Off Grid Energy Supply Solution

Sustainable Energy Solution for Off-Grid energy supply in the Kvarken Archipelago Vasa, Finland

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EPS

Vasa, Finland 2012

Project report

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Abstract

Today it is often diesel generators which provide the energy supply for remote islands in the archipelago. This project is about the development of a model for evaluation of energy needs but also to find a concept for replacing old generators by sustainable energy solution. The evaluation model was used to calculate the heat and electricity needs of two specific islands. The project included also the task to find a way to store excess energy. After comparing methods of storing energy, hydrogen fuel cells were found to have important advantages. They can store large amount of energy, are relatively cheap and are environmentally friendly. Solar and wind energy have been chosen as the main power sources. Sun and wind are widely known and available in the archipelago and obtaining energy out of these sources is known technology. The rare thing is the storage by hydrogen fuel cells. Storage by hydrogen fuel cells consists of four main stages: namely production, storage, utilization and reutilization.

This research shows that it is technically possible to use wind and solar power as main energy sources as well as storing energy in hydrogen fuel cells to create an autonomous off-grid power supply all year round.

Language: English Keywords: Sustainable energy, fuel cell, archipelago

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Projekt rapport

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Abstrakt

Idag är det ofta dieselgeneratorer som sköter om energiförsörjningen för avlägsna öar i skärgården. Detta projekt handlar dels om att utveckla en modell för att utvärdera dylika energibehov och dels om att finna ett koncept för att ersätta gamla generatorer med hållbara energilösningar. I projektet används utvärderingsmodellen för att beräkna värme- och elektricitetsbehovet på två specifika öar. I projektet ingick också att finna ett sätt att lagra överskottsenergin. Efter att ha jämfört olika metoder för energilagring, visade det sig att vätgasbränsleceller har betydande fördelar. Vätgasbränslecellen kan lagra stora mängder energi samt är förhållandevis billig och miljövänlig. Sol- och vindenergi valdes som de primära energikällorna. Sol och vind är kända och tillgängliga källor i skärgården och att skapa energi ur dessa källor är välkänd teknik. Det som är mera ovanligt är energilagring i bränsleceller. Förvaring av energi tack vare vätebränsleceller innehåller fyra huvudsakliga steg, nämligen produktion, lagring, användning och återanvändning.

Denna forskning visar att det är tekniskt möjligt att använda vind- och solkraft som huvudsakliga energikällor samt att lagra energin i vätebränsleceller året om och på så sätt skapa en självständig och hållbar energiförsörjning.

Språk: Engelska Nyckelord: Hållbar energi, bränslecell, skärgård

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Summary

Introduction

This project is a research on the technological possibility to provide nature stations in the Kvarken archipelago with sustainable energy.

Archipelago

The Kvarken Archipelago, located southeast of Vasa in Finland, became Finland's first UNESCO Natural World Heritage Site in July 2007. *(kvarken.fi)* It is known as 'an internationally valuable natural area with many important habitats and endangered species. The area is characterised by its small scale and its biological and geomorphological diversity'. *(kvarkenguide.org (1))* The archipelago consists of a group of islands. Some of those islands contain buildings. For example, Mickelsörarna, located northwest in the archipelago, has 'an old coast guard station, which was closed in 1993, now serves as a nature station' *(kvarkenguide.org(2))*. Valsörarna, located west of Mickelsörarna, is declared a bird sanctuary in 1948. Valsörarna's landmark, the red-painted 36-metre tall iron lighthouse, was designed in 1886 in Paris by the same firm that later built the Eiffel Tower. *(kvarkenguide.org (3)).* On Äbbskär, part of Valsörarna, there is also an old coast guard station.

Goals

Diesel generators supply the current power supply. This project consists of two main goals. Firstly, the development of a tool to evaluate the energy needs of the existing buildings. Secondly, the design of a sustainable, mostly autonomous solution that provides energy for the buildings on Mickelsörarna and Valsörarna. In this project sustainability denotes: minimal impact to the environment in the long-term. Not only the emissions of the system should be significantly lower than the current diesel system, the new solution should last about 20 years with low maintenance costs. The most autonomous factor refers to the fact that, the islands are inaccessible during the winter, due to the ice conditions.

The buildings have different energy needs. Valsörarna's coast guard station is bigger than the old coast guard station on Mickelsörarna. The building on Mickelsörarna has, a summer café. The electricity needs are for those reasons different. To develop a solution the electricity needs would have to be known. To calculate the needs the developed Energy Evaluation Model is used. The heating requirements of the buildings are similar. During the winter, the buildings need to be heated, to a stable five degrees Celsius. If the buildings experience high temperature fluctuations, the buildings will suffer from the climate and from falling into decay.

Possible energy sources

To produce sustainable energy in the archipelago there are different sources to exploit. Climate, weather, tide, waves and geothermal possibilities to generate energy from natural sources have been researched. The options were presented to the project owner and the project manager. During a project meeting all options were presented. During this meeting it was decided that Wind and Sun, with an energy backup by creating and storing hydrogen, would be the best possible sources to fulfill the energy needs throughout the year. In combination with a backup bio fuel generator, in case of complete system failure, this concept should provide an uninterrupted power supply throughout the year.

Primary System

As stated above there are three energy systems in this concept. The primary system contains a wind turbine and solar panels for the production of energy. The chosen wind turbine is a 12-meter tall, 10 kW turbine. In combination with a more specific chosen amount of solar panels the energy needs of the buildings are mostly covered. The combination of a wind turbine and solar panels is chosen on the weather data. In winter when the energy demand of the buildings is the highest, the wind is mostly stronger than in the summer. On Mickelsörarna where a café is open during the summer, solar panels are installed, as the average wind speeds are lower in the summer months, but the Solar Insolation is significantly bigger. When the demand of energy is bigger than the production, the stored hydrogen will supply the extra need. The hydrogen is created in times when the demand is lower then the production.

Secondary System

The excess energy that the main system produces is used to create hydrogen. Hydrogen is the source of backup energy when the main system output is not sufficient. Hydrogen is created out of purified water using an electrolyzer. The chemical reaction in the electrolyzer is:

$2\ H_2O(\mathit{l}) + \text{Electricity (1.23 V)} \dashrightarrow 2\ H_2(\mathit{g}) + O_2(\mathit{g})$

The created oxygen disperses into the air. The most adequate hydrogen storage system for the characteristics of this project (remote isolated location, automated, easy maintenance, safety, available space) is to use a pressurized steel tank containing gaseous hydrogen at no more than 30 bar.

- It is cheaper than other similar solutions, like composite tanks.
- It can operate at cold temperatures (liquid storage requires cryogenic temperatures).
- It doesn’t require a heat input to extract the hydrogen (solid storage does).
- It is safe. In case of leakages, gaseous hydrogen dissipates easily in the air.

The backup system is designed so that it can supply non-stop energy for 7 days. To utilize the stored oxygen, a fuel cell is required. A Proton Exchange Membrane Fuel Cell is the most suitable for this project. Some advantages of a PEM FC are:

- Safer thanks to lack of hazardous chemicals
- Quick start-up
- Low temperature operation
- Few or no moving parts at all
- Maintenance becomes a less important issue
- They are scalable, from a small number of cells to a large stack depending on the need
- Efficiencies from 35 to 60 for electricity
- Efficiencies up to 85 or 90% for CHP (combined heat and power)

The chemical reaction in the Fuel Cell is:

$2\ H_2(g) + O_2(g) \text{-->} 2\ H_2O(l)$

The electrolyzer needs to be fed water with a high grade of purity. This purified water needs to be transported and stored on the islands. The hydrogen is converted back to water vapor in the fuel cell. The water vapor can be retrieved to reuse it. It will run through a condenser and transported back to the purified water storage. It is in theory a closed cycle. In reality there will always be a certain level of losses. This makes it usable to size the purified water storage, not just big enough to fill the hydrogen tank, but a little bigger to take the losses into account.

Backup Generator

Due to the inaccessibility of the islands during the months when there is ice, the concept solution provides an emergency back-up generator. A control system is programmed that the generator will start automatically when both the primary and secondary system fail. It is a biofuel engine, designed for remote rural areas. It provides enough energy to keep the building heated to a stable 5 degrees Celsius.

Heating and ventilation

The heating system in the buildings on the islands is radiators on the wall with an inside water temperature of 45 degrees Celsius. The water is at the moment heated by generators. To heat up the water in the radiators a Heat pump will be installed. A vertical Ground Source Heat Pump is chosen for the following reason:

- There are no moving parts
- No view pollution
- No seasonal influence, therefore a stable temperature input
- High heat profit thanks to a high input temperature

Ventilation is another important factor for the prevention of structural damage on a building. Ventilation can happen naturally or mechanically. Naturally means that natural forces penetrate outside air into a building. Mechanical ventilation forces air in or out a building using electrically driven fans. Research on ventilation shows that the buildings in the archipelago benefit the most from a Heat Recovery Ventilation system. A heat exchanger transfers the heat of the outgoing air to the incoming air. This results in a substantial decrease of heat losses.

Control system

To control the system is automated by a programmed PLC. It is programmed in a way that it operates autonomously. But in case of a system error it is possible to remotely overrule the automated operations and start or shut down subsystems manually.

Conclusion

The results of this project are an Energy Evaluation Model and a Concept solution for sustainable energy supply for remote buildings in the Kvarken archipelago. The evaluation model is a useful tool for engineers for the estimation of the electricity and heat needs of a building. The concept solution is divided into four sizes. Two generic sizes, sized smaller than 5 kW and five to 10 kW. Moreover, two specific solutions are produced, one concept for Mickelsörarna and another concept for Valsörarna.

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List of Units

ºC	Celsius Degree
g	Gram
m^2	Square meter
m^3	Cubic meter
m/s	Meter per second
l	Liter
%	Percentage
W	Watts
kW	Kilowatts
kWh	Kilowatts hour
T	Temperature
J	Joules

List of Abbreviations

1^{ST}	First
2^{ND}	Second
AC	Alternate Current
ASHP	Air Surface Heat Pump
Avg	Average
CHP	Combined Heat and Power
Co LTD	Limited Company
CO_2	Carbone Dioxide
COP	Coefficient of Performance
DC	Direct Current
E	East
EDLC	Electric Double Layer Capacitor
Elec.	Electricity
EPS	European Project Semester
ERV	Energy Recovery Ventilation
G.K.	Green Kingdom
GSHP	Ground Source Heat Pump
H_2	Hydrogen
HP	Heat Pump
HRV	Heat Recovery Ventilation
i.e.	For Example
MS	Microsoft
MW	Megawatts
N	North
NE	Northeast
NRCan	Natural Resources Canada ??
ND	No Date
NW	Northwest
O.Y.	*Osakeyhtiö,* Limited Company
P	Pressure
PEM	Polymer Electrolyte Membrane
S	South
SE	Southeast
STP	Standard Temperature and Pressure
SW	Southwest
SWHP	Surface Water Heat Pump
TINOX	Titanium Nitride Oxide
UNESCO	United Nations Educational, Scientific and Cultural Organization
U.S.	United States
VDC	Volts Direct Current
W	West

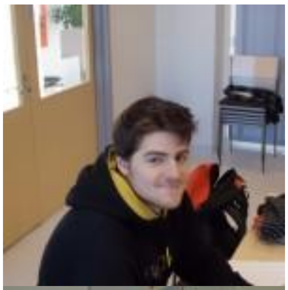
Preface

European Project Semester (EPS)

The European Project Semester is a program offered by ten European universities in eight countries throughout Europe. The purpose is to prepare engineering students with all the necessary skills to face the challenges of today's world economy. The students meet in international teams of 2-10 students from these different countries to work on their dedicated projects. International student teams are composed to match the students' specializations and capabilities as well as to develop their inter-cultural communication and teamwork skills. (Yrkeshögskolan Novia, 2012)

Six students from Spain, the Netherlands, Belgium, China and Finland compose the EPS spring 2012 - team. All students have different degrees as mechanical engineering, electrical engineering, product development and human technology engineering.

Members



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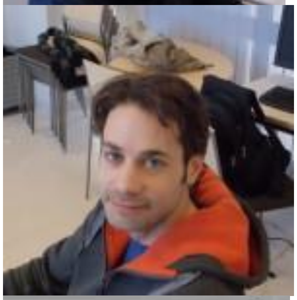

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Thanks to

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Roger Nylund	*Project advisor, Head of Industrial Management*
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Kim Westerlund	*Sales Manager at Novia UAS*
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Lars-Johan Andersson	*Senior Development Manager at Wärtsilä*
Kari Hallantie	Head of Metsähallitus, Vasa
Niklas Frände	*Research and Development engineer at Novia UAS*

1 Introduction

1.1 Task

The Kvarken Archipelago near Vasa is a group of islands located on the western shore of the Gulf of Bothnia. It became Finland’s first and only natural UNESCO world heritage site in July 2007. (Kvarken World Heritage, n.d.)It is an internationally valuable natural area with many important habitats and endangered species. The area is characterized by its small size and its biological and geomorphological diversity (Anders Enetjärn, Lise-Lotte Molander, n.d.). Some of the islands in the archipelago contain buildings. These buildings are old coastguard stations that nowadays serve as nature stations. More information about the buildings is given in chapter 3.1 on Mickelsörarna and in 3.2 on Valsörarna. The nature stations are only used in the summer for recreational and tourism purposes. In the winter the concrete buildings suffer from the cold and humidity. They need to be heated to prevent decay.

This European Project Semester (EPS) comprises two tasks. The first task was to make an evaluation model for the energy demands for remote places like Mickelsörarna and Valsörarna. The model may contain technical terms, so people that are comfortable with these terms can use the model. This part of the project will continue during the summer for other islands and harbor stations. The usability of this evaluation model is an important factor in this assignment. The second task was to research and develop a sustainable solution for the energy demands on Mickelsörarna, Valsörarna and a generic solution for other buildings in the archipelago.

The EPS project group was encouraged by the management to look for an innovative solution, to think outside the box. Cost would not be a big issue, if the solution was found satisfactory.

1.2 Goals

The goal of this EPS is to generate a sustainable and mostly autonomous solution for buildings in the Kvarken archipelago. This means that it can last for many years with little maintenance needed. Another important aspect is the whole system being environmentally friendly, without any harmful emissions to nature. The new solution should not only be sustainable and autonomous, but also an investment to lower the costs in a time range of 20 years.

1.3 Tools

To help this EPS group to succeed, tools are given by Novia University of Applied Sciences, or arranged by project members themselves. The most used tools are:

- Lectures
- Tritonia Academic Library
- Internet
- Weekly meetings
- MS Project
- Experts from commercial companies

In the first phase of this project, **lectures** were given about different subjects in relation to the project. The purpose of these lectures was to get to know each other and learning the expertise needed for this project.

The project started with two introduction days to get to know the campus, the city and the group members. The lectures started with 'team building and cultural difference' sessions, given by Mr Roger Nylund. The same week, Christian Nelson gave the group a guided tour of the university library Tritonia, as well as the digital resource database. Furthermore, there was a lecture called 'Project work, my way' by Mr Jan Teir. Mr Jan Teir is the owner of this project. His experience and expertise in project work is a guidance in this assignment. He also gave a lesson on 'MS Project', to use the software as a planning tool. Next to that there were 'energy solutions' lectures by Mr Ronnie Sundsten and Brush-up English by Ms Ulla-Maj Söderback.

The **library** was used to gather knowledge and information about energy solutions, electricity needs, off grid examples and fuel cell basics. The main source in this project is however the **Internet**. Information given by questionable internet sources are avoided or double-checked.

An important tool during this project were the **Project Meetings**. Every week there was at least one project meeting with the project owner and the project manager. During these meetings the students had to present their research, decisions and accomplishments of the previous week. The role of chairman and secretary were rotary, so that every team member had the opportunity to learn from this experience. During the project meetings the project manager and project owner gave feedback and guidance to the team.

At the end of the engineering phase (phase II) specific answers about the final solutions were desired. To get these answers experts were contacted and asked if they were willing to cooperate. Some experts were lecturers; some **experts** were from **commercial companies.**

1.4 Limitations

This project aimed for a sustainable energy solution for remote places in the Kvarken archipelago in Finland. The weather conditions in the archipelago and the location of these islands are two factors that have made the result of this project relevant in only this region. The purpose of the project is to generate a plausible specific and generic solution for buildings in the archipelago, taking these two factors into account. The reasons why the solutions have been chosen will be substantiated and the used technology will be explained in an understandable way, without that previous knowledge of the matter being necessary.

2 Project

2.1 Work Methodology

The European project semester in Vasa offered by Novia University of Applied Sciences is focused on energy and environment. EPS projects may also contain other essential elements, such as communication, management, planning, European law, innovation, marketing and language. (European Project Semester, KL, 15-12-2011). Novia's EPS website states: *'The EPS-program is crafted to address the design requirements of the degree and prepare engineering students with all the necessary skills to face the challenges of today's world economy.'* (Yrkeshögskolan Novia, 2012)

To successfully complete this project, it is split up in three phases. The three phases are:

- Phase I: Brainstorming and Idea Generation
- Phase II: Engineering
- Phase III: Documentation

Every phase has a different organization. The roles of Project Leader and Project Administrator change every phase and are decided in Phase I. **Phase I** consists of brainstorming and idea generation. The goals are made clear, concept ideas are generated, and the choices made are backed up with facts.

Phase II is the engineering phase. This is the phase where calculations and concept drawings are made about the final decisions in the project

Last phase is **phase III**, the documentation phase. In this phase the final report is written and the project presentation is made. At the end of the phase the final report is handed in and an oral presentation of the project is given.

Communication

A weekly project meeting is carried out in order to communicate the progress of this project to the project owner and project manager. During these meetings the Project leader hands in a written Weekly Status Report, which contains the following information:

- Summary of tasks completed in previous week
- Summary of tasks scheduled for completion next week
- Summary of issue status and resolutions
- Summary of the project status
- Summary of time usage (per student) including tasks
- All above-mentioned summaries are made with the same template

Desk research

Desk research is the main research method used in this project, with the Internet as primary information source. The project started without any previous research. During all phases, desk research has been used to obtain knowledge and data about e.g. similar projects. It started in phase I with looking at the current state of technology. In phase II it was used to find the right equipment, suppliers but also additional knowledge. In phase III it was used to gather and apply knowledge about writing regulations for scientific reports.

2.2 Logo

To enhance the group coherence and presentation, the EPS team created a logo *(Figure 1).* The logo has been used on every presentation material used outside the team.

Figure 1: EPS Spring 2012 team logo

The logo is a green leaf with the name of the project team, eps2012s. The name is just an abbreviation of European Project Semester 2012 Spring. The team adopted this name and used it throughout the rest of the project. The leaf and the green represent the sustainability factor in this project.

2.3 Ekenäs Fair

Phase I was ended with a presentation of the concept on the Novia environmental fair in Ekenäs. The Environmental Fair 2012 is an event jointly organized by Novia University of Applied Sciences, the City of Raseborg and Ekenäs Energy Company (Yrkeshögskolan Novia, 2012). The main goal of the fair was to learn how to prepare and present this project at a fair. To accomplish this goal two posters, a business card and a presentation were produced. *(Appendix 01: Ekenäs Fair Posters and Appendix 02: Business Card)*

2.4 Website

To inform anyone interested in this project, there is a website**.** http://eps2012s.novia.fi.This address is mentioned on the business cards. The website contains information about the project, the team members and the archipelago. It will be kept up to date, until the end of the project, to inform the interested persons about the latest developments in this EPS project.

2.5 Visit to Mickelsörarna

This EPS started on February 1, 2012. At that time the archipelago was covered in ice. Due to the ice conditions in the archipelago it was impossible to go safely to the islands. This meant that the team had to work with the information provided by Novia and pictures of the buildings on the islands. In April, after the melting of the ice the team visited Mickelsörarna. The main purpose of the visit was to extract data and to get an impression of the state of the building. The building was closely inspected, and the amount of electricity for the appliances was checked. Besides that the team had the opportunity to exchange thoughts with the responsible engineers of the building on Mickelsörarna *(Figure 2)*.

Figure 2: Visit to Mickelsörarna

3 Energy demands

In this chapter, the use of the energy evaluation model is explained, and the results of this model applied on the nature stations of Mickelsörarna and Valsörarna are shown.

3.1 Energy evaluation model

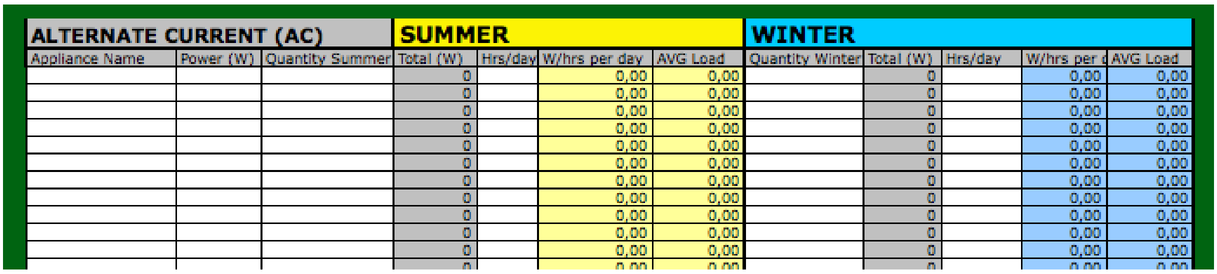
As mentioned in chapter 1.1, the energy evaluation model is the second aspect of the project.

The result is a spreadsheet made for calculating the electricity needs as well as the heat losses for a building. The evaluation is suitable for off-grid, remote buildings, as they can be found on e.g. Mickelsörarna and Valsörarna. To use it correctly, both models include an instruction manual *(Appendix 03: Instruction Manual Electricity Evaluation).*

3.1.1 Electric Evaluation

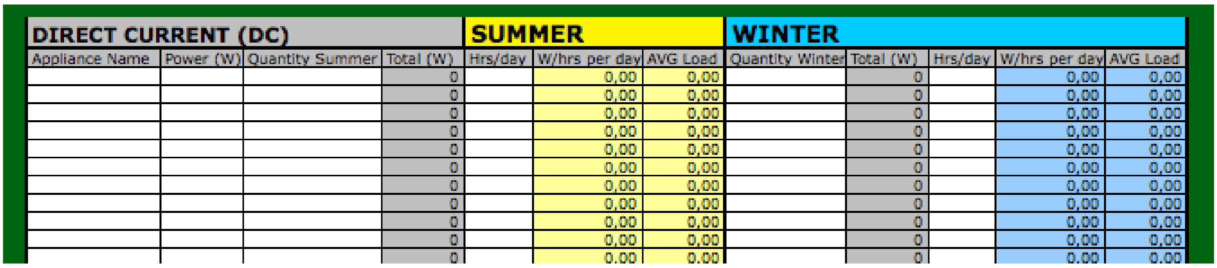
The electric evaluation consists of two parts. The AC (Alternate Current)*(Figure 3)* and the DC (Direct Current)*(Figure 4).* The person who uses the evaluation model needs to know the power consumption of all the appliances that are or will be used in the building, the quantity and the amount of hours that the appliances run in summer and in winter.

By filling in the white cells with this data the model calculates the average and peak electricity consumption, depending on the season. If an appliance is not used during wintertime, change the quantity to 0. This means that the model will not take the appliance into account in the calculations about total energy.



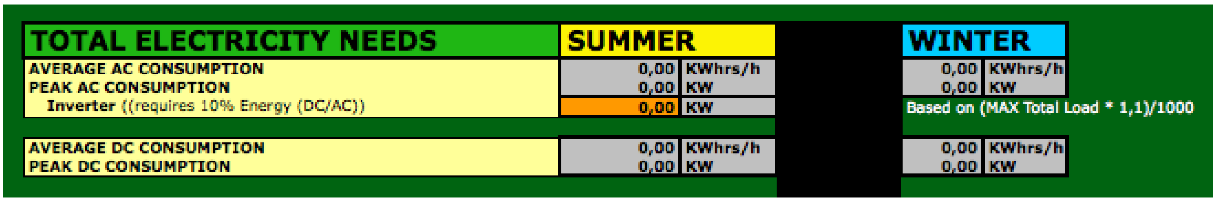
ALTERNATE CURRENT (AC)			SUMMER				WINTER				
Appliance Name	Power (W)	Quantity Summer	Total (W)	Hrs/day	W/hrs per day	AVG Load	Quantity Winter	Total (W)	Hrs/day	W/hrs per d	AVG Load
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00

Figure 3: Electric Evaluation Model-AC load



DIRECT CURRENT (DC)				SUMMER			WINTER				
Appliance Name	Power (W)	Quantity Summer	Total (W)	Hrs/day	W/hrs per day	AVG Load	Quantity Winter	Total (W)	Hrs/day	W/hrs per day	AVG Load
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0.00	0.00		0		0.00	0.00

Figure 4: Electric Evaluation Model-DC load

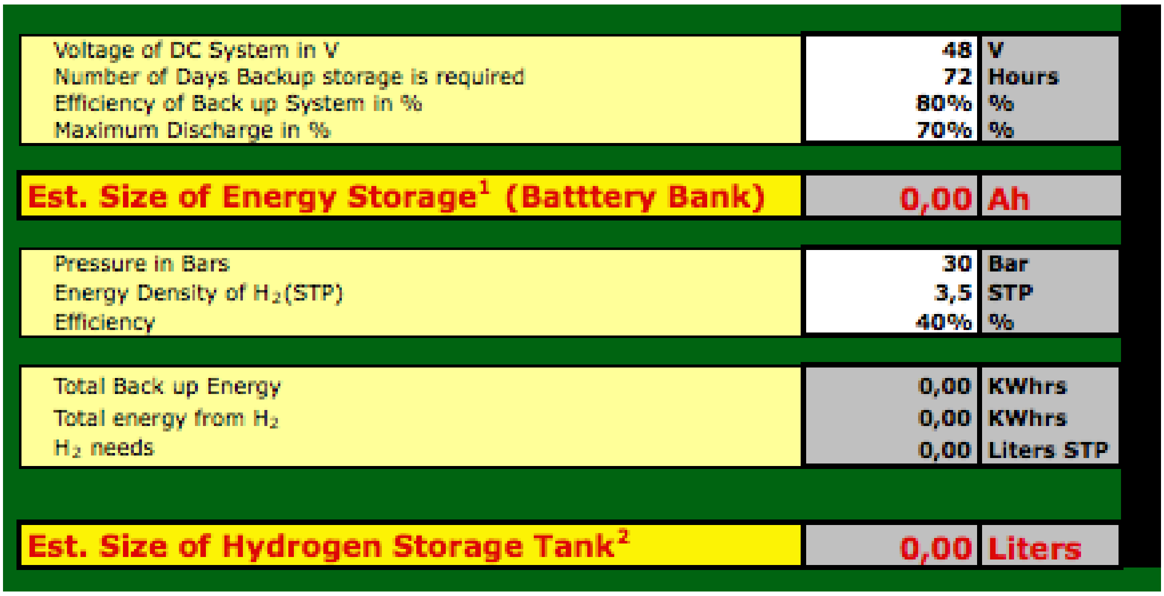


TOTAL ELECTRICITY NEEDS	SUMMER		WINTER	
AVERAGE AC CONSUMPTION	0,00	KWhrs/h	0,00	KWhrs/h
PEAK AC CONSUMPTION	0,00	KW	0,00	KW
Inverter ((requires 10% Energy (DC/AC))	0,00	KW	Based on (MAX Total Load * 1,1)/1000	
AVERAGE DC CONSUMPTION	0,00	KWhrs/h	0,00	KWhrs/h
PEAK DC CONSUMPTION	0,00	KW	0,00	KW

Figure 5: Electric Evaluation Model-Total electricity needs

At the bottom of the Electric Evaluation sheet there is a summary of the Electricity needs *(Figure 5).*The average consumption and the peak consumption are calculated. These numbers are needed in further calculations of the size of the installation for the power supply.

Due to the unreliable power supply, generated by sustainable energy sources (e.g. wind energy), a secondary power supply is needed. It is used to cover the electricity needs when the energy generated by the primary system is not enough (e.g. not enough wind when using a wind turbine). This model calculates the size of a battery bank and the size of a hydrogen tank for a fuel cell backup system (*Figure 6*).



Voltage of DC System in V	48	V
Number of Days Backup storage is required	72	Hours
Efficiency of Back up System in %	80%	%
Maximum Discharge in %	70%	%
Est. Size of Energy Storage[1] (Batttery Bank)	**0,00**	**Ah**
Pressure in Bars	30	Bar
Energy Density of H_2(STP)	3,5	STP
Efficiency	40%	%
Total Back up Energy	0,00	KWhrs
Total energy from H_2	0,00	KWhrs
H_2 needs	0,00	Liters STP
Est. Size of Hydrogen Storage Tank[2]	**0,00**	**Liters**

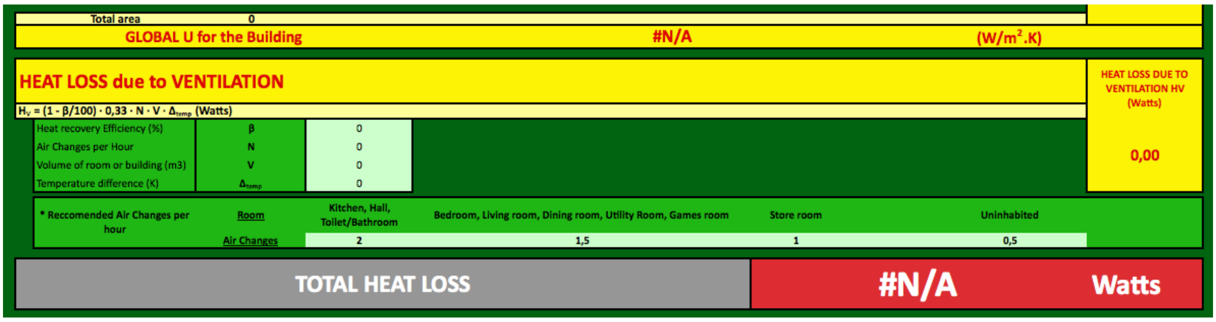
Figure 6: Electric Evaluation Model-Secondary power supply

3.1.2 Heating Evaluation

The total heat loss is calculated by the sum of the losses due to transmission and ventilation. Both are given after the input of building and environment information such as wall area and components (windows and doors), construction materials, used ventilation system and temperature difference.

It will be used to establish a correct idea of the energy consumption of the investigated building. The use of the model starts with filling in the data for the losses due to ventilation *(Figure 7)*:

- **Outside** minimum average temperature [in Celsius degrees].
- **Ground** minimum average temperature (approximate) [in Celsius degrees].
- **Inside** objective temperature [in Celsius degrees].
- Approximate **Volume** of building [in m^3].
- **Air changes** per hour (see table on the bottom).
- Air Heat Recovery System **Efficiency**. If there is none, write 0 (zero) [in %].


Total area 0
GLOBAL U for the Building #N/A (W/m^2.K)

HEAT LOSS due to VENTILATION

$H_V = (1 - \beta/100) \cdot 0,33 \cdot N \cdot V \cdot \Delta_{temp}$ (Watts)

Heat recovery Efficiency (%)	β	0
Air Changes per Hour	N	0
Volume of room or building (m3)	V	0
Temperature difference (K)	Δ_{temp}	0

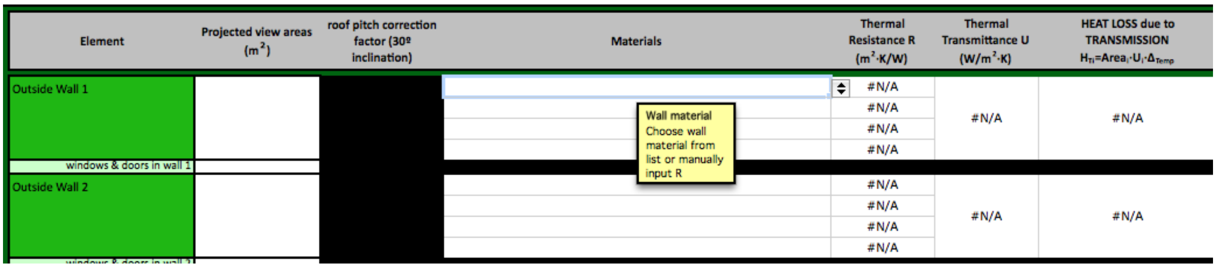
HEAT LOSS DUE TO VENTILATION HV (Watts)
0,00

* Reccomended Air Changes per hour	Room	Kitchen, Hall, Toilet/Bathroom	Bedroom, Living room, Dining room, Utility Room, Games room	Store room	Uninhabited
	Air Changes	2	1,5	1	0,5

TOTAL HEAT LOSS #N/A Watts

Figure 7: Heating Evaluation Model-Heat loss due to ventilation

The following step is the surfaces of the building. Starting with the wall area and materials *(Figure 8)*. It is possible to choose up to four different materials per wall. Then the size of the windows and doors are filled in. This results in the calculation of thermal transmittance of the building.

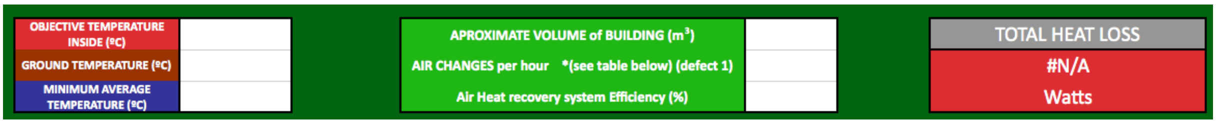


Element	Projected view areas (m^2)	roof pitch correction factor (30º inclination)	Materials	Thermal Resistance R (m^2·K/W)	Thermal Transmittance U (W/m^2·K)	HEAT LOSS due to TRANSMISSION H_{Ti}=Area$_i$·U$_i$·Δ_{Temp}
Outside Wall 1				#N/A #N/A #N/A #N/A	#N/A	#N/A
windows & doors in wall 1						
Outside Wall 2				#N/A #N/A #N/A #N/A	#N/A	#N/A

Wall material
Choose wall material from list or manually input R

Figure 8: Heating Evaluation Model-Heat loss due to transmission

The model creates a summary with the total heat loss of the building in Watts*(Figure 9).*


OBJECTIVE TEMPERATURE INSIDE (ºC)
GROUND TEMPERATURE (ºC)
MINIMUM AVERAGE TEMPERATURE (ºC)

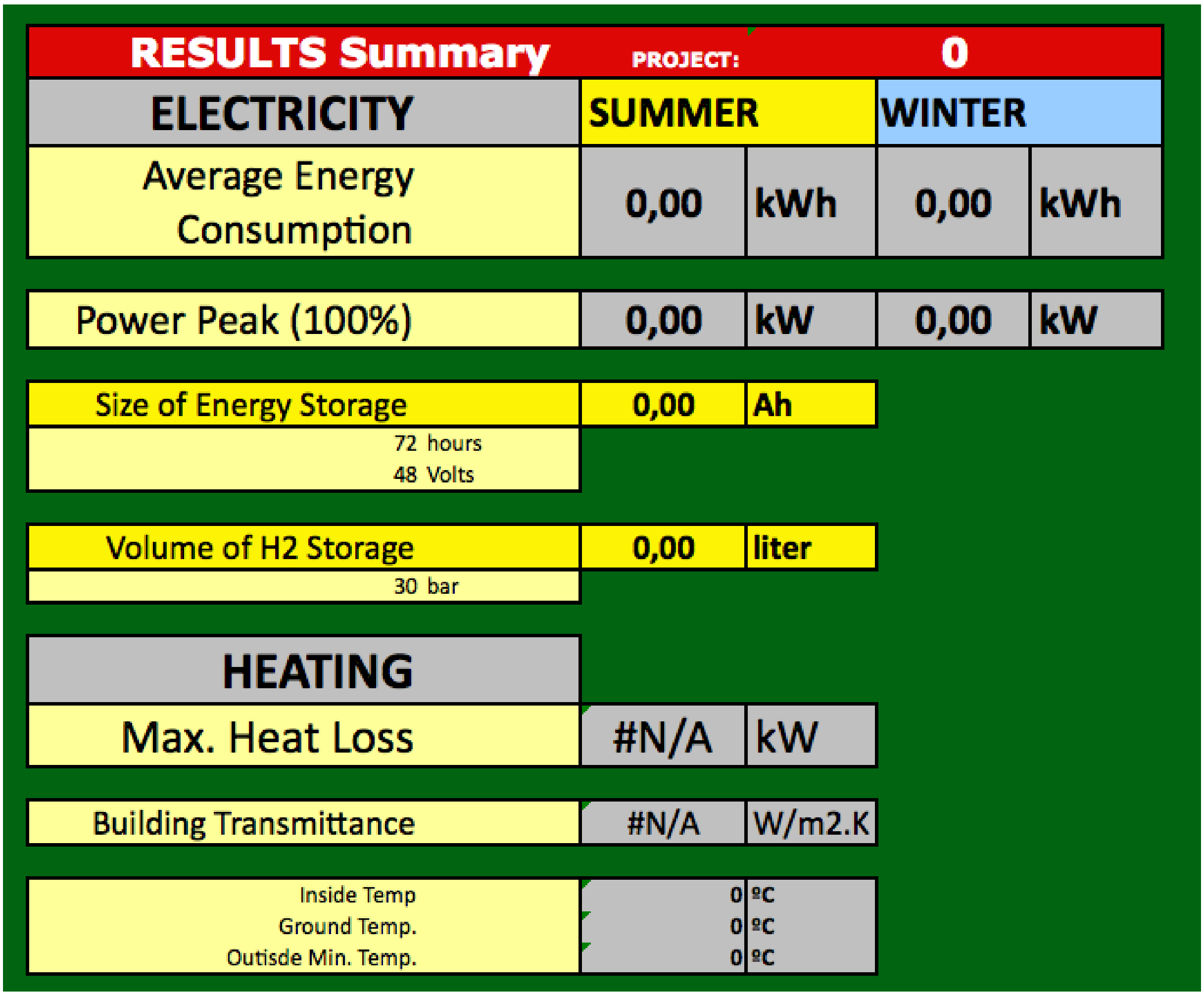
APROXIMATE VOLUME of BUILDING (m^3)
AIR CHANGES per hour *(see table below) (defect 1)
Air Heat recovery system Efficiency (%)

TOTAL HEAT LOSS
#N/A
Watts

Figure 9: Heating Evaluation Model-Heat loss summary

3.1.3 Summary

The last sheet of the Evaluation Model is a summary of the complete evaluation *(Figure 10)*.



RESULTS Summary	**PROJECT:**		**0**	
ELECTRICITY	**SUMMER**		**WINTER**	
Average Energy Consumption	**0,00**	**kWh**	**0,00**	**kWh**
Power Peak (100%)	**0,00**	**kW**	**0,00**	**kW**
Size of Energy Storage	**0,00**	**Ah**		
72 hours 48 Volts				
Volume of H2 Storage	**0,00**	**liter**		
30 bar				
HEATING				
Max. Heat Loss	#N/A	kW		
Building Transmittance	#N/A	W/m2.K		
Inside Temp	0	ºC		
Ground Temp.	0	ºC		
Outisde Min. Temp.	0	ºC		

Figure 10: Evaluation Model-Summary

These numbers can be used for the design of the building and for the design of the power and heating systems.

The developed EEM comes with this report. Because it is a digital working model, it is added to this report. It is to be found on a CD that is located is the back of this report. The CD contains the EEM as well as the manual how to use the model

3.2 Mickelsörarna

Mickelsörarna is a group of islands in the Kvarken archipelago. They are located at the northeast corner of Kvarken and the group comprises almost 300 islands. Relatively deep waters surround the large and small-forested islands. (Enetjärn & Molander, 2002)

On one of the islands called Kummelskäret, there is a former coastguard station which nowadays serves as a nature station *(Figure 11)* This building needs a sustainable electricity and heat generating solution. The station contains a café, which is open for tourists during the summer. Furthermore, there is a mobile phone base station, which has a constant electricity demand throughout the year.

The owner of the building is the Finnish forest administration (Forststyrelsen/Metsähallitus).

Figure 11: Nature station on Mickelsörarna (ÖFPL/Göran Strömfors, n.d.)

To dimension the power and heating systems, the demands needed to be known. The best option would have been to apply the Energy Evaluation Model as shown in chapter 3.1. However, most of the building construction data required to apply the Model was not available. Therefore, the calculations were based on the existing data from different sources, provided by the Project Managing Director.

Data:

- Document1: Tilastoja Suomen ilmastosta 1981-2010
- Data extracted from it can be found in the appendices (Appendix 07: Weather Data).
- Document2: Osa 1- sähkölaite ja kulutuskartoitus
- Document3: Osa 2- 97-07 kulut
- Document4: Osa 4-5 Optimaalinen energiantuotantosunnitelma

Mr. Kari Hallantie provided other basic information and blueprints, from the Finnish Forest Administration (Forststyrelsen/Metsähallitus) *(Appendix 05: Blueprints Valsörarna).*

Below follows a summary of the data gathered from the aforementioned sources:

- Main building (the one that has to be heated):
  - Located in the highest point of the island
  - Built in 1987
  - 2 stories + guard tower + basement
  - 689 m^2 useful surface
  - 1994 m^3 volume
- Electricity production:
  - 2 Diesel generators (75kW and 50kW) (Ford 2525E and Ford 2526E)
  - Wind turbine (3.2 kW) (Whisper 500)
  - Solar panels (2.1 kW) (Neste Oy NP100G/24)
- Thermal energy production:
  - Oil fired water heater (Riello 3062 428TI) (glycol instead of water)
  - Diesel generators exhaust gas waste heat collectors for hot water
- Operation 1997 to 2008
  - Fuel consumption 76250 l
  - 57850 l to electrical energy production
  - Max. 578500 kWh of energy, efficiency of about 30% => about 173000 kWh
  - 18400 l to heating
  - Heating only used during the winter
  - Generators oversized => running 10-30% load
  - Mobile phone station 35 kWh/day, 12780 kWh/year, 2000 to 2007, total 102200 kWh
  - Cafeteria open during summer months

3.2.1 Heating

Due to the lack of specific data of the heat needs for the main building in Mickelsörarna, the heat needs had to be calculated in some other way. Among the data available there was the fuel consumption for heating purposes and the amount of fuel used to generate electricity, which are detailed in *Table 1*. However, the fact that the exhaust heat from the diesel generators for electricity production was recovered made the calculations more imprecise because of the assumptions made.

Table 1: Heat needs on Mickelsörarna

	Fuel Burning	**Waste from Elec. Production**
Fuel consumed / 11 years (l)	18400	57850
Fuel consumed / year (l)	1673	5259
Efficiency	*90%	*40%
Energy density(kWh/ l)	9,8	
Months ON	6	12
Energy (kwh)	14753	20616
Total energy / year	**35369 kWh**	
Power (kW)	3,37	2,35
Total power	**5,7 kW**	

***assumptions**

Assumptions

There is a level of uncertainty with the results obtained due to some assumptions that had to be made. These are the assumptions:

- Efficiency of the fuel oil burners: 90%
- Efficiency of the exhaust heat recovery system: 40%
- Energy density of Diesel fuel: 9,8 kWh/l (it differs depending on the fuel)

Reliable historic climate information was necessary in order to estimate when and how much heating was needed. Taking the weather data into account, one can see how the temperature drops below 10º from October until May, and below 0ºC from December to March *(Table 2 and Figure 12).*

Table 2: Average temperatures during the winter and usage of heating estimation

Month	Avg. temp (ºC)	Heating usage
Sep	10,6	Off
Oct	5,8	50%
Nov	1,2	50%
Dec	-2	100%
Jan	-4,5	100%
Feb	-5,5	100%
Mar	-3,1	100%
Apr	1	50%
May	6	50%
Jun	11,1	Off

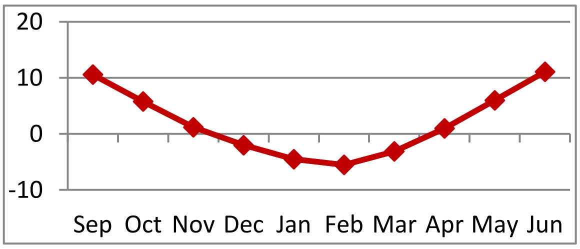


Figure 12: Average temperatures from September to June

After the calculations the conclusion reached was that the amount of **Power needed for heating Mickelsörarna**’s building is about **5.7 kW**, From that the used energy in a year becomes **35369 kWh of Energy**.

3.2.2 Electricity

The electricity has been produced combining the following systems:

- 2 Diesel generators (75kW and 50kW) (Ford 2525E and Ford 2526E)
- Wind turbine (3.2 kW) (Whisper 500)
- Solar panels (2.1 kW) (Neste Oy NP100G/24)

The electrical energy is necessary to feed the heating system, the electrical appliances in the building and the Mobile Phone Station. During the summer months a cafeteria/restaurant service operates in the building *(Table 3).*

Table 3: Electricity consumption detailed

	Time	**kWh / day**	**Power**	**kWh / year**		**Yearly electricity consumption**
Mobile Phone Station	all year	**35**	**1,5**	12775	12775	**20470 kWh**
Restaurant	5 months	**45**	**1,9**	6843	**7695**	
Stand by	7 months	**4**	**0,17**	852		

Electrical needs for heating

This table shows the consumption for the past years. The solution concept presented in this report uses a heat pump to provide the heating energy needed in the building. The mentioned heat pump needs electricity to run and produce the 5.7 kW of heat needed. The COP used for the calculations was 3. Therefore, to achieve those 5.7 kW of heat power, the electrical need is 5.7/3. That means less than 2 kW of electricity. Water pumps are also part of the system. Taking that into account and to make up for the assumptions made during the heat needs calculations, the electricity need for the heating system used will be 3.3 kW.

Electrical needs for the building

The Energy Evaluation Model developed by the EPS team was applied to calculate the electrical needs of the building in Mickelsörarna. This is the result obtained *(Table 4).*

Table 4: Electricity needs for Mickelsörarna obtained with the energy evaluation model

TOTAL ELECTRICITY NEEDS	**SUMMER**			**WINTER**	
AVERAGE AC CONSUMPTION	**3,35**	**KWhrs/h**		**5,00**	**KWhrs/h**
PEAK AC CONSUMPTION	**13,29**	**KW**		**5,38**	**KW**
Inverter ((requires 10% Energy DC/AC))	**14,62**	**KW**			

The detailed spreadsheet with the appliances can be found in *Appendix 08: Mickelsörarna Electricity Needs.*

Conclusion

As a conclusion the average Power Demand for Mickelsörarna is about **3.3 kW in the summer** (Cafeteria/Restaurant + Mobile Phone Station), and **4.4 kW in the winter** (Heating + Mobile Phone Station). Especially in summer, when the power demand is less steady, the need to cover the possible demand peaks must be taken into account.

3.3 Valsörarna

Valsörarna is another part of the archipelago, located west from Mickelsörarna and more central in the Kvarken area. The islands are known for their important bird sanctuary and the 36-metre tall iron lighthouse *(Figure 13)*. The lighthouse was designed in 1886 in Paris by the same firm that later built the Eiffel Tower. On Äbbskär, an island of Valsörarna, there is a coast guard station that also needs a sustainable energy solution. (Enetjärn & Molander, 2002)

The owner of this building is different than the owner of Mickelsörarna, namely the Finnish State properties. (Senatfastigheter).

Figure 13: Lighthouse on Valsörarna (ÖFPL/Göran Strömfors, n.d.)

For Valsörarna no information on electricity consumption or heat needs was available. The study case had to be based on blueprints and documents of the building for the calculation of the heat losses due to construction. Those documents were requested of the Finnish State Property (Senatfastigheter), the owner of the building on Valsörarna.

These are the documents on which the calculations were based:

-Blueprints (Copies of these can be found in Appendix 05: Blueprints Valsörarna.

• LEIKKAUS	*CUT VIEW*
• JULKISIVUJA: LOUNAASEEN, LUOTEESEEN	*FACADES: SW, NW*
• JULKISIVUJA: KAAKKOON, KOILLISEEN	*FACEDES: SE, NE*
• KELLARI	*BASEMENT*
• 1. KERROS	*1^{ST} FLOOR*
• 2. KERROS	*2^{ND} FLOOR*
• ULLAKKO	*ATTIC (guard tower)*

-Documents:

RAKENNUSSELITYS Mv-asema Valassaaret, ARKKITEHTIOTOIMISTO SALMINEN JA VÄRÄLÄ OY,

Helsinki 1982. (*BUILDING DESCRIPTION Nature Station Valsörana)*

Below there is a summary of the data obtained from the aforementioned sources:

-Main building (the one that has to be heated):

- Built in 1982
- 2 stories + guard tower + basement
- Around 760 m^2 surface
- Around 1864 m^3 volume

-Different floor/wall/roof types transmittances:

- Floor AP1: k=0,33 W/m^2ºC (outer region), k=0,33 W/m^2ºC (inner region)
- Floor VP1: k=0,42 W/m^2ºC
- Floor VP2: k=0,42 W/m^2ºC
- Floor VP4: k=0,24 W/m^2ºC
- Roof YP1: k=0,17 W/m^2ºC
- Wall US1: k=0,43 W/m^2ºC
- Wall US1: k=0,43 W/m^2ºC
- Wall US2: k=0,35 W/m^2ºC
- Wall US3: k=0,23 W/m^2ºC
- Wall US4: k=0,24 W/m^2ºC

-Windows are a 3-glass with air gap + 2-glass with air gap.

-Average minimum temperature in the coldest months is -20ºC.

3.3.1 Heating

The determination of the heat needs was made by calculating the heat losses of the building, according to its construction, building material, weather data, etc. the Energy Evaluation Model was used.

The areas of every wall, floor, ceiling, windows and doors had to be calculated as a first step to be able to apply the Energy Evaluation Model. Then there was data available for most surfaces and the calculation could be done *(Table 5)*.

Table 5: Building heat loss calculation using energy evaluation model summary

T inside	5	ºC
T outside	-20	ºC
T ground	0	ºC
HEAT LOSS THROUGH		
Walls	2490,5125	Watts
Windows	3744,290865	Watts
Doors	625	Watts
Basement	1446,51	Watts
Roof	1118,9375	Watts
Ventilation	618,75	Watts
TOTAL HEAT LOSS	**10044**	**Watts**

The complete calculation sheet can be found in *Appendix 10: Valsörarna Heat Needs.*

Some assumptions had to be made to estimate the transmittance of surfaces of which data was missing. Conservative criteria were used to decide which values would be used for the calculations. These assumptions are listed below.

Assumptions

- Surfaces and volumes were calculated from the blueprints
- k of walls with no data: 0,25 W/m^2ºC
- k for all roof types will be the same
- 1 complete air change per day with an air heat recovery efficiency of 50%

The calculated result is the **Heat Loss**. The heat need for the VALSÖRARNA's Nature Station Building is therefore: **10kW**.

3.3.2 Electricity

The electrical energy is necessary to feed the heating system and the electrical appliances in the building. There was no data used about the way electricity has been produced earlier.

Electrical needs for heating

As calculated in chapter 3.3.1, the heat loss of the building is about 10 kW in the coldest days. Calculating with a COP of 3 for the heat pump, we can obtain that the electrical power need of the heating system is around 3,3kW.

Electrical needs for the building

The Energy Evaluation Model developed by the EPS team was applied to calculate the electrical needs of the building on Valsörarna. In this building there is no cafeteria/restaurant, so the energy need during the summer period is very low. Even the average need is low, around 1.5 kW is used for the building appliances. The electricity demand of the building will come in peaks.

This is the result obtained *(Table 6)*:

Table 6: Electricity needs for Valsörarna obtained with the energy evaluation model

TOTAL ELECTRICITY NEEDS	**SUMMER**			**WINTER**	
AVERAGE AC CONSUMPTION	**0,50**	**KWh/h**		**4,37**	**KWh/h**
PEAK AC CONSUMPTION	**9,20**	**KW**		**17,20**	**KW**
Inverter ((requires 10% Energy (DC/AC))	**10,12**	**KW**			

The complete calculation sheet can be found in *Appendix 09: Valsörarna Electricity Needs.*

Conclusion

As a conclusion, the average Power Demand for Valsörarna is about **0,5 kW in summer**, and **5 kW in winter** (mainly for the heating system). The need to cover the possible demand peaks in summer, when there might be visitors in the building, must be taken into account.

4 Different concepts

At the end of the brainstorming phase (phase I) three different concepts were generated. One of these had to be chosen for further investigation and calculation in this project. The requirements were set at the beginning of this project. It had to be autonomous, sustainable, low-maintenance and last for approximately 20 years. The three different concepts are:

- Storage by Hydrogen
- Storage by Super Capacitors
- Waste to energy

4.1 Storage by Hydrogen

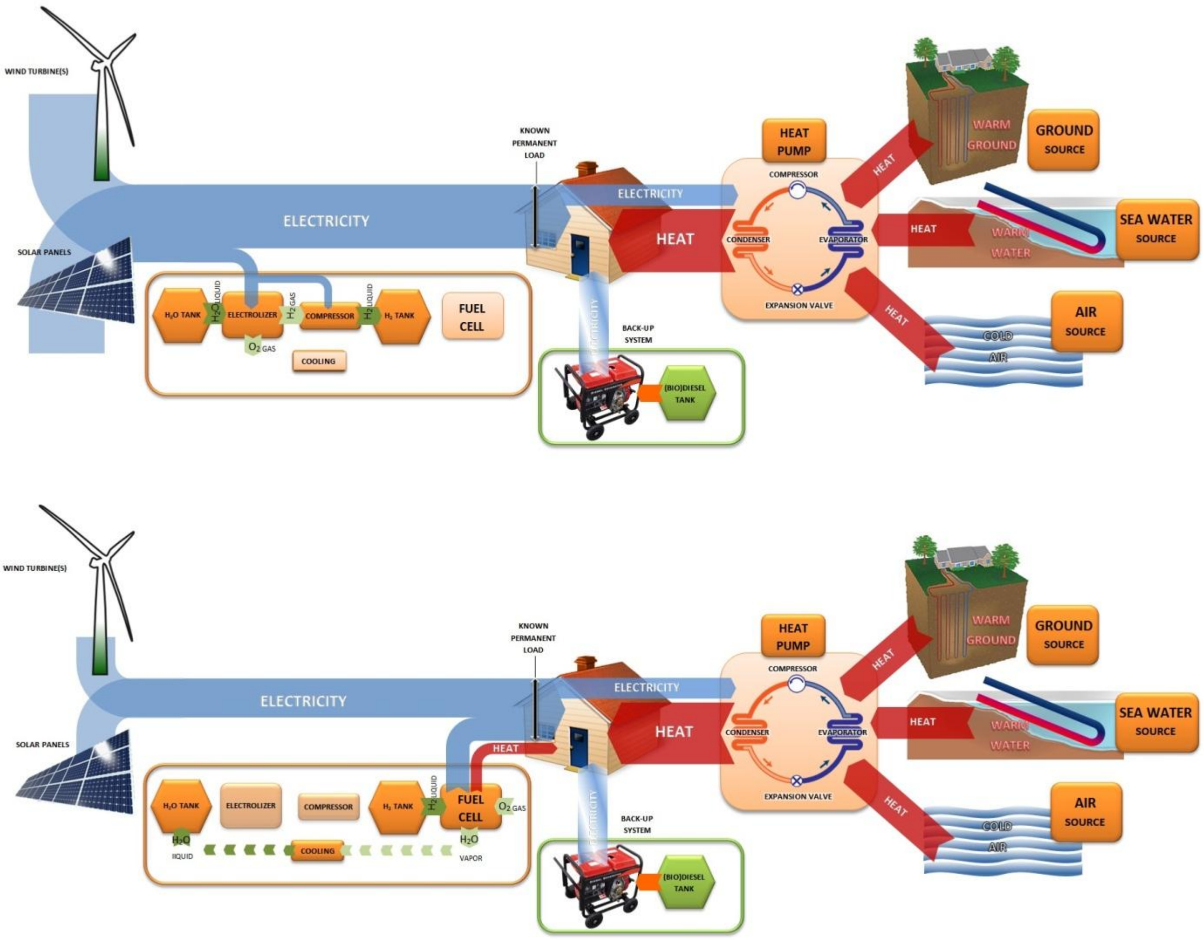


Figure 14: Different concepts - Stored by hydrogen

Figure 14 shows the first concept. This concept uses a wind and solar power as main power system, which, when the production exceeds the demand, converts water into hydrogen, and when the production is not big enough for the demand, that hydrogen is converted again into water and electricity. This hybrid system is chosen because of the favorable weather data and the fact that one of the islands already owns a wind turbine and solar panels. The main challenge in this project is the storage of electricity. In this concept the excess energy from the main power source is conducted to an electrolyzer that converts purified water into hydrogen and oxygen. The hydrogen is stored in a tank. When there is not enough power available from the main power system, the hydrogen is released into a fuel cell, which converts the hydrogen into electricity. The heat is supplied by a heat pump. This is known technology in Finland. The heat extracted by the collecting pipes can come from earth, water or air. This has to be investigated in the next stage.

Advantages of using hydrogen as a fuel for energy storage are:

- 2.5 to 3 times more efficient than gasoline.
- No CO_2 emissions.
- It is not toxic.
- In case it leaks, it dissipates very easily in the air.
- It can be stored under pressure, reducing storage space.

The disadvantages are:

- The total system has a low efficiency (up to 60% electricity, up to 85% with heat recovery)
- Young technology
- Expensive

This concept was forwarded to the Engineering Phase for further investigation and calculations.

4.2 Storage by Super Batteries

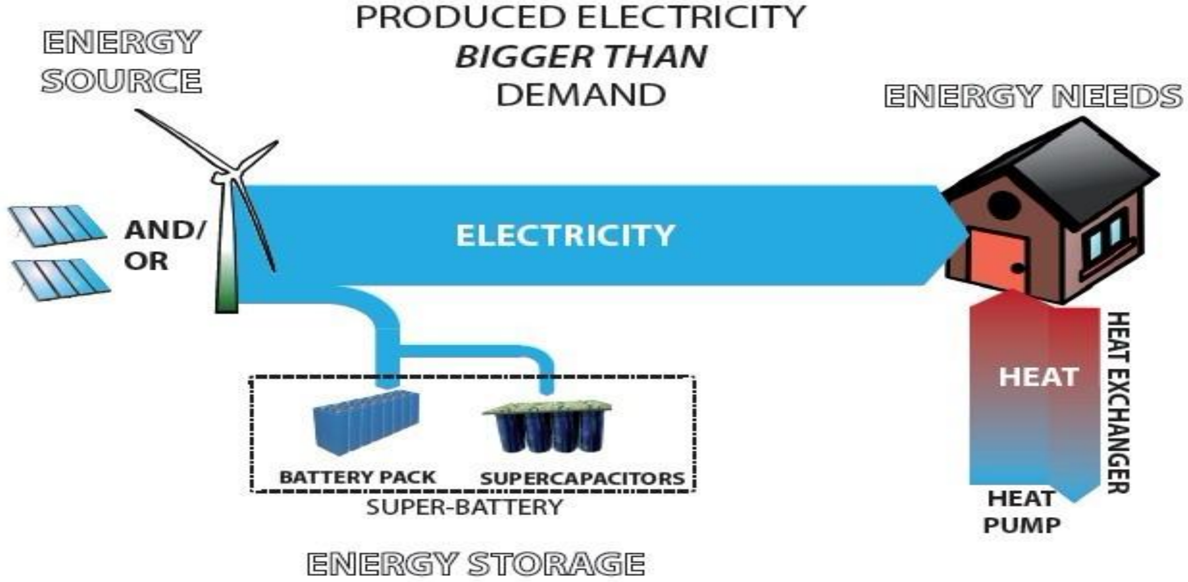


Figure 15: Different concepts - Stored by super batteries

The second concept is similar to the concept ‘Storage by Hydrogen’. The difference is the method of storing excess electricity *(Figure 15).* Instead of using hydrogen and a fuel cell or traditional batteries, the excess electricity in this concept, is stored by super batteries. A super battery is a conventional battery in conjunction with a super capacitor. A super capacitor (also known as EDLC, electric double layer capacitor) differs from a regular capacitor in that it has a very high capacitance.

Advantages of using super batteries are:

- Uninterrupted Power Supply
- Extends the lifetime of a battery (up to 4 times)
- 25% of the cost of a NiMH battery

Disadvantages are:

- High self-discharge rate
- Requires sophisticated control and switching equipment
- Spark hazard when shorted

This concept was forwarded as well. More research was needed to choose between Storage by Hydrogen and Storage by Super Batteries.

4.3 Waste to energy

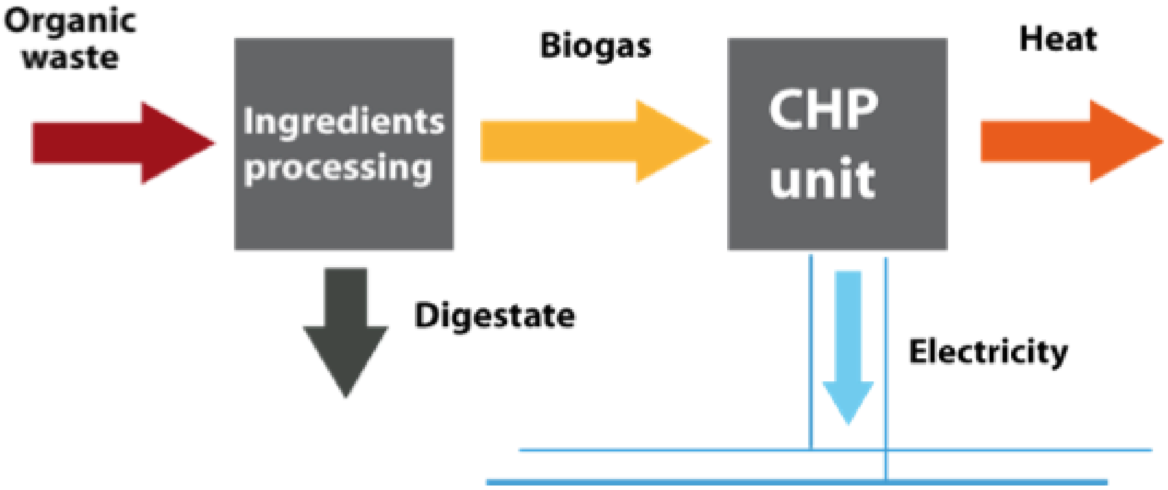


Figure 16: Different concepts- Waste to energy

The final concept creates electricity and heat out of waste. *Figure 16* is a schematic view of this concept. Raw materials as biomass, sewage, municipal waste and green waste are gathered and placed in a Combined Heat Power unit (CHP unit). In this concept waste is burned, and the energy obtained from the waste is converted into electricity and heat. There is an island in Denmark (Bornholm) that is partially powered by a waste to energy concept. The major difference is that Bornholm is inhabited and the islands in the archipelago are not.

Advantages of Waste to Energy are:

- Reduction of Landfill Disposal
- Greenhouse Gas Emissions reduction
- The fuel obtained cheaply
- Biogas can be stored

The disadvantages of this system are:

- The islands are uninhabited
- No one to operate the plant all year round
- No production of waste all round the year, as it is uninhabited

Due to these substantial disadvantages, the Waste to Energy concept was discarded.

4.4 Other discarded possibilities

The presence of water around the islands makes the possibility to gain energy from water movement an interesting subject for research. The kinetic energy created by waves, tide or currents can be converted into electric power. The use of compressed air is also a way to store energy. In this chapter we discuss these different possibilities with the reasons why they were discarded.

4.4.1 Wave energy

Waves are created by the wind blowing over the sea surface. The water absorbs the energy from the wind and starts to move in phase. Waves are thus basically an direct effect of wind energy. A system to exploit this wave energy is called Wave Energy Converter (WEC). A WEC installation has two major disadvantages when compared to wind turbines, it is twice as expensive and it needs constant maintenance.

In the Gulf of Bothnia, the average wave size is small. When the wind speeds are highest, it is winter and the sea is frozen, so no energy can be gained (WindFinder, 2012).

4.4.2 Tidal energy

Tidal energy, or tidal power, is a form of hydropower that converts the energy of tides in electricity. Tides are more predictable than wave, wind and solar energy.

The Gulf of Bothnia has no tides or significant currents, which is the reason why current and tidal power is discarded as a usable system. Furthermore, this system involves high costs, limited suitable building sites for barrages and it affects the costal environment (darvill.clara.net, 27-02-2012).

4.4.3 Storage

Hydroelectric energy

This method stores energy in form of water. The water is pumped to a higher located water storage, and released through turbines to generate electricity during periods of high electrical demand. This system responds quickly and accurately to the increasing or decreasing demand. The hydroelectric system is discarded because of the absence of height differences in the archipelago, and the small usable space (darvill.clara.net, 2012).

Compressing air in a cave

Energy can also be stored by compressing air. When the electrical demand is low, the excess electricity is used to compress air. The compressed air is stored in natural underground caves. The efficiency of this system is over 75% (REUK, 2012). However, this system is discarded because of the absence of caves in the archipelago.

