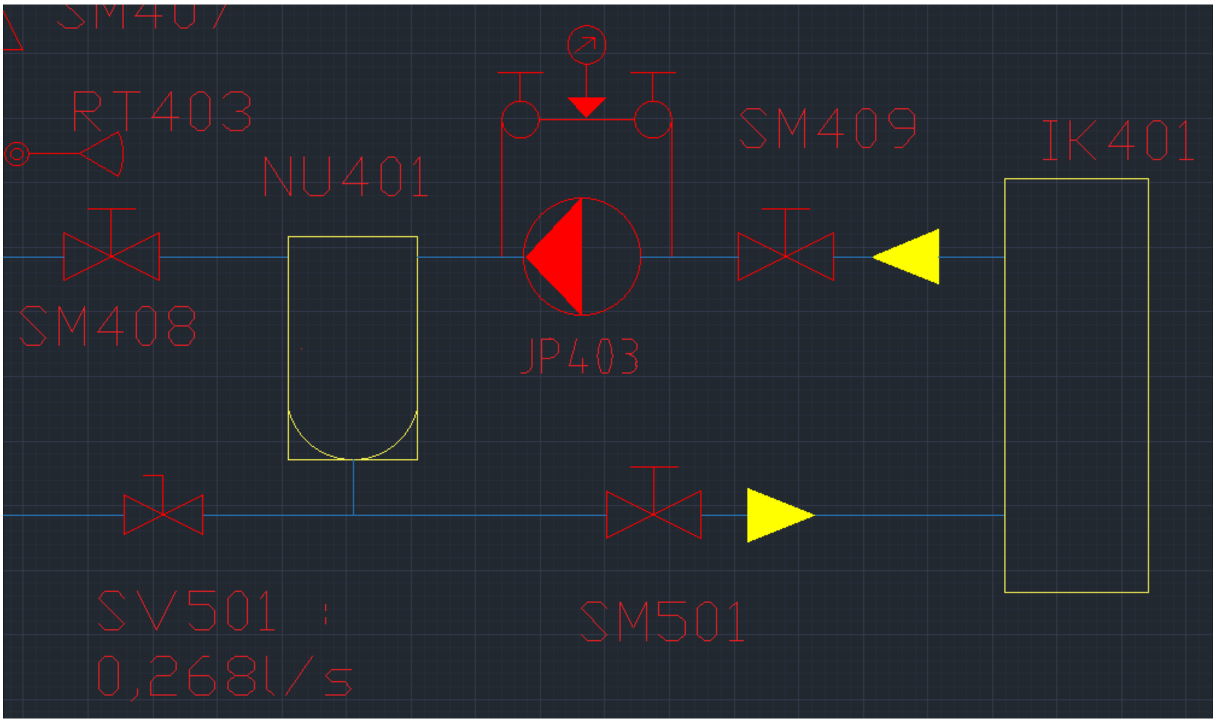


Figure 28, Water circulation between NU401 and IK401

System 320 001 is a figure that shows the water flowing to the different heat contributors all through the building. The idea is to use as little space as possible to the most affordable price. In conversations with different people with much experience and expertise, the solution regarding not deliver to hot water to the heat pump *Figure 28* was regarded as the best and cheapest way of action. [71]

In conversation with the same experts, the regulation of water to the heat batteries was discussed. In *Figure 29* some of the experts argued that the pump was regulated regarding water flow, and therefore it is no need for valve: SV501. The system is not big enough that this will do any difference in the case of running the building. And other people of expertise argued that the deviation of the pump, JP 401, is too big. When in full use the deviation is up to 20%. The problem they argued is not in full use, but when the pump is running with less than 100% capacity. When reduced to 50% capacity the deviation on the pump is still 20% of the 100% capacity. This can become a problem when the use of the facility is under 100%, for example, a spring day where there is little, but some use of the building. The heat battery can experience to little water. It comes down to price on the valve, and how accurate measurements of the water flow the costumer's desire.

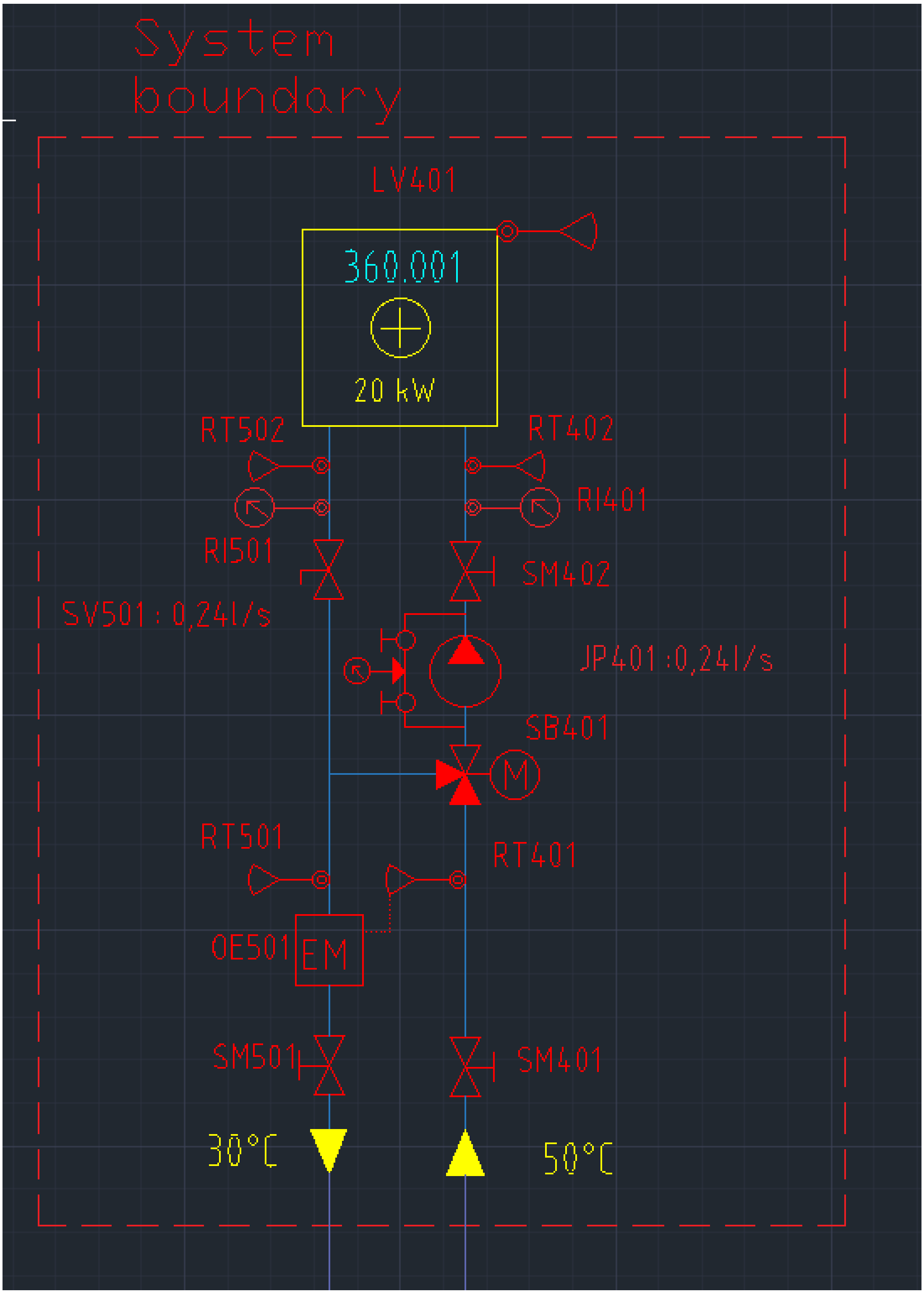


Figure 29, Heat battery

4.4.2 360 001

Figure 30 shows the proposed design of the aggregate that controls airflow in and out regarding the facility except for the environmental chamber. System 350 002 illustrates a split unit and a cooling battery in a parallel circuit. The split unit has one outside part as mentioned in. *4.1.1*

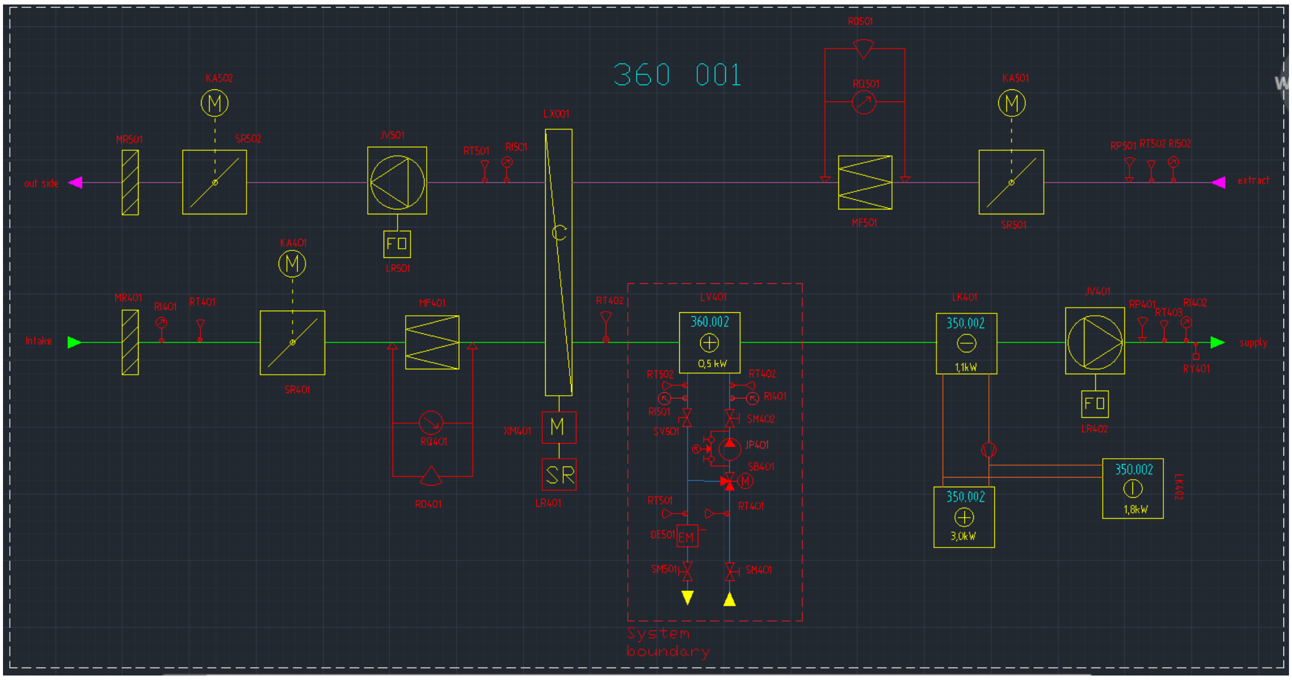


Figure 30, Air handling unit

4.4.3 360 002

Figure 31 shows the proposed design for the COTES simulation results. The idea is to reuse as much energy as possible and still use simple components. In figure 23 the component named: "mixer", is illustrated with four dampers which are regulated whit motors to mix the air correctly. In system 350 002 there is also an outside part to get rid of the heat. This heat is not reused in any of the systems. For the heat battery that is delivering a temperature up to 125 °C as *Figure 24* shows the easiest solution is an electric battery because the high-temperature water will not be easy to use because water evaporates. In system 350 001 the heat from the compressor is reused in the heating prosses of the air which shall carry the water out of the inlet air. In figure 23 system 360 001 has a water temperature of 50 °C in and 30 °C out, and the temperature in the room is sett to reach 50 °C. that means that the final heat battery will not likely be able to deliver necessary heat. That is the way a secondary backup heat battery may be necessary to reach the wanted end temperature.

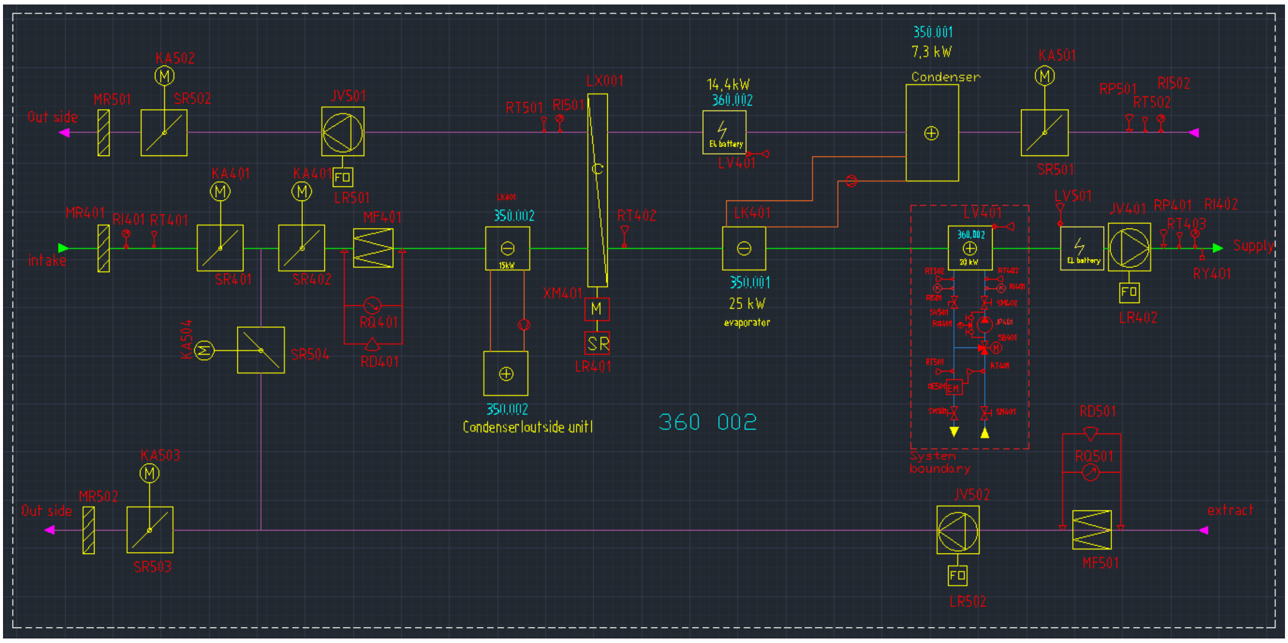


Figure 31, Air handling unit

4.5 Cost analysis and component list results

An approximately cost analysis is conducted for the technical system, which includes both HVAC systems. The prices are list prices without taxes, discount for ventilation contractors and mounting costs. Prices for the water ducts is not calculated and will need further research.

Room	Product	Price [NOK]
Training chamber	Dehumidifier including cooling batteries	350 000
Training chamber	Humidifier inc. necessary equipment	100 000
Training chamber	Control system	80 000
Training chamber	Ducts	28720
Training chamber	Valves	13728
Training chamber	Dampers	16466
Training chamber	Silencer	740
	Total	589 654
Locker, hall and Control	Air handling unit inc. control system	78 430
Locker, hall and Control	Heat pump	67 827
Locker, hall and Control	Ducts	22976
Locker, hall and Control	Valves	2067
Locker, hall and Control	Dampers	5170
Locker, hall and Control	Silencer	846
Locker, hall and Control	Radiators 3 pieces	18000
Locker, hall and Control	Tank inc. peak load	10875
Control	Air split unit	70000
	Total	276 191

Table 3, Cost analysis and components

4.6 Running costs

To find the operating costs for the building, a total effect demand is calculated. This is done for both the cooling and heating parts. The locker room, hallway, and control room values are determined in SIMIEN. The values for the environmental chamber are calculated with COTES room-calculator. A "worst-case" scenario, running costs over a year, and maximum heating with very low temperature outside are all calculated.

4.6.1 Cooling worst case

Locker and hallway: $53\ W$

Control room: $1733\ W$

Environmental chamber: $10.4kW + 20.6kW + 11.6kW \quad = 42.6kW$

Total: $53W + 1733W + 42600W =$44386W

This effect demand is captioned as the "worst-case" scenario on a hot summer day in Bergen with dimensioning outdoor temperature practiced, which is 25 $°C$. To calculate the cost, an electricity price in Norway from Q4 in 2019 for service industries is used. At this point, the electricity price for this industry was 0.431 kroner/kWh (0.0349 BP/kWh). [76]

Operating costs:

$$\frac{44386W}{\frac{1000W}{kW}} * \frac{0.431kroner}{kWh} = 19.13kroner/h$$

This expense excludes all technical equipment in the rooms, lighting, and fan power. The number might be higher when accounting for building physics.

4.6.2 Heating worst case

Dimensioning outdoor temperature is utilized to get a "worst-case" scenario about the cost of running the system for one hour.

Heat pump: $\frac{1.9kW+17.2kW}{3} \approx 6.4kW$

Where 1.9 kW is taken from SIMIEN and $17.2kW$ from Cotes room calculator.

Regulation air environmental chamber: 11.6 kW

Operating cost:

$$(6,4kW + 11,6kW) * \frac{0,431kroner}{kWh} = 7.76\ kroner/h$$

This cost excludes technical equipment in the rooms, lightning, fan power and humidification.

4.6.3 Maximum heating winter

The heating battery for the environmental chamber has a maximum power of 25kW which means the highest temperature difference that is possible to get is given as:

$$\frac{25kW}{\frac{1.2kg}{m^3} * 1\frac{kJ}{kg°C} * \frac{1075m^3}{h}\frac{1h}{3600s}} = \Delta T$$

$$\Delta T \approx 69.8°C$$

This means that if it is $-20°C$ in Bergen the highest temperature that it is possible to get is: $-20°C + 69{,}8°C = 49.8°C$

4.6.4 Heating and cooling over a year

To calculate the running cost over a year it is paid attention to the transmission heat loss, but not any other loss like for instance ventilation loss or infiltration loss. The internal loads are not paid attention to in this calculation. U-values that has been used is taken from TEK 17 §14-3, which contains energy qualities for a building. Instead of "worst-case" temperatures an average temperature for each month in Bergen is used. This might lead to a more exact result compared to "worst-case". Some assumptions are done and can be found in *Table 4*. It is assumed that the environmental chamber will be cooled and heated at an average of three hours each day, which means it will be 1095 (365*3) hours cooling and 1095 hours heating a year. This calculation is only done for the environmental chamber and not for control room, locker room and hallway.

