ADVISORY REPORT

RENEWABLE ENERGY FOR A DOME VILLAGE

MD Tahsinul Islam

407402

Hanze University of Applied Sciences

Internship Year 2

Preface

In the second year of the International Mechanical Engineering program, it is mandatory to participate in a practical internship. With the help of this internship, a better picture can be sketched of what the content of the course entails and what can be done with it in practice.

The internship took place at EnTranCe (Energy Transition Center) in the period from 01-09-2020 to 18-12-2020 for a total of 560 working hours. During my internship, the main assignment was to prepare an advisory report on which would be the best renewable energy source for 150 dome houses in Blauwestad. I would like to thank my internship supervisors Mr. R. de Vrieze, Mr. Wouter Swart Ranshuysen & Mrs. Henmar Moesker for their contribution to my internship.

I also want to thank my project team for sharing information, which allowed me to further complete my project. Also, a special recognition to my fellow intern Dirksz RA, Randall (r.a.dirksz@st.hanze.nl) for providing me with the specifics, dimensions, and diagrams of the dome houses themselves. Finally, I would like to thank my internship supervisor from Hanze University Groningen, Mr. Tamizh Munuswamy who also guided me well in my times of need during the internship and gave useful advice.

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Summary

A dome is a geodesic dome that is resistant to external weather influences and is very strong in its own right. The purpose of a dome is to give a different interpretation to current construction techniques because current construction techniques are insufficiently in step with the rapidly changing world. The Open Building concept is a solution for this. Modular building is central here because Open Building means that the supporting structure is separate from the infill, thus offering space for prefabricated modular building shells and the interpretation within this shell. This is necessary as many buildings today are vacant or unnecessarily demolished because they are inflexible and adaptive to future changes. In this way and with the most efficient form, raw material waste is prevented with the D®oome project.

It has been decided to investigate the possible energy sources for realizing a Dome village. There are more possibilities within all fields of a village than with a single building, and more coherent ideas can arise.

The primary goal of the internship is to conduct research into the generation of green energy within this context of a dome village in Blauwestad, Groningen and to investigate the possible source of renewable energy for it. The research question is: Which is the best possible renewable energy source for a village consisting of 150 dome houses?

Based on the results, advice can be given based on the results of the research.

The report provides a full study of the possibilities with regard to the generation of green energy. Various topics were discussed, namely; ground, wind, sun, hydrogen and bioenergy. The research can be used to calculate the amount of energy that will be needed to provide the Dome village with green energy.

With 31.15 m^2 of solar panels, a household can be fully supplied with energy. Solar panels are very financially attractive, and the durability period is extremely long.

Households cannot be supplied with warm energy with only solar collectors.

In practice, solar collectors are often used in a system, for example in combination with a heat pump, heat exchanger and / or underfloor heating system. The yield can be increased with a heat pump and / or a heat exchanger. With only solar collectors, the costs of the gas can be reduced and people are less dependent on a supplier.

Out of all the investigated sources, the best way to provide the Dome village with green energy is a combination of solar panels.

This is financially feasible, but this source might be replaced in the future. More renewable energy sources are being invented every year. In the future there may be a possibility to use tidal kiting energy or even electronic magnetic radiative energy.

1. Introduction

This chapter describes the context, reason, objective and the research question.

1.1 Context Description

The reason behind this research is to carry out the internship during the second year of the International Mechanical Engineering program. The internship period must comply with 560 working hours and is held at EnTranCe. During the internship, one main assignment was carried out along with a secondary assignment during the third month which was given by Henmar Moeskar.

The primary goal of the internship report is to clearly research the generation of green energy within this context of a dome village and to investigate the best possible source of green energy.

1.2 Problem analysis

A green village consisting of 150 dome houses and a supermarket is to be made possible in Blauwestad, Groningen. It is necessary to provide renewable energy for this village up to the inhabitant's demands. After analysing a few different types of renewable energy sources, the ideal one has to be picked.

1.3 Objective

The objective is to gain insight into the possibilities for a dome village in the context of generating green energy.

1.4 Question

The objective raises a number of questions about the possibilities of generating energy. The main question is as follows:

- Which is the best possible renewable energy source for a village in Blauwestad, Groningen consisting of 150 dome houses that originates from outside the dome house?

Chapter one describes the cause and purpose of the report. This chapter also contains a problem analysis goal and research question that were used for the research. Chapter two describes the internship company and how this company is organized. As follows, consumption is put in the context of households in today's society.

Research has been conducted into the possibilities of generating green energy, this is discussed in the several following chapters. Finally, advice and recommendations are discussed in the conclusion chapter.

2. Company background

EnTranCe (Center of Expertise Energy) is a research centre that contributes to the slow but inevitable transition to a clean and affordable energy supply. The founder of EnTranCe is Wim van Gemert, who was active until April 2018 as a leading lecturer in Energy Transition at Hanze University of Applied Sciences, Groningen. In the expertise centre, scientists, students, companies and social institutions work together to share their knowledge. Hereby the regional knowledge economy is strengthened to cooperate. Various issues are solved, both practical issues and theoretical issues.

Figure 1 Entrance Logo

Professionals are also trained at EnTranCe and they are advised to participate in the masterclasses of the energy academy. For example, students from different disciplines from different study-years' work together (bachelor, master or MBO courses). There are many opportunities to develop yourself and this is also motivated at this company.

During the internship, it was standard on Wednesday afternoon that the entire project team comes together online. During these meetings it was discussed where everyone stands and what information they need. Students were linked to stakeholders who are active in a specific field in which the student is also involved. This created a collaboration between companies, teachers and students. Due to circumstances caused by the COVID-19 outbreak, all the meetings were held online on Microsoft Teams. If one wanted, there could also be good networking here, which would come in handy during a project or for the future.

EnTranCe is organized into several branches. The abbreviations for those branches stand for:

RE: Lectorate Life Sciences & Renewable Energy

E&N: Energy Transition and Networks Research Group

Wind: Wind Energy Professorship

LNG: Lectorate Sustainable LNG Technology

ET: Energy Transition Research Group

CBSS: Lectorate Communication, Behavior & the Sustainable Society

E&R: Lectorate Energy & Law

3. Energy Consumption

Every household needs heat and electricity, which is a basic need in today's society. The energy consumption per household varies. This has several causes; people who work full-time, work part-time and or have a family or live alone. Each household has its own energy consumption, but this study is based on the average. This average is a number that can be used for calculations and provides a fixed number. All the following gas and electricity consumption figures are based on the average number of residents in a Dutch household [1]. For this research, it is 2.17. Thus, the average number of residents in each dome house is also considered to be 2.17.

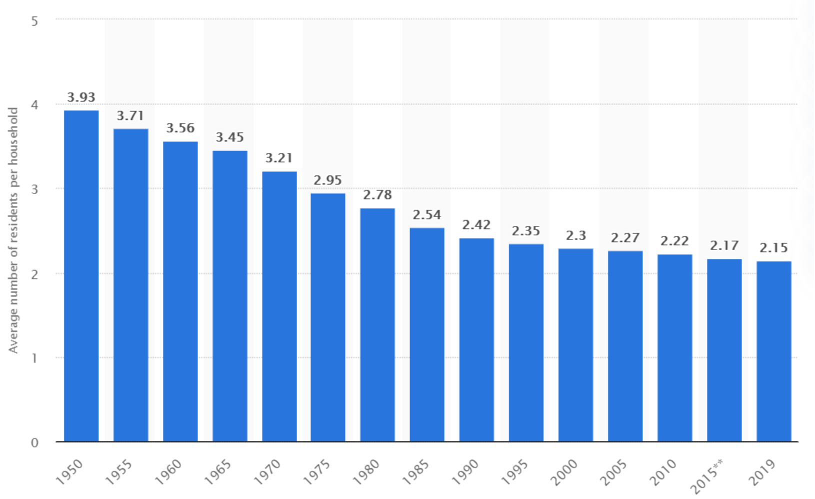


Figure 2 Average number of residents per household in the Netherlands

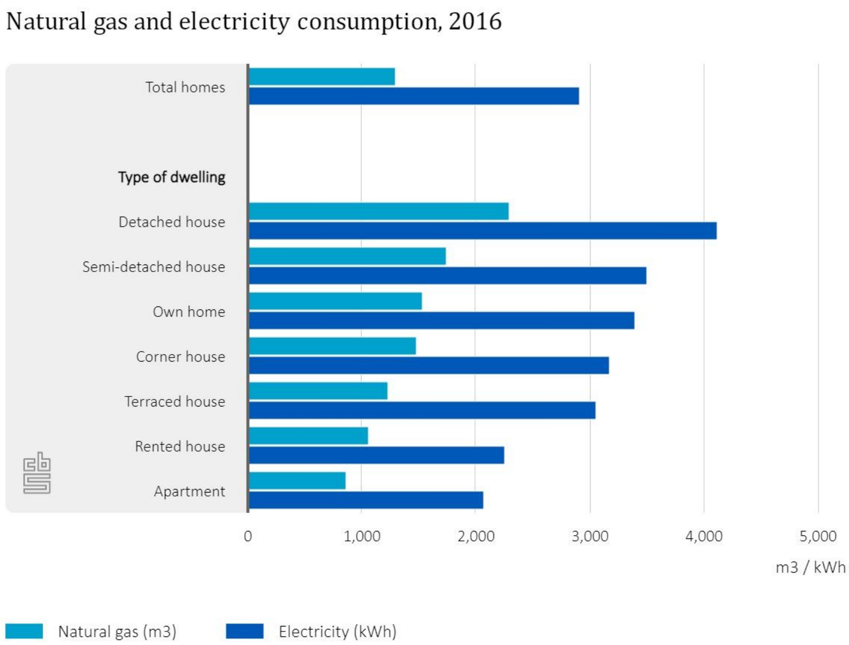


Figure 3 Natural Gas and Electricity Consumption in Dutch households, 2016

3.1 Gas consumption

An average household consumed about 1300 m^3 per year in 2016 (CBS) [2]. If this gas consumption is higher, the household will consist of more than 2.17 people. Consumption also differs per type of house, see (*Table 1*).

Property Type	Average consumption per year (m^3)
Semi-detached house	1750
Own home	1530
Cornerhouse	1480
Terraced house	1240
Rented house	1060
Apartment	870
Detached house	2300
On average, all types of houses	1300

Table 1

Mainly natural gas is used for central heating, electric stove, boiler and cooking. The heating is used the most and is therefore the largest cost item. The heating is largely used during the winter period. There is a chance that less use will be made of warm energy in the future because the winters may become less cold compared to the past. At an average outside temperature of 20 degrees or higher, it is assumed that the heating will not start.

3.2 Electricity consumption

Electricity consumption mainly depends on the size of the household. Furthermore, the electrical appliances also have an influence on the consumption per household. This is very different and not everyone uses the same devices. The consumption of electricity has been reduced significantly by the increasingly efficient use of appliances. The average consumption per household is around 2910 kWh per year (CBS) [2]. (*Table 2*) shows those numbers per property type.