Underwater air bags:

Another solution is to store compressed air in flexible underwater accumulators. *'The weight of the water keeps the air at pressure. Stored air is then released and converted back to electricity when required.'* (Tomorrow is greener, n.d.). This system is discarded because it requires a water depth of 600 meter and the water depth around the archipelago is too shallow.

Conclusion

A summary of the forwarded solutions to the engineering phase is made below in *Table 7*. The main power system uses wind and solar power. The heat will be provided by a heat pump and excess energy will be stored as hydrogen or by using super batteries.

Table 7: Summary of the forwarded solutions

PRIMARY POWER SOURCE	SECONDARY POWER SOURCE + STORAGE	HEAT SOURCE
Wind Turbine	Batteries	Air
	Super Batteries	Seawater
Photovoltaic Panel		
	Electrolyzer + H_2 Storage + Fuel cell	Ground
Wind Turbine + Photovoltaic Panel		
		Exhaust Heat Recovery
		Energy Recovery Ventilation

The following steps in the engineering phase were:

- How much energy is needed?
- How much energy is there in the wind?
- How much energy is there in the sun?
- How is the energy going to be stored? (Hydrogen or batteries)
- How much energy does need to be stored?

5 Systems

In this chapter the different systems that were forwarded from phase I are investigated and described. Based on this information the final decisions about the systems are made. The used systems are divided into Electricity, Heating and Ventilation, and a Control and Monitoring system.

5.1 Electricity

The electricity demand will be covered at all times by using a combination of different systems. These are a Primary System, which will be responsible for the main power load, a Secondary System, which will store energy and convert it into electricity when the Primary System can’t fulfill the demand, and finally there will be an emergency back-up system, in case there is a malfunction in the aforementioned systems.

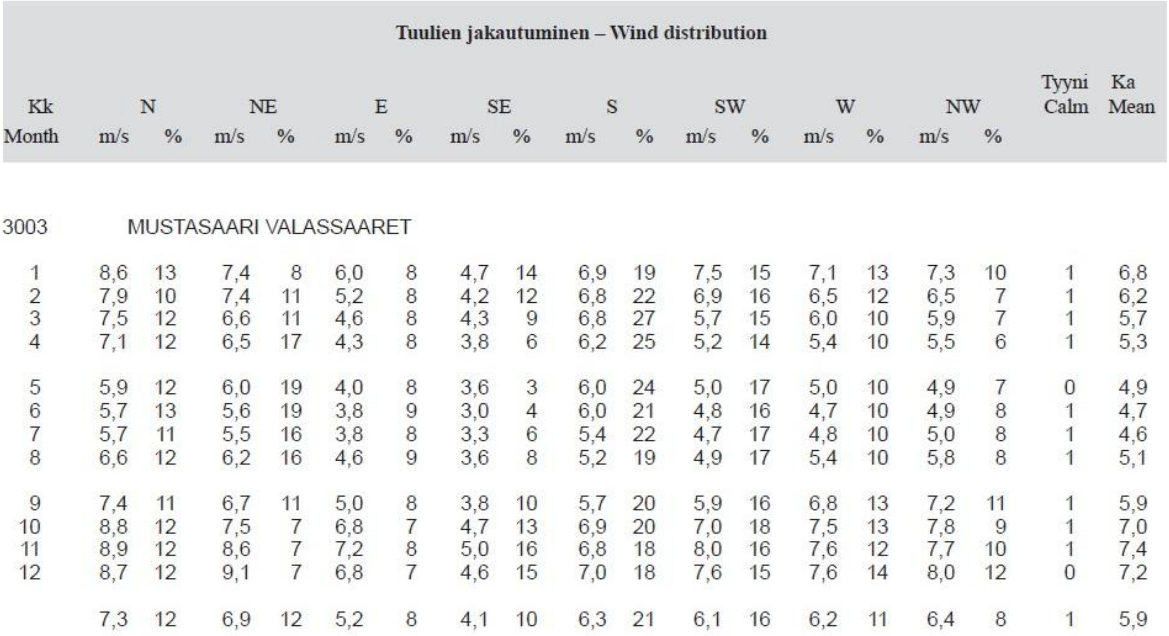
5.1.1 Primary system

The primary system is responsible for obtaining the necessary amount of energy to cover the electricity needs of the islands. During the whole year the needs differ from island to island, depending on the amount of electrical appliances in the building and the presence of an eventual base station and radar station. The different available sources of renewable energy and the ways to use these sources to generate electricity are researched and described in this chapter.

Available energy sources

The main source of renewable energy in the archipelago is wind. This is because the wind is available the whole year round. In *Table 8* the exact information about average wind speed and directions can be found.

Table 8: Wind speed



Tuulien jakautuminen – Wind distribution

3003 MUSTASAARI VALASSAARET

Kk Month	N m/s	N %	NE m/s	NE %	E m/s	E %	SE m/s	SE %	S m/s	S %	SW m/s	SW %	W m/s	W %	NW m/s	NW %	Tyyni Calm	Ka Mean
1	8,6	13	7,4	8	6,0	8	4,7	14	6,9	19	7,5	15	7,1	13	7,3	10	1	6,8
2	7,9	10	7,4	11	5,2	8	4,2	12	6,8	22	6,9	16	6,5	12	6,5	7	1	6,2
3	7,5	12	6,6	11	4,6	8	4,3	9	6,8	27	5,7	15	6,0	10	5,9	7	1	5,7
4	7,1	12	6,5	17	4,3	8	3,8	6	6,2	25	5,2	14	5,4	10	5,5	6	1	5,3
5	5,9	12	6,0	19	4,0	8	3,6	3	6,0	24	5,0	17	5,0	10	4,9	7	0	4,9
6	5,7	13	5,6	19	3,8	9	3,0	4	6,0	21	4,8	16	4,7	10	4,9	8	1	4,7
7	5,7	11	5,5	16	3,8	8	3,3	6	5,4	22	4,7	17	4,8	10	5,0	8	1	4,6
8	6,6	12	6,2	16	4,6	9	3,6	8	5,2	19	4,9	17	5,4	10	5,8	8	1	5,1
9	7,4	11	6,7	11	5,0	8	3,8	10	5,7	20	5,9	16	6,8	13	7,2	11	1	5,9
10	8,8	12	7,5	7	6,8	7	4,7	13	6,9	20	7,0	18	7,5	13	7,8	9	1	7,0
11	8,9	12	8,6	7	7,2	8	5,0	16	6,8	18	8,0	16	7,6	12	7,7	10	1	7,4
12	8,7	12	9,1	7	6,8	7	4,6	15	7,0	18	7,6	15	7,6	14	8,0	12	0	7,2
	7,3	12	6,9	12	5,2	8	4,1	10	6,3	21	6,1	16	6,2	11	6,4	8	1	5,9

Table source: (Finnish Meteorological Institute, 2012)

This data is collected by a weather station on Valsörarna, located 30 km southwest of Mickelsörarna. The complete document is *Appendix 07: Weather Data*. Based on the aforementioned data, wind is a considerable power source in this area. The use of a wind turbine will make maximum advantage of this available source.

A second energy source is the sun. There is a difference in the amount of sun power available in winter and summer. Below is a *Table 9* with the average sun isolation along the year.

Table 9: Solar insolation

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Insolation, kWh/m²/day	0.13	0.70	1.81	3.69	5.28	5.91	5.43	4.03	2.42	0.99	0.29	0.05
Clearness, 0 - 1	0.25	0.39	0.43	0.51	0.53	0.52	0.51	0.48	0.45	0.37	0.34	0.20
Temperature, °C	-7.01	-7.9	-4.3	0.71	7.16	12.37	15.42	14.39	10.09	5.09	-0.3	-4.1

Table source: (Chinci, 2011)

The table above shows the solar insolation. Insolation is the amount of radiation that strikes the surface of the earth in a given time. With the insolation the amount of energy that can be obtained from the sun is calculated. In this area, the solar energy is only usable during the spring and summer months, the rest of the year the amount of energy that can be obtained is insignificant. This means that depending on solar energy as a single energy source is not reliable. Another factor to take into account is snow. It is likely that during the winter the solar panels will be covered with snow. However, like mentioned before, during the winter months the solar energy that can be obtained is insignificant.

Based on the available sources, a study of the viability of different systems or a combination of systems that could ensure a big enough power availability around the year was required.

Wind turbines

Wind turbines can be divided into two big groups: vertical and horizontal wind turbines. The vertical turbine's axis is located perpendicularly to the wind direction, they don't need to be oriented to face the wind. They are less efficient, because of their configuration. The wind that makes them rotate also slows them down when it pushes the backside of the blades. The horizontal turbine's axis works parallel to the wind, therefore it needs to be continuously oriented to face the wind. These wind turbine's are more efficient because none of the blades are moving against the wind *(Figure 17)* Each of those groups can be divided according to the different blade shapes or configurations possible for them.

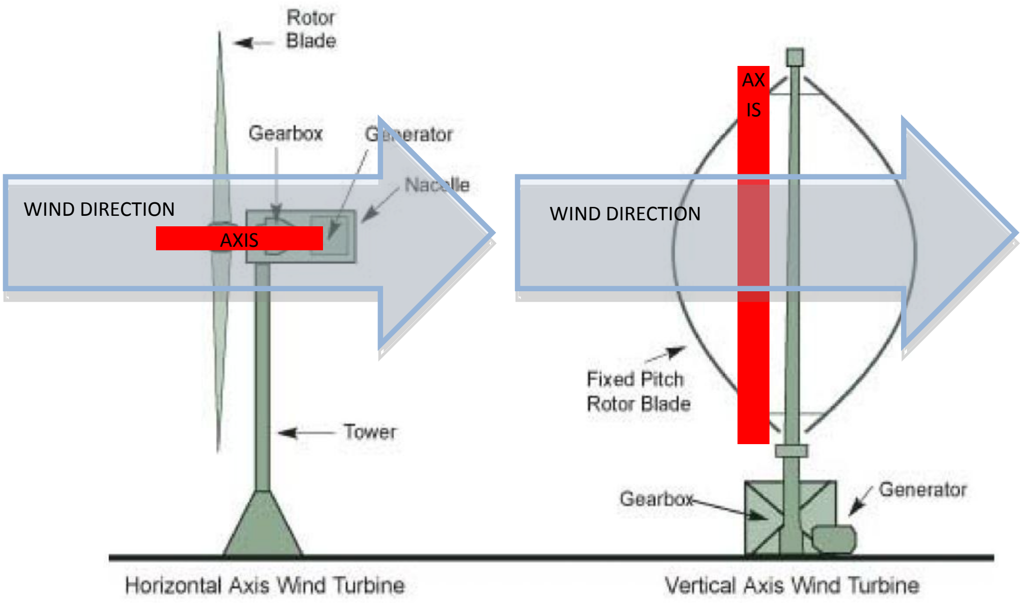


Figure 17: Vertical and Horizontal wind turbines configurations (Gregor Hopkins, 2007)

The two systems operate differently, but their functioning principle is the same: to extract part of the energy in the wind to create electricity. That energy is found in the moving air molecules. Since they have a mass and a speed, they contain kinetic energy.

Kinetic Energy in 1m^3 of air:

Kinetic Energy: E_K = ½ m · v^2

- Energy E[Joules]
- Mass m[kg]
- Velocity v[m/s]
- Mass of air at sea level is around 1,23 kg/m^3

Then, the power available from each square meter of that moving air is:

Wind Power: P_W = ½ density · v^3

- Power P_W [W/m^2]
- Density [kg/m^3]
- Velocity v[m/s]

For the most common type of wind turbines (horizontal axis) the area swept by the blades is:

Swept area: A = $\pi \cdot R^2$

- Swept area $A[m^2]$
- Radius R[m]

Therefore, the available power in the wind that passes through a wind turbine is:

Power Available: P_A $= ½ \cdot 1{,}23 \cdot v^3 \cdot \pi \cdot R^2$

- P_A [W]
- 1,23 kg/m^3 (Air density)
- Velocity v[m/s] (Wind Speed)
- Blade Radius R[m]

To collect that energy from wind, wind turbines convert the kinetic energy into mechanic energy, by turning a shaft, which is connected to a rotor. That rotor is turning inside a stator, and there the mechanical energy is converted to electric energy. The amount of energy in the wind after the turbine is lower, since it loses speed. That energy differential is what has been transformed into electricity by the wind turbine *(Figure 18)*. Typically wind turbines are able to use about 30-40% of that available power from the wind and can be scaled to obtain from a few hundred watts up to several megawatts of clean power.

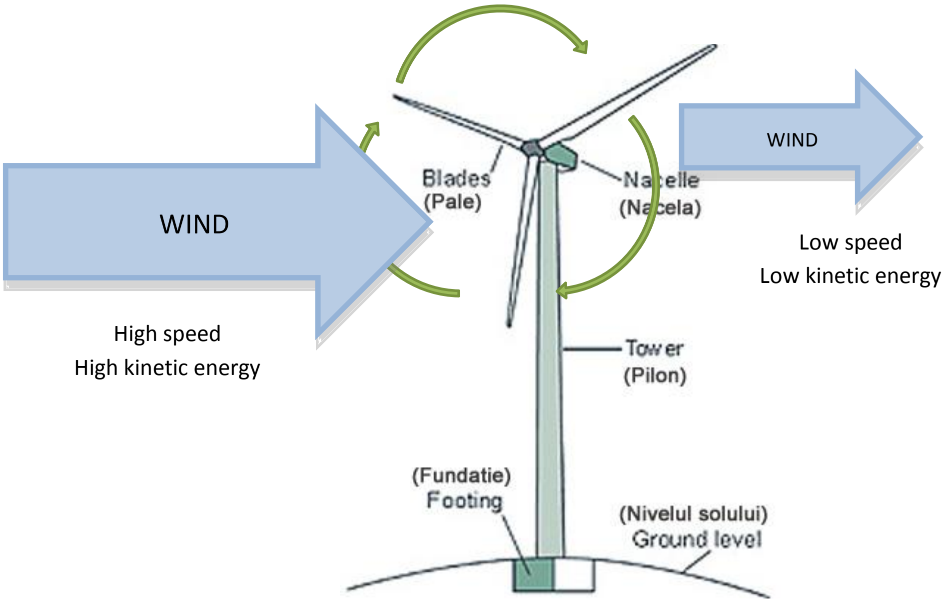


Figure 18: Wind energy diagram (LP ELECTRIC SRL, 2004)

Solar Panels

There are basically two ways of getting energy from the sun: collecting thermal energy and converting electromagnetic radiation into electricity by photovoltaic solar panels or solar cells.

The thermal energy collector may not be a suitable option for this project, due to the location of the buildings. This far north, the amount of thermal energy that can be collected from the sun is too small. Moreover, during the winter months the snow may be a problem for the system. More information about solar heat collectors can be found in chapter 5.2.2.

A solar cell converts sun radiation into electricity using the photovoltaic effect (Hertz effect). This is the emission of electrons from matter. When this matter gets hit by electromagnetic radiation, this radiation will be absorbed. Since the solar radiation that reaches the Earth is quite stable (changes slowly), those electrons emitted become an electric flow or current. One solar cell can only produce a very small amount power, therefore cells are mounted in panels, forming arrays, to reach a reasonable power output *(Figure 19)*. The efficiency of the solar panels to exploit the solar isolation is around 15 %.

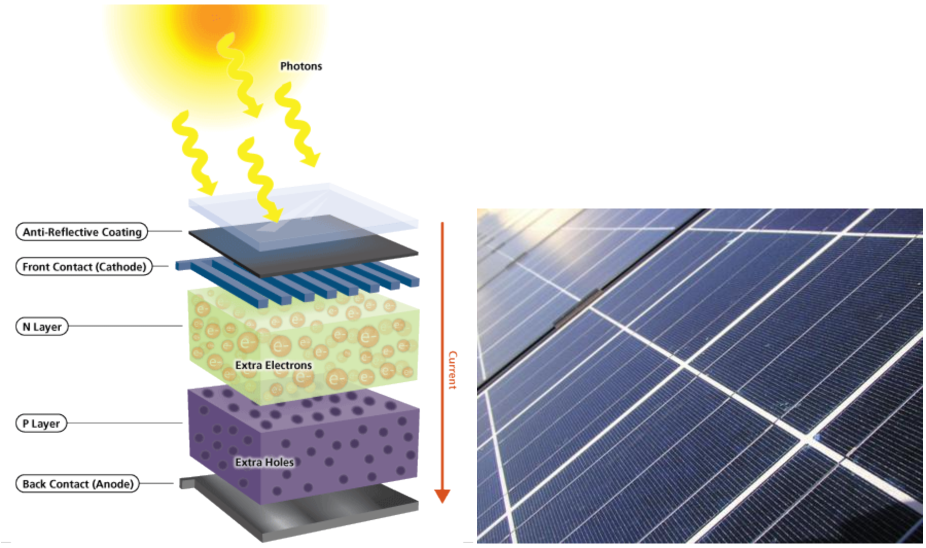


Figure 19: Solar cell panels functioning (Advanced Energy Industries, Inc, 2012) (Greenteam Renewables Ltd, 2012)

Around 175 PW (PetaWatts, 1PW = 10^{15}W) of solar radiation in all its forms (insolation) arrive to the earth in the upper atmosphere. One third or less of that amount gets reflected back to space. The rest is absorbed by clouds, oceans and landmasses. The principle of solar panels is to collect part of that power and convert it into a usable form of energy *(Figure 19)*.

"Solar Radiation Reaching the Earth

The intensity of the solar radiation reaching us is about 1369 watts per square metre [W/m^2]. This is known as the Solar Constant. It is important to understand that it is not the intensity per square metre of the Earth's surface but per square metre on a sphere with the radius of 149,596.000 km and with the Sun at its centre.

The total solar radiation intercepted by the Earth is the Solar Constant multiplied by the cross section area of the Earth. If we now divide the calculated number by the surface area of the Earth, we shall find how much solar radiation is received, on average, by a square metre of the Earth's surface. Thus, the average solar radiation S per square metre of the Earth's surface is:

Sun Power $= S\cdot\pi.r^2/4\pi r^2 = 1369/4 \approx 342$ W/m^2

where S in the Solar Constant in W/m^2 and r is the Earth's radius.

Solar Radiation Reaching the Earth Surface

However, our calculations are not yet finished because we have not yet considered the influence of the Earth's atmosphere. The value we have calculated is for the average solar radiation intensity at the outer regions of the Earth's atmosphere. What we want to know is how much of this radiation reaches the earth surface where we are

*The atmosphere absorbs about 68 W/m^2 and reflects 77 W/m^2 (Wallace and Hobbs 1977). The radiation reaching the Earth's surface is therefore on average **198 W/m^2**, i.e. 58% of the radiation intercepted by the Earth."* (Dr. Ron Nielsen, 2005)

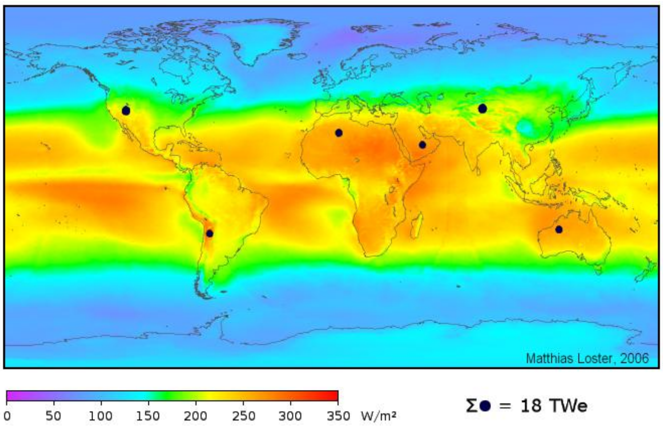


Figure 20: Average Insolation 1991-1993 (Matthias Loster, 2010)

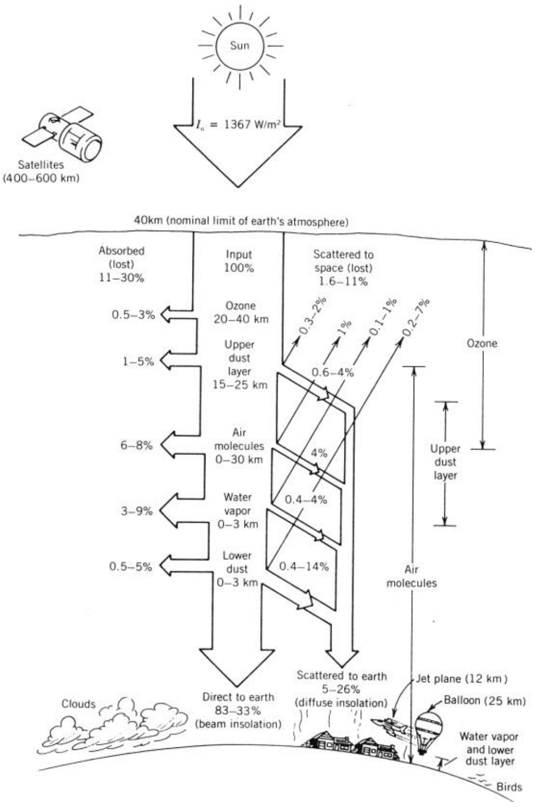


Figure 21: Sun Power reaching the Earth (William B. Stine, Michael Geyer, 2001)

Conclusion

Out of the gathered information the conclusion can be made that the use of a hybrid system for the main power system would be the best option. Hybrid means that two different energy sources will complement each other to cover the energy needs throughout the year. In chapter 4 all the studied options to obtain energy are discarded, except Wind and Sun. Solar energy can cover a bigger demand during the summer and wind energy can cover a bigger demand during the winter.

5.1.2 Secondary system

In a stand-alone, off the grid system electrical power availability represents a great challenge. One of the main goals of the EPS project was to obtain that power somehow sustainably. There are ways to produce power using clean renewable sources. In this case the ones chosen were Wind and Sun. The availability of these sources is intrinsically uncertain. Therefore, a way to store the excess electrical energy produced while the demand is smaller than the production was necessary. The main problem is that electrical energy cannot be stored as itself. It has to be transformed in some other form of energy that can be stored. These are the different forms of energy and some examples of how they could be stored, as well as their main advantages and disadvantages *(Table 10).*

Table 10: Comparison of forms of energy and their storage

Form	**Storage**	**Advantages**	**Disadvantages**
Electrical energy	*Not possible*	-	-
Kinetic energy	Increasing the speed of a flywheel	Very high efficiency	Technically complicated, several moving parts, high maintenance
Potential (gravitational) energy	Pumping up water into a tank or damp	High efficiency	Big space and construction needed
Thermal energy	Heating up a fluid or gas in an isolated tank	High efficiency	Big losses, limited amount storable
Chemical energy	Converting a substance into another one, that when converted back would release energy	Reliable, low maintenance, big storage capacity and easily expandable	Low efficiency, young technology, cost

For the small size of the installations in the Kvarken Archipelago, as well as the automated nature of the solution searched, it became clear that the best way to store that electricity would be as chemical energy.

Different systems studied

Three ways to store energy in a chemical form were studied:

- Super Batteries
- Batteries
- Hydrogen (Electrolyzer + Tank + Fuel Cell)

Super Batteries

A super capacitor is known as a double layer capacitor. They store electricity by physically separating positive and negative charges—unlike batteries, which do so chemically. It polarizes two conducting plates who are made of a porous material to store energy electro statically. Due to this material the plates have bigger surface and thus an increased storage capacity. This mechanism is highly reversible, and allows the ultra capacitor to be charged and discharged hundreds of thousands of times (supercapacitors.org, n.d.).

Super capacitors in a hybrid system are usually referred to as super batteries or ultra batteries. In this case the super capacitor is used as a buffer between device and battery. The super capacitor is able to handle short interruptions; the battery is needed to store enough energy for longer interruptions.

Table 11 Below shows the advantages and limitations of super capacitors.

Table 11: Advantages and disadvantages of super capacitors

Advantages	Virtually unlimited cycle life; can be cycled millions of time
	High specific power; low resistance enables high load currents
	Charges in seconds; no end-of-charge termination required
	Simple charging; draws only what it needs; not subject to overcharge
	Safe; forgiving if abused
	Excellent low-temperature charge and discharge performance
Disadvantages	Low specific energy; holds a fraction of a regular battery
	Linear discharge voltage prevents using the full energy spectrum
	High self-discharge; higher than most batteries
	Low cell voltage; requires serial connections with voltage balancing
	High cost per watt

Table Source: (Isidor Buchmann, 2012)

As the above table shows, a super capacitor has very high self-discharge rate. The stored energy of a super capacitor decreases from 100 to 50 percent in 30 to 40 days. A nickel-based battery self-discharges 10 to 15 percent per month (Isidor Buchmann, 2012).

The conjunction between a super capacitor and a battery is promising. At this moment, however, the state of technology of super capacitors is at the top of innovation. The ultra capacitors are currently not available for this project.

Batteries

Many different types of batteries exist. The main concept by which they work is always the same. When a device is connected to a battery, a reaction occurs that produces electrical energy. This is known as an electrochemical reaction. The Italian physicist Count Alessandro Volta first discovered this process in 1799 when he created a simple battery from metal plates and brine-soaked cardboard or paper (Marshall Brain, Charles W. Bryant and Clint Pumphrey, 2012).

Advantages:

- Know technology
- Easily sizable
- Low cost recharging

Disadvantages:

- No complete discharge, usually 70% discharge rate
- Costs, over 20 years, at least 2 battery banks are needed
- Takes time to charge
- Die suddenly, no smart chips inside batteries

(George Loker, n.d.)

Rechargeable batteries are used as a backup source for energy. On Mickelsörarna there is an existing battery bank. The lifetime of a battery is about 7 years. A goal of this project was to create a solution that, after the investment, has low costs for 20 years. Replacing the battery bank every seven years means that this goal is not reached. Comparing costs shows that, due to the purchase of multiple battery banks, storing by hydrogen is economically more reasonable.

Hydrogen

Compressed hydrogen is another way to store chemical energy, as it can be scaled up or down to suit the needs. Hydrogen is generated from water. As a fuel it is 2.5 to 3 times more efficient than fossil fuels. There are no CO_2 emissions if natural sources are used to produce that hydrogen. It is safe because it is not toxic and since it is the lightest element existing, it dissipates very easily in the air. Hydrogen can be stored under high pressure, making the space required for the tanks smaller.

Comparison and Conclusion

Table 12: Comparison of fuel cell and battery

Technical Comparison	**Battery**	**Fuel cell**
Capacity	depends on the number of batteries	depends on the size of the fuel storage
Efficiency	higher	low (40%-50%)
Fuel storage location	inside	outside
programmable control	no	yes
lifespan	<10 years	>10 years
Maintenance cost	low	low
20+ years cost	high	low
Installation	easy	complex (combine electrolyzer and H_2 storage)
Ambient temperature range	need air conditioning	wide
Environmental impact	has pollution	almost zero emission

As *Table 12* shows, batteries have a shorter lifespan than fuel cells. For example, '*lead-acid batteries have a lifetime shorter than ten years even in optimal conditions (ambient temperature 20° C or less), due to their inherent chemical instability*' (Anders Ocklind, 2005). This is because that both the capacity and reliability of the battery usually degrade with time. The capacity of the battery reduces very fast at low temperature. This is a disadvantage in cold climates as it is in Finland. Normally, before the battery dies it should be replaced, just in case some problems should occur. Furthermore, replacing the battery also increases the total cost. (Anders Ocklind, 2005)

'*Hydrogen fuel cell systems are best suited for the applications in which the power need is low (<10 kW) and the energy needs are high (>10 kWh)*' (Anders Ocklind, 2005), as shown in *Figure 22* below.

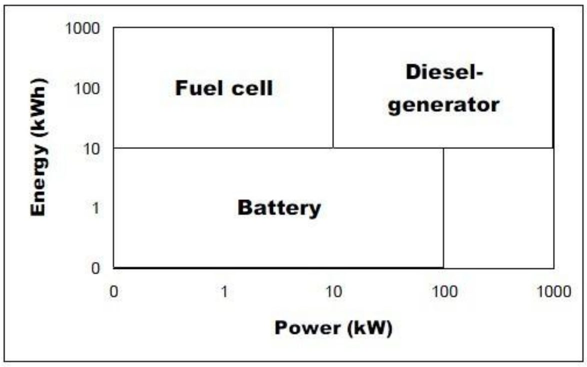


Figure 22: Solutions for different power and energy needs applications (Anders Ocklind, 2005)

For the buildings on the islands that the EPS project team are working with, the power needs are normally below 6 kW and the energy needs are far bigger than 10 kWh, therefore the best solution for the project is to use hydrogen fuel cell systems.

HYDROGEN system choice

The reasons to use hydrogen as an energy storage system are the following:

- It is generated from water + electricity, no other chemical products supply needed.
- 2.5 to 3 times more efficient than gasoline.
- No CO_2 emissions if generated with renewable power sources.
- It is not toxic.
- In case it leaks, it dissipates very easily in the air.
- It can be stored under pressure, reducing storage space.

There are three main stages to be studied in the process: Production, Storage and Utilization. Another aspect that will also be considered is the Reutilization of Water from the Fuel Cell. Lastly, the safety issues must be considered during the entire process.

The aforementioned stages are analyzed, described and calculated in Appendix 11: there are also the tables with the main characteristics of the different technologies for every system, with their advantages, disadvantages and reasons for choosing or discarding them.

Hydrogen production: PROTON EXCHANGE MEMBRANE (PEM) ELECTROLYZER

The choice made was to get the hydrogen from **Splitting Water Molecules**, particularly with a **Polymer Electrolyte Membrane** (or PEM) Electrolyzer, since it was the system that suited better the requirements and needs for the project. The main characteristics of PEM electrolyzes and the reasons why it is the best option are:

- There is no liquid electrolyte, simplifies the design significantly
- The PEMs can operate with a high pressure output
- They use an acid polymer membrane
- They are suitable for both mobile and stationary applications
- Large turn-down ratio, meaning that they can operate efficiently off their peak power zone
- They are safer than other kinds of electrolyzers thanks to the lack of hazardous chemicals
- The PEMs can be built in a small size because of the high pressure that can be reached
- They offer quite high efficiencies for CHP (combined heat and power)

Next is a brief explanation of the system inside a PEM electrolyzer (more detailed in Appendix 11: Secondary Power System).

Polymer electrolyte membrane (PEM) electrolysis

The REDOX reaction that takes place in the electrolysor:

Anode (oxidation): $2\ H_2O \rightarrow O_2 + 4\ H^+ + 4e^-$ $E^o_{ox} = -1.23\ V$

Cathode (reduction): $2\ H^+ + 2e^- \rightarrow H_2$ $E^o_{red} = 0.00\ V$

The negative voltage in the oxidation of the anode means that the reaction needs energy to take place.

This could be simplified by combining the two previous reactions:

Overall reaction: $2\ H_2O(l)$ + Electricity (1.23 V) --> $2\ H_2(g) + O_2(g)$

Even though it is the best choice for the circumstances, there are some challenges that should be mentioned: PEM technology is not as a mature technology as alkaline, due to the relatively high cost, the low capacity (enough for the project needs), an efficiency up to 60% for electricity, and up to 85% for CPH. In the past few years PEM technology and performance have improved significantly.

The electrolyzer model that has been chosen of the different situations is shown in *Table 13* below. More information about this electrolyzer can be found in Appendix 17: Electrolyzer Datasheet

Table 13: PEM electrolyzer choice for each application

Application	Choice
Smaller needs concept (<=3.5 kW)	Acta Energy AES200*
Bigger needs conpcet (3.5 to 5 kW)	
Mickelsörarna (4.4 kW)	
Valsörarna (5kW)	

*This device is suitable for all the different systems.

Hydrogen storage: Pressurized Gas Steel Tank

The most adequate hydrogen storage system for the characteristics of this project (remote isolated location, automated, easy maintenance, safety, available space) is to use a pressurized steel tank containing gaseous hydrogen at no more than 30 bar.

The reasons for making that choice are the following:

- It is cheaper than other similar solutions, like composite tanks.
- It can operate at cold temperatures (liquid storage requires cryogenic temperatures).
- It doesn't require a heat input to extract the hydrogen (solid storage does).
- It is safe. In case of leakages, gaseous hydrogen dissipates easily in the air.

To calculate the size of the tank needed for every one of the four different specific applications of the concept some different factors were studied. These factors are:

- Electrolyzer Output and efficiency	depend on model
- Fuel Cell Input and efficiency	depend on model
- Energy availability from hydrogen time	1week
- Power density of hydrogen under STP	3.2 - 3.5 Wh/l

Calculations can be found in Appendix 11: Secondary Power System

Therefore the adequate tank for each one of the applications should be as follows *(Table 14)*:µ

Table 14: Pressurised gas steel tank choice for each application

Application	**H_2 tank**
Smaller needs concept (<=3.5 kW)	< 15000 liters H_2 @ 30bar,25ºC
Bigger needs concept (3.5 to 5 kW)	15000-20000 liters H_2 @ 30bar,25 ºC
Mickelsörarna (4.4 kW)	20000 liters H_2 @ 30bar,25 ºC
Valsörarna (5kW)	20000 liters H_2 @ 30bar,25 ºC

Hydrogen usage: PROTON EXCHANGE MEMBRANE (PEM) FUEL CELL

Fuel cells are the best way to convert the chemical energy stored in hydrogen into electricity. Particularly Polymer Membrane Fuel Cells are the most suitable choice for the project because of their characteristics:

Following, there is a brief explanation of the system inside a PEM fuel cell (more detailed in Appendix 11: Secondary Power System).

Proton Exchange Membrane (PEM) FUEL CELL

PEMs use a solid polymer as an electrolyte and carbon electrodes containing platinum catalysts that are very sensitive to CO. They are suitable for light-duty applications (cars, buildings). It makes them an ideal replacement for rechargeable batteries *(Figure 23 and Table 15).* More characteristics and advantages of these PEM fuel cells are listed below:

- High power density (W/m³)
- Safer due to lack of hazardous chemicals
- Low temperature operation which results in a quick start-up (short warp-up time)
- Few or no moving parts at all
- Low weight and volume
- Maintenance becomes a less important issue
- They are scalable, from a small number of cells to a large stack depending on the need
- Efficiencies from 35 to 60 for electricity
- Efficiencies up to 85 or 90% for CHP (combined heat and power)
- PEM fuel cells have zero emissions
- No combustion process means no NOx or SOx
- Very low noise and vibrations, if any

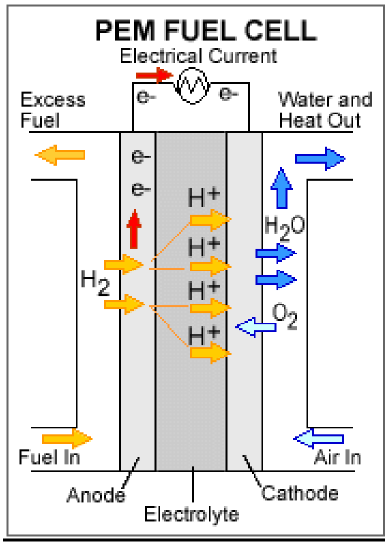
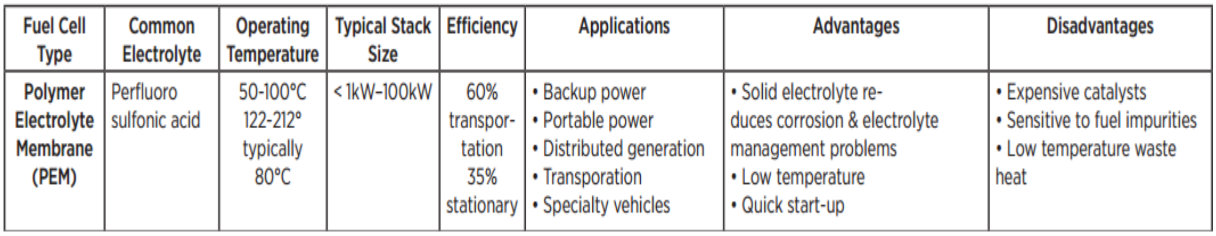


Figure 23: Fuel cell operation diagram (U.S. DEPARTMENT OF ENERGY, Energy Efficiency & Renewable Energy (EERE), 2011)

The chemical reaction that takes place inside a fuel cell is the same as in the electrolyzer, but naturally it is reversed, with an input of H2 and O2 and an output of H2O and electricity (and heat):

Anode:	$H_2 \text{ --> } 2H^+ + 2e^-$	$E^o = 0V$
Cathode:	$\frac{1}{2} O_2 + 2H^+ + 2e^- \text{ --> } H_2O$	$E^o = 1.23V$
Overall reaction:	$H_2 + \frac{1}{2} O_2 \text{ --> } H_2O$	$E^o = 1.23V$

Table 15: PEM fuel cells characteristics



Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Efficiency	Applications	Advantages	Disadvantages
Polymer Electrolyte Membrane (PEM)	Perfluoro sulfonic acid	50-100°C 122-212° typically 80°C	< 1kW–100kW	60% transportation 35% stationary	• Backup power • Portable power • Distributed generation • Transporation • Specialty vehicles	• Solid electrolyte reduces corrosion & electrolyte management problems • Low temperature • Quick start-up	• Expensive catalysts • Sensitive to fuel impurities • Low temperature waste heat

Table Source: (U.S. DEPARTMENT OF ENERGY, Energy Efficiency & Renewable Energy (EERE), 2011)

According to the electricity needs calculated for each of the applications, the choices for the Fuel Cell that fit each of the concepts best are found below in *Table 16*. More information about these fuel cells can be found in Appendix 18,19 and 20

Table 16: PEM fuel cell choice for each application

Application	Type
Smaller needs concept (<=3.5 kW)	ReliOn T-2000® 4kW Outdoor Configuration
Bigger needs conpcet (3.5 to 5 kW)	Dantherm DBX5000
Mickelsörarna (4.4 kW)	Dantherm DBX5000
Valsörarna (5kW)	Dantherm DBX5000

Water reutilization

The electrolyzer needs to be fed water with a high grade of purity. Therefore, this water must be brought to the islands and stored waiting to be used to produce hydrogen. This hydrogen will be converted into water vapor in the fuel cell, while electricity is generated. Then the vapor will be conducted through a condenser where it will condense into pure water. This water will be reutilized by the electrolyzer. In this way the system is closed, and the need for a constant input of pure water for the electrolyzer can be neglected. Nevertheless, the system will never be 100% closed, as there will always be a certain level of water loss. For that reason the size of this pure water storage should be enough to fill the hydrogen tank, plus a little bigger, to fulfill the assumed losses *(Figure 24).*

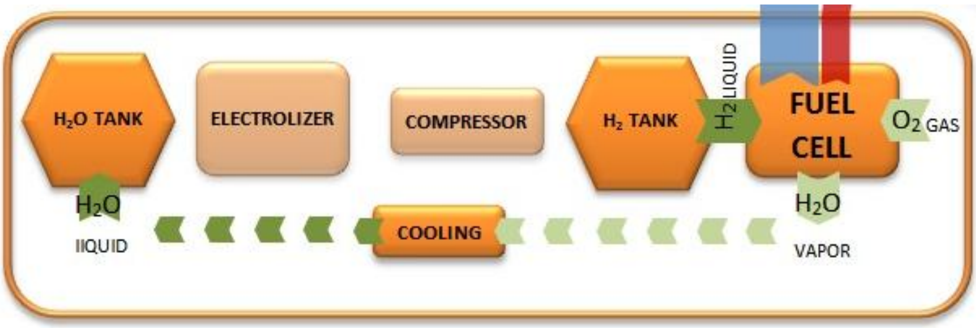


Figure 24: Water reutilization diagram

Hydrogen safety and regulations

'It is important to understand the properties of hydrogen and safety requirements for storage, refueling and use of hydrogen. Hydrogen displays extreme characteristics, either very low (density ignition energy at stoichiometric ratio) or very high (buoyancy in air, diffusion coefficient in air, flammability range, velocity of laminar burning at stoichiometric ratio, heat of combustion and detonation sensitivity) as compared to other fuels (methane, propane, gasoline vapour).' Minna Nissilä (Minna Nissilä, 2011).

Therefore, there is a risk with hydrogen unless some safety measures are taken into account, due to the aforementioned characteristics and some others, such as:

- Colourless and odourless
- One can asphyxiate by breathing hydrogen
- Very wide flammability limits in air mixtures (4 to 75%)
- Low ignition energy
- Almost invisible flame
- Small molecular size promotes leaks and diffusion
- Highly reactive with oxygen and other oxidizers
- High flame temperature
- Negative Joule-Thomson coefficient: leaking gas warms and may spontaneously ignite
- Can diffuse into or react with certain metals

Hydrogen is the smallest element that exists. This makes leakages easy, even through the solid metal walls of a tank, which can also react with H_2. The reaction causes changes in the mechanical properties of the metal. Hydrogen will ignite in air with a concentration three times smaller than it would take to ignite gasoline (4 to 75%). It burns in with a pale blue flame, almost invisible, thus you could discover a fire by walking into it. It can accumulate in closed spaces, but easily disperses in open spaces.

For those reasons, special care must be taken with hydrogen systems.

Regulations

These are the regulations to follow when installing and operating hydrogen systems (electrolyzers, storage and fuel cells, and transportation):

CHEMICAL SAFETY
Chemicals Act (744/1989)
Act on the safety of the handling of dangerous chemicals and explosives (390/2005)
Decree on the industrial handling and storage of dangerous chemicals (59/1999)

ATEX
European Directive 99/92/EC (also known as the 'ATEX Workplace Directive')
In Finland: **Government decree on prevention of the danger caused by explosive atmospheres (576/2003)**
European Directive 94/9/EC (also known as 'the ATEX Equipment Directive')
In Finland: **Decree on equipment and protective systems intended for use in potentially explosive atmospheres (917/1996)**
Decision of Ministry of trade and industry on equipment and protective systems intended for use in potentially explosive atmospheres (918/1996)

PRESSURE EQUIPMENT
Pressure equipment Act (869/1999)
Decision of Ministry of Trade and Industry on pressure equipment safety (953/1999)

ENVIRONMENTAL PORTECTION
Environmental protection Act (86/2000)

RESCUE
Rescue Act (468/2003) and the Government Decree on rescue (787/2003) *If still up to date*

LAND USE AND BUILDING
Land use and building Act (132/1999) and the Land use and building decree (895/1999)

MACHINERY AND TECHNICAL DEVICES
Act on the conformity of certain technical devices to relevant requirements (1016/2004)
Government decree on machinery safety (400/2008)

Conclusion

For the secondary power system, the most suitable solution that fitted the needs of the project is to use a hydrogen system. It will consist of a combination of a PEM electrolyzer, a compressed gas steel tank to store it and a PEM fuel cell and a water-cooling and reutilization system.

Once each one of the cases has been studied, the conclusion reached is that for every one of them there has to be some variation as regards the choice of the products (except for the electrolyzer, the model chosen suits all the studied cases).

Hydrogen is a potentially dangerous material, if not processed and stored correctly. Therefore a list of directives and regulations must be followed to ensure the safety functioning of the system once it is operating in its location.

5.1.3 Back-up Generator

The islands in the archipelago are uninhabited during the winter season. Because of the ice conditions the islands in the archipelago are inaccessible during the winter. Due to the inaccessibility, maintenance of buildings and equipment during the winter season is impossible. The minimum required temperature inside the buildings is five degrees Celsius. To ensure this demand, there is a back-up generator in this concept, besides a primary and secondary energy system,

In case of a complete system failure, the generator will start automatically ensuring that the heat needs are satisfied. If the fuel cell is turned off for any reason, there is the possibility to start the generator manually.

If necessary, the possibility exists to use the generator to cover the biggest peaks in the energy demand. However, it is impossible to automate the system in a way that the generator starts when there is a power peak. The startup time of the generator is too slow. If there is an expected high power peak, the generator has to be started manually.

Based on this information the requirements are set. The generator needs be to established:

- Biofuel engine
- Remotely started
- Hydrocarbon free emissions
- External Fuel Tank Option
- Security monitoring
- Integration in renewable systems

Telgenco 48-5

Figure 25: Backup generator-TELGENCO 48-5 (Telgenco, 2012)

The Quiet48-5 (48 V DC, 5kW, *Figure 25*) made by Telgenco is designed for remote rural areas and integration in a renewable energy solution. Key benefits of the generator chosen for this concept are:

- 100% Biofuel engine option
- Automated Remote Control
- Full engine and monitoring control
- Clean 48 VDC Power output
- Environmentally inert materials
- Environment Operating Temperature: -40 / +55 Celsius
- Optional external tank connection

The specifications of this backup generator suit the needs of this project. Telgenco is a company that is committed to protecting the environment. This generator is made of environmental inert materials and designed to be almost completely recycled at the end of its life. (Telgenco, 2012).

The bio fuel engine option allows the system to be used as a totally hydrocarbon free renewable energy exchange with consequent environmental benefits. In this project where the main goal was to make a sustainable solution, this aspect is essential. The energy needs for the heating in this project are approximately 3,5 kW. This is during the coldest weeks when the temperature drops to -27° Celsius. Telgenco makes two generators in this line, a 2 kW and a 5 kW. As stated above, the 2 kW is not sufficient for the heating needs all year round. This 5 kW generator generates a 48 V DC current. Most equipment used in the buildings are 230 V AC, therefore it needs to be inverted to 230 V AC. An inverter is already scheduled in this concept; the generator needs to be wired to the inverter as well.

5.2 Heating

Heating is an important aspect for the maintenance of concrete buildings in winter. The buildings need a constant inside temperature of 5°C. Without this heat, the lifetime of a concrete building will shorten drastically.

The research done during the project shows that the use of a heat pump is the most suitable system to provide the necessary heat.

5.2.1 Heat pump

The function of a heat pump *(Figure 26)* is based on the phase changes of a refrigerant. Thermal energy is absorbed from a primary source (ground, water or air) and transported by a pipe loop to the evaporator of the heat pump. The first heat exchange happens in the evaporator as the liquid refrigerant turns in to vapor. The temperature and pressure of the vapor increase by using a compressor. In the condenser of the heat pump, the vapor turns into a liquid again. The released energy is transferred into the output heating circuit. An expansion valve is placed after the condenser causing the refrigerant to cool.

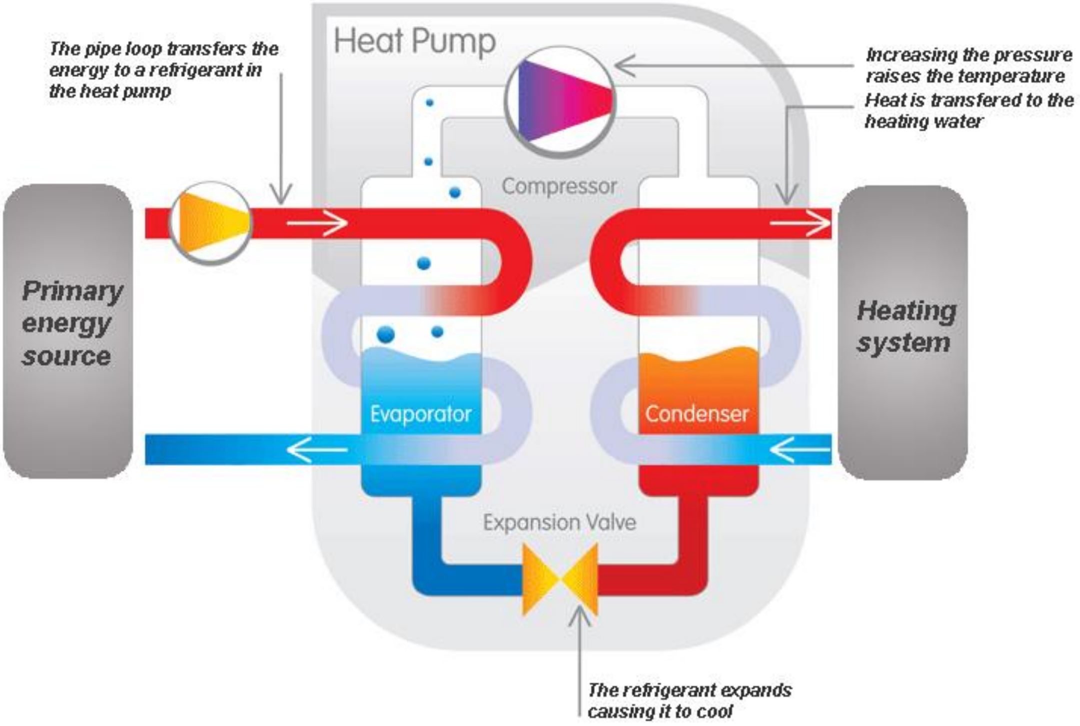


Figure 26: Working of a Heat Pump (Radiant Floor, 2011) / Modified

COP

COP, the abbreviation of Coefficient Of Performance, is the ratio between the quantity of heat delivered and the energy required by the heat pump. This is used to compare the efficiency of heat pumps. The COP is dependent on the difference between the source temperature and the desired output temperature. The bigger the difference, the smaller the COP.

An electric resistance heater has a COP of 1. Therefore an electric resistance has an efficiency of 100%. Usually, a heat pump has a COP between 2 and 5. A COP of 3 means that the system has an efficiency of 300%. The COP can be calculated with the equation below *(*Figure 27):.

$$COP = \frac{Quantity\ of\ Heat\ Delivered}{Energy\ Required\ by\ the\ Heat\ Pump}$$

Figure 27: The equation of COP calculation

Heat source

A heat pump (HP) can get its heat from three main sources:

- Ground (GSHP)
    - Closed/Open loop
- Surface Water (WSHP)
    - Closed/Open loop
- Air (ASHP)

The **ground source heat pump** collects the solar energy that is absorbed and stored in the ground during the summer. Around 46% of the Sun’s energy is absorbed by the earth (Figure 28).

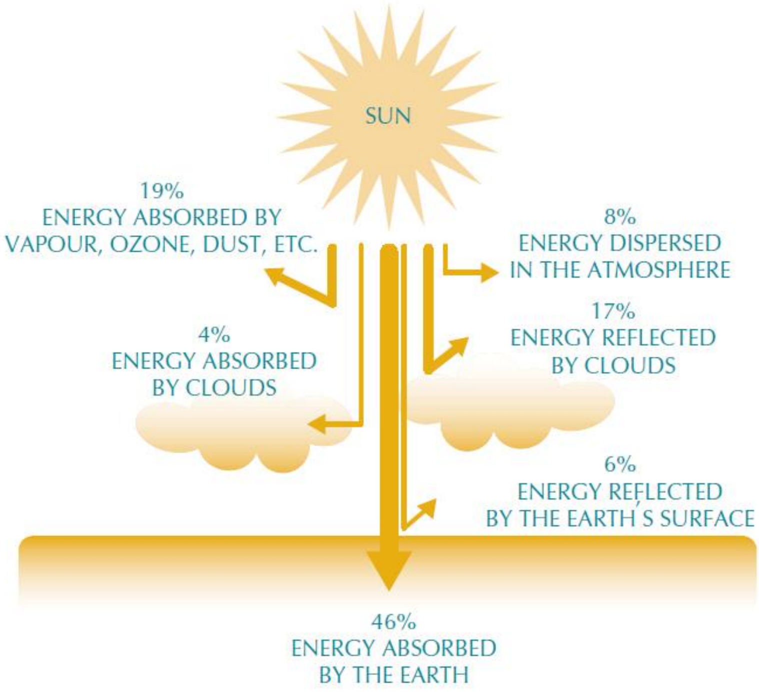


Figure 28: Distribution of solar energy (NRCan, 2002)

Because of the high heat storage capacity and a low thermal conductivity of the earth, the heat that is stored in the summer provides a free renewable source of energy that can easily provide enough energy to heat-up a building in the winter. Another characteristic of the ground is that a few meters of surface soil insulate the earth below. This means that at a certain depth you will get a constant ground temperature throughout the whole year. (NRCan, 2002)

There are two ways *(Figure 29 and Figure 30)* to collect the heat from the ground, a closed loop and an open loop piping system. The heat collecting pipes of the closed loop system can be buried horizontally or vertically depending on the available space and climate conditions. Brine with anti-freeze properties is used in the pipes.

Figure 29: Horizontal GSHP (Thermia Partners Oy, n.d.)

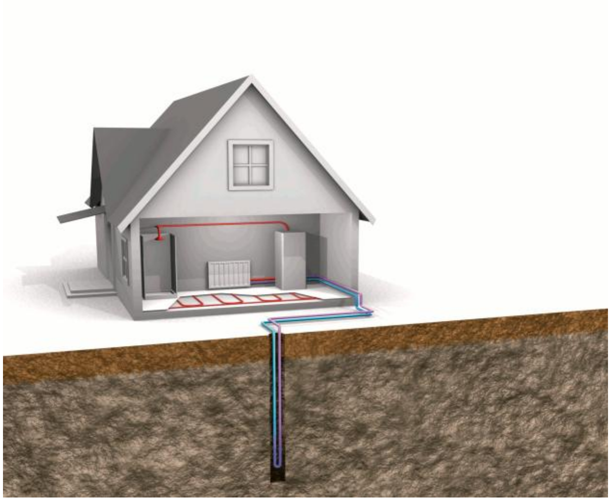


Figure 30: Vertical GSHP (Thermia Partners Oy, n.d.)

The open loop piping system uses a well to pump up ground water to the heat exchanger in the HP *(Figure 31).* The water is then returned to a separate injection well. Corrosion and the possibility of fouling decrease of the water flow are the major issues in this system.

Figure 31: Open loop GSHP (Industrial boilers, 2011)

A HP can also use **surface water** as heat source *(Figure 32).* Surface water can be a pond, a lake, a river or the sea. Similar to GSHPs, the difference can be made between closed loop and open loop systems. The pipes of the close loop system are immersed in the water body and are kept on the bottom with weight.

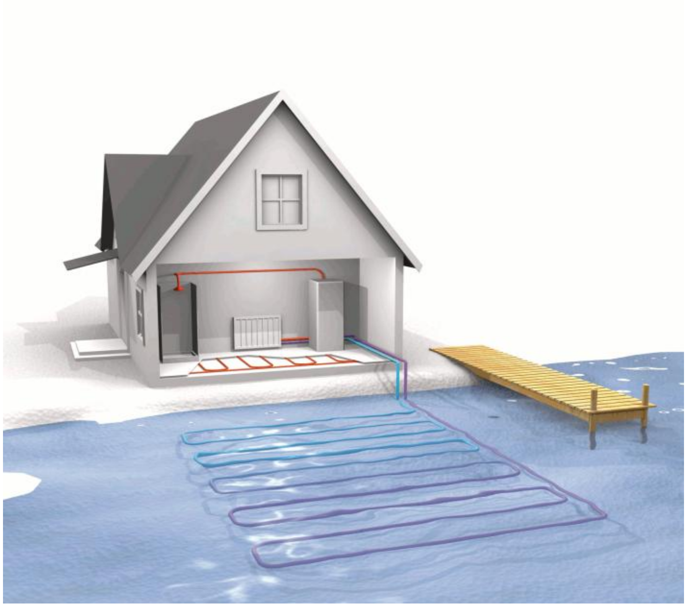


Figure 32: Closed loop WSHP (Thermia Partners Oy, n.d.)

The open loop system withdraws water from the water supply by using a pump. The water flows through the heat exchanger in the HP *(Figure 33)* and then flows back in the water body. For this system the use of a water body with a certain amount of current is preferable.

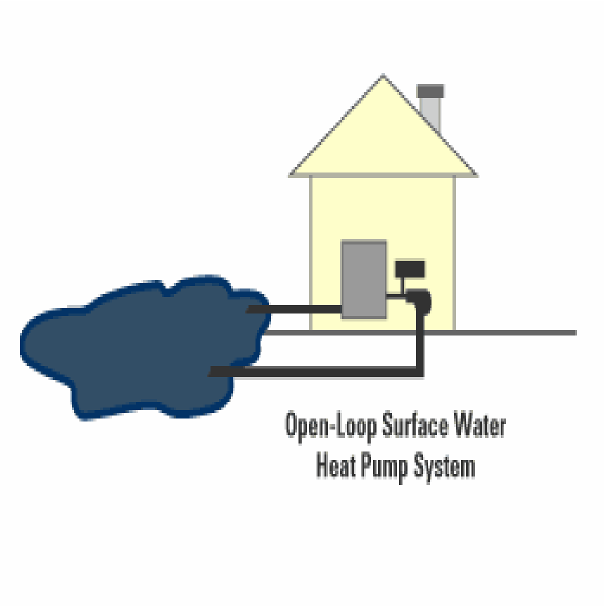


Figure 33: Open loop WSHP (Southern Company, 2012)

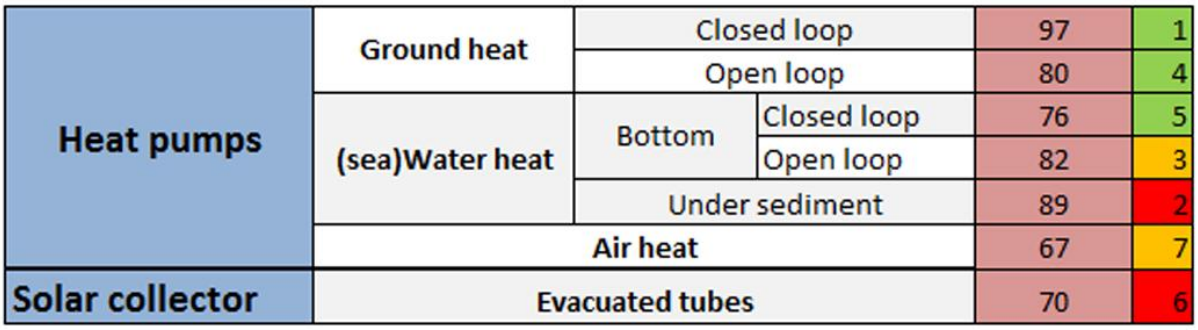
The **air source** heat pump (ASHP, *Figure 34)* uses the air as a heat source. The pump aspires the outside air and conducts it to the heat exchanger in the HP. In the heat exchanger the heat gets transferred to air or water which is used to heat the building.

Figure 34: Air source heat pump (Thermia Partners Oy, n.d.)

5.2.2 Heating trade-off

In the trade-off a comparison is made between all the possible heating solutions based on 8 different criteria (Appendix 12: Heating & Ventilation Trade-off). A score between 1 and 5 is given for each criteria of each solution (a 5 is the best score). This score is multiplied by a factor of importance. The factor, also between 1 and 5, marks the importance of the criteria in relation to the solutions. In the end the scores of each criteria are added to a total. This gives a good general view of the qualities of every solution.

The results of this trade-off are shown in the figure below *(Figure 35).*



Heat pumps	**Ground heat**	Closed loop		97	1
		Open loop		80	4
	(sea)Water heat	Bottom	Closed loop	76	5
			Open loop	82	3
		Under sediment		89	2
	Air heat			67	7
Solar collector	**Evacuated tubes**			70	6

Figure 35: Comparison of all the possible heating solutions

Evacuated Heat Tubes

The trade-off contains solar collectors as one solution. This has nothing to do with heat pumps, but the use of evacuated heat tubes is a solution worth looking at. It is a very efficient way to collect solar radiation to heat up water. The collector is made of a vacuum tube with a heat pipe in the middle. This heat pipe transports the collected heat to a heat exchanger that is in contact with the water storage tank.

With the Titanium – Nitride – Oxide (TINOX) absorber coating, 98% of the incoming solar radiation can be absorbed, and temperatures above 230°C are achievable (Dr. F. Mahjouri, 2004).

Unfortunately, due to the big amount of snow in winter, the pipes get covered and stop working. Removing the snow should be done delicate because the pipes are very fragile. Replacing the pipes each time one breaks can get very expensive.

Conclusion

The first two options that are discarded are evacuated tubes and the ‘under sediment’ heat pump. The evacuated tubes because of the reasons mentioned in the paragraph before. The sediment heat pump is discarded for the reason that there are too many rocks in the sediment, which would make it very difficult and expensive to bury the pipes in the sediment.

Furthermore, air source heat pumps are not efficient in cold climates such as in Finland. Mitsubishi came up with a hyper heating pump system that uses a so called ‘H2i® technology’. These cold climate heat pumps can work in temperatures that reach -30°C with a COP of 1.5 to 3.0. The reason for discarding this option is the reliability. The heat pump contains a lot of moving parts. That increases the risk of failure and shortens the lifetime of the system. An example of this system can be found in Appendix 12.

Three possible heating options remain: the ground source heat pump and the open and the closed loop water-sea heat pump. The advantages and disadvantages of these three systems are summarized below.