It is not looked at the humidifer, which will use some energy. Therefore, the actual cost might be higher than described in the table. To find a more accurate cost over a year the humidifier needs to be included, this requires further research.

Roof [W/m²K]	Area roof [m²]	Wall [W/m²K]	Area wall [m²]	Floor [W/m²K]	Area floor [m²]	Window[W/m²K]	Area window [m²]
0,18	30	0,18	40	0,22	30	1,2	2
Month	Average. Temperatur [℃]		Transmission heat loss[W]	Ventilation heating [W]	Transmission heat loss cooling [W]	Ventilation cooling [W]	
January	1		1058,4	29875,0	518,4	37466,7	Assume RF 50%
February	0,7		1064,9	29767,5	511,9	37466,7	Assume RF 50%
March	2,3		1030,3	30340,8	546,5	37466,7	Assume RF 50%
April	4,9		974,2	31272,5	602,6	37466,7	Assume RF 50%
May	9,1		883,4	32777,5	693,4	37466,7	Assume RF 50%
June	11,9		823,0	33780,8	753,8	37466,7	Assume RF 50%
July	13,4		790,6	34318,3	786,2	37466,7	Assume RF 50%
August	13,6		786,2	34390,0	790,6	37466,7	Assume RF 50%
September	11		842,4	33458,3	734,4	37466,7	Assume RF 50%
October	7,7		913,7	32275,8	663,1	37466,7	Assume RF 50%
November	4,1		991,4	30985,8	585,4	37466,7	Assume RF 50%
December	1,9		1039,0	30197,5	537,8	37466,7	Assume RF 50%
		Total	11197,4	383440,0	7724,2	449600,0	

Total cost heating [NOK]		Total cost cooling [NOK]	
1240	Assume 3 hours heating each day	1523	Assume 3 hours each day
1116	Assume 3 hours heating each day	1522	Assume 3 hours each day
1257	Assume 3 hours heating each day	1524	Assume 3 hours each day
1251	Assume 3 hours heating each day	1526	Assume 3 hours each day
1349	Assume 3 hours heating each day	1530	Assume 3 hours each day
1342	Assume 3 hours heating each day	1532	Assume 3 hours each day
1407	Assume 3 hours heating each day	1533	Assume 3 hours each day
1410	Assume 3 hours heating each day	1533	Assume 3 hours each day
1331	Assume 3 hours heating each day	1531	Assume 3 hours each day
1330	Assume 3 hours heating each day	1528	Assume 3 hours each day
1240	Assume 3 hours heating each day	1525	Assume 3 hours each day
1252	Assume 3 hours heating each day	1523	Assume 3 hours each day
15527		18331	

Table 4, Costs of heating and cooling

To keep the environmental chamber cooled down to -23 $°C$ 1095 hours a year with the assumption that the average relative humidity in Bergen is 50% it will cost: 18331, - NOK.

To keep the environmental chamber at $50°C$ 1095 hours a year with explained assumptions it will cost: 15527, - NOK.

5. Discussion

5.1 NS 3031

As explained in *section 2.1* the guideline NS 3031 has been withdrawn by Standard Norge. [77] In the HVAC industry it has been a discussion about making a new standard, revise NS 3031, or using an international standard that is attached better to Building Information Modeling (BIM). [78] The industry pointing at NS 3031 is simply due to manual calculation should not be too complicated, but when using BIM it is to simplify. [78] Standard Norge is a member of European Committee for Standardization (CEN). For this reason, NS 3031 needed to be withdrawn because Standard Norge has committed that NS 3031 creates conflict with European standards. Since the Norwegian regulations refer to NS 3031 this is still used in the thesis. The standard that conflicts with NS 3031 is the European standard NS-EN ISO 52000-1. [77] SIMIEN is directly connected to NS 3031 and use this standard to verify if the building meets the requirements in the standard. In this thesis, the standard has been used because this is the recommendation from Standard Norge. According to Jens O Gran in Standard Norge, a temporary solution will be released. The standard is called SN-NSPEK 3031 and will work temporarily as a reference document towards TEK 20 and Energimerkeordningen. [79]

Since building students are writing a bachelor thesis about BIM this could have been used as a solution to find energy requirements and airflow in the different rooms. In some BIM programs, it is also possible to use a CFD analysis to find out the movement of the air in the given room. By using these tools, the calculations would have been more dynamic and more connected to each other than with NS 3031. Due to this complexity, NS 3031 has been used to do calculations.

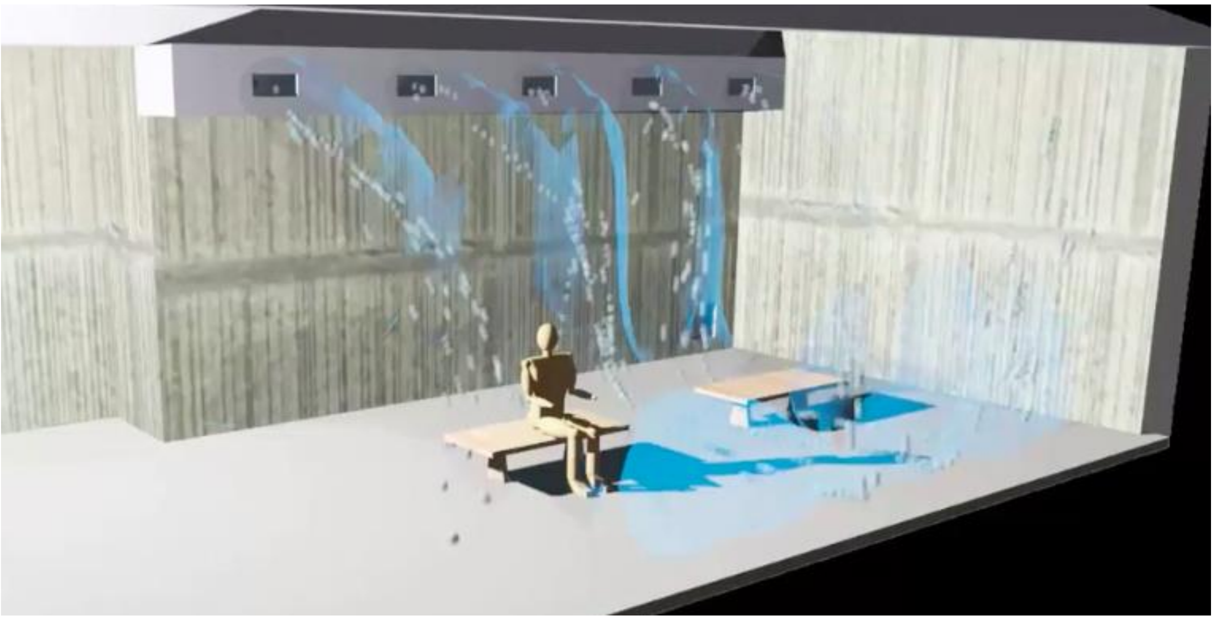


Figure 32, Showing inlet air flow [80]

5.2 The system in the environemtal chamber

5.2.1 Cooling

For the cooling part, other solutions have been discussed. First of all, a discussion about local cooling in the room was discussed. Important aspects that have been taken into account for moving away from this solution was the ability to change the temperature, sound level, and area efficiency. Therefore, the opportunity of getting one system for cooling, heating, and humidification using inlet air. One disadvantage of ventilation cooling is the low CP value. Water and other cooling refrigerants have a higher CP value, which leads to higher energy efficiency. Temperature and speed at inlet air are important so the athletes do not feel draft in the room, this is challenging with an HVAC cooling system. Therefore, the placement of air valves is crucial. A proposal of placement has been suggested in section *3.2.2*. To get an exact picture of the movement of the air in the room a CFD analysis is necessary.

5.2.2 Heating

Such as for the cooling part in the environmental chamber, local heating has been addressed. After discussing ventilation heating compared to heating in the room the final decision is inlet air heating. Arguments for and against are very similar to the cooling part. In addition to the arguments that are similar to the cooling part, a local heating system needs heaters or other heating elements that require space and also collect dust. People with much expertise and experience have expressed that heaters with high temperature might burn the dust on the surface of the heat elements, which will create a smell.

5.2.3 Humidity

From *Results from Cotes room calculator*, section *4.3* it is shown that the humidity will be a minimum of 8% with an internal load at 8 kg/h. If it is necessary to get it even dryer than this in the room, then another system or a dehumidifier will be needed. This can be a possible solution if 8% in RH is too high for the demands. The discussion about the necessary with a dehumidifier in the room has a few arguments for and against. The main advantage will be that it is possible to get the room even dryer, hence it will lead to a wider range of RH in the room. To get a comparison the relative humidity in the Sahara-desert has an average level at 25% and the environmental chamber manages 8%. [81] With a dehumidifier in the room it will also be a few disadvantages. The dehumidifier will occupy some of the space from the room, also increase the cost, and the automation of the system will be a bit more complex than only dehumidify the inlet air. To get a clear picture of how dry the room can be with a dehumidifier, further research needs to be done.

5.2.4 Airflow

Byggforskserien includes different numbers of airflow at different activity levels. This has been used to calculate the demand for airflow to the environmental chamber and control room, locker room and hallway. The material load that has been used might be higher or lower because of material is not chosen in the thesis. To calculate exact cooling and heating demand, building physic calculations needs to be done, this requires further research about materials in the chamber.

5.2.5 Refrigerant

The information in section *2.2.14* refrigerants, the use of HFK, HFO, and Blend are not recognized as a good environmental decision. Ammonia, Propane, and CO_2 are preferable options. As earlier explained, ammonia is some of the most affordable refrigerant on the market, but in this system, there will not be possible to use copper pipes. It requires a need for an oil separator, it might make up for the less expansive ammonia. Also, the high-temperature pressure from the compressor is a downside. CO_2 is a good option but often used in bigger systems. Smaller pipes can be an advantage and the CO_2 seem like a nice workable substance. After consulting with various people with much experience and expertise, the use of propane was considered as the best refrigerant in this project, due to the size of the system and project. The downside can be that the refrigerant is highly flammable.

5.2.6 Calculations

For both, heating and cooling it is done calculations about necessary effect demand and running costs for a “worst-case” scenario and yearly costs for heating. These calculations are estimated and might be higher with including solar irradiance, building physics, and humidification, but they will give an estimated price of running the chamber. A U-value for the door in the environmental chamber is not paid attention to, this might change the result of the running costs and also increase the effect needed. It is also calculated a maximum temperature at the inlet air with -20 $°C$ as outdoor temperature, this is done to get an indication about what happens if it is colder than -12 $°C$. This calculation is only observed at the required energy for cooling down the air too. The calculation in the result part shows that with -20 $°C$ as an outdoor temperature it will not be possible to get in the chamber, but very close without paying attention to any other than cooling effect. According to YR.no climate data coverage from the last 5 years, the coldest it has been at Florida in Bergen is. Climate data coverage from YR.no from the last 5 years at Florida in Bergen is used to find the highest temperature from 2015 to 2020. These values tell that it has been higher temperatures than the dimensioning outdoor temperature in Bergen every year during the last five years. In 2019 the maximum temperature at the measure station at Florida, Bergen was. Because of the cooling battery after the desiccant wheel, it might be possible to still cool down the inlet air. As explained in section *2.1.1* a new normal period is coming next year, it might be interesting to look at the new dimensioning outdoor temperature and take that in consideration when designing the cooling batteries and PLS system for the chamber. Because the temperature after the desiccant wheel it is not done.

6. Conclusion and further work

6.1 Conclusions

A HVAC system including *humidification*, that allows human sub. and comsumer products to experience a range of environmental conditions determent by temperature and humidity is designed. This includes all technical installations that are necessary to meet the requirements.

The environmental chamber will be able to go from -20 to 50 $°C$ with a change in relative humidity from 8% - 95%. System drawings from Autocad and data from COTES makes these requiremnts possible.

A breakthrough in the research was to change the dew point in the cooling part. This led to a solution with a dehumidification process before cooling down the inlet air. Both, heating and cooling are designed to be done by the inlet air. An important aspect that has been taken into account is the space-efficiency this system is compared to heat and cooling in the chamber. The products that has been used is “off the shelf” products, with a cost analysis of estimated price for the technical system included in result part. Where the estimated price for the technical system in the building is 870,000, - NOK excluded the mounting costs.

6.2 Further work

There is still some further work that needs to be done to complete the design of the building.

- Building physics must be researched to give an exact energy demand
- Optimize the use of excess heat from system *360 002*
- Pressure loss in ducts
- Prices of water ducts
- Price of mounting costs
- Draw every HVAC component into the 3D model
- Soundlevel of the components
- Research if it is necessary with heating cables under environmental chamber
- CFD analysis of air stream in the rooms, especially for the environmental chamber
- Calculate more accurate energy savings from solar film at roof

7. References

[1] Statsbygg, «Eksempel TFM Komponentkoding,» Statsbygg.no, 5 February 2019. [Internett]. Available: https://www.statsbygg.no/globalassets/files/publikasjoner/prosjekteringsanvisninger/0_generelle/pa_0702_vedlegg2eksempeltfmkomponentkoding.pdf. [Funnet 25 April 2020].

[2] M. N. PhD Sawka, J. D. PhD Periard og S. PhD Racinais, «Heat acclimatization to improv athletic performance in warm-hot environments,» *Sports Science Exchange* , vol. 28, nr. 153, pp. 1-6, 2015.

[3] Weather Atlas, «Monthly weather forecast and climate Doha, Qatar,» Weather Atlas, 1 January 2020. [Internett]. Available: https://www.weather-atlas.com/en/qatar/doha-climate#temperature. [Funnet 30 Mach 2020].

[4] Weather Atlas, «Monthly weather forecast and climate Singapore, Singapore,» Weather Atlas, 1 Januar 2020. [Internett]. Available: https://www.weather-atlas.com/en/singapore/singapore-climate#climate_text_1. [Funnet 30 Mars 2020].

[5] S. B. Strømme og H. T. Hammel, «Physiology.org,» Jurnal of applaed physiology, 01 December 1967. [Internett]. Available: https://journals.physiology.org/doi/abs/10.1152/jappl.1967.23.6.815. [Funnet 30 Mach 2020].

[6] R. J. Grant, «Climatic Training Facility,» 1 November 2019. [Internett]. Available: https://drive.google.com/drive/folders/1ue4rqnqBiKRuBamciaA4EVHo8rhN-yaH. [Funnet 5 Februar 2020].

[7] Olympiatoppen, «Olympiatoppen,» Norge, 1 January 1988. [Internett]. Available: https://www.olympiatoppen.no/om_olympiatoppen/page714.html. [Funnet 30 March 2020].

[8] Olympiatoppen, «Olympiatoppen,» Norge, 1988. [Internett]. Available: https://www.olympiatoppen.no/om_olympiatoppen/organisasjon/page725.html. [Funnet 13 March 2020].

[9] Olympiatoppen, «Olympiatoppen,» Norge, 1 January 1988. [Internett]. Available: https://www.olympiatoppen.no/om_olympiatoppen/aktuelt/page9613.html. [Funnet 3 March 2020].

[10] Welltech, «Welltech,» Well tech instrument Co, 1 October 1992. [Internett]. Available: http://www.temperature-humidity-chamber.com/news.html. [Funnet 22 February 2020].

[11] Hypoxico, «Hypoxico Altitude Training Systems,» Hypoxico, 1 January 1995. [Internett]. Available: https://hypoxico.com/product/altitude-room-conversion/. [Funnet 23 February 2020].

[12] Welltech, «News,» [Internett]. Available: http://www.temperature-humidity-chamber.com/news.html. [Funnet 10 April 2020].

[13] A. Blow, «Training Articles,» 10 August 2018. [Internett]. Available: https://www.trainingpeaks.com/blog/how-to-calculate-your-sweat-rate/.

[14] Kommunal- og moderniseringsdepartementet, «Lovdata.no,» 01 January 2020. [Internett]. Available: https://lovdata.no/dokument/NL/lov/2008-06-27-71. [Funnet 04 May 2020].

[15] Byggforskserien, «Hva er byggforskserien,» Byggforsk, [Internett]. Available: https://www.byggforsk.no/side/198/hva_er_byggforskserien?fbclid=IwAR1hqhcjkMXVab6QrQJHkZS8KPknguXfFm8LRAnwvcbr-Su3S8Zv4KfTQFY. [Funnet 05 May 2020].

[16] IBPSA-NORDIC, «Commercial software SIMIEN,» [Internett]. Available: http://ibpsa-nordic.org/commercial%20software/simien.html. [Funnet 4 February 2020].

[17] E. Sandberg, i *Prenøk Prosjektering av energianlegg*, Skarland press, 2020.

[18] N. Ecobox, «arkitektur.no,» 04 April 2020. [Internett]. Available: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=2ahUKEwiJ1qyXps7oAhXRyKYKHToZBt0QFjAAegQIBxAB&url=http%3A%2F%2Fwww.arkitektur.no%2Fstartpakke-arkitekter%3Fiid%3D355707%26pid%3DNAL-Article-Files.Native-InnerFile-File%26attach%3D1&usg=AOvVaw1xJCF0aCPmOur09-e0wWpr.

[19] Steinsvik Arkitekter AS, «Arkitektur.no,» 1 January 2015. [Internett]. Available: http://www.arkitektur.no/startpakke-arkitekter?iid=355707&pid=NAL-Article-Files.Native-InnerFile-File&attach=1. [Funnet 1 April 2020].

[20] Condair, «Condair,» 1 January 2020. [Internett]. Available: https://www.condairgroup.com/know-how/hx-diagram. [Funnet 9 April 2020].

[21] Condair, «Condair,» Condair, 1 January 2020. [Internett]. Available: https://www.condair.se/befuktning-raadgivare-installatorer/ix-och-hx-diagram. [Funnet 20 March 2020].