Property Type	Average consumption per year (kWh)
Semi-detached house	3500
Own home	3400
Cornerhouse	3180
Terraced house	3060
Rented house	2260
Apartment	2070
Detached house	4120
On average, all types of houses	2910

Table 2

According to a research paper [3] released in 2014 by Professor Martien Visser of Hanze University of Applied Sciences, the value of 1 m^3 gas is approximately equal to 10 kWh of electricity. Continuing on this narrative, the average gas consumption per year in a Dutch household in terms of kWh would be

$$\boxed{1300 * 10 = 13{,}000 \text{ kWh}}$$

The majority of energy consumption of a Dutch home is for heating purposes, i.e. gas consumption.

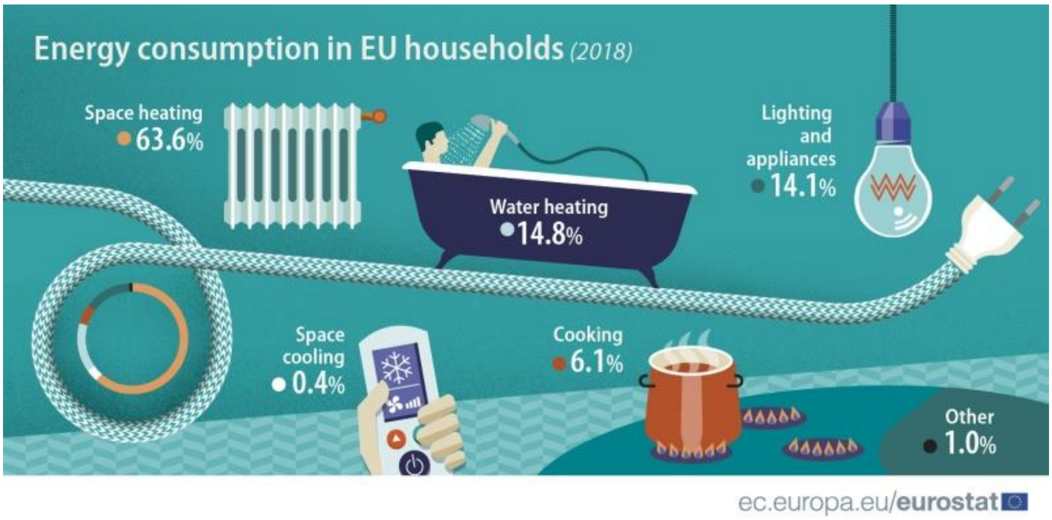


Figure 4 Breakdown of Energy Consumption in European households, 2018

According to author Robin Niessink [4] from ECN, the mean COP of a ground source heat pump in the Netherlands is 4.3 in case of a delivery temperature of 35-40°C. Continuing on this narrative, the final energy requirement for heating an average house after taking the COP into account would be

$$\boxed{13{,}000/4.3 = 3023 \text{ kWh.}}$$

Finally, combining the heating and electricity requirement of an average Dutch household, it turns out that the minimum amount at energy to be provided per year is

$$\boxed{2910+3023 = 5933 \text{ kWh} \sim 6000 \text{ kWh}}$$

The minimum amount of energy that a renewable source has to provide to a dome house per year has to be at least 6000 kWh.

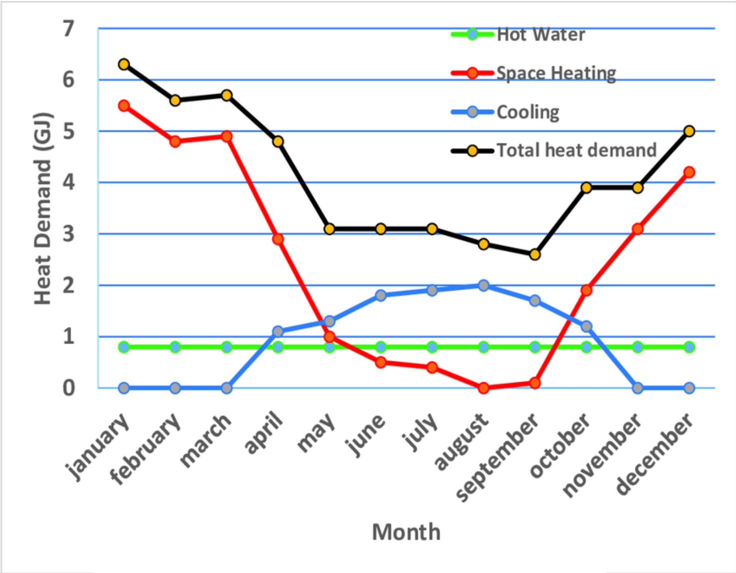


Figure 5 Breakdown of Heat Demand in Dutch households' month by month

3.3 Energy consumption supermarket

The energy consumption differs per company. Companies are divided into the non-food sector and the food sector. Supermarkets are part of the food sector and have a different average consumption compared to the non-food sector. Electricity consumption in particular is higher. At a supermarket it has been found that 16 m^3 of gas and 467 kWh of electricity is consumed per square meter. An Albert Heijn supermarket has an average area of 1270 m^2 (Statista, 2016) [5], which means that 20,320 m^3 of gas and 593,090 kWh of electricity is consumed annually.

Following Professor Martien Visser's conversion rate from m^3 of gas to kWh of electricity, that would be

20,320 * 10 = 203,200 kWh

The average COP of a supermarket heat pump is always 1 less than that of ground-based household heat pumps. Thus, following the same calculation methods as before, the final energy requirement for heating would be

203,200/3.3 = 61,575 kWh

Combining the final heating and electricity requirement, the annual energy requirement of the supermarket it turns out to be

(467 kWh * 1270 m^2) + 61,575 kWh = 654,665 kWh

3.4 Overall Final Energy Requirement

With 6000 kWh per dome house, with a grand total of 150 houses, and a single Albert Heijn supermarket, the overall final energy requirement of the dome village turns out to be

(6000*150) +654665 = 1,554,665 kWh

Based on this energy consumption number, several renewable energy sources will be examined and the source that provides this energy with the least amount of costs and environmental hazards, best durability and reusability will be considered to be the most suitable.

4. Concept

Various types of renewable energy sources are discussed in the sections below. Section 4.1 takes a look into the dome houses themselves. In paragraph 4.2, the village infrastructure is discussed.

4.1 Dome Houses

The Dome village consists of 150 households surrounded by trees and the artificial Oldambtmeer lake. The trees create a bio-atmosphere that gives a natural feeling in the village.

The technical specifications of each individual dome house are provided in the tables (*Table 3* & *Table 4*) below:

Room specifications:

Name of the room	**Tally**
Bedroom	3
Kitchen	1
Bathroom	1
Storage Room	1
Living Room	1
Total number of rooms	**7**

Table 3

Dimensions of the house:

Specification	**Measurement**
Diameter	20 m
Height	10 m
Total surface area	660 m^2
Bottom surface area	310 m^2
Volume	9702 m^3

Table 4

The dome houses are made from steel and double insulated glass. There is 1 window for every room (square inside triangle). A couple of figures are added below which demonstrate what the dome houses will look like

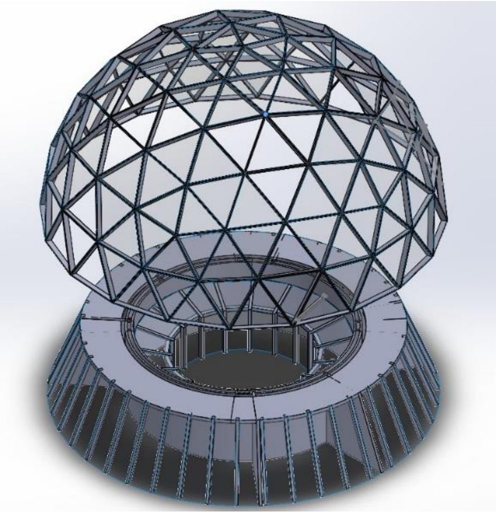


Figure 6 Dome house from a top down view

Figure 7 Dome house from a side view

4.2 Village Infrastructure

It is considered that the Dome village has a supermarket. There are many trees, in between there are also roads and paths so that one can leave the village. The trees are also located between the houses (Domes) to provide shade for cooling. There is a park to the southern side of the village beside the lake itself. The following plot map is taken from the website of the village itself; which can be accessed here.