Option I: Ground source heat pump

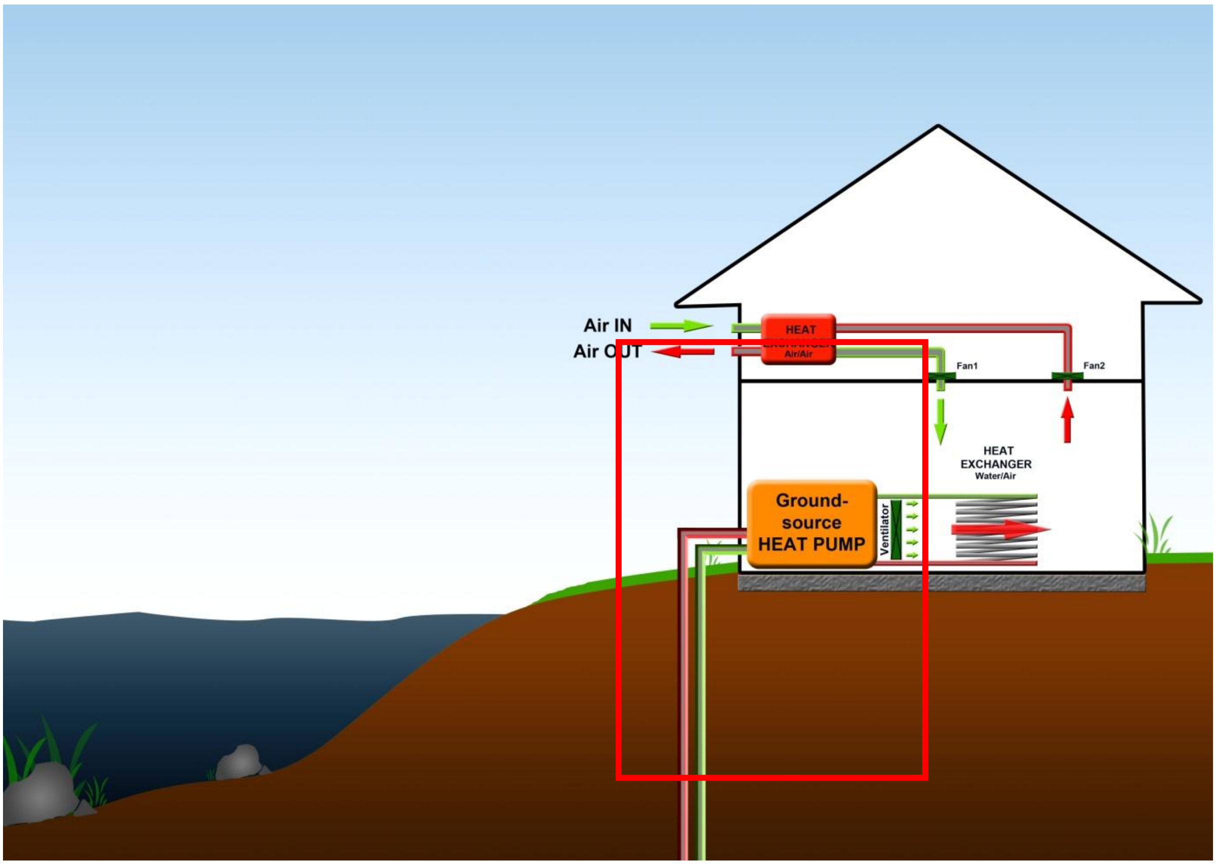


Figure 36: GSHP

Table 17: Advantage and disadvantage of ground source heat pump

Advantages	Disadvantages
Sustainable • No maintenance • No moving parts • Buried in the ground	**Expensive** • System • Transportation to the island • Borehole drilling
Reliable • No seasonal influence • Stable input temperature	
Efficient • High heat profit because of the high input temperature	
Not visible from the outside	
Longest lifetime	

Option II: Closed loop water source heat pump

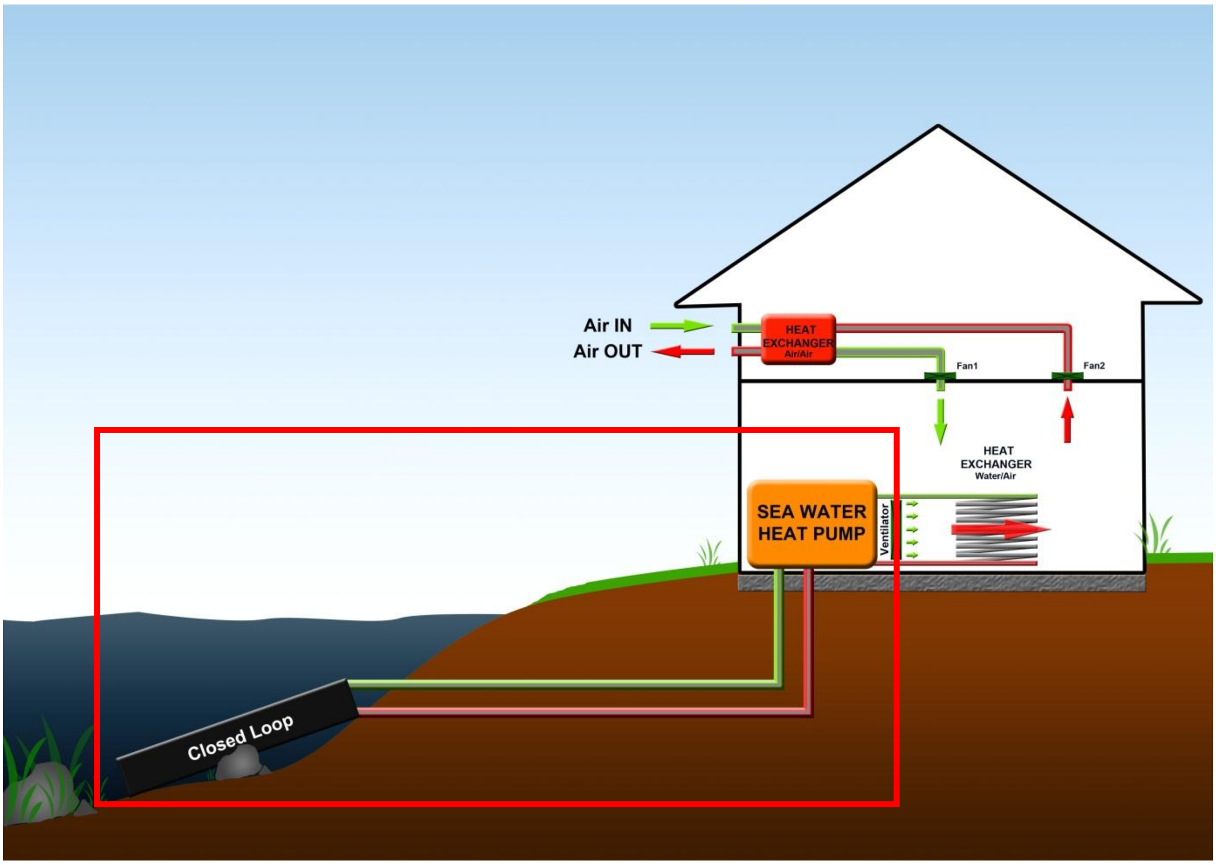


Figure 37: Closed loop WSHP

The advantages and disadvantages of option II is made in comparison with option III in the *Table* 18.

below

Option III: Open loop water source heat pump

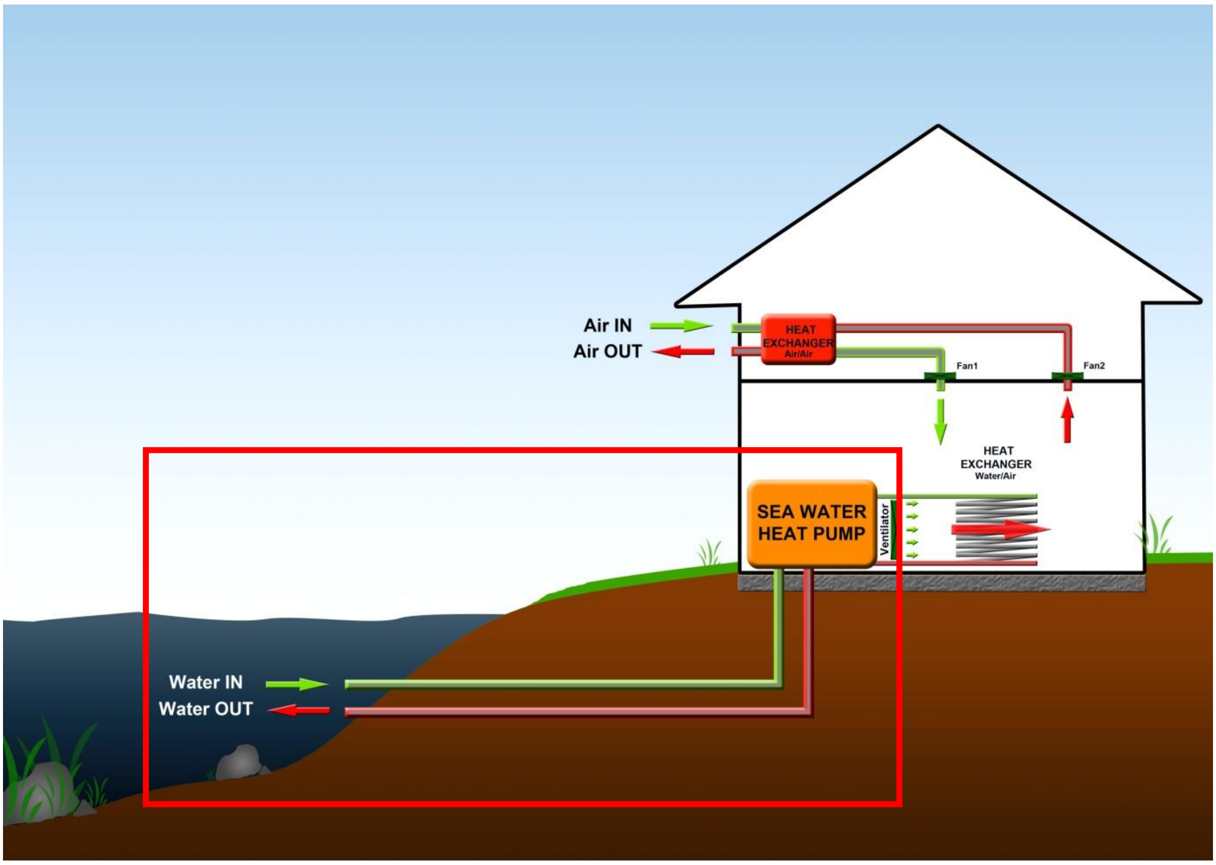


Figure 38: Open loop WSHP

Table 18: Advantages and disadvantages of closed loop and open loop WSHP

Option II: Closed loop WSHP		Option III: Open loop WSHP	
Advantages	Disadvantages	Advantages	Disadvantages
Use of a anti-freeze brine • Higher heat profit	Less efficient • One heat exchange more	Cheap • Less pipes	Corrosion by seawater • Adequate equipment • Expensive
No maintenance	Possible damage by storm	Efficient • One heat exchange less	No anti-freeze brine • Outgoing water can freeze • Small heat profit
	More expensive • Longer pipes	Small risk of damage	Maintenance of filters
	Higher electricity consumption • Bigger pumps		

5.2.3 Ground source heat pump

Further investigation of the three possible options that are left by using the trade-off, the decision is made to use the vertical loop GSHP.

Heat input

Brine in the vertical collecting pipes is absorbing the heat. The pipes are placed in boreholes with a depth of 100 to 200m. At that depth the ground has a stable temperature. The figure below shows that in Finland the ground temperature stabilizes to 6°C at a depth of 7m *(Figure 39).*

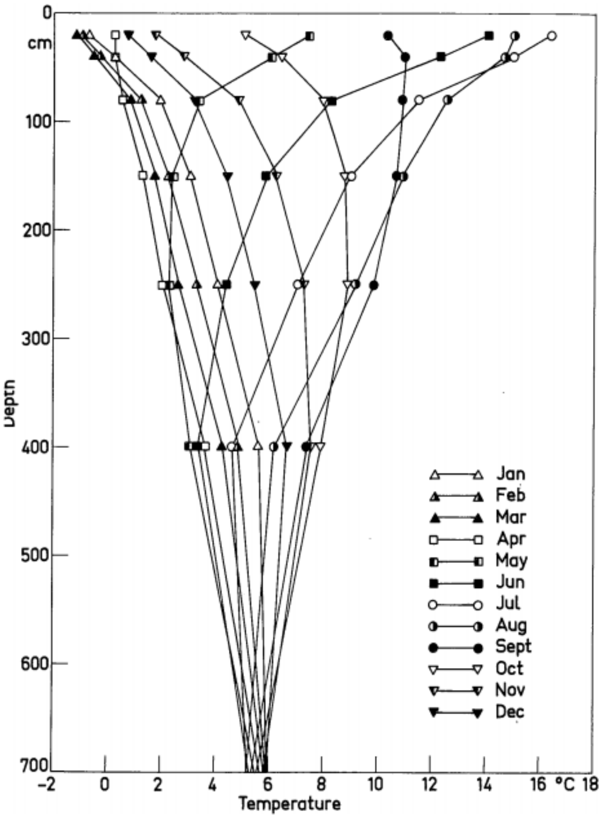


Figure 39: Ground temperature versus depth (R.Lemmelä, Y.Sucksdorff, u.d.)

This ground property makes the GSHP more efficient than any other conventional heating technologies.

Heat output

After the fluid in the pipe loop has collected the ground heat, it exchanges its heat with the heat pump. The pump increases the heat (the working of a heat pump can be read in paragraph '4.2.1 Heat pump') and delivers it to a hot water accumulator. From there, the hot water can be used in a radiator or floor heating system.

5.3 Ventilation

Ventilation is the process of renewing the used inside air of a room by fresh outside air. It helps to control the humidity, reduce indoor pollutants and odors, avoid moisture and assures a healthy and comfortable living environment. High humidity levels can even lead to structural damage of the building. Ventilation can happen naturally or mechanically. (U.S. Department of Energy, 2011)

5.3.1 Natural vs. Mechanical

Natural ventilation

Natural ventilation is the penetration of outside air into a building by natural forces. These forces can be wind or pressure difference and are dependent on the weather conditions. The fresh air can penetrate through cracks, small holes, and openings around doors or simply by opening a window. It is an uncontrolled passive process that requires neither energy nor maintenance. In cold climate regions, this kind of ventilation is not recommended because of the higher heat losses. (U.S. Department of Energy, 2011)

Mechanical ventilation

Mechanical ventilation or whole-house ventilation forces the air to move inside and/or outside a building. A uniform air movement is created by electrically driven fans and conducted by pipes. In this way, the air exchange is able to happen deeper in a building and is easier to control. (U.S. Department of Energy, 2011)

There are three types of mechanical ventilation systems:

- Exhaust ventilation
- Supply ventilation
- Balanced ventilation
  - Energy Recovery Ventilation (ERV)
  - Heat Recovery Ventilation (HRV)

Exhaust ventilation systems work by extracting the inside air of a room, to create a lower pressure than outside the building *(Figure 40).* This pressure difference induces an incoming fresh airflow that penetrates the room through leakage in the building shell or/and, more preferable, through intentional vents. Adjustable, passive vents are placed in windows or walls to prioritize the incoming flow rather than rely on the building leakage. If the pressure difference created by the ventilation system is too small, the passive vents won't work efficiently. (U.S. Department of Energy, 2011)

'Exhaust ventilation systems are most applicable in cold climates. In climates with warm humid summers, depressurization can draw moist air into building wall cavities, where it may condense and cause moisture damage.' (U.S. Department of Energy, 2011)

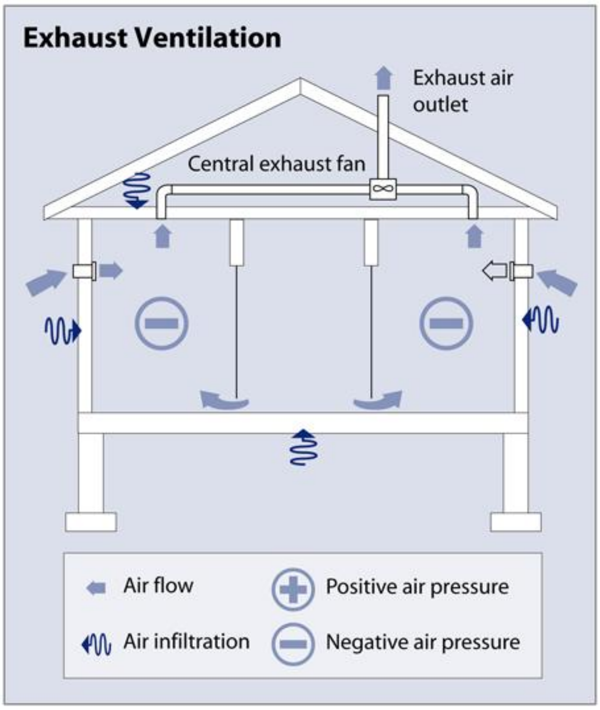


Figure 40: Exhaust Ventilation (U.S. Department of Energy, 2011)

Supply ventilation works in the opposite way than the exhaust ventilation by creating a higher pressure inside the building *(Figure 41).* This pressure forces a fresh supply of air into the room and drives exhaust air outside the building. Supply ventilation allows the incoming air to be filtered and dehumidified. In cold climates however, the system has the potential to create moisture problems due to condensation on the cold exterior walls. This can induce mold, mildew, and decay. (U.S. Department of Energy, 2011)

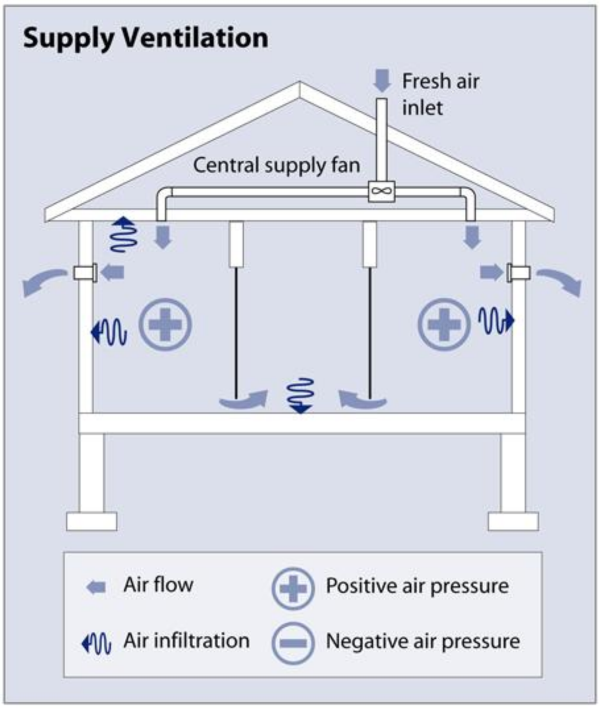


Figure 41: Supply Ventilation (U.S. Department of Energy, 2011)

In a **Balanced ventilation** system, the incoming and outgoing airflow is equal or balanced (Figure 42). It is a combined exhaust and supply ventilation system, thus it requires the double amount of fans, ducts and pipes. This system can be equipped with an energy or heat recovery system. Based on the recovery system you can divide balanced ventilation into two groups: Energy Recovery Ventilation (ERV) and Heat Recovery Ventilation (HRV). The difference between ERV and HRV is the way the heat exchanger works. The heat exchanger in an ERV-system transfers a certain amount of water vapor along with the heat, while an HRV-system only transfers heat. (U.S. Department of Energy, 2011)

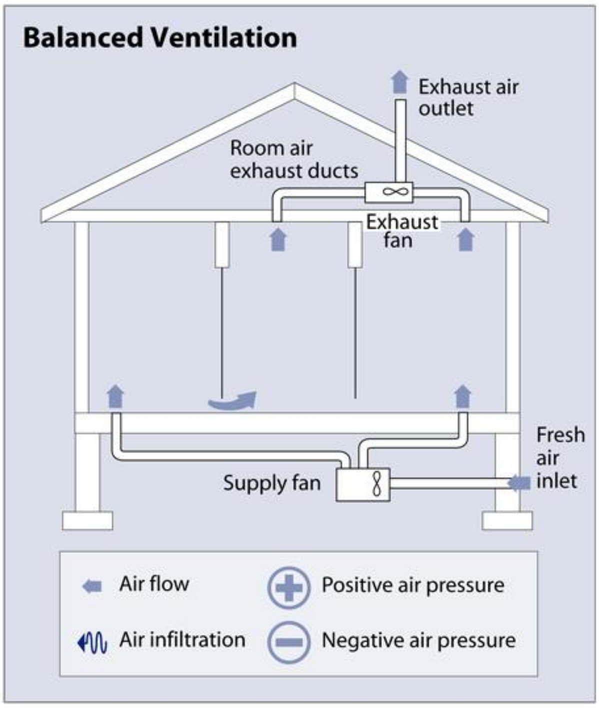


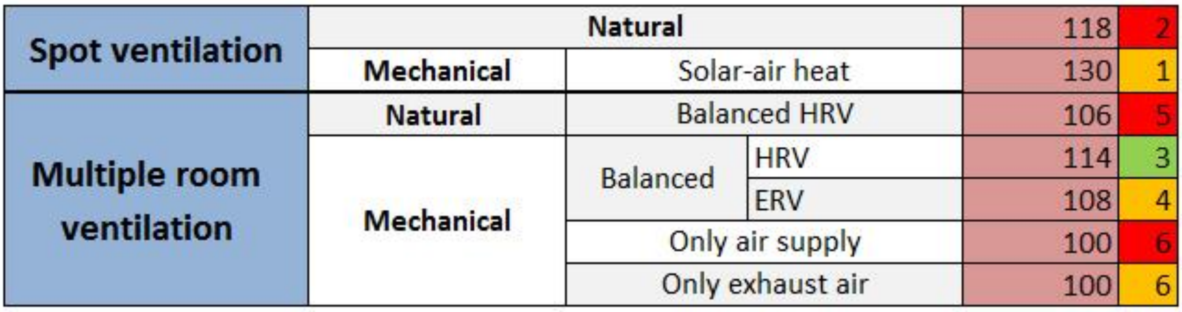
Figure 42: Balanced Ventilation (U.S. Department of Energy, 2011)

Conclusion

Both exhaust and supply ventilation systems don't recuperate the heat from the outgoing airflow or remove the moist from the incoming air before it enters the building. This results in higher heating costs compared to a balanced ventilation system equipped with an energy recovery system. Most of the energy recovery systems have an efficiency of 70 to 80%, or even more in climates with extreme winters. (U.S. Department of Energy, 2011)

5.3.2 Ventilation trade-off

In the trade-off a comparison is made between all the possible ventilation solutions based on nine different criteria(Appendix 12: Heating & Ventilation Trade-off). The result of this trade-off is shown in the figure below *(Figure 43).* The working of a trade-off, is described in chapter 5.2.2 Heating trade-off. The ventilation trade-off contains one more criteria than the heating trade-off, namely the humidity control.



Spot ventilation	**Natural**			118	2
	Mechanical	Solar-air heat		130	1
Multiple room ventilation	**Natural**	Balanced HRV		106	5
	Mechanical	Balanced	HRV	114	3
			ERV	108	4
		Only air supply		100	6
		Only exhaust air		100	6

Figure 43: Ventilation trade-off

The first main distinction that can be made by the possibilities is the amount of rooms that need to be ventilated. Single room called 'Spot ventilation' and multiple room ventilation. These distinctions can both be divided into natural and mechanical ventilation (see chapter 4.3.1 Natural vs. Mechanical Ventilation).

Solar-air heat

The trade-off contains a spot ventilation solution called solar air heat. It is a system in the form of a rectangular panel that uses solar radiation to heat up air and blows it into the building.

Solarventi Ltd. is a company in Denmark that has invented and sells these solar-air heat panels. A Solarventi panel is an '*efficient air-based solar collector, which would operate solely on sunlight and independently of connection to the mains supply*.' (Solarventi, n.d.). A solarventi panel (Figure 44) consists of three parts.

- Hot air collector
- Small solar panel
- Fan

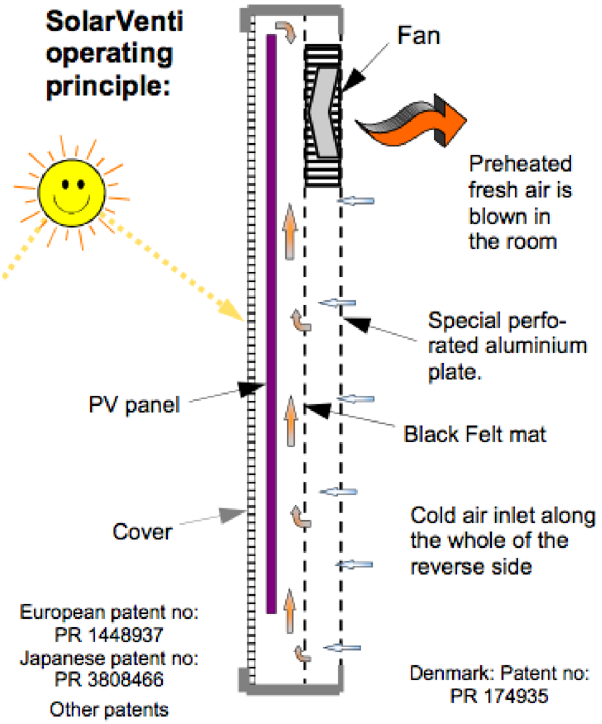


Figure 44: Solarventi Panel (Solarventi, n.d.)

Air is let in through the backside of the panel by a special perforated aluminum plate. The Sun heats a black felt mat. The warmth of this black felt math is transferred to the air that is sucked in. The warm air is blown into the building by a fan. The fan is powered by a small solar panel that is integrated on the front side of the panel. The airflow is between 25 and 150 cubic meter with a temperature rise between 15 and 40 degrees Celsius. The amount of airflow can be changed, the smaller the airflow, the higher the temperature of the air that is forced in.

Based on the results of the trade-off, the Solarventi panels *(Figure 45)* are the best solution. However, these panels are made to prevent moist in single spaces and small buildings, such as summerhouses, garages, caravans and even boats. Since the buildings on the islands are substantially bigger and they contain a lot of different rooms, this solution will not be used as the main ventilation system.

Later in the report (in chapter 5.3.3 Rain penetration/ specific solution) this system is chosen to prevent rain from penetrating into the southern walls and to force the moist in the walls back out.

Figure 45: Solarventi (Svångemåla News, 2010)

Conclusion

The first discarded solutions are (see red cells in Figure 43):

- Natural spot ventilation
- Multiple room Natural HRV
- Air supply ventilation

Natural spot ventilation is discarded due to the high heat losses and no possibility to control the air inlet and outlet. **Multiple room natural HRV** is a system that is driven by internal building airflows. These flows are induced by the wind blowing onto the building (pressure difference) and the density difference between warm and cold air. If the airflows in the building are not sufficient, fans are used as flow controllers. This system is not likely to be used in existing buildings, as it requires a close integration with the building design (Eimund Skåret, Peter Blom, Trygve Hestad, n.d.).

For this reason, and because of the total absence of data about the airflows inside the buildings in the archipelago, this solution is discarded. Air supply ventilation is not likely to be used in cold climates because the system has the potential to cause moisture problems in cold climates. It also requires maintenance of the filter system for the incoming air, and it contributes to higher heating costs because of the absence of a heat recovery system.

Among the remaining solutions the best solution is the balanced HRV. This system is equipped with a heat exchanger that transfers the heat of the outgoing air to the incoming air. This results in a substantial decrease of the heat losses and heating costs.

5.3.3 Rain penetration

Rain Penetration refers to 'ingress of rainwater above ground at various points in the external envelope of the construction that is through roofs, walls, chimneys and openings such as windows and doors'. (The Society for the Protection of Ancient Buildings, n.d.)

Rain penetration is caused by three main factors: water on the outside walls, openings and permits to passage and forces that drive the water in the walls. If one of those three factors is removed, the rain penetration problem is eliminated.

Water on the outside walls

Driving Rain is typically the largest source of moisture for the above-grade building enclosure. The control of management of rainwater should be one of the most important considerations for designers. (Ontario Association of Architects, n.d.) In this report the design of the buildings is not taken into consideration; the buildings in this project are already built. The buildings in the archipelago are left to their autonomous systems of preservation during the winter. The elements cannot be stopped, but there are measures that can be taken to prevent water being on the walls after the building stage. These solutions will be presented later in this report.

Openings to permit Passage

Openings that permit the passage of water are quite numerous on the face of a building in the form of pores, cracks, poorly bonded interfaces and joints between elements or materials. (G.K. Garden, 1963) Smalls cracks and joints can be covered with impermeable or semi-impermeable coatings. This is difficult to achieve, as the coatings have to be applied perfectly. Maintenance of a perfect joint is even harder due to differential movements between parts and different flex levels of the materials.

Covering the complete building with an impermeable sealant is not a solution. Old buildings need to 'breathe'. The moist that is forced in has to evaporate back out.

Forces that drive the water in the walls

Rain Penetration will only occur when there is a force available to move the water through the opening. This force can be gravity, kinetic energy of the raindrops, capillary suction and air pressure differences. Air pressure differences are produced by wind blowing at the walls. Relatively low velocity airflow can also carry fine water droplets or snow into the wall to create the same problem. Water can be raised a considerable distance and caused to flow into a wall when an air pressure difference is added to capillary suction. (G.K. Garden, 1963)

General Solutions

General solutions applied to the problem of rain penetration can be classified in three main solutions:

- Deflection
- Drainage
- Drying

Deflection can be realized by multiple solutions. Landscaping and chosen site are of great importance of deflecting the wind over or along the building. Next step of deflection is the design of the building. Overhanging roofs protect the wall from direct winds. As seen in *Figure 46* the size of the overhang correlates directly with the probability of rain-related damage. (Ontario Association of Architects, n.d.)

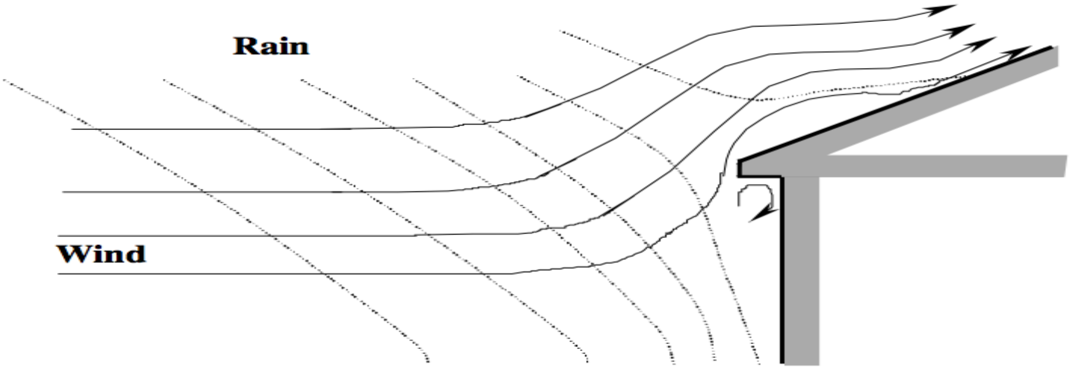


Figure 46: Roof overhang (Ontario Association of Architects, 2012)

Drainage assumes that the water will penetrate the outer surface but will be removed by an assembly within the wall. Wood and masonry leak significant amounts of water

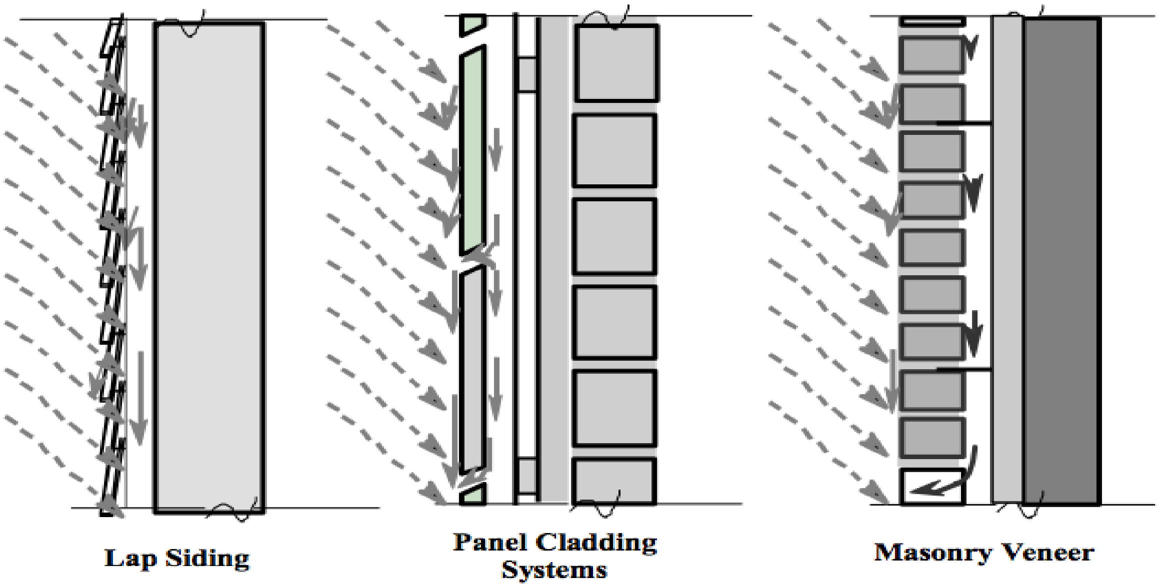


Figure 47: Screen drained walls (Ontario Association of Architects, 2012)

The design of screen-drained walls is most realistic and practical. In this case this would be useless, as the building exists already. *Figure 47* shows different options of screen drained walls.

Despite all efforts to deflect and drain the rainwater, field experience has shown that some water always penetrates into the walls. A **Drying** solution has to be provided for this water. Moisture can be removed out of walls by:

1. Evaporation

2. Vapor transport

3. Drainage

4. Ventilation

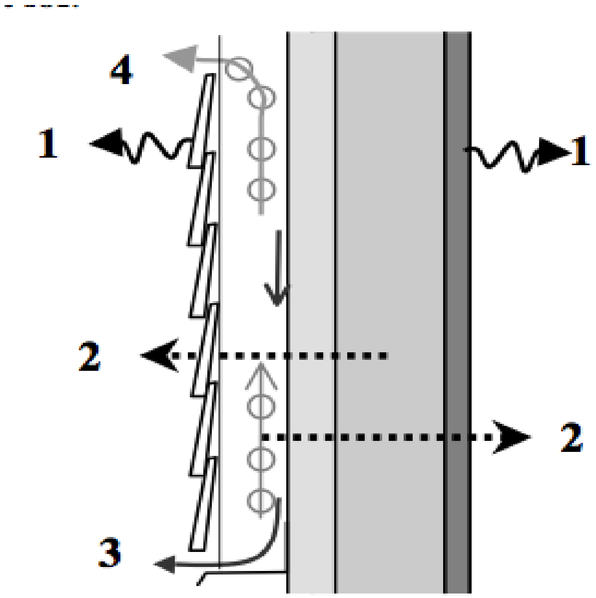


Figure 48: Drying mechanism in walls (Ontario Association of Architects, 2012)

Figure 48 shows that **evaporation** can occur from the inside or outside surfaces. **Vapor transport** can occur by diffusion, air leakage or both. **Drainage** is the fastest method of removing large amounts of water. Thereby it is one of the most important measures against rain penetration. Removing all water is impossible due to the capillary forces and the absorbance of the materials. **Ventilation** in the form of air movement or diffuse drying can only remove the remaining water. Air movement can move a large quantity of water. It is however hard to control the airflow, expensive in terms of energy and potentially dangerous for the quality of the air inside. (Ontario Association of Architects, n.d.) A modern approach is therefore to limit the airflow through the walls to nearly zero. Diffuse drying can transport moisture in both ways through the wall. In cold weather the moisture is forced outside, and in warm weather the moist is forced inside the building. Inward drying is an important mechanism for sustaining buildings.

Weather Archipelago

The Kvarken archipelago has an annual precipitation of 500 / 550 mm *(Figure 49).*

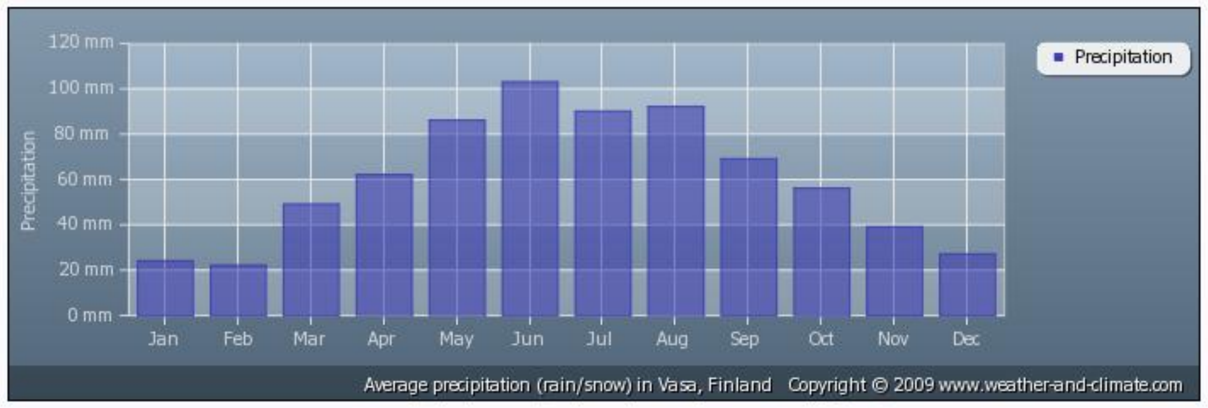


Figure 49: Precipitation data (World Weather and Climate Information, 2009)

As seen in the figure, most of this precipitation falls during the summer months.

The building is heated to five degree Celsius for maintenance purposes. During the months when it is colder, the wind is 6,5 m/s on average with mostly southern directions *(Table 19).*

Table 19: Wind direction and speed

Month	AVG ºC	AVG wind direction	AVG wind speed (m/s)	Probability wind speed >8 m/s(%)
November	+2	ENE	7,2	49
December	-2	SSE	7,2	66
January	-3	SE	6,7	50
February	-7	S	6,1	39
March	-1	WSW	6,7	48
April	+2	SSW	5	32

Table source: (WindFinder, 2012)

This means that the southern walls are mostly exposed to the rain/snow and wind during the winter season.

The south walls are not only exposed to the wind and precipitation, but also to the sun. This can be used as an advantage of the building. The shortest amount of daylight during winter in the archipelago is 4.11 hours *(Figure 50).*

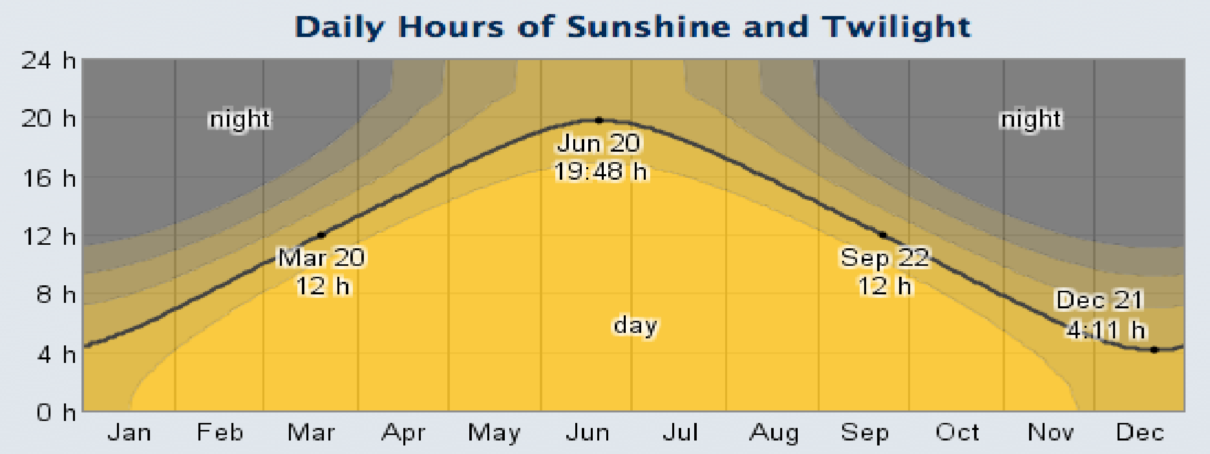


Figure 50: Daily hours of sunshine and twilight (WeatherSpark, 2012)

This sun can be changed into energy by the use of solar panels.

Specific Solution

The data above shows that the southern walls are mostly exposed by precipitation and wind. An advantage of this climate is that these walls are exposed to the sun as well. Deflection by landscaping is hard in the archipelago. The vegetation has a hard time growing due to the cold climate and the rocky ground. A fence to deflect the wind will work, but will pollute the view of the archipelago. Drainage of rainwater is taken care of in the design stage of the building. The roofs do have an overhang and drainage can occur by gravity. Therefore to get rid of the problem of rain penetration, the ventilation should be improved.

The use of **Solarventi** panels can protect the southern walls from rain penetration and provide extra heat and ventilation to dry the walls and eliminate the moist (more information about these Solarventi panels can be found in chapter 5.3.2, Ventilation trade-off / Solar-air heat). The panels are maintenance free and work autonomous. In the archipelago this is a great advantage, as it is impossible to go to any of the islands, due to the ice conditions during the winter. Even when the complete power and heating systems shuts down, a little heating and ventilation will occur by using these panels.

5.4 Control and monitoring system

The location of the islands makes it difficult to reach the installations during the winter months. Due to this fact the systems needed to be automated and remotely controllable. Since the solutions consists of several different subsystems, a monitoring system was necessary to control the power distribution as well as the heating and ventilation systems.

The table below shows the active elements of the system.*(Table 20)*

Table 20: Active elements of the system

Main power system	Secondary power system	Heating and Ventilation
Wind Turbine Solar Panels	Electrolyzer Hydrogen Tank Fuel Cell *Emergency Generator	Heat Pump Water Accumulator Radiators Pump Ventilation Fans

The basics of the automated functioning of the system goes as follows:

- There is a main switch to turn the whole power system ON or OFF.
- There is an individual switch to turn each sub-system ON or OFF.
- When the Production (Wind Power and Sun Power together) are bigger than the building Demand, the extra electricity goes to the Electrolyzer, and therefore Hydrogen is produced.
- This will stop when the Hydrogen Tank is full (objective pressure is reached, 30 BAR), or when the Production (Wind + Sun) is again smaller than the Demand.
- When the Production is smaller than the Demand, the Fuel Cell will start taking Hydrogen from the Hydrogen Tank and with that, produce electricity. This will go until the Demand is smaller than the Production again.
- The Emergency Generator will start producing electricity if the Hydrogen tank empties (pressure drops below minimum for the Fuel Cell), or if the Fuel Cell is OFF.
- The Heat Pump will start heating up water when the temperature in the Water Accumulator drops below the minimum set (40ºC) and stop when it rises above the maximum set (50ºC).
- The Radiator's pump will make the water from the accumulator run when the Inside Temperature drops below the minimum set (5ºC) and stop when it rises above the maximum set (10ºC).
- The ventilation system will run for 1 hour twice a day or when the humidity reaches a determined level (to be determined) and stop when it goes below the minimum acceptable level (to be determined).
- There will be a Safety system monitoring the operating temperatures of the elements in the system, which will shut the element down and send a warning signal to the monitoring station.
- There will be a Safety system monitoring the concentration of Hydrogen, so if it reaches a level above the acceptable, the Hydrogen sub-system will be shut down and a warning signal will be sent to the monitoring station.

- There will be a Safety valve in the Hydrogen Tank that will release hydrogen, if for some reason the pressure in the tank goes above the limit set for the input from the electrolyzer (30 BAR for the electrolyzer output, 35 bars for the security valve).
- There will be a manual Stop command, which will stop all the sub-systems until a manual Start is done again. (System ON/OFF switch).

To do that, several sensors of different types will be needed. These are the minimum amount of sensors needed for an automated operation. If any other parameters are needed or wanted. The sensor net can easily be upgraded.

Below there is the list of sensors necessary, with the denomination used in the Grafcet *(Table 21).*

Table 21: List of sensors organized by type

<table>
<tr><th>TEMPERATURE SENSORS</th><th>FLOW-METER</th></tr>
<tr><td rowspan="5">T_{in}
T_{out}
T_{0m}
T_{60m}
T_{120m}
$T_{accumulator}$
$T_{electrolyzer}$
T_{H2tank}
$T_{fuel\ cell}$
$T_{water\ tank}$</td><td>$E_{production}$</td></tr>
<tr><td>LEVEL-METERS</td></tr>
<tr><td>Accumulator level
Pure water tank level
Emergency generator fuel level</td></tr>
<tr><td>HYGROMETER</td></tr>
<tr><td>H</td></tr>
<tr><td>PRESSURE SENSOR</td><td>H_2 CONCENTRATION METER</td></tr>
<tr><td>P_{H2T}</td><td>$H_{2\ concentration}$</td></tr>
</table>

With those sensors there will be enough data to monitor. These sensors are not only used mainly for operating or safety reasons, but also to have a data log of the parameters of the system (live data, averages, peaks…)

The following table shows the proposed monitoring parameters.

Table 22: Monitoring Layout Example

POWER SYSTEM	ON/OFF				
WIND TURBINE	ON/OFF	Enabled/Disabled			
SOLAR PANELS	ON/OFF	Enabled/Disabled			
ELECTROLYZER	ON/OFF	Enabled/Disabled			
FUEL CELL	ON/OFF	Enabled/Disabled			
HEAT PUMP	ON/OFF	Enabled/Disabled			
RADIATORS PUMP	ON/OFF	Enabled/Disabled			
VENTILATION	ON/OFF	Enabled/Disabled			
WIND TRUBINE POWER	#	W	WIND TURBINE POWER week average	#	W
			WIND TURBINE POWER month average	#	W
			WIND TURBINE ENERGY 24h	#	Wh
			WIND TURBINE ENERGY month	#	Wh
			WIND TURBINE ENERGY total	#	Wh
SOLAR PANELS POWER	#	W	SOLAR PANELS POWER week average	#	W
			SOLAR PANELS POWER month average	#	W
			SOLAR PANELS ENERGY 24h	#	Wh
			SOLAR PANELS ENERGY month	#	Wh
			SOLAR PANELS ENERGY total	#	Wh
POWER DEMAND	#	W	POWER DEMAND week average	#	W
			POWER DEMAND month average	#	W
			ENERGY DEMAND month	#	Wh
			ENERGY DEMAND total	#	Wh
ELECTROLYZER PRODUCTION	#	l/min	ELECTROLYZER PRODUCTION week average	#	l/min
			ELECTROLYZER PRODUCTION month average	#	l/min
			ELECTROLYZER PRODUCTION total	#	l
ELECTROLYZER TEMPERATURE	#	ºC			
FUEL CELL PRODUCTION	#	W	FUEL CELL PRODUCTION week average	#	W
			FUEL CELL PRODUCTION month average	#	W
			FUEL CELL PRODUCTION total	#	Wh
FUEL CELL TEMPERATURE	#	ºC		#	
H2 STORAGE	#	Kg			
H2 STORAGE PRESSURE	#	BAR			
H2 STORAGE TEMPERATURE	#	ºC			
H2 CONCENTRATION IN AIR	#	%			
TEMPERATURE INSIDE	#	ºC	TEMPERATURE INSIDE week average	#	ºC
			TEMPERATURE INSIDE month average	#	ºC
TEMPERATURE OUTSIDE	#	ºC	TEMPERATURE OUTSIDE week average	#	ºC
			TEMPERATURE OUTSIDE month average	#	ºC
HUMIDITY IN WALLS	#	%	HUMIDITY IN WALLS week average	#	%
			HUMIDITY IN WALLS month average	#	%
TEMPERATURE GROUND	#	ºC	TEMPERATURE GROUND week average	#	ºC
			TEMPERATURE GROUND month average	#	ºC
TEMPERATURE 60m	#	ºC	TEMPERATURE 50m week average	#	ºC
			TEMPERATURE 50m month average	#	ºC
TEMPERATURE 120m	#	ºC	TEMPERATURE 100m week average	#	ºC
			TEMPERATURE 100m month average	#	ºC
HOT WATER ACCUMULATOR LEVEL	#	l			
HOT WATER ACCUMULATOR TEMP.	#	ºC			
PURE WATER TANK LEVEL	#	l			
PURE WATER TANK TEMP.	#	ºC			

Most of the elements composing the system will be able to be over-ridden remotely, either by turning them ON or OFF, if this is considered necessary for any reason.

The over-ride feature will be for these elements:

- SYSTEM
- WIND TURBINE
- SOLAR PANELS
- ELECTROLYZER
- FUEL CELL
- HEAT PUMP
- RADIATORS PUMP
- VENTILATION

The sensors and switches placing can be seen in the SENSOR DIAGRAM (Appendix 13). The basic layout for the CONTROL SYSTEM will as seen below, divided by independent sub-systems. It is written as GRAFCETs, so it can be implemented in any PLC later *(Figure 51 - 57).*

Power distribution

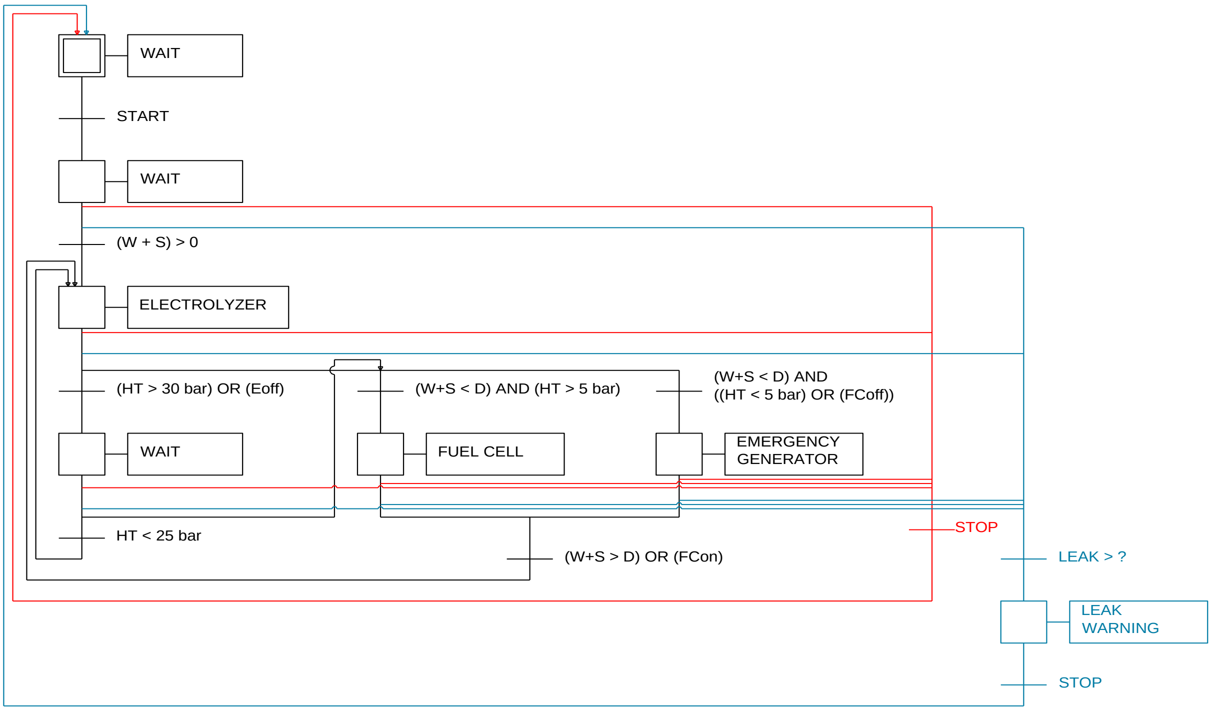


Figure 51: Power Distribution Grafcet

Heat pump operation

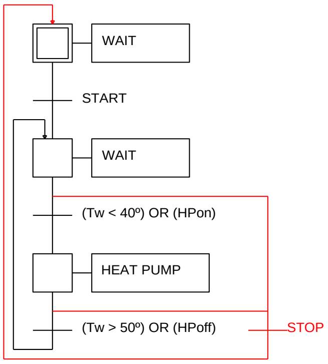


Figure 52: Heat Pump Operation Grafcet

Radiators Pump Operation

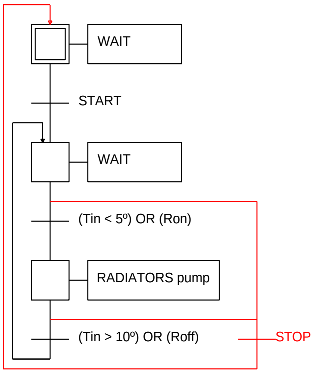


Figure 53: Radiators Pump Operation Grafcet

Ventilation Opearation

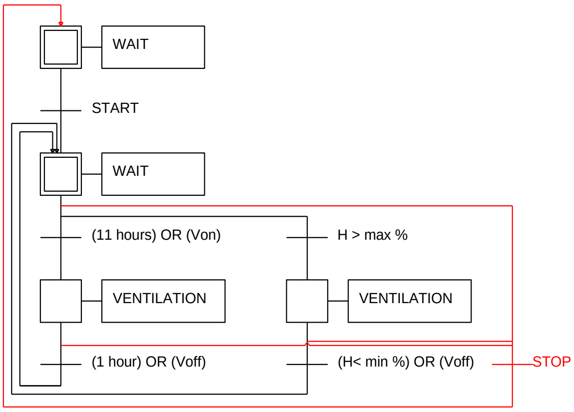


Figure 54: Ventilation Operation Grafcet

6 Results

The result of this project is a solution for the energy needs for the buildings in the islands, both for heating and for electricity. It accomplishes the initial goals, being a sustainable, autonomous, remotely controllable and reliable system. There a two generic solutions for different energy needs ranges and two specific solutions for Mickelsörarna and for Valsörarna.

In this chapter every solution is described in detail. An overview of the differences between the different solutions can be seen in Chapter 6.5, Summary.

6.1 Final concepts

6.1.1 Generic solution small

Electricity

Primary system

This is a generic solution for a system with less than 6kW of energy needs. The electrical system should supply around 3,5 kW. The range for the wind turbines is not detailed. The difference between the sizes of the wind turbines is big. It means that the wind turbine could oversupply the installation. However, when a smaller device is not enough, it will be necessary.

This generic solution contains a hybrid system composed of a wind turbine with a power output of 10 kW and solar panels with a power output of 6 kW. The turbine's manufacturer is Anhui Hummer Dynamo Co. LTD, the model is H8.0 10kW. The complete wind turbine's datasheet is found in *Appendix 14: Wind Turbine Datasheet*. The solar panels' manufacturer is Xuzhou Aibo Energy Technology Co. LTD, the model is AB200M and the provider of these solar panels is a company from Vasa called Sunergy, A.Y. A datasheet of solar panels is shown in *Appendix 15: Solar Panel Datasheet.*

The amount of energy obtained from this system depends on the period of the year. During winter the Power output is around 4.8 kW and during the summer the Power output is around 3.5 kW. This means that the energy obtained is considerable higher during the winter.

The price of the wind turbine depends on the type of installation. The total price with a single-phase converter is **12634,45€** and the price with a three phase converter is **13178,98€.** Transportation costs from Shanghai to Helsinki is **196,09€**. The detailed budget of the wind turbine and transportation is shown in *Chapter 6.1.3 Mickelsörarna.*

The price of the solar panels is approximate. The exact price is obtained when the panels are ordered. One system of 6 kW solar panels and 2 pieces Outback 80 Flexmax regulators cost around 10.000 €, transportation to Vasa included.

Secondary system

For a smaller generic solution, the brief data of each component is listed in the following tables. More detailed data sheets will be found in Appendix 17: Electrolyzer Datasheet.

Table 23: Electrolyzer-Acta AES200

Company	Acta Energy
model	AES200
H2 production rate	200 l/h
Standard working pressure	15 bar
Maximum allowable pressure	30 bar
purity@30 bar	99.94 %
Purity with additional purification	99.999 %
Water consumption	0.16 l/h
Water conductivity@20 ºC	5-10 µS/cm (Distilled water only)
Power consumption	1060 W
Dimension-(AxBxC)	180mm x190 mm x300 mm
Weight(without water)	20.5 kg

Table source: (Acta Energy, n.d.)

Table 24: Hydrogen tank for smaller generic solution

Volume	< 15000 liters
Pressure	30 bar
Stored temperature	ambient temperature

As regards the fuel cell, the company is called ReliOn. ReliOn focuses mainly on the telecom and military markets. They make fine products for stationary applications as well. Their fuel cells have high quality and different outputs. They allow the customer to configure the product to suit the load. For the smaller generic solution, where the electricity needs is smaller than 3.5 kW, ReliOn T-2000® 4kW Outdoor Configuration is chosen. Two ReliOn T-2000(2 kW) fuel cells consist of one ReliOn T-2000® 4kW Outdoor Configuration. The data is listed below in *Table 25.*

Table 25: Fuel cell-ReliOn T2000®4kW outdoor configuration

Company		ReliOn	
Model		ReliOn T-2000	ReliOn T-2000® 4kW Outdoor Configuration
Physical	**Dimensions (w x d x h)**	53.3cm x54.6cm x 66cm	183cm x137cm x 104cm
	Weight	61 to 110 kg	
	Mounting	23’’ rack mount	
Performance	**Rated net power**	0 to 2 kW	0 to 4 kW
	Rated current	0 to 40A@48VDC	
	DC voltage	24 or 48 VDC nominal	24 or 48 VDC nominal
Fuel(H_2)	**Composition**	Purity 99.95%	Purity 99.95%
	Supply pressure to unit	0.24 to 0.41 bar	0.24 to 0.41 bar
	Consumption	30 slpm @ 2 kW	30 slpm @ 2 kW
	Hydrogen storage capacity	n/a	n/a
Operation	**Ambient temperature**	2°Cto 46°C	-40°Cto 46°C
	Relative humidity	0-95% non-condensing	
	Altitude	-60m to 4206m	
	Location	Indoors	Outdoors
Safety	**Compliance**	UL/CSA/CE	NEBS Level3/Seismic Zone 4
Emissions	**Water**	Max.30mL/kWh	
	Noise	53 dBA @3.28 ft/1 meter	
Monitoring	**Remote**	System configuration& status/historical& operational data	Capability
	Communications	RJ45/DB9/Dry Contact	

Table source: (ReliOn, Inc, 2012)

Heating & Ventilation

For the **heating** of the generic solution, the assumption has been made that the building contains an existing radiator system. The hot water that is needed in this system will be provided by a GSHP in connection with an accumulator. The accumulator contains a water/glycol mixture to prevent the fluid of freezing. To obtain a minimum inside temperature of 5 °C, the mixture will be heated to 45°C.

A Finnish company named Gebwell Ltd will provide the used HP installation. The company is specialized in environmentally friendly solutions for heating and cooling (Gebwell.Ltd, n.d.).

The specific HP type is the Gebwell T6. This HP has a heat output of 6kW and a COP of around 3. The volume of the accumulator is 1000 liters. More technical information about the HP is found in Appendix 12, Heating and Ventilation Trade-off.

For the **ventilation** of the generic solution the assumption has been made that the building had no existing ventilation system. The chosen system is an HRV system. The manufacturer of the ventilation components is FläktWoods. They provide a wide range of ventilation and heat recovery equipment. Retailers can be found in Turku and Espoo, Finland (Flaktwoods, n.d.).

The solution is presented below. *Figure 55.*

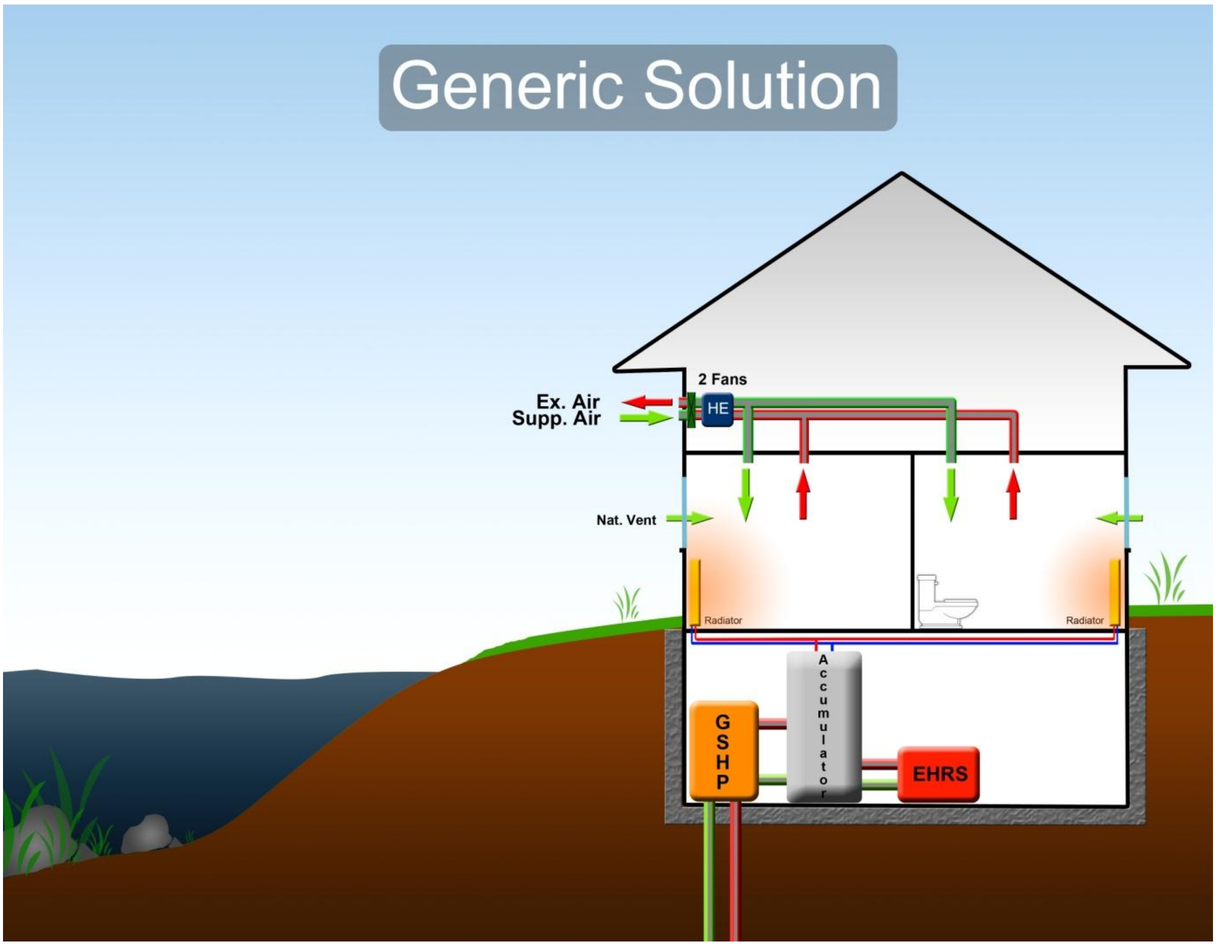


Figure 55: Generic heating and ventilation solution

A summary of the used heating and ventilation equipment for the small generic solution is shown below *Table 26.*

Table 26: Heating and ventilation for generic solution small

Generic solution small				
Building	**Total area**			**/**
	Total volume			**/**
	Heating demand			**>6kW**
Heating	**Heat pump**		**Heat source**	**Ground**
			Propreties	**Vertical**
				Closed loop
			Manufacterer	**Gebwell Ltd.**
			Type	**Gebwell T6**
			Heating output	**6kW**
			COP	**3**
			Power	**2kW**
			Borehole depth	**120m**
			Pipe length	**240m**
	Heat storage	**Accumulator**	**Manufacterer**	**Gebwell**
			Volume	**1000l**
			Contents	**Water-glycol**
			Back-up resistor	**6**
	Exhaust heat recovery		**Heat source**	**Fuel cell**
	Heat output		**Radiators**	**45°C/30°C**
Ventilation	**Air supply**	**Natural**		**Opening the windows**
				Cracks in the walls
		Mechanical	**Ducts**	**/**
			Fans	**/**
			Pipes	**/**
	Exhaust air	**Mechanical**	**Ducts**	**/**
			Fans	**/**
			Pipes	**/**
			Moist control	**/**
			Clock system	**2h/day**
	Heat recovery		**Type**	**Rotary heat exchanger**
			Manufacterer	**Fläktwoods**

6.1.2 Generic solution big

Electricity

Primary system

This generic solution has been calculated for an installation from 6 to 10 kW. The electrical installation should cover an energy need from 3.5 to 5 kW. This solution is calculated in a way that supplies around 5 kW of energy all year round. The electrical needs are similar to those on Mickelsörarna. The components of the primary energy system are the same; a hybrid system composed of a 10 kW wind turbine and a 12 kW solar panel.

The wind turbine is the model H8.0 10kW from Anhui Hummer Dynamo Co. LTD. The complete datasheet is found in *Appendix 14, Wind Turbine Datasheet.* The solar panel is model AB200M from Xuzhon Aibo Energy Technology Co. LTD, the provider is a local company from Vasa called Sunergy, A.Y. The complete datasheet is found in *Appendix 15, Solar Panel Datasheet.* Both devices are made in China. In *Chapter 6.1.3, Mickelsörarna* there are tables and graphs about the energy produced by these devices.

The price of the wind turbine depends on the type of installation. The total price with a single-phase converter is **12634,45€**. The price with a three phase converter is **13178,98€.** Transportation costs from Shanghai to Helsinki are **196,09€.** A detailed budget of the wind turbine and transportation is found in *Chapter 6.1.3, Mickelsörarna.*

The price of solar panels depends on multiple factors. The exact costs can only be given when the panels are ordered. The approximate price for a 12 kW solar panel with 3 Outback 80 Flexmax regulators is about **20.000€**. Transportation to Vasa is included in the price.

Secondary system

For the bigger generic solution, the same electrolyzer is chosen as shown in *Table 23*. The following tables show the rest of the components.

Table 27: Hydrogen tank for bigger generic solution

Volume	15000 liters – 20000 liters
Pressure	30 bar
Stored temperature	ambient temperature

A fuel cell called DBX5000 from a company named Dantherm is chosen. The following table lists its main parameters.

Table 28: Fuel cell-Dantherm DBX5000

Company	Dantherm		
model	DBX5000		
Power output	W	Continuous	5000
Voltage output	VDC	Fixed within	-47 to -57
Voltage input	VAC	For standby operation	90 – 264/50-60Hz
Hydrogen purity	%	Commercial grade 3.5	Min 99.95
Inlet pressure	Barg	Nominal to valve block	5
consumption	Nm^3/kWh	Average at max. load	0.95
Ambient temperature	°C	Operational(optional)	-20(-40) to +40(-55)
Integration cabinet temperature	°C	Operational	0 to +60
Storage temperature	°C	Weather protected	-45 - +70
Cabinet dimensions	mm	H x W x D	611 x 500(450) x 555
Weight	Kg	Stand alone module	75 kg
Ingress protection	IP-class	External to internal	55
Air flow	m3/h	Exhaust to outside	200-1600
Backup start up time	Sec.	Depends on batteries	Installation dependent
Interface/system monitoring	-	Standard configuration	RJ45 TCP/IP –CAN Bus Display panel
Voltage free outputs alarms	-	Goes open on fault	DB15 with 4 channels
Visual indication alarms	-	display	1
Interface- DC	-	On front panel	175 Amp Anderson type
Interface- AC(only DIB version)	-	On front panel	IEC 320 C14
Hydrogen	Fitting	-	8 mm Tube
Important note	DBX requires fresh air supply and ducting of exhaust air to outside ambient.DBX can only work when equipped with Dantherm Power Valve Block and a fuel regulator supplied by or approved by Dantherm Power		

Table source: (Dantherm Power A/S, 2009)

Heating & Ventilation

For the big generic solution an HP with 10kW heat output is used, namely the Gebwell T10. Technical information about the HP is found in *Appendix 12, Heating & Ventilation Trade-off*.

The **ventilation** system is identical to the one used the small generic solution (see chapter 6.1.1, Generic solution small/ Heating& Ventilation). The presentation of the heating and ventilation system is the same as in *Figure 54.* A summary of the used heating and ventilation equipment for the small generic solution is shown in the following table (*Table 29).*

Table 29: Heating and ventilation solution for generic solution big

Generic solution big				
Building	Total area and volume			/
	Heating demand			6-10kW
Heating	Heat pump		Heat source	Ground
			Propreties	Vertical
				Closed loop
			Manufacterer	Gebwell Ltd.
			Type	Gebwell T10
			Heating output	10kW
			COP	3
			Power	3,3kW
			Borehole depth	120m
			Pipe length	240m
	Heat storage	Accumulator	Manufacterer	Gebwell
			Volume	2000l
			Contents	Water-glycol
			Back-up resistor	6
	Exhaust heat recovery		Heat source	Fuel cell
	Heat output		Radiators	45°C/30°C
Ventilation	Air supply	Natural		Opening the windows
				Cracks in the walls
		Mechanical	Ducts	/
			Fans	/
			Pipes	/
	Exhaust air	Mechanical	Ducts	/
			Fans	/
			Pipes	/
			Moist control	/
			Clock system	2h/day
	Heat recovery		Type	Rotary heat exchanger
			Manufacterer	Fläktwoods

6.1.3 Mickelsörarna

Electricity

Primary system

Mickelsörarna is currently powered by a hybrid method. There are two diesel generators, a 75kW generator and a 50 kW generator. To reduce the use of the generators a model of the Whisper 500, 3.2 kW wind turbine and 21, 100 Watt PV solar panels is installed. As back up a fluid Solar 1500 battery bank has been installed. The battery has a maximum discharge of 70%. Therefore the control unit is programmed to start the generator when the battery is discharged to 35% (Tuomo Riikonen, 2008)

The generators are old and oversized. The efficiency is therefore, less than 30%. The fuel consumption on Mickelsörarna was 76.250 liters between 1997 and 2007. The generators consume about 6 liters per hour. The high consumption of fuel and the price of transportation results in high costs for the owner.