[22] T. Wigenstad, «Sintefbok.no,» 2009. [Internett]. Available: https://www.sintefbok.no/book/index/561/prosjektveileder_forenklet_anlegg_for_vannbaaren_oppvarming_av_boliger. [Funnet 25 March 2020].

[23] H. G. a. E. Tähti, Industrial Ventilation Design Guidebook, Canada: Academic press, 2001.

[24] A. Fakheri, «Link-Springer,» Springer, 27 Juni 2018. [Internett]. Available: https://link-springer-com.galanga.hvl.no/referenceworkentry/10.1007%2F978-3-319-26695-4_19#Sec1. [Funnet 30 Mars 2020].

[25] R. A.-W. G. M. M. B. M. Nasif, «Energy and buildings,» Science direct assets, 19 Mai 2010. [Internett]. Available: https://pdf.sciencedirectassets.com/271089/1-s2.0-S0378778810X00081/1-s2.0-S0378778810001829/main.pdf?X-Amz-Security-Token=IQoJb3JpZ2luX2VjEPj%2F%2F%2F%2F%2F%2F%2F%2F%2F%2FwEaCXVzLWVhc3QtMSJHMEUCIQCn3Xhd58j4aBy0i0aabVjhs4THBFAaoWVuIaqtv%2B9axwIgD1XzxcI2ns. [Funnet 30 Mars 2020].

[26] D. Zijdemans, «2.2.2.5 Ventilasjonsvarme,» i *Vannbaserte oppvarmings- og kjølesystemer*, Oslo, Skarland Press AS, 2012, pp. 53-54.

[27] TTC Norge AS, «TTC.no,» [Internett]. Available: http://www.ttc.no/wp-content/uploads/2017/11/Varmebatterier-HW.pdf. [Funnet 5 March 2020].

[28] D. Zijdemans, «2.3.2.3 Ventilasjonskjøling,» i *Vannbaserte oppvarmings- og kjølesystemer*, Oslo, Skarland Press AS, 2012, p. 61.

[29] Ø. Gran, «snl.no,» 14 February 2009. [Internett]. Available: https://snl.no/absolutt_fuktighet. [Funnet 07 May 2020].

[30] E. Samuelsen, «snl.no,» 06 September 2017. [Internett]. Available: https://snl.no/relativ_fuktighet. [Funnet 07 May 2020].

[31] Cotes, Regissør, *How does an absorption dehumidifier work?.* [Film].

[32] Munters, «Munters,» [Internett]. Available: https://www.munters.com/en/solutions/dehumidification/.

[33] Tekna, «Tekna,» 12 January 2016. [Internett]. Available: https://bygg.tekna.no/typiske-ventilasjonslosninger-i-naeringsbygg/. [Funnet 02 March 2020].

[34] P. henriksen, «VVSforum,» VVsforum, 10 April 2015. [Internett]. Available: https://www.vvsforum.no/2015/enkel-mate-a-forbedre-en-bygnings-energieffektivitet/. [Funnet 12 Februar 2020].

[35] N. C, Kompendium i Ventilasjonsteknikk, Tromsø: University of Tromsø, 2015.

[36] Lakeside, «Lakesideac,» Lakeside, 1 January 2020. [Internett]. Available: https://www.lakesideac.com/services/duct-work. [Funnet 8 February 2020].

[37] J. E. Brumbaugh, «Heating System Components, Gas and Oil Burners, and Automatic Controls,» i *Audel HVAC Fundamentals, Volume 2* , England, John Wiley & Sons, Incorporated, 2004, pp. 445-460.

[38] J. knudtsen, «Canvas,» Norconsult, 31 October 2019. [Internett]. Available: https://hvl.instructure.com/courses/9320/files?preview=629393. [Funnet 31 Mars 2020].

[39] Automatisk verden, «automatiskverden.no,» 28 November 2018. [Internett]. Available: https://www.automatiskverden.no/shuntventil/. [Funnet 23 March 2020].

[40] Mads Mysen, «SINTEF,» SINTEF, 19 November 2013. [Internett]. Available: https://www.sintef.no/contentassets/aab32f3b1f47475f91c7f61f46469b6d/mysen_prinsipplosninger-krav-og-kontroll.pdf. [Funnet 6 April 2020].

[41] S. G. Peter, «SINTEF,» PostDoc HiOA, 19 November 2013. [Internett]. Available: https://www.sintef.no/contentassets/aab32f3b1f47475f91c7f61f46469b6d/schild_innregulering-og-overlevering.pdf. [Funnet 29 January 2020].

[42] ITBguiden, «itbguiden,» ITB, 11 April 2018. [Internett]. Available: http://www.itbguiden.no/tverrfaglig-koordinering/riv-vvs/ventilasjon/. [Funnet 6 April 2020].

[43] C. Nystad, «uit.no,» 2017. [Internett]. Available: https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&ved=2ahUKEwiw69yshMLoAhXR-ioKHRfyCqUQFjACegQIARAB&url=https%3A%2F%2Fmunin.uit.no%2Fbitstream%2Fhandle%2F10037%2F12979%2FNystad%2520C.%25202017%2520Kompendium%2520i%2520Ventilasjonsteknikk.pdf%3Fsequence%3D3%26isAllowed%3Dy&usg=AOvVaw3WrnWJ2RueahNbOgm-QWlk. [Funnet 30 03 2020].

[44] P. G. S. Mads Mysen, «SINTEF,» SINTEF, 1 January 2013. [Internett]. Available: https://www.sintef.no/contentassets/aab32f3b1f47475f91c7f61f46469b6d/behovsstyrt-ventilasjon-dcv-krav-og-overlevering.pdf. [Funnet 7 April 2020].

[45] Institute of Public Health, «FHI,» 15 January 2015. [Internett]. Available: https://www.fhi.no/globalassets/dokumenterfiler/rapporter/2015/anbefalte-faglige-normer-for-inneklima-pdf.pdf. [Funnet 8 April 2020].

[46] Enoisecontrol, «Enoisecontrol,» 1 Januar 2020. [Internett]. Available: https://www.enoisecontrol.com/products/duct-silencers/. [Funnet 2 April 2020].

[47] L. A. B. a. A. V. R.-K. D. V. Bazhenov, «Link Springer,» Andreev Acoustics Institute, 25 February 1999. [Internett]. Available: https://link-springer-com.galanga.hvl.no/content/pdf/10.1134/1.29878.pdf. [Funnet 2 April 2020].

[48] Noise and vibration control, «Hush Duct,» BRD, 1 January 2020. [Internett]. Available: https://hushcore.net/wp-content/uploads/2016/09/Hush-Duct-v.3.pdf. [Funnet 2 April 2020].

[49] L. C. Y. T. J. P. Xiang YU, «Inter Noice,» The University of Western Australia, 16 November 2014. [Internett]. Available: file:///Users/eiriksvortevik/Downloads/Internoise2014.pdf. [Funnet 2 April 2020].

[50] DB Noise Reduction, «DB Noise Reduction,» DB Noise Reduction, 1 January 2020. [Internett]. Available: http://www.dbnoisereduction.com/technical_data_and_specifications/tds05_circular_silencers.php?p=vns&pp=dts. [Funnet 6 April 2020].

[51] KCRS, «Kinetics Noise Control,» Kinetics Noise Control inc., January 1 2020. [Internett]. Available: https://kineticsnoise.com/industrial/silencers/rectangular.html. [Funnet 3 April 2020].

[52] Noie Reduction, «DBNoise Reduction,» DB Noise Reduction, 1 January 2020. [Internett]. Available: http://www.dbnoisereduction.com/technical_data_and_specifications/tds01_rectangular_silencers.php?p=vns&pp=dts. [Funnet 3 April 2020].

[53] DB Noise Reduction, «DB Noise Reduction,» DB Noise Reduction, 1 January 2020. [Internett]. Available: http://www.dbnoisereduction.com/technical_data_and_specifications/tds01_rectangular_silencers.php?p=vns&pp=dts. [Funnet 4 April 2020].

[54] Standard Norge, «Standard,» Standard Norge, 1 September 2019. [Internett]. Available: https://www.standard.no/no/Nettbutikk/produktkatalogen/Produktpresentasjon/?ProductID=1045700. [Funnet 3 April 2020].

[55] Byggteknisk forskrift (TEK 17), «the building quality directorate,» building technical regulations, 1 January 2017. [Internett]. Available: https://dibk.no/byggereglene/byggteknisk-forskrift-tek17/13/iv/13-6/. [Funnet 3 April 2020].

[56] Labor Inspectorate, «Labor Inspectorate,» Norwegian State, 1 January 2020. [Internett]. Available: https://translate.google.com/?hl=no#view=home&op=translate&sl=no&tl=en&text=desibel. [Funnet 3 April 2020].

[57] Nydal, Roald, «7. Kuldeteknisk anlegg, Kompressoren,» i *Praktisk Kuldeteknikk*, Bergen, Roald Nydal, 2013, p. 44.

[58] R. Nydal, «Kuldemedier,» i *Praktisk kuldeteknikk*, Bergen, Roald Nydal, 2013, p. 47.

[59] L. Småland og J. Øverland, «Valg av Kuldemedier til bygningskilatisering,» *Norsk VVS*, vol. 63, nr. 01, p. 9, 2020.

[60] A. Johnson, «What are HFC REfrigerants?,» RefrigerantHQ, 13 September 2018. [Internett]. Available: https://refrigeranthq.com/what-are-hfc-refrigerants/. [Funnet 06 April 2020].

[61] European commission, «The Montreal Protocol,» 2007. [Internett]. Available: https://ec.europa.eu/clima/sites/clima/files/docs/montreal_prot_en.pdf. [Funnet 06 April 2020].

[62] Varmepumpeinfo.no, «Hva er COP,» Varmepumpeinfo.no, 31 January 2019. [Internett]. Available: https://www.varmepumpeinfo.no/sporsmal-og-svar-om-varmepumper/hva-er-cop. [Funnet 06 April 2020].

[63] R. Tamum, «What you need to know about theHFC refrigerant phase-out,» Facilitiesnet, 7 October 2017. [Internett]. Available: https://www.facilitiesnet.com/hvac/article/What-You-Need-To-Know-About-the-HFC-Refrigerant-Phase-Out--17286. [Funnet 06 April 2020].

[64] C. Schaschke, «A Dictionary of Chemical Engineering,» i *Dictionary of Chemical Engineering*, Oxford, Oxford Paperback Reference , 2014, pp. 75-78.

[65] The Editors of Encyclopaedia Britannica , «Britannica,» ENCYCLOPÆDIA BRITANNICA, 8 January 2018. [Internett]. Available: https://www.britannica.com/technology/condenser-cooling-device. [Funnet 15 April 2020].

[66] B. Orr, «HVAC School,» HVAC School, 1 March 2019. [Internett]. Available: https://www.hvacrschool.com/tag/condenser/. [Funnet 19 February 2020].

[67] ENOVA, «Purchasing supervisor, air to water heat pump,» 1 February 2019. [Internett]. Available: file:///Users/eiriksvortevik/Downloads/Kj%C3%B8psveileder%20luft-til-vann-varmepumpe.pdf. [Funnet 17 April 2020].

[68] J. Stene, «Sintef energy research,» SINTEF, 20 January 2006. [Internett]. Available: https://www.sintef.no/globalassets/project/annex32/oppvarmingssystemer_tra6182_20061.pdf. [Funnet 17 April 2020].

[69] Novemacooling, «Novema cooling AS,» 1 January 2020. [Internett]. Available: https://novemakulde.no/01/dot20_10.pdf. [Funnet 17 April 2020].

[70] Shutterstock, «Shutterstock,» Shutterstock, 1 January 2015. [Internett]. Available: Typical energy sources for low-temperature systems are heat pumps and solar collectors. With a low-temperature system the water temperature will be around 40-45 °C. A high-temperature heat system comprises near –and district heating systems, bio boiler, p. [Funnet 7 February 2020].

[71] Kompetansebiblioteket, «Kompetansebiblioteket,» NemiTek, 1 February 2017. [Internett]. Available: http://kompetansebiblioteket.no/Varmenormen/5_Varmeavgivere_og_kjoleelementer/4_5_8_Varmepumper.aspx?searchStr=dimensjonering%20varmepumpe. [Funnet 3 May 2020].

[72] GreenMatch, «Heat pump,» GreenMatch, 16 October 2019. [Internett]. Available: https://www.varmepumpe-pris.no/luft-til-vann-varmepumpe. [Funnet 17 April 2020'].

[73] NAL ECOBOX, «Architecture,» NAL ECOBOX, 1 January 2018. [Internett]. Available: file:///Users/eiriksvortevik/Downloads/4_energi%20(2).pdf. [Funnet 6 May 2020].

[74] SINTEF byggforsk, «421.503 Luftmengder i ventilasjonsanlegg. Krav og anbefalinger,» SINTEF byggforskserien, 1 December 2017. [Internett]. Available: https://www-byggforsk-no.galanga.hvl.no/dokument/2753/luftmengder_i_ventilasjonsanlegg_krav_og_anbefalinger. [Funnet 6 February 2020].

[75] S. B. Ole., «Komponenter,» i *Ventilation Ståbi*, 1471 København K, PRAXIS - Nyt Teknisk Forslag, 2015, pp. 294-296.

[76] Statistisk Sentralbyrå, «ssb.no,» 13 February 2020. [Internett]. Available: https://www.ssb.no/elkraftpris. [Funnet 06 May 2020].

[77] Standard Norge, «standard.no,» 01 January 2018. [Internett]. Available: https://www.standard.no/nyheter/nyhetsarkiv/energi-og-klima/2018-nyheter/beregning-av-bygningers-energiytelse--gjelder-ns-3031-fortsatt/. [Funnet 01 March 2020].

[78] Building Smart, «Building Smart,» 10 November 2013. [Internett]. Available: https://buildingsmart.no/nyhetsbrev/2013-10/er-ns-3031-for-simplifisert-til-a-brukes-i-energisimulering. [Funnet 31 March 2020].

[79] J. Gran, Interviewee, *Employer Standard Norge.* [Intervju]. 01 April 2020.

[80] Autodesk, Regissør, *Building HVAC.* [Film].

[81] K. Loudin, «Rumer Loudin,» 10 December 2013. [Internett]. Available: https://www.rumerloudin.com/2013/12/how-low-humidity-affects-you-and-your-home/.

[82] S. H. Knut, «DIBK,» Direktoratet for byggkvalitet, 12 April 2012. [Internett]. Available: https://dibk.no/globalassets/byggesaksdagene/tek03sandli.pdf?fbclid=IwAR3j15_oDyXaGC9lIKA96cJQMv7wPNqK3JmfSfjWP2ixeH6em7rYXyx82PQ. [Funnet 6 May 2020].

8. List of figures

List of tables

Appendex A.1

This is a standard table used to determined airflow in different zones.

Rom nr.	Romfunksjon	Ventilasjonsprinsipp			
		Fortrengning	Omrøring	Gulvareal m^2	Person-belastning (antall)
1	Training chamber	☐	☐	30	4
2	Changing room	☐	☐	8,4	
3	Comtrol room	☐	☐	6,9	2
4	Hall	☐	☐	13,7	4

Table 5, Airflow table

Rom nr.	Romfunksjon	Faktorvurdering ved prosjekteringen, luftmengder					
		a) Personbelastning		b) Byggematerialer/ inventar		c) Prosess og aktivitet, ev. kjemikalier	a) + b) + c)
		Per pers m^3/h [a]	l/sek	Per m^2 [b]	l/sek	l/sek	l/sek
1	Training chamber	250		2,5	0,7	0	
2	Changing room	26	7,22	2,5	0,7		
3	Comtrol room	26	7,22	2,5	0,7		
4	Hall	26		2,5	0,7		

Table 6, Airflow table [74] [82]

Rom nr.	Romfunksjon	utvidelse	Valgt ventilasjon		
		a) + b) + c)	Tilluft	Avtrekk	Luftv.
		m^3/h	m^3/h	m^3/h	l/m^2
1	Training chamber	1075	1075	1075	
2	Changing room	21		159,25	
3	Comtrol room	69,25		69,25	
4	Hall	138,25	159,25		

Table 7, Airflow table

Appendex A.2

SIMIEN
Resultater sommersimulering

Summer results

Simulated with highest possible heat in the different rooms.