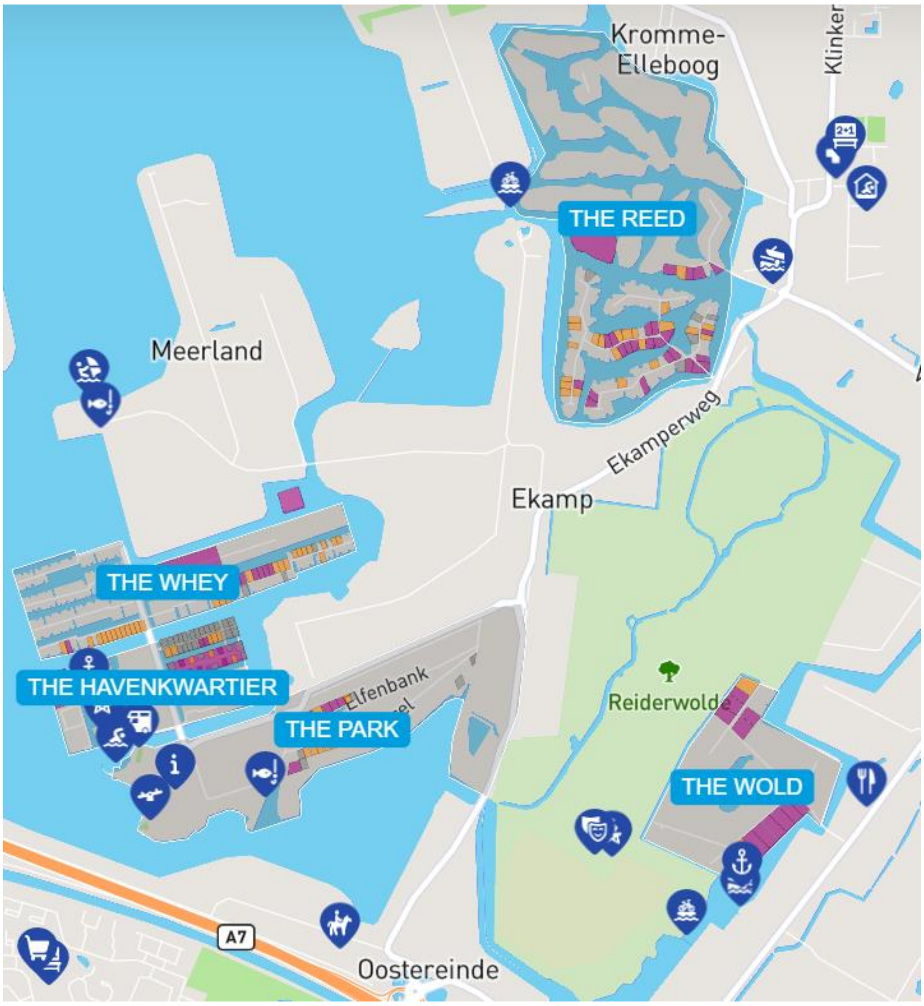


Figure 8 Plot map of Blauwestad

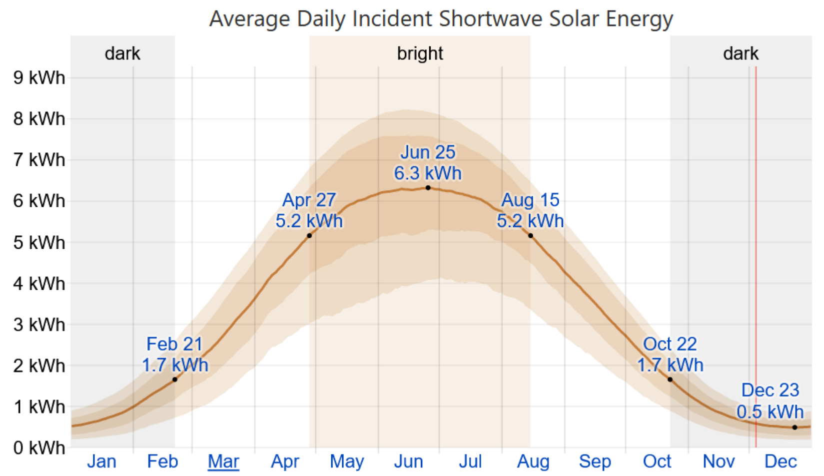
The artificial lake Oldambtmeer is an 8 km^2 area water body which was constructed as part of the Blauwestad project around the place where Lake Huninga used to be around the place where Lake Huninga used to be. In addition to the construction of the Oldambtmeer, 3.5 km^2 of new nature have also been created by the Blauwestad project, many recreational facilities and the opportunity to live in the new village of and the chance to live in the new village. There is a large beach and it is a water sports area. 25 kilometres of dikes have been built around the lake. Most of it can be done on foot or by bicycle. With 14 million m^3 of water, the Oldambtmeer is one of the larger lakes in the Netherlands, and after Lauwersmeer, the largest in the province of Groningen. With a minimum depth of 1.3 meters, it is suitable for sailing boats and smaller motor yachts. Finally, the lake has two marinas, Reiderhaven and Marina Midwolda.

5. Solar Panels

The following graph from Weatherspark.com illustrates the total daily incident shortwave solar energy reaching the surface of the ground over a wide area, taking full account of seasonal variations in the length of the day, the elevation of the Sun above the horizon, and absorption by clouds and other atmospheric constituents. Shortwave radiation includes visible light and ultraviolet radiation. The average daily incident shortwave solar energy experiences *extreme* seasonal variation over the course of the year.

The brighte*r* period of the year lasts for 3.6 months, from April 27 to August 15, with an average daily incident shortwave energy per square meter above 5.2 kWh. The brightest day of the year is June 25, with an average of 6.3 kWh.

The darker period of the year lasts for 4.0 months, from October 22 to February 21, with an average daily incident shortwave energy per square meter below 1.7 kWh. The darkest day of the year is December 23, with an average of 0.5 kWh.



The average daily shortwave solar energy reaching the ground per square meter (orange line), with 25th to 75th and 10th to 90th percentile bands.

Figure 9

The title ''The Most Efficient Solar Panel 2020'' goes to the Sunpower Maxeon 3 400W (Clean Energy reviews 2020) [6]. It is an N-type IBC cell type with an efficiency of 22.6% and a maximum power delivery of 400W. This panel is chosen for the dome village. All detailed technical specifications of the panel can be found here.

Figure 10 Demonstration photo of SunPower's Maxeon 3 400W Solar Panel

5.1 Financial Costs

The calculations of the solar panels are made using the full load hours and the peak power for each panel. This gives an indication of how much the yield is per hour per panel. The average installation cost of a 6kW solar unit is €15,300 (Modernize) [7].

The result is not an exact value because the peak power is used. The solar panels do not produce peak power throughout the day, as this is a specific moment during the day. The electricity yield will therefore be lower than in calculations. However, the solar panels ensure that the Dome village can be independent.

SunPower Maxeon 3 400W panel Power per panel = 400 W Area of a single panel = 1.69 m * 1.05 m = 1.78 m^2 Efficiency of each panel = 0.226 Full Load hours of a Year = 854 hours Price per panel = €379 Yield of the solar panel = Power per panel * Full Load Hours of a Year = 400 W * 854 hours = 341.6 kWh ~ 342 kWh

For the minimum 6000 kWh energy demand of a single house, the number of panels required is

6000 kWh / 342 kWh = 17.5

Thus, the total number of needed solar panels for 150 houses would be

150 * 17.5 = 2625

For the supermarket, the required number of panels would be

654,665 kWh / 342 kWh = 1914

Finally, the overall number of solar panels for the entire village would be

2625 + 1914 = 4539

Finally, the total cost of 3886 SunPower Maxeon 3 solar panels, (including installation) will be

(4539* 379) = €1,720,281

5.2 Durability

SunPower claims that their Maxeon panels are proven with an expected useful life of 40 years and that they have almost 4x stronger durability than conventional panels in actual field testing across 8 years.

5.3 Reusability [8]

Currently, solar panels at their end-of-life stage are processed in existing recycling plants for glass or metals. Mechanical processes are used to separate the materials. Technical recycling yields of up to 90% by weight are obtained, mostly comprising of aluminium frames and glass. Energy is also recovered from the incineration of the plastic fraction. Solar recycling is mandatory under the EU's WEEE Directive. This legislation is based on the extended producer responsibility (EPR) principle, whereby companies putting panels on the market of member states (MS) are responsible for organising and financing its end-of-life management. Under the WEEE Directive, solar panels are in a category of electronic waste with an 85% recovery target, 80% of which consists of reuse and recycling.

5.4 Environmental Impacts [9]

Solar PV cells do not use water for generating electricity per say. However, as in all manufacturing processes, some water is used to manufacture solar PV components. CSP plants that use wet-recirculating technology with cooling towers withdraw between 2270 and 2460 litres of water per megawatt-hour of electricity produced. The PV cell manufacturing process includes a number of hazardous materials, most of which are used to clean and purify the semiconductor surface. These chemicals, similar to those used in the general semiconductor industry, include hydrochloric acid, sulfuric acid, nitric acid, hydrogen fluoride, 1,1,1-trichloroethane, and acetone. Workers also face risks associated with inhaling silicon dust. Finally, while there are no global warming emissions associated with generating electricity from solar energy, there are emissions associated with other stages of the solar life cycle, including manufacturing, materials transportation, installation, maintenance, and decommissioning and dismantlement. Most estimates of life-cycle emissions for photovoltaic systems are between 0.07 and 0.18 pounds of carbon dioxide equivalent per kilowatt-hour.

5.5 Placement within the Village

The solar panels cannot be placed on top of the dome houses as usual because unlike conventional houses, the dome houses don't have flat V-shaped roofs. Thus, the panels have to be laid out some place within the village where they will produce power and then the power will be transported to the dome houses. As shown in the figure below (*Figure 11*), there are 3 possible locations (marked in black boxes) where the solar panels can be placed out for generation of energy.

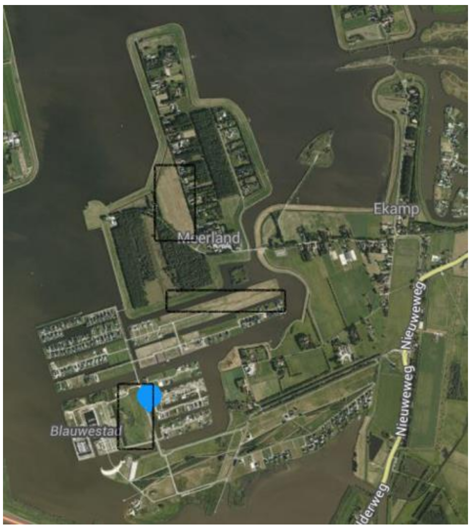


Figure 11 Possible locations for placing solar panels

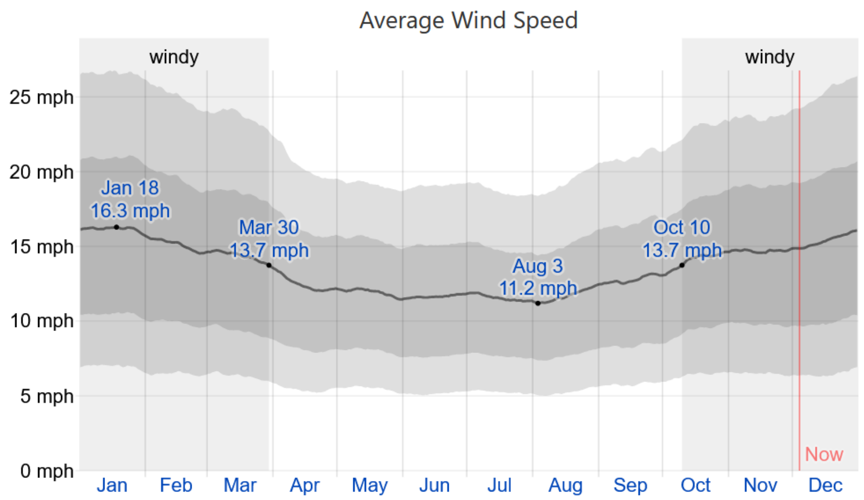
6. Wind Turbines

The following graph from WeatherSpark.com demonstrates the wide-area hourly average wind speed at 10 meters above the ground. The wind experienced at any given location is highly dependent on local topography and other factors, and instantaneous wind speed and direction vary more widely than hourly averages.

The average hourly wind speed in Groningen experiences significant seasonal variation over the course of the year.

The windier part of the year lasts for 5.6 months, from October 10 to March 30, with average wind speeds of more than 13.7 miles per hour. The windiest day of the year is January 18, with an average hourly wind speed of 16.3 miles per hour.

The calmer time of year lasts for 6.4 months, from March 30 to October 10. The calmest day of the year is August 3, with an average hourly wind speed of 11.2 miles per hour.



The average of mean hourly wind speeds (dark gray line), with 25th to 75th and 10th to 90th percentile bands.

Figure 12

The model of the wind turbine that is chosen is made by a Dutch company called FORTIS and the model's name is Alize' Off-Grid System. The wind turbine hub should be mounted at least 10 meters above any obstruction within 400 meters. This wind turbine has massive amount of annual yield and is the largest wind turbine of the FORTIS product range.

Figure 13 Demonstration picture of FORTIS' Alize wind turbine

The graph picture below illustrates the power that can be generated by the Alize' on various wind average windspeeds. For example, it can produce 10kW at 15 m/s average wind speed. The power generation keeps increasing with increasing wind speed and peaks out at a wind speed of 15 m/s. After that there is a sharp fall in power generation because such high speeds (20 m/s, 25 m/s) are dangerous zones and the wind turbine might fall in operational hazards and the safety mechanics kick in to reduce the power generation.