Another significant cost is the maintenance of the generator. The costs of maintenance between 1997 and 2007 were 17.400. The maintenance of the generators accounts 80% of the total maintenance costs. Furthermore, the old diesel generators have a high level of pollution.

The primary system that will be used is hybrid. For this project hybrid means, composed of a Wind Turbine and Solar Panels. The wind turbine produces more energy in winter, in contrast to the solar panels that only create significant energy in summer. By using a hybrid system, the different energy needs for summer and winter will be covered.

- *Wind Power*

The turbine chosen is *H8.0 10000W* from the company *Anhui Hummer Dynamo Co. LTD.* The turbine has been selected for the reason that the power curve is very suitable for the wind speed averages on Mickelsörarna. Furthermore, this device has a good efficiency and a small size, the tower is 12 meters high. The complete datasheet of the turbine is found in *Appendix 14, Wind Turbine Datasheet.*

The total amount of energy obtained is higher in winter than in summer. In winter there is, on an average, more wind. The wind turbine produces more energy in winter then it does in summer. The energy needs have seasonal differences, hence the reason to go hybrid. During the winter the wind turbine is the main source of energy, it should therefore supply most of the energy demand. During the coldest weeks however, there are periods without wind. During the winter the energy required is approximately 100 kWh/day. The energy obtained from the wind turbine is calculated as follows:

Firstly, the Power Out of the turbine is calculated for each month, based on the Power curve of the Wind Turbine and the wind speed average [1]. Then, the amount of energy obtained by the wind turbine is calculated per month:

$$Wind\ Energy\ per\ Month = Power\ Out\ x\ 24\ hours\ x\ Days\ [1]$$

The Power-Out of the turbine is multiplied by the number of hours in a day and the number of days in that specific month. The sum of these calculations *(Table 30)* gives the total amount of energy that can be obtained from the wind using a Wind Turbine per year. *(kW/h)*

Table 30: Wind energy per month summary

Month	Wind Speed (m/s)	Power Out (W) [1]	Energy Wind (kWh/month) [2]
January	6,8	3900	2808
February	6,2	3400	2448
March	5,7	2900	2088
April	5,3	2200	1584
May	4,9	1800	1296
June	4,7	1600	1152
July	4,6	1450	1044
August	5,1	2000	1440
September	5,9	3000	2160
October	7	4200	3024
November	7,4	4600	3312
December	7,2	4400	3168

The following figure shows the curve of wind energy during the year. It shows the difference between winter and summer months regarding the obtained energy.

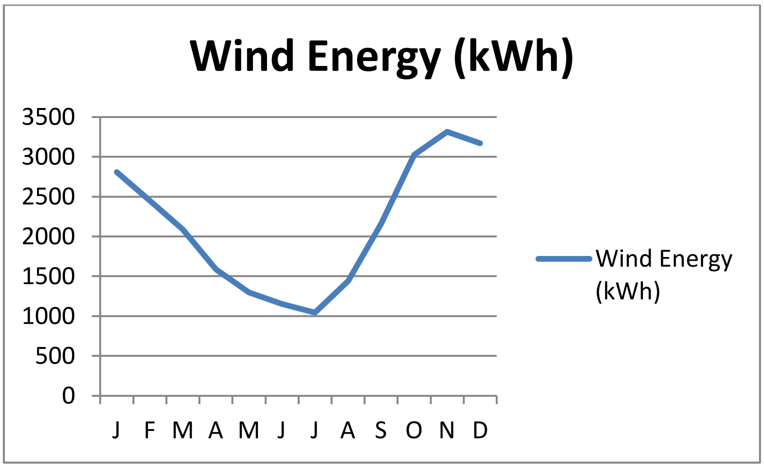


Figure 56: Wind energy per year curve

The total price of the wind turbine depends on the type of installation. There is a total price for single-phase installation and a different price for three-phase installation. Both budgets are shown in the next table *(Table 31)*.

Table 31: Wind turbine H8.0 budget

WIND TURBINE: H8.0 10000W		
Wind turbine	8.038,00 USD	6062,30 €
PLC Controller	836,00 USD	630,52 €
Gried Tied Rectifier	630,00 USD	475,15 €
Dumping Load	801,00 USD	604,12 €
Gried Tied Converter (singe phase)	4820,00 USD	3635,27 €
Gried Tied Converter (three phase)	5542,00 USD	4179,80 €
12m guyed tower	1627,00 USD	1227,09 €
TOTAL (single phase converter)	**16752,00 USD**	**12634,45 €**
TOTAL (three phase converter)	**17474,00 USD**	**13178,98 €**

This price is free on board Shanghai. The transportation from Shanghai to Helsinki costs 65 USD/CBM. The total volume of the turbine is 4 CBM, meaning that the transportation will cost 260USD, (**169,09€**). This shipping price does not include any port costs in Helsinki, e.g. customs cost, import duties, etc.

- *Solar Power*

The Solar Panel chosen comes from a company called *Xuzhou Aibo Energy Technology Co.,Ltd.* located in China. The model of the device is *AB200M.* The budget, advice and datasheet were obtained from a local company in Vasa specialized in Solar Panels. The company is called *Sunergy a.y.* The complete datasheet of the solar panels is found in *Appendix 15, Solar Panel Datasheet.*

The main reasons for choosing these solar panels are: warranty of order, good quality of performance, and good cell efficiency: 17.9%. The cell efficiency is an important factor. It is a calculation on the capacity of the exploitation of the received insolation. This system has 60 units of 200W solar panels, multiplying this numbers calculates that this solar system has 12.000W of power.

Solar panels are only usable during the spring and summer months. In that time of the year the insolation is sufficient to obtain a significant quantity of energy. With the data of the solar insolation the amount of energy that the solar panels can obtain from the sun is calculated with equation [2]

$$Total\ Energy\ obtained = Insolation\ x\ Total\ Area\ x\ Efficiency\ [2]$$

The insolation data is per square meters, and it is necessary to know the total area of the solar panels. The area that this system covers is calculated with equation [3] by using the data on the datasheet of the solar panels:

$$Total\ Area = 60\ solar\ panels\ x\,\frac{1.27664m^2}{solar\ panel} = \ 76.5984\ m^2\ [3]$$

The total insolation that the solar panels receive is calculated by knowing the total area of the system and the monthly insolation data *(Appendix 07: Weather Data)*. The following step is to take the efficiency of the solar panel into account *(Table 32).*

Table 32: Solar energy per month

Month	Insolation (kWh/m^2)	TOTAL SIZE SOLAR PANELS* (m^2) [1]	EFFICIENCY (%)	SOLAR ENERGY (kWh) [2]
January	4,03	76,5984	17,9	55,25578781
February	19,6	76,5984	17,9	268,7378266
March	56,11	76,5984	17,9	769,3305841
April	110,7	76,5984	17,9	1517,820276
May	163,68	76,5984	17,9	2244,235074
June	177,3	76,5984	17,9	2430,980441
July	168,33	76,5984	17,9	2307,991752
August	124,93	76,5984	17,9	1712,929422
September	72,6	76,5984	17,9	995,4268474
October	30,69	76,5984	17,9	420,7940764
November	8,7	76,5984	17,9	119,2866883
December	1,55	76,5984	17,9	21,25222608

The following figure shows the amount of energy obtained from solar panels all year round.

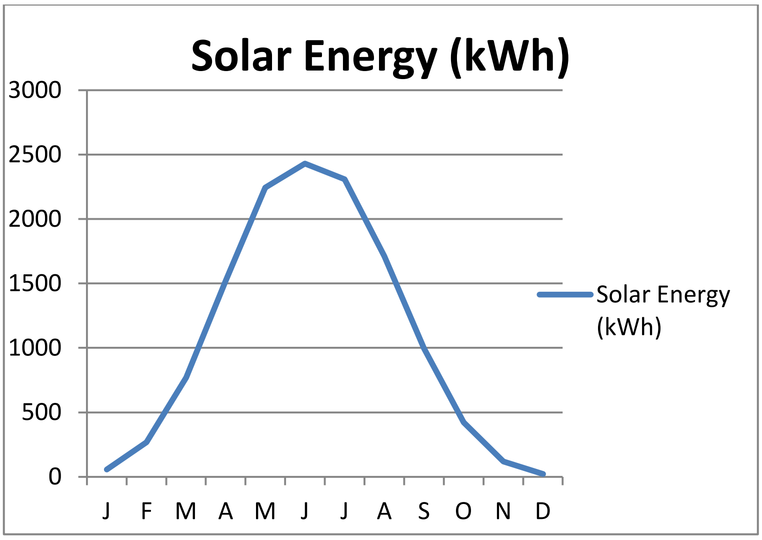


Figure 57: Solar energy per month curve

The exact price of the solar system can be given when the order is placed. This is because prices change frequently. They depend on e.g. the stock at the storage and other variable factors.

The total price of the solar system containing 12 kW Solar Panel and 3 pieces Outback 80Flexmax regulators will be around **20.000€.** The transportation to Vasa is included in this price.

Secondary system

Electrolyzer for Mickelsörarna can be seen in Table 23. The fuel cell is also the same for the big generic solution, which can be seen in *Table 28*. The following table shows the hydrogen tank *(Table 33).*

Table 33: Hydrogen tank for Mickelsörarna

Volume	~20000 liters
Pressure	30 bar
Stored temperature	ambient temperature

Heating & Ventilation

The **heating** solution for Mickelsörarna is a Gebwell T10 HP connected to a 2000-liter water accumulator. The accumulator is already present in the building from the previous heating system. It is equipped with a back-up resistor and connected to an exhaust heat recovery system that provides extra heat from the fuel cell. The accumulated hot water will be used in the existing radiator system.

The **ventilation** system is already installed in the building. It is an exhaust ventilation system with tubes that only go to the kitchen, bathrooms and storage rooms. Fresh air comes into the building through cracks, small holes, and openings around doors or by opening a window. The building requires one total air renewal every day. Therefore, the fans will work two hours a day. The system will be equipped with a humidity control system that turns the fans on whenever the humidity inside the building reaches a set level.

The following figure shows the heating and ventilation solution for Mickelsörarna (*Figure 58).*

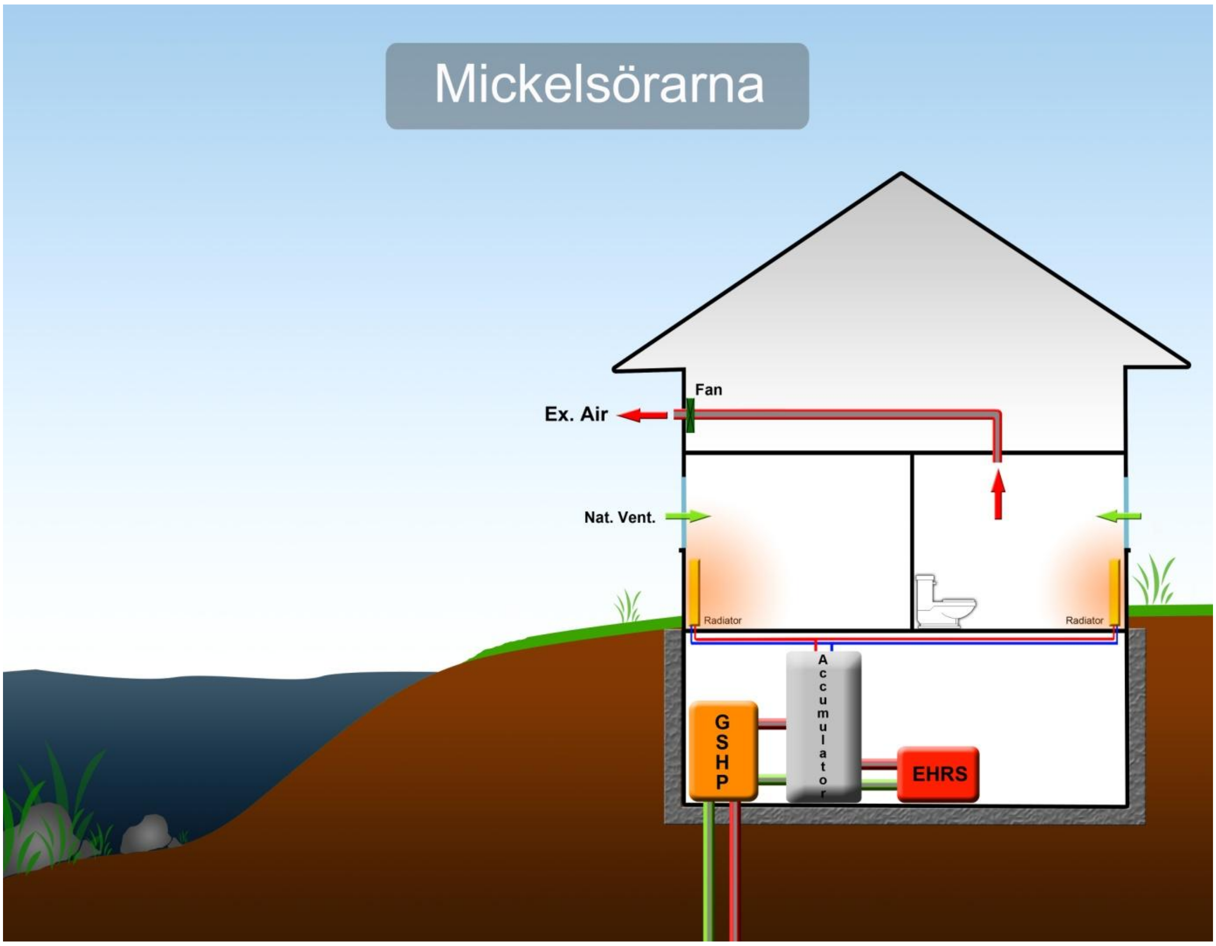


Figure 58: Heating and ventilation solution for Mickelsörarna

A summary of the used heating and ventilation equipment for Mickelsörarna is shown in *Table 34* below.

Table 34: Data of heating and ventilation solution for Mickelsörarna

Mickelsörarna				
Building	Total area			689 m^2
	Total volume			1994 m^3
	Heating demand			6 kW
Heating	Heat pump		Heat source	Ground
			Propreties	Vertical
				Closed loop
			Manufacterer	Gebwell Ltd.
			Type	Gebwell T10
			Heating output	10kW
			COP	3
			Power	3,3kW
			Borehole depth	120m
			Pipe length	240m
	Heat storage	Accumulator	Volume	2000l
			Contents	Water-glycol
			Back-up resistor	6
	Exhaust heat recovery		Heat source	Fuel cell
	Heat output		Radiators	45°C/30°C
Ventilation	Air supply		Natural	Opening the windows
				Cracks in the walls
	Exhaust air	Mechanical	Ducts	Storage rooms
				Bathrooms
				Kitchen
			Fans	
			Pipes	
			Moist control	
			Clock system	2h/day
	Heat recovery			/

6.1.4 Valsörarna

Electricity

Primary system

The electrical needs for Valsörarna are calculated with the evaluation model. There is a big difference in energy needs throughout the year. The energy need during summer is about 10% of the energy need in the winter. The reason for this difference is the heating system that keeps the building on a steady temperature of five degrees Celsius inside. The exact energy is therefore difficult to cover with a hybrid system.

For this specific situation of Valsörarna there is a big energy need during the winter and a significant smaller need during the summer. A hybrid system on this island is superfluous. As there is not much solar insulation during the winter, our decision was to use just a wind turbine. During the winter months the wind speed average is approximately 2 m/s per second higher than in the summer months.

The chosen device for Valsörarna is a wind turbine with an output of 10 kW. The manufacturer is Anhui Hummer Dynamo Co. LTD, and the model of wind turbine is H8.0 10kW. This system has been chosen because it is a system that supplies more electricity during the winter than during the summer, which is what the island needs. The complete datasheet of this wind turbine is found in *Appendix 14, Wind Turbine Datasheet.*

The data of wind speed averages and the power curve of the wind turbine are used to calculate the Power Out of the turbine. In the summer months the energy output of the wind turbine is about 2 kW and during the winter the energy output is around 4.8 kW. During the summer months the systems generate more energy than needed. However, a smaller wind turbine would not satisfy the needs during the winter months.

The price of this wind turbine depends on the type of installation. The total price with a single-phase converter is **12634,45€**. The price with a three phase converter is **13178,98€.** Transportation costs from Shanghai to Helsinki are **196,09€**. The detailed budget of the wind turbine and transportation is found in *Chapter 6.1.3, Mickelsörarna.*

Secondary system

The secondary system solution for Valsörarna is the same as for Mickelsörarna. Detailed information can be found in *Chapter 6.1.3, Mickelsörarna*.

Heating & Ventilation

The **heating** system that is used on Valsörarna is identical to the one used on Mickelsörarna *Chapter 6.1.3, Mickelsörarna/ Heating& Ventilation*.

The **ventilation** of the building is also an exhaust ventilation system, like in the building on Mickelsörarna. The systems differ in two ways. The first is that every room contains its duct and ventilation tube, not only the kitchen, bathrooms and storage rooms. The other way is the penetration of the fresh air inside the building. The windows permit the air to pass through the specially built window jamb (for the technical drawing see *Appendix 5: Window Ventilation*). There is also inevitably air coming through cracks, small holes and openings around doors. The blueprints of the ventilation can be found in Appendix 05: Blueprints Valsörarna.

The figure below shows the heating and ventilation solution for Valsörarna *(Figure 59)*.

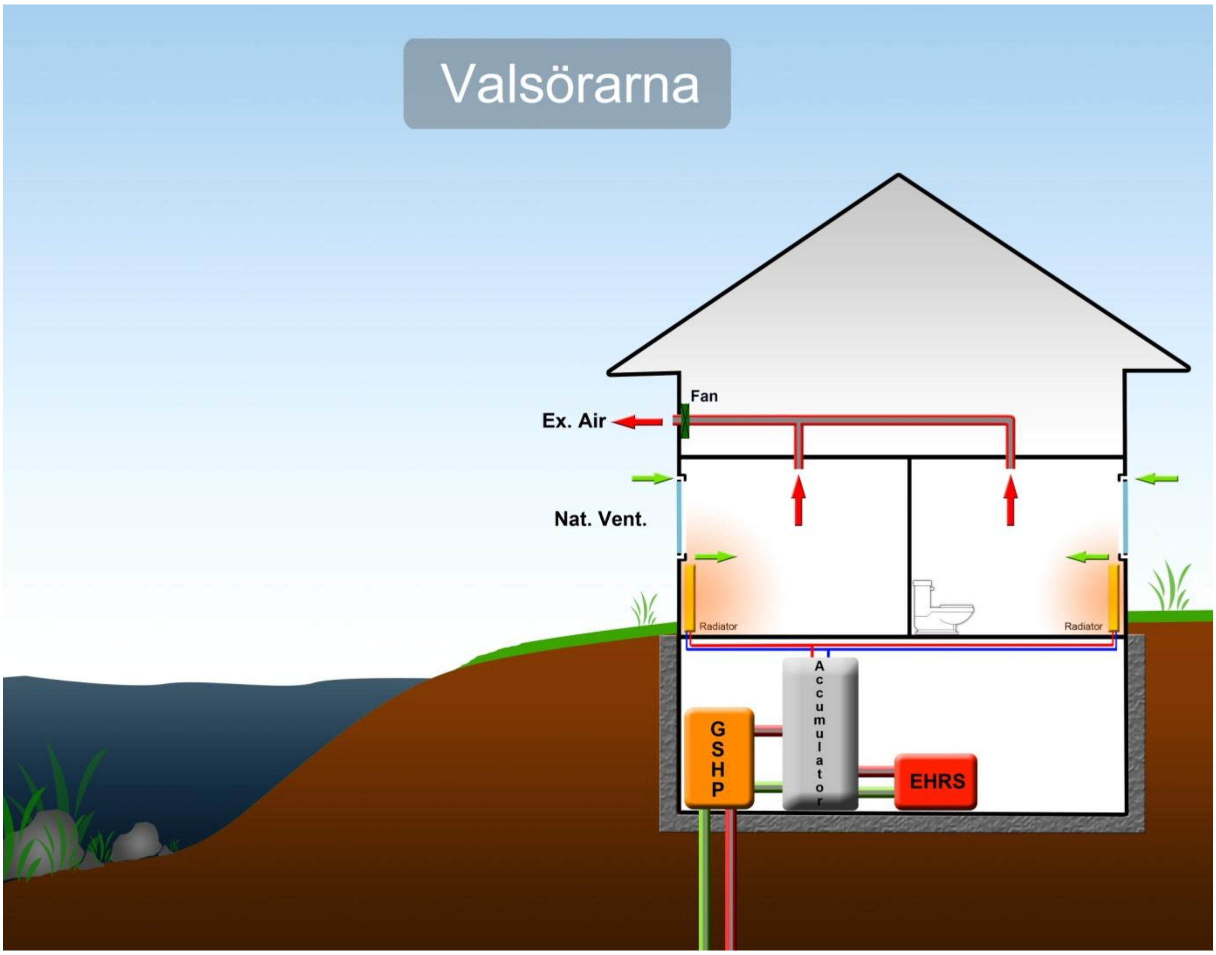


Figure 59: Heating and ventilation solution for Valsörarna

A summary of the used heating and ventilation equipment for Valsörarna is shown in *Table 35* below.

Table 35: Data of heating and ventilation solution for Valsörarna

Valsörarna				
Building	Total area			760 m^2
	Total volume			1864 m^3
	Heating demand			10 kW
Heating	Heat pump		Heat source	Ground
			Propreties	Vertical
				Closed loop
			Manufacterer	Gebwell Ltd.
			Type	Gebwell T10
			Heating output	10kW
			COP	3
			Power	3,3kW
			Borehole depth	120m
			Pipe length	240m
	Heat storage	Accumulator	Volume	2000l
			Contents	Water-glycol (30%)
			Back-up resistor	6
	Exhaust heat recovery		Heat source	Fuel cell
	Heat output		Radiators	45°C/30°C
Ventilation	Air supply		Natural	through the windows
				Cracks in the walls
	Exhaust air	Mechanical	Ducts	1/room
			Fans	6
			Pipes	6 types
			Moist control	
			Clock system	2h/day
	Heat recovery			/

6.2 Summary

Table 36 is an overview of all the components of the four concept solutions. The chosen components are most suitable for each solution.

Table 36: Final product choices

	GENERIC small	**GENERIC bigger**	**MICKELSÖRARNA**	**VALSÖRARNA**
Heat need	< 6 kW	6 to 10 kW	5.7 kW	10 kW
Electrical appliances	1.5 kW (estimation)	1.5 kW (estimation)	3.3 kW	0.5 kW (calc. with 1.5)
POWER NEED*	**<3.5kW**	**3.5 to 5 kW**	**4.4 kW**	**5 kW**
WIND TURBINE	Anhui Hummer Dynamo H8.0 10 kW	Anhui Hummer Dynamo H8.0 10 kW	Anhui Hummer Dynamo H8.0 10 kW	Anhui Hummer Dynamo H8.0 10 kW
SOLAR PANELS	Xuzhou Aibo Energy Tec. AB200M 30x200W=6 kW	Xuzhou Aibo Energy Tec. AB200M 60x200=12 kW	Xuzhou Aibo Energy Tec. AB200M 60x200W=12 kW	*Not necessary*
ELECTROLYZER	Acta AES200 200 l/h H_2 @ 30 bar 1060 W input	Acta AES200 200 l/h H_2 @ 30 bar 1060 W input	Acta AES200 200 l/h H_2 @ 30 bar 1060 W input	Acta AES200 200 l/h H_2 @ 30 bar 1060 W input
STORAGE	<15,000 l gas H_2 @ 30 bar	15,000-20,000 l gas H_2 @ 30 bar	~20,000 l gas H_2 @ 30 bar	~20,000 l gas H_2 @ 30 bar
FUEL CELL	ReliOn T-2000® 4kW Outdoor Config. (0 to 4 kW) 24/48VDC	Dantherm DBX5000 5 kW ,48 VDC	Dantherm DBX5000 5 kW ,48 VDC	Dantherm DBX5000 5 kW ,48 VDC
HEAT PUMP Ground Source, Closed Loop	Gebwell T6 2kW + accumulator (1000l) + EHR	Gebwell T10 3.3 kW + accumulator + EHR	Gebwell T10 3.3 kW + accumulator (2000l) + EHR	Gebwell T10 3.3 kW + accumulator + EHR
VENTILATION	(1 kW) Supply pipes & Exhaust pipes + HR + moist control + timer	(2 kW) Supply pipes & Exhaust pipes + HR + moist control + timer	(1 kW) Existing System + moist control + timer	(1 kW) Existing System + moist control + timer
Emergengy GENERATOR	Telgenco quiet48-5 (5kw – 48 VDC)	Telgenco quiet48-5 (5kw – 48 VDC)	Telgenco quiet48-5 (5kw – 48 VDC)	Telgenco quiet48-5 (5kw – 48 VDC)

7 Discussion

7.1 Evaluation

The goal of this EPS project was to generate a sustainable and mostly autonomous solution for buildings in the Kvarken archipelago. The result of this project is a concept solution based on wind and solar energy, where excess energy is stored via hydrogen and converted into electricity when the wind and solar energy is not sufficient. The generated electricity can then be used to power the heating system, the ventilation system and the different appliances in the buildings.

The data given to the project team, by the project manager was not sufficient to make a fully specified and detailed solution. The result is as correct as possible, but at some stages there is a level of assumption. These assumptions are taken into account in the calculations made to determine the type and size of the chosen installations. It is possible that the presented solution may be oversized. It is oversized since in this project it is better to have an oversized system than an undersized system.

7.2 Validity

In this project there were some aspects that had to be estimated. Therefore, it is possible that the validity is a bit off. The estimations were made in a way that the system would not fail. E.g. the calculations are sized in a way that the system will definitely not be undersized and therefore not usable.

7.3 Reliability

The results of this project are reliable. The work methodology is used correctly; experts checked the results and the goals are achieved. The Energy Evaluation Model is designed and used as input for the concept. Where possible, the data has been double-checked. Data was available from Mickelsörarna; this data is used to check the reliability of the Energy Evaluation Model. The data calculated with the Energy Evaluation Model is accurate compared to the given data. The model also provided the data that was used in the calculations on Valsörarna, which means that the calculations were right. However, assumptions had to be made about the amount of working hours of the electric appliances.

7.4 Future

This project contained two main goals. The first objective was to make a model to estimate the energy needs. The second objective was to design a concept solution for Mickelsörarna, Valsörarna and similar remote off grid buildings in the archipelago. The output of this project is an Energy Evaluation Model and a concept solution. The Energy Evaluation Model is a tool made for engineers to make a fast estimation of the heating and electricity needs. The concept solution can be used as input for sustainable solutions in the Kvarken Archipelago near Vasa, Finland. Further research about piping, wiring and the control system is needed to make this concept solution in reality. It is however useful to use this project as input for similar projects.

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Appendices

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1 The Project

1.1 Appendix 01: Ekenäs Fair Posters

What

The goal of this European Project Semester is to provide sustainable energy for buildings on the Kvarken achipelago. The islands contain several pilot- and naturestations that have a certain demand of electricity and heating. The EPS team investigates a generic solution for the islands energy demands.

Kvarken is part of the UNESCO's World Heritage

Why

In the winter the buildings need heating to handle the cold and the humidity. In the summer there is a higher energy need compared to the winter due to the visitors. Currently the stations energy is provided by fuel consuming methods that are not nature friendly. Finding sustainable alternatives solves this issue.

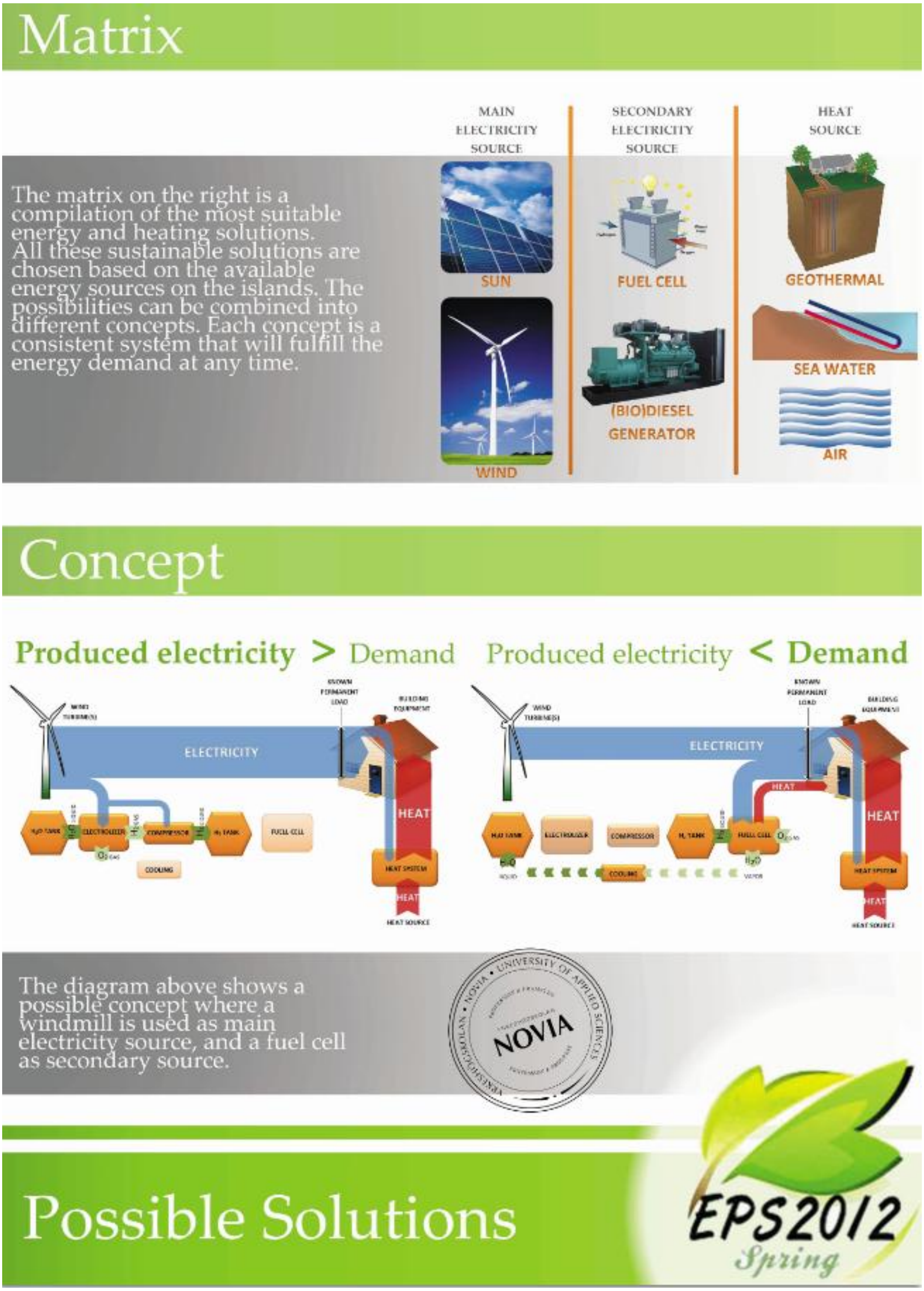
Buildings on Mickelsörarna

How

Nowadays there are many different possibilities for sustainable energy. Finding the best suitable solution using the advantages of the archipelago is the challenge. By comparing all the possible alternatives, a final concept will be generated that can be applied on any designated island.

Sustainable Energy Solutions
For the Kvarken archipelago

Figure 1: Poster Ekenäs Fair 01



Matrix

The matrix on the right is a compilation of the most suitable energy and heating solutions. All these sustainable solutions are chosen based on the available energy sources on the islands. The possibilities can be combined into different concepts. Each concept is a consistent system that will fulfill the energy demand at any time.

Concept

Produced electricity > Demand

Produced electricity < Demand

The diagram above shows a possible concept where a windmill is used as main electricity source, and a fuel cell as secondary source.

Possible Solutions

Figure 2: Poster Ekenäs Fair 02

1.2 Appendix 02: Business Card

EPS2012
Spring

European Project Semester 2012

Wolffskavägen 33
65200 Vaasa
Tfn +358(0)6 328 5559
eps2012s@novia.fi
eps2012s.novia.fi

NOVIA

Figure 3: Business Card

2 Energy Demands

2.1 Appendix 03: Instruction Manual Electricity Evaluation

INSTRUCTIONS

*Fill the white cells, rest cannot be modified

Start:

Make a list of all appliances. Make sure AC (ALTERNATE CURRENT) and DC (DIRECT CURRENT) are separated.

Fill in the quantity of each appliance and the Power (Watts) *(1 Kw = 1000Watts).* Fill in the quantity of the appliances running during SUMMER and during WINTER. (i.e. If a heating device is only used during winter fill in a 0 in quantity in SUMMER and a 1 in WINTER)

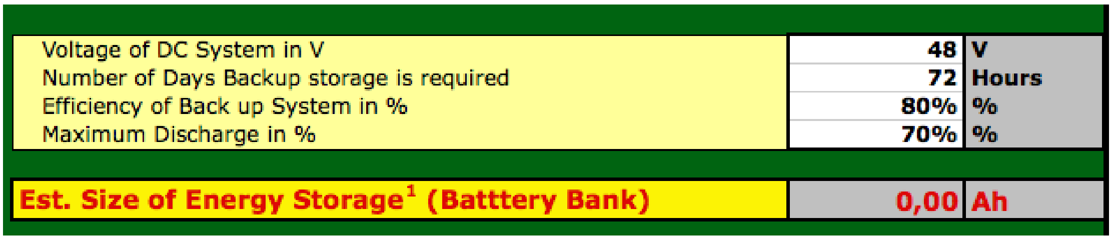
Fill in the average amount of Hours per Day the appliance is used during SUMMER and WINTER.

The Summary below the table shows a rough calculation about

- The **Average** Consumption **DC** in kWhrs/h
- The **Peak** Consumption **DC** in kW
- The **Average** Consumption **AC** in kWhrs/h
- The **Peak** Consumption **AC** in kW
- The size of the **Inverter** needed (DC/AC)

Storing energy in an off-grid installation is useful for days when the primary energy source is not sufficient. This model provides two calculation models for storing energy.

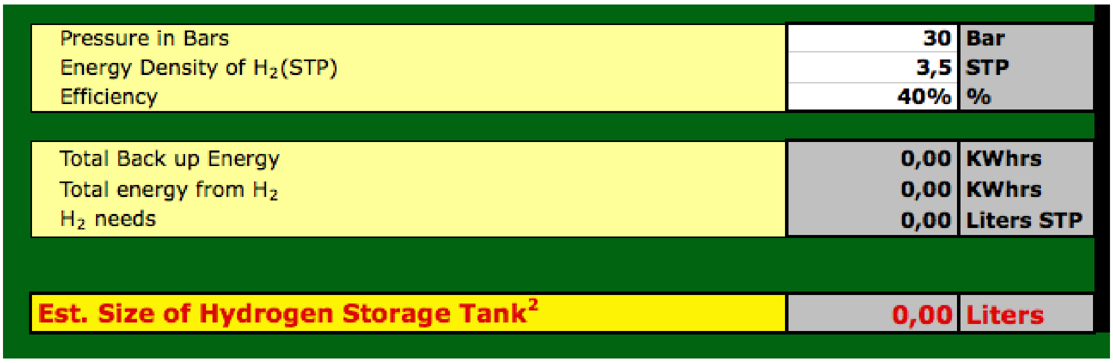
The first is a battery bank. Fill in the **Voltage** (DC) of the system, the **Hours** of energy storage, the **Efficiency** and the **Maximum discharge** of the batteries. The model will calculate the ***Estimated Size of the Battery Bank***



Voltage of DC System in V	**48**	**V**
Number of Days Backup storage is required	**72**	**Hours**
Efficiency of Back up System in %	**80%**	**%**
Maximum Discharge in %	**70%**	**%**
Est. Size of Energy Storage[1] (Batttery Bank)	**0,00**	**Ah**

When you choose to use a Fuel Cell as a storage device, fill the efficiency of the fuel cell (usually between 40% en 50%). Fill in the STP *(Standardized Temperature Pressure)* (usually between 3.2 and 3.5) and fill at what pressure the hydrogen in to be stored. The Model will calculate the:

- Total Back up Energy *in kWhrs*
- Total energy from H_2 *in kWhrs*
- H_2 Needs *in Liters STP*
- ***Estimated Size of the Hydrogen storage tank***



Pressure in Bars	30	Bar
Energy Density of H_2(STP)	3,5	STP
Efficiency	40%	%
Total Back up Energy	0,00	KWhrs
Total energy from H_2	0,00	KWhrs
H_2 needs	0,00	Liters STP
Est. Size of Hydrogen Storage Tank[2]	**0,00**	**Liters**

2.2 Appendix 04: Instruction Manual Heating Evaluation

INSTRUCTIONS

*Fill the blank cells. Rest of cells cannot be modified.

Introduce:

- **Outside** minimum average temperature [in Celsius degrees].
- **Ground** minimum average temperature (approximate) [in Celsius degrees].
- **Inside** objective temperature [in Celsius degrees].
- Approximate **Volume** of building [in m^3].
- **Air changes** per hour (see table on the bottom).
- Air Heat Recovery System **Efficiency**. If there is none, write 0 (zero) [in %].

Then start entering **surfaces data**, the *Thermal Resistance R* and *Thermal Transmittance U* values will appear once the *Material* is chosen. In case the material is not listed, the R and U values can be manually changed [R in (m^2·K/W)] [U in (W/m^2·K)].

Outside Wall i: enter the wall´s surface [in m^2]. You can choose 4 materials for each wall (different or repeated), if you don´t need 4, leave the *Material* cell empty and write 0 (zero) as the R value for the ones you don´t need.

Windows & Doors in Wall i: enter the surface to subtract from that wall that is occupied by windows or doors [in m^2]. If there´s no doors or windows in that wall, leave the *Material* cell empty and write 0 (zero) as the R value for the ones you don´t need.

Roof i: enter the roof´s surface from the plane view [in m^2], a correction factor (1.15 for 30 degrees is defect, but you can change it) will be applied to take in account the pitch. Enter the material of the roof. The roof surface can be divided in 2 if there are 2 different types of roof. If there´s only 1 type of roof, write 0 (zero) in the *Area* cell, leave the *Material* cell empty and write 0 (zero) as the U value for the second roof type.

Floor: enter the floor´s surface [in m^2], then enter the material of the floor.

Window Type i: enter the surface for each window [in m^2] for that type. Then enter the material of that type of window. You can divide the total amount of windows in 4 different types. If there are not 4 different types, write 0 (zero) in the *Area* cell, leave the *Material* cell empty and write 0 (zero) as the U value for the window types that are not necessary.

Number of type i windows: enter the amount of windows of that type (same area, same material).

Door Type i: enter the surface for each door [in m^2] for that type. Then enter the material of that type of door. If there is just one type of door, write 0 (zero) in the *Area* cell, leave the *Material* cell empty and write 0 (zero) as the U value for the second door type.

Number of type i doors: enter the amount of doors of that type (same area, same material).

Check that in the column HEAT LOSS due to TRANSMISSION there is not anything that is not a number. If there is something different to a number, please check the steps above again.

The materials table can be modified with new R or U values. Also with new materials; however, if that happens the formulas for columns Materials, Thermal Resistance and Thermal Transmittance must be modified as well. You will need the password for that.

RESULTS

In the TOTAL **HEAT LOSS due to TRANSMISSION H_T** column you will find the amount of heat loss through the surfaces in Watts.

In the **HEAT LOSS due to VENTILATION H_V** column you will find the amount of heat loss for the air changes in Watts.

In the **GLOBAL U FOR THE BUILDING** (orange cells in the center) you will find the overall U value in W/m^2·K for the building being studied. That will give an idea of how well insulated the building is.

BUILDING HEAT LOSS CALCULATOR

TOTAL HEAT LOSS #N/A Watts

HEAT LOSS due to TRANSMISSION

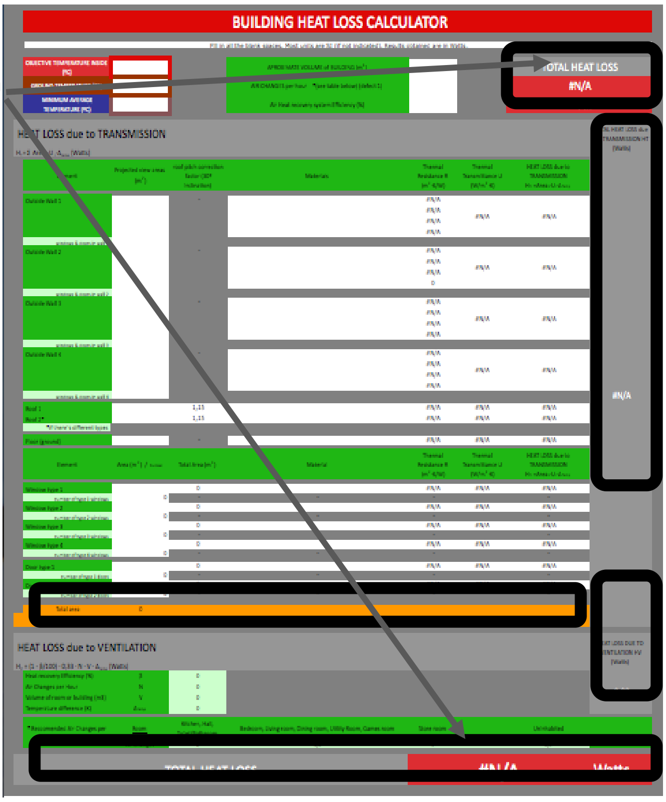
GLOBAL U for the Building #N/A (W/m^2·K)

HEAT LOSS due to VENTILATION

0,00

TOTAL HEAT LOSS #N/A Watts

In the **TOTAL HEAT LOSS** (red cells on the bottom and on the top right) you will find the total amount of heat loss of the building according to the data introduced in Watts.



BUILDING HEAT LOSS CALCULATOR

TOTAL HEAT LOSS #N/A

HEAT LOSS due to TRANSMISSION

#N/A

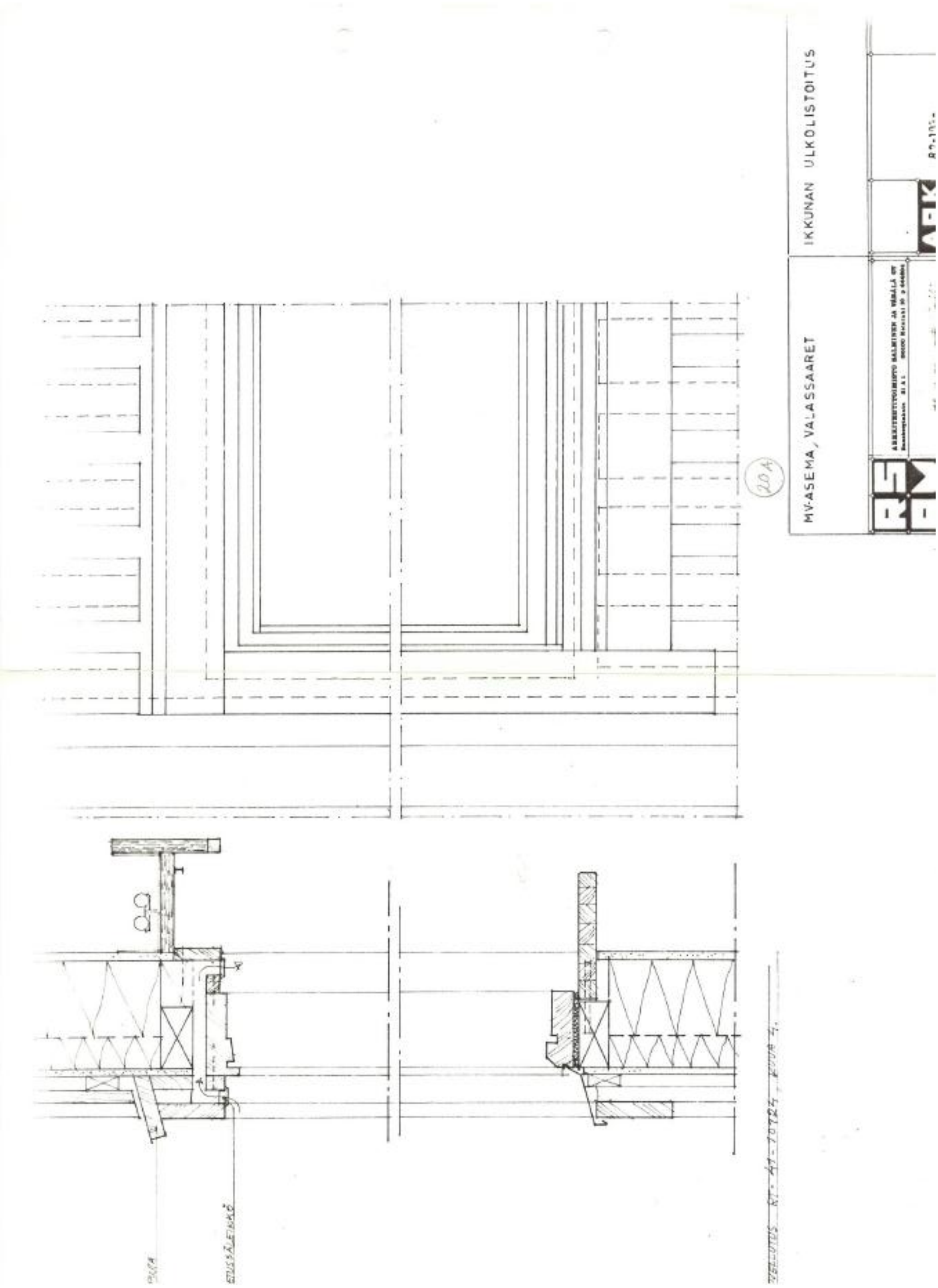
HEAT LOSS due to VENTILATION

GLOSSARY

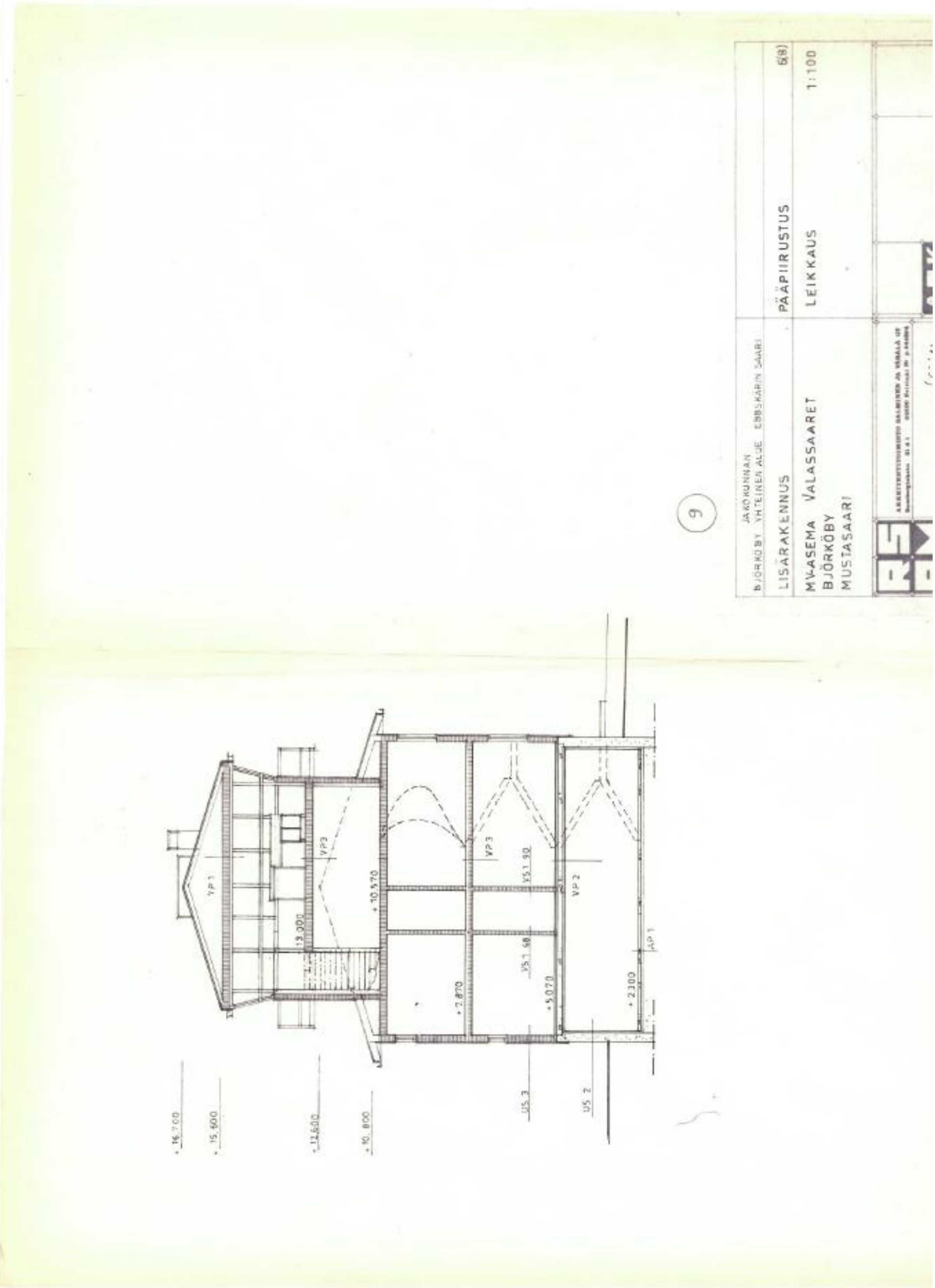
ºC	degrees Celsius
K	degrees Kelvin
W	Watts (1 kilowatt (kW) = 1000 Watts (W))
B	Heat Recovery System Efficiency (%)
V	volume of the building
N	number of air changes per hour
R_i	thermal resistance $R=1/U$
U_i	thermal transmittance $U=1/R$
Δ_{Temp}	temperature gap
H_T	heat loss due to transmission (W)
H_V	heat loss due to ventilation (W)

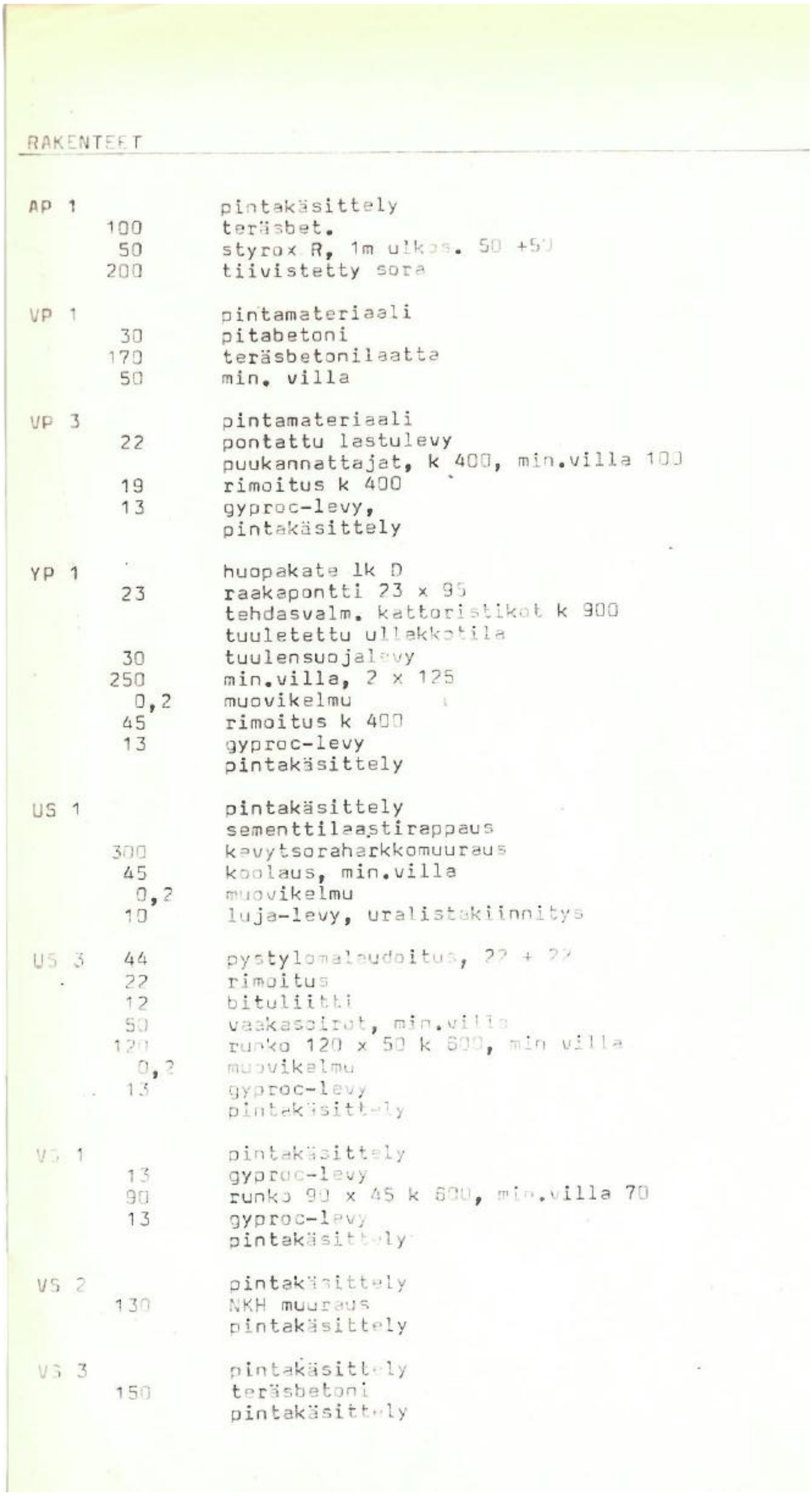
2.3 Appendix 05: Blueprints Valsörarna

2.3.1 Blueprint: Window Ventilation



2.3.2 Blueprint: Floor materials

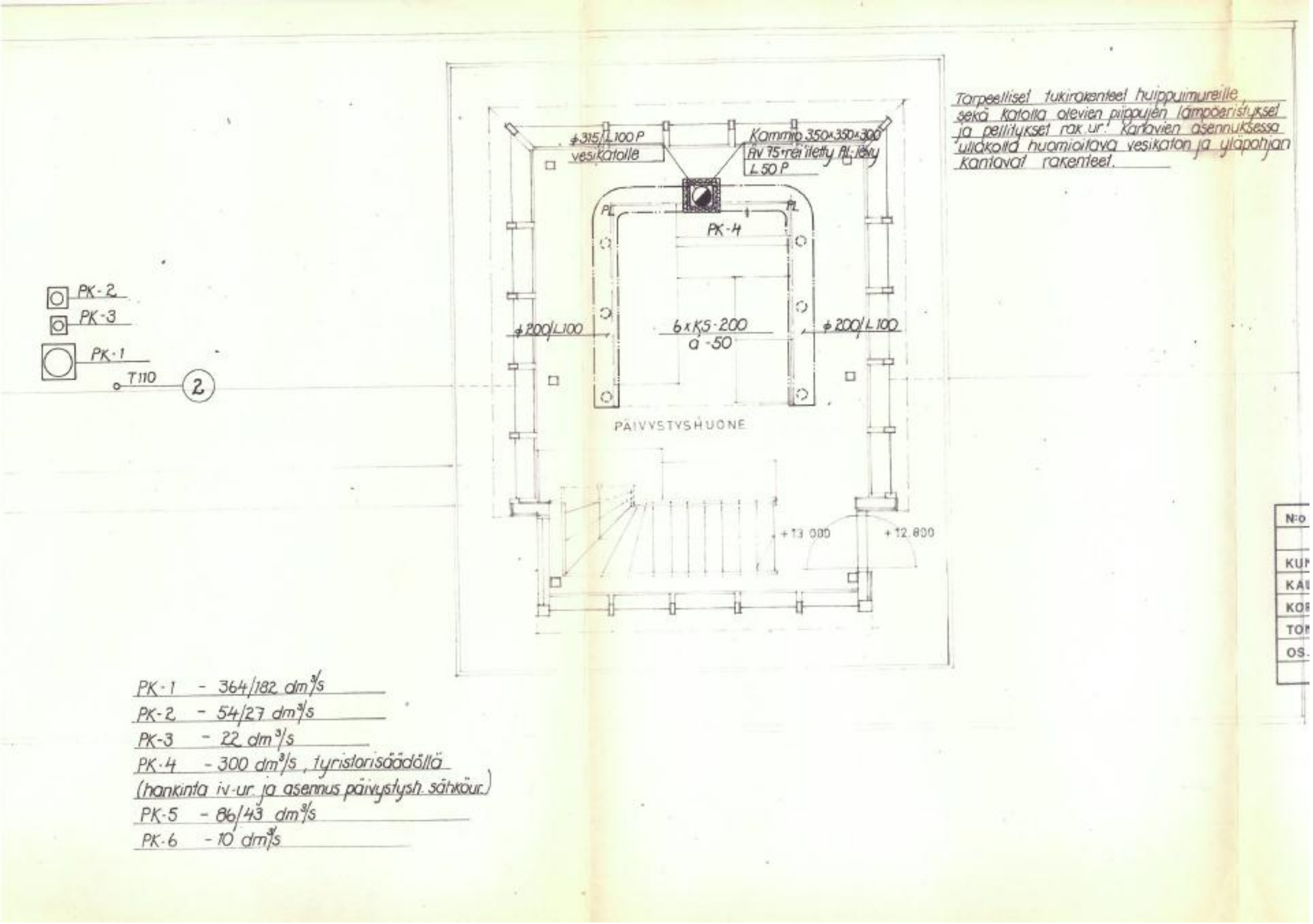




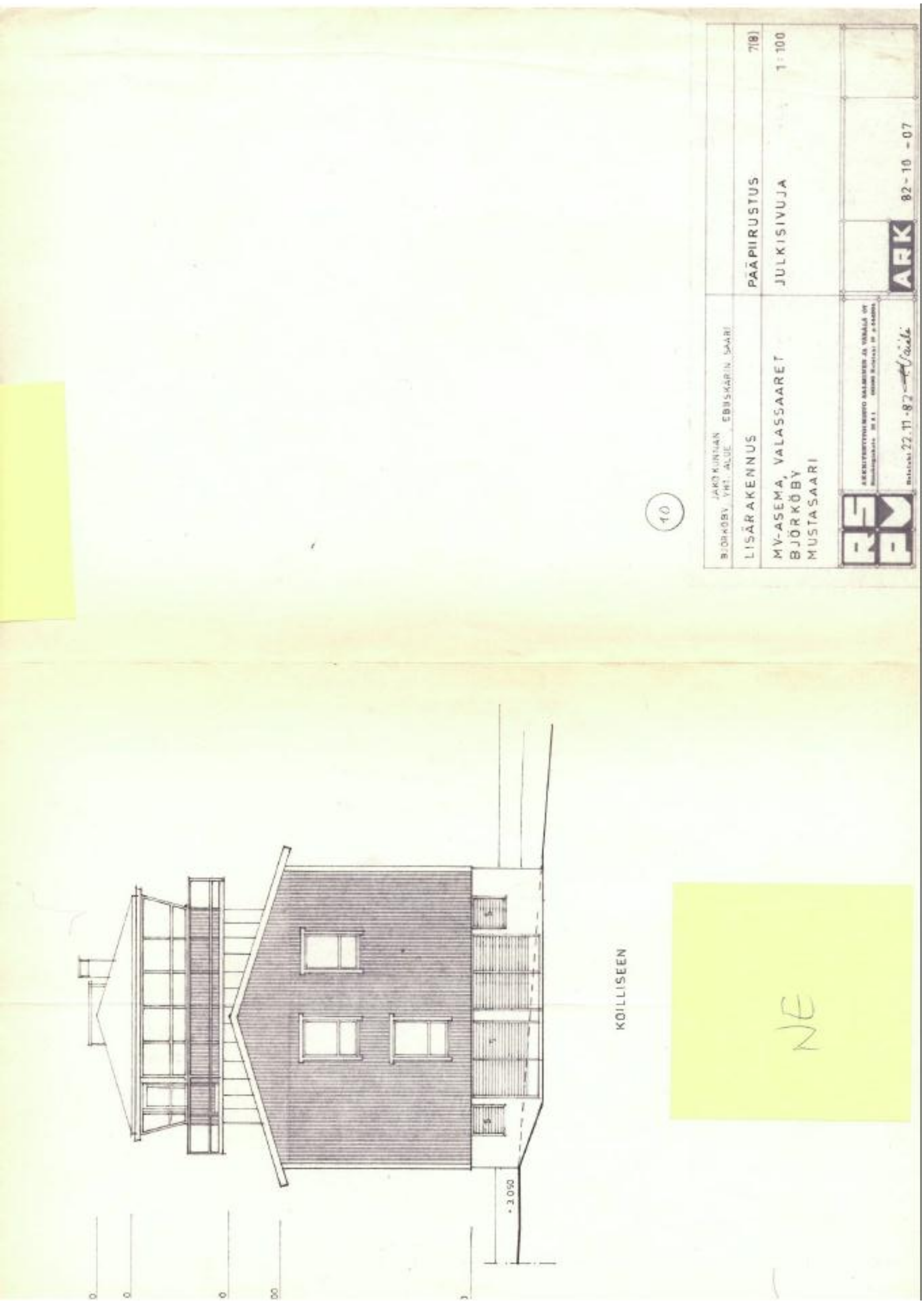
RAKENTEET

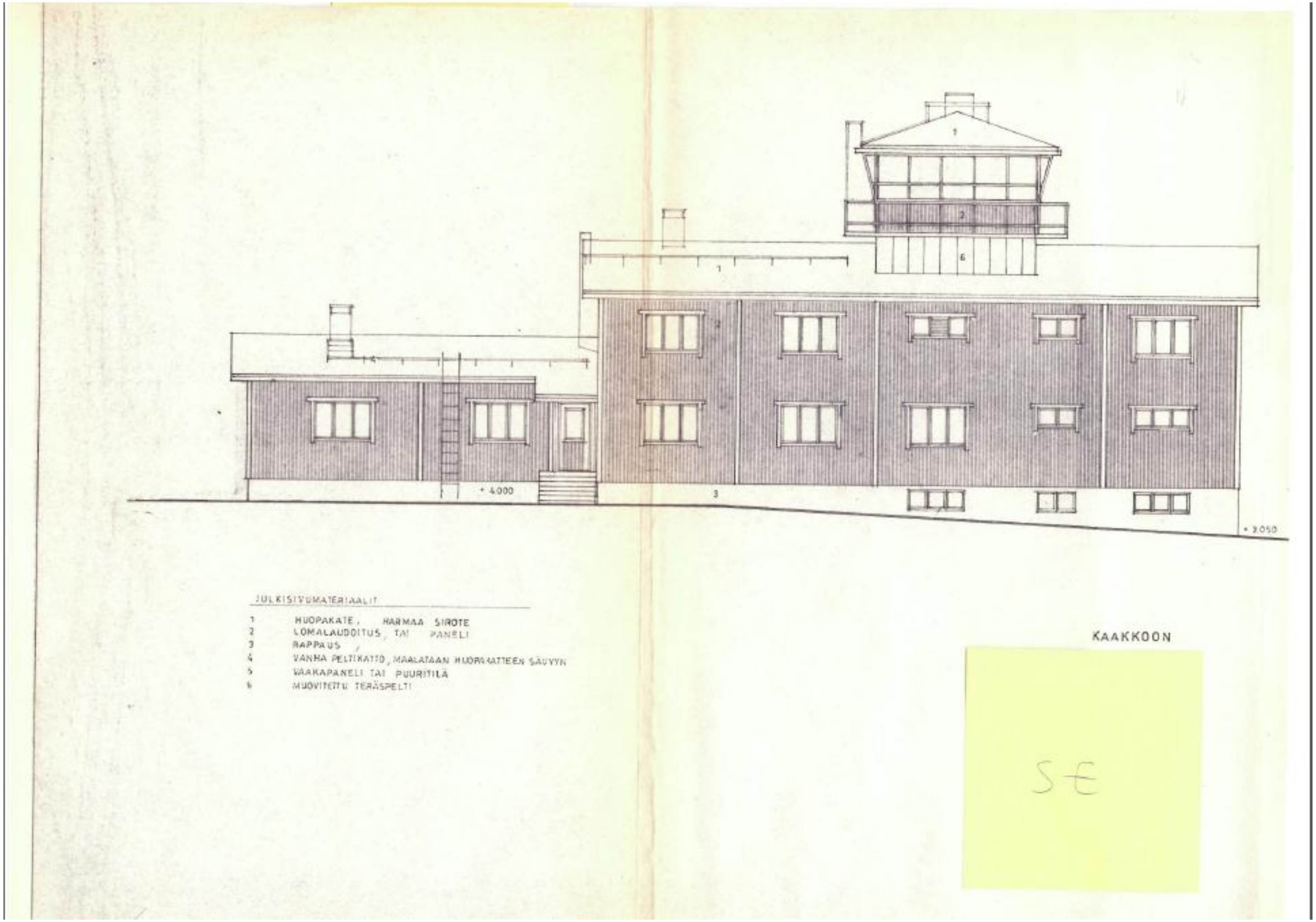
AP 1		pintakäsittely
	100	teräsbet.
	50	styrox R, 1m ulkos. 50 +50
	200	tiivistetty sora
VP 1		pintamateriaali
	30	pitabetoni
	170	teräsbetonilaatta
	50	min. villa
VP 3		pintamateriaali
	22	pontattu lastulevy
		puukannattajat, k 400, min.villa 100
	19	rimoitus k 400
	13	gyproc-levy,
		pintakäsittely
YP 1		huopakate lk D
	23	raakapontti 23 x 95
		tehdasvalm. kattoristikot k 900
		tuuletettu ullakkotila
	30	tuulensuojalevy
	250	min.villa, 2 x 125
	0,2	muovikelmu
	45	rimoitus k 400
	13	gyproc-levy
		pintakäsittely
US 1		pintakäsittely
		sementtilaastirappaus
	300	kevytsoraharkkomuuraus
	45	koolaus, min.villa
	0,2	muovikelmu
	10	luja-levy, uralistakiinnitys
US 3	44	pystylomalaudoitus, 22 + 22
	22	rimoitus
	12	bituliitti
	50	vaakasoirot, min.villa
	120	runko 120 x 50 k 600, min villa
	0,2	muovikelmu
	13	gyproc-levy
		pintakäsittely
VS 1		pintakäsittely
	13	gyproc-levy
	90	runko 90 x 45 k 600, min.villa 70
	13	gyproc-levy
		pintakäsittely
VS 2		pintakäsittely
	130	NKH muuraus
		pintakäsittely
VS 3		pintakäsittely
	150	teräsbetoni
		pintakäsittely