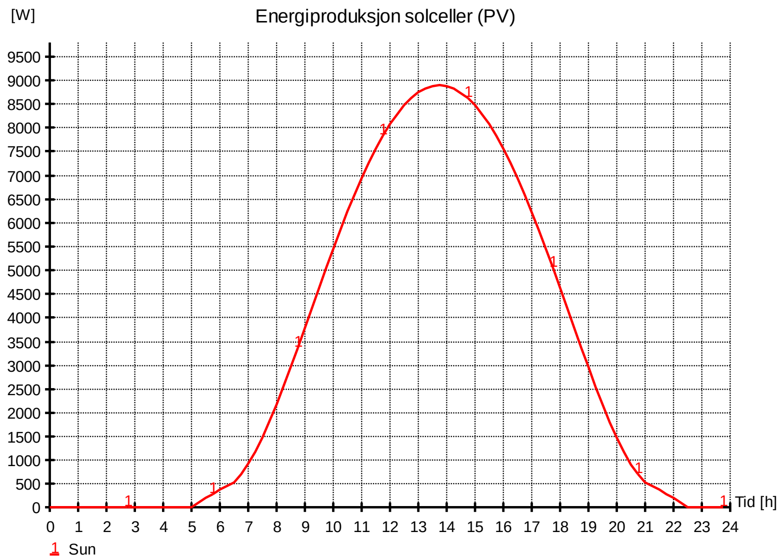


Figure 33,

Control room

Sammendrag av nøkkelverdier for KR		
Beskrivelse	Verdi	Tidspunkt
Maks. inneluftttemperatur	22,6 °C	18:15
Maks. operativ temperatur	22,7 °C	18:15
Maks. CO2 konsentrasjon	767 PPM	16:00
Maksimal effekt kjølebatterier:	466 W / 67,5 W/m²	14:45
Installert effekt kjølebatterier	207 W / 30,0 W/m²	14:45
Maksimal effekt lokal kjøling:	1733 W / 251,1 W/m²	14:15
Installert effekt lokal kjøling	1290 W / 187,0 W/m²	14:15

Figure 34,

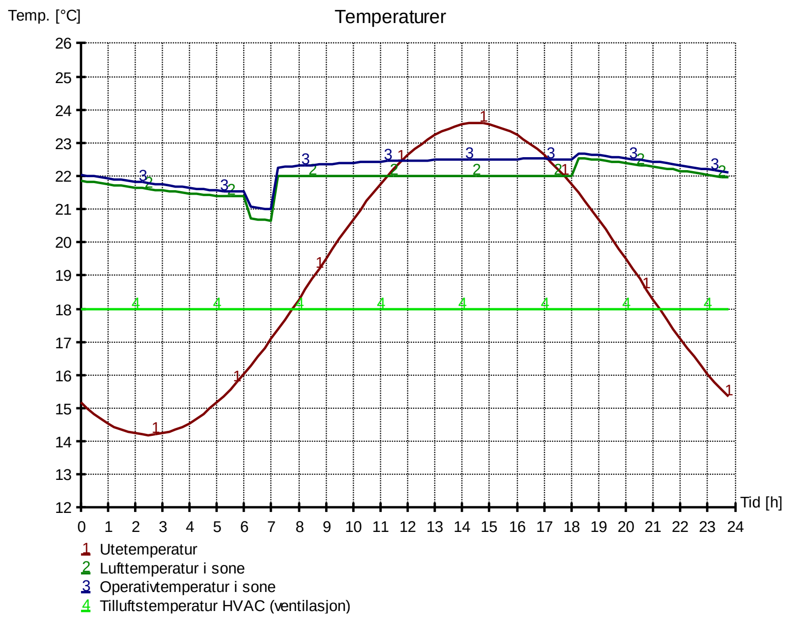


Figure 35,

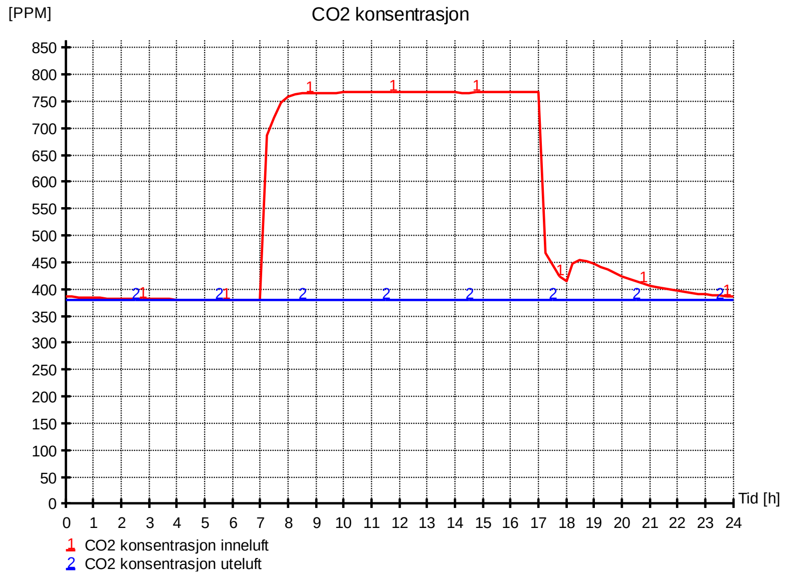
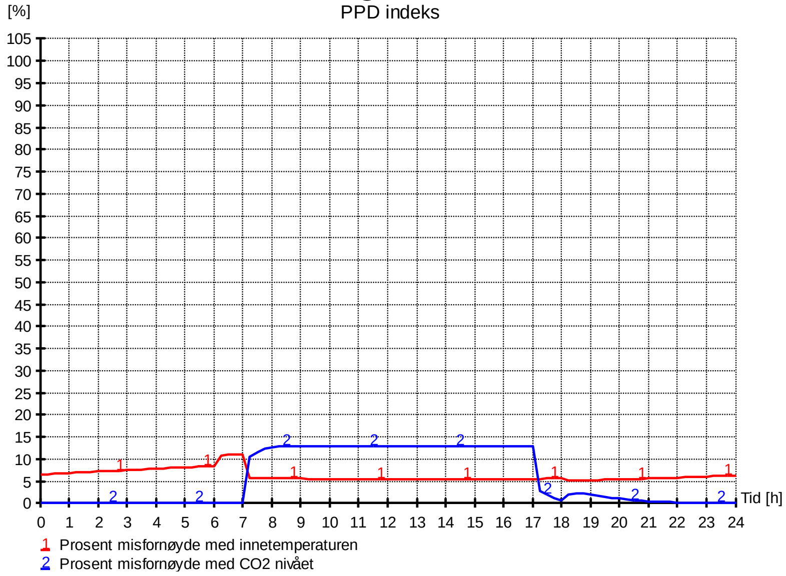


Figure 36,



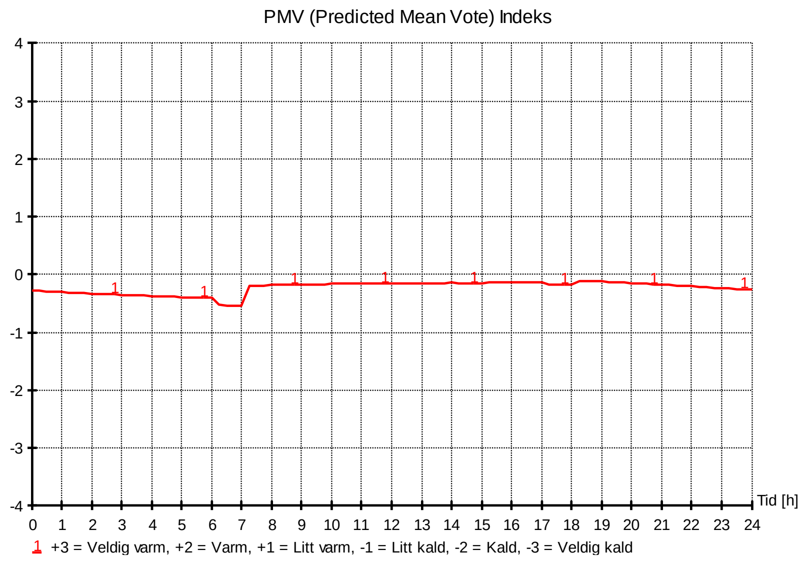


Figure 37,

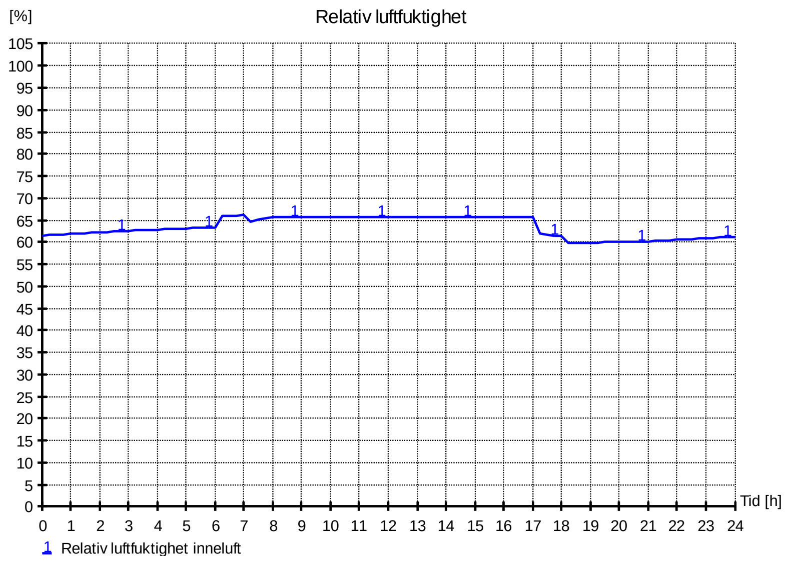


Figure 38,

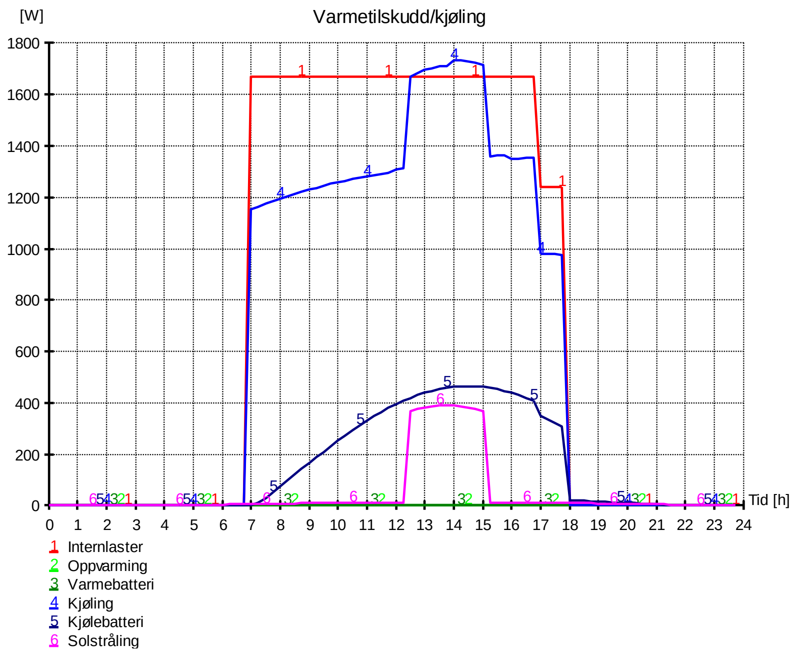


Figure 39,

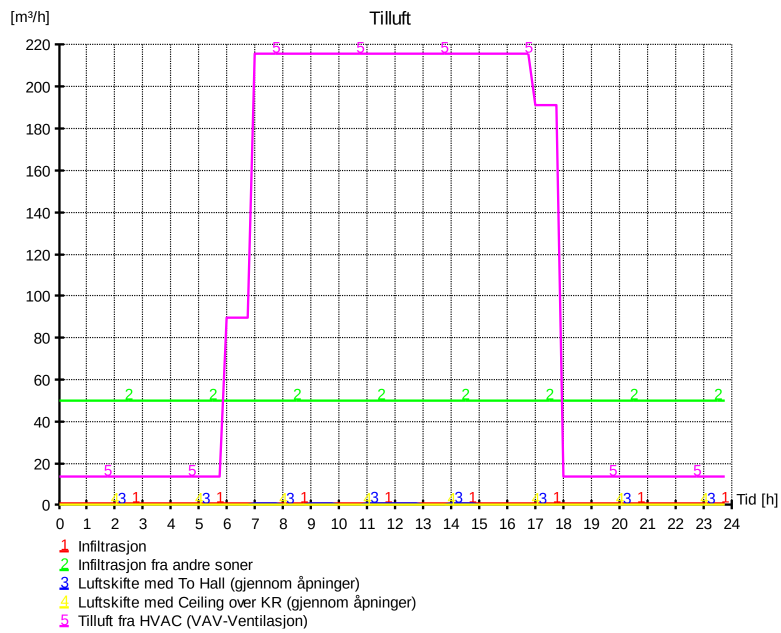


Figure 40,

Hallway and locker room

Sammendrag av nøkkelverdier for Hall and locker room		
Beskrivelse	Verdi	Tidspunkt
Maks. inneluftttemperatur	23,0 °C	15:45
Maks. operativ temperatur	23,0 °C	16:00
Maks. CO2 konsentrasjon	687 PPM	15:00
Maksimal effekt kjølebatterier:	619 W / 28,0 W/m²	14:45
Installert effekt kjølebatterier	906 W / 41,0 W/m²	14:45
Maksimal effekt lokal kjøling:	53 W / 2,4 W/m²	15:00
Installert effekt lokal kjøling	884 W / 40,0 W/m²	15:00