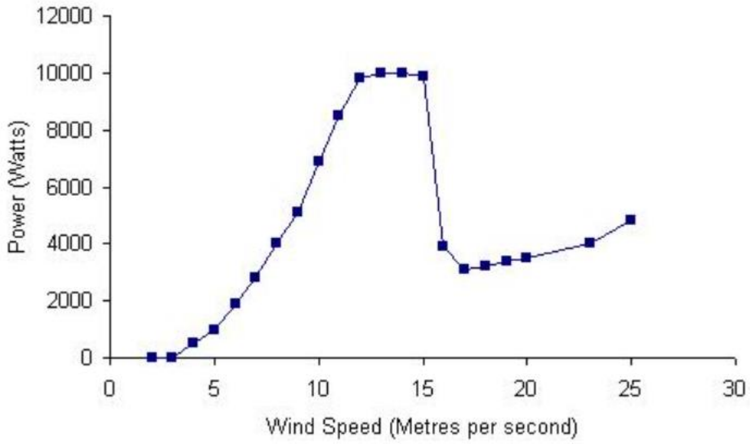


Figure 14 Power generated by Alize depending on wind speed

According to the 2018 FORTIS brochure, the Off-grid Alize' comes in the following package

Article no.	Off-Grid System	Price in EURO
10-10-20	10kW Turbine with 6.3m diameter, Brake Switch, SW10 Grid Feed Inverter, display, two dump load boxes, Power Curve programming included,Energy Management by 3 Controllers [for 48VDC Battery Charging / loads] and incl. software programming. **Output for loads: 400VAC 3-phase + N + PE**	On request

Figure 15 Alize Off-Grid wind turbine package from FORTIS

After some more research and inquiry, it turns out that each unit of Off-Grid Alize' wind turbine will cost €40000 (including installation). The turbine has an annual yield of 22MWh at 6 m/s wind speed. All detailed technical specifications of the Alize' wind turbine can be found here.

6.1 Financial Costs

First, for the 150 dome houses, the total amount of required energy per year is

6000 kWh * 150 = 900,000 kWh = 900 MWh

With an annual yield of 22 MWh per wind turbine, one of them can provide the energy need of

22MWh / 6 MWh = 3.7 houses

Therefore, a total of 41 FORTIS Alize’ Off-grid wind turbines would be required to provide the 150 dome houses with their annual energy demand. The combined purchase and installation costs of 41 of these machines would be

€40,000 * 41= €1,640,000

For the supermarket, the total energy demand is 654,665 kWh or 654.665 MWh. With an annual yield of 22 MWh per turbine, the number of turbines needed to provide the supermarket with sufficient energy would be

654.665 MWh / 22 MWh = 30

Therefore, a total of 30 FORTIS Alize’ Off-grid wind turbines would be needed to provide the supermarket with its annual energy demand. The combined purchase and installation costs of 30 of these machines would be

€40,000 * 30= €1,200,000

Finally, the total purchase and installation cost of all 71 wind turbines for the whole village will be

1,640,000 + 1,200,000 = €2,840,000

6.2 Durability

The installation procedure will be done by a Fortis Certified System Partner. The turbines are maintenance free and come with a 5-year warranty. FORTIS claims that the average lifetime of the turbines is over 20 years.

6.3 Reusability

Padraig Belton writes in a BBC article [10] about the reusability of dead wind turbines. Old wind turbines in the USA are being cut into pieces, stacked and buried. This leads to zero reusability. The composite materials that are used for making wind turbines are extremely difficult to recycle. Although, an American company called Global Fiberglass Solutions has been transforming the composite materials into pellets and pyrolysis which can be used for other industries such as glues, paints, and concrete. However, the large majority of the composite materials are disposed in landfills. Closer to home in Rotterdam, unwanted blades have been put to a different use. The Dutch city boasts a 1200 m^2 children's playground called Wikado. In short, it is possible to reuse expired wind turbines, but the methods are very tricky and not as straightforward as other renewable sources. So, there are very limited scopes of reusability when it comes to wind turbines.

6.4 Environmental Impacts [11]

The burial of old turbines and disposal of their composite materials into landfills are immensely non-eco-friendly way to dispose of them. Spinning turbine blades can pose a threat to flying wildlife like birds and bats. Wind turbines have one of the lowest global warming potentials per unit of electrical energy generated by any power source. Wind power doesn't consume water for continuous operation and has near negligible emissions directly related to its electricity production. Wind turbines when isolated from the electric grid, produce negligible amounts of carbon dioxide, carbon monoxide, sulphur dioxide, nitrogen dioxide, mercury and radioactive waste when in operation.

Overall, the environmental hazards of household wind turbines are quite limited and relatively negligible when compared to large scale commercial wind turbines and wind farms.

6.5 Placement within the Village

As for the wind turbines, they can be placed in the same 3 possible marked locations in the figure (*Figure 11*) for solar panels. Both wind turbines and solar panels perform best when they are in open spaces and have no obstructions. They're not damaged by natural phenomenon such as rain, heavy winds, snow, etc. although their performance in energy generation will drop in those cases. The energy will be generated by the wind turbines placed in those open areas and then it will be transported to the village.

7. Biomass

Biomass is by far the most consumed form of renewable energy in the Netherlands.

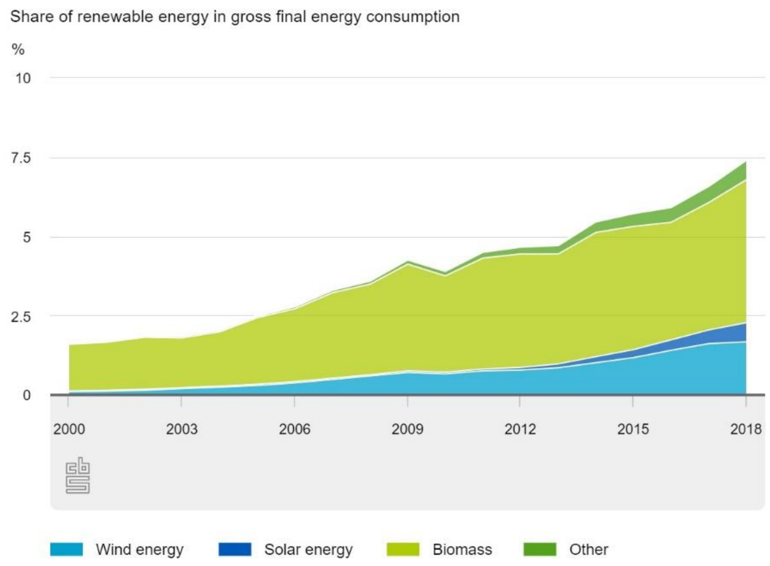


Figure 16 Share of different types of renewable energy in gross final energy consumption in the Netherlands

As shown in the following (*Figure 16*), pellets or wood chips are stored in the storage room, where later they are automatically or manually fed into the biomass boiler. As the fuel enters the boiler, the material is ignited either by elements or an electric blower on the initial start-up. The hot gases are then passed through a heat exchanger and the heat is transferred to the water used in the central heating system. This heat could be also stored in a buffer storage, which can store heating water for long periods due to their thermal efficiency and layering properties. When used in conjunction with effective mixing and loading valves, they can help to get the best use out of a biomass boiler.

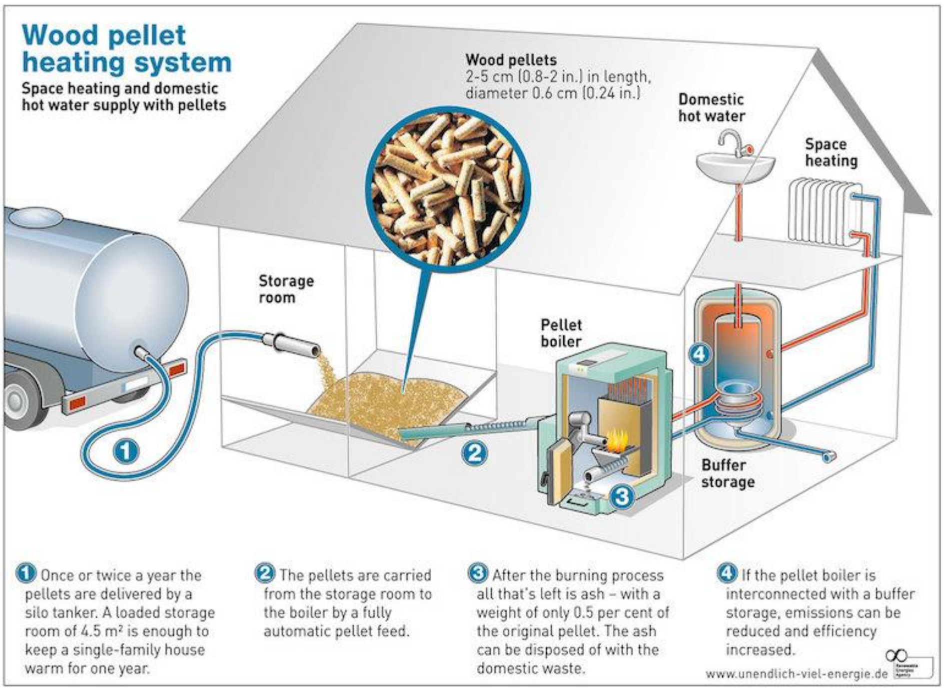


Figure 17 Working process of a wood pellet Biomass boiler

7.1 Boiler sizing

Calculating the required boiler capacity (typically stated in kilowatts, kW) is slightly complicated. Fortunately, there are some rules of thumb could be used to work out approximate figures. A single dome requires 6000 kWh energy annually. This number has to be converted to kW so that the hours are removed. This is done by dividing the energy consumption in kWh by the number of full load hours the boiler will be running for. Since boiler use varies daily, weekly and seasonally, a simplification called Full Load Heating Hours Equivalent or FLHE is used. For a domestic Dutch property, it is expected to be about 1100 FLHE (CBS, 2015) [12]. Therefore, the equivalent full load hours for a 3-bedroom house would be

6000 kWh / 1100 hrs = 5.45 kW

For the supermarket, the annual energy need is 654,665 kWh. Thus, the equivalent full load hours of the supermarket would be

654,665 kWh / 1100 hrs = 595 kW

7.2 Annual Biomass Consumption and Storage Space

Firstly, the energy demand must be converted to biomass quantities. The energy densities of biomass fuels are mentioned above (*Table 5*). Before calculating biomass quantities, it is important to make another boiler efficiency adjustment. The efficiency of a pellet boiler is around 95%. So, in order to generate 6000 kWh, a 95% efficient biomass boiler will require an input of

6000 kWh / 95% = 6315 kwh

Fuel Type	Price per unit	kWh per unit	Cent per kWh	Density Kg/m3
Wood chips	€100 / tonne	3,500kWh/ tonne	2.9c/ kWh	275
Wood pellets	€200 / tonne	4,800kWh/ tonne	4.2c / kWh	650
Wood logs	€80 / tonne	4000KWh / tonne	3.2c / kwh	400

Table 5

- Wood chips = 6315 kWh ÷ 3500 kWh/tonne = 1.8 tonnes (at 30% moisture content)
- Wood pellets = 6315 kWh ÷ 4800 kWh/tonne = 1.3 tonnes
- Logs = 6315 ÷ 4000 kWh/tonne = 1.6 tonnes (20% air dried stacked logs)

Next, the biomass quantities must be converted into required storage space. Each type of biomass has a different bulk density (*Table 5*).