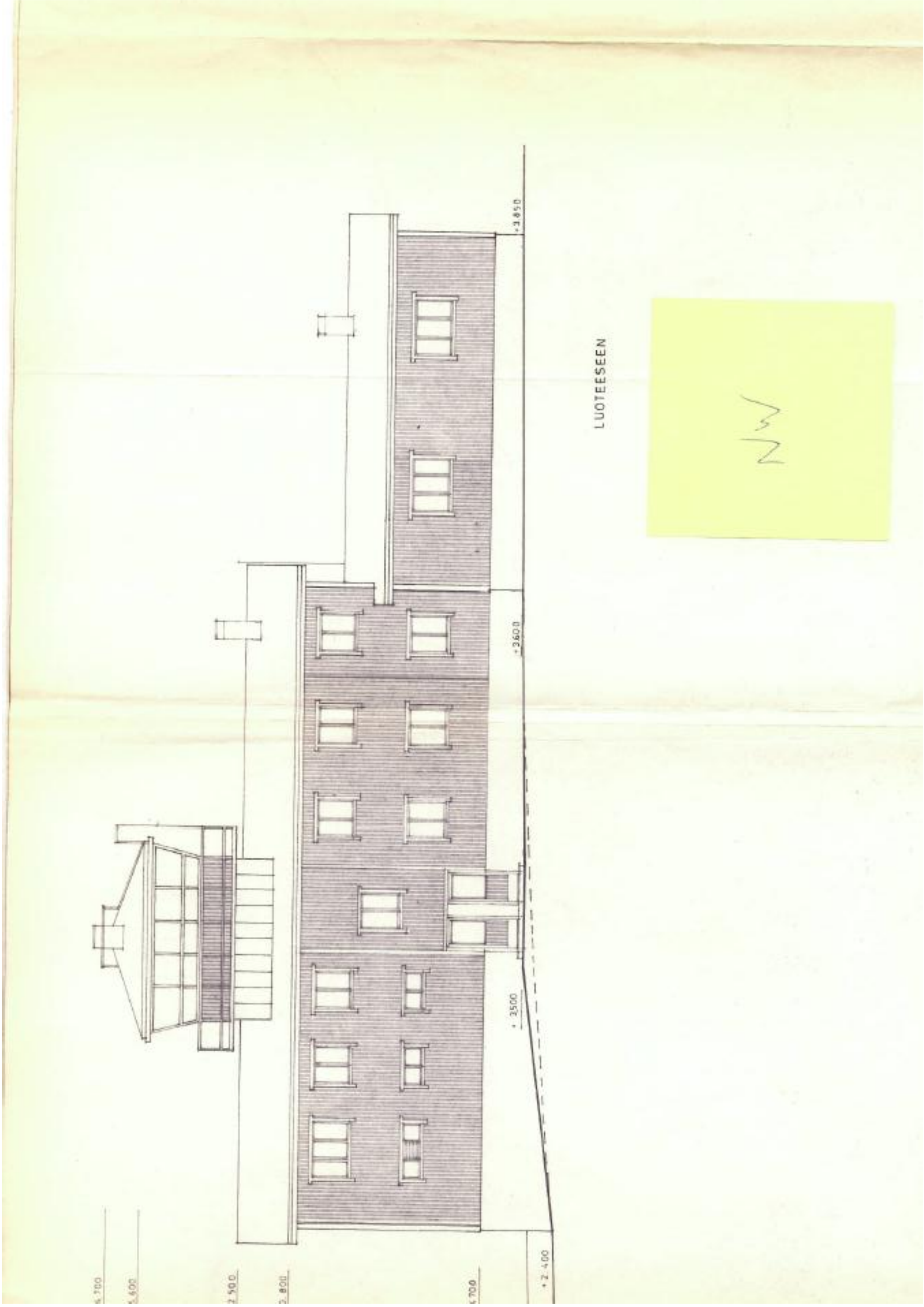
2.3.1 Blueprint Pipe types and Airflow



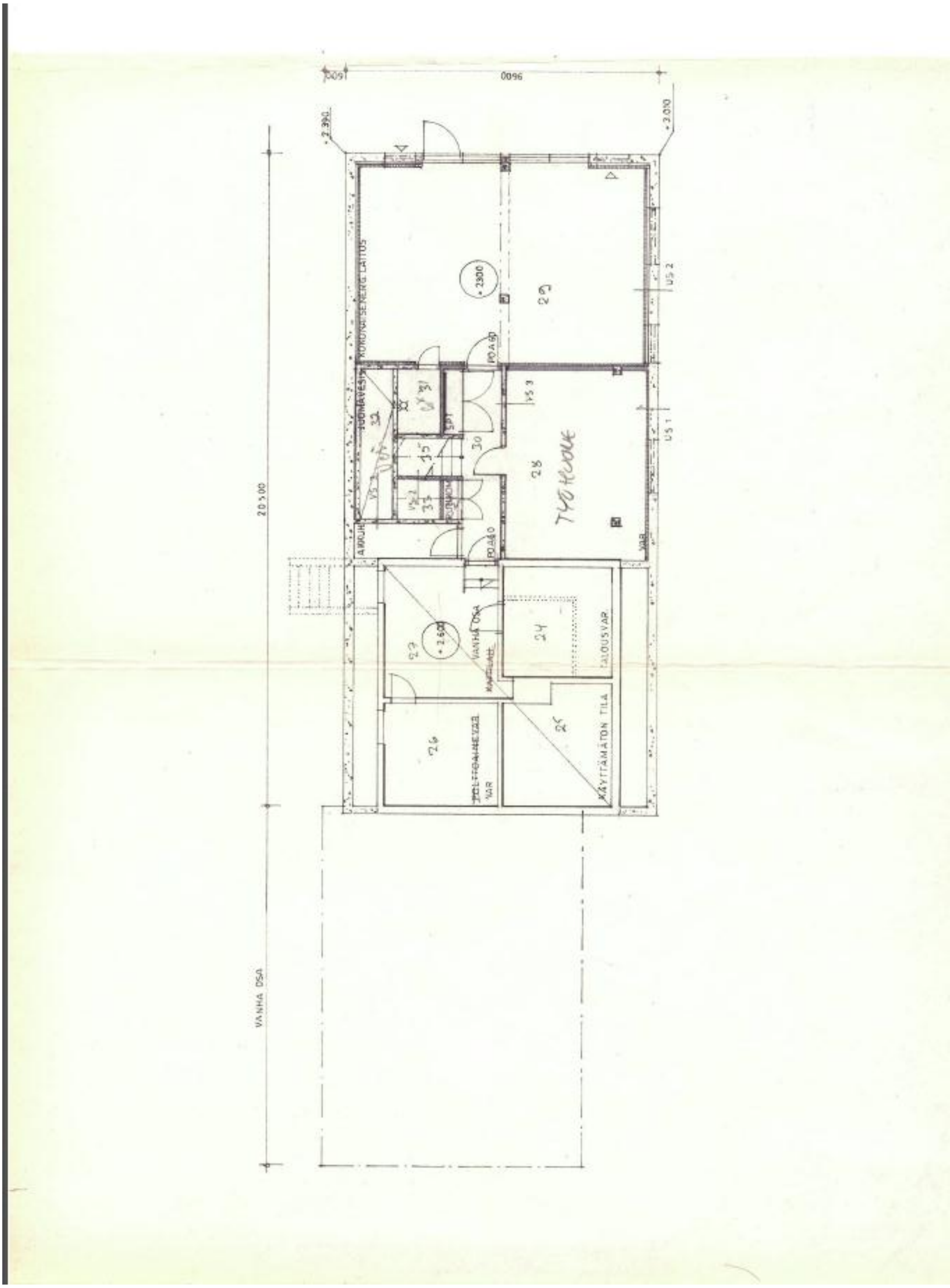
2.3.3 Blueprint Building Valsorärna




1
2
6
1
2
+ 4000
3
+ 3.050
JULKISIVUMATERIAALIT
1 HUOPAKATE, HARMAA SIROTE
2 LOMALAUDOITUS, TAI PANELI
3 RAPPAUS
4 VANHA PELTIKATTO, MAALATAAN HUOPAKATTEEN SÄVYYN
5 VAAKAPANELI TAI PUURITILÄ
6 MUOVITETTU TERÄSPELTI
KAAKKOON
SE


LUOTEESEEN
NW
+3.850
+3.600
+3.500
+2.400
6.700
5.600
2.500
3.800
4.700

2.3.4 Blueprint Basement



⑤

BJÖRKÖBY, JAKOKUNNAN YHT. ALUE, EBBSKÄRIN SAARI

LISÄRAKENNUS

MV-ASEMA, VALASSAARET
BJÖRKÖBY
MUSTASAARI

PÄÄPIIRUSTUS 2(8)

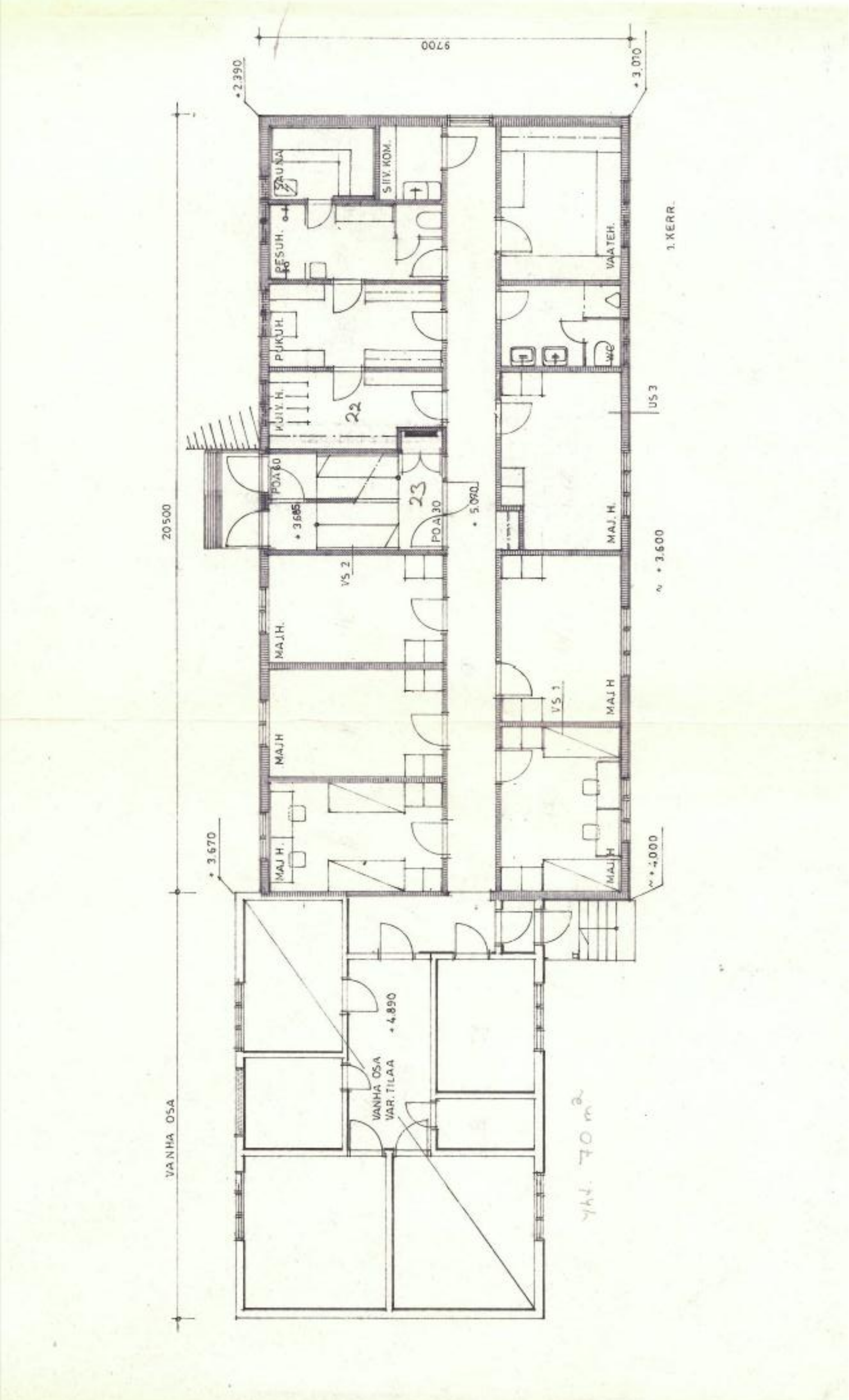
POHJAPIIRROS 1:100
KELLARI

RS
PV

22.11-82

ARK 82-103-02

2.3.5 Blueprint First Floor



6

KORKEUDET MERIVEDEN 0-PISTEESTÄ

JAKOKUNNAN
BJÖRKÖBY, YHTEINEN ALUE, EBBSKÄRIN SAARI

LISÄRAKENNUS

PÄÄPIIRUSTUS 3(8)

MV-ASEMA, VALASSAARET
BJÖRKÖBY
MUSTASAARI

POHJAPIIRROS 1 : 100
1. KERROS

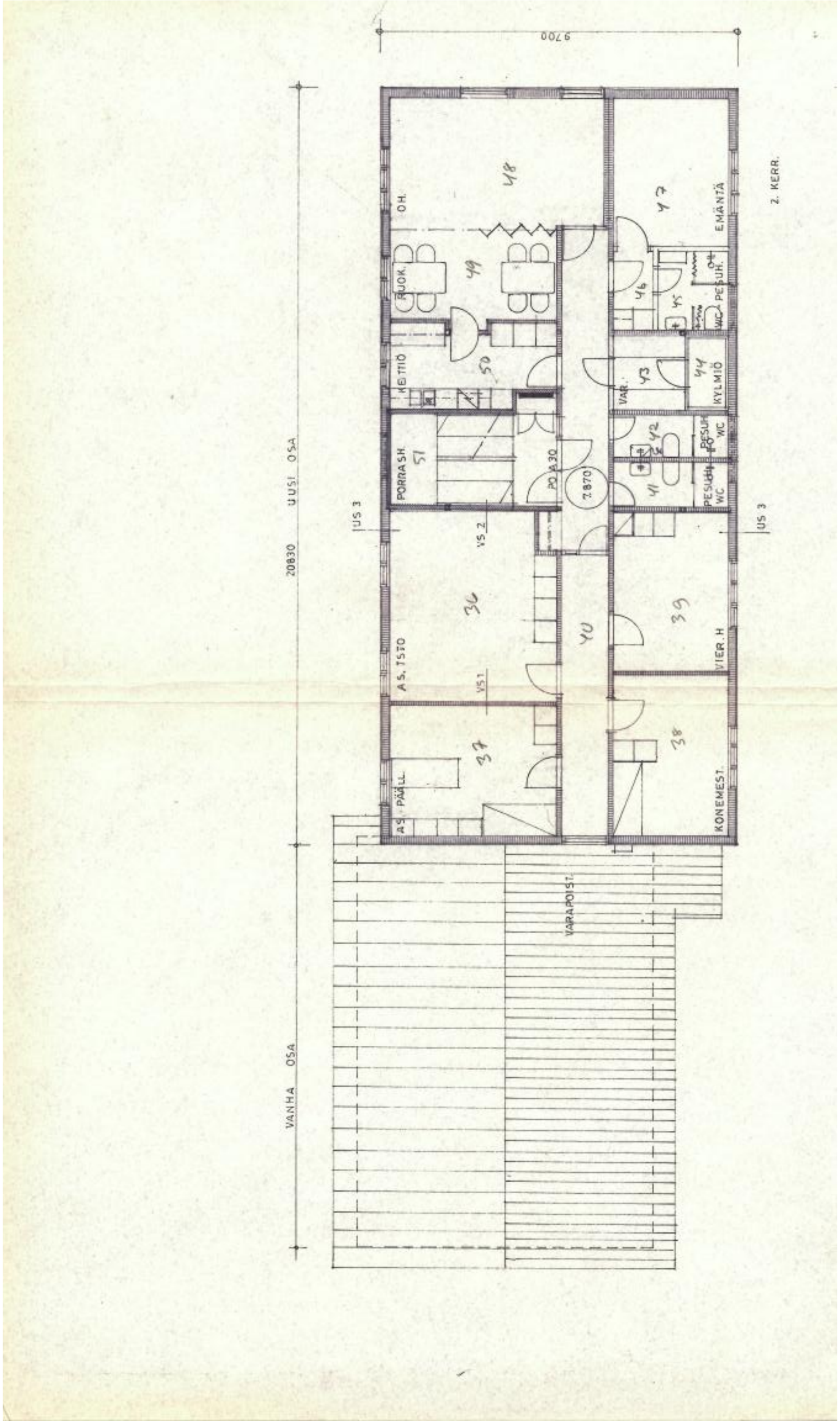
RS
PV

ARKKITEHTITOIMISTO SALMINEN JA VÄRÄLÄ OY

Helsinki 22.11-82

ARK 82-103-03

2.3.6 Blueprint Second Floor



⑦

JAKOKUNNAN
BJÖRKÖBY, YHT. ALUE , EBBSKÄRIN SAARI

LISÄRAKENNUS

MV-ASEMA, VALASSAARET
BJÖRKÖBY
MUSTASAARI

PÄÄPIIRUSTUS 4(8)

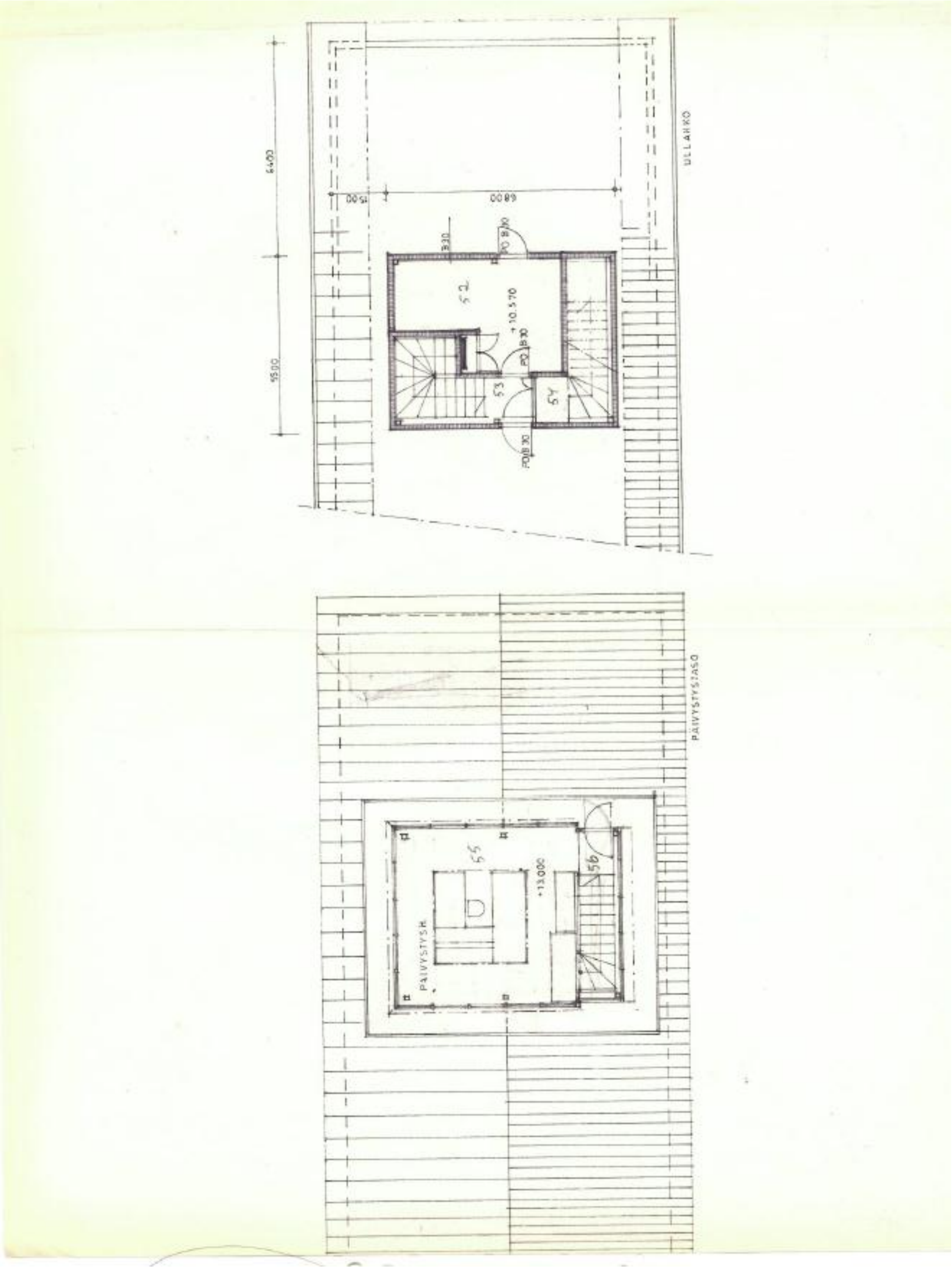
POHJAPIIRROS 1:100
2. KERROS

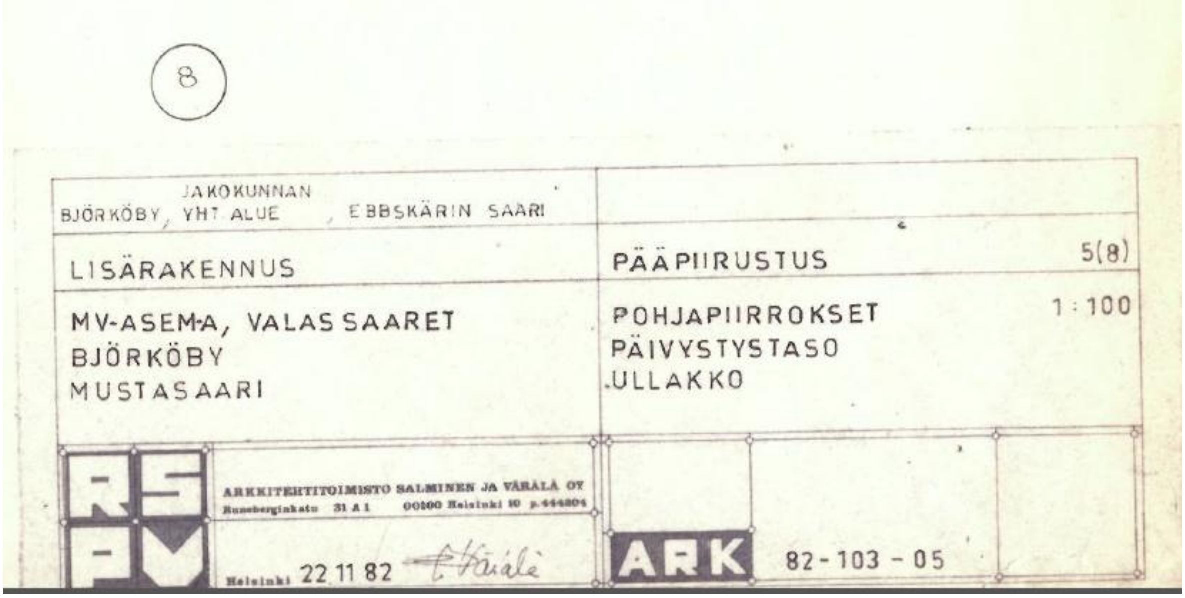
ARKKITEHTITOIMISTO SALMINEN JA VÄRÄLÄ OY

22 11 82

ARK 82-103-04

2.3.7 Blueprint Guard Tower





⑧

JAKOKUNNAN
BJÖRKÖBY, YHT ALUE, EBBSKÄRIN SAARI

LISÄRAKENNUS

MV-ASEMA, VALAS SAARET
BJÖRKÖBY
MUSTASAARI

PÄÄPIIRUSTUS 5(8)

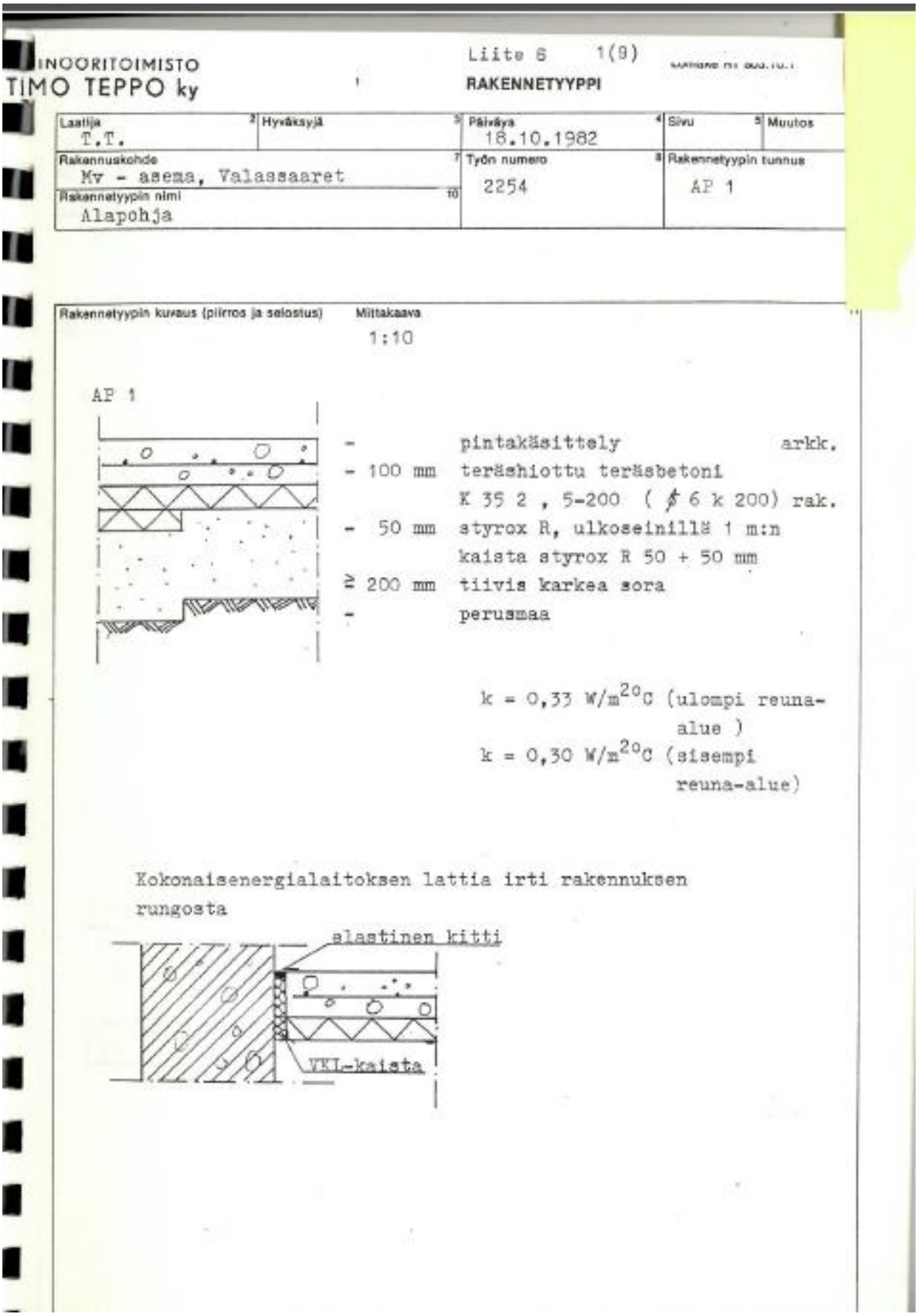
POHJAPIIRROKSET 1:100
PÄIVYSTYSTASO
ULLAKKO

ARKKITEHTITOIMISTO SALMINEN JA VÄRÄLÄ OY
Runeberginkatu 31 A 1 00100 Helsinki 10 p.444804

Helsinki 22 11 82 Värälä

ARK 82-103-05

2.3.8 Blueprint Construction Details 1



INOORITOIMISTO
TIMO TEPPO ky

Liite 6 1(9)
RAKENNETYYPPI

Laatija: T.T.
Hyväksyjä:
Päiväys: 18.10.1982
Sivu:
Muutos:
Rakennuskohde: Mv - asema, Valassaaret
Työn numero: 2254
Rakennetyypin tunnus: AP 1
Rakennetyypin nimi: Alapohja

Rakennetyypin kuvaus (piirros ja selostus)
Mittakaava 1:10

AP 1

-	pintakäsittely	arkk.
- 100 mm	teräshiottu teräsbetoni K 35 2 , 5-200 (∅ 6 k 200)	rak.
- 50 mm	styrox R, ulkoseinillä 1 m:n kaista styrox R 50 + 50 mm	
≥ 200 mm	tiivis karkea sora	
-	perusmaa	

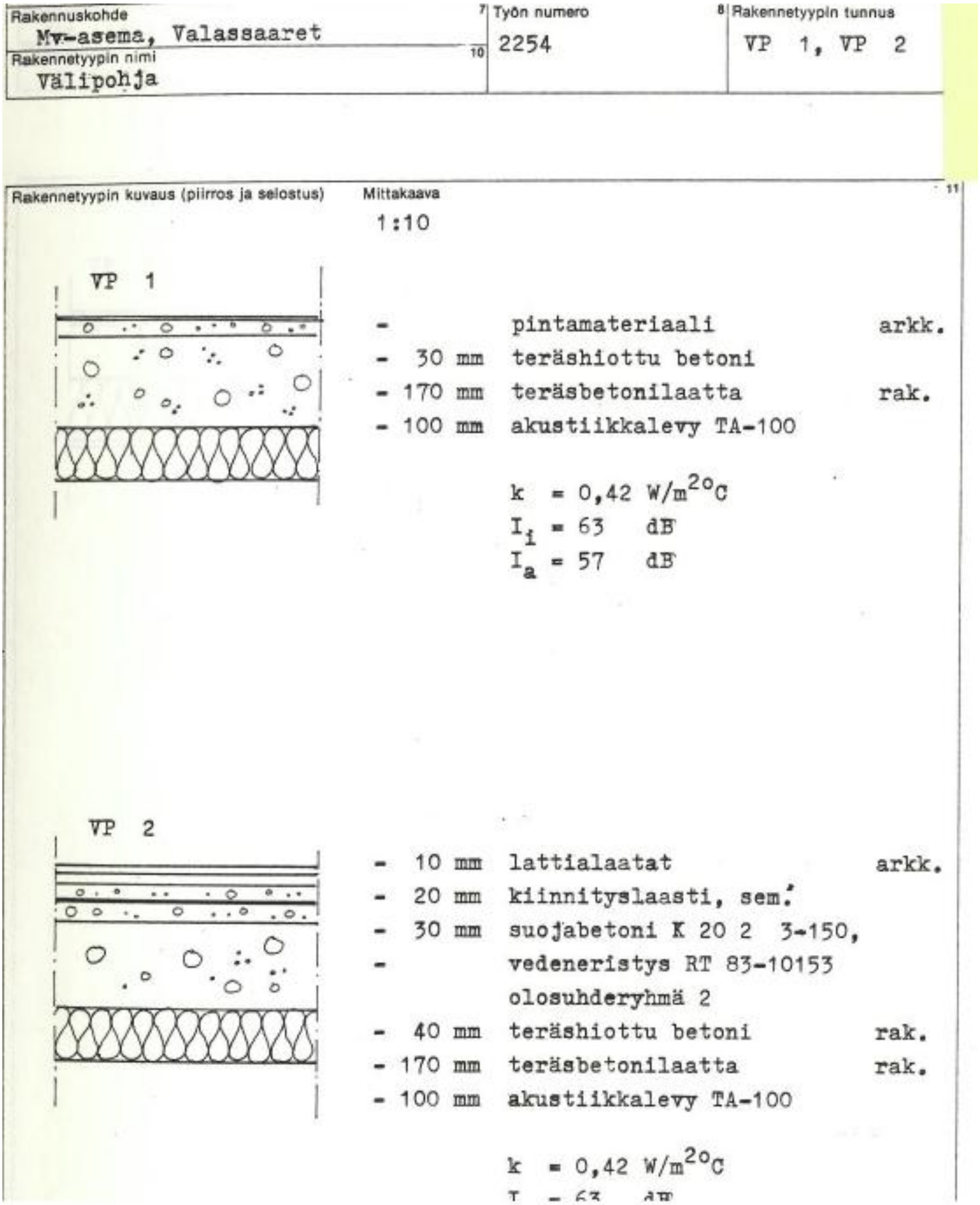
k = 0,33 W/m²°C (ulompi reuna-alue)
k = 0,30 W/m²°C (sisempi reuna-alue)

Kokonaisenergialaitoksen lattia irti rakennuksen rungosta

elastinen kitti

VKL-kaista

2.3.9 Blueprint Construction Details 2



Rakennuskohde
Mv-asema, Valassaaret

Rakennetyypin nimi
Välipohja

7 Työn numero
2254

8 Rakennetyypin tunnus
VP 1, VP 2

Rakennetyypin kuvaus (piirros ja selostus)

Mittakaava
1:10

11

VP 1

- pintamateriaali arkk.
- 30 mm teräshiottu betoni
- 170 mm teräsbetonilaatta rak.
- 100 mm akustiikkalevy TA-100

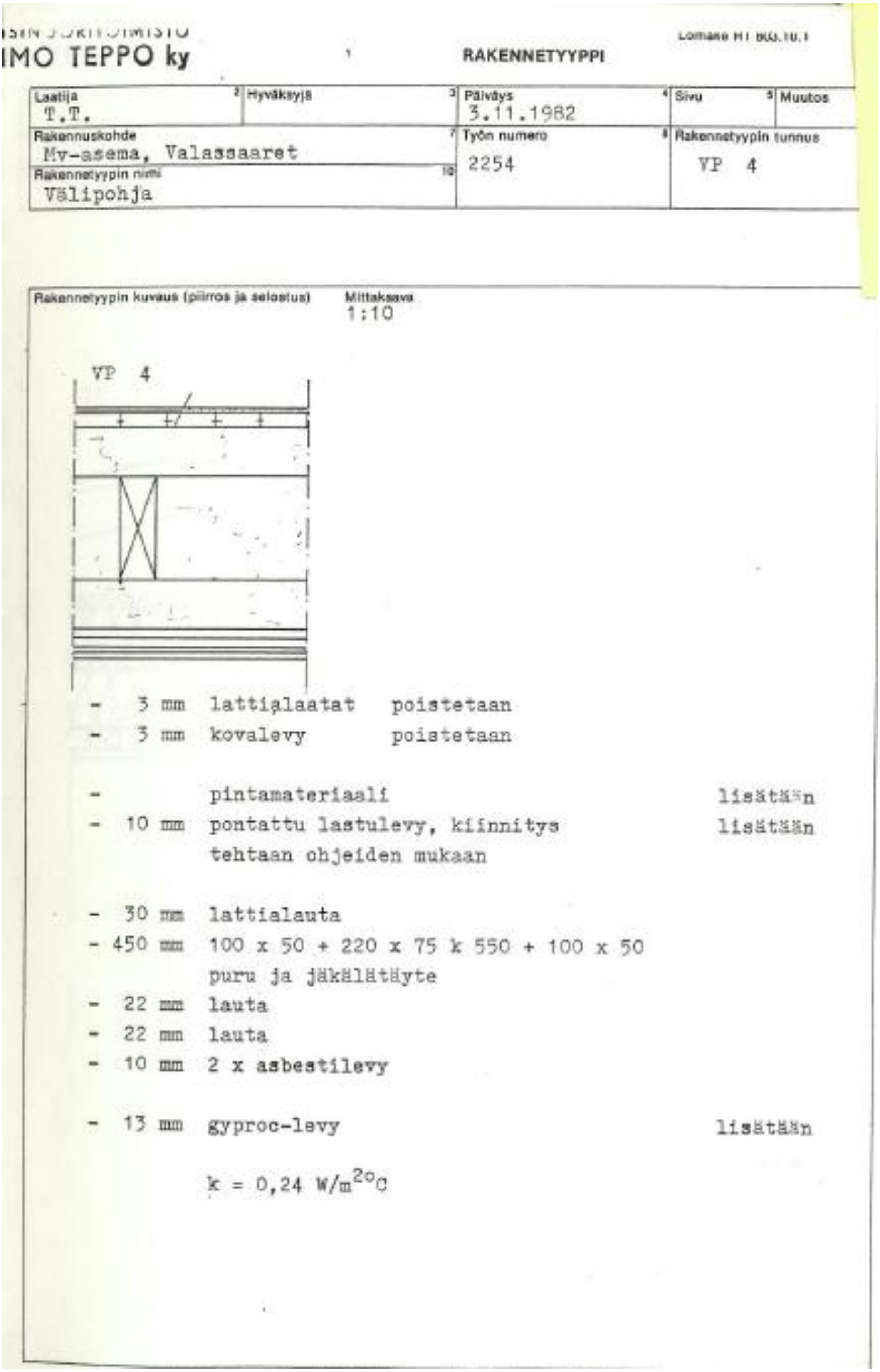
k = 0,42 $W/m^2 {}^oC$
I_i = 63 dB
I_a = 57 dB

VP 2

- 10 mm lattialaatat arkk.
- 20 mm kiinnityslaasti, sem.
- 30 mm suojabetoni K 20 2 3-150,
- vedeneristys RT 83-10153 olosuhderyhmä 2
- 40 mm teräshiottu betoni rak.
- 170 mm teräsbetonilaatta rak.
- 100 mm akustiikkalevy TA-100

k = 0,42 $W/m^2 {}^oC$
I = 63 dB

2.3.10 Blueprint Construction Details 3



IMO TEPPO ky

RAKENNETYYPPI

Laatija T.T.	Hyväksyjä	Päiväys 3.11.1982	Sivu	Muutos
Rakennuskohde Mv-asema, Valassaaret		Työn numero 2254	Rakennetyypin tunnus VP 4	
Rakennetyypin nimi Välipohja				

Rakennetyypin kuvaus (piirros ja selostus)

Mittakaava
1:10

VP 4

- 3 mm lattialaatat poistetaan
- 3 mm kovalevy poistetaan

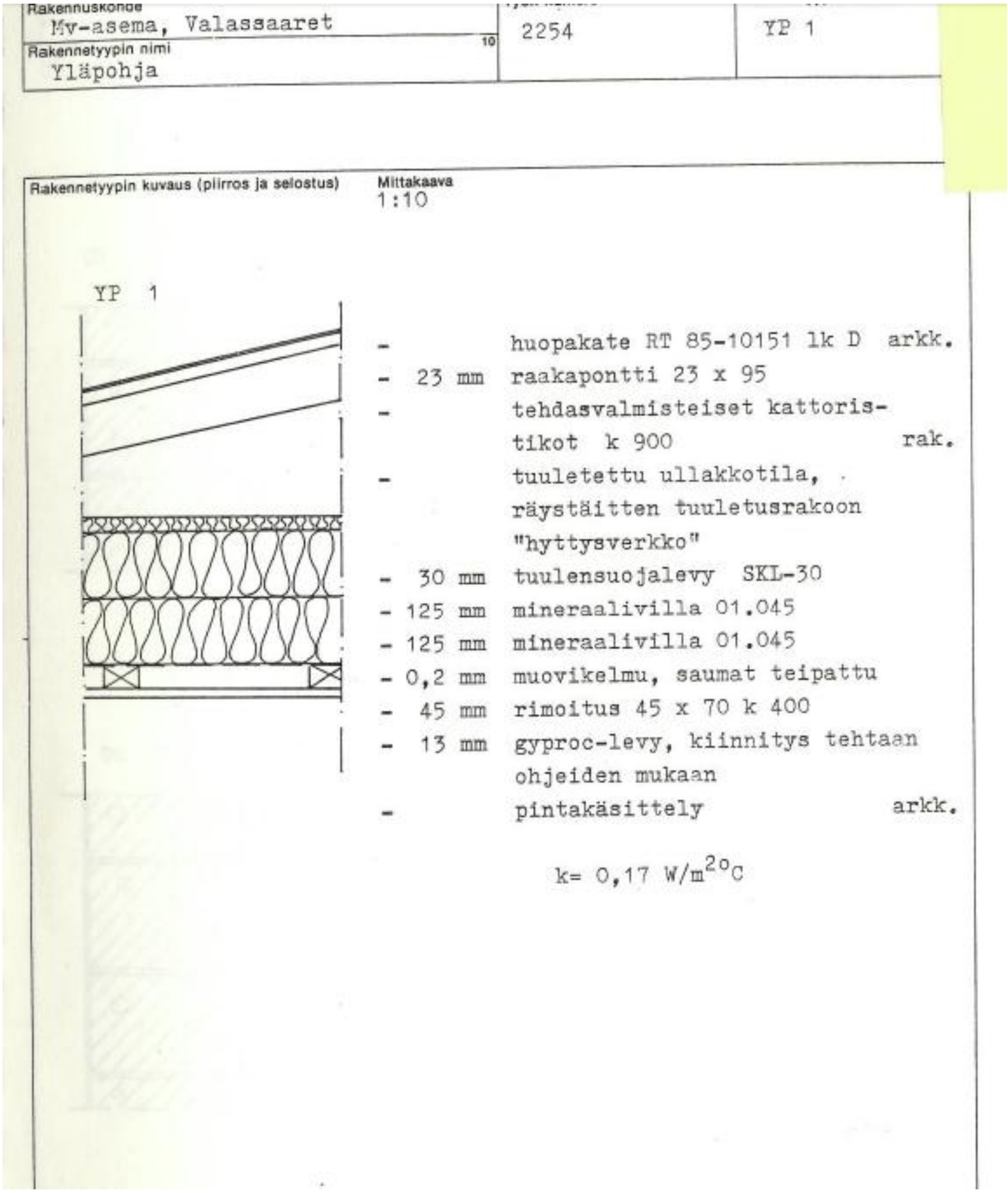
- pintamateriaali lisätään
- 10 mm pontattu lastulevy, kiinnitys tehtaan ohjeiden mukaan lisätään

- 30 mm lattialauta
- 450 mm 100 x 50 + 220 x 75 k 550 + 100 x 50 puru ja jäkälätäyte
- 22 mm lauta
- 22 mm lauta
- 10 mm 2 x asbestilevy

- 13 mm gyproc-levy lisätään

$k = 0{,}24\ W/m^{2}{}^{o}C$

2.3.11 Blueprint Construction Details 4



Rakennuskohde
Mv-asema, Valassaaret
Rakennetyypin nimi
Yläpohja

2254

YP 1

Rakennetyypin kuvaus (piirros ja selostus)

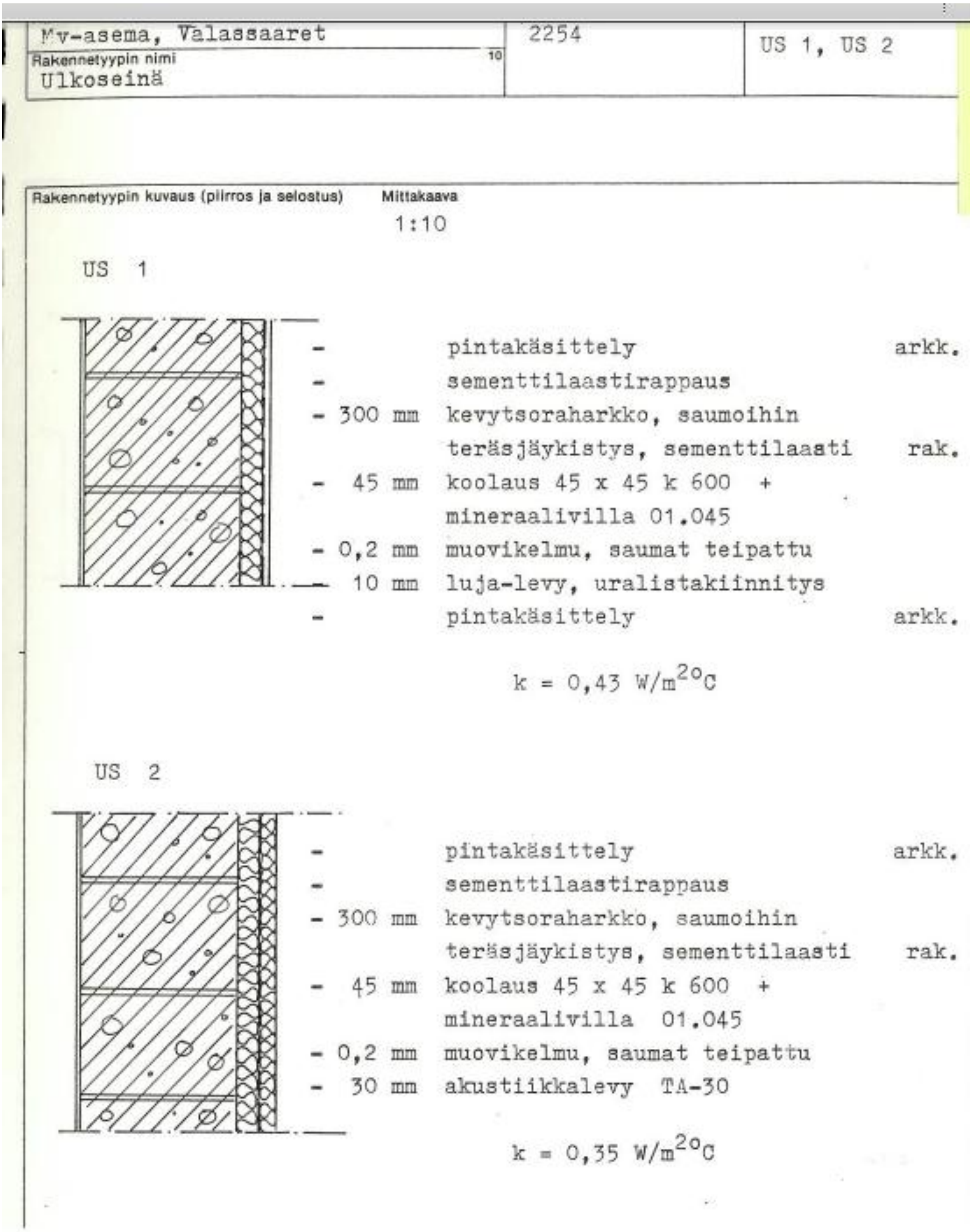
Mittakaava
1:10

YP 1

- huopakate RT 85-10151 lk D arkk.
- 23 mm raakapontti 23 x 95
- tehdasvalmisteiset kattoristikot k 900 rak.
- tuuletettu ullakkotila, räystäitten tuuletusrakoon "hyttysverkko"
- 30 mm tuulensuojalevy SKL-30
- 125 mm mineraalivilla 01.045
- 125 mm mineraalivilla 01.045
- 0,2 mm muovikelmu, saumat teipattu
- 45 mm rimoitus 45 x 70 k 400
- 13 mm gyproc-levy, kiinnitys tehtaan ohjeiden mukaan
- pintakäsittely arkk.

k= 0,17 $W/m^2 {}^oC$

2.3.12 Blueprint Constructions Details 5



Mv-asema, Valassaaret

10

2254

US 1, US 2

Rakennetyypin nimi

Ulkoseinä

Rakennetyypin kuvaus (piirros ja selostus)

Mittakaava

1:10

US 1

-		pintakäsittely	arkk.
-		sementtilaastirappaus	
-	300 mm	kevytsoraharkko, saumoihin teräsjäykistys, sementtilaasti	rak.
-	45 mm	koolaus 45 x 45 k 600 + mineraalivilla 01.045	
-	0,2 mm	muovikelmu, saumat teipattu	
-	10 mm	luja-levy, uralistakiinnitys	
-		pintakäsittely	arkk.

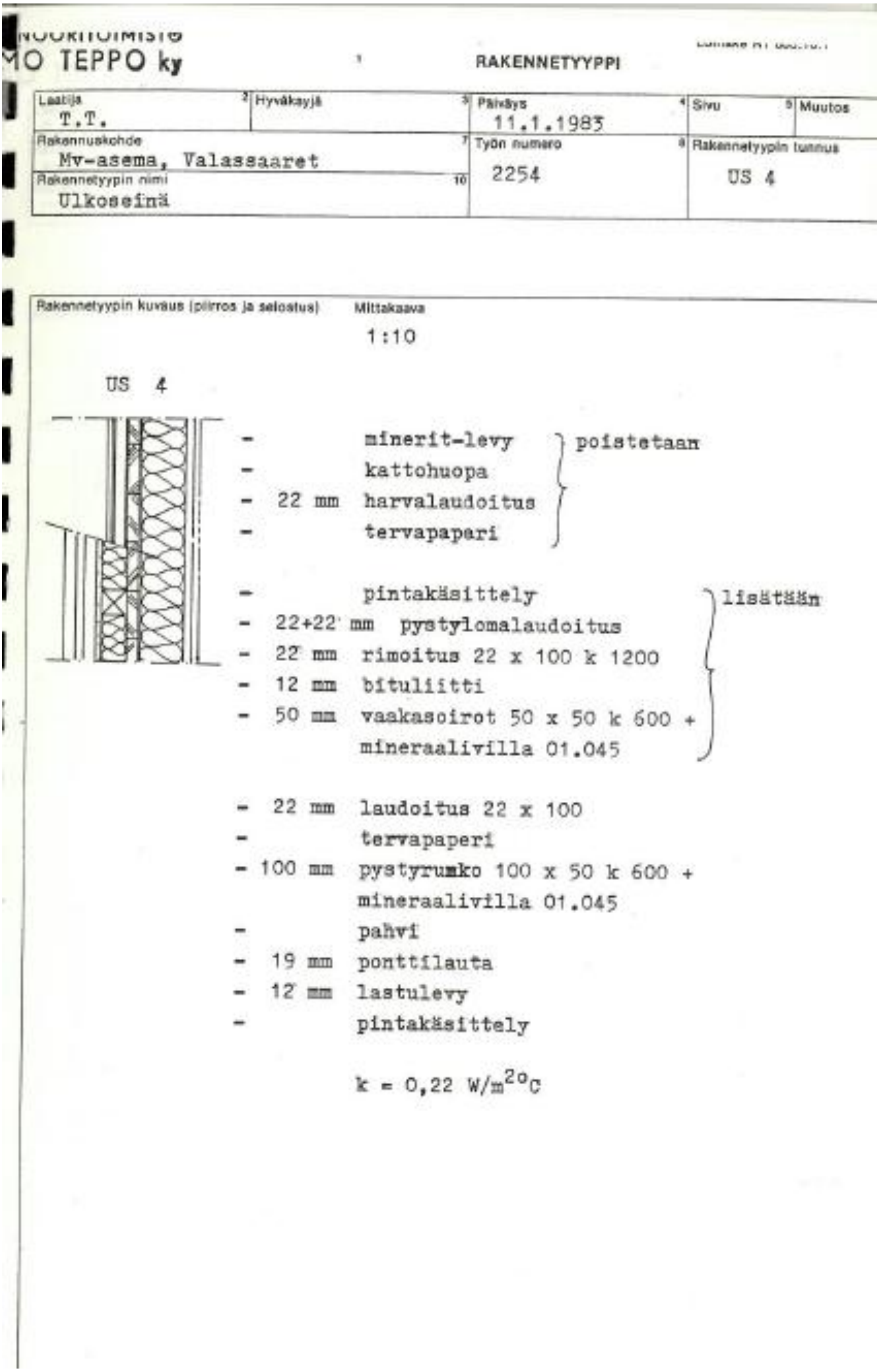
$k = 0{,}43\ W/m^{2o}C$

US 2

-		pintakäsittely	arkk.
-		sementtilaastirappaus	
-	300 mm	kevytsoraharkko, saumoihin teräsjäykistys, sementtilaasti	rak.
-	45 mm	koolaus 45 x 45 k 600 + mineraalivilla 01.045	
-	0,2 mm	muovikelmu, saumat teipattu	
-	30 mm	akustiikkalevy TA-30	

$k = 0{,}35\ W/m^{2o}C$

2.3.13 Blueprint Construction Details 6



MO TEPPO ky

1 RAKENNETYYPPI

Laatija: T.T.
2 Hyväksyjä:
3 Päiväys: 11.1.1983
4 Sivu:
5 Muutos:
Rakennuskohde: Mv-asema, Valassaaret
7 Työn numero: 2254
8 Rakennetyypin tunnus: US 4
Rakennetyypin nimi: Ulkoseinä
10

Rakennetyypin kuvaus (piirros ja selostus)

Mittakaava 1:10

US 4

- minerit-levy
- kattohuopa
- 22 mm harvalaudoitus
- tervapaperi

poistetaan

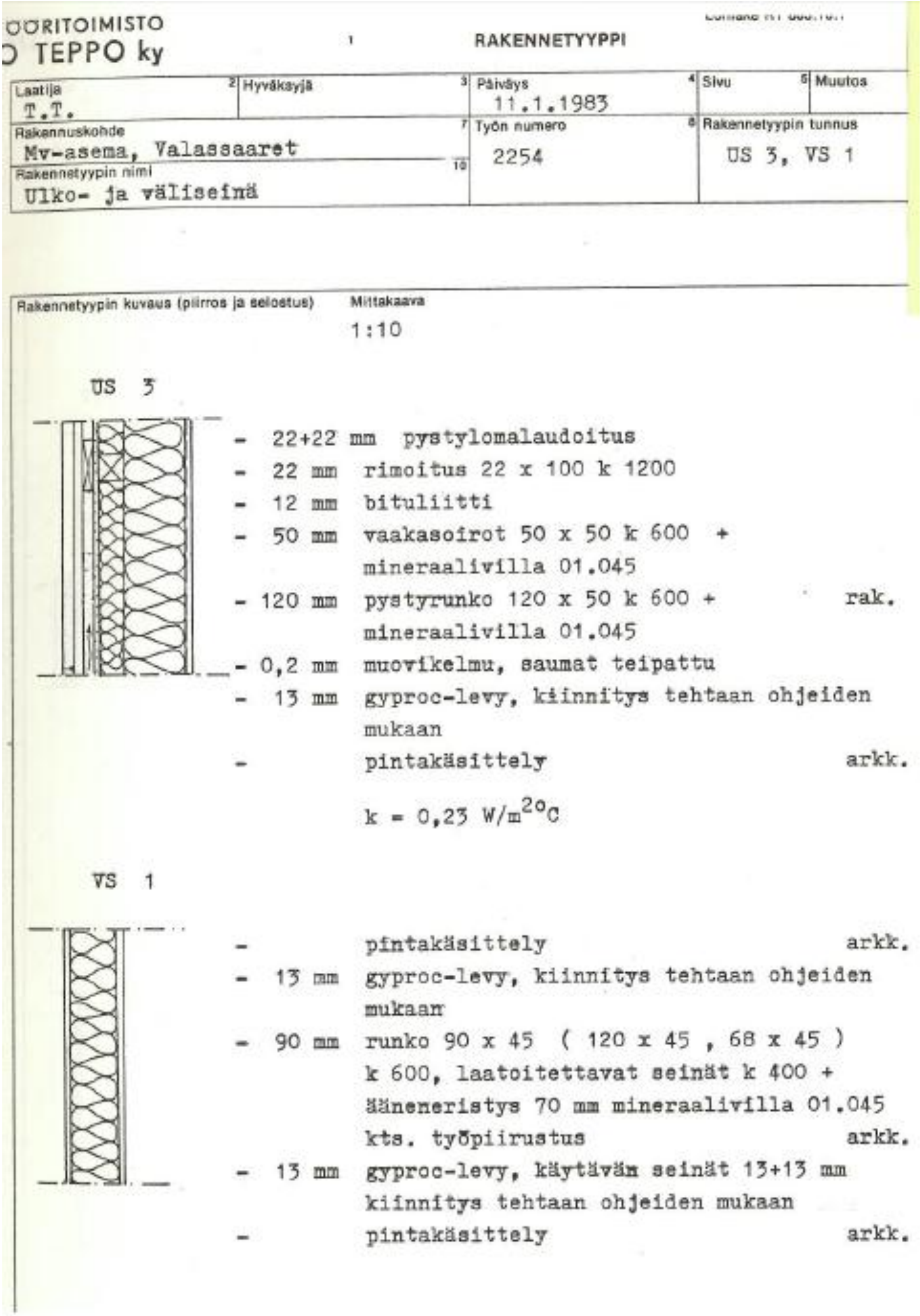
- pintakäsittely
- 22+22 mm pystylomalaudoitus
- 22 mm rimoitus 22 x 100 k 1200
- 12 mm bituliitti
- 50 mm vaakasoirot 50 x 50 k 600 + mineraalivilla 01.045

lisätään

- 22 mm laudoitus 22 x 100
- tervapaperi
- 100 mm pystyrunko 100 x 50 k 600 + mineraalivilla 01.045
- pahvi
- 19 mm ponttilauta
- 12 mm lastulevy
- pintakäsittely

$k = 0{,}22\ W/m^{2\circ}C$

2.3.14 Blueprint Construction Details 7



OORITOIMISTO
TEPPO ky

1 RAKENNETYYPPI

1 Laatija
T.T.

2 Hyväksyjä

3 Päiväys
11.1.1983

4 Sivu

5 Muutos

Rakennuskohde
Mv-asema, Valassaaret

7 Työn numero
2254

8 Rakennetyypin tunnus
US 3, VS 1

Rakennetyypin nimi
Ulko- ja väliseinä

10

Rakennetyypin kuvaus (piirros ja selostus)

Miittakaava
1:10

US 3

- 22+22 mm pystylomalaudoitus
- 22 mm rimoitus 22 x 100 k 1200
- 12 mm bituliitti
- 50 mm vaakasoirot 50 x 50 k 600 + mineraalivilla 01.045
- 120 mm pystyrunko 120 x 50 k 600 + mineraalivilla 01.045 rak.
- 0,2 mm muovikelmu, saumat teipattu
- 13 mm gyproc-levy, kiinnitys tehtaan ohjeiden mukaan
- pintakäsittely arkk.

$k = 0,23\ W/m^2{}^oC$

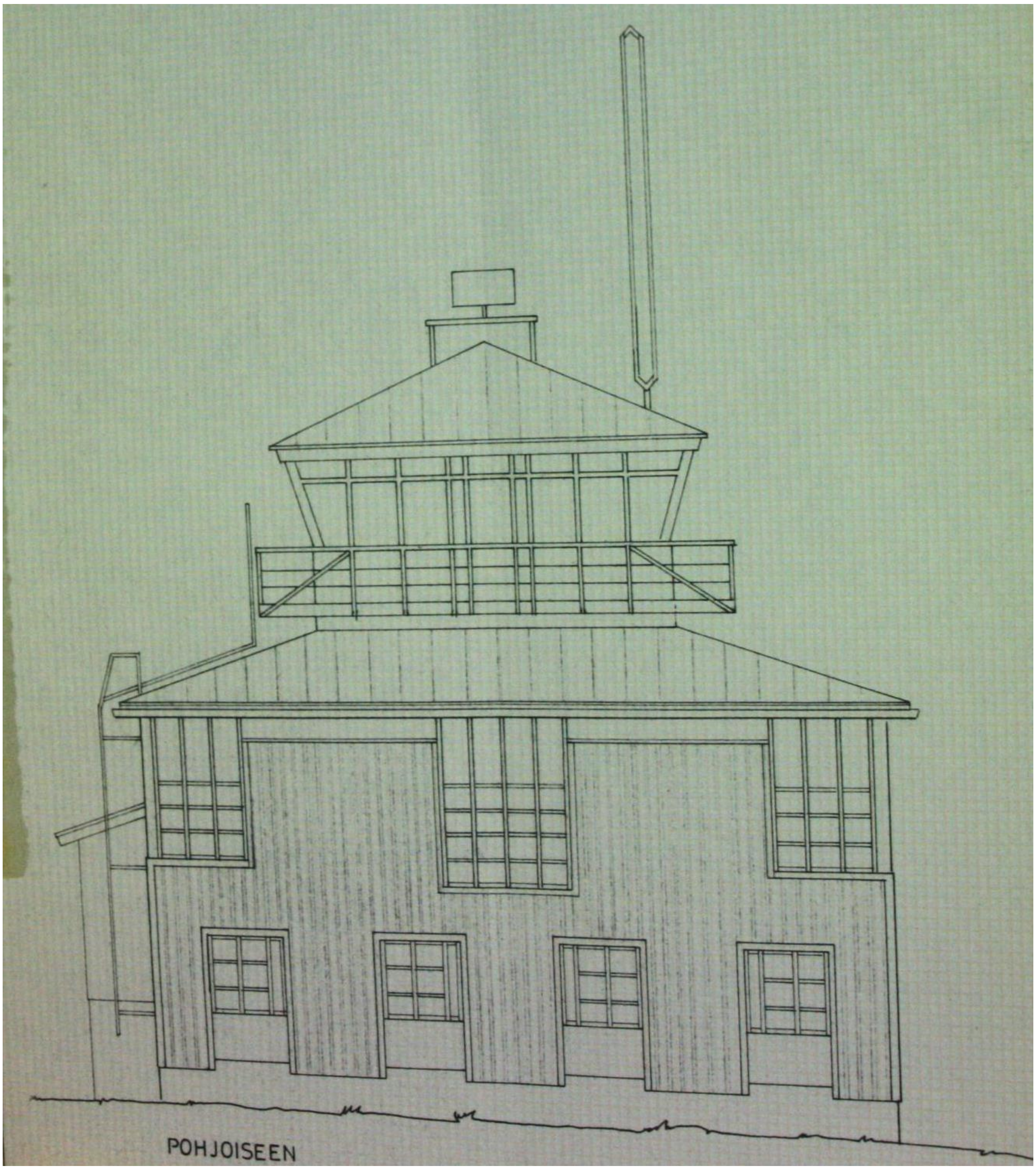
VS 1

- pintakäsittely arkk.
- 13 mm gyproc-levy, kiinnitys tehtaan ohjeiden mukaan
- 90 mm runko 90 x 45 (120 x 45 , 68 x 45) k 600, laatoitettavat seinät k 400 + ääneneristys 70 mm mineraalivilla 01.045 kts. työpiirustus arkk.
- 13 mm gyproc-levy, käytävän seinät 13+13 mm kiinnitys tehtaan ohjeiden mukaan
- pintakäsittely arkk.