Figure 41,

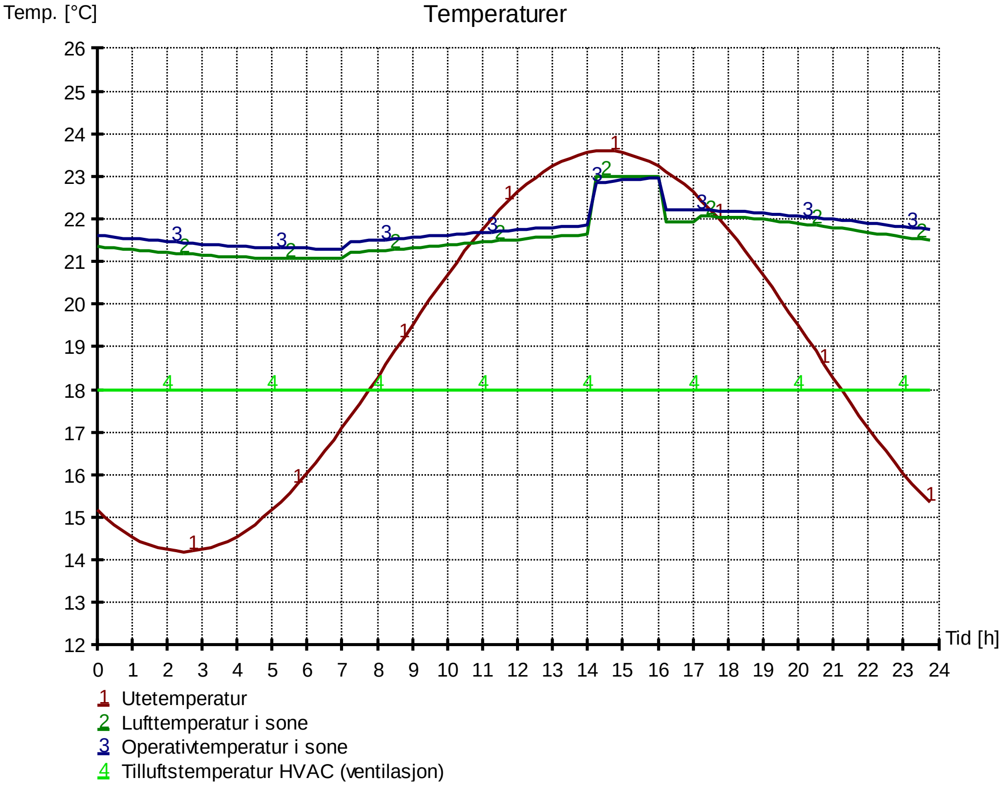


Figure 42,

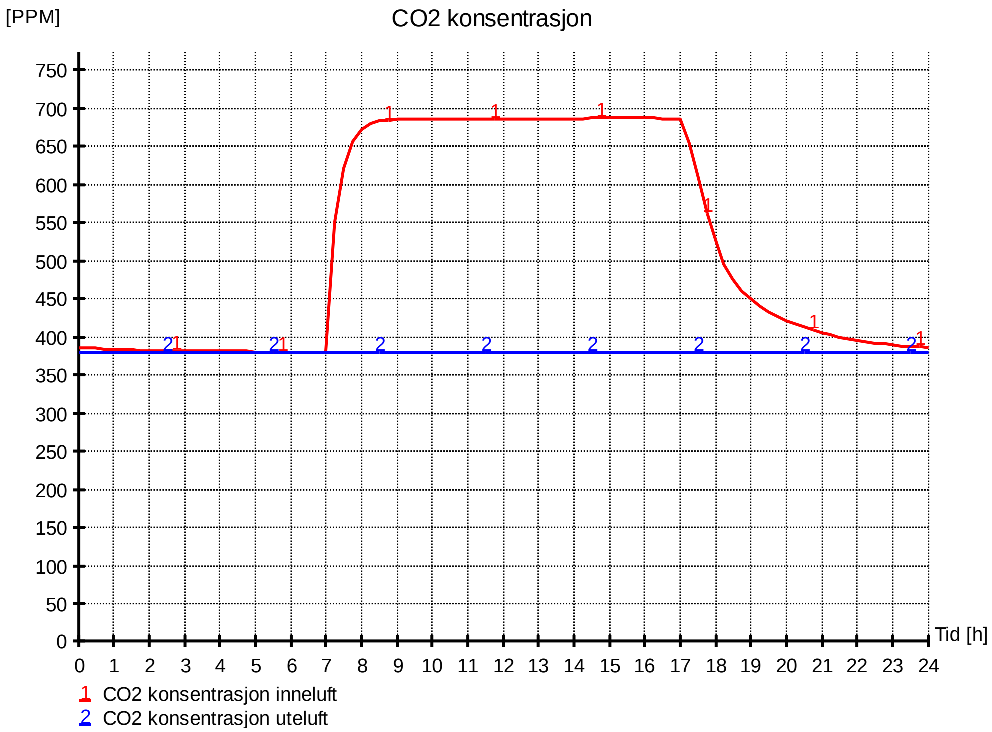


Figure 43,

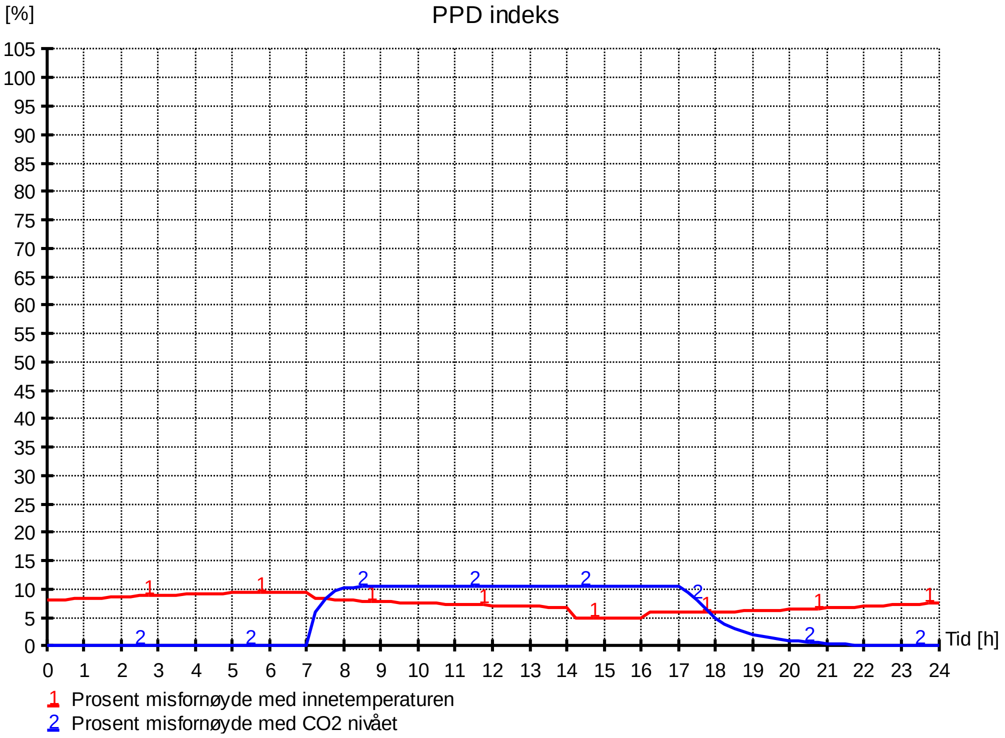


Figure 44,

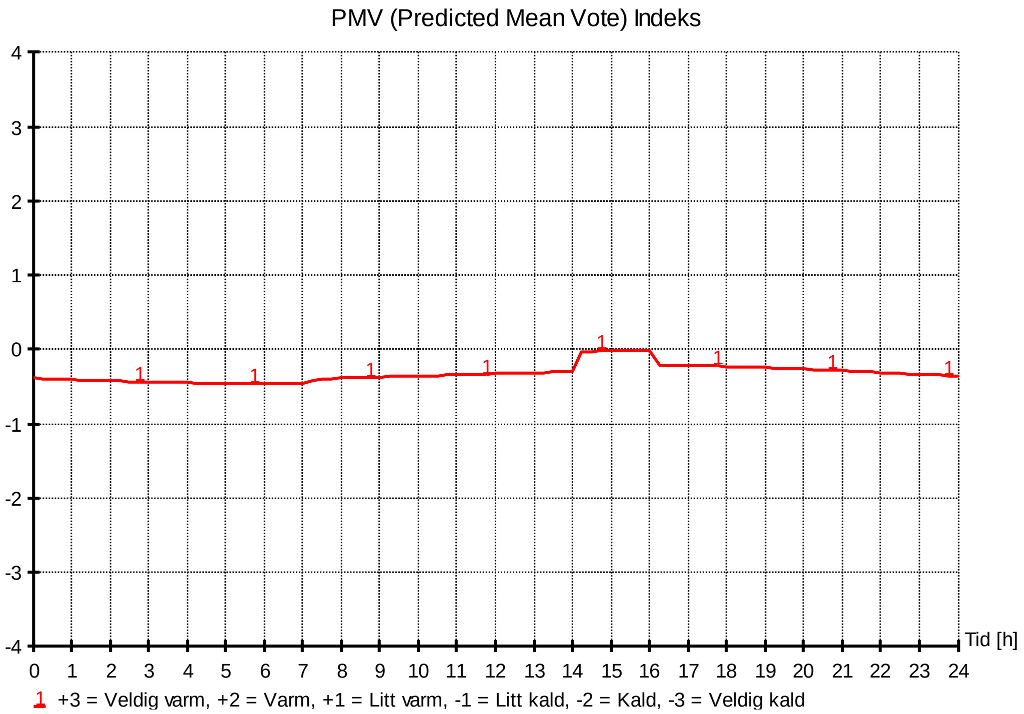


Figure 45,

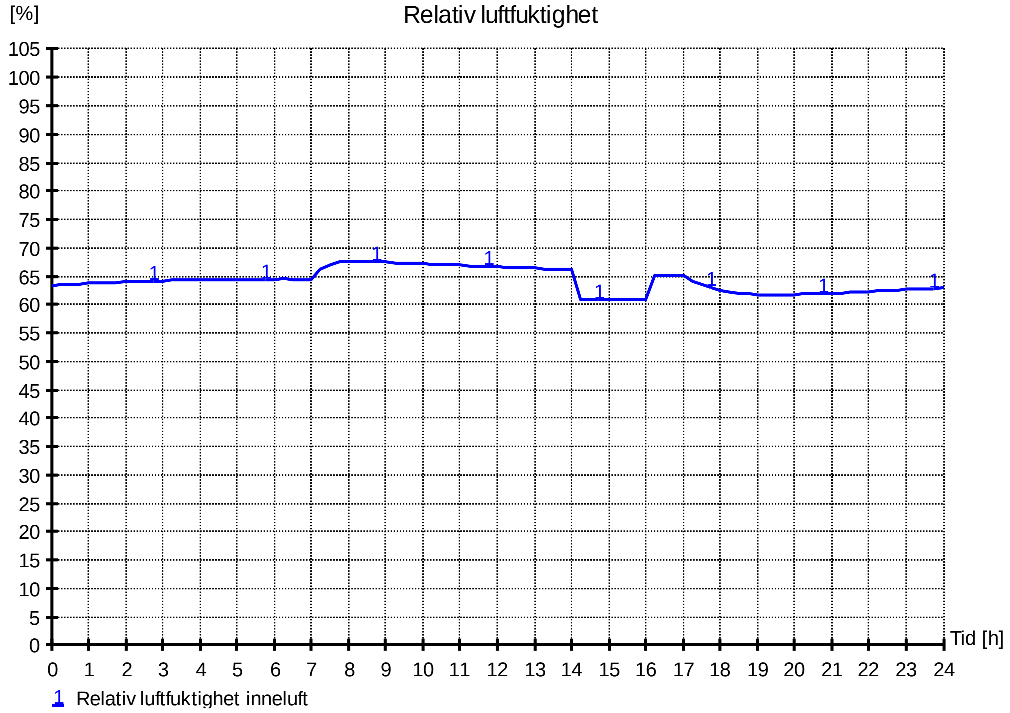


Figure 46,

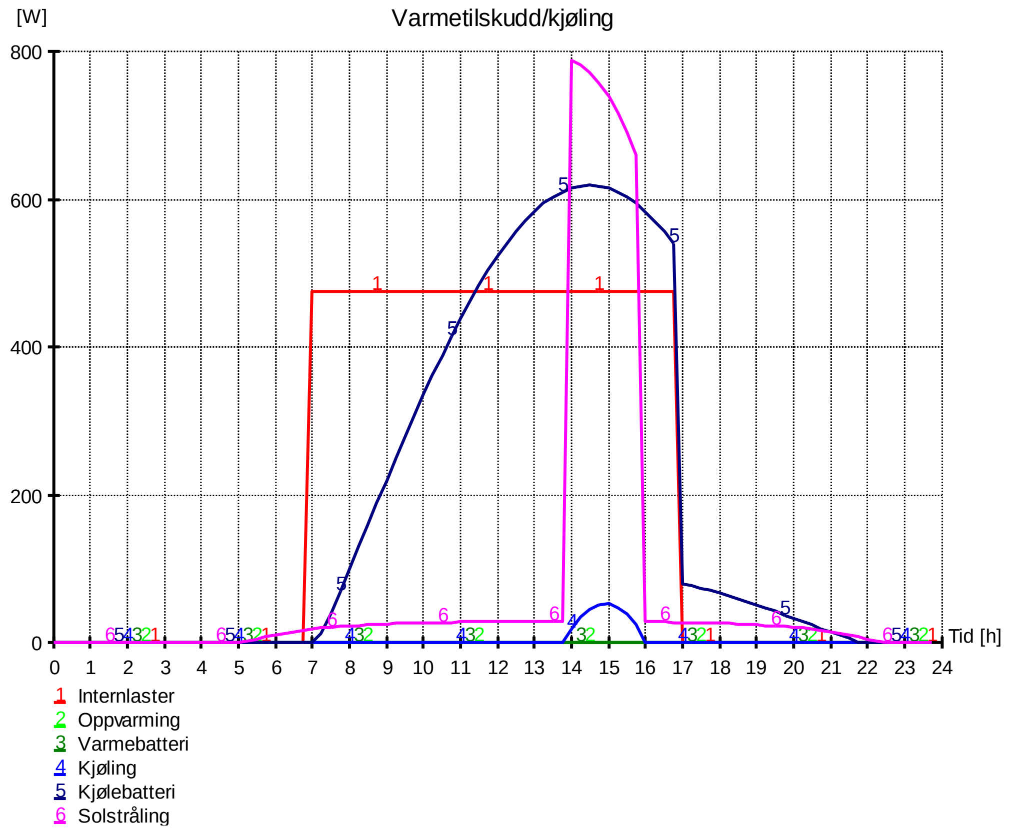


Figure 47,

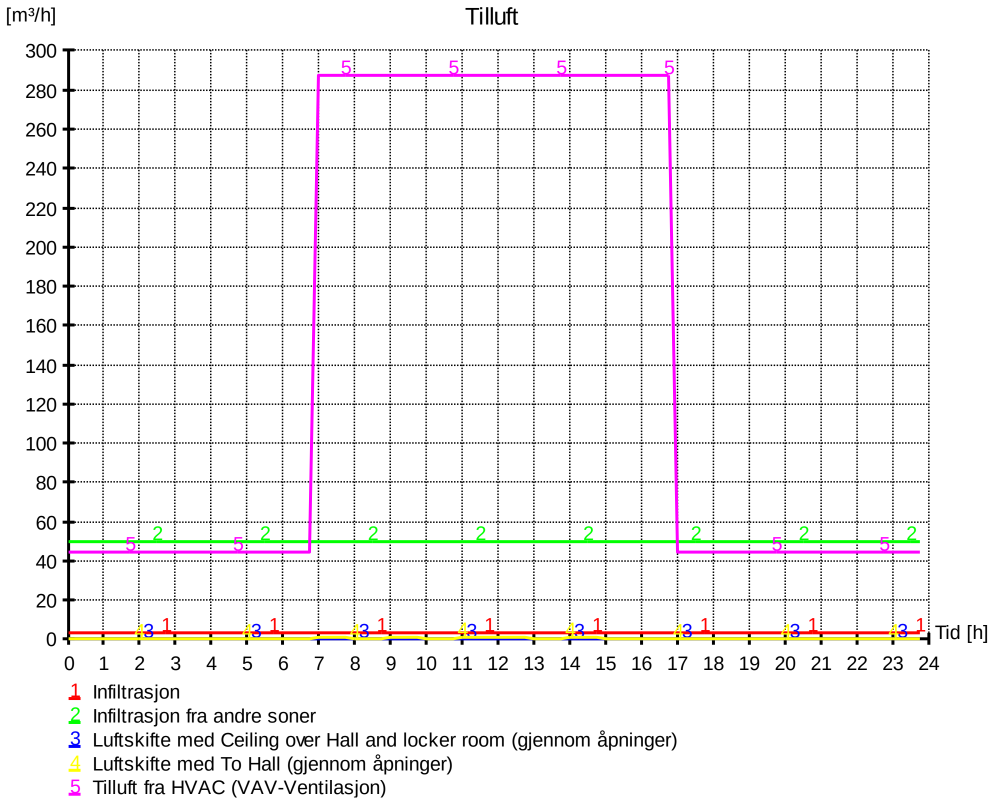

[m³/h]
Tilluft
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Tid [h]
1 Infiltrasjon
2 Infiltrasjon fra andre soner
3 Luftskifte med Ceiling over Hall and locker room (gjennom åpninger)
4 Luftskifte med To Hall (gjennom åpninger)
5 Tilluft fra HVAC (VAV-Ventilasjon)

Figure 48,

SIMIEN
Resultater vintersimulering

Winter results

Simulated regarding cooldest environment

Control room

Sammendrag av nøkkelverdier for KR		
Beskrivelse	Verdi	Tidspunkt
Min. innelufttemperatur	19,0 °C	02:30
Min. operativ temperatur	19,3 °C	22:15
Maks. CO2 konsentrasjon	575 PPM	12:30
Maksimal effekt varmebatterier:	120 W / 17,4 W/m²	06:15
Installert effekt varmebatterier	207 W / 30,0 W/m²	06:15
Maksimal effekt oppvarmingsanlegg:	577 W / 83,6 W/m²	07:00
Installert effekt romoppvarming	0 W / 0,0 W/m²	07:00