- Wood chip = 1.8 tonnes = 1800 kg ÷ 275 kg/m^3 = 6.5 m^3
- Wood pellets = 1.3 tonnes = 1300 kg ÷ 650 kg/m^3 = 2 m^3

• Logs = 1.6 tonnes = 1600 kg ÷ 400 kg/m^3 = 4 m^3

All the above calculations are done by taking a general/broadline concept into account and not any specific boiler model into mind.For a 3-bedroom property, storage space is likely to be a major constraint and therefore a biomass storage space larger than 5 m^3 is likely to be unfeasible. In case of the dome houses, there is a storage room of 5 m^2 per house. Therefore, by using a wood pellet boiler, only 1 delivery a year would be needed to store 1.25 (6000 kWh / 4800 kWh) tonnes as it takes up the least amount of storage space and requires the least amount of quantity.

7.3 Choosing an appropriate Biofuel & Boiler Model

After reviewing all the calculations in the previous section, a decision needs be made about the type of fuel that is best for burning. A good quality wood has to have higher density so that it burns slower and generates more heat. Another factor to consider is the minimal amount of ash remaining after burning and preferably, the least amount of smell. The final factor to be considered is the need to thread or season the wood before burning. Based on all these requirements, wood pellets are the best fuel source for the biomass boiler since:

- Wood pellets are the easiest to handle of the wood fuel types.
- They are much more controllable than logs.
- Pellets also take up less space in a fuel store than wood chips or logs.
- Pellets produce less ash than wood chips or logs.
- Pellets require the least amount per year when compared to the other 2 choices.

For the model of the pellet boiler, the one that is chosen is the Viessmann Vitoligno 300-C. For the dome houses, the unit with an output rating of 2.4-8 kW is chosen, and for the supermarket, the unit with an output rating of 18-48 kW is picked. It is an automatic fed boiler and one of the leading models in the industry. Full technical specifications and details about the Vitoligno 300-C can be found here .

Figure 18 Demonstration photo of a Viessmann Vitoligno 300-C pellet boiler

Some further calculations can be done by taking the Vitoligno model into account instead of a general one as done in section 7.2. According to Viessmann themselves, there are a few rules of thumb for the calculations which are shown below

RULE OF THUMB:

- Per 1 kW heat demand = 0.9 m^3 of the space (incl. non-usable space)
- Non-usable storage space: ⅔ of the room
- 1 m^3 pellets = 650 kg
- Energy content: approx. 5 kWh/kg

Figure 19 Rule of Thumb for calculations from Viessmann

The heating demand of the house is 5.45 kW (section 7.1). Keeping this in mind, some calculations are carried out in the table below (*Table 6*).

Specification	Calculation	Result
Volume of Storage Space	5.45 kW * 0.9 m^3	4.905 m^3
Non-usable Space	4.905 m^3 * (2/3)	3.27 m^3
Amount of needed pellets annually	3.27 m^3 * 650 kg	2125 kg

Table 6

It is seen that the volume of the storage space is larger for the Vitoligno model than the general trend (2 m^3), but it is still adequate enough to fit in the dome house which has a 5 m^3 storage space. Furthermore, the amount of needed pellets per year is almost double the amount of the general one.

7.5 Financial Costs

Based on research, it was found out that as a general guide for domestic installations the price per installed kW (including flue, fuel storage, fuel feed, commissioning and design) is around €750 - €1000. So, a 15kW pellet boiler would cost a minimum of €11,250.

Log boilers tend to be cheaper than both wood chip and wood pellet boilers; for example, a 20kW system suitable for a 3 or 4 bed property would cost in the region of €500-750 per kW installed (€2,000). Larger boilers (>20kW) tend to be cheaper.

However, for the Vitoligno 300-C, the cost of each unit (including all installation costs) is €10,000 [13]. For the supermarket, the 18-48 kW model is chosen and assuming that the boilers provide the minimum amount of energy, it would need 33 boilers (595 kW / 18 kW).

Therefore, for 150 dome houses and a supermarket, the total cost for the pellet boilers would be

(150 * €10,000) + (33 * 10,000) = €1,830,000

7.6 Durability

Viessmann ensures a warranty of 2 years for the boilers. Multiple sources state that a well-maintained biomass boiler should last at 15 years and all the way up to 20 years [14].

7.7 Reusability

Plastic packaging is essential to keep the pellets dry, so dispensing with the packaging, or going for a more environmentally sound alternative is possible in the Netherlands. In 2010, the UK introduced an initiative known as the boiler scrappage scheme. For every old G-rated boiler (i.e. very inefficient models) that someone would scrap, they would receive a €440 voucher that could be put towards a new boiler (Viessmann UK) [15]. Unfortunately, the Dutch government had never introduced any such initiative. So, the best method for reusability of an old biomass boiler would be to take it to a local council and dispose it as bulky waste collection or to take it to a scrapyard and have it recycled.

7.8 Environmental Impacts

The burning of biomass result in both carbon dioxide and nitrogen dioxide emissions. However, the carbon produced is the same quantity as what was absorbed by the plant during its lifetime, so the total carbon emission is negligible. If the burning process within a boiler is faulty or the system has not been set up correctly, then the emissions (due to the incomplete combustion of the fuel) can produce carbon monoxide, benzene and volatile organic gases, amongst other toxic substances that can be carcinogenic. So, it is vital to ensure that all the boilers are installed correctly and looked after well. The ash produced by most biomass boilers is considered to be a compostable component. This can be used by horticulturalists for compost or simply be sent to landfill as this is a harmless natural material. However, researchers from the UK in 2017 [16] have expressed major arguments against biomass energy sources stating that any form of burning for energy production, whether be it pellets, wood or oil, is critically dangerous for the environment. Overall, biomass energy is mostly a well-approved source of energy when it comes to environmental impacts although there are some doubters and critics.

7.9 Placement within the Village

Unlike solar panels and wind turbines, it is best for the biomass boilers to be inside the house to function accordingly. Each house has a storage room for the boiler where it is kept, and each house will hoist its own boiler inside it. For the supermarket, the numerous numbers of boilers can either be placed within the large storage spaces or they can be placed outside as well in the 3 possible areas that have been mentioned before in solar panels and wind turbines.

8. Geothermal Energy

There are currently 24 doublets in the Netherlands. The majority of the projects are in greenhouse horticulture and in the provinces of South Holland and North Holland. Of the 24 doublets in the Netherlands, 20 are in production. Geothermal energy is an amazing alternative to fossil fuels and natural gas. In 2019, geothermal energy in the Netherlands saved 168 million m^3 of natural gas and 300,000 tons of carbon dioxide (Think Geoenergy, 2019) [17].

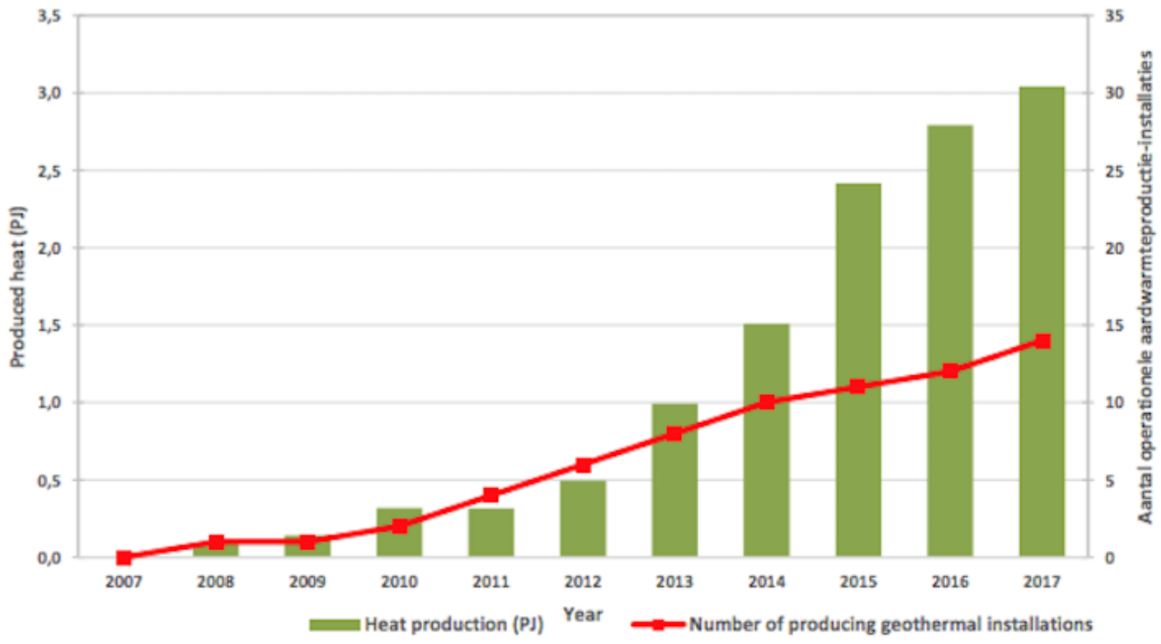


Figure 20 Annual production of Geothermal Energy in the Netherlands

The average soil temperature of the Netherlands at varying depths over a few decades is shown in the figure chart below (*Figure 19*). The temperature has to be at least 10 degrees Celsius for a geothermal heat pump to operate. A closed loop horizontal geothermal heat pump is chosen. Such a configuration needs trenches that are 1.8 m to 3 m deep. In the chart, it is seen that the temperature 1 m below the ground is always above 11 degrees Celsius. And, since the horizontal configuration needs trenches that are at least 1.8 m deep, it can be safely assumed that the temperature down there is more than 11 degrees, and thus more than the needed minimum operating temperature of the pump.

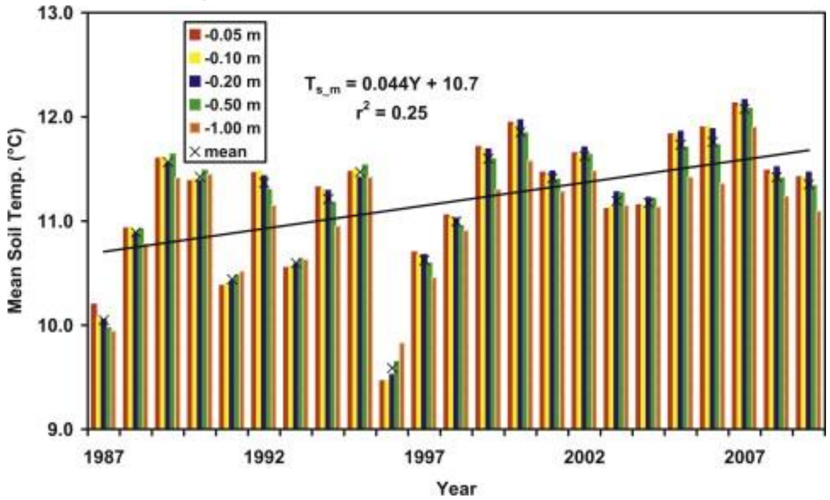


Figure 21 Soil temperature in the Netherlands (Jacobs, Heusinkveld, Holtslag, 2011)

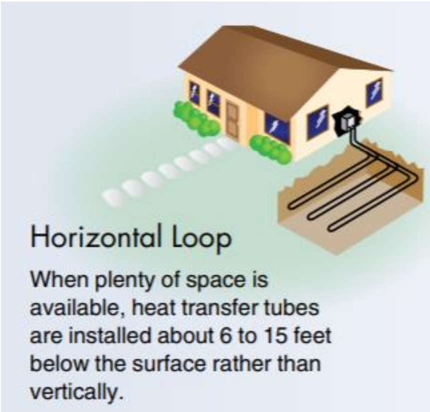


Figure 22 A Horizontal Loop of a Geothermal Heat Pump

Horizontal systems are better for the village because they are the better choice over vertical loops in rural areas [18]. Furthermore, horizontal loops are far less cheap than vertical loops. For the heat pump model, the chosen is the Viessmann Vitocal 222-G. With heating outputs of between 5.8 and 10.4 kW, they are ideal for use in detached houses and should easily fulfil the energy demand of a dome house. With its refrigerant circuits with a fixed heating output, in three output sizes, and an electronically controlled expansion valve, it achieves a COP of up to 4.8. More detailed and technical specifications of the pump can be found here.