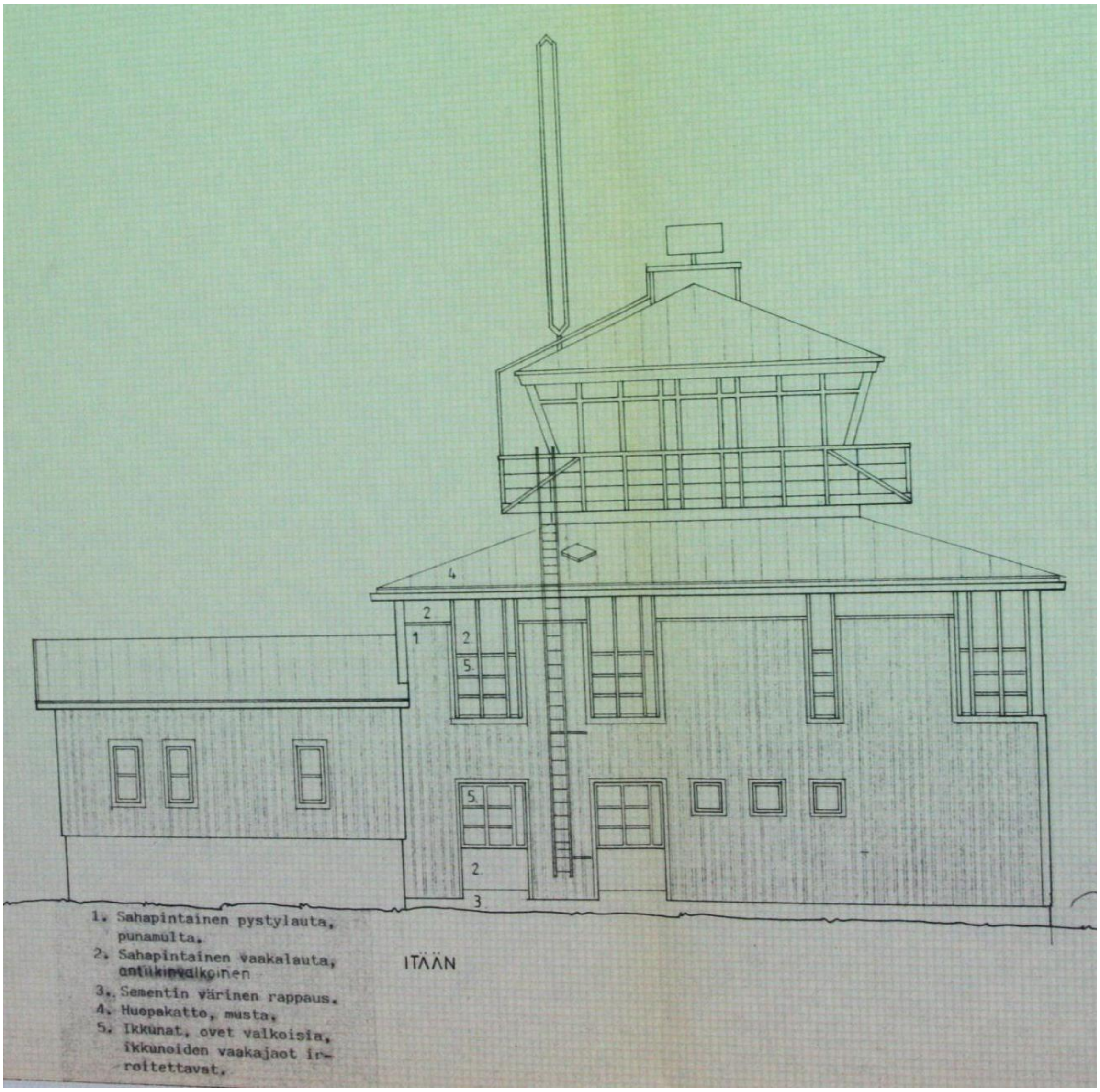
SOURCE: (Senate Fastigheter, Vaasan yliopisto, Vaasa, Finland.)

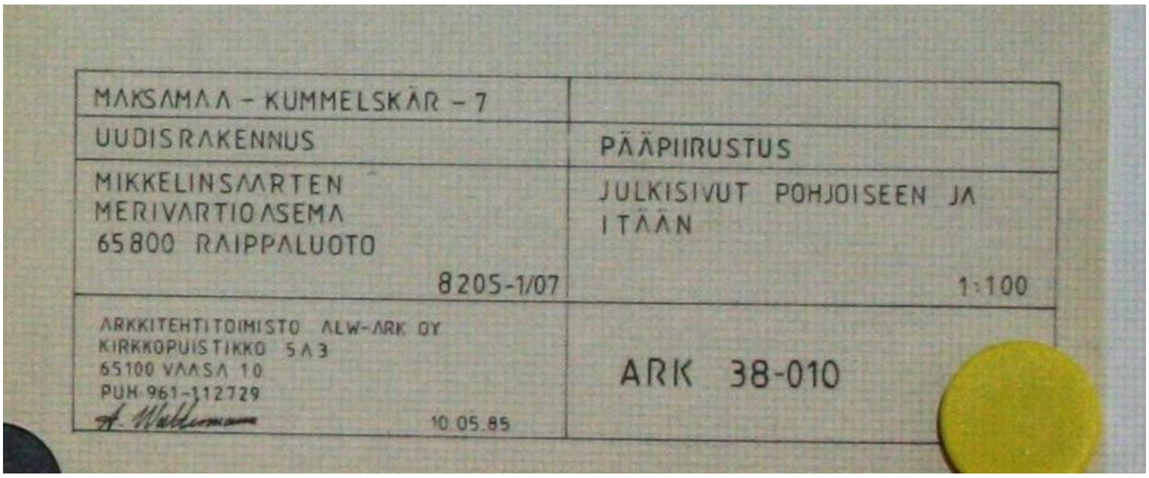
2.4 Appendix 06: Blueprint Mickelsorärna

2.4.1 Blueprint Mickelsorärna 1



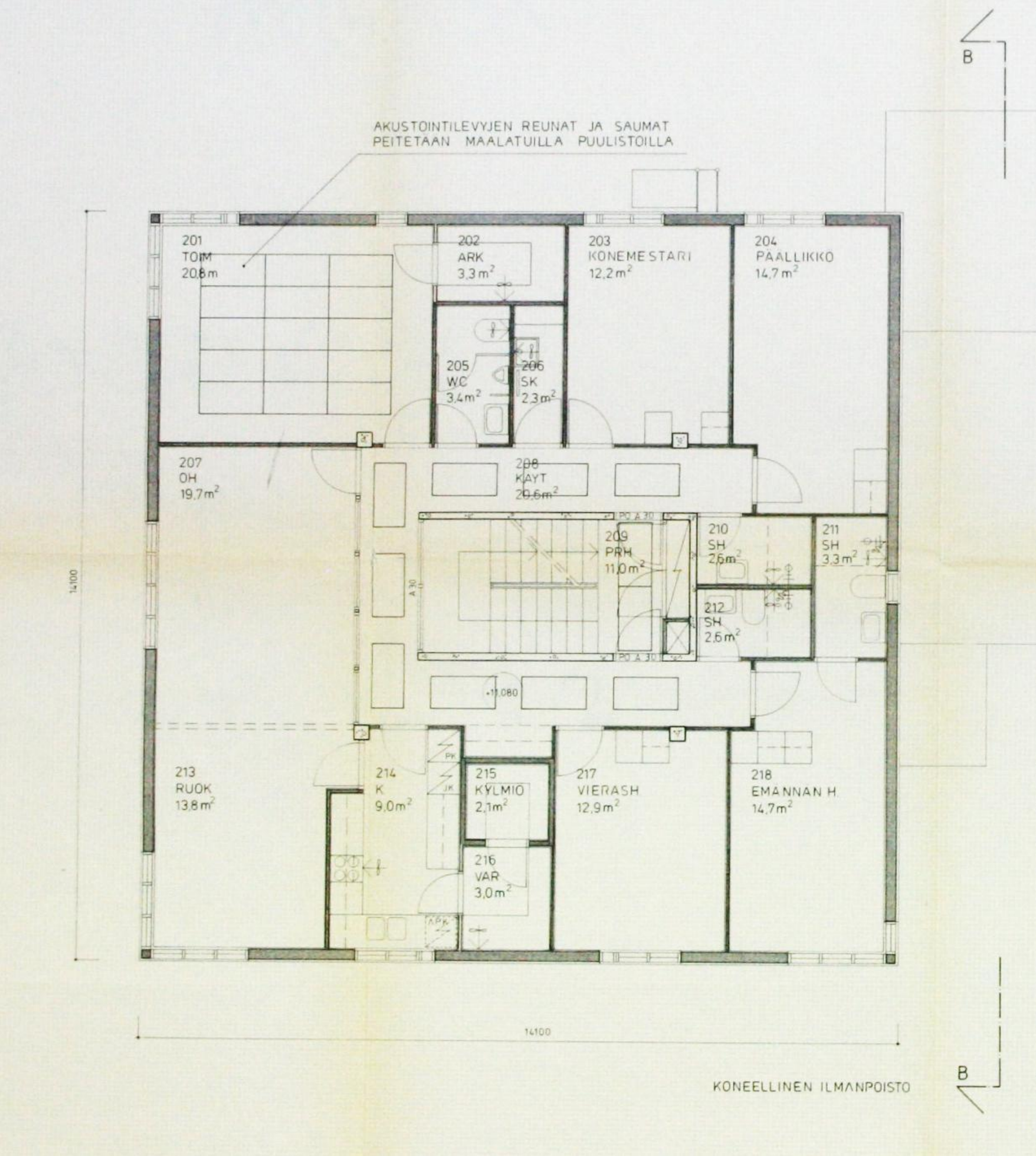
2.4.2 Blueprint Mickelsorärna 2





MAKSAMAA – KUMMELSKÄR – 7	
UUDISRAKENNUS	PÄÄPIIRUSTUS
MIKKELINSAARTEN MERIVARTIOASEMA 65800 RAIPPALUOTO 8205-1/07	JULKISIVUT POHJOISEEN JA ITÄÄN 1:100
ARKKITEHTITOIMISTO ALW-ARK OY KIRKKOPUISTIKKO 5 A 3 65100 VAASA 10 PUH 961-112729 10.05.85	ARK 38-010

2.4.3 Blueprint Mickelsorärna 3



MAKSAMAA - KUMMELSKAR - 7

UUDISRAKENNUS

MIKKELINSAARTEN
MERIVARTIOASEMA
65800 RAIPPALUOTO
8205-1/07

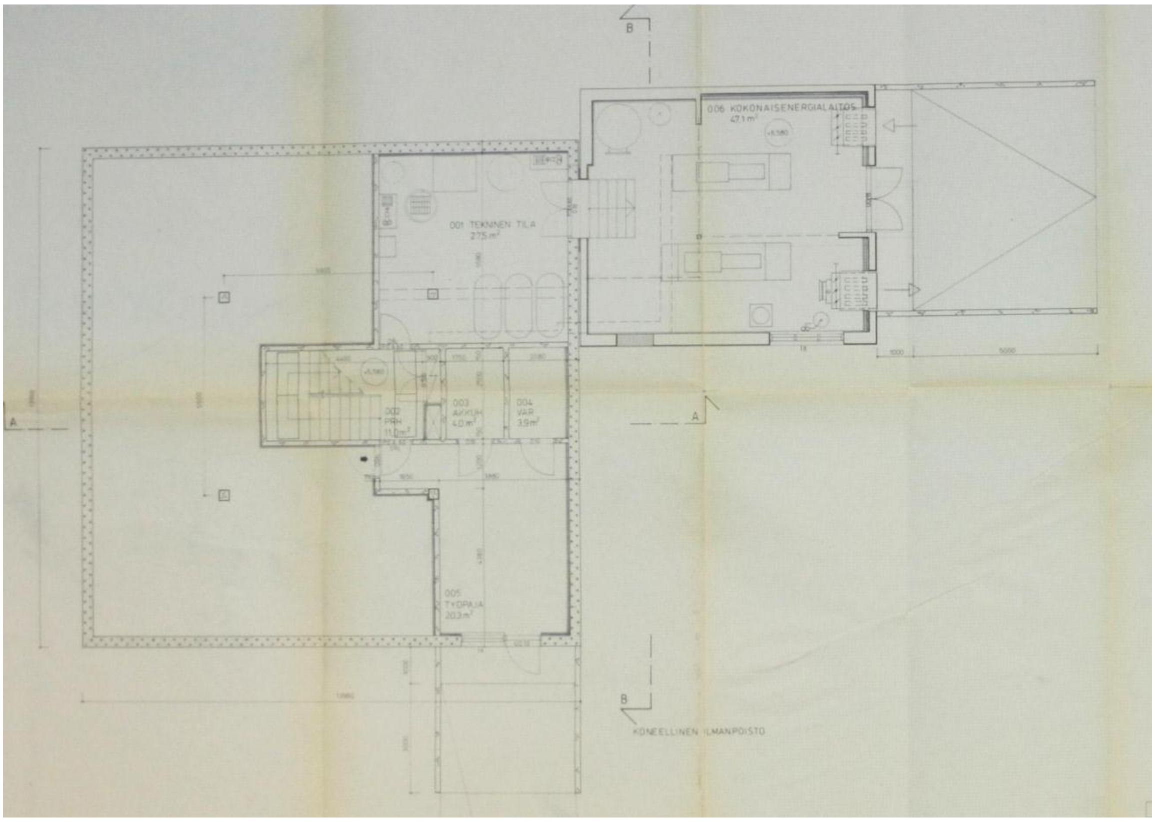
ALAKATTOPIIRUSTUS

POHJAPIIRUSTUS
2 KERROS
1: 50

ARKKITEHTITOIMISTO
ALW-ARK OY
KIRKKOPUISTIKKO 5A3
PUH. 961-112729
65100 VAASA
01.11.85

ARK 38-503

2.4.4 Blueprint Mickelsorärna 4




MAKSAMAA – KUMMELSKAR – 7
UUDISRAKENNUS
MIKKELINSAARTEN
MERIVARTIOASEMA
65800 RAIPPALUOTO
8205 -1/07

ALAKATTOPIIRUSTUS
KELLARIKERROS
1 : 50

ARKKITEHTITOIMISTO
ALW- ARK OY
KIRKKOPUISTIKKO 5 A3
PUH 961- 112729
65100 VAASA
01.11.85

ARK 38- 501

SOURCE: (Forest Department, Building B13 Yliopistonranta, Vaasa, Finland.)

2.5 Appendix 07: Weather Data

Table 1: Air Temperature, Extreme Temperatures And Days

	P_{air} (hPa)	air temp. (ºC)					extreme temp. (ºC)						temperature days			
		0 UTC	6 UTC	12 UTC	18 UTC	mean	avg. Max	avg. Min	absol. max	year	absol. Min	year	Max <25	Max <0	Min <0	Min <-10
jan	1007	-4,6	-4,6	-4,3	-4,4	-4,5	-2,3	-6,9	6,4	1991	-27,8	1986	-	17	28	8
feb	1010	-5,7	-6,1	-4,9	-5,3	-5,5	-3,2	-8,1	5,6	1992	-27,2	1985	-	18	26	10
mar	1010	-3,7	-4,1	-1,9	-2,9	-3,1	-0,7	-5,7	7,3	2004	-23,2	1987	-	15	28	7
apr	1013	0,1	0,5	2,4	1,2	1	3,6	-1,1	16,6	2002	-14	1985	-	3	18	0
may	1014	4,6	5,7	7,4	6,3	6	9,1	3,5	21,5	1992	-4,5	1981	-	0	2	-
jun	1011	9,6	10,8	12,5	11,6	11,1	14,1	8,7	25,3	1989	1,5	1985	0	-	-	-
jul	1011	13,9	14,9	16,6	15,7	15,3	17,9	13	27,5	2003	6,6	2008	0	-	-	-
aug	1011	14	14,4	16,2	15,2	14,9	17,3	12,9	26	2006	5,6	1986	0	-	-	-
sep	1011	10,1	9,9	11,7	10,6	10,6	12,7	8,7	22	2002	0,7	1986	-	-	-	-
oct	1010	5,6	5,4	6,4	5,8	5,8	7,4	4,2	15	2000	-8	1992	-	0	3	-
nov	1009	1,2	1,1	1,4	1,2	1,2	2,8	-0,5	9,5	1999	-15,6	2002	-	5	16	0
dec	1008	-2	-2,1	-1,9	-1,9	-2	-0,1	-4	7	2000	-22,6	1985	-	13	23	4
AVG.	1010	3,6	3,8	5,1	4,4	4,2	6,6	2,1	27,5		-27,8		0	71	144	29

(Tilastoja Suomen ilmastosta 1981-2010. Finnish Meteorological Institute. , 2012)

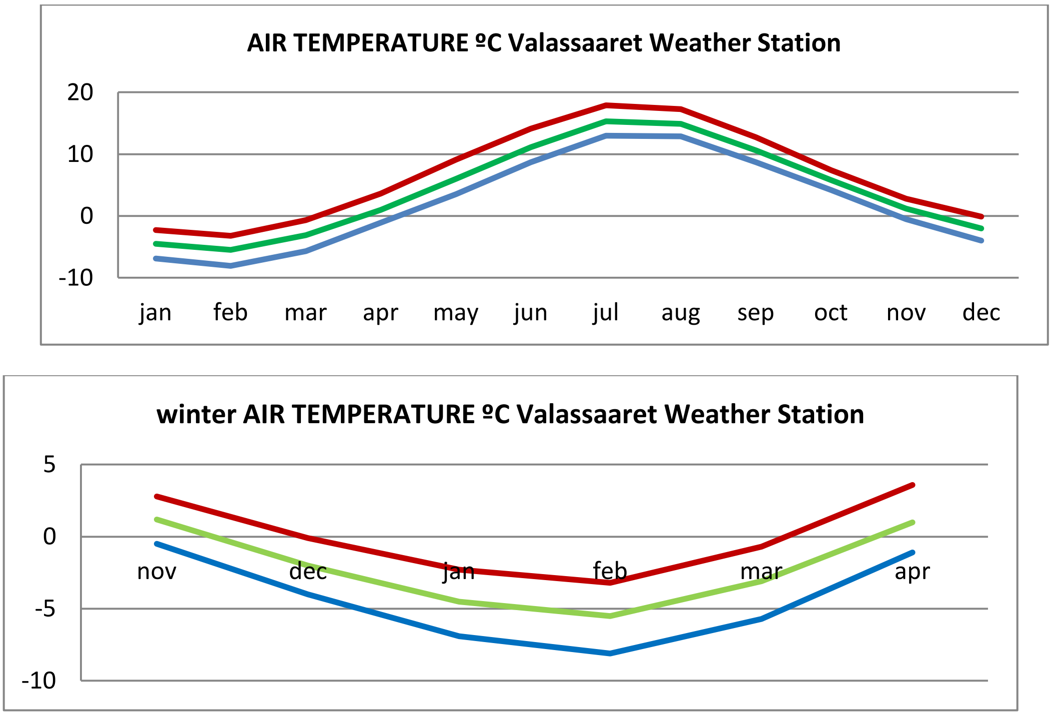


Figure 4: Air Temperature Graph

Table 2: Relative Humidity And Precipitation

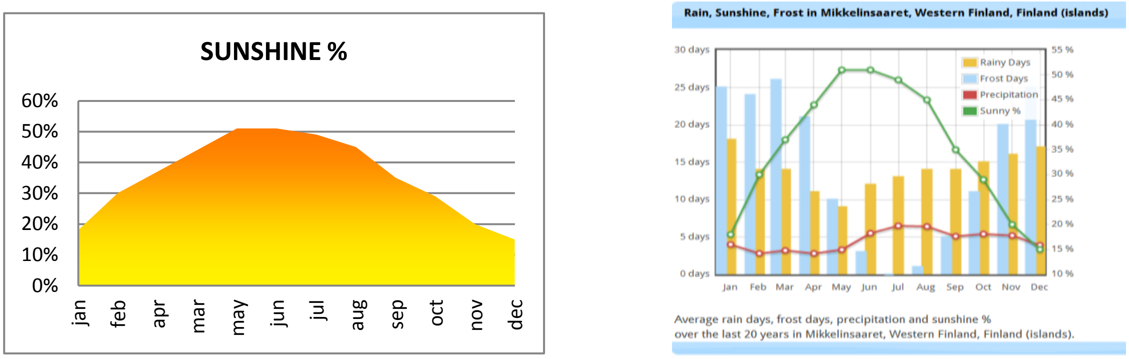
	relative humidity %					precipitation mm										
	time UTC										precipitation days				snow depth cm	
	0	6	12	18	mean	mean	max	year	min	year	>=0,1mm	>=1mm	>=10mm	daily prec.	first to 15th	15th to last
1	87	87	86	86	87	39	74,5	1990	9,5	1996	19	10	0	18,9	18	23
2	87	88	85	87	87	30	62,3	1999	1,3	1994	14	7	0	16,9	25	29
3	88	89	83	87	87	31	55,8	2008	8	2005	14	8	0	19,9	33	29
4	86	84	77	82	82	22	65,4	2000	1,3	2002	10	5	0	23,5	19	9
5	85	81	72	77	79	32	72,5	1982	3,6	1994	10	6	1	23,5	1	-
6	86	81	73	76	79	39	98,6	1981	0,4	1982	10	6	1	37,6	-	-
7	87	82	74	79	81	51	134,3	2008	2	1994	11	7	2	59,9	-	-
8	86	83	75	79	81	54	92,9	1985	12,5	1994	13	8	2	42,1	-	-
9	84	85	76	81	82	49	103,8	1992	10,9	2008	13	8	1	44,2	-	-
10	84	84	80	82	83	54	103,3	2006	13,2	2005	16	10	1	25,7	1	1
11	85	86	84	84	85	53	104,6	1996	10,2	1993	18	10	1	24,4	1	5
12	87	87	86	86	87	43	89,7	1993	10,7	2002	18	10	1	23,7	5	13
	86	85	79	82	83	497	134,3		0,4		166	95	10	59,9		

(Tilastoja Suomen ilmastosta 1981-2010. Finnish Meteorological Institute. , 2012)

Table 3: Sunshine %

Month	Sunshine %
jan	0,18
feb	0,3
apr	0,37
mar	0,44
may	0,51
jun	0,51
jul	0,49
aug	0,45
sep	0,35
oct	0,29
nov	0,2
dec	0,15

(Chinci Word Atlas , 2011)



Average rain days, frost days, precipitation and sunshine %
over the last 20 years in Mikkelinsaaret, Western Finland, Finland (islands).

Figure 5: Sunshine %

Table 4: Wind Distribution

	wind distribution																	
	N		NE		E		SE		S		SW		W		NW		calm	mean
	m/s	%	m/s	%	m/s	%	m/s	%	m/s	%	m/s	%	m/s	%	m/s	%		
1	8,6	13	7,4	8	6	8	4,7	14	6,9	19	7,5	15	7,1	13	7,3	10	1	6,8
2	7,9	10	7,4	11	5,2	8	4,2	12	6,8	22	6,9	16	6,5	12	6,5	7	1	6,2
3	7,5	12	6,6	11	4,6	8	4,3	9	6,8	27	5,7	15	6	10	5,9	7	1	5,7
4	7,1	12	6,5	17	4,3	8	3,8	6	6,2	25	5,2	14	5,4	10	5,5	6	1	5,3
5	5,9	12	6	19	4	8	3,6	3	6	24	5	17	5	10	4,9	7	0	4,9
6	5,7	13	5,6	19	3,8	9	3	4	6	21	4,8	16	4,7	10	4,9	8	1	4,7
7	5,7	11	5,5	16	3,8	8	3,3	6	5,4	22	4,7	17	4,8	10	5	8	1	4,6
8	6,6	12	6,2	16	4,6	9	3,6	8	5,2	19	4,9	17	5,4	10	5,8	8	1	5,1
9	7,4	11	6,7	11	5	8	3,8	10	5,7	20	5,9	16	6,8	13	7,2	11	1	5,9
10	8,8	12	7,5	7	6,8	7	4,7	13	6,9	20	7	18	7,5	13	7,8	9	1	7
11	8,9	12	8,6	7	7,2	8	5	16	6,8	18	8	16	7,6	12	7,7	10	1	7,4
12	8,7	12	9,1	7	6,8	7	4,6	15	7	18	7,6	15	7,6	14	8	12	0	7,2
	7,3	12	6,9	12	5,2	8	4,1	10	6,3	21	6,1	16	6,2	11	6,4	8	1	5,9

(Tilastoja Suomen ilmastosta 1981-2010. Finnish Meteorological Institute. , 2012)

Table 5: Wind Speed and Direction (During Winter months)

nov. to apr	N	NE	E	SE	S	SW	W	NW		avg
	m/s	m/s	m/s	m/s	m/s	m/s	m/s	m/s		
11	8,9	8,6	7,2	5	6,8	8	7,6	7,7		7,475
12	8,7	9,1	6,8	4,6	7	7,6	7,6	8		7,425
1	8,6	7,4	6	4,7	6,9	7,5	7,1	7,3		6,9375
2	7,9	7,4	5,2	4,2	6,8	6,9	6,5	6,5		6,425
3	7,5	6,6	4,6	4,3	6,8	5,7	6	5,9		5,925
4	7,1	6,5	4,3	3,8	6,2	5,2	5,4	5,5		5,5
AVG	8,11666667	7,6	5,68333333	4,43333333	6,75	6,81666667	6,7	6,81666667	6,61458333	

(Tilastoja Suomen ilmastosta 1981-2010. Finnish Meteorological Institute. , 2012)

Table 6: Wind Distribution (During Winter months)

nov. to apr	N	NE	E	SE	S	SW	W	NW
	%	%	%	%	%	%	%	%
11	12	7	8	16	18	16	12	10
12	12	7	7	15	18	15	14	12
1	13	8	8	14	19	15	13	10
2	10	11	8	12	22	16	12	7
3	12	11	8	9	27	15	10	7
4	12	17	8	6	25	14	10	6
AVG	11,8333333	10,1666667	7,83333333	12	21,5	15,1666667	11,8333333	8,666667

(Tilastoja Suomen ilmastosta 1981-2010. Finnish Meteorological Institute. , 2012)

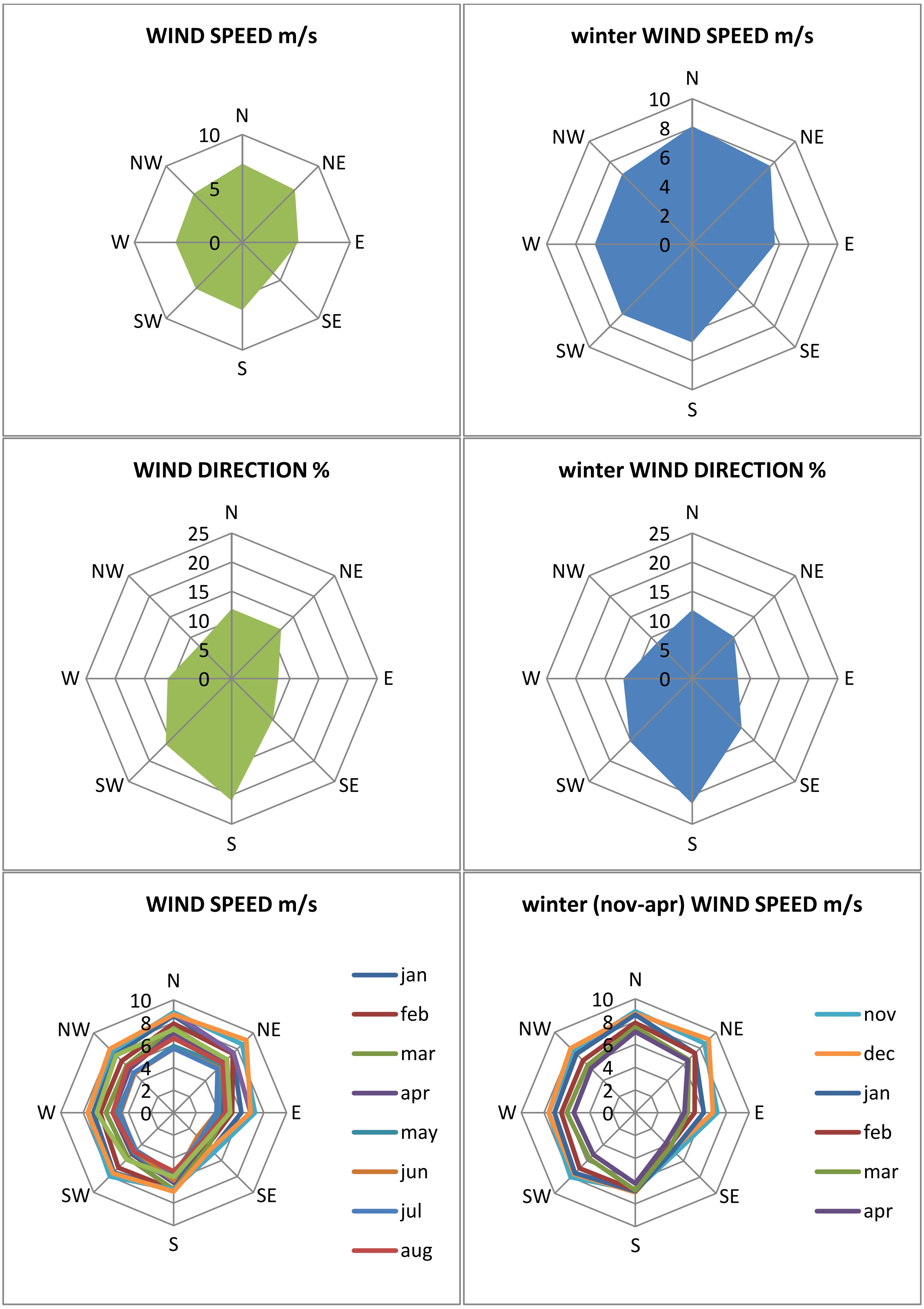


Figure 6: Wind Speed, Distribution and Direction

(Tilastoja Suomen ilmastosta 1981-2010. Finnish Meteorological Institute. , 2012)

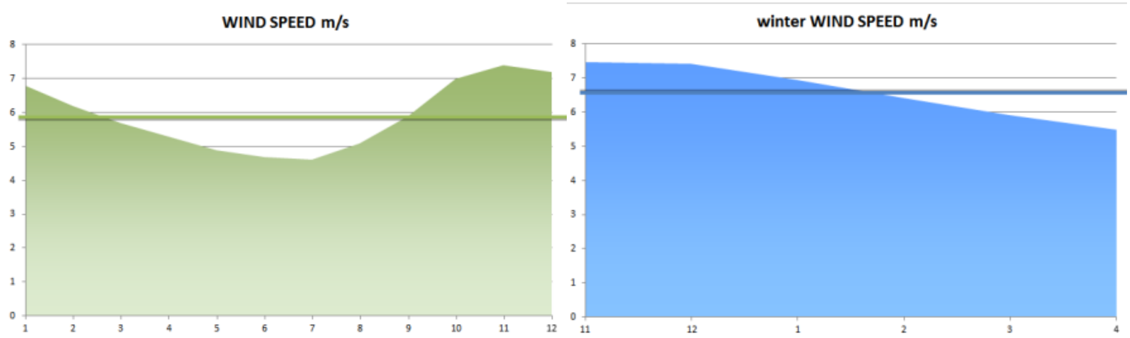
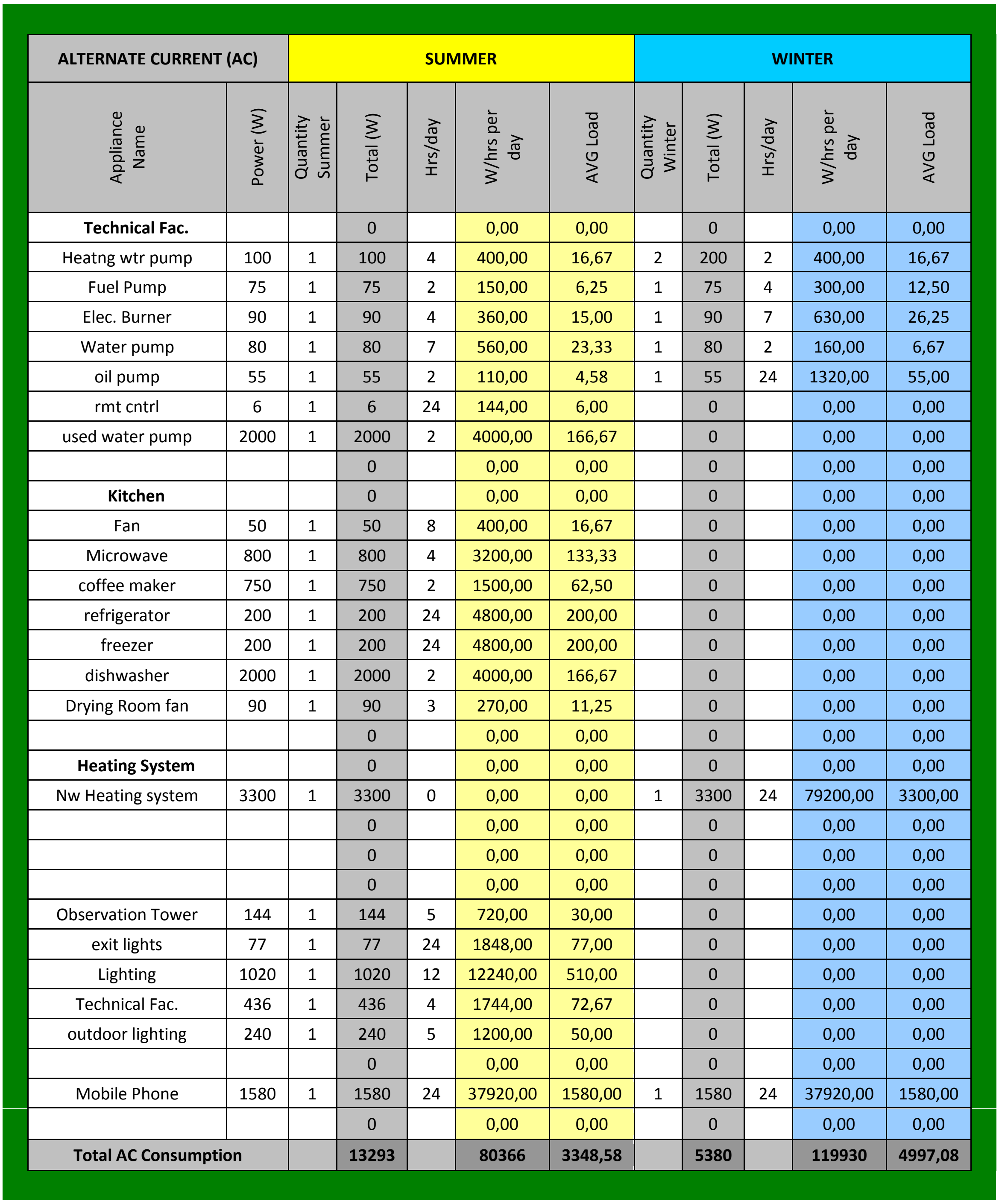


Figure 7: Wind Speed and Average

(Tilastoja Suomen ilmastosta 1981-2010. Finnish Meteorological Institute. , 2012)

2.6 Appendix 08: Mickelsörarna Electricity Needs

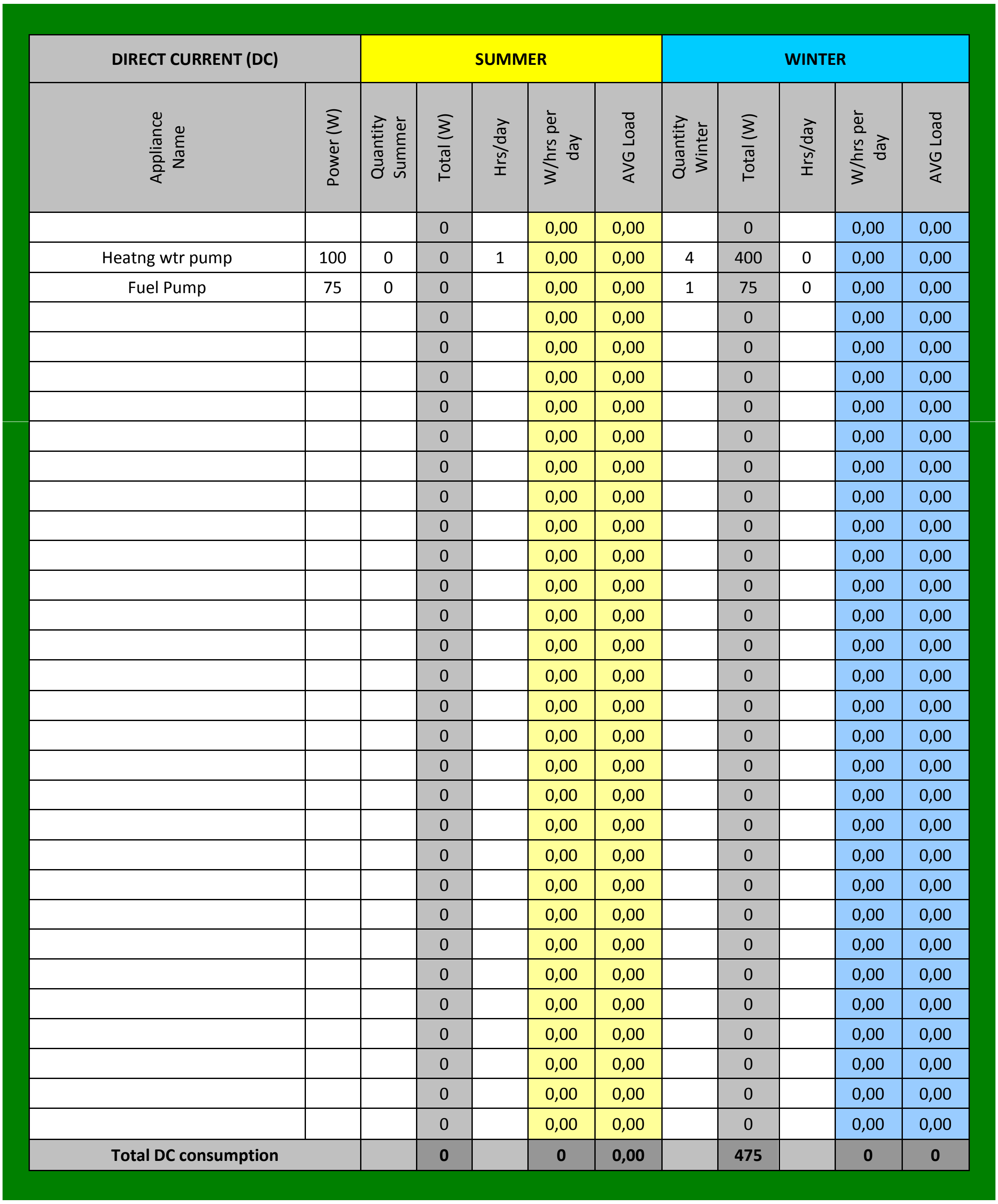
AC APPLIANCES



ALTERNATE CURRENT (AC)		SUMMER					WINTER				
Appliance Name	Power (W)	Quantity Summer	Total (W)	Hrs/day	W/hrs per day	AVG Load	Quantity Winter	Total (W)	Hrs/day	W/hrs per day	AVG Load
Technical Fac.			0		0,00	0,00		0		0,00	0,00
Heatng wtr pump	100	1	100	4	400,00	16,67	2	200	2	400,00	16,67
Fuel Pump	75	1	75	2	150,00	6,25	1	75	4	300,00	12,50
Elec. Burner	90	1	90	4	360,00	15,00	1	90	7	630,00	26,25
Water pump	80	1	80	7	560,00	23,33	1	80	2	160,00	6,67
oil pump	55	1	55	2	110,00	4,58	1	55	24	1320,00	55,00
rmt cntrl	6	1	6	24	144,00	6,00		0		0,00	0,00
used water pump	2000	1	2000	2	4000,00	166,67		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
Kitchen			0		0,00	0,00		0		0,00	0,00
Fan	50	1	50	8	400,00	16,67		0		0,00	0,00
Microwave	800	1	800	4	3200,00	133,33		0		0,00	0,00
coffee maker	750	1	750	2	1500,00	62,50		0		0,00	0,00
refrigerator	200	1	200	24	4800,00	200,00		0		0,00	0,00
freezer	200	1	200	24	4800,00	200,00		0		0,00	0,00
dishwasher	2000	1	2000	2	4000,00	166,67		0		0,00	0,00
Drying Room fan	90	1	90	3	270,00	11,25		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
Heating System			0		0,00	0,00		0		0,00	0,00
Nw Heating system	3300	1	3300	0	0,00	0,00	1	3300	24	79200,00	3300,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
Observation Tower	144	1	144	5	720,00	30,00		0		0,00	0,00
exit lights	77	1	77	24	1848,00	77,00		0		0,00	0,00
Lighting	1020	1	1020	12	12240,00	510,00		0		0,00	0,00
Technical Fac.	436	1	436	4	1744,00	72,67		0		0,00	0,00
outdoor lighting	240	1	240	5	1200,00	50,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
Mobile Phone	1580	1	1580	24	37920,00	1580,00	1	1580	24	37920,00	1580,00
			0		0,00	0,00		0		0,00	0,00
Total AC Consumption			**13293**		**80366**	**3348,58**		**5380**		**119930**	**4997,08**

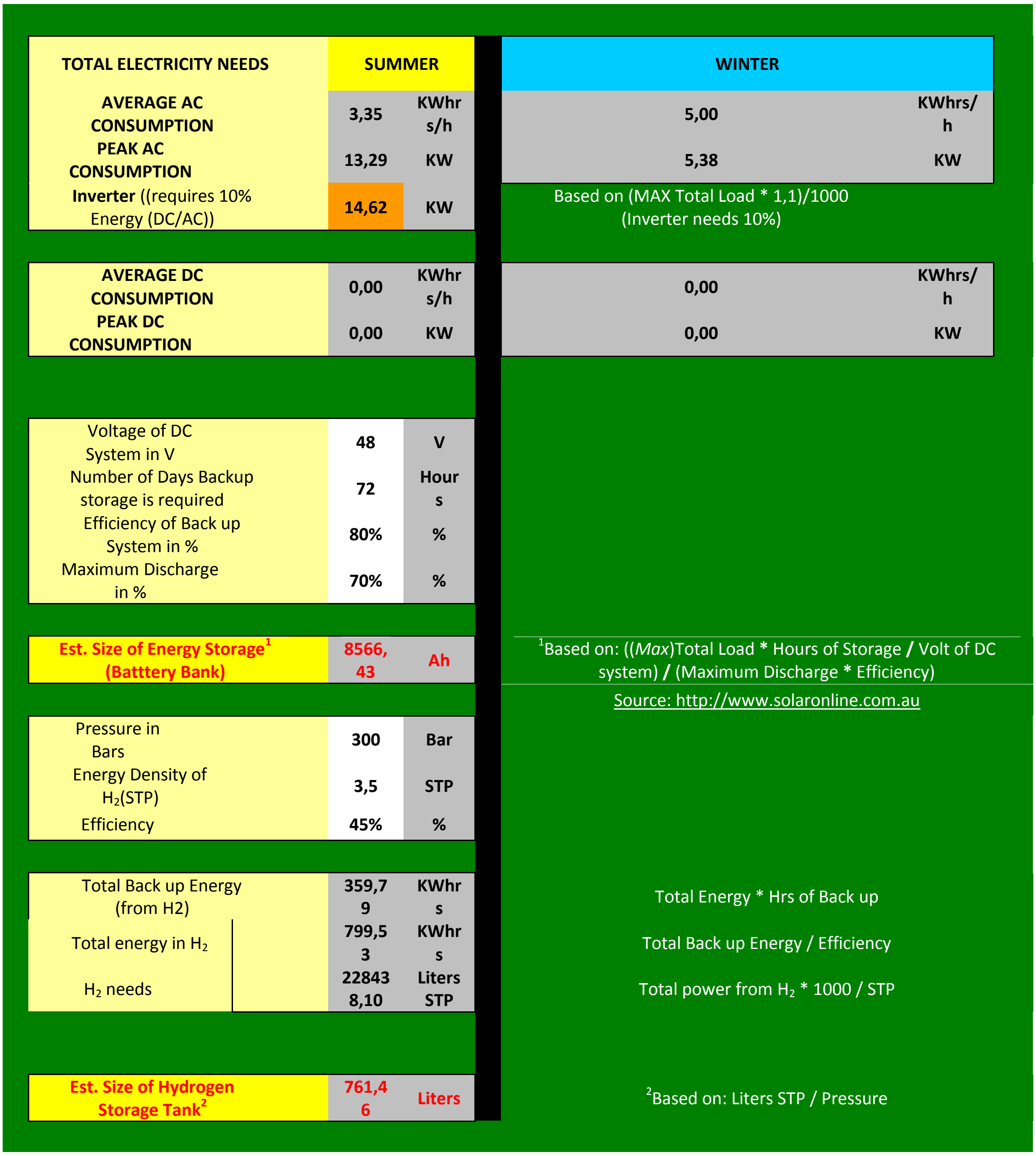
(Spreadsheet obtained from the Project Manager.)

DC APPLIANCES



DIRECT CURRENT (DC)		SUMMER					WINTER				
Appliance Name	Power (W)	Quantity Summer	Total (W)	Hrs/day	W/hrs per day	AVG Load	Quantity Winter	Total (W)	Hrs/day	W/hrs per day	AVG Load
			0		0,00	0,00		0		0,00	0,00
Heatng wtr pump	100	0	0	1	0,00	0,00	4	400	0	0,00	0,00
Fuel Pump	75	0	0		0,00	0,00	1	75	0	0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
Total DC consumption			**0**		**0**	**0,00**		**475**		**0**	**0**

RESULTS



TOTAL ELECTRICITY NEEDS	SUMMER		WINTER	
AVERAGE AC CONSUMPTION	**3,35**	**KWhrs/h**	**5,00**	**KWhrs/h**
PEAK AC CONSUMPTION	**13,29**	**KW**	**5,38**	**KW**
Inverter ((requires 10% Energy (DC/AC))	**14,62**	**KW**	Based on (MAX Total Load * 1,1)/1000 (Inverter needs 10%)	
AVERAGE DC CONSUMPTION	**0,00**	**KWhrs/h**	**0,00**	**KWhrs/h**
PEAK DC CONSUMPTION	**0,00**	**KW**	**0,00**	**KW**
Voltage of DC System in V	**48**	**V**		
Number of Days Backup storage is required	**72**	**Hours**		
Efficiency of Back up System in %	**80%**	**%**		
Maximum Discharge in %	**70%**	**%**		
Est. Size of Energy Storage[1] (Batttery Bank)	**8566,43**	**Ah**	[1]Based on: ((*Max*)Total Load * Hours of Storage **/** Volt of DC system) **/** (Maximum Discharge * Efficiency) Source: http://www.solaronline.com.au	
Pressure in Bars	**300**	**Bar**		
Energy Density of H_2(STP)	**3,5**	**STP**		
Efficiency	**45%**	**%**		
Total Back up Energy (from H2)	**359,79**	**KWhrs**	Total Energy * Hrs of Back up	
Total energy in H_2	**799,53**	**KWhrs**	Total Back up Energy / Efficiency	
H_2 needs	**228438,10**	**Liters STP**	Total power from H_2 * 1000 / STP	
Est. Size of Hydrogen Storage Tank[2]	**761,46**	**Liters**	[2]Based on: Liters STP / Pressure	

2.7 Appendix 09: Valsörarna Electricity Needs

AC APPLIANCES

ALTERNATE CURRENT (AC)		**SUMMER**					**WINTER**				
Appliance Name	Power (W)	Quantity Summer	Total (W)	Hrs/ day	W/hrs per day	AVG Load	Quantity Winter	Total (W)	Hrs/ day	W/hrs per day	AVG Load
			0		0,00	0,00		0		0,00	0,00
Fans			0		0,00	0,00		0		0,00	0,00
Exhaust Fan 1	400	1	400	1	400,00	16,67	1	400	1	400,00	16,67
Exhaust Fan 2	400	1	400	1	400,00	16,67	1	400	1	400,00	16,67
Exhaust Fan 3	300	1	300	1	300,00	12,50	1	300	1	300,00	12,50
Drying Fan 1	400	1	400	1	400,00	16,67	1	400	1	400,00	16,67
Exhaust Fan 4	400	1	400	1	400,00	16,67	1	400	1	400,00	16,67
Exhaust Fan 5	400	1	400	1	400,00	16,67	1	400	1	400,00	16,67
Exhaust Fan 6	400	1	400	24	9600,00	400,00	1	400	24	9600,00	400,00
			0		0,00	0,00		0		0,00	0,00
Pumps			0		0,00	0,00		0		0,00	0,00
Pump 1	300	1	300	0	0,00	0,00	1	300	18	5400,00	225,00
Pump 2	300	1	300		0,00	0,00	1	300	1	300,00	12,50
Pump 3	300	1	300		0,00	0,00	1	300	1	300,00	12,50
Pump 4	300	1	300		0,00	0,00	1	300	1	300,00	12,50
Pump 5	500	1	500		0,00	0,00	1	500	1	500,00	20,83
Pump 6	1500	1	1500		0,00	0,00	1	1500	1	1500,00	62,50
Pump 7	2500	0	0		0,00	0,00	1	2500	0	0,00	0,00
Pump 8	2500	0	0		0,00	0,00	1	2500	1	2500,00	104,17
Pump 9	3000	0	0		0,00	0,00	1	3000	1	3000,00	125,00
			0		0,00	0,00		0		0,00	0,00
Boiler	5000	0	0	0	0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
Small Purification	2200	0	0	0	0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
Alarm Sensors	0	1	0	24	0,00	0,00	1	0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
Heat Pump	3300	1	3300	0	0,00	0,00	1	3300	24	79200,00	3300,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
			0		0,00	0,00		0		0,00	0,00
Total AC Consumption			**9200**		**11900**	**495,83**		**17200**		**104900**	**4370,83**

(Senate Fastigheter, Vaasan yliopisto, Vaasa, Finland.)

NO DC APPLIANCES

RESULTS

TOTAL ELECTRICITY NEEDS	SUMMER		WINTER	
AVERAGE AC CONSUMPTION	0,50	KWhrs/h	4,37	KWhrs/h
PEAK AC CONSUMPTION	9,20	KW	17,20	KW
Inverter ((requires 10% Energy (DC/AC))	10,12	KW	Based on (MAX Total Load * 1,1)/1000 (Inverter needs 10%)	
AVERAGE DC CONSUMPTION	0,00	KWhrs/h	0,00	KWhrs/h
PEAK DC CONSUMPTION	0,00	KW	0,00	KW
Voltage of DC System in V	48	V		
Number of Days Backup storage is required	72	Hours		
Efficiency of Back up System in %	80%	%		
Maximum Discharge in %	70%	%		
Est. Size of Energy Storage[1] (Batttery Bank)	7492,86	Ah	[1]Based on: ((*Max*)Total Load * Hours of Storage **/** Volt of DC system) **/** (Maximum Discharge * Efficiency) Source: http://www.solaronline.com.au	
Pressure in Bars	30	Bar		
Energy Density of H_2(STP)	3,5	STP		
Efficiency	40%	%		
Total Back up Energy	35,70	KWhrs	Total Power * Hrs of Back up	
Total energy from H_2	89,25	KWhrs	Total Back up Power / Efficiency	
H_2 needs	25500,00	Liters STP	Total power from H_2 * 1000 / STP	
Est. Size of Hydrogen Storage Tank[2]	850,00	Liters	[2]Based on: Liters STP/ Pressure	

2.8 Appendix 10: Valsörarna Heat Needs

T inside	5			TOTAL HEAT LOSS		10044		Watts
T outside	-20							
Tground	0	area (m2)	type	U (W/m2.K)		heat loss		Total
WALLS	*no data on the old building, will use * as U for those walls*					*	0,25	2490,5125
NW	new	93,22	US 3	0,23		536,015		
	old	28,68	?	0,25		179,25		
NE	new	57,645	US 3	0,23		331,4588		
	old	0	?	0,25		0		
SE	new	106,8	US 3	0,23		614,1		
	old	26,68	?	0,25		166,75		
SW	new	32,685	US 3	0,23		187,9388		
	old	30	?	0,25		187,5		
guard tower		46	B 30	0,25		287,5		
WINDOWS		small	0,36	medium	0,72	big	2,16	3744,290865
		triple glass 0,418, air cavity 0,18, single glass 0,026						
NW	new	17,28		1,60		692,3077		
	old	4,32		1,60		173,0769		
NE	new	6,48		1,60		259,6154		
	old	0		1,60		0		
SE	new	16,2		1,60		649,0385		
	old	4,32		1,60		173,0769		
	basement	2,88		1,60		115,3846		
SW	new	1,44		1,60		57,69231		
	old	0		1,60		0		
guard tower		40,54		1,60		1624,099		
tilt + corners correction factor	1,15							
DOORS								625
NW	new	12,5		1		312,5		
	old	0		1		0		
NE	new	10,5		1		262,5		
	old	0		1		0		
SE	new	0		1		0		
	old	2		1		50		
SW	new	0		1		0		
	old	0		1		0		
BASEMENT								1446,51
about half of the wall under ground level, so will take the avg. temp. between outside and ground to calculate the temp gap.								
NW	type US 2	28,75		0,35		150,9375		
	type US 1	27,5		0,43		177,375		
	?	27,5		0,4		165		
NE	type US 2	13,5		0,35		70,875		
	type US 1	0		0,43		0		
SE	type US 2	17,5		0,35		91,875		
	type US 1	33,75		0,43		217,6875		
	?	24,62		0,4		147,72		
SW	?	20		0,4		120		
floor	AP 1	196,8		0,31		305,04		
ROOF								1118,9375
	new	159,75		0,17	*1	678,9375		
	old	88		0,2	*2	440		
	tower	0		0,17		0		
**1 no clear data, but will use the same value for both new roofs; *2 no data, will use a value with less isolation that the new roof*								
VENTILATION								618,75
Heat recovery Efficiency (%)	β	50				618,75		
Air Changes per Hour	N	0,083333						
Volume of room or building (m3)	V	1800						
Temperature difference (K)	Δ_{temp}	25						
						TOTAL		10044 Watts

3 Systems

3.1 Appendix 11: Secondary Power System

3.1.1 Hydrogen Production

There are different possibilities when it comes to H_2 production. This is a comparison of them and their main characteristics:

3.1.1.1 Hydrogen from FOSSIL FUELS

Production From Natural Gas

- **Steam Reforming (steam methane reforming – SMR)**
  Endothermic conversion of methane and water vapor into hydrogen and carbon monoxide. Needs an external heat input Carbon monoxide can be further converted to carbon dioxide and hydrogen in a water-gas shift reaction.

$$CH_4 + H_2O + \text{heat} \dashrightarrow CO + 3H_2$$
$$CO + H_2O \dashrightarrow CO_2 + H_2 + \text{heat}$$

- **Partial Oxidation (POX)**
  Exothermic combustion of methane with oxygen to produce carbon monoxide and hydrogen. No need for any external heat input.

$$CH_4 + \tfrac{1}{2}\, O_2 \dashrightarrow CO + 2H_2 + \text{heat}$$

- **Auto-thermal reforming (ATR)**
  Combination of both- Total reaction is exothermic. Outlet 950 to 1100 ºC and up to 100 bar. Gas purification rises costs and lowers global efficiency.

Production From Coal

Variety of existing gasification processes. Most favorable is high-temperature entrained flow process, because maximizes carbon conversion to gas and avoids accumulation of char, tars and phenols. Typical reaction, carbon becomes carbon monoxide and hydrogen. Requires heat input. Produced carbon monoxide is further converted to carbon dioxide and hydrogen through water-gas shift reaction. It’s commercially available, but more complex than producing from natural gas. Cost of resulting hydrogen is higher, too.

Comparison Table 07:

Table 7: Comparison of hydrogen from Fossil Fuel systems

Technology	Natural Gas SMR	Natural Gas POX or ATR	Coal
Benefits	High efficiency Emissions Costs for large units	Smaller size Costs for small units Simple system Exothermic	Commercially mature Exothermic
Challenges	Complex system Sensitive to natural gas quality Endothermic	Lower efficiency H2 purification Emissions/flaring	Most complex system Resulting H2 cost

3.1.1.2 Hydrogen from SPLITTING OF WATER

Water Electrolysis

Water is split into hydrogen and oxygen using electrical energy.

- **Alkaline electrolysis**
  Uses an aqueous caustic solution (KOH) as an electrolyte circulating through the cells, which are arranged in a stack. It is suitable for stationary applications, can operate with pressures up to 25 bar. It is a mature technology widely applied. Suitable for remote operation. Reactions that take place inside the alkaline electrolysis cell:

  Electrolyte: $4H_2O \text{ --> } 4H^+ + 4OH^-$
  Cathode: $4H^+ + 4e- \text{ --> } 2H_2$
  Anode: $4OH^- \text{ --> } O_2 + 2H_2O + 4e^-$
  Sum: $2H_2O \text{ --> } O_2 + 2H_2$

  It is still a challenge to design and manufacture electrolyzing equipment with higher efficiency and larger turn-down ratios, at lower costs.

- **Polymer electrolyte membrane (PEM) electrolysis**
  It requires no liquid electrolyte, which simplifies the design significantly. It uses an acid polymer membrane. Higher operation pressures of up to several hundred bars. It's suited for both stationary and mobile applications. Higher turndown ratio. No KOH electrolyte makes it safer. Higher densities allow them to have a more compact design.

  Anode (oxidation): $2\ H_2O \rightarrow O_2 + 4\ H^+ + 4e^-$ $E^o_{ox} = -1.23\ V$
  Cathode (reduction): $2\ H^+ + 2e^- \rightarrow H_2$ $E^o_{red} = 0.00\ V$

  The negative voltage in the oxidation of the anode means that the reaction needs energy to take place.

  This could be simplified considering the electrolyzer as a whole, then:

  Overall reaction: $2\ H_2O(l) + \text{Electricity } (1.23\ V) \text{ --> } 2\ H_2(g) + O_2(g)$

Not as mature technology as alkaline, due to relatively high cost, low capacity (enough for this project needs), not great efficiency (up to 60% for electricity, and up 85 for CPH). In the last years PEM technology and performance has improved significantly.

- **High-temperature electrolysis**

  Electrical energy needed to split water at 1000ºC is considerably lower that at 100ºC (low-temp. electrolysis), therefore, significantly higher efficiencies can be achieved. Most extended technology is Solid Oxide Electrolyzer Cell (SOEC) based on a reversible Solid Oxide Fuel Cell (SOFC), operating at 700 to 1000ºC, range in which electrode reactions are more reversible.

  It's still a young technology. Current challenges relate to thermo-mechanical stress resistant materials development (same challenges as for the SOFC).

Comparison Table 08:

Table 8: Comparison of hydrogen from Splitting Water systems

Technology	Alkaline	PEM	High-temperature
Benefits	Suits stationary Up to 25 bar Remote operation	No liquid electrolyte Simple design High pressure Mobile & Stationary Large turn-down ratio Safer Small size (compact) Efficiency for CHP	Higher efficiency Reversible Fuel Cell
Challenges	Low efficiency Small turn-down ratio Cost	Evolving technology High cost Low capacity (enough) Efficiency for only electricity	Needs more R&D Materials

Photo-Electrolysis (Photolysis)

Electrolyzer coupled to a Photovoltaic system. It offers flexibility, the output can be used directly as electricity or to run the electrolyzer. Light is used to split water directly into hydrogen and oxygen. It has great potential for cost reduction of hydrogen production.

It still needs material and engineering systems R&D. efficiencies only up to 15-20%.

Photo-Biological Production (Biophotolysis)

Two steps: photosynthesis and hydrogen production catalyzed by hydrogenases, for example algae and cyanobacteria, or artificial photosynthesis

Photosynthesis: $2H_2O \text{ --> } 4H^+ + 4e^- + O_2$
Hydrogen Production: $4H^+ + 4e^- \text{--> } 2H_2$

High-Temperature Decomposition

At a temperature of about 3000ºC 10% of water is split, the remaining 90% can be recycled. To reduce operation temperatures, other processes can be used:

- Thermo-chemical cycles
- Hybrid systems coupling thermal and electrolytic decomposition
- Direct catalytic decomposition via a ceramic membrane
- Plasma-chemical decomposition in a double-stage CO2 cycle.

Up to 50% efficiencies can be expected for the aforementioned processes. There is still R&D to be done concerning corrosion resistant materials, heat exchangers, and heat storage, thou.

3.1.1.3 BIOMASS to Hydrogen

In biomass production, the gasses created contain hydrogen, in a manner similar to the gasification of coal. However, these gases are rarely used, due to the unrefined products with inconsistent quality of the biomass generation side products. Also, quite a big amount of biomass is needed in relation to the hydrogen production.

Hydrogen will be produced in an ELECTROLYZER, using pure water and electricity as inputs:

3.1.2 Choice: Pem Electrolyzer

3.1.2.1 Different PEM electrolyzers (Table 09, Table 10)

Table 9: Comparison of PEM Electrolyzers

Product	H_2 prod. rate (l/h)	H_2 pressure (bar)	H_2 purity (%)	Power (kW)	Comments / Reasons for discarding
HOGEN GC 300	18	13.8	99.9999	<1	Low H_2 flow rate, data missing
HOGEN GC 600	36	13.8	99.9999	<2	
HOGEN GC 4200	252	13.8	99.9999	3.2	Low H_2 pressure, high power consumption
HOGEN HP 10	260	166	99.995	?	Data missing, high pressure
HOGEN HP 40	1050	166	99.995	?	
HOGEN H2m	2000	16/31	99.9995	14.6	Consumed too much power
HOGEN H4m	4000	16/31	99.9995	28	
HOGEN H6m	6000	16/31	99.9995	40.8	
HOGEN C10	10000	31	99.9998	62	
HOGEN C20	20000	31	99.9998	120	
HOGEN C30	30000	31	99.9998	174	
Acta Energy AES100	100	15/30	99.999	0.53	**Suitable for the islands, work at 30 bar, high H_2 purity, low power consumption**
Acta Energy AES200	**200**	**15/30**	**99.999**	**1.06**	
Acta Energy AES300S	300	15/30	99.999	1.59	
Acta Energy AES300L	300	15/30	99.999	1.59	
Acta Energy AES500	500	15/30	99.999	2.65	
Acta Energy AES1000	1000	15/30	99.999	5.3	Consumed too much power
Electric Hydrogen HG02	200	14.7	99.90	1	Low H_2 pressure

Table 10: PEM ELECTROLYZER choice for each application:

Application	Choice
Smaller needs concept (<=3.5 kW)	Acta Energy AES200
Bigger needs conpcet (3.5 to 5 kW)	
Mickelsörarna (4.4 kW)	
Valsörarna (5kW)	

This device is suitable for all the different systems.

3.1.3 Hydrogen Storage

When it came to choose a storage type for hydrogen, the technical aspects that had to be taken in account were:

- Pressure
- Storage Size
- Temperature
- Reliability
- Safety
- Storage cost

Following there is an overview of the most common ways to store hydrogen, which were the ones that were looked into before a choice was made. The main characteristics of each of the systems are mentioned as well.

3.1.3.1 GASEOUS Hydrogen

Metal Tanks

Steel tanks are not the most suitable solution for hydrogen storage: the small size of hydrogen molecules makes it easy for them to escape through the metal when hydrogen is stored under a high pressure. Also they are very heavy in relation to the amount of pressure they can withstand. But those issues should not be a problem if the storage pressure is not great, and space availability is not critical. Also they are a lot less expensive than composite tanks.

Composite Tanks

Carbon fiber wrapped storage tanks can stand bigger pressures, in the range of 350 to 700 bars, while maintaining lower weight. They are also corrosion resistant. Composite tanks have been commercially available and proved for a long time. However, they are costly, considering the amount of hydrogen that can be stored in them.

3.1.3.2 LIQUID Hydrogen

Cryogenic Liquid Hydrogen (LH_2)

Liquid hydrogen has a much bigger energy density that pressurized gas. High storage density at lower pressures that gas. It needs to be contained in an insulated cryogenic tank, and to put it in there, a great amount of energy is needed. The liquefaction process, the insulated containers and the boil-off re-capture systems are the main challenges for R&D on LH2.

3.1.3.3 SOLID Hydrogen

It’s a very promising technology. Storage in solid materials is safe and efficient, is needs a lower volume, lower pressure and offers a more pure output than gaseous or liquid storage. However, it requires extreme temperatures to operate, either cryogenic or very high, depending on the specific technology. More R&D needs to be done before it becomes an interesting option for a situation like the one being studied in this project, mainly due to heat management issues. Some of the options for solid hydrogen storage are:

- Rechargeable Hydrides
- Carbon and other high surface area materials
- H2O-reactive Chemical Hydrides
- Thermal Chemical Hydrides

Comparison Table 11:

Table 11: Comparison of hydrogen Storage systems

Technology	**GASEOUS**	**LIQUID**	**SOLID**
Benefits	Ambient temperature Safe Simple technology Available Cheapest	Lower pressure	Lower pressure Safest
Challenges	Higher pressure Possibility of burning if there leakage accumulates	Needs cryogenic temperatures (big energy demand) Tank must be isolated Expensive	Needs heat to release the hydrogen (big energy demand) Expensive Undeveloped technology

3.1.4 Choice: Pressurised Gas Tank

3.1.4.1 Different PRESSURISED GAS TANKS

Customized hydrogen gaseous steel tank. Assumed fuel cell efficiency is 45%.