Figure 49,

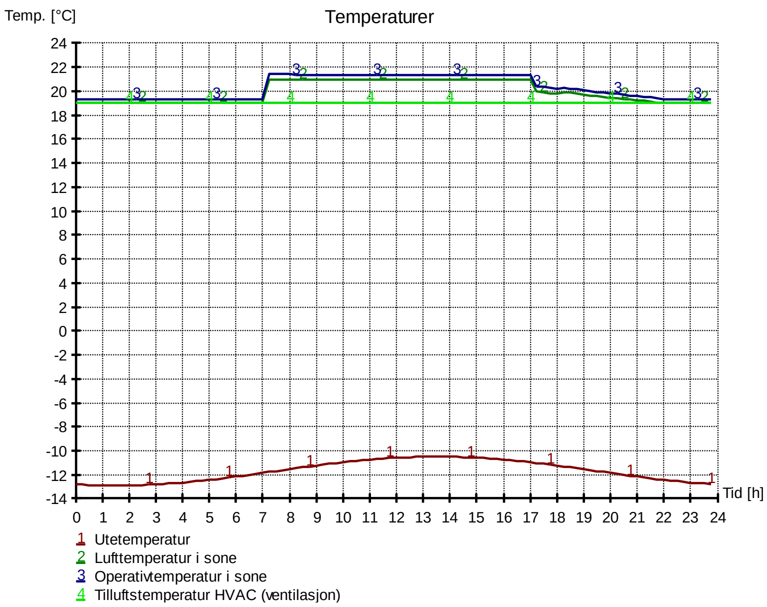


Figure 50,

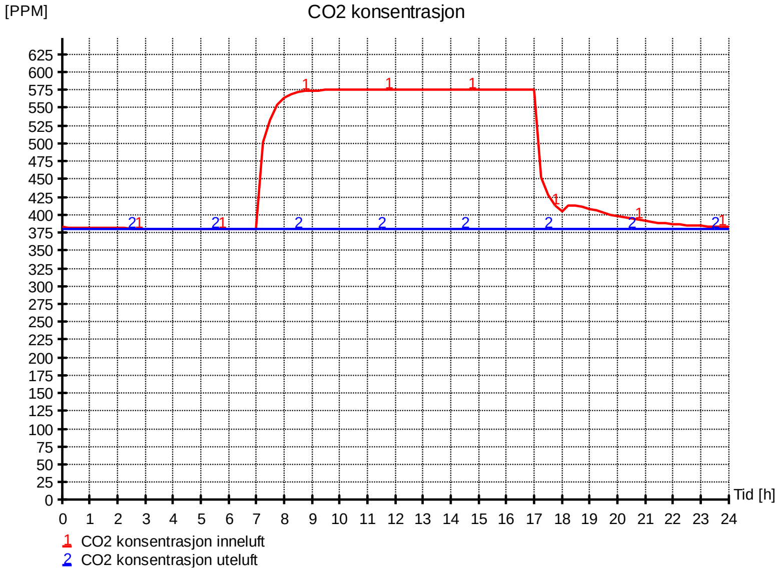


Figure 51,

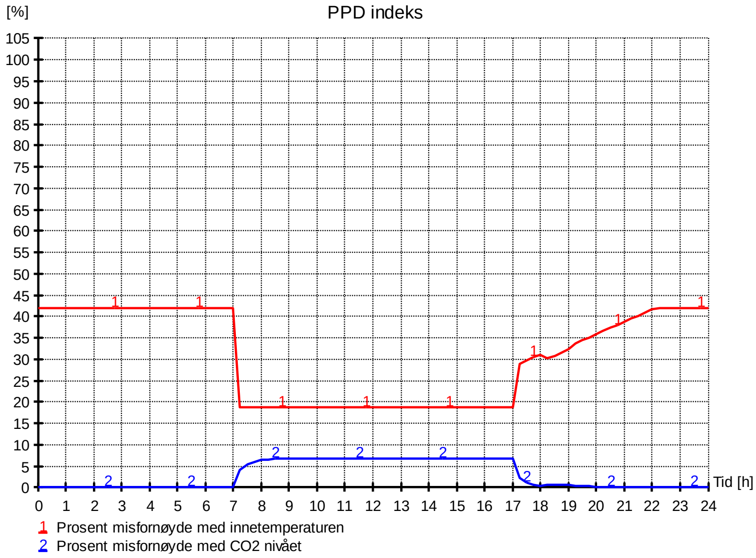


Figure 52,

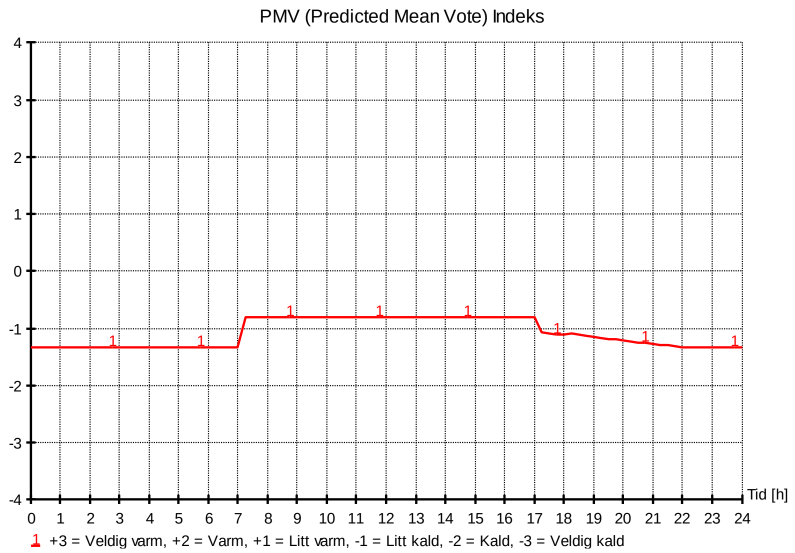


Figure 53,

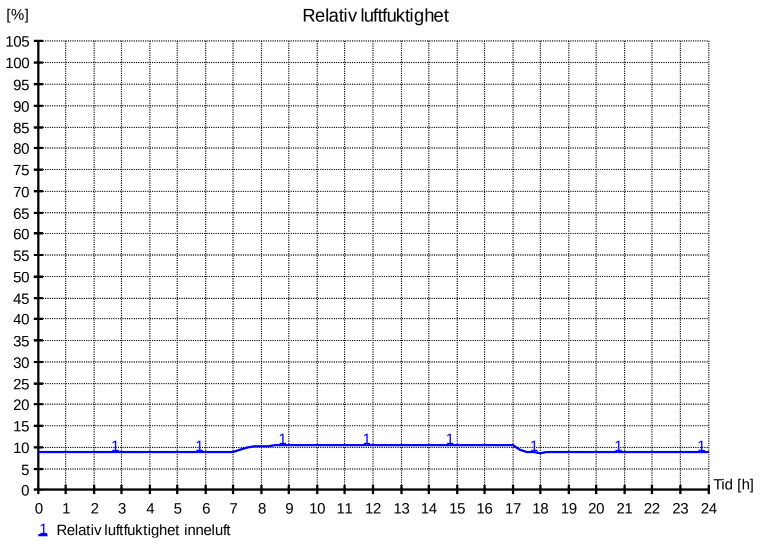


Figure 54,

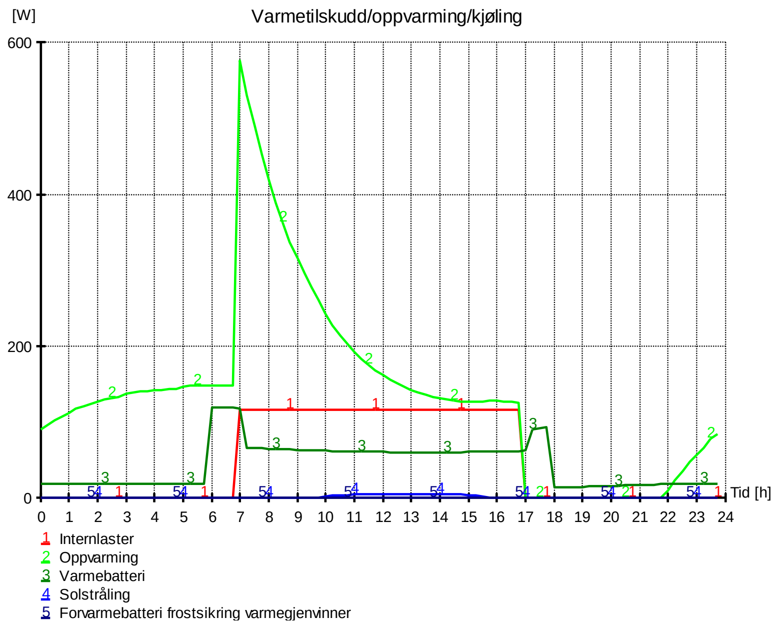


Figure 55,

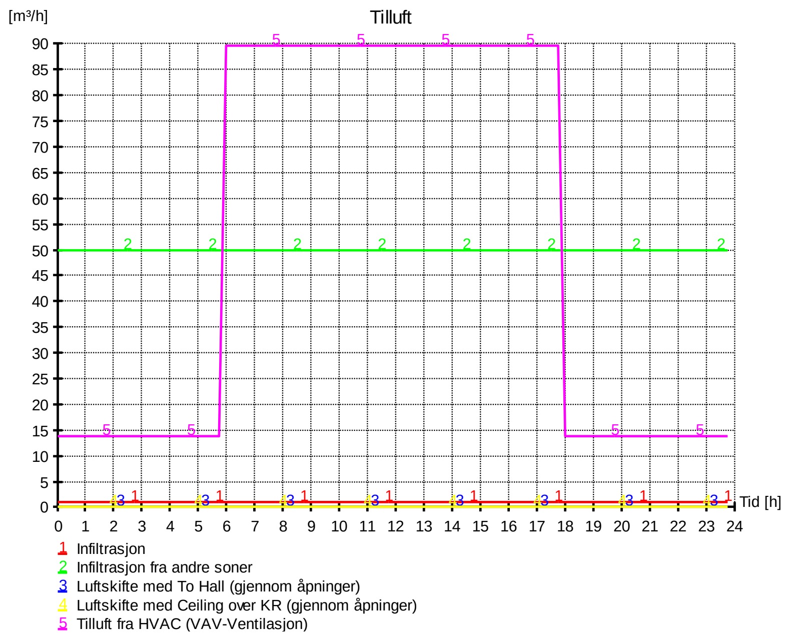


Figure 56,

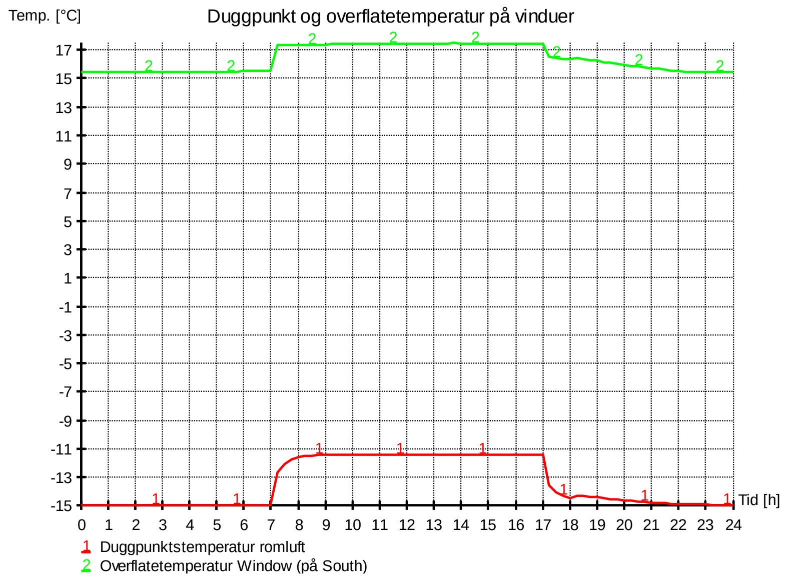


Figure 57,

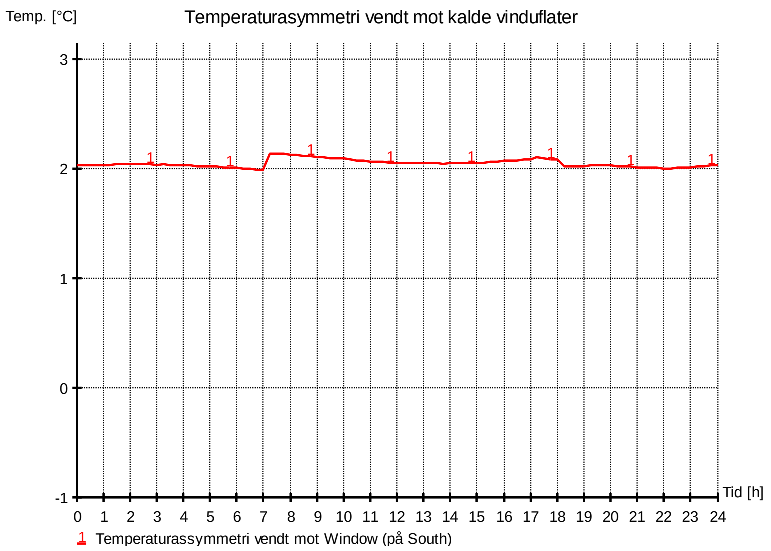


Figure 58,

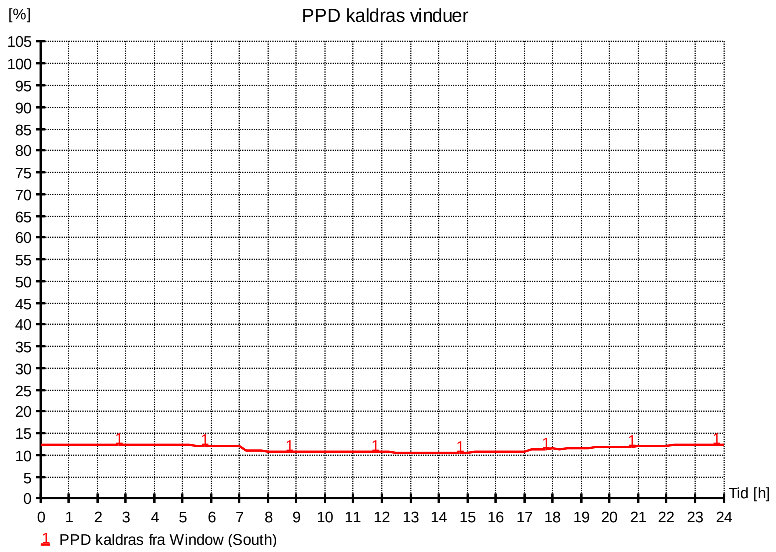


Figure 59,

Hallway and locker room

Sammendrag av nøkkelverdier for Hall and locker room		
Beskrivelse	Verdi	Tidspunkt
Min. inneluftemperatur	19,0 °C	00:15
Min. operativ temperatur	19,3 °C	07:00
Maks. CO2 konsentrasjon	469 PPM	13:00
Maksimal effekt varmebatterier:	380 W / 17,2 W/m²	07:15
Installert effekt varmebatterier	663 W / 30,0 W/m²	07:15
Maksimal effekt oppvarmingsanlegg:	1322 W / 59,8 W/m²	07:00
Installert effekt romoppvarming	2066 W / 93,5 W/m²	07:00