Figure 23 Veissmann Vitocal 222-G Geothermal Heat Pump

8.1 Financial Costs

Since the COP of the heat pump is 4.8 and the and the annual energy demand of a dome house is 6000 kWh, the pump would need (6000 kWh/4.8) or 1250 kWh electricity to deliver that energy. The individual purchase price of the WW6500 is €9400 (Boiler Guide) [19]. However, when including the installation cost and groundwork cost, the total price turns out to be €44,000 per dome house (Green Match, 2020) [20]. So, the total costs for 150 dome houses would be

150 * €44,000 = €6,600,000

For the supermarket, there are no available commercial geothermal heat pumps that can supply the market with its insanely high energy demand in a financially feasible way. The only way to get such a high amount of geothermal energy would be from industrial geothermal power plants which are located on natural sites that are very active and constantly spew out heat all year along. However, operating such a large-scale industrial power plant for just one single supermarket is not a decision any engineer would make, and it is simply out of the option.

8.2 Durability

Geothermal heat pump systems have an average 20+ year life expectancy for the heat pump itself and 25 to 50 years for the underground infrastructure (US Dept. of Energy, 2011) [21].

8.3 Reusability

Large scale geothermal power plants often create solid by products which contain valuable minerals that can be recovered and recycled for other industrial uses. However, when it comes to residential heat pumps, there aren't many scopes of innovative reusability. The best that a customer can do is to return old heat pumps to the manufacturer or to sell it to a scrapyard where it will be recycled in conventional ways. For the ground loops, geothermal installers will dig them up and take them away for recycling when they are out of commission.

8.4 Environmental Impacts

The U.S. Environmental Protection Agency (EPA) [22] have called ground source heat pumps (geothermal heat pumps) the most energy-efficient, environmentally clean, and cost-effective space conditioning systems available**.** Geothermal systems are 100 % electric which means that they emit no carbon monoxide, carbon dioxide or other greenhouse gases that can be harmful. However, as heat pumps, they need considerable quantities of electricity for their operation and they contain refrigerants of very high greenhouse potential, in case they leak to the environment. Therefore, their environmental impact is limited to contribution to the greenhouse effect due to electricity consumption and due to possible refrigerant leakages. Due to the higher efficiency of the geothermal heat pumps (COP = 4 to 6) compared with air source heat pumps (COP = 2,5 to 3,5) and fossil fuels (efficiency = 80-90%), overall impact to the greenhouse effect is significantly less than burning fossil fuels or using air source heat pumps.

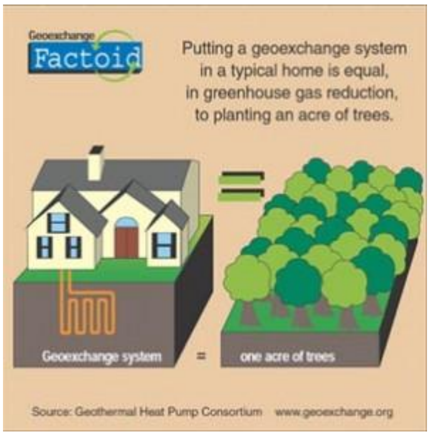


Figure 24 Healthy impact of geothermal energy on the environment

8.5 Placement within the Village

The geothermal heat pumps each would have to be placed directly under each dome house with the ground looping work done nearby. There is no scope of placing the heat pumps in a different location other than directly under the house or otherwise the looping would have to be way too long and the already absurd installation costs would reach unimaginable numbers.

9. Hydrogen Fuel Cell

A home fuel cell is an electrochemical cell used for power generation, similar to larger industrial stationary fuel cells, but built at a smaller scale for residential use. An environmentally friendly energy source for fuel cells, hydrogen is in use in vehicles and ships already in operation, among other things. Fuel cell heating systems have been used in living spaces in Japan, for example, since 2009. Over 200,000 such systems are now in use there. These fuel cells are used for providing heat and electricity which include combined heat and power (CHP), uninterruptible power systems (UPS) and primary power units.

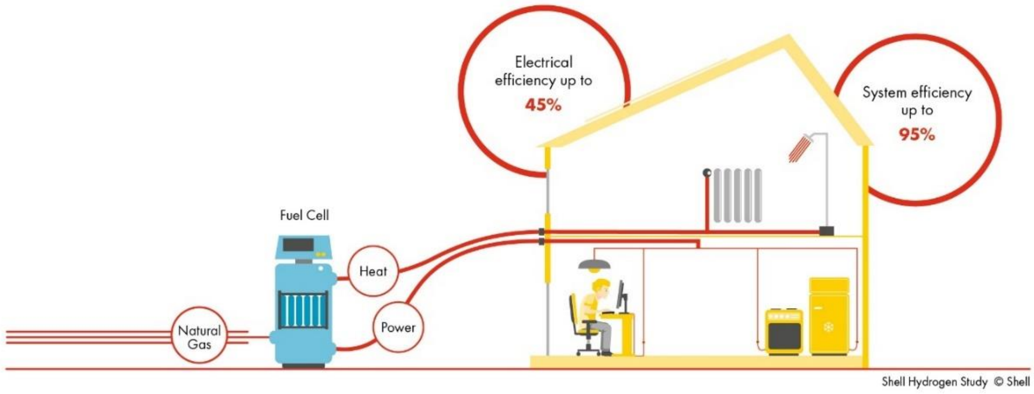


Figure 25 How a hydrogen fuel cell works

For the dome houses, the hydrogen fuel cell that is chosen is the Viessmann Vitovalor PT2. This fuel cell won the 2018 Innovation of the Year: Technology - Physical and also Home Energy Product of the Year, at the Energy Awards ceremony in London. All technical specifications, detailed working procedure, and how the hydrogen is extracted from natural gas can be found in the references [23, 24, 25, 26].

With a thermal output of up to 30.8 kW, it covers the heat requirement of an average four -person family - and at peak load times is supported by the integrated gas condensing boiler. The maximum electrical output of 18 kWh produced during the course of the day is sufficient for the average basic requirement of a household. Viessmann themselves say that with optimal integration, a single fuel cell can generate 6,000 kWh / year of energy per year, which precisely meets the yearly energy demand of a dome house.

For the supermarket, a different model of fuel cell has to be chosen as residential fuel cells aren't up to the power demand of a supermarket. Since a market has to be active for 24 hours a day throughout the year because of heating and cooling demand to keep products in optimal conditions, the amount of active hours is considered to be 8760 hours. Thus, the energy consumption of the supermarket in kW will be 73 kW (645665 kWh/ 8760 hrs). The fuel cell that can provide this kind of high energy output is the Ballard FC velocity-HD with its 85-kW energy output option. This fuel cell is currently used for heavy duty tasks such as providing power for trucks, buses and rams. It should also be capable of delivering the energy demand of the supermarket. All technical specifications of the Ballard fuel cell can be found here.

Figure 26 Demonstration photo of Viessmann Vitolator PT2

Figure 27 Ballrd FCveloCity-HD heavy duty fuel cell

9.1 Financial Costs

The Viessmann Vitovalor 300-P fuel cell boiler has been reduced in price from €20,000 to €11,000, largely as a result of Viessmann's participation in the new European PACE project [27]. As a single fuel cell is enough to meet a dome house's yearly energy demand, thus 150 of these cells would be needed. So, the total price of them would be

150 * €11,000 = €1,650,000

For the supermarket, a single Ballard cell is enough to provide its annual energy consumption. Each of the veloCity-HD cells cost €100,000 [27].

Therefore, the total cost for all hydrogen power for the village will be

€1,65,000 + €100,000 = €1,750,000

9.2 Durability

Viessmann claims that the fuel cells have a lifetime of 80,000 working hours. This is very short when compared to other renewable sources. Viessmann cover all parts and labour within the fuel cell for breakdowns and failure for ten years.

9.3 Reusability [29]

Fuel cell manufacturers provide a refurbishment program for fuel cell stacks that have reached the end of life. The customer returns the fuel cell stack to after which the manufacturer replaces the membrane electrode assembly (MEA) while reusing the existing hardware and plates. The used MEA is then sent to a third-party for recovery of the platinum and other precious metals. This process can generally be done for fuel cell stacks that are ten years old or less and will typically save customers 30% of the cost of purchasing a new fuel cell stack. Typically, more than 95% of the precious metals in the MEA are reclaimed during this process. The majority of the remainder of components in a fuel cell stack are recycled using ordinary recycling processes. When taking a broader look at a fuel cell module and not only a fuel cell stack, a number of other more standardized components are involved. These include electronics, pumps, valves, hoses and metal for housing and frames as the main components. These components are all commonly used components which are easily recycled and meet standard regulations, such as WEEE for general recycling.

9.4 Environmental Impacts

By oxidising molecular hydrogen, the only direct by-product of their energy generation is water. To be used as an energy source, hydrogen has to be separated from its compound. Natural gas has proven suitable as a source fuel for this. The hydrogen is extracted from the natural gas in an electro-chemical process and at the same time, separated from the other remaining gases. The extraction process must be done correctly to ensure no leakage or otherwise it could be hazardous for the environment. Hydrogen fuel cells have been widely touted as an environmentally friendly alternative to conventional fossil fuels. However, Tracey Tromp and colleagues at the California Institute of Technology [30] in USA have used models of the atmosphere to show that the inevitable emissions produced by fuel cell technology could substantially damage the ozone layer. But for now, hydrogen fuel cells are extremely environmentally friendly, and more research has to be carried out to definitively prove if they're hazardous in the future.

9.5 Placement within the Village

Domestic Hydrogen fuel cells by design are meant to be placed either inside a house or right outside the house where they can be constantly fed with Hydrogen can be attended to quickly in case of any failures or malfunctions. They aren't supposed to be placed collectively far from the houses they are providing energy to.

10. Conclusion

During this project, research was conducted into a Dome village. The advantage of a Dome (geodesic dome) is that it requires little building material and is very weather resistant.