Then for different FC productions (Table 12), (Table 13):

Table 12: PRESSURISED GAS STEEL TANK size depending on the FC power:

Fuel cell power (kW)	**Backup time (h)**	**Total energy (kWh)**	**Energy from H_2[1] @STP[2] (kWh)**	**H_2 volume @STP[2] (liter)**	**H_2 tank[3] Pressure (bar)**	**H_2 tank[3] Size (liter)**
1	168	168	373	106667	30	3881
2	168	336	747	213333	30	7762
3	168	504	1120	320000	30	11643
4	168	672	1493	426667	30	15525
5	168	840	1867	533333	30	19406
6	168	1008	2240	640000	30	23287
7	168	1176	2613	746667	30	27168
8	168	1344	2987	853333	30	31049
9	168	1512	3360	960000	30	34930
10	168	1680	3733	1066667	30	38812
11	168	1848	4107	1173333	30	42693
12	168	2016	4480	1280000	30	46574

[1]. Energy Density of H2 (STP) = 3.2 - 3.5 Watt-hours/liter

(Stuart Island Energy Initiative, n.d.)

[2]. STP = standard temperature/pressure = 0ºC (32 F) and 1 bar (≈1 atmosphere)

(Stuart Island Energy Initiative, n.d.)

[3]. H_2 tank pressure and size are calculated at 25ºC. Actually temperature doesn't matter. Because in the ideal gas law, the temperature unit is Kelvin, 0ºC = 273 K, 25°C=298 K. The ratio of these two Kelvin temperature is always close to 1, so this doesn't affect the equation.

Table 13: PRESSURISED GAS STEEL TANK choice for each application:

Application	**H_2 tank**
Smaller needs concept (<=3.5 kW)	ReliOn T-2000® 4kW Outdoor Configuration
Bigger needs conpcet (3.5 to 5 kW)	Dantherm DBX5000
Mickelsörarna (4.4 kW)	Dantherm DBX5000
Valsörarna (5kW)	20000 liters H_2 @ 30bar,25 ºC

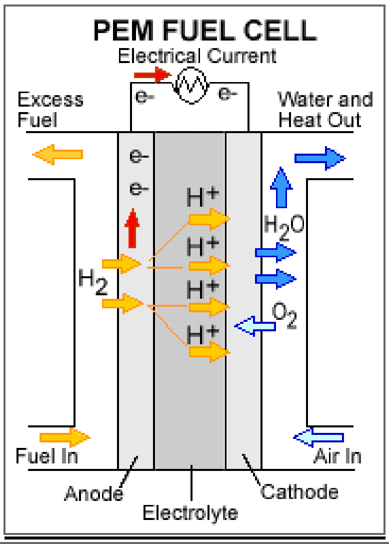
3.1.5 Hydrogen Utilization

Fuel cells are the best way to convert the chemical energy stored in hydrogen into electricity efficiently. There is a wide variety of fuel cell technologies already commercially available which have been proved to work satisfactorily both in stationary and mobile applications. The basics of the fuel cell imply few or no moving parts, making maintenance an unimportant issue. They are scalable, meaning that one can have from a small number of cells to a large stack of them, depending on the power delivery needed. Efficiencies for fuel cells go from 35 to 60 when used only for electricity production, but can grow up to 85 or 90% if used in CHP (combined heat and power) systems. Fuel cells have very low emissions, and since there is no combustion process, there is no emission of NOx or SOx. Also they produce very low noise and vibrations, if any, due to their lack of moving parts.

Following there is a review of the most used fuel technologies exposing the main characteristics of each:

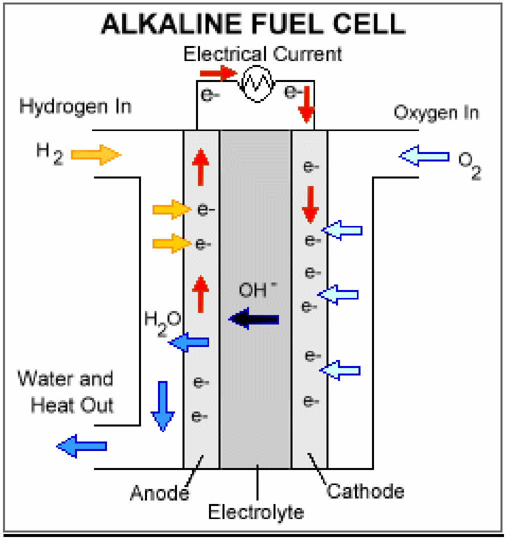
3.1.5.1 POLYMER ELECTROLYTE MEMBRANE (PEM)

PEMs, also called Proton Exchange Membrane FC, have high power density, operate at low temperatures (around 80ºC), so they can start-up quickly (short warm-up time), and can quickly vary the output to fit the needs. They have low weigh and volume. PEMs use a solid polymer as an electrolyte and carbon electrodes containing platinum catalyst, which is very sensitive to CO. They are suitable for light-duty applications (cars, buildings…). It makes them an ideal replacement for rechargeable batteries.



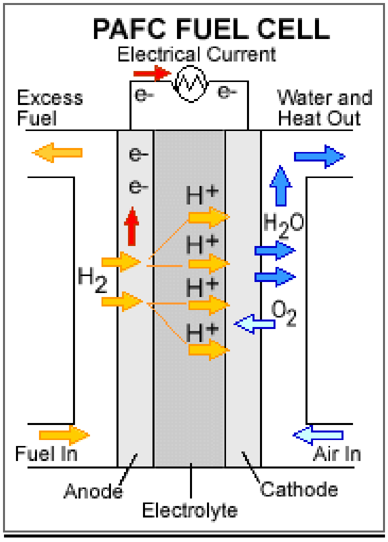
3.1.5.2 ALKALINE (AFC)

Alkaline FC were the first to be developed. Wide range of operating temperatures for different models (from 20 to 250ºC). They use a potassium hydroxide in water as electrolyte, making possible the use of non-precious metals as catalysts. They are very sensitive to carbon contamination.



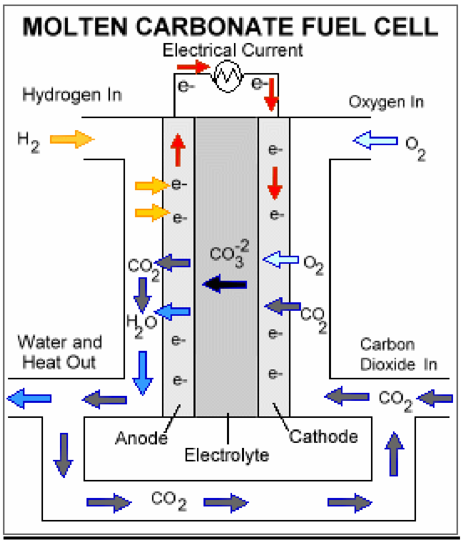
3.1.5.3 PHOSPHORIC ACID (PAFC)

Widely used nowadays. They use liquid phosphoric acid as the electrolyte and carbon electrodes containing platinum as catalysts. They operate at about 175ºC. Fuel flexibility (can work with good tolerance of impurities in hydrogen, up to 1.5% of CO).



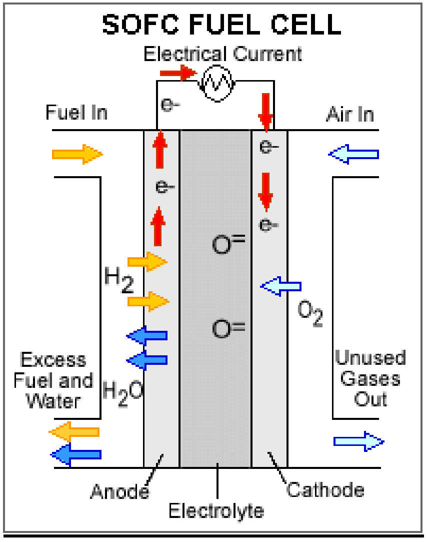
3.1.5.4 MOLTEN CARBONATE (MCFC)

MCFCs operate at high temperatures around 650ºC. They require an input of CO2. The electrolyte used is a molten carbonate salt mixture suspended in an inert matrix and don't need precious metals as catalysts, due to the high temperatures. Used in big power production systems, up to a few MW.



3.1.5.5 SOLID OXID (SOFC)

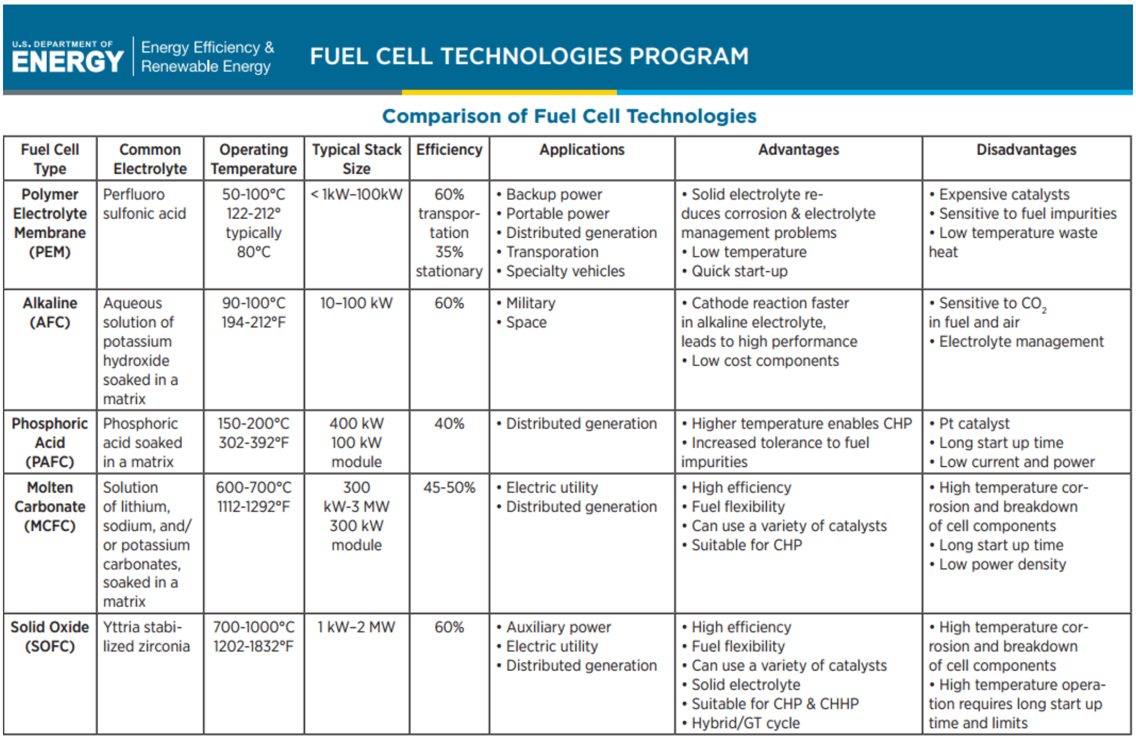
SOFCs operate at very high temperatures, up to 1000ºC. They use a hard non-porous ceramic compound as electrolyte and they tolerate well sulfurs presence and also CO, which can even be used as fuel. SOFC can be built in shapes other that the plate-like typical configuration. They are still quite a young technology. They are scalable and suitable for stationary applications.



(U.S. Department of Energy, Energy Efficiency & Renewable (EERE), 2011)

Below a table with the main data, applications, advantages and disadvantages of each fuel cell type or technology is shown Table 14:

Table 14: COMPARISON OF FUEL CELL TECHNOLOGIES



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

FUEL CELL TECHNOLOGIES PROGRAM

Comparison of Fuel Cell Technologies

Fuel Cell Type	Common Electrolyte	Operating Temperature	Typical Stack Size	Efficiency	Applications	Advantages	Disadvantages
Polymer Electrolyte Membrane (PEM)	Perfluoro sulfonic acid	50-100°C 122-212° typically 80°C	< 1kW–100kW	60% transportation 35% stationary	• Backup power • Portable power • Distributed generation • Transporation • Specialty vehicles	• Solid electrolyte reduces corrosion & electrolyte management problems • Low temperature • Quick start-up	• Expensive catalysts • Sensitive to fuel impurities • Low temperature waste heat
Alkaline (AFC)	Aqueous solution of potassium hydroxide soaked in a matrix	90-100°C 194-212°F	10–100 kW	60%	• Military • Space	• Cathode reaction faster in alkaline electrolyte, leads to high performance • Low cost components	• Sensitive to CO_2 in fuel and air • Electrolyte management
Phosphoric Acid (PAFC)	Phosphoric acid soaked in a matrix	150-200°C 302-392°F	400 kW 100 kW module	40%	• Distributed generation	• Higher temperature enables CHP • Increased tolerance to fuel impurities	• Pt catalyst • Long start up time • Low current and power
Molten Carbonate (MCFC)	Solution of lithium, sodium, and/or potassium carbonates, soaked in a matrix	600-700°C 1112-1292°F	300 kW-3 MW 300 kW module	45-50%	• Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Suitable for CHP	• High temperature corrosion and breakdown of cell components • Long start up time • Low power density
Solid Oxide (SOFC)	Yttria stabilized zirconia	700-1000°C 1202-1832°F	1 kW–2 MW	60%	• Auxiliary power • Electric utility • Distributed generation	• High efficiency • Fuel flexibility • Can use a variety of catalysts • Solid electrolyte • Suitable for CHP & CHHP • Hybrid/GT cycle	• High temperature corrosion and breakdown of cell components • High temperature operation requires long start up time and limits

(U.S. Department of Energy, Energy Efficiency & Renewable Energy (EERE), 2011)

3.1.6 Choice: Fuel Cell

- *Different FUEL CELLS (Table 15, Table 16):*

Table 15: Comparison of PEM Fuel Cells

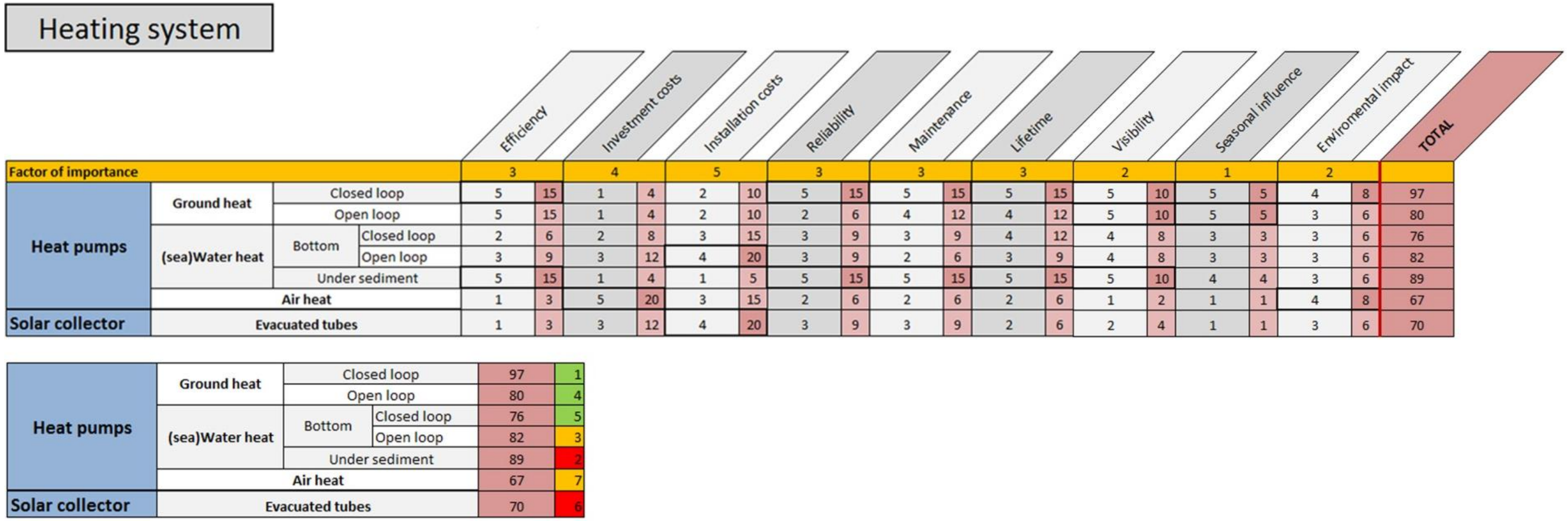
Product	H_2 flow rate (l/h)	H_2 purity (%)	H_2 pressure (bar)	Power output (W)	Comments / Reasons for discarding
GreenHub 500	390	99.999	4-8	0.4 kW	Fuel-cells of greenhub gensets are not designed for a continuous 24/7 running profile
GreenHub 1000	840	99.999	4-8	0.8 kW	
GreenHub 2000	1680	99.999	4-8	1.6 kW	
GreenHub 3000	2520	99.999	5-8	2.55 kW	
GreenHub 4000	3600	99.999	7-10	3.4 kW	
GreenHub 5000	5040	99.999	7-10	4.25 kW	
Fronius 50F	3300	99.999	5-15	4 kW	Too high purity, ambient temperature is higher than +3ºC
Dantherm DBX5000	4750	99.95	6	5 kW	Meets the electricity needs of both islands, can operate below -20ºC
ReliOn T2000	1800	99.95	0.24-0.41	2 kW	Scalable, flexible config. from 600 Watts to a full 2000 Watt capacity
ReliOn T2000 4kW Outdoor		99.95		4 kW	Modular configurations, can work at ambient temp. from -40ºC to 46℃ high reliability, ease of maintenance, simplicity of design
ReliOn T2000 6kW Outodoor		99.95		6 kW	
ReliOn T2000 Outodoor		99.95		8 kW	
ReliOn E2500 10kW 32U23 Cabinet		99.95		10 kW	
ReliOn T2000 12 kW Outdoor		99.95		12 kW	

Table 16: PEM FUEL CELL choice for each application:

Application	Type
Smaller needs concept (<=3.5 kW)	<15000 liters H_2 @ 30bar, 25ªC
Bigger needs conpcet (3.5 to 5 kW)	15000-20000 liters H_2 @ 30bar, 25ªC
Mickelsörarna (4.4 kW)	20000 liters H_2 @ 30bar, 25ªC
Valsörarna (5kW)	20000 liters H_2 @ 30bar, 25ªC

3.2 Appendix 12: Heating & Ventilation Trade-Off.

3.2.1 Heating System Trade-Off



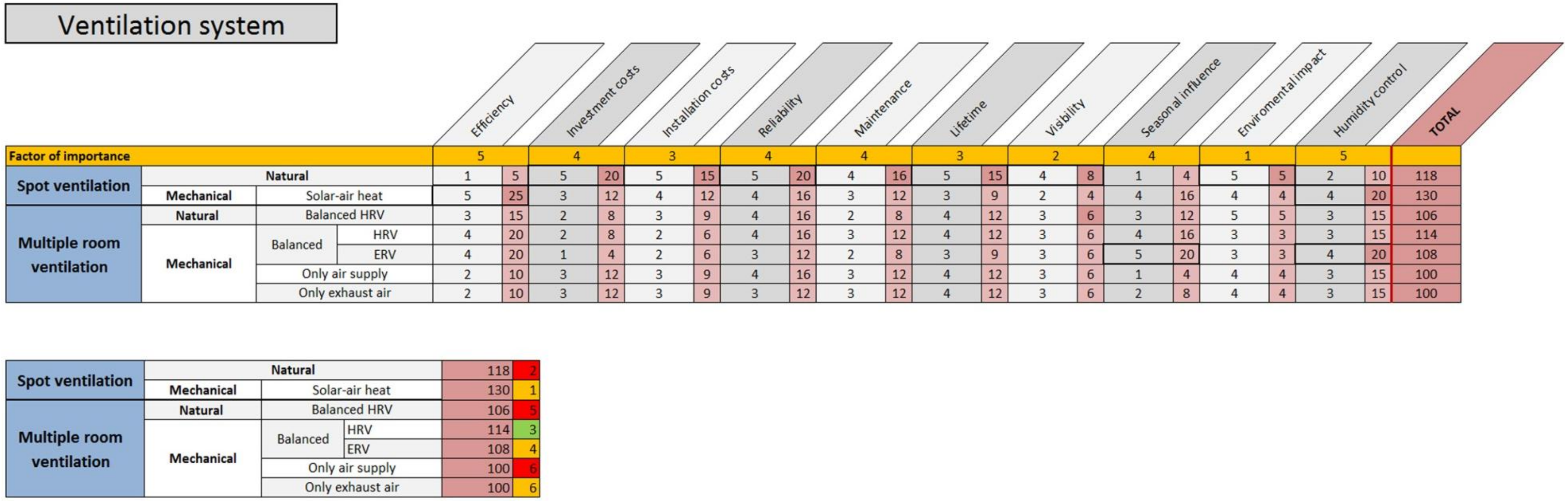
Heating system

				Efficiency		Investment costs		Installation costs		Reliability		Maintenance		Lifetime		Visibility		Seasonal influence		Environmental impact		TOTAL
Factor of importance				3		4		5		3		3		3		2		1		2		
Heat pumps	Ground heat	Closed loop		5	15	1	4	2	10	5	15	5	15	5	15	5	10	5	5	4	8	97
		Open loop		5	15	1	4	2	10	2	6	4	12	4	12	5	10	5	5	3	6	80
	(sea)Water heat	Bottom	Closed loop	2	6	2	8	3	15	3	9	3	9	4	12	4	8	3	3	3	6	76
			Open loop	3	9	3	12	4	20	3	9	2	6	3	9	4	8	3	3	3	6	82
		Under sediment		5	15	1	4	1	5	5	15	5	15	5	15	5	10	4	4	3	6	89
	Air heat			1	3	5	20	3	15	2	6	2	6	2	6	1	2	1	1	4	8	67
Solar collector	Evacuated tubes			1	3	3	12	4	20	3	9	3	9	2	6	2	4	1	1	3	6	70

Heat pumps	Ground heat	Closed loop		97	1
		Open loop		80	4
	(sea)Water heat	Bottom	Closed loop	76	5
			Open loop	82	3
		Under sediment		89	2
	Air heat			67	7
Solar collector	Evacuated tubes			70	6

Figure 8: Heating System Trade-Off

3.2.2 Ventilation System Trade-Off



Ventilation system

				Efficiency		Investment costs		Installation costs		Reliability		Maintenance		Lifetime		Visibility		Seasonal influence		Enviromental impact		Humidity control		TOTAL
Factor of importance				5		4		3		4		4		3		2		4		1		5		
Spot ventilation	Natural			1	5	5	20	5	15	5	20	4	16	5	15	4	8	1	4	5	5	2	10	118
	Mechanical	Solar-air heat		5	25	3	12	4	12	4	16	3	12	3	9	2	4	4	16	4	4	4	20	130
Multiple room ventilation	Natural	Balanced HRV		3	15	2	8	3	9	4	16	2	8	4	12	3	6	3	12	5	5	3	15	106
	Mechanical	Balanced	HRV	4	20	2	8	2	6	4	16	3	12	4	12	3	6	4	16	3	3	3	15	114
			ERV	4	20	1	4	2	6	3	12	2	8	3	9	3	6	5	20	3	3	4	20	108
		Only air supply		2	10	3	12	3	9	4	16	3	12	4	12	3	6	1	4	4	4	3	15	100
		Only exhaust air		2	10	3	12	3	9	3	12	3	12	4	12	3	6	2	8	4	4	3	15	100

Spot ventilation	Natural			118	2
	Mechanical	Solar-air heat		130	1
Multiple room ventilation	Natural	Balanced HRV		106	5
	Mechanical	Balanced	HRV	114	3
			ERV	108	4
		Only air supply		100	6
		Only exhaust air		100	6

Figure 9: Ventilation System Trade-Off

3.2.3 Explanation of different criteria.

Table 17: Explanation of different criteria

Criteria	Explanation
Efficiency	A percentage as a result of what is actually performed by a system, with what can be achieved with the same consumption of resources. High percentage, gives a better score.
Investment costs	The initial fee one has to pay for installing the complete system. Low price, gives a better score.
Installation costs	The cost to place and install system . Transportation costs are taken into account. The cheaper it is to operate the solution, the better is the score.
Reliability	The ability of a system to perform its intentional function without failing. This is often expressed as mean time between failures. If the time between failures is long, the score will be high.
Maintenance	Actions necessary for repairing or restoring a piece of equipment, machine, or system to the specified condition. This to maximize its useful lifetime. The lower the maintenance needed, the higher the score.
Lifetime	The time in which the system is running without replacing it. The longer the lifetime, the higher the score
Visibility	The capability of providing a unobstructed view, clear from all equipment, machines, or systems. If the system is affecting the view of the landscape, the score will be low
Seasonal influence	Influence that the seasons have on the system and its operation. A low seasonal influence, gives a high score.
Environmental impact	The way an installation and its operation affects the ecosystem. Low level of damage, gives high score.
Humidity control	Capacity of the system to control the humidity inside the building. High control capacity, gives high score.

3.2.4 Air source heat pump.

ZUBA-CENTRAL

Heating & Cooling. Evolved.

HEATING AND AIR CONDITIONING FOR WHOLE-HOME, YEAR-ROUND COMFORT

Energy-efficient. Easy to install. Extremely quiet. Zuba-Central is simply the new and better way to heat and cool your home or small business.

THE ZUBA-CENTRAL HEAT PUMP

Cooling

In summer, heat pump works like an air conditioner which cools your home by moving heat from indoor through the air handler to outdoor.

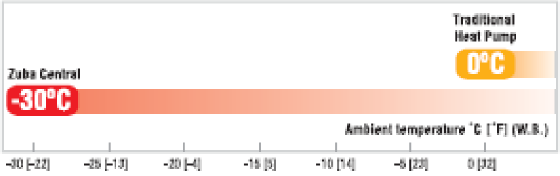
Heating

In winter, heat pump works in reverse. It absorbs heat from the outdoor air and moves it indoor to warm up your home.

Zuba-Central is a Heat Pump which provides heating and cooling to your home through ductwork. It is ranked among the most energy-efficient and cost-effective ways of transferring heat from one place to another.

OUTSTANDING PERFORMANCE

Zuba-Central's unique H^2i technology has you covered even during the coldest winter days.



Compared to other means of heating, heat pumps are very efficient, but only as long as outside temperatures stay above 0°C. From this point and below, a supplemental heating system has to be used.

Now with Zuba-Central, not only will you get the benefits of a heat pump above 0°C, but all the way below!

HYPER-HEAT INVERTER (H^2i)

The secret behind Zuba-Central's high-heating performance, even under extremely low outdoor temperatures, is our exclusive Hyper-Heat Inverter (H^2i) technology. It maximizes the benefits and efficiencies you can get from a heat pump.

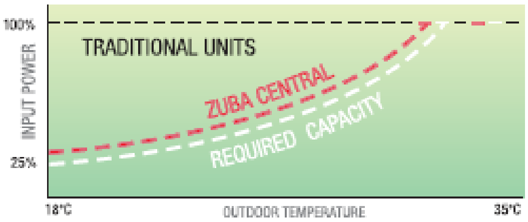
In addition, the unique defrost mechanism – which prevents automatic defrosting when not required – gives the system a quick start-up time and provides continuous heating.

EFFICIENTLY GREEN

Thinking Green Has Never Been So Efficient.

Now you can keep more money in your pocket while reducing your carbon footprint. The Zuba-Central system uses ozone-friendly R-410A refrigerant which produces no CFCs or HCFCs, and has zero Ozone Depletion Potential (ODP). This is not only beneficial to the environment but also translates into better overall performance and energy efficiency than traditional R-22 based systems.

Through the use of our VSCI Technology (Variable Compressor Speed Inverter) the Zuba-Central system is able to dynamically adjust heating and cooling capacities to match actual requirements of your home, which means you pay only for the required energy when you need it.

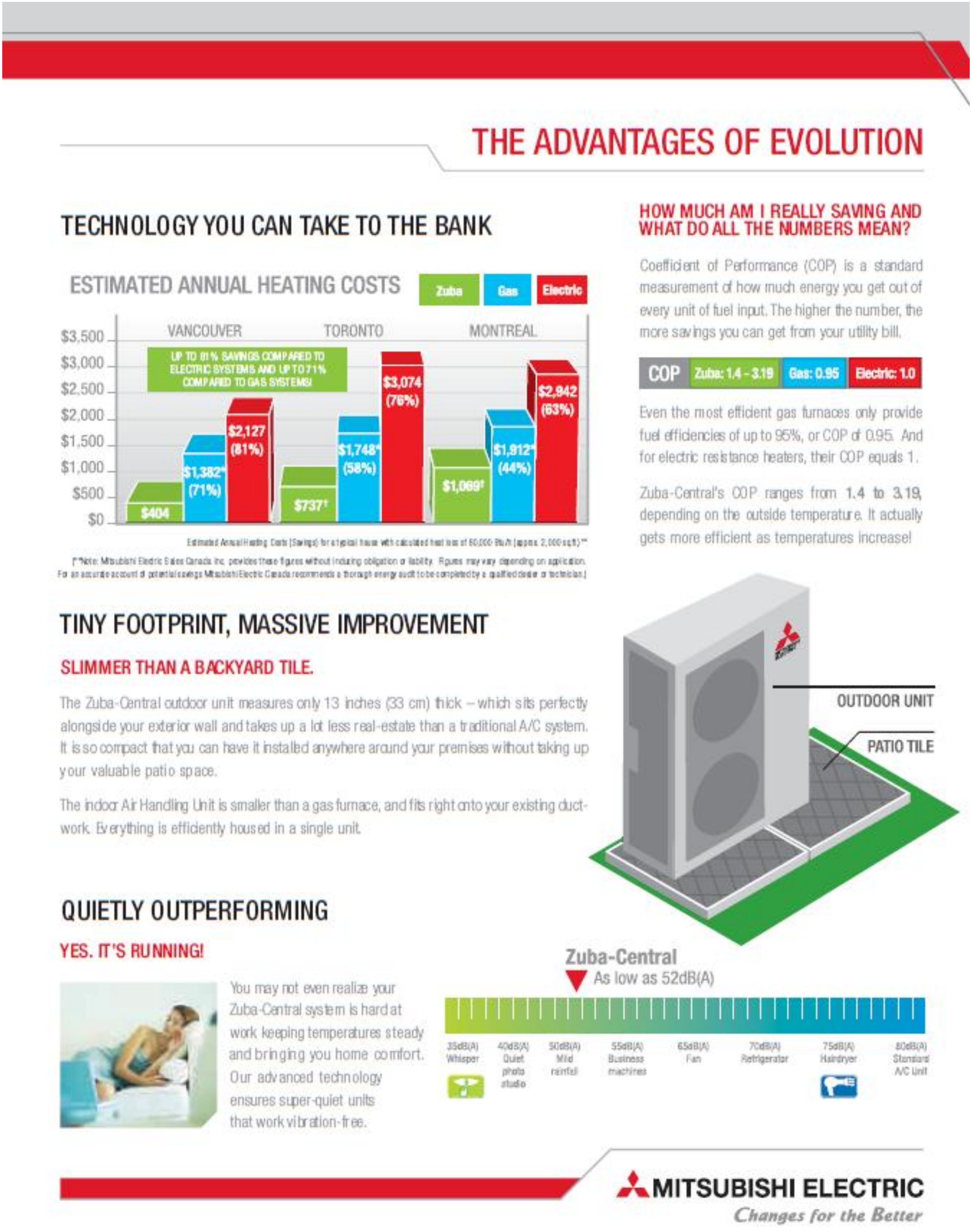


Zuba-Central is an Energy Star® qualified heat pump with a SEER[1] of 15.0 in cooling mode and an HSPF[2] of 9.4 in heating mode. Together with a high-efficiency ECM motor, you can be sure that you're always getting the most from your utility bill and giving the most back to the environment.

1. SEER (Seasonal Energy Efficiency Ratio) 2. HSPF (Heating Seasonal Performance Factor)

ENERGY STAR
HIGH EFFICIENCY
HAUTE EFFICACITÉ

15.0 SEER & 9.4 HSPF



THE ADVANTAGES OF EVOLUTION

TECHNOLOGY YOU CAN TAKE TO THE BANK

Estimated Annual Heating Costs (Savings) for a typical house with calculated heat loss of 60,000 Btu/h (approx. 2,000 sq.ft.)**

(**Note: Mitsubishi Electric Sales Canada Inc. provides these figures without inducing obligation or liability. Figures may vary depending on application. For an accurate account of potential savings Mitsubishi Electric Canada recommends a thorough energy audit to be completed by a qualified dealer or technician.)

HOW MUCH AM I REALLY SAVING AND WHAT DO ALL THE NUMBERS MEAN?

Coefficient of Performance (COP) is a standard measurement of how much energy you get out of every unit of fuel input. The higher the number, the more savings you can get from your utility bill.

COP	Zuba: 1.4 - 3.19	Gas: 0.95	Electric: 1.0

Even the most efficient gas furnaces only provide fuel efficiencies of up to 95%, or COP of 0.95. And for electric resistance heaters, their COP equals 1.

Zuba-Central's COP ranges from 1.4 to 3.19, depending on the outside temperature. It actually gets more efficient as temperatures increase!

TINY FOOTPRINT, MASSIVE IMPROVEMENT

SLIMMER THAN A BACKYARD TILE.

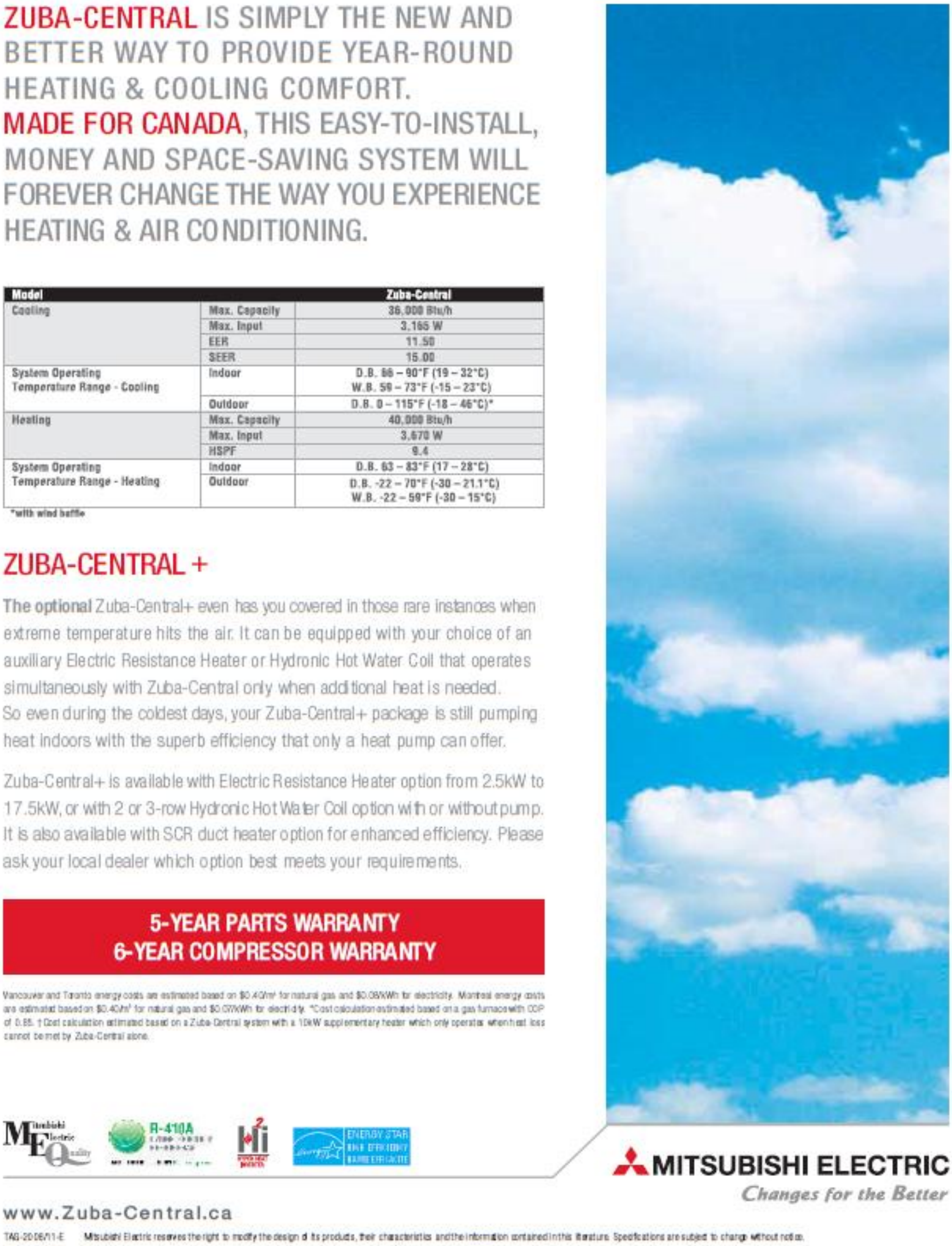
The Zuba-Central outdoor unit measures only 13 inches (33 cm) thick – which sits perfectly alongside your exterior wall and takes up a lot less real-estate than a traditional A/C system. It is so compact that you can have it installed anywhere around your premises without taking up your valuable patio space.

The indoor Air Handling Unit is smaller than a gas furnace, and fits right onto your existing duct-work. Everything is efficiently housed in a single unit.

QUIETLY OUTPERFORMING

YES. IT'S RUNNING!

You may not even realize your Zuba-Central system is hard at work keeping temperatures steady and bringing you home comfort. Our advanced technology ensures super-quiet units that work vibration-free.



ZUBA-CENTRAL IS SIMPLY THE NEW AND BETTER WAY TO PROVIDE YEAR-ROUND HEATING & COOLING COMFORT.
MADE FOR CANADA, THIS EASY-TO-INSTALL, MONEY AND SPACE-SAVING SYSTEM WILL FOREVER CHANGE THE WAY YOU EXPERIENCE HEATING & AIR CONDITIONING.

Model		Zuba-Central
Cooling	Max. Capacity	36,000 Btu/h
	Max. Input	3,165 W
	EER	11.50
	SEER	15.00
System Operating Temperature Range - Cooling	Indoor	D.B. 66 – 90°F (19 – 32°C) W.B. 59 – 73°F (-15 – 23°C)
	Outdoor	D.B. 0 – 115°F (-18 – 46°C)*
Heating	Max. Capacity	40,000 Btu/h
	Max. Input	3,670 W
	HSPF	9.4
System Operating Temperature Range - Heating	Indoor	D.B. 63 – 83°F (17 – 28°C)
	Outdoor	D.B. -22 – 70°F (-30 – 21.1°C) W.B. -22 – 59°F (-30 – 15°C)

*with wind baffle

ZUBA-CENTRAL +

The optional Zuba-Central+ even has you covered in those rare instances when extreme temperature hits the air. It can be equipped with your choice of an auxiliary Electric Resistance Heater or Hydronic Hot Water Coil that operates simultaneously with Zuba-Central only when additional heat is needed. So even during the coldest days, your Zuba-Central+ package is still pumping heat indoors with the superb efficiency that only a heat pump can offer.

Zuba-Central+ is available with Electric Resistance Heater option from 2.5kW to 17.5kW, or with 2 or 3-row Hydronic Hot Water Coil option with or without pump. It is also available with SCR duct heater option for enhanced efficiency. Please ask your local dealer which option best meets your requirements.

5-YEAR PARTS WARRANTY
6-YEAR COMPRESSOR WARRANTY

Vancouver and Toronto energy costs are estimated based on $0.40/m^3 for natural gas and $0.08/kWh for electricity. Montreal energy costs are estimated based on $0.40/m^3 for natural gas and $0.07/kWh for electricity. *Cost calculation estimated based on a gas furnace with COP of 0.85. † Cost calculation estimated based on a Zuba-Central system with a 10kW supplementary heater which only operates when heat loss cannot be met by Zuba-Central alone.

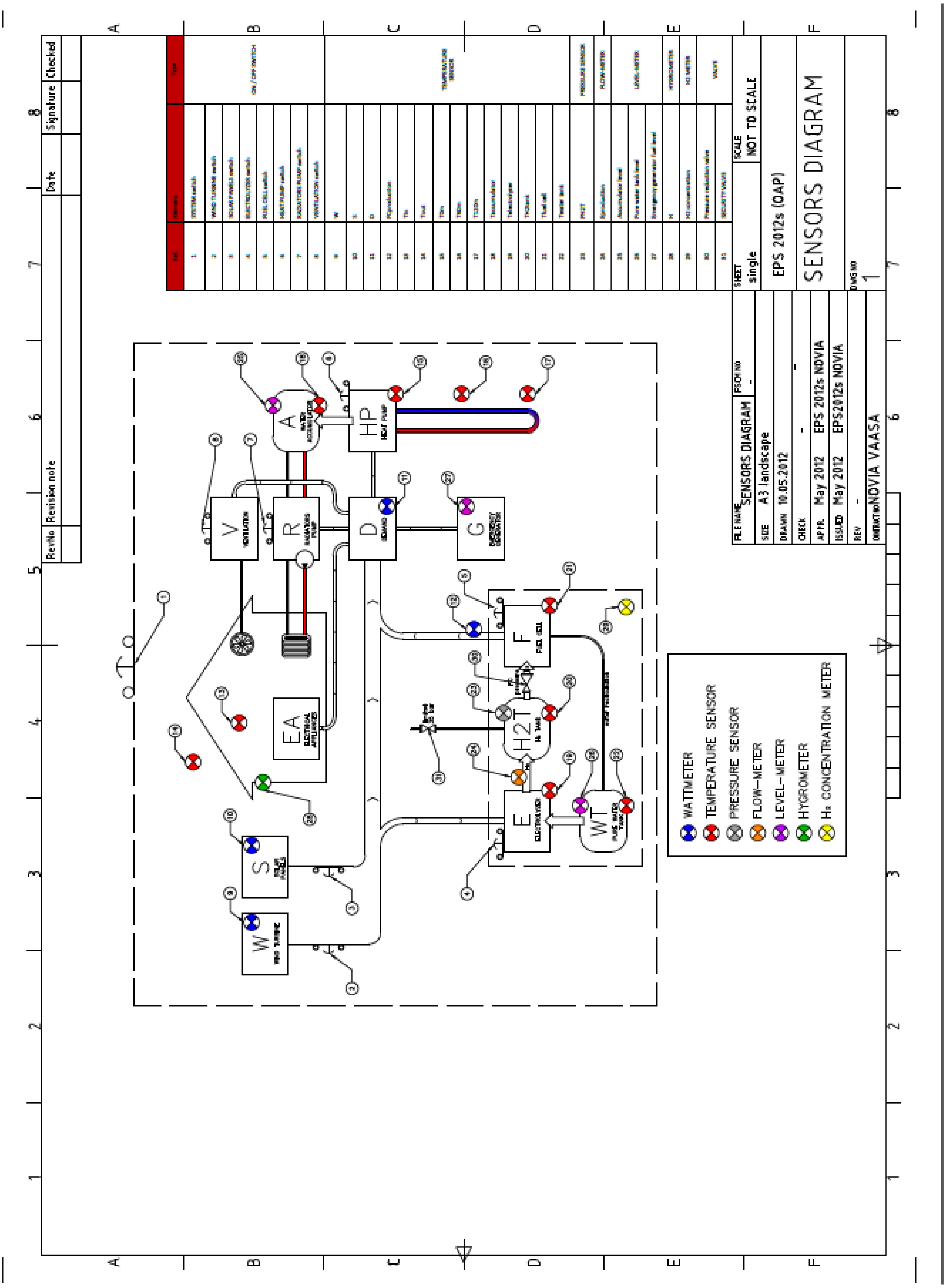
MITSUBISHI ELECTRIC
Changes for the Better

www.Zuba-Central.ca

TAG-2008/11-E Mitsubishi Electric reserves the right to modify the design of its products, their characteristics and the information contained in this literature. Specifications are subject to change without notice.

(ZUBA-CENTRAL, 2008)

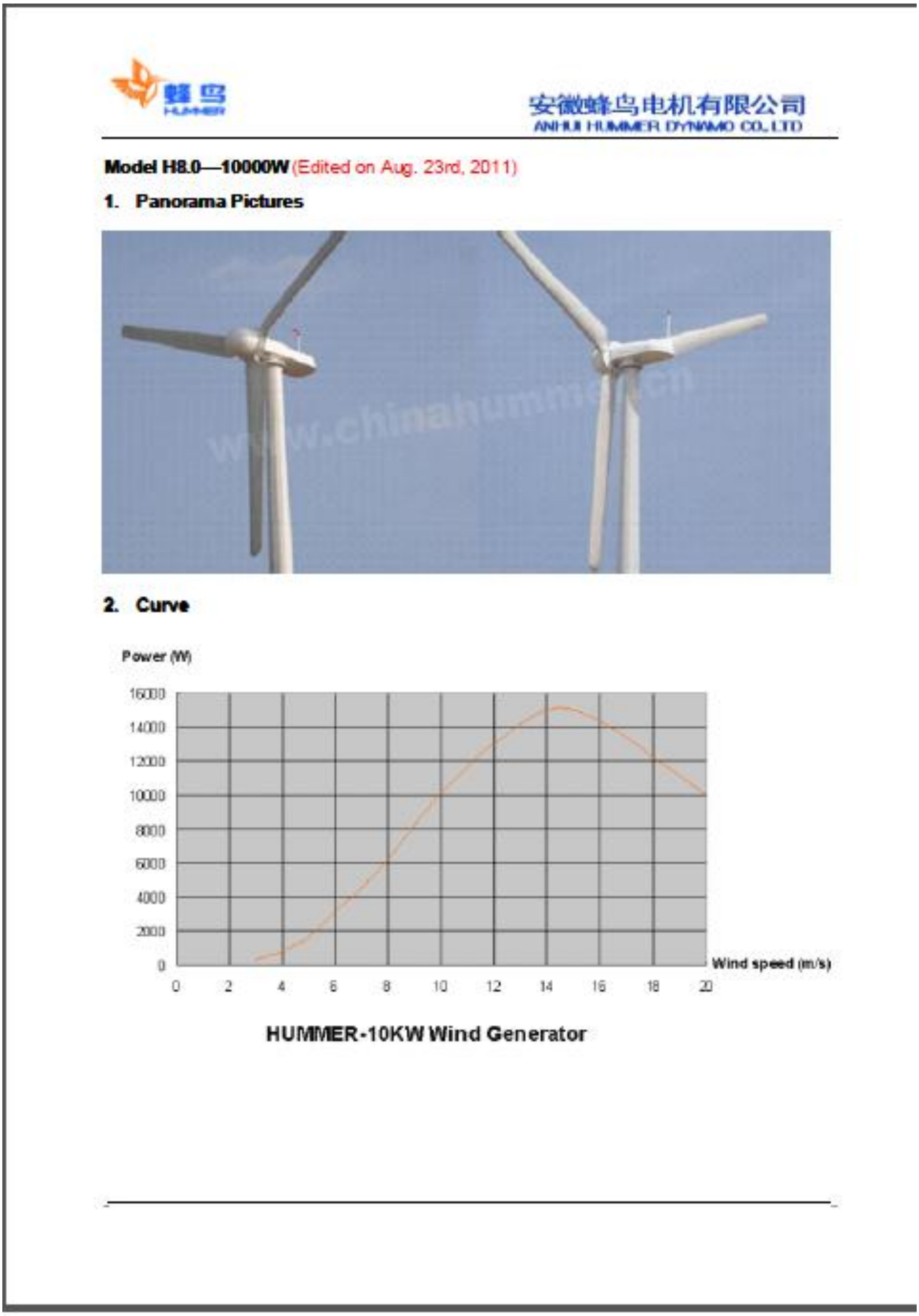
3.3 Appendix 13: Sensors Diagram



Figure??: SENSORS DIAGRAM

4 Results

4.1 Appendix 14: Wind Turbine Datasheet



蜂鸟 HUMMER

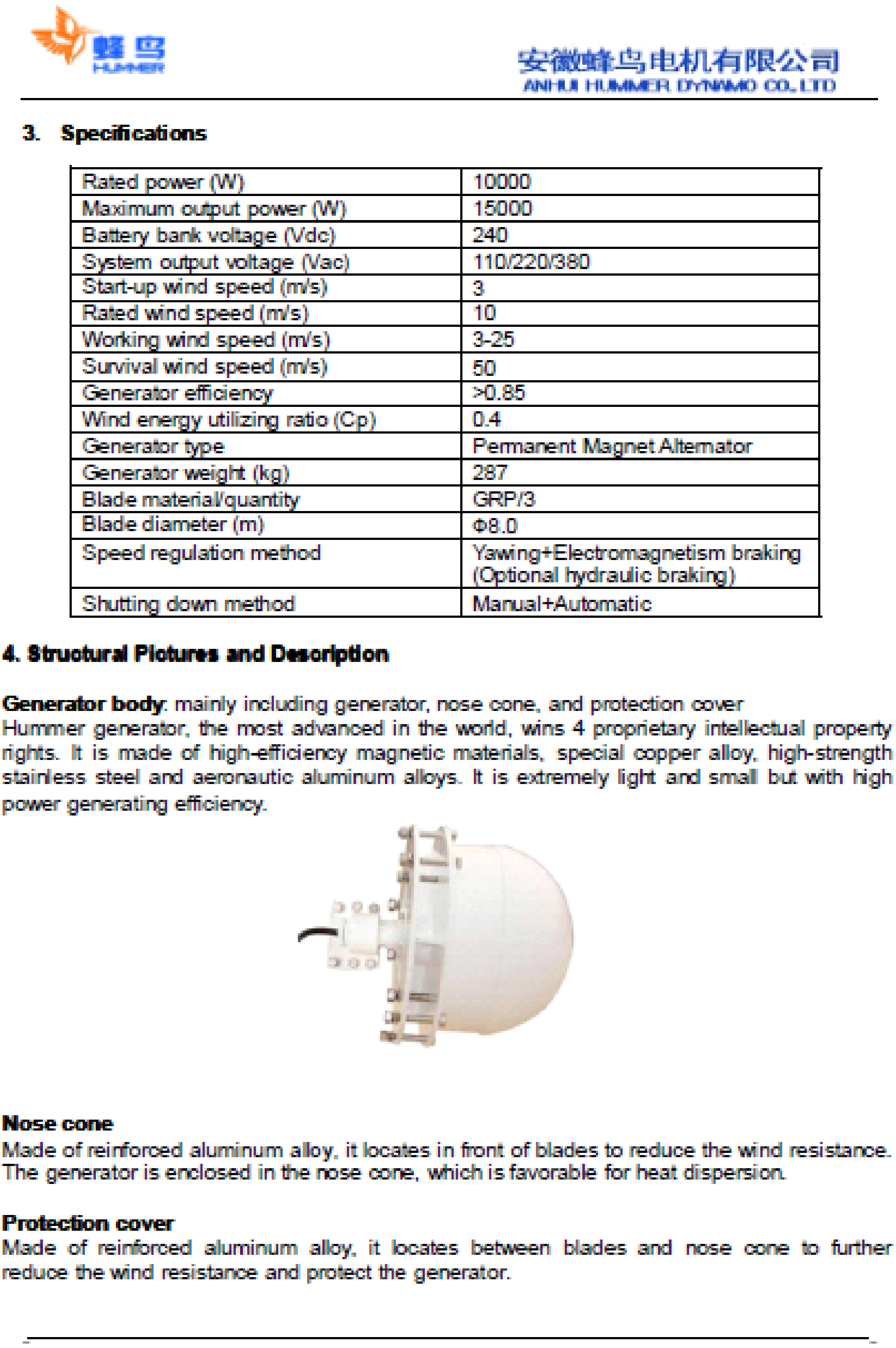
安徽蜂鸟电机有限公司
ANHUI HUMMER DYNAMO CO., LTD

Model H8.0—10000W (Edited on Aug. 23rd, 2011)

1. Panorama Pictures

2. Curve

HUMMER-10KW Wind Generator



3. Specifications

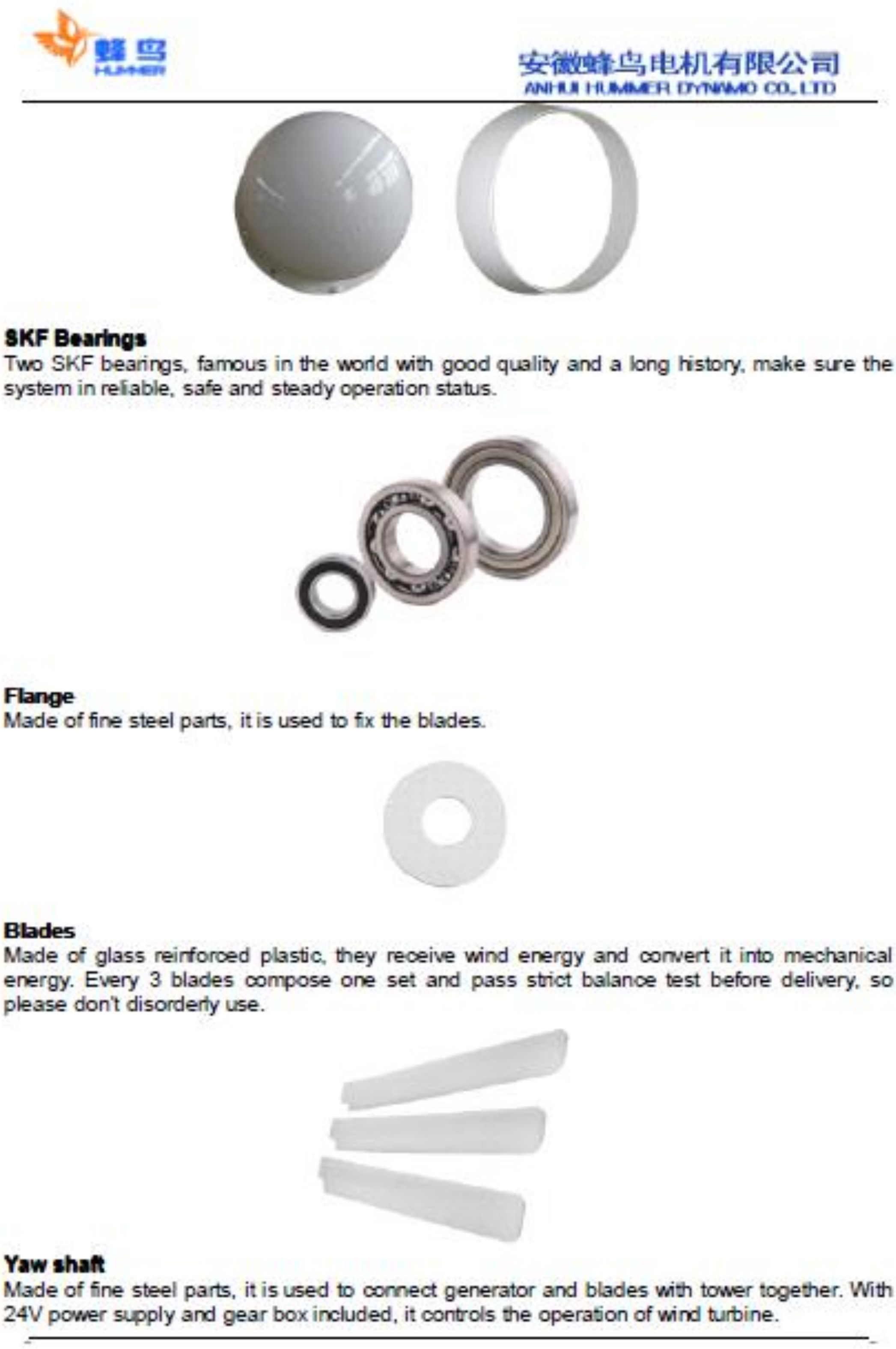
Rated power (W)	10000
Maximum output power (W)	15000
Battery bank voltage (Vdc)	240
System output voltage (Vac)	110/220/380
Start-up wind speed (m/s)	3
Rated wind speed (m/s)	10
Working wind speed (m/s)	3-25
Survival wind speed (m/s)	50
Generator efficiency	>0.85
Wind energy utilizing ratio (Cp)	0.4
Generator type	Permanent Magnet Alternator
Generator weight (kg)	287
Blade material/quantity	GRP/3
Blade diameter (m)	Φ8.0
Speed regulation method	Yawing+Electromagnetism braking (Optional hydraulic braking)
Shutting down method	Manual+Automatic

4. Structural Pictures and Description

Generator body: mainly including generator, nose cone, and protection cover
Hummer generator, the most advanced in the world, wins 4 proprietary intellectual property rights. It is made of high-efficiency magnetic materials, special copper alloy, high-strength stainless steel and aeronautic aluminum alloys. It is extremely light and small but with high power generating efficiency.

Nose cone
Made of reinforced aluminum alloy, it locates in front of blades to reduce the wind resistance. The generator is enclosed in the nose cone, which is favorable for heat dispersion.

Protection cover
Made of reinforced aluminum alloy, it locates between blades and nose cone to further reduce the wind resistance and protect the generator.



蜂鸟 HUMMER

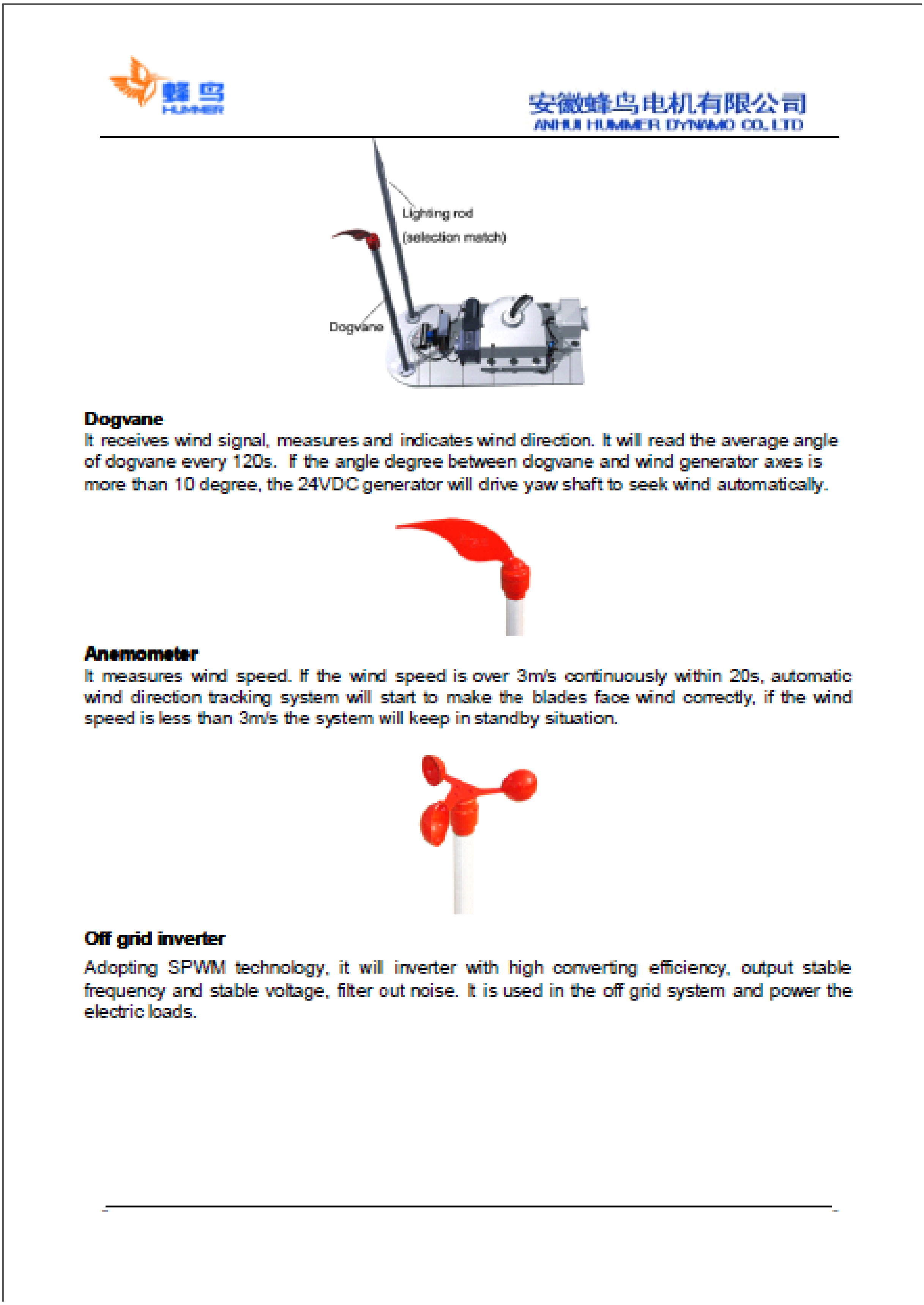
安徽蜂鸟电机有限公司
ANHUI HUMMER DYNAMO CO., LTD

SKF Bearings
Two SKF bearings, famous in the world with good quality and a long history, make sure the system in reliable, safe and steady operation status.

Flange
Made of fine steel parts, it is used to fix the blades.

Blades
Made of glass reinforced plastic, they receive wind energy and convert it into mechanical energy. Every 3 blades compose one set and pass strict balance test before delivery, so please don't disorderly use.

Yaw shaft
Made of fine steel parts, it is used to connect generator and blades with tower together. With 24V power supply and gear box included, it controls the operation of wind turbine.



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ANHUI HUMMER DYNAMO CO., LTD

Dogvane

It receives wind signal, measures and indicates wind direction. It will read the average angle of dogvane every 120s. If the angle degree between dogvane and wind generator axes is more than 10 degree, the 24VDC generator will drive yaw shaft to seek wind automatically.

Anemometer

It measures wind speed. If the wind speed is over 3m/s continuously within 20s, automatic wind direction tracking system will start to make the blades face wind correctly, if the wind speed is less than 3m/s the system will keep in standby situation.

Off grid inverter

Adopting SPWM technology, it will inverter with high converting efficiency, output stable frequency and stable voltage, filter out noise. It is used in the off grid system and power the electric loads.

蜂鸟 HUMMER

安徽蜂鸟电机有限公司
ANHUI HUMMER DYNAMO CO.,LTD

Grid tied inverter

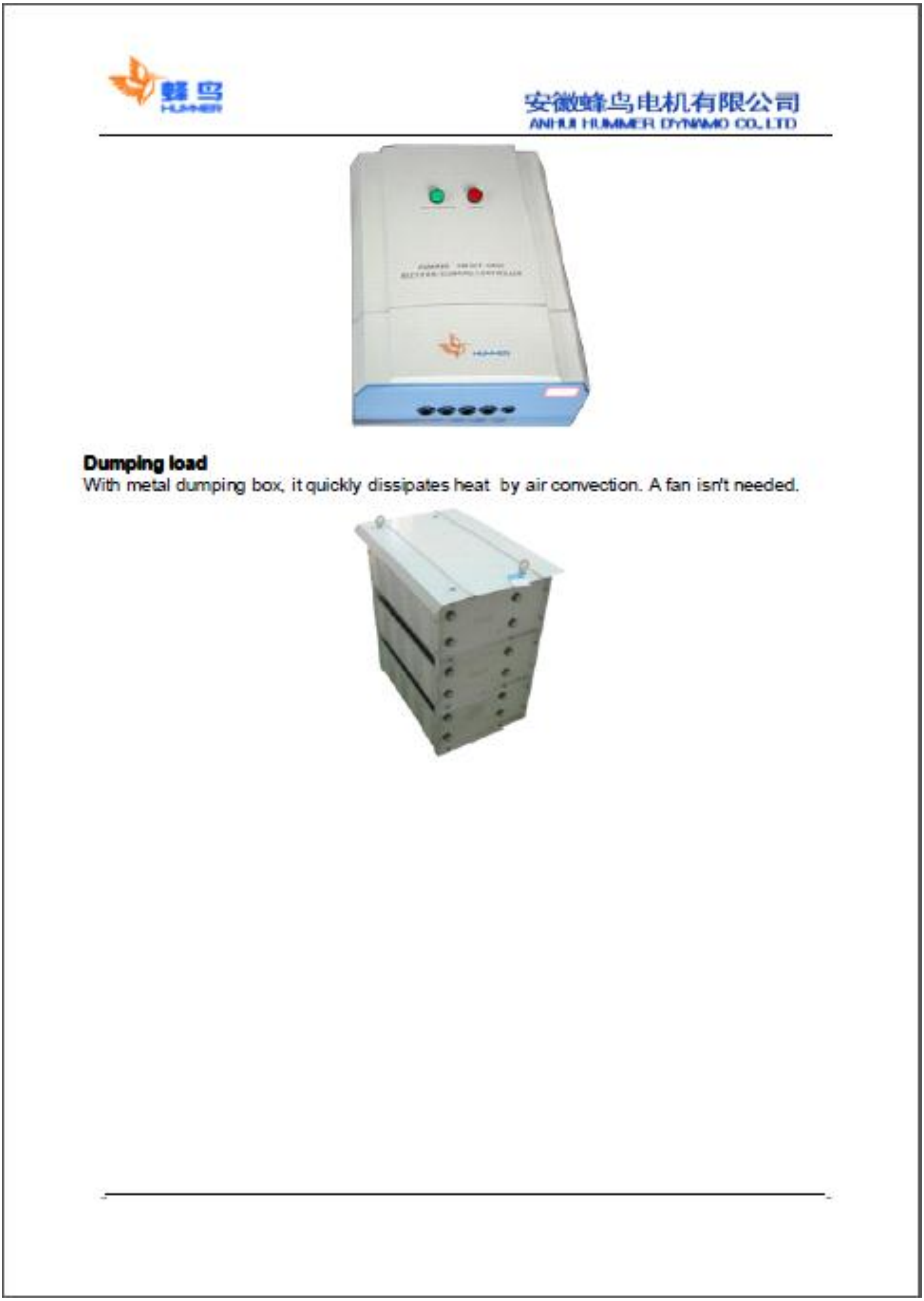
Adopting MPPT and IGBT technologies, It inverters with high power generating capacity and wide AC voltage range. It connect with state grid and the energy storing device isn't needed.