Figure 60,

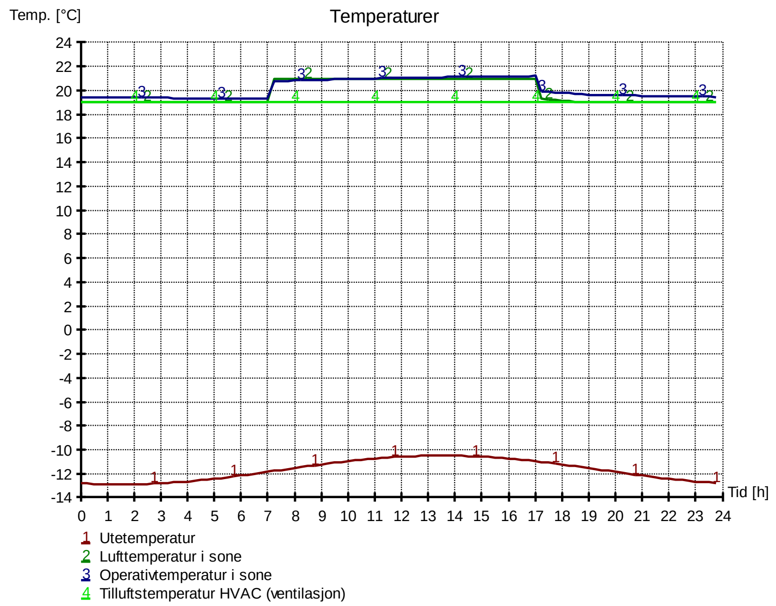


Figure 61,

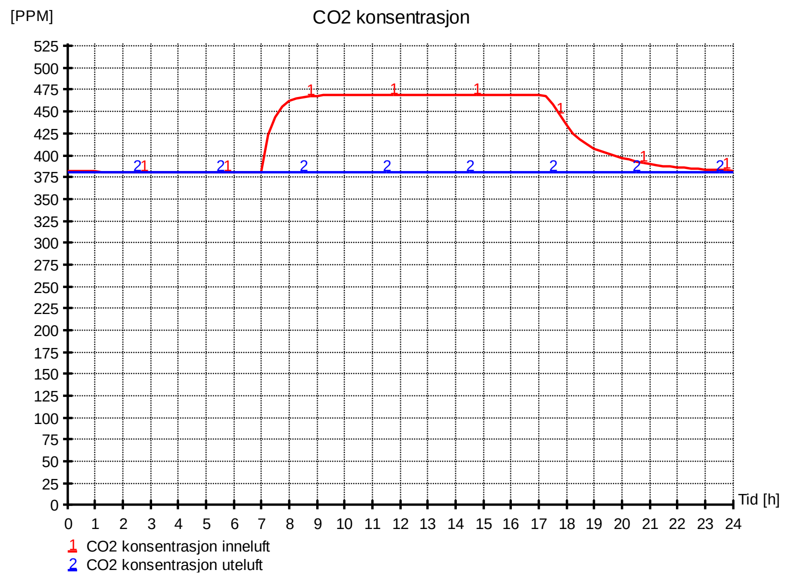


Figure 62,

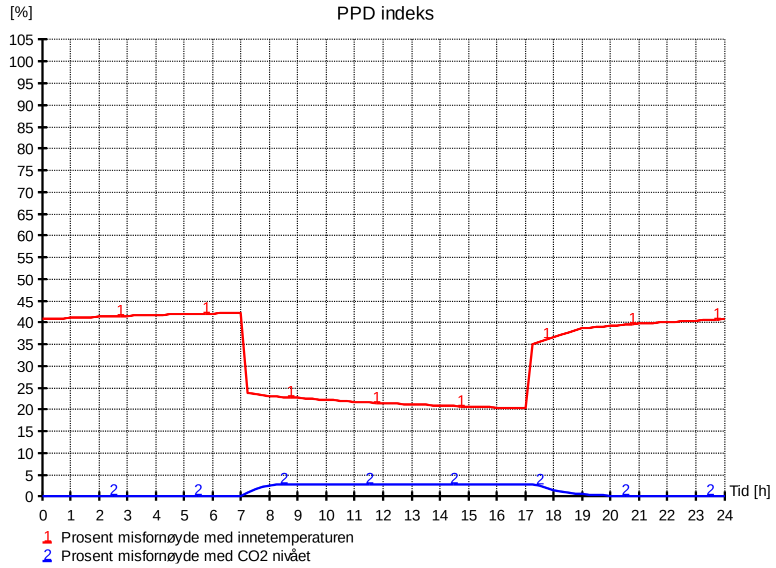


Figure 63,

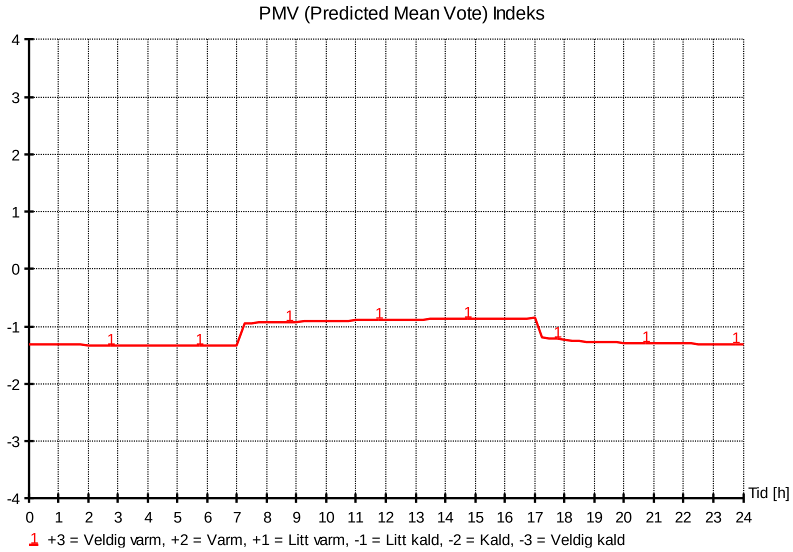


Figure 64,

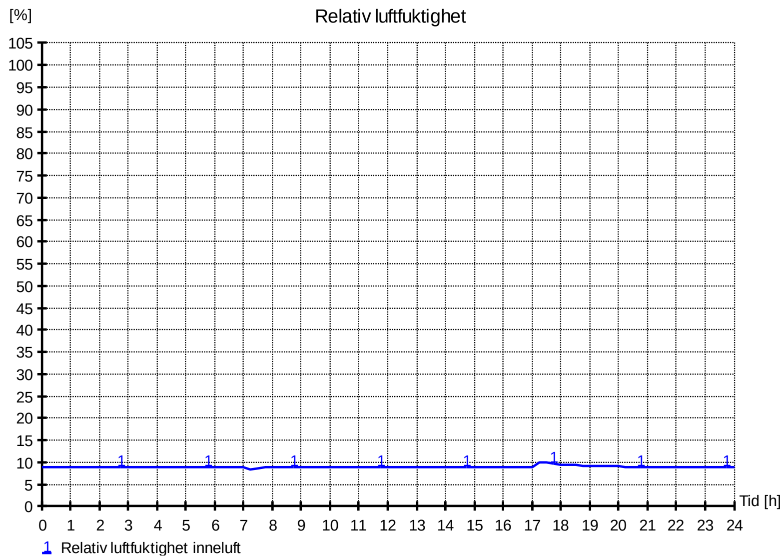


Figure 65,

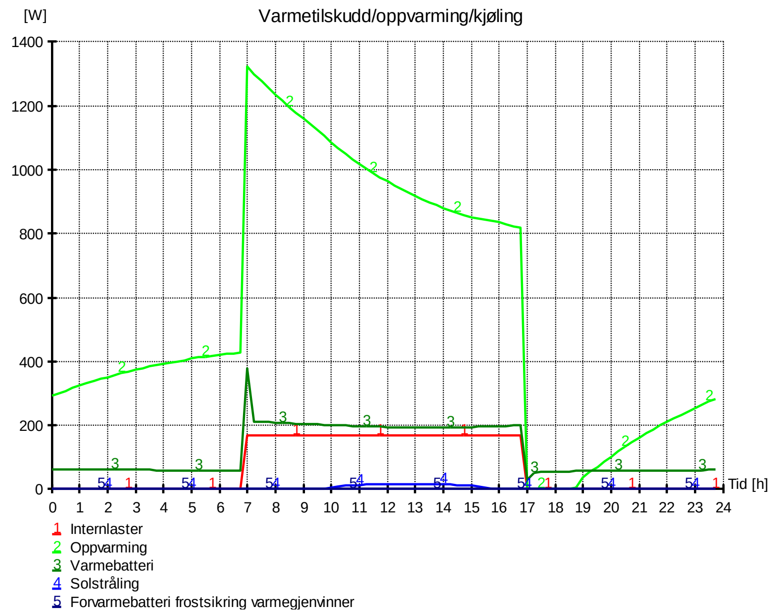


Figure 66,

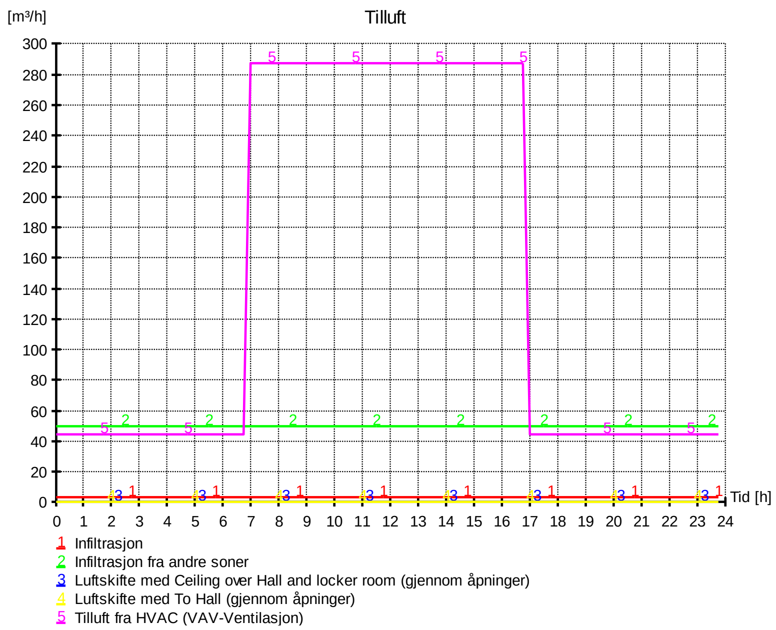


Figure 67,

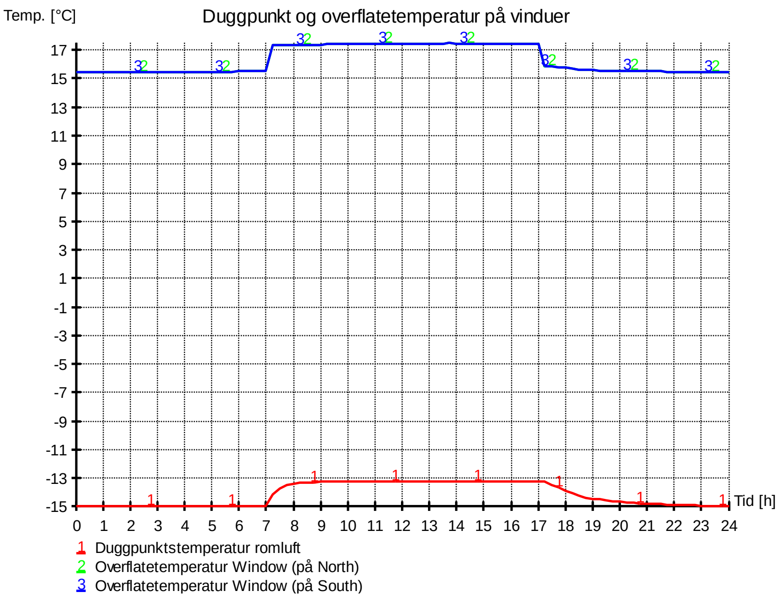


Figure 68,

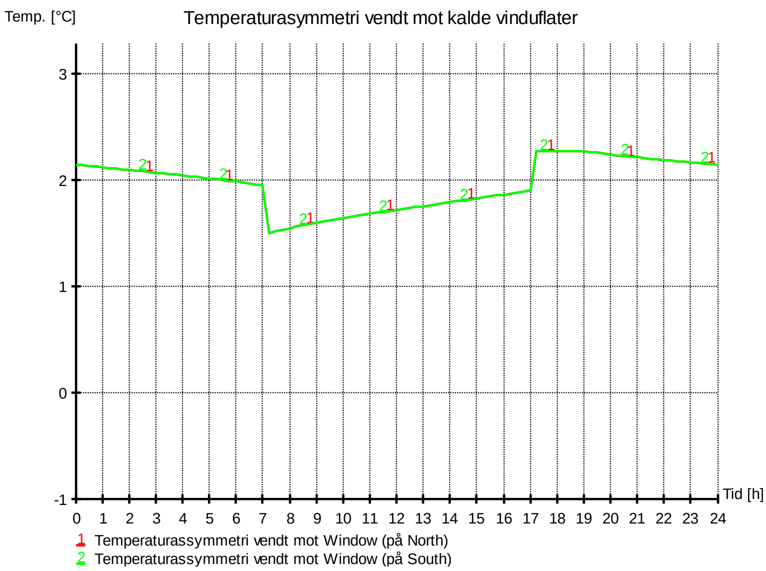


Figure 69,

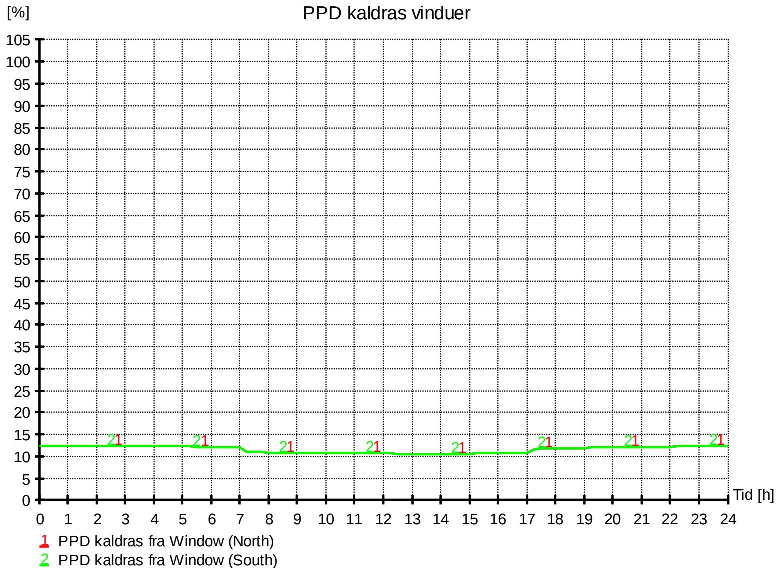

[%]
PPD kaldras vinduer
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
Tid [h]
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
1 PPD kaldras fra Window (North)
2 PPD kaldras fra Window (South)

Figure 70,

Appendex A.3

In data summer

Control room

Inndata rom/sone	
Beskrivelse	Verdi
Oppvarmet gulvareal	6,9 m²
Oppvarmet luftvolum	22,2 m³
Normalisert kuldebroverdi	0,06 W/(m²K)
Varmekapasitet møbler/interiør	6,0 Wh/m² (Tungt møblert rom)
Lekkasjetall (luftskifte v. 50pa)	0,60 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	21
Driftsdager i Februar	20
Driftsdager i Mars	23
Driftsdager i April	22
Driftsdager i Mai	21
Driftsdager i Juni	19
Driftsdager i Juli	0
Driftsdager i August	12
Driftsdager i September	22
Driftsdager i Oktober	21
Driftsdager i November	22
Driftsdager i Desember	18

Figure 71,

Inndata fasade/yttervegg	
Beskrivelse	Verdi
Navn:	South (fasade)
Totalt areal	17,0 m²
Retning (0=Nord, 180=Sør)	180°
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	48 mm dobbeltveggkonstr, 450 mm isolasjon Uverdi: 0,09 W/m²K

Figure 72,

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Window (Vindu(er) på South)
Antall vinduer	1
Høyde vindu(er)	0,80 m
Bredde vindu(er)	1,89 m
Karm-/ramme faktor	0,20
Karm/rammekonstruksjon	U-verdi: 1,30 W/m²K Kuldebroverdi: 0,08 W/mK
Vindustype	Egendefinert Uverdi: 0,80 W/m²K
Konstant (fast) solskjerming	To lag glass, hvorav det indre er energispareglass Total solfaktor: 0,55
Overheng	Dybde : 0,38 m Avstand fra vindu: 1,27 m

Figure 73,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	To TC (skillekonstruksjon)
Totalt areal	4,7 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	Lettklinkervegg, 150 mm Uverdi: 1,32 W/m²K
Vendt mot annen sone	Egendefinert sone Varmetapsfaktor: 0,00

Figure 74,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	Window to TC (skillekonstruksjon)
Totalt areal	1,0 m²
Konstruksjonstype	Vindu
Vendt mot annen sone	Sone med lik temperatur

Figure 75

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	To CR (skillekonstruksjon)
Totalt areal	4,3 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Figure 76

Inndata sonekobling	
Beskrivelse	Verdi
Navn:	To Hall (sonekobling)
Koblet sone	Hall and locker room
Totalt areal	12,3 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	Standard konstruksjon Uverdi: 0,25 W/m²K
Infiltrasjon mellom soner	25,0 m³/h
Luftskifte gjennom store åpninger	Åpningsareal: 1,7 m² Åpningshøyde: 2,1 m Driftstimer: 06:00 Prosent åpen i driftstiden: 25 %

Figure 77,

Inndata sonekobling	
Beskrivelse	Verdi
Navn:	Ceiling over KR (sonekobling)
Koblet sone	Adict
Totalt areal	6,9 m²
Konstruksjonstype	Tak
Innv. akkumulerende sjikt	Lett himling Varmekapasitet 3,0 Wh/m²K
Konstruksjon	Standard konstruksjon Uverdi: 0,25 W/m²K
Infiltrasjon mellom soner	25,0 m³/h
Luftskifte gjennom store åpninger	Åpningsareal: 0,0 m² Åpningshøyde: 0,0 m Driftstimer: 00:00 Prosent åpen i driftstiden: 0 %

Figure 78,

Inndata gulv mot friluft/kryprom/grunn	
Beskrivelse	Verdi
Navn:	Floor (gulv)
Oppvarmet gulvareal	7,0 m²
Gulvtype	Gulv på grunn
Utvendig omkrets	5,00 m
Tykkelse grunnmur	0,40 m
Grunnforhold	Fjell Varmekapasitet: 556 Wh/m³K Varmeledningsevne: 3,50 W/mK
Ekstra kantisolering	Type: Vertikal Navn: Egendefinert Høyde/bredde: 0,30 m Tykkelse: 30,0 cm Varmeledingsevne: 0,03 W/mK
Innv. akk. sjikt gulv	Fliser (7 mm) + betong Varmekapasitet 63,0 Wh/m²K
Gulvkonstruksjon	Egendefinert Uverdi: 0,15 W/m²K

Figure 79,

Inndata VAV-Ventilasjon	
Beskrivelse	Verdi
Navn:	HVAC (VAV)
Systemtype	Prøver å holde CO2 konsentrasjonen under 1000 PPM
Systemtype	Prøver å holde romtemperaturen under 26.0 °C
Luftmengde	Maks.: 31.3 m³/h/m²; Min.: 13.0 m³/h/m²; Utenfor: 2.0 m³/h/m²; Helg: 2.0 m³/h/m²
Tilluftstemperatur	19.0 °C
Annen tilluftstemperatur sommer	Tilluftstemperatur sommer: 18.0 °C Sommermåneder: Mai - August
Driftstid	Timer med drift: 12:00
Varmebatteri	Ja Maks. kapasitet: 30 W/m²
Kjølebatteri	 Maks. kapasitet: 30 W/m²
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.5 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.85
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	2.00 kW/m³/s

Figure 80,

Inndata belysning	
Beskrivelse	Verdi
Navn:	Loads (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 2,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 10:00

Figure 81,

Inndata teknisk utstyr (internlast)	
Beskrivelse	Verdi
Navn:	Loads (internlaster, teknisk utstyr)
Effekt/Varmetilskudd teknisk utstyr	I driftstiden; Effekt: 180,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 11:00

Figure 82,

Inndata varmetilskudd personer (internlast)	
Beskrivelse	Verdi
Navn:	Loads (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 60,0 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 0,0 W/m² Antall arbeidstimer: 10:00

Figure 83,

Inndata oppvarming	
Beskrivelse	Verdi
Navn:	Heat (no Need) (oppvarming)
Settpunkttemperatur i driftstid	22,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	0 W/m²
Konvektiv andel oppvarming	0,00
Driftstid	00:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Ja
Turtemperatur	50,0 °C
Returtemperatur	30,0 °C
Spesifikk pumpeeffekt	0,10 kW/(l/s)

Figure 84,

Inndata lokal kjøling	
Beskrivelse	Verdi
Navn:	Cooling (lokal kjøling)
Settpunkttemperatur	22,0 °C
Maks, kapasitet	187 W/m²
Konvektiv andel kjøling	0,50
Driftstid	11:00 timer drift pr døgn
Kjøling på helge/feriedager	Nei
Kjøling via vannbårent anlegg	Ja
Turtemperatur	14,0 °C
Returtemperatur	17,0 °C
Spesifikk pumpeeffekt	0,80 kW/(l/s)

Figure 85,

Hallway and locker room

Inndata rom/sone	
Beskrivelse	Verdi
Oppvarmet gulvareal	22,1 m²
Oppvarmet luftvolum	75,0 m³
Normalisert kuldebroverdi	0,06 W/(m²K)
Varmekapasitet møbler/interiør	0,0 Wh/m² (Ingen møbler)
Lekkasjetall (luftskifte v. 50pa)	0,60 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	21
Driftsdager i Februar	20
Driftsdager i Mars	23
Driftsdager i April	22
Driftsdager i Mai	21
Driftsdager i Juni	19
Driftsdager i Juli	0
Driftsdager i August	12
Driftsdager i September	22
Driftsdager i Oktober	21
Driftsdager i November	22
Driftsdager i Desember	18

Figure 86,

Inndata fasade/yttervegg	
Beskrivelse	Verdi
Navn:	North (fasade)
Totalt areal	31,5 m²
Retning (0=Nord, 180=Sør)	0°
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	48 mm dobbeltveggkonstr, 450 mm isolasjon Uverdi: 0,09 W/m²K

Figure 87,

Inndata ytterdør	
Beskrivelse	Verdi
Navn:	Ytterdør (ytterdør)
Areal inkl. karm/ramme	2,7 m²
Dørtype	Egendefinert Uverdi: 0,80 W/m²K

Figure 88,

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Window (Vindu(er) på North)
Antall vinduer	1
Høyde vindu(er)	0,80 m
Bredde vindu(er)	1,89 m
Karm-/ramme faktor	0,20
Karm/rammekonstruksjon	U-verdi: 1,30 W/m²K Kuldebroverdi: 0,08 W/mK
Vindustype	Egendefinert Uverdi: 0,80 W/m²K
Konstant (fast) solskjerming	To lag glass, hvorav det indre er energispareglass Total solfaktor: 0,55
Overheng	Dybde : 0,38 m Avstand fra vindu: 1,27 m

Figure 89,

Inndata ytterdør	
Beskrivelse	Verdi
Navn:	Door to TC (ytterdør)
Areal inkl. karm/ramme	2,7 m²
Dørtype	Superisolert dør Uverdi: 0,80 W/m²K

Figure 90,

Inndata fasade/yttervegg	
Beskrivelse	Verdi
Navn:	South (fasade)
Totalt areal	14,6 m²
Retning (0=Nord, 180=Sør)	180°
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	48 mm dobbeltveggkonstr, 450 mm isolasjon Uverdi: 0,09 W/m²K

Figure 91,

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Window (Vindu(er) på South)
Antall vinduer	2
Høyde vindu(er)	0,80 m
Bredde vindu(er)	1,89 m
Karm-/ramme faktor	0,20
Karm/rammekonstruksjon	U-verdi: 1,30 W/m²K Kuldebroverdi: 0,08 W/mK
Vindustype	Egendefinert Uverdi: 0,80 W/m²K
Konstant (fast) solskjerming	To lag glass, hvorav det indre er energispareglass Total solfaktor: 0,55
Overheng	Dybde : 0,38 m Avstand fra vindu: 1,27 m

Figure 92,

Inndata gulv mot friluft/kryprom/grunn	
Beskrivelse	Verdi
Navn:	Floor (gulv)
Oppvarmet gulvareal	22,1 m²
Gulvtype	Gulv på grunn
Utvendig omkrets	13,16 m
Tykkelse grunnmur	0,40 m
Grunnforhold	Fjell Varmekapasitet: 556 Wh/m³K Varmeledningsevne: 3,50 W/mK
Ekstra kantisolering	Type: Vertikal Navn: Egendefinert Høyde/bredde: 0,30 m Tykkelse: 30,0 cm Varmeledingsevne: 0,03 W/mK
Innv. akk. sjikt gulv	Fliser (7 mm) + betong Varmekapasitet 63,0 Wh/m²K
Gulvkonstruksjon	Egendefinert Uverdi: 0,15 W/m²K

Figure 93,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	To TC (skillekonstruksjon)
Totalt areal	6,3 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	Lettklinkervegg, 150 mm Uverdi: 1,32 W/m²K
Vendt mot annen sone	Egendefinert sone Varmetapsfaktor: 0,00

Figure 94,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	Wall to west (skillekonstruksjon)
Totalt areal	9,9 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Figure 95,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	Door to locker room (skillekonstruksjon)
Totalt areal	1,7 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Figure 96,

Inndata sonekobling	
Beskrivelse	Verdi
Navn:	Ceiling over Hall and locker room (sonekobling)
Koblet sone	Adict
Totalt areal	22,1 m²
Konstruksjonstype	Tak
Innv. akkumulerende sjikt	Tung himling Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Standard konstruksjon Uverdi: 0,25 W/m²K
Infiltrasjon mellom soner	25,0 m³/h
Luftskifte gjennom store åpninger	Åpningsareal: 2,0 m² Åpningshøyde: 2,0 m Driftstimer: 00:00 Prosent åpen i driftstiden: 25 %