The main question of this research is as follows: Which is the best possible renewable energy source for a village consisting of 150 dome houses in Blawestad, Groningen that originates from outside the dome house? Various generation sources have been investigated so far and to help make a decision, a table has been made below (*Table 7*) where each renewable energy source is given a grade on 4 different fields; Financial Costs, Durability, Reusability, and Environmental Impacts. The source with the highest total average is considered to be the best renewable energy source and is picked for the dome village. The grading system of the table is as follows: Very Poor = 1, Poor = 2, Average = 3, Good = 4, Very Good = 5.

Renewable Energy Source	**Monetary Costs Rating**	**Durability Rating**	**Reusability Rating**	**Environmental Impacts Rating**	**Average Overall Rating**
Solar Panels	5	5	4	3	4.25
Wind Turbines	2	3	2	4	2.75
Biomass Energy	3	3	3	3	3
Geothermal Energy	1	4	3	5	3.25
Hydrogen Fuel Cell	4	1	4	3	3

Table 7

From the table, it is clear that solar panels are the clear winners. It is easy to understand why when solar panels are the least expensive, lasts the longest amount of time, has great reusability potentials, and are generally quite good for the environment. However, the calculations are based on peak power. This means that the yield will differ in practice. But this gives a good indication that it is possible to supply a village with electricity.

Wind turbines are almost double the cost of solar panels, lasts half the lifetime of solar panels and have very poor reusability potential. However, they are excellent for the environment and have almost no repercussions what so over, but it isn’t enough to make up for the other negative points.

Biomass energy is more expensive than solar panels and biomass boilers don’t have the life expectancy of solar panels. The reusability of biomass energy is also quite limited in the Netherlands and in recent years it has been found that bioenergy is more hazardous to the environment than previously thought.

Geothermal energy might have excellent impacts on the environment and last a long time, but the absolutely ludicrous price to install them makes this choice very unattractive.

Finally, hydrogen fuel cells are still being developed in the world but aren’t good enough because of extremely short life cycles and more environmental hazards than previously thought, despite having very attractive costs and reusability potential.

For now, solar panels would still be the best source of renewable energy for the dome village. However, this may change in the future as new renewable energy sources such as electro-magnetic radiative energy and tidal kiting energy are being realized and are now in their infancy.

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11.2 Reflection Report on the Internship

My internship experience at EnTrance was rough at the start but I managed to recover from it and turned into a successful one. Overall, I'd say I have learned quite a lot about the topics I have researched on in the past 4 months and have gained major interest in renewable energy.

The first month was by far the harshest one. I was still in the summer vacation mentality and could hardly force myself to sit down and do some proper research work. I attended all the weekly meetings and events but had barely done any work from my behalf. By the end of the month, I had done only a mere 79 hours of work. It was quite a disastrous start to the internship.

As the second month began, I was in regrettable state and was very frustrated with myself for not utilizing the first month properly. I finally managed to get myself to concentrate on research work and do what I should have been doing from the previous month. However, I still had to suffer from my procrastination of the first month because once I started to focus on my work, I realized that the research question that I set and worked on a bit in the previous month is too complicated and would need more time than 4 months to finish. So, I had to discard all that work I did in those 79 hours. So essentially, the entire first month was wasted because of my own faults. But, I figured that out in time and set a new proper research question which I quickly started to work on and made rapid progress in the second month. I made sure to attend all the weekly meetings with the supervisor as often as possible.

I carried on with my progress in the third month. This is the month where I made all the core developments of my research work. I contacted Jacqueline from EnTrance and together with 2 fellow interns, I started going to the Energy Academy Europe building in Zernikelaan, 4 days a week to work in an academic atmosphere. Those sessions went quite well and the 3 of us shared some valuable information within us to help out the research work. Besides that, I also worked by myself at home a lot to finish all the research work. We also had a couple of physical meetings with the supervisors at EnTrance and I was present there. By the end of the third moth, I had stared laying out the structure of the final report and putting in bits and pieces that I had already finalized.

The last month of the internship was mostly about bringing all my research work together in 1 place and making the report itself. I had a few one on one meetings with both my Hanze supervisor and company supervisor to get their feedback on a draft version of the report and ask them questions and issues I was facing with the research. After taking all of their suggestions into account, I made appropriate changes to the report and finished it on time.

I'm very happy with myself because despite wasting an entire month, I was able to complete a full report which my supervisors approved of. Even though the beginning was quite rough, the ending turned out to be satisfactory.

11.3 Information Form

Name intern : MD Tahsinul Islam

Student number : 407402

Name Hanze supervisor: Tamizh Munuswamy

Internship period: from 1/09/2020 until 18/12/2020

During the internship I can be reached at the following addresses:

Monday-friday:

Street: Vondellaan 71 39

Postal code and city: 9721 LB, Groningen

Phone: 0638694992

E-mail: m.t.islam@st.hanze.nl

Weekend:

Street: Vondellaan 71 39

Postal code and city: 9721 LB, Groningen

Phone: 0638694992

Company details:

Full company name: IWP EnTrance, Energy Academy Europe

Street: Zernikelaan 17

Postal code and city: 9747 AA, Groningen

Phone: 050-595 6500

Company supervisor details:

Name: Wouter Swart Ranshuysen

Function: Lecturer/Researcher

Department: Renewable Energy at EnTranCe

Phone: +31620300395

E-mail: w.f.j.swart.ranshuysen@pl.hanze.nl

11.4 Personal Development Plan Internship (PDP Internship)

Name intern: MD Tahsinul Islam	Name Hanze supervisor: Tamizh Munuswamy	School: Hanze University of Applied Sciences
Name company: IWP EnTrance	Name company supervisor: Wouter Swart Ranshuysen	

Introduction

The first month of my internship at Entrance has had its ups & lows, but the overall final result turned out to be positive & I achieved the goals that I set when the program began. The most important lessons that I have learned about myself from this month are:

1. I am capable of working well online with people I've never met before in real life.
2. I can continuously work online from home on a project, although with not as much as efficiency if I had been able to travel to the work place every day.
3. I like studying topics on renewable energy and its different sources a lot. My whole internship is based around renewable energy and I'm liking it a lot.

Apart from these, I also learnt some genuinely useful skills, among which the most notable ones are:

1. How to have a professional online meeting with tutors and mentors, either one on one or in a group.
2. How to continue the research work from someone and carry on with it adding in my own work into it.
3. How to research independently without a mentor for a temporary period of time as my mentor fell ill and was out for 2 weeks.

Planning

It is best to show my plans, goals, & qualities through their appropriate ways. I will begin with a SWOT analysis which highlights my strengths, weaknesses, opportunities, & threats.

SWOT analysis:

Strengths	**Weaknesses**	**Opportunities**	**Threats**
The ability to capture the summary of a topic very quickly and using it to learn the broader picture in my own ways	The tendency to waste time that I could have utilised for studying	Plenty of more research work to come where my quick ability to grasp something can be useful	Lost time can never be recovered. So, time wasting can restrict my grades at lower levels in the future

Very punctual and consistent in attending meetings	Lack of pre knowledge about some subjects of renewable energy	Regular attendance is appreciated by mentors and can enable me to gain favours	Having no previous existing knowledge about something can be disastrous especially in a short internship
Getting along with people from different backgrounds and maintaining good friendships with them and also working with them to solve mutual problems	Insufficiency of curiosity towards topics that are outside the research question	Scope to meet several engineering students from other fields and have well maintained relations to solve engineering problems	Not exploring topics outside my prescribed question can limit my ability to add more dimensions into my research

Examples of mentioned strengths:

1. I made a lot of work on the Manifesto that had to be done during the IWP kick off week. I came up with several points, made and edited most of the Powerpoint slides that were in the final presentation.
2. Throughout the whole internship so far, I haven't missed a single meeting with my mentors, whether be it from Hanze or Entrance.
3. I've met some students from other engineering fields durin the IWP week. A few of them are working under the same mentor as I am and we meet online every week and share research work together.

Examples of mentioned weaknesses:

1. At the end of the first month, I am behind schedule as I haven't put in the required number of hours the internship obliges me to.
2. The insufficiency of pre-knowledge about renewable energy was a barrier to my choice of research question. I was given 4 topics to choose from and as I didn't have much pre knowledge about them, it took me longer than usual to choose the topic I wanted to work on.
3. During the first month, I only did work on renewable energy topics that I knew such as solar, wind, and turbine, but didn't bother looking at other ones such as geothermal, biomass, hydrogen, etc. Although, from now on, I plan to look into those other sources as well.

Now, I will follow up with a SMART goals chart which shows my objectives & how I fulfilled them.

SMART goals:

Initial Goal	Successfully complete the internship by fulfilling all the needed criteria
Specific	Completing the internship by working the required amount of hours, making the final advisory report, and submitting all other necessary documents such as logbooks, forms and agreements.
Measurable	Achieve the 20 ECTS upon completion of the internship
Achievable	I definitely have the required skills needed to achieve this goal.
Relevant	I set this objective at the start of the internship, which was the perfect time for such a long-term goal
Time-Bound	The final date for submitting the advisory report for the internship is during the second week of December.
Smart Goal	Successful completion of the internship and achievement of the 20 ECTS

Finally, a Personal Development Plan (PDP) will conclude this part of the portfolio.

Personal Development Plan:

Main Objective	Achieve the 20 ECTS by completing all the steps of the internship
Strengths that will help to complete the objective	Attending meetings regularly, the ability to grasp the concept of a topic in a short time, good team worker
Key areas to be developed with my goals in mind	Time management, project collaboration, exploring more branches of renewable energy

Skills/Knowledge/Qualifications to be gained	Gain knowledge about different branches of uncommon renewable energy, learn how to write a proper advisory report, have an internship experience for future ones
Date of achievement of the goals	Mid December

Achievements:

I have learnt plenty of things from both outside & inside the program. I will list the things that I have learned in tables for the convenience of easy reading and general tidiness.

Learning experiences	**How they improved my skills / How they showed I already have them**
Using Microsoft Office in more depth	I learned how to use Word, Excel, & PowerPoint in more detail and also mastered plenty of tricks to make utilisation of them easier & more convenient, which boosted my MS Office skills
Using Engineering Software Programs	I learned how to use essential programs that are used in engineering such as Mathcad, thus developing my software skills
Creating manifestos	My knowledge regarding what a manifesto is was very scant before this internship. Now, I have learned what it fully is and how to make one
Knowledge regarding renewable energy subjects	I was always curious about diving into renewable energy and I got to do that very deeply during this internship
Socializing	I met numerous people from different study backgrounds in the meetings, & have continued to work with a handful of them.

Future Challenges:

My plans for the next months are quite simple. I want to keep progressing at a steady rate and achieve all possible 20 credits. Unfortunately, I'm behind schedule at the moment. But I will try hard and soul and make up for lost time and successfully complete this internship at Entrance.

11.5 Logbooks

Logbook Month 1 (Part 1)

Name: MD Tahsinul Islam	Name lecturer: Myriam Jansen, changed to Tamizh Munuswamy
Name company Energy Transition Center	School: Hanze
Phone work/mobile: +31 63 86 94 992	

Month: 1

Total working hours:	79 hours
Sum of previous hours of internship:	+0 hours
Total work hours including this log book:	79 hours

Intern's opinion of his internship so far:

I have made the logbook for the first month on this document. I tried my best to be honest and not put in fake hours. However, I did slack quite a bit during week 2,3 & 4. But I tried to make it up somewhat in the last week. I am quite disappointed that the entire internship has been online so far and that I can't enjoy a proper experience which I had envisioned a year earlier. However, maintaining safety and health to prevent the possibility of contracting COVID 19 is more important than work enjoyment.

I am very aware that I am behind schedule on the number of hours I need to put in, but I plan to make up for lost time in the upcoming months.

As of now I have my internship research question finalized and I will spend most of October on making up for lost time by gathering data and doing research.

Remarks by company supervisor about the internship so far:

Seen by company supervisor:

Name: Wouter Swart Ranshuysen

Signature:

Signature student: Tahsinul Islam

MD Tahsinul Islam

Logbook Month 1 (Part 2):

Internship Timer

Student: MD Tahsinul Islam

Week 1

Day	Date (2020)	Time (hours)	Topic of Work
Tuesday	1/09	6	IWP Entrance week
Wednesday	2/09	6	IWP Entrance Manifesto Work
Thursday	3/09	6	Manifesto Work & Summary

Friday	4/09	2	Research
Saturday	5/09	0	
Sunday	6/09	0	
Monday	7/09	0	
		Total = 20	

Week 2

Day	Date	Time	Topic of Work
Tuesday	8/09	2	Preliminary research
Wednesday	9/09	5	Mentor meeting
Thursday	10/09	1.5	Research
Friday	11/09	1	Research
Saturday	12/09	1	Research
Sunday	13/09	0	
Monday	14/09	2.5	OnStage Documentation
		Total = 13	

Week 3

Day	Date	Time	Topic of Work
Tuesday	15/09	3	Research
Wednesday	16/09	1	Research
Thursday	17/09	3	OnStage Documentation
Friday	18/09	4	Creating first parts of final advisory report
Saturday	19/09	2	Research
Sunday	20/09	0	
Monday	21/09	0	
		Total = 13	

Week 4

Day	Date	Time	Topic of Work
Tuesday	22/09	2	Creating Word documents
Wednesday	23/09	2.5	Creating Word documents
Thursday	24/09	3	Re-evaluating research question
Friday	25/09	3	Research
Saturday	26/09	2	Creating word documents
Sunday	27/09	0	
Monday	28/09	0	
		Total = 12.5	

Week 5 ‘

Day	Date	Time	Topic of Work
Tuesday	29/09	3	Research
Wednesday	30/09	3	Personal Development Plan preliminary drafts
Thursday	31/09	3	Personal Development Plan
Friday	1/10	3	Re-evaluating research question again
Saturday	2/10	3	Research
Sunday	3/10	3	Making Word documents
Monday	4/10	2.5	Making Word documents

		Total = 20.5	

Logbook Month 2 (Part 1)

Name: MD Tahsinul Islam

Name lecturer: Jonathan Hofman , changed to Tamizh Munuswamy

Name company Energy Transition Center

School: Hanze

Phone work/mobile: +31 63 86 94 992

Month: 2

Total working hours: 156 hours

Sum of previous hours of internship: +79 hours

Total work hours including this logbook: 235 hours

Intern's opinion of his internship so far:

I'm glad to report I have made up for lost time from the previous month. I had slacked a lot in the previous month and came no where close to the required number of hours I had to work. However, I'm now back on schedule and steadily progressing. I have started physically going to Entrance with 2 fellow internship mates and have worked there for quite a few days. Overall, the logbook report for this month is very positive and I'm happy with my work so far.

Remarks by company supervisor about the internship so far:

Seen by company supervisor:

Name: Signature:

W. Swart Ranshuysen

Signature student: Tahsinul Islam

MD Tahsinul Islam

Logbook Month 2 (Part 2):

Internship Timer

Student: MD Tahsinul Islam

Week 1

Day	Date (2020)	Time (hours)	Topic of Work
Thursday	1/10	7	Research work
Friday	2/10	7	Research work
Saturday	3/10	7	Research work and making documents
Sunday	4/10	0	
Monday	5/10	7	Research work
Tuesday	6/10	6	Team meeting &Research work
Wednesday	7/10	7	Meeting with Tamizh and

			Wouter, and Research work
		Total = 41	

Week 2

Day	Date	Time	Topic of Work
Thursday	8/10	6	Research Work
Friday	9/10	5.5	Research work
Saturday	10/10	0	
Sunday	11/10	6	Research work and creating documents
Monday	12/10	6	Research work
Tuesday	13/10	6	Research work
Wednesday	14/10	5	Weekly meeting and creating documents
		Total = 34.5	

Week 3

Day	Date	Time	Topic of Work
Thursday	15/10	7	Research work
Friday	16/10	6.5	Research work
Saturday	17/10	7	Research work
Sunday	18/10	0	
Monday	19/10	7	Research work
Tuesday	20/10	7.5	Research work
Wednesday	21/10	7	Weekly meeting and research work
		Total = 42	

Week 4

Day	Date	Time	Topic of Work
Thursday	22/10	6	Research Work
Friday	23/10	6	Creating documents
Saturday	24/10	6.5	Research work and creating documents
Sunday	25/10	0	
Monday	26/10	6	Physical meeting with Henmar Moesker at Entrance and Research Work
Tuesday	27/10	6	Online work meeting with fellow intern and Research work
Wednesday	28/10	5.5	Weekly meeting and creating documents
		Total = 36	

Week 5 '

Day	Date	Time	Topic of Work
Thursday	29/10	1.5	Research Work
Friday	30/10	1	Research work
Saturday	31/10	0	N/A
		Total = 2.5	

Logbook Month 3 (Part 1)

Name: MD Tahsinul Islam

Name lecturer: Jonathan Hofman , changed to Tamizh Munuswamy

Name company Energy Transition Center School: Hanze

Phone work/mobile: +31 63 86 94 992

Month: 3

Total working hours:	201 hours
Sum of previous hours of internship:	+235 hours
Total work hours including this log book:	436 hours

Intern's opinion of his internship so far:

I have made significant advancements in the third month. My final advisory report is already underway and is gradually taking a fine shape. I have attended most of the team meetings, both physically and online. Besides, me and my fellow interns also carried out a side assignment given to us by Henmar Moeskar. It was a breath of fresh air from the usual research I've been doing so far and I enjoyed it. Overall, I'm on schedule and will finish the remaining hours of the internship on the final month. I had discussed and came to an agreement with my Hanze supervisor that my deadline of submitting the report will be 18 December. So I should have enough time to complete the rest of the remaining hours.

Remarks by company supervisor about the internship so far:

Seen by company supervisor:

Name: Signature:

W. Swart Ranshuysen

Signature student: Tahsinul Islam

MD Tahsinul Islam

<u>Logbook Month 3 (Part 2):</u>

Internship Timer

Student: MD Tahsinul Islam

Week 1

Day	Date (2020)	Time (hours)	Topic of Work
Sunday	1/11	0	
Monday	2/11	7	Research work and team meeting with Henmar Moeskar
Tuesday	3/11	8	Research work and making documents
Wednesday	4/11	7	Research work and weekly meeting
Thursday	5/11	7	Research work
Friday	6/11	7	Research work
Saturday	7/11	8	Weekly meeting and Research work
		Total = 44	

Week 2

Day	Date	Time	Topic of Work

Sunday	8/11	0	
Monday	9/11	8	Group meeting & Research work
Tuesday	10/11	8.5	Research work
Wednesday	11/11	8	Research work and creating documents & weekly meeting
Thursday	12/11	8.5	Research work
Friday	13/11	7.5	Research work
Saturday	14/11	7	Creating documents
		Total = 47.5	

Week 3

Day	Date	Time	Topic of Work
Sunday	15/11	0	
Monday	16/11	8.5	Meeting with Henmar and Research work
Tuesday	17/11	8.5	Research work
Wednesday	18/11	8	Weekly meeting and Research work
Thursday	19/11	8	Research work
Friday	20/11	8	Research work
Saturday	21/11	8	Research work
		Total = 49	

Week 4

Day	Date	Time	Topic of Work
Sunday	22/11	0	
Monday	23/11	9.5	Creating documents

Tuesday	24/11	9.5	Research work and creating documents
Wednesday	25/11	8	Weekly meeting and creating documents
Thursday	26/11	8.5	Physical meeting with Henmar Moesker at Entrance and Research Work
Friday	27/11	8	Online work meeting with fellow intern and Research work
Saturday	28/11	8	Research work
		Total = 51.5	

Week 5 ʻ

Day	Date	Time	Topic of Work
Sunday	29/11	0	Research Work
Monday	30/11	9	Final presentation of Henmar's assignment and research work
		Total = 9	

<u>Logbook Month 4 (Part 1):</u>

Name: MD Tahsinul Islam

Name lecturer: Jonathan Hofman , changed to Tamizh Munuswamy

Name company Energy Transition Center

School: Hanze

Phone work/mobile: +31 63 86 94 992

Month: 4

Total working hours: 124 hours

Sum of previous hours of internship: +436 hours

Total work hours including this log book: 560 hours

Intern's opinion of his internship so far:

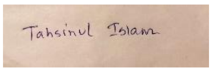
This is the final month of the internship. This month was mostly about having meetings with the supervisors, taking their feedback on a draft version of the report, making changes and then finalizing the report. The final report turned out to be quite satisfactory to me and I'm happy with the work I've been able to complete.

Remarks by company supervisor about the internship so far:

Seen by company supervisor:

Name: Signature:

W. Swart Ranshuysen

Signature student: 

MD Tahsinul Islam

Logbook Month 4 (Part 2):

Internship Timer

Student: MD Tahsinul Islam

Week 1

Day	Date (2020)	Time (hours)	Topic of Work
Tuesday	1/12	7	Research work
Wednesday	2/12	7	Online meeting and research work
Thursday	3/12	7	Making documents
Friday	4/12	8.5	Research work and making documents
Saturday	5/12	8	Research work
Sunday	6/12	0	
Monday	7/12	7	Research work
		Total = 44.5	

Week 2

Day	Date	Time	Topic of Work
Tuesday	8/12	7.5	Research Work
Wednesday	9/12	8	Research work and Weekly meeting
Thursday	10/12	8	Meeting with Hanze supervisor and research work
Friday	11/12	8	Research work and creating documents

Saturday	12/12	8	Research work
Sunday	13/12	0	
Monday	14/12	8	Creating documents and more research work
		Total = 47.5	

Week 3

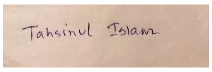
Day	Date	Time	Topic of Work
Tuesday	15/12	8	Finalizing report
Wednesday	16/12	8	Finalizing report
Thursday	17/12	8	Finalizing report
Friday	18/12	8	Finalizing report and submission
		Total = 32	

11.6 Form Evaluation & Assessment Functioning

MIDTERM EVALUATION, To be filled in by INTERN AND COMPANY SUPERVISOR

Name student: MD Tahsinul Islam	Name Hanze supervisor: Tamizh Munuswamy
Name company supervisor: Wouter Swart Ranshuysen	School: Hanze University Date: 30/10/2020
Filled in : O company supervisor : O intern	Signature:
Concerns: O midterm evaluation functioning O final evaluation/