PLC controller

As adopting Siemens CPU the technology of touch screen, it will alarm automatically and regulate the operation situation of wind generator. Users can also set the parameters according to actual needs.

Rectifier/ dumping controller

It rectifies AC current generated by wind generator into DC current and charge the battery bank. It also controls the dumping load.



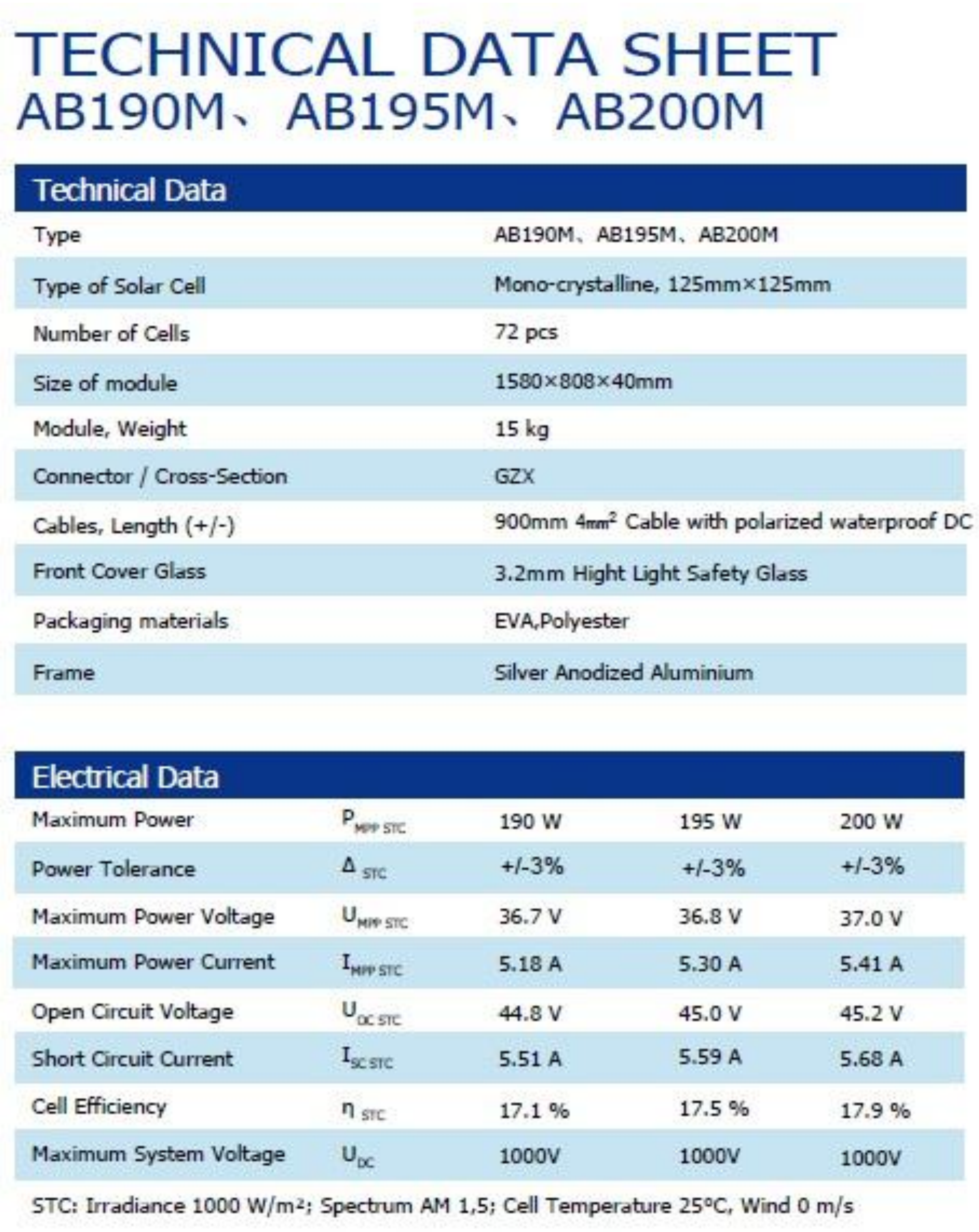
安徽蜂鸟电机有限公司
ANHUI HUMMER DYNAMO CO.,LTD

Dumping load

With metal dumping box, it quickly dissipates heat by air convection. A fan isn't needed.

(Anhui Hummer Dynamo Co., Ltd., 2011)

4.2 Appendix 15: Solar Panel Datasheet



TECHNICAL DATA SHEET
AB190M、AB195M、AB200M

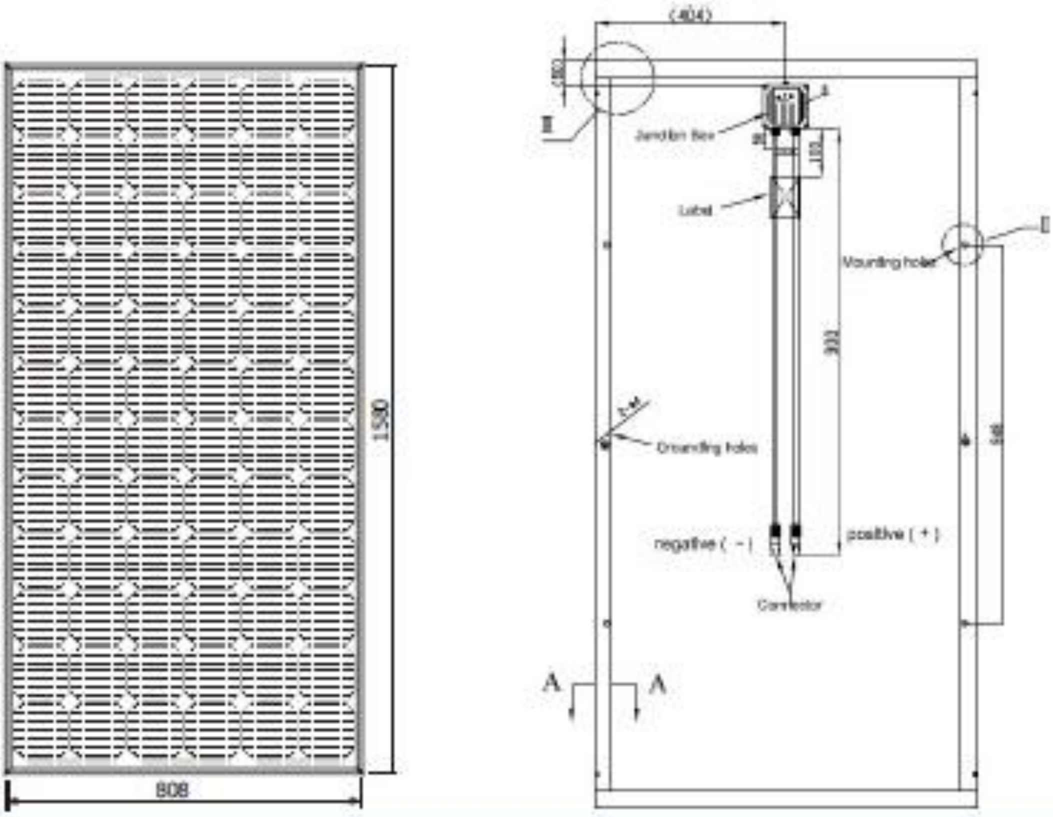
Technical Data

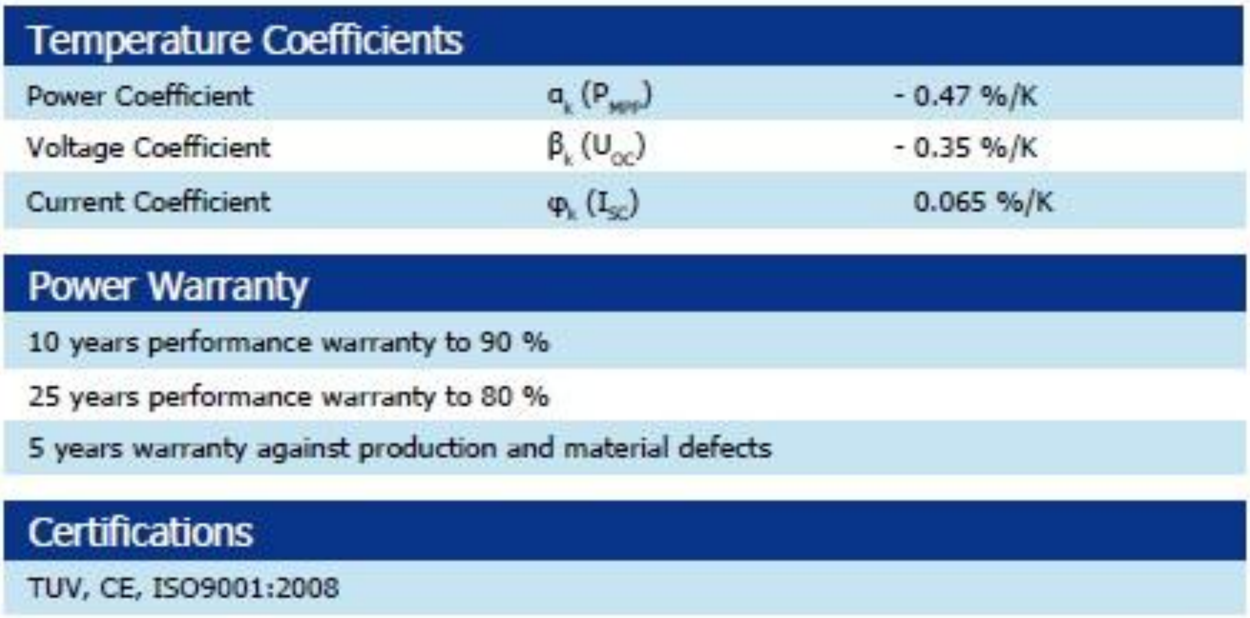
Type	AB190M、AB195M、AB200M
Type of Solar Cell	Mono-crystalline, 125mm×125mm
Number of Cells	72 pcs
Size of module	1580×808×40mm
Module, Weight	15 kg
Connector / Cross-Section	GZX
Cables, Length (+/-)	900mm $4mm^2$ Cable with polarized waterproof DC
Front Cover Glass	3.2mm Hight Light Safety Glass
Packaging materials	EVA,Polyester
Frame	Silver Anodized Aluminium

Electrical Data

Maximum Power	$P_{MPP\ STC}$	190 W	195 W	200 W
Power Tolerance	Δ_{STC}	+/-3%	+/-3%	+/-3%
Maximum Power Voltage	$U_{MPP\ STC}$	36.7 V	36.8 V	37.0 V
Maximum Power Current	$I_{MPP\ STC}$	5.18 A	5.30 A	5.41 A
Open Circuit Voltage	$U_{OC\ STC}$	44.8 V	45.0 V	45.2 V
Short Circuit Current	$I_{SC\ STC}$	5.51 A	5.59 A	5.68 A
Cell Efficiency	η_{STC}	17.1 %	17.5 %	17.9 %
Maximum System Voltage	U_{DC}	1000V	1000V	1000V

STC: Irradiance 1000 W/m²; Spectrum AM 1,5; Cell Temperature 25°C, Wind 0 m/s





Temperature Coefficients

Power Coefficient	α_k (P_{MPP})	- 0.47 %/K
Voltage Coefficient	β_k (U_{OC})	- 0.35 %/K
Current Coefficient	φ_k (I_{SC})	0.065 %/K

Power Warranty

10 years performance warranty to 90 %

25 years performance warranty to 80 %

5 years warranty against production and material defects

Certifications

TUV, CE, ISO9001:2008

(Xuzhou Aibo Energy Technology Co.,Ltd, 2012)

4.3 Appendix 16: Generator Datasheet

TELGENCO

Quiet48-5

5 kW 48V DC
Quiet Integrated
Power System

Overview

Quiet48-5 is Telgenco's ultra quiet 5kW 48V DC diesel powered battery charging system. Quiet48-5 provides over 100 amps of clean DC output to plug directly into an existing 48V battery bank or to replace it altogether with Quiet48-5 internal battery bank.

The Quiet48-5 is designed primarily to provide DC power for communications sites in urban environments or remote rural areas. The standard Quiet48-5 system includes diesel engine, fuel tank, battery bank and Remote Power Controller housed within a vandal resistant acoustic enclosure. The acoustic design is integral to all Telgenco gensets, our philosophy is to make the Quiet48-5 at full operating speed quieter than a modern diesel engined car at idle. This allows Quiet48-5 to be deployed in locations where conventional gensets would cause a noise nuisance.

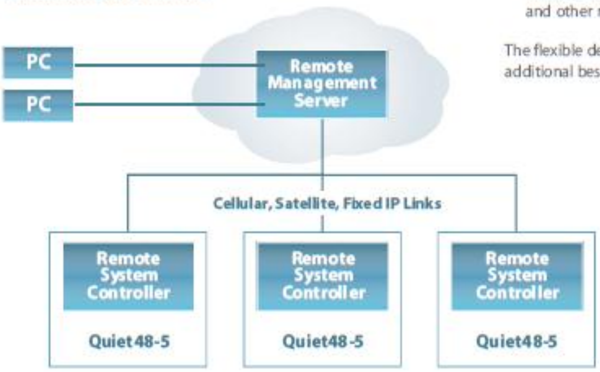
The Quiet48-5 also has a number of integrated component options including a solar PV charging controller, a mains powered rectifier and an AC supply inverter (for dual AC/DC output). These options are all integrated with the remote control system and central software providing operators of the system with unrivalled visibility of the site power status. The options can save operators money and reduce the number of descrete boxes on a site. All the optional components are housed within the Quiet48-5 vandal resistant enclosure improving overall site security.

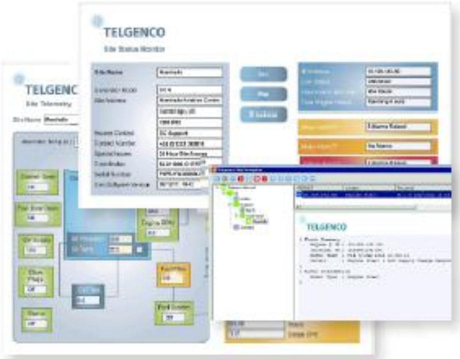
Key Benefits

The Quiet48-5 is a state of the art system with a number of key benefits over more conventional generators. Key benefits include:

- Automated remote control
- Full engine monitoring and control
- Predictive maintenance logging and alerting
- System alarms optionally delivered via SMS and email
- Internal UMTS/GPRS wireless modem with GPS
- Extremely quiet operation
- Clean 48V DC output
- Integral 48V battery bank
- leak free bunded internal fuel tank
- Rugged vandal resistant construction
- 100% Biofuel engine option
- Integrated solar PV charging option
- Integrated mains rectifier option

Telgenco Remote Generator Monitoring and Control





Remote Power Controller

The Telgenco Remote Power Controller is mounted within the Quiet48-5 enclosure. It monitors and manages a wide range of critical engine and fuel system parameters as well as generator site security.

The Remote Power Controller interfaces back to the Telgenco Remote Management Server via fixed IP, satellite or the built-in 9 Band UMTS/GPRS modem. For Mobile or rental environments the Remote Power Controller also provides accurate GPS based position reporting for asset tracking.

The Remote Power Controller undertakes multiple management functions in the Quiet48-5 including:

- Auto start management
- Fuel system monitoring & reporting
- Lubrication system monitoring & reporting
- Cooling system monitoring & reporting
- Filter conditions monitoring & reporting
- Engine and environment temperature monitoring & reporting
- Recording engine hours
- Security monitoring & reporting
- Unauthorised system movement detection
- DC charging management
- Battery condition management
- Genset voltage control
- Geographic location reporting
- Video monitoring of genset site
- Remote communications and monitoring of solar PV and other renewable controllers

The flexible design of the Remote Power Controller allows additional bespoke monitoring functionality to be easily added.

Battery Protection

From the outset the Quiet48-5 has been developed to provide a safe and controlled system for charging DC battery banks. The system monitors the battery voltage, the battery temperature and the load current and uses internal algorithms to provide the correct amount of voltage into the battery bank for the given conditions. The algorithms control the engine speed 50 times per second to vary the voltage to the appropriate level. Varying the engine speed according to load also has the advantage of saving fuel. In addition to the software control there are built-in hardware protection circuits to ensure that the battery bank is not overcharged under any circumstances.

Renewable Energy Integration

The Quiet48-5 has been designed from the outset to be easily integrated into a renewable energy solution. The Quiet48-5 can be supplied with an optional 48V solar PV charging controller with either a 4 kW or 8 kW solar capacity. This controller is integrated with the Remote Power Controller to provide full remote visibility of the entire system including solar output and battery status. When the power demand is not met by the solar output or the energy stored in the battery bank the Quiet48-5 automatically starts its diesel alternator.

The Quiet48-5 has a 100% biofuel compatible engine option, this allows the system to be used as a totally hydrocarbon free renewable energy exchange with consequent environmental benefits.

Rugged and Ultra Quiet Construction

The outer skin of the Quiet48-5 is constructed from 3mm thick zinc coated steel plate which is polyester powder coated for lasting durability. The outer skin is designed to resist vandal and theft attacks and dramatically reduce vulnerability compared with conventional thin sheet construction. The Quiet48-5 has a 50mm thick thermal and acoustic insulation layer sandwiched between the outer skin and an internal galvanised steel skin. This significantly reduces the engine noise radiating out of the enclosure. The exhaust is passed through two sequential silencers and the intake and exhaust air travel in and out of the enclosure via acoustic silencers. This attention to sound reduction ensures that the Quiet48-5 has a SPL lower than 50 dBA at 10m.

Combined DC and AC output

While the standard output of the Quiet48-5 products is DC in some circumstances customers have some AC devices on site that they want protected from power failure. An example of this might be a communications site in a hot location where functional air conditioning is critical to the stability of the communications electronics. To accommodate this we are able to include an optional inverter to provide a proportion of the power in either 100, 110, or 240V AC. Under this scenario in the event of the incoming power failing the DC communications system and the AC cooling system will continue to function normally.

Environmental Protection and Emissions Compliance

Telgenco is committed to protecting the environment. Our Quiet48-5 are manufactured from environmentally inert materials and designed to be almost completely recycled at their end of life. The internal fuel tank is fully enclosed within a leak free bund with active leak detection and alarms. The fuel filler has an integral overfill protection system ensuring spill free refuelling. The engines we use are compliant with European and US emissions standards including Tier 4 Interim.

Warranty, Support and Finance

All Quiet48-5 systems are sold with a comprehensive 3 year warranty on parts and labour and a 7 year corrosion warranty. At the end of the warranty period there is an option to purchase an extended warranty. Telgenco provide comprehensive support and training during the installation and commissioning phase of new deployments. After installation we provide 3rd tier support to your system managers on an as required basis. For larger deployments (of 50 or more systems) we can provide a financing scheme to qualifying companies, this can spread the capital costs of systems over several years improving the project payback period.

About Telgenco

Telgenco (part of Controllis Limited) is based in the UK with headquarters in Cambridge, the heart of the Silicon Fen high-tech cluster. Controllis was founded in 2008 with a vision to provide remotely managed systems for a range of different markets. Our engineering team is made up of highly experienced engineers, software developers and technicians from the Telecommunications, Power Generation, Defence and Formula 1 Motorsport sectors. The company is privately owned and funded by the management team, a number of private investors and a UK based defence and aerospace company.

TELGENCO

Quiet48-5 Specifications

Power Output	100 A DC at 48V to 65V
Voltage Ripple	<100 millivolts peak
Engine	Perkins 3 Cylinder 1100cc or Lister Petter 2 900cc (customer choice)
Fuel	Diesel, Indirect Injection, Up to B100 with Lister Engine Option
Built in Remote Power Controller	Auto Engine Start
	Electronic Throttle Control
	48V Intelligent Charging System
	12V Intelligent Charging System
	Battery Temperature Monitoring
	Fuel Level
	Oil Level
	Oil Filter Pressure Drop
	Fuel Filter Pressure Drop
	Air Filter Pressure Drop
	Coolant Temperature
	Oil Temperature
	Environmental Temperature
	Exhaust Temperature
	Oil Quality Sensor (Optional)
Communications	Ethernet with built-in UMTS/GSM (see Remote System Controller datasheet for full details)
Internal Fuel Tank	200 litres
	Optional external fuel tank connection
Frame Construction	All Welded Steel
Corrosion Protection	All external components galvanised or hot zinc sprayed
Paint	Oven Baked Polyester Powder Coated
Colour	Standard RAL7035 (Other colours optional)
Noise Level	<50 dB(A) at 10m free field
Emissions	EURO stage IV and EPA Tier4 Compliant
Environmental Operating Temperature	-40C to +55C
Dimensions WxHxD	1510 x 1888 x 1100
Weight	650Kg

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(TELGENCO, 2012)

4.4 Appendix 17: Electrolyzer Datasheet

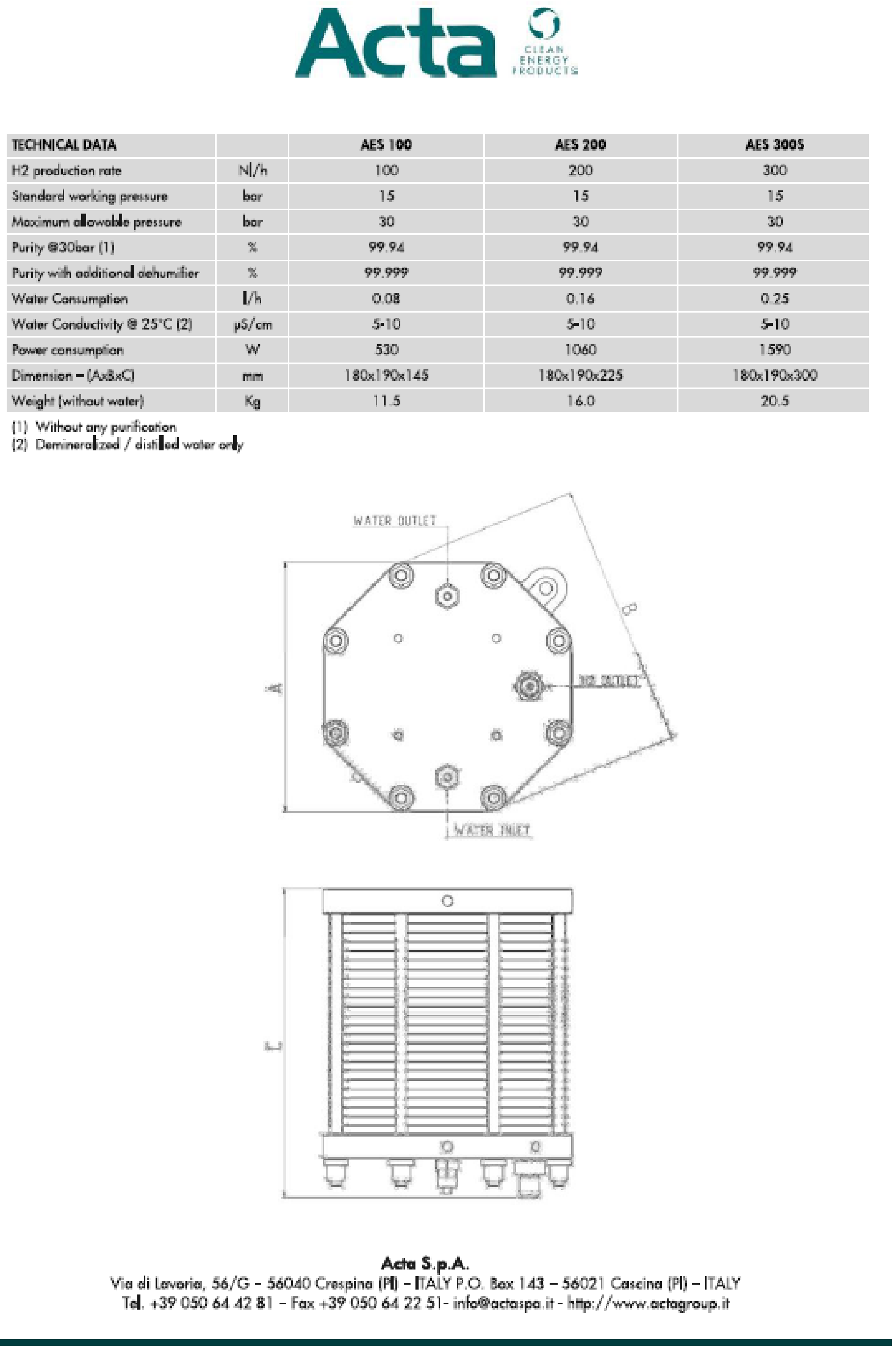
AES 100 – 200 – 300S

Acta Energy's 100, 200 and 300S stacks produce dry, pure and compressed hydrogen at 30 bar. Innovative technology, patented by ACTA and using solid polymeric membrane, produces hydrogen of excellent quality at the low cost typical of liquid electrolyte electrolysers.
Acta's stacks can be used in electrolyzers for the distributed generation of hydrogen in domestic, industrial and vehicle applications, combined directly with intermittent renewable energy (wind and solar).

FEATURES
Produces compressed, pure, dry hydrogen at 30 bar
Directly interfaced with renewable power sources
Safe
Compact
Simple
Low cost, competitive to liquid electrolyte systems

HYDROGEN SPECIFICATION
H_2 Purity: 99.94 % @ 30 bar (without any purification system)
99.999% with optional purification system
Purity residual: H_2O @ 30 bar 600 ppm

WATER SPECIFICATION
Distilled Water (Conductivity at 25 °C): 5 – 10 μS/cm
only 1% Potassium Carbonate (non consumed)



TECHNICAL DATA		AES 100	AES 200	AES 300S
H2 production rate	Nl/h	100	200	300
Standard working pressure	bar	15	15	15
Maximum allowable pressure	bar	30	30	30
Purity @30bar (1)	%	99.94	99.94	99.94
Purity with additional dehumifier	%	99.999	99.999	99.999
Water Consumption	l/h	0.08	0.16	0.25
Water Conductivity @ 25°C (2)	µS/cm	5-10	5-10	5-10
Power consumption	W	530	1060	1590
Dimension – (AxBxC)	mm	180x190x145	180x190x225	180x190x300
Weight (without water)	Kg	11.5	16.0	20.5

(1) Without any purification
(2) Demineralized / distilled water only

Acta S.p.A.
Via di Lavoria, 56/G – 56040 Crespina (PI) – ITALY P.O. Box 143 – 56021 Cascina (PI) – ITALY
Tel. +39 050 64 42 81 – Fax +39 050 64 22 51- info@actaspa.it - http://www.actagroup.it

(ACTA S.p.A.)

4.5 Appendix 18: Fuel Cell Dantherm DBX5000 Datasheet

DATA SHEET: BACK UP POWER

Dantherm Power

DBX5000H48-B-HV

Dantherm Battery eXtender – DBX5000

TECHNOLOGY

Dantherm Power systems are complete Backup Power solutions designed and configured to be installed in both in- or out- door applications for telecom and related networks. The solutions can be configured as both integrated and stand-alone modules.

The Battery eXtender uses hydrogen fuel cell technologies with fully integrated power management and various configurations possible.

WHERE TO USE BATTERY EXTENDER BACKUP POWER SOLUTIONS?

The Dantherm Battery eXtender (DBX) is installed in parallel with batteries. The DBX is ideal in environments with an unstable mains (grid) where equipment must be protected from power outages and business continuity demands reliable backup power. In case of mains power outage the batteries will provide Backup instantly and the DBX-module provides support when the DC bus voltage drops or when a timer set point is reached.

FEATURES

- Very low maintenance cost (site visits only required every 5 years)
- Prevents batteries from deep discharge, thereby extending life
- Very low noise, can be installed almost anywhere
- No lead pollution and no harmful substances or emissions
- Easy to increase Backup time to 8, 12, 24, 48 or even 168 hours or more
- Compact, modular and scalable systems for network growth
- Programmable Self-test ensures system readiness
- Floating GND – can work in both -48VDC and +48VDC
- Very high power density in relation to weight as well as volume
- Fuel storage in up to three strings for hot-swap and easy monitoring

CONFIGURATIONS

- Mounts in 19" and 23" racks, 2 or 4 post cabinets/racks
- Parallel with batteries and other modules for redundancy and higher capacity
- Can be mounted in outdoor cabinets, shelters or similar
- Easy to install on existing shelter sites

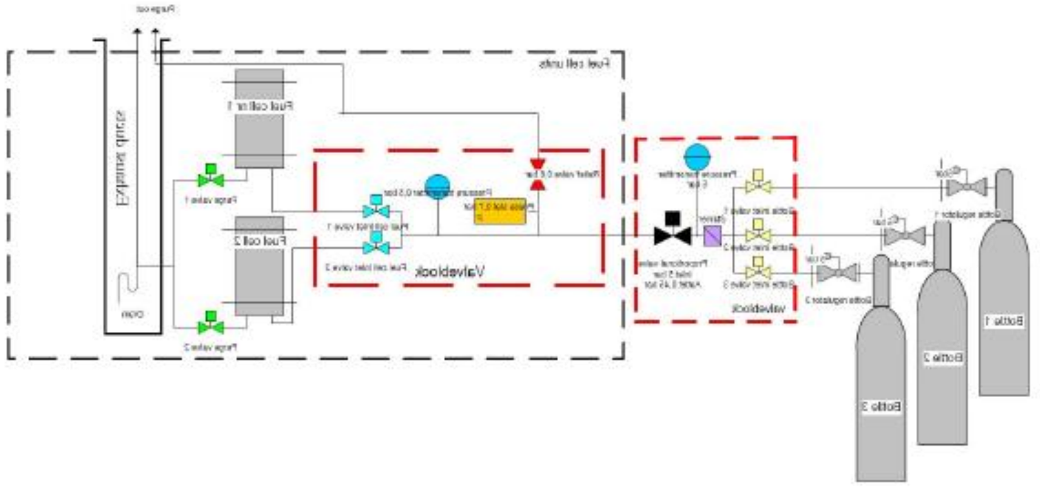
PRODUCT CODE – DBX5000H48-B-HH

- DBX: Dantherm Battery eXtender
- 5000: Nominal stack output power – End of Life
- H: Hydrogen fuelled
- 48: 48 VDC range (fixed voltage within (47 - 57 VDC))
- AC-input voltage: (Please clarify on order)
  - A: 110 VAC
  - B: 230 VAC
- Air-flow: (Please clarify on order)
  - HH: Horizontal in – Horizontal out
  - HV: Horizontal in – Vertical out

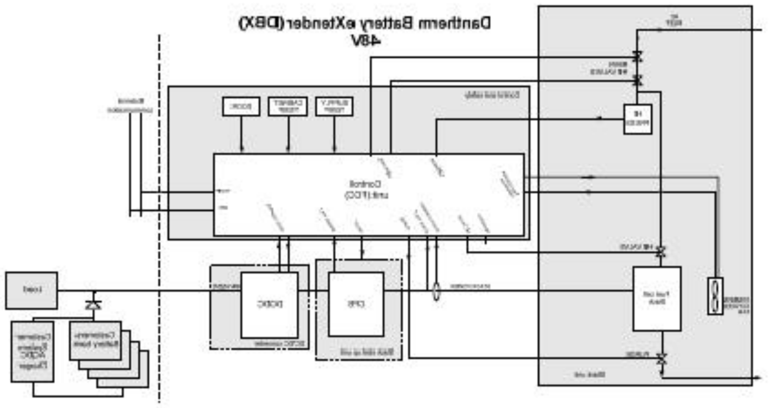
OPTIONS

- Dantherm Instant Backup (DIB) Upgrade kit with battery-free bridge power
- Fuel Regulators with fittings for local thread types
- Hoses and tubing, fuel manifolds
- Hydrogen storage cabinets in various sizes
- Cold climate kit (for operation below -20°C and/or low load)

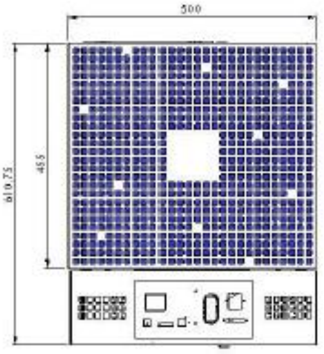
BLOCK DIAGRAM:



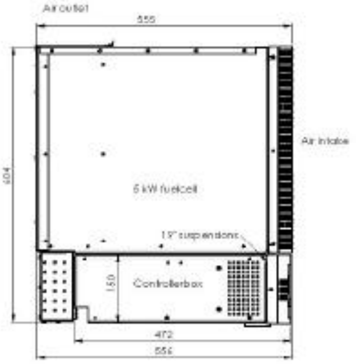
ELECTRICAL DIAGRAM:



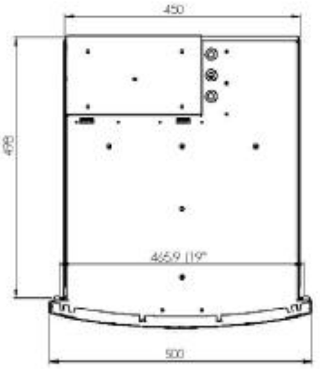
DIMENSIONS DBX5000:



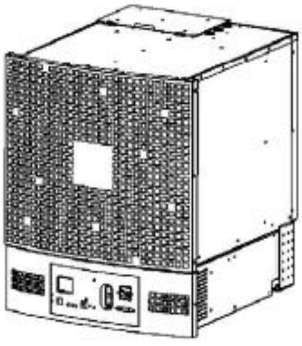
Front view



Side view



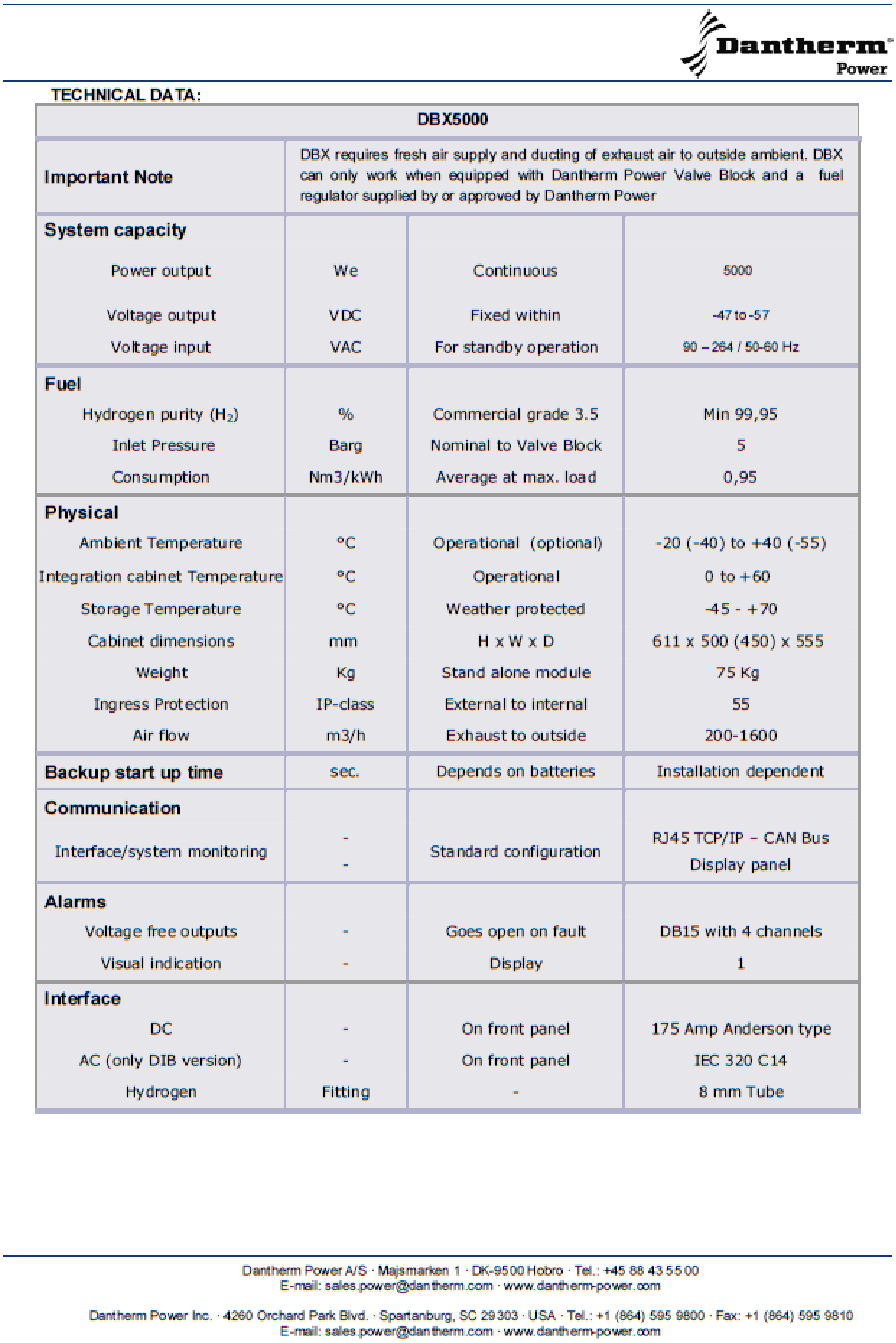
Top view



Iso view

CONTROLLER INTERFACE:

Front panel – Valve Block, Alarm, CAN, TCP/IP & LED's - AC-input, DC-out & current sharing



Dantherm Power

TECHNICAL DATA:

DBX5000			
Important Note	DBX requires fresh air supply and ducting of exhaust air to outside ambient. DBX can only work when equipped with Dantherm Power Valve Block and a fuel regulator supplied by or approved by Dantherm Power		
System capacity			
Power output	We	Continuous	5000
Voltage output	VDC	Fixed within	-47 to -57
Voltage input	VAC	For standby operation	90 – 264 / 50-60 Hz
Fuel			
Hydrogen purity (H_2)	%	Commercial grade 3.5	Min 99,95
Inlet Pressure	Barg	Nominal to Valve Block	5
Consumption	Nm3/kWh	Average at max. load	0,95
Physical			
Ambient Temperature	°C	Operational (optional)	-20 (-40) to +40 (-55)
Integration cabinet Temperature	°C	Operational	0 to +60
Storage Temperature	°C	Weather protected	-45 - +70
Cabinet dimensions	mm	H x W x D	611 x 500 (450) x 555
Weight	Kg	Stand alone module	75 Kg
Ingress Protection	IP-class	External to internal	55
Air flow	m3/h	Exhaust to outside	200-1600
Backup start up time	sec.	Depends on batteries	Installation dependent
Communication			
Interface/system monitoring	- -	Standard configuration	RJ45 TCP/IP – CAN Bus Display panel
Alarms			
Voltage free outputs	-	Goes open on fault	DB15 with 4 channels
Visual indication	-	Display	1
Interface			
DC	-	On front panel	175 Amp Anderson type
AC (only DIB version)	-	On front panel	IEC 320 C14
Hydrogen	Fitting	-	8 mm Tube

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E-mail: sales.power@dantherm.com · www.dantherm-power.com

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E-mail: sales.power@dantherm.com · www.dantherm-power.com

(Dantherm Power A/S, 2009)

4.6 Appendix 19: Fuel Cell ReliOn T2000 Datasheet

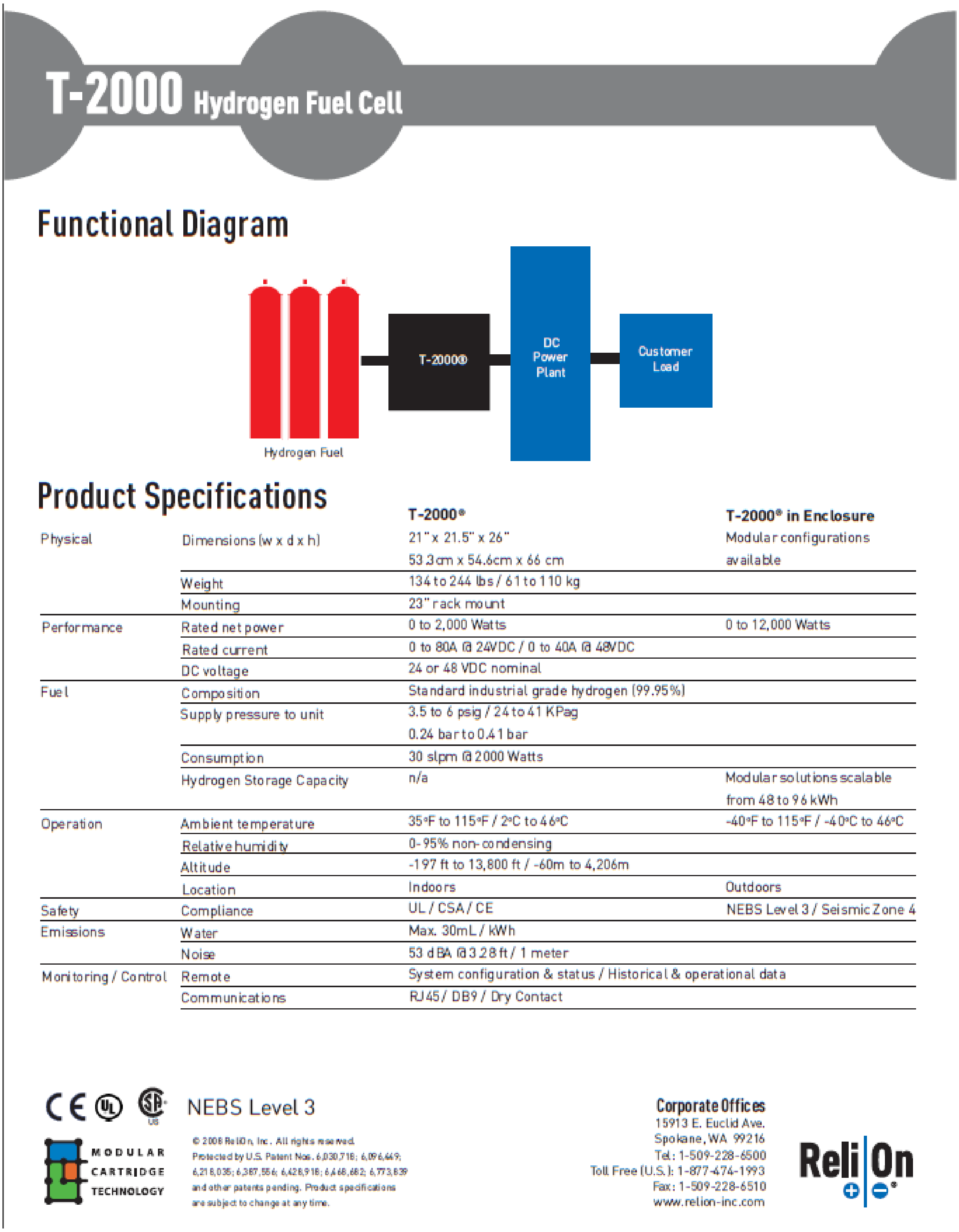
T-2000 Hydrogen Fuel Cell

The T-2000® hydrogen fuel cell - ultrareliable, ultraclean. Designed specifically for communications backup power applications within wireless and wireline telecommunications, utility and government sectors with the only emission being water. The T-2000® uses patented Modular Cartridge Technology® for hot-swappable high reliability, ease of maintenance, and simplicity of design.

Ultra-Scalable

The T-2000® incorporates modular electronics cards which enable scalability by providing flexible configuration from 600 Watts to a full 2,000 Watt capacity in one chassis. Or combine multiple T-2000®s to provide higher outputs for a variety of site requirements.

A New Era in Critical Backup Power



T-2000 Hydrogen Fuel Cell

Functional Diagram

Product Specifications

		T-2000®	T-2000® in Enclosure
Physical	Dimensions (w x d x h)	21" x 21.5" x 26" 53.3cm x 54.6cm x 66 cm	Modular configurations available
	Weight	134 to 244 lbs / 61 to 110 kg	
	Mounting	23" rack mount	
Performance	Rated net power	0 to 2,000 Watts	0 to 12,000 Watts
	Rated current	0 to 80A @ 24VDC / 0 to 40A @ 48VDC	
	DC voltage	24 or 48 VDC nominal	
Fuel	Composition	Standard industrial grade hydrogen (99.95%)	
	Supply pressure to unit	3.5 to 6 psig / 24 to 41 KPag 0.24 bar to 0.41 bar	
	Consumption	30 slpm @ 2000 Watts	
	Hydrogen Storage Capacity	n/a	Modular solutions scalable from 48 to 96 kWh
Operation	Ambient temperature	35°F to 115°F / 2°C to 46°C	-40°F to 115°F / -40°C to 46°C
	Relative humidity	0-95% non-condensing	
	Altitude	-197 ft to 13,800 ft / -60m to 4,206m	
	Location	Indoors	Outdoors
Safety	Compliance	UL / CSA / CE	NEBS Level 3 / Seismic Zone 4
Emissions	Water	Max. 30mL / kWh	
	Noise	53 dBA @ 3.28 ft / 1 meter	
Monitoring / Control	Remote	System configuration & status / Historical & operational data	
	Communications	RJ45 / DB9 / Dry Contact	

NEBS Level 3

MODULAR CARTRIDGE TECHNOLOGY

Protected by U.S. Patent Nos. 6,030,718; 6,096,449; 6,218,035; 6,387,556; 6,428,918; 6,468,682; 6,773,839 and other patents pending. Product specifications are subject to change at any time.

Corporate Offices
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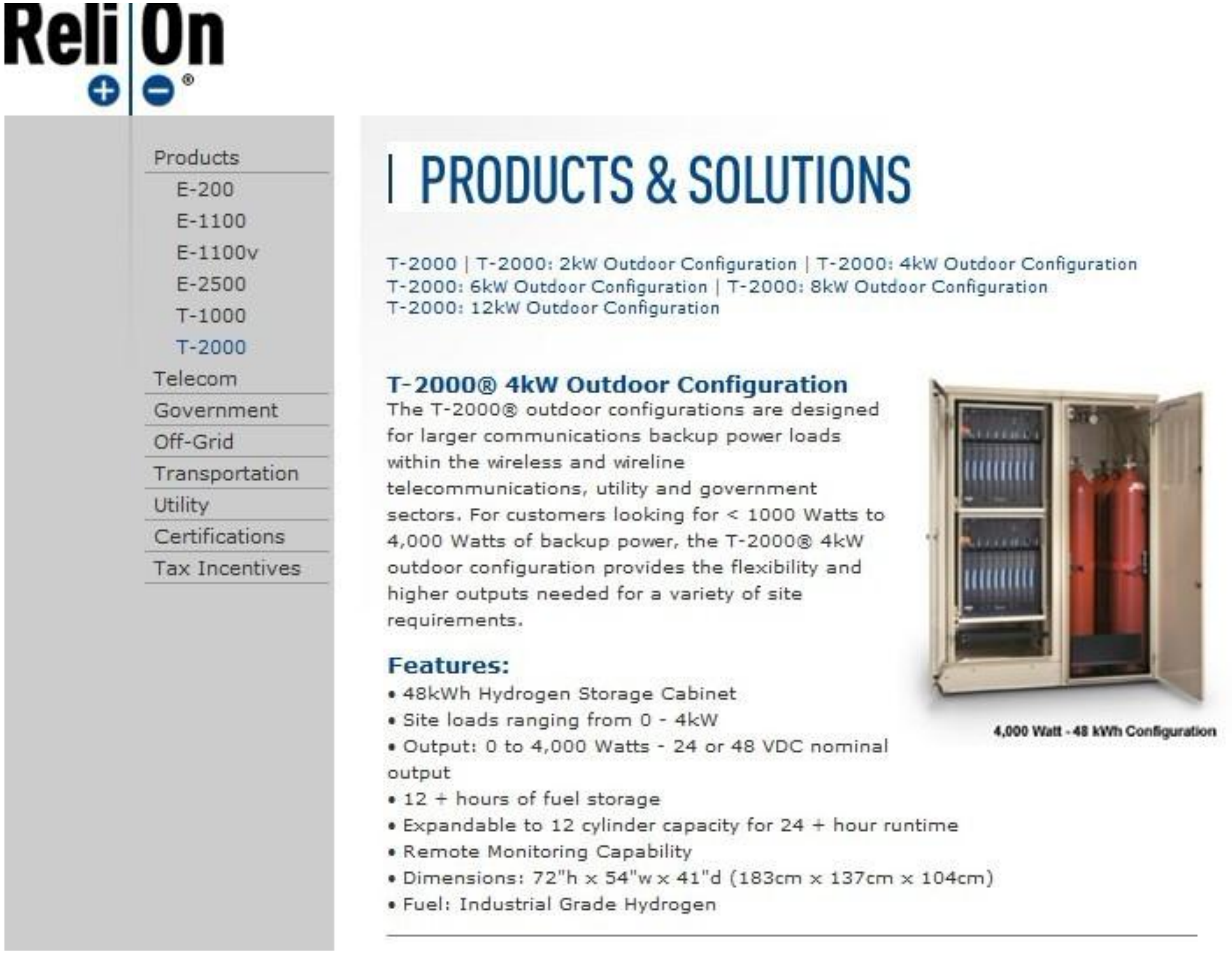
Spokane, WA 99216
Tel: 1-509-228-6500
Toll Free (U.S.): 1-877-474-1993
Fax: 1-509-228-6510
www.relion-inc.com

(ReliOn, Inc. , 2008)

4.7 Appendix 20: 4 kW Outdoor Configuration Datasheet



ReliOn®

- Products
  - E-200
  - E-1100
  - E-1100v
  - E-2500
  - T-1000
  - T-2000
- Telecom
- Government
- Off-Grid
- Transportation
- Utility
- Certifications
- Tax Incentives

PRODUCTS & SOLUTIONS

T-2000 | T-2000: 2kW Outdoor Configuration | T-2000: 4kW Outdoor Configuration
T-2000: 6kW Outdoor Configuration | T-2000: 8kW Outdoor Configuration
T-2000: 12kW Outdoor Configuration

T-2000® 4kW Outdoor Configuration

The T-2000® outdoor configurations are designed for larger communications backup power loads within the wireless and wireline telecommunications, utility and government sectors. For customers looking for < 1000 Watts to 4,000 Watts of backup power, the T-2000® 4kW outdoor configuration provides the flexibility and higher outputs needed for a variety of site requirements.

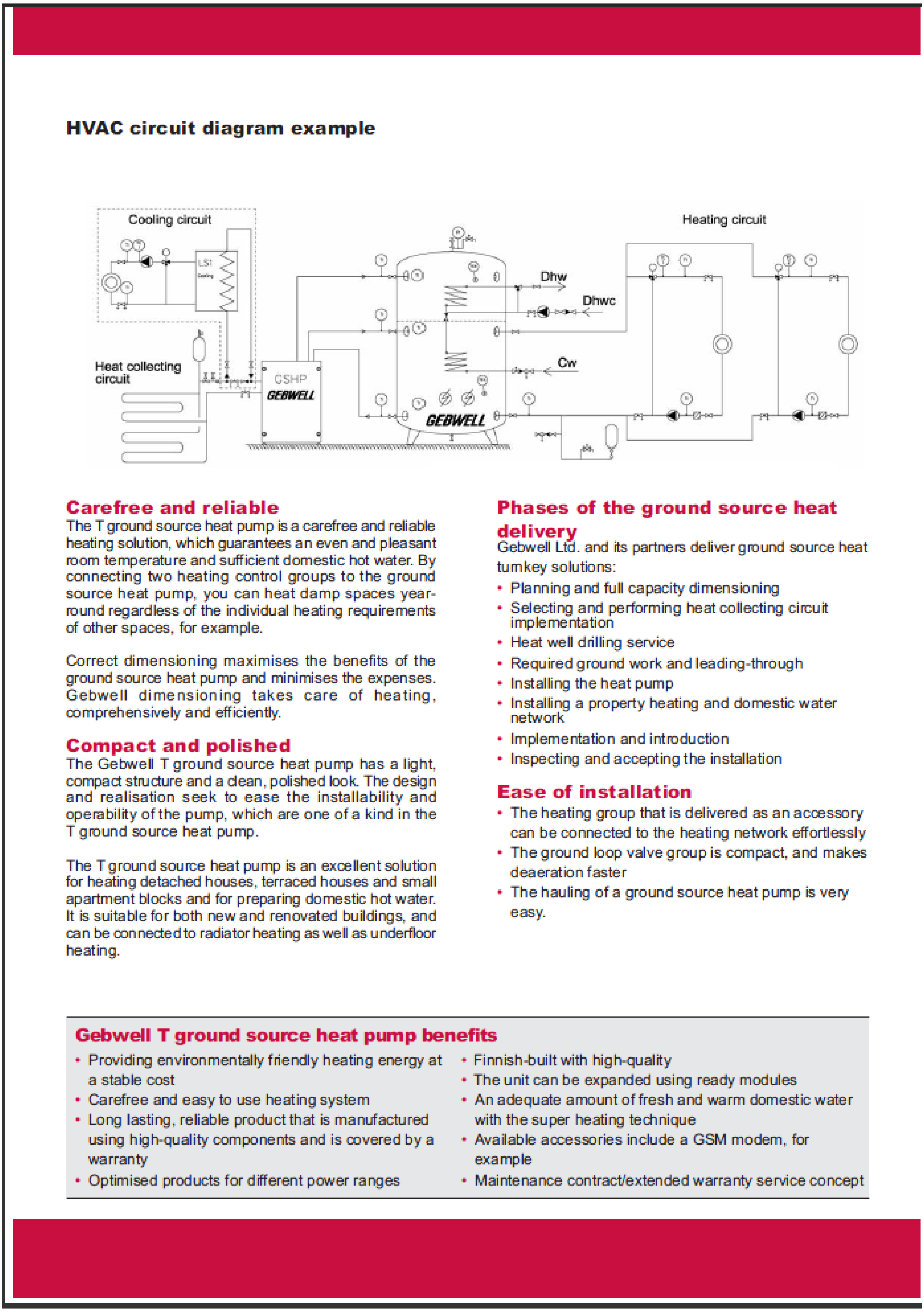
4,000 Watt - 48 kWh Configuration

Features:

- 48kWh Hydrogen Storage Cabinet
- Site loads ranging from 0 - 4kW
- Output: 0 to 4,000 Watts - 24 or 48 VDC nominal output
- 12 + hours of fuel storage
- Expandable to 12 cylinder capacity for 24 + hour runtime
- Remote Monitoring Capability
- Dimensions: 72"h x 54"w x 41"d (183cm x 137cm x 104cm)
- Fuel: Industrial Grade Hydrogen

(ReliOn, Inc. , 2012)

4.8 Appendix 22: Gebwell T GSHP technical datasheet



HVAC circuit diagram example

Carefree and reliable

The T ground source heat pump is a carefree and reliable heating solution, which guarantees an even and pleasant room temperature and sufficient domestic hot water. By connecting two heating control groups to the ground source heat pump, you can heat damp spaces year-round regardless of the individual heating requirements of other spaces, for example.

Correct dimensioning maximises the benefits of the ground source heat pump and minimises the expenses. Gebwell dimensioning takes care of heating, comprehensively and efficiently.

Compact and polished

The Gebwell T ground source heat pump has a light, compact structure and a clean, polished look. The design and realisation seek to ease the installability and operability of the pump, which are one of a kind in the T ground source heat pump.

The T ground source heat pump is an excellent solution for heating detached houses, terraced houses and small apartment blocks and for preparing domestic hot water. It is suitable for both new and renovated buildings, and can be connected to radiator heating as well as underfloor heating.

Phases of the ground source heat delivery

Gebwell Ltd. and its partners deliver ground source heat turnkey solutions:

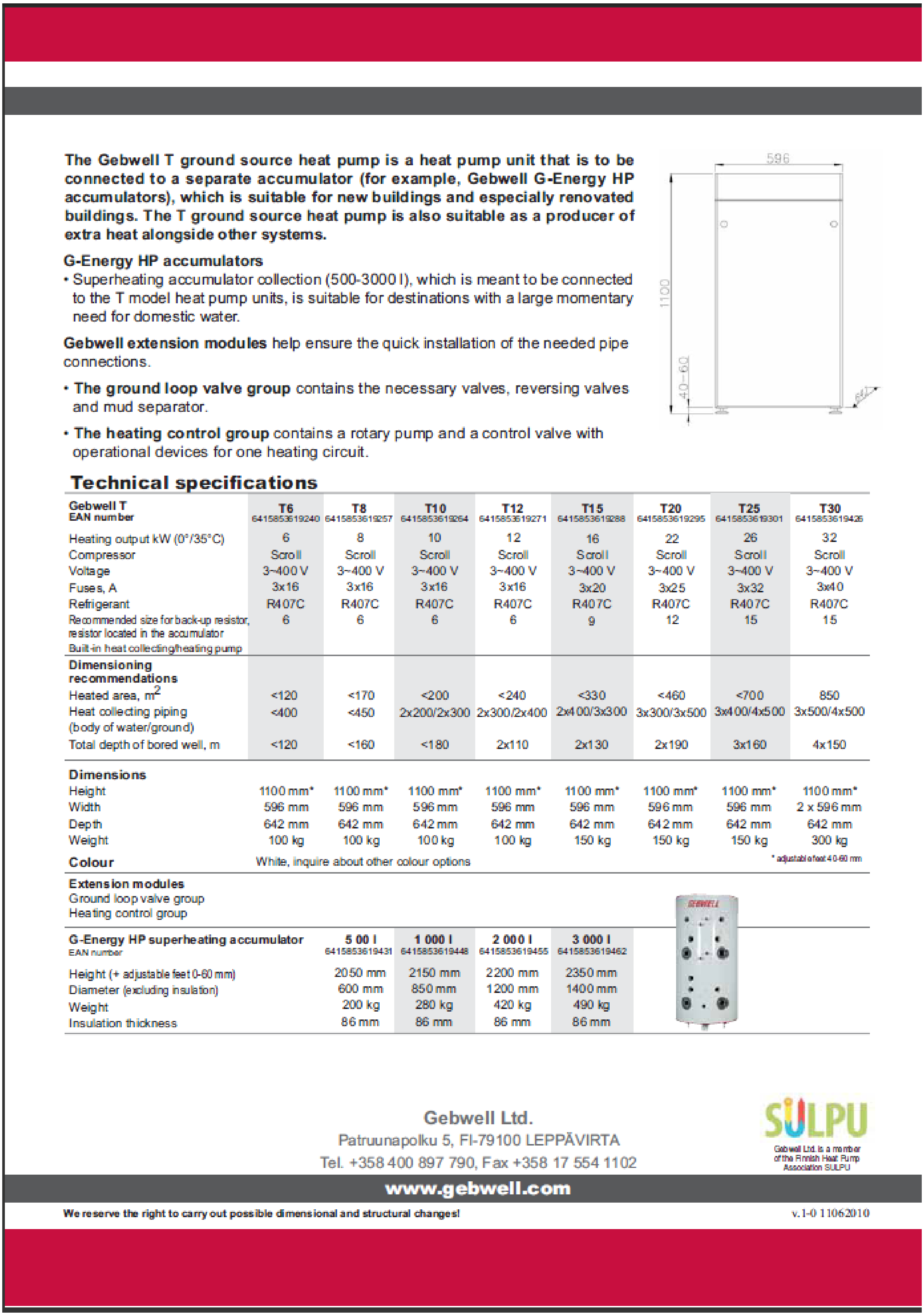
- Planning and full capacity dimensioning
- Selecting and performing heat collecting circuit implementation
- Heat well drilling service
- Required ground work and leading-through
- Installing the heat pump
- Installing a property heating and domestic water network
- Implementation and introduction
- Inspecting and accepting the installation

Ease of installation

- The heating group that is delivered as an accessory can be connected to the heating network effortlessly
- The ground loop valve group is compact, and makes deaeration faster
- The hauling of a ground source heat pump is very easy.

Gebwell T ground source heat pump benefits

- Providing environmentally friendly heating energy at a stable cost
- Carefree and easy to use heating system
- Long lasting, reliable product that is manufactured using high-quality components and is covered by a warranty
- Optimised products for different power ranges
- Finnish-built with high-quality
- The unit can be expanded using ready modules
- An adequate amount of fresh and warm domestic water with the super heating technique
- Available accessories include a GSM modem, for example
- Maintenance contract/extended warranty service concept



The Gebwell T ground source heat pump is a heat pump unit that is to be connected to a separate accumulator (for example, Gebwell G-Energy HP accumulators), which is suitable for new buildings and especially renovated buildings. The T ground source heat pump is also suitable as a producer of extra heat alongside other systems.

G-Energy HP accumulators

- Superheating accumulator collection (500-3000 l), which is meant to be connected to the T model heat pump units, is suitable for destinations with a large momentary need for domestic water.

Gebwell extension modules help ensure the quick installation of the needed pipe connections.

- **The ground loop valve group** contains the necessary valves, reversing valves and mud separator.
- **The heating control group** contains a rotary pump and a control valve with operational devices for one heating circuit.

Technical specifications

Gebwell T **EAN number**	**T6** 6415853619240	**T8** 6415853619257	**T10** 6415853619264	**T12** 6415853619271	**T15** 6415853619288	**T20** 6415853619295	**T25** 6415853619301	**T30** 6415853619426
Heating output kW (0°/35°C)	6	8	10	12	16	22	26	32
Compressor	Scroll	Scroll	Scroll	Scroll	Scroll	Scroll	Scroll	Scroll
Voltage	3~400 V	3~400 V	3~400 V	3~400 V	3~400 V	3~400 V	3~400 V	3~400 V
Fuses, A	3x16	3x16	3x16	3x16	3x20	3x25	3x32	3x40
Refrigerant	R407C	R407C	R407C	R407C	R407C	R407C	R407C	R407C
Recommended size for back-up resistor, resistor located in the accumulator	6	6	6	6	9	12	15	15
Built-in heat collecting/heating pump								
Dimensioning recommendations								
Heated area, m^2	<120	<170	<200	<240	<330	<460	<700	850
Heat collecting piping (body of water/ground)	<400	<450	2x200/2x300	2x300/2x400	2x400/3x300	3x300/3x500	3x400/4x500	3x500/4x500
Total depth of bored well, m	<120	<160	<180	2x110	2x130	2x190	3x160	4x150
Dimensions								
Height	1100 mm*	1100 mm*	1100 mm*	1100 mm*	1100 mm*	1100 mm*	1100 mm*	1100 mm*
Width	596 mm	596 mm	596 mm	596 mm	596 mm	596 mm	596 mm	2 x 596 mm
Depth	642 mm	642 mm	642 mm	642 mm	642 mm	642 mm	642 mm	642 mm
Weight	100 kg	100 kg	100 kg	100 kg	150 kg	150 kg	150 kg	300 kg
Colour	White, inquire about other colour options							

* adjustable feet 40-60 mm

Extension modules
Ground loop valve group
Heating control group

G-Energy HP superheating accumulator EAN number	**5 00 l** 6415853619431	**1 000 l** 6415853619448	**2 000 l** 6415853619455	**3 000 l** 6415853619462
Height (+ adjustable feet 0-60 mm)	2050 mm	2150 mm	2200 mm	2350 mm
Diameter (excluding insulation)	600 mm	850 mm	1200 mm	1400 mm
Weight	200 kg	280 kg	420 kg	490 kg
Insulation thickness	86 mm	86 mm	86 mm	86 mm

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SULPU
Gebwell Ltd. is a member of the Finnish Heat Pump Association SULPU

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We reserve the right to carry out possible dimensional and structural changes!

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(Gebwell Ltd., 2010)

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