Figure 97,

Inndata sonekobling	
Beskrivelse	Verdi
Navn:	To Hall (sonekobling)
Koblet sone	KR
Totalt areal	12,3 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	Standard konstruksjon Uverdi: 0,25 W/m²K
Infiltrasjon mellom soner	25,0 m³/h
Luftskifte gjennom store åpninger	Åpningsareal: 1,7 m² Åpningshøyde: 2,1 m Driftstimer: 06:00 Prosent åpen i driftstiden: 25 %

Figure 98,

Inndata VAV-Ventilasjon	
Beskrivelse	Verdi
Navn:	HVAC (VAV)
Systemtype	Prøver å holde CO_2 konsentrasjonen under 1000 PPM
Systemtype	Prøver å holde romtemperaturen under 26.0 °C
Luftmengde	Maks.: 13.0 m³/h/m²; Min.: 13.0 m³/h/m²; Utenfor: 2.0 m³/h/m²; Helg: 2.0 m³/h/m²
Tilluftstemperatur	19.0 °C
Annen tilluftstemperatur sommer	Tilluftstemperatur sommer: 18.0 °C Sommermåneder: Mai - August
Driftstid	Timer med drift: 10:00
Varmebatteri	Ja Maks. kapasitet: 30 W/m²
Kjølebatteri	 Maks. kapasitet: 41 W/m²
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.5 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.85
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	2.00 kW/m³/s

Figure 99,

Inndata oppvarming	
Beskrivelse	Verdi
Navn:	Heat (oppvarming)
Settpunkttemperatur i driftstid	21,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	94 W/m²
Konvektiv andel oppvarming	0,50
Driftstid	10:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Ja
Turtemperatur	50,0 °C
Returtemperatur	30,0 °C
Spesifikk pumpeeffekt	0,50 kW/(l/s)

Figure 100,

Inndata belysning	
Beskrivelse	Verdi
Navn:	loads (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 3,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 10:00

Figure 101,

Inndata varmetilskudd personer (internlast)	
Beskrivelse	Verdi
Navn:	loads (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 18,5 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 0,0 W/m² Antall arbeidstimer: 10:00

Figure 102,

Inndata lokal kjøling	
Beskrivelse	Verdi
Navn:	Cooling (lokal kjøling)
Settpunkttemperatur	23,0 °C
Maks, kapasitet	40 W/m²
Konvektiv andel kjøling	0,50
Driftstid	11:00 timer drift pr døgn
Kjøling på helge/feriedager	Nei
Kjøling via vannbårent anlegg	Ja
Turtemperatur	14,0 °C
Returtemperatur	17,0 °C
Spesifikk pumpeeffekt	0,80 kW/(l/s)

Figure 103,

In data winter

Control room

Inndata rom/sone	
Beskrivelse	Verdi
Oppvarmet gulvareal	6,9 m²
Oppvarmet luftvolum	22,2 m³
Normalisert kuldebroverdi	0,06 W/(m²K)
Varmekapasitet møbler/interiør	6,0 Wh/m² (Tungt møblert rom)
Lekkasjetall (luftskifte v. 50pa)	0,60 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	21
Driftsdager i Februar	20
Driftsdager i Mars	23
Driftsdager i April	22
Driftsdager i Mai	21
Driftsdager i Juni	19
Driftsdager i Juli	0
Driftsdager i August	12
Driftsdager i September	22
Driftsdager i Oktober	21
Driftsdager i November	22
Driftsdager i Desember	18

Figure 104,

Inndata fasade/yttervegg	
Beskrivelse	Verdi
Navn:	South (fasade)
Totalt areal	17,0 m²
Retning (0=Nord, 180=Sør)	180°
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	48 mm dobbeltveggkonstr, 450 mm isolasjon Uverdi: 0,09 W/m²K

Figure 105,

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Window (Vindu(er) på South)
Antall vinduer	1
Høyde vindu(er)	0,80 m
Bredde vindu(er)	1,89 m
Karm-/ramme faktor	0,20
Karm/rammekonstruksjon	U-verdi: 1,30 W/m²K Kuldebroverdi: 0,08 W/mK
Vindustype	Egendefinert Uverdi: 0,80 W/m²K
Konstant (fast) solskjerming	To lag glass, hvorav det indre er energispareglass Total solfaktor: 0,55
Overheng	Dybde : 0,38 m Avstand fra vindu: 1,27 m

Figure 106,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	To TC (skillekonstruksjon)
Totalt areal	4,7 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	Lettklinkervegg, 150 mm Uverdi: 1,32 W/m²K
Vendt mot annen sone	Egendefinert sone Varmetapsfaktor: 0,00

Figure 107,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	Door (skillekonstruksjon)
Totalt areal	1,7 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Figure 108,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	Window to TC (skillekonstruksjon)
Totalt areal	1,0 m²
Konstruksjonstype	Vindu
Vendt mot annen sone	Sone med lik temperatur

Figure 109,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	To CR (skillekonstruksjon)
Totalt areal	4,3 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Figure 110,

Inndata sonekobling	
Beskrivelse	Verdi
Navn:	To Hall (sonekobling)
Koblet sone	Hall and locker room
Totalt areal	12,3 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	Standard konstruksjon Uverdi: 0,25 W/m²K
Infiltrasjon mellom soner	25,0 m³/h
Luftskifte gjennom store åpninger	Åpningsareal: 1,7 m² Åpningshøyde: 2,1 m Driftstimer: 06:00 Prosent åpen i driftstiden: 25 %

Figure 111,

Inndata sonekobling	
Beskrivelse	Verdi
Navn:	Ceiling over KR (sonekobling)
Koblet sone	Adict
Totalt areal	6,9 m²
Konstruksjonstype	Tak
Innv. akkumulerende sjikt	Lett himling Varmekapasitet 3,0 Wh/m²K
Konstruksjon	Standard konstruksjon Uverdi: 0,25 W/m²K
Infiltrasjon mellom soner	25,0 m³/h
Luftskifte gjennom store åpninger	Åpningsareal: 0,0 m² Åpningshøyde: 0,0 m Driftstimer: 00:00 Prosent åpen i driftstiden: 0 %

Figure 112,

Inndata gulv mot friluft/kryprom/grunn	
Beskrivelse	Verdi
Navn:	Floor (gulv)
Oppvarmet gulvareal	7,0 m²
Gulvtype	Gulv på grunn
Utvendig omkrets	5,00 m
Tykkelse grunnmur	0,40 m
Grunnforhold	Fjell Varmekapasitet: 556 Wh/m³K Varmeledningsevne: 3,50 W/mK
Ekstra kantisolering	Type: Vertikal Navn: Egendefinert Høyde/bredde: 0,30 m Tykkelse: 30,0 cm Varmeledingsevne: 0,03 W/mK
Innv. akk. sjikt gulv	Fliser (7 mm) + betong Varmekapasitet 63,0 Wh/m²K
Gulvkonstruksjon	Egendefinert Uverdi: 0,15 W/m²K

Figure 113,

Inndata VAV-Ventilasjon	
Beskrivelse	Verdi
Navn:	HVAC (VAV)
Systemtype	Prøver å holde CO2 konsentrasjonen under 1000 PPM
Systemtype	Prøver å holde romtemperaturen under 26.0 °C
Luftmengde	Maks.: 31.3 m³/h/m²; Min.: 13.0 m³/h/m²; Utenfor: 2.0 m³/h/m²; Helg: 2.0 m³/h/m²
Tilluftstemperatur	19.0 °C
Annen tilluftstemperatur sommer	Tilluftstemperatur sommer: 18.0 °C Sommermåneder: Mai - August
Driftstid	Timer med drift: 12:00
Varmebatteri	Ja Maks. kapasitet: 30 W/m²
Kjølebatteri	 Maks. kapasitet: 30 W/m²
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.5 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.85
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	2.00 kW/m³/s

Figure 114,

Inndata belysning	
Beskrivelse	Verdi
Navn:	Loads (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 2,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 10:00

Figure 115,

Inndata varmetilskudd personer (internlast)	
Beskrivelse	Verdi
Navn:	Loads (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 15,0 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 0,0 W/m² Antall arbeidstimer: 10:00

Figure 116,

Inndata oppvarming	
Beskrivelse	Verdi
Navn:	Heat (no Need) (oppvarming)
Settpunkttemperatur i driftstid	21,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	0 W/m²
Konvektiv andel oppvarming	0,00
Driftstid	10:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Ja
Turtemperatur	50,0 °C
Returtemperatur	30,0 °C
Spesifikk pumpeeffekt	0,10 kW/(l/s)

Figure 117,

Inndata lokal kjøling	
Beskrivelse	Verdi
Navn:	Cooling (lokal kjøling)
Settpunkttemperatur	22,0 °C
Maks, kapasitet	187 W/m²
Konvektiv andel kjøling	0,50
Driftstid	11:00 timer drift pr døgn
Kjøling på helge/feriedager	Nei
Kjøling via vannbårent anlegg	Ja
Turtemperatur	14,0 °C
Returtemperatur	17,0 °C
Spesifikk pumpeeffekt	0,80 kW/(l/s)

Figure 118,

Hallway and locker room

Inndata rom/sone	
Beskrivelse	Verdi
Oppvarmet gulvareal	22,1 m²
Oppvarmet luftvolum	75,0 m³
Normalisert kuldebroverdi	0,06 W/(m²K)
Varmekapasitet møbler/interiør	0,0 Wh/m² (Ingen møbler)
Lekkasjetall (luftskifte v. 50pa)	0,60 ach
Skjerming i terrenget	Moderat skjerming
Fasadesituasjon	Flere eksponerte fasader
Driftsdager i Januar	21
Driftsdager i Februar	20
Driftsdager i Mars	23
Driftsdager i April	22
Driftsdager i Mai	21
Driftsdager i Juni	19
Driftsdager i Juli	0
Driftsdager i August	12
Driftsdager i September	22
Driftsdager i Oktober	21
Driftsdager i November	22
Driftsdager i Desember	18

Figure 119,

Inndata fasade/yttervegg	
Beskrivelse	Verdi
Navn:	North (fasade)
Totalt areal	31,5 m²
Retning (0=Nord, 180=Sør)	0°
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	48 mm dobbeltveggkonstr, 450 mm isolasjon Uverdi: 0,09 W/m²K

Figure 120,

Inndata ytterdør	
Beskrivelse	Verdi
Navn:	Ytterdør (ytterdør)
Areal inkl. karm/ramme	2,7 m²
Dørtype	Egendefinert Uverdi: 0,80 W/m²K

Figure 121,

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Window (Vindu(er) på North)
Antall vinduer	1
Høyde vindu(er)	0,80 m
Bredde vindu(er)	1,89 m
Karm-/ramme faktor	0,20
Karm/rammekonstruksjon	U-verdi: 1,30 W/m²K Kuldebroverdi: 0,08 W/mK
Vindustype	Egendefinert Uverdi: 0,80 W/m²K
Konstant (fast) solskjerming	To lag glass, hvorav det indre er energispareglass Total solfaktor: 0,55
Overheng	Dybde : 0,38 m Avstand fra vindu: 1,27 m

Figure 122,

Inndata ytterdør	
Beskrivelse	Verdi
Navn:	Door to TC (ytterdør)
Areal inkl. karm/ramme	2,7 m²
Dørtype	Superisolert dør Uverdi: 0,80 W/m²K

Figure 123,

Inndata fasade/yttervegg	
Beskrivelse	Verdi
Navn:	South (fasade)
Totalt areal	14,6 m²
Retning (0=Nord, 180=Sør)	180°
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	48 mm dobbeltveggkonstr, 450 mm isolasjon Uverdi: 0,09 W/m²K

Figure 124,

Inndata vinduselement	
Beskrivelse	Verdi
Navn:	Window (Vindu(er) på South)
Antall vinduer	2
Høyde vindu(er)	0,80 m
Bredde vindu(er)	1,89 m
Karm-/ramme faktor	0,20
Karm/rammekonstruksjon	U-verdi: 1,30 W/m²K Kuldebroverdi: 0,08 W/mK
Vindustype	Egendefinert Uverdi: 0,80 W/m²K
Konstant (fast) solskjerming	To lag glass, hvorav det indre er energispareglass Total solfaktor: 0,55
Overheng	Dybde : 0,38 m Avstand fra vindu: 1,27 m

Figure 125,

Inndata gulv mot friluft/kryprom/grunn	
Beskrivelse	Verdi
Navn:	Floor (gulv)
Oppvarmet gulvareal	22,1 m²
Gulvtype	Gulv på grunn
Utvendig omkrets	13,16 m
Tykkelse grunnmur	0,40 m
Grunnforhold	Fjell Varmekapasitet: 556 Wh/m³K Varmeledningsevne: 3,50 W/mK
Ekstra kantisolering	Type: Vertikal Navn: Egendefinert Høyde/bredde: 0,30 m Tykkelse: 30,0 cm Varmeledingsevne: 0,03 W/mK
Innv. akk. sjikt gulv	Fliser (7 mm) + betong Varmekapasitet 63,0 Wh/m²K
Gulvkonstruksjon	Egendefinert Uverdi: 0,15 W/m²K

Figure 126,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	To TC (skillekonstruksjon)
Totalt areal	6,3 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	Lettklinkervegg, 150 mm Uverdi: 1,32 W/m²K
Vendt mot annen sone	Egendefinert sone Varmetapsfaktor: 0,00

Figure 127,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	Wall to west (skillekonstruksjon)
Totalt areal	9,9 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Figure 128,

Inndata skillekonstruksjon	
Beskrivelse	Verdi
Navn:	Door to locker room (skillekonstruksjon)
Totalt areal	1,7 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Vendt mot annen sone	Sone med lik temperatur

Figure 129,

Inndata sonekobling	
Beskrivelse	Verdi
Navn:	Ceiling over Hall and locker room (sonekobling)
Koblet sone	Adict
Totalt areal	22,1 m²
Konstruksjonstype	Tak
Innv. akkumulerende sjikt	Tung himling Varmekapasitet 63,0 Wh/m²K
Konstruksjon	Standard konstruksjon Uverdi: 0,25 W/m²K
Infiltrasjon mellom soner	25,0 m³/h
Luftskifte gjennom store åpninger	Åpningsareal: 2,0 m² Åpningshøyde: 2,0 m Driftstimer: 00:00 Prosent åpen i driftstiden: 25 %

Figure 130,

Inndata sonekobling	
Beskrivelse	Verdi
Navn:	To Hall (sonekobling)
Koblet sone	KR
Totalt areal	12,3 m²
Konstruksjonstype	Vegg
Innv. akkumulerende sjikt	Gipsplate 13mm Varmekapasitet 2,4 Wh/m²K
Konstruksjon	Standard konstruksjon Uverdi: 0,25 W/m²K
Infiltrasjon mellom soner	25,0 m³/h
Luftskifte gjennom store åpninger	Åpningsareal: 1,7 m² Åpningshøyde: 2,1 m Driftstimer: 06:00 Prosent åpen i driftstiden: 25 %

Figure 131,

Inndata VAV-Ventilasjon	
Beskrivelse	Verdi
Navn:	HVAC (VAV)
Systemtype	Prøver å holde CO_2 konsentrasjonen under 1000 PPM
Systemtype	Prøver å holde romtemperaturen under 26.0 °C
Luftmengde	Maks.: 13.0 m³/h/m²; Min.: 13.0 m³/h/m²; Utenfor: 2.0 m³/h/m²; Helg: 2.0 m³/h/m²
Tilluftstemperatur	19.0 °C
Annen tilluftstemperatur sommer	Tilluftstemperatur sommer: 18.0 °C Sommermåneder: Mai - August
Driftstid	Timer med drift: 10:00
Varmebatteri	Ja Maks. kapasitet: 30 W/m²
Kjølebatteri	 Maks. kapasitet: 41 W/m²
Vannbåren distribusjon til kjølebatteri	Delta-T: 6.0 °C SPP: 0.5 kW/(l/s)
Varmegjenvinner	Ja, temperaturvirkningsgrad: 0.85
Vifter	Plassering tilluftsvifte: Etter gjenvinner Plassering avtrekksvifte: Etter gjenvinner
SFP-faktor vifter	2.00 kW/m³/s

Figure 132,

Inndata oppvarming	
Beskrivelse	Verdi
Navn:	Heat (oppvarming)
Settpunkttemperatur i driftstid	21,0 °C
Settpunkttemperatur utenfor driftstiden	19,0 °C
Maks. kapasitet	94 W/m²
Konvektiv andel oppvarming	0,50
Driftstid	10:00 timer drift pr døgn
Vannbårent oppvarmingsanlegg	Ja
Turtemperatur	50,0 °C
Returtemperatur	30,0 °C
Spesifikk pumpeeffekt	0,50 kW/(l/s)

Figure 133,

Inndata belysning	
Beskrivelse	Verdi
Navn:	loads (internlaster, belysning)
Effekt/Varmetilskudd belysning	I driftstiden; Effekt: 3,0 W/m²; Varmetilskudd: 100 % Utenfor driftstiden; Effekt: 0,0 W/m²; Varmetilskudd: 100 % På helg/feriedager; Effekt: 0,0 W/m²; Varmetilskudd: 100 % Antall timer drift pr døgn: 10:00

Figure 134,

Inndata varmetilskudd personer (internlast)	
Beskrivelse	Verdi
Navn:	loads (internlaster, varmetilskudd personer)
Varmetilskudd personer	I arbeidstiden: 4,7 W/m² Utenfor arbeidstiden: 0,0 W/m² Ferie/helgedager: 0,0 W/m² Antall arbeidstimer: 10:00

Figure 135,

Inndata lokal kjøling	
Beskrivelse	Verdi
Navn:	Cooling (lokal kjøling)
Settpunkttemperatur	23,0 °C
Maks, kapasitet	40 W/m²
Konvektiv andel kjøling	0,50
Driftstid	11:00 timer drift pr døgn
Kjøling på helge/feriedager	Nei
Kjøling via vannbårent anlegg	Ja
Turtemperatur	14,0 °C
Returtemperatur	17,0 °C
Spesifikk pumpeeffekt	0,80 kW/(l/s)

Figure 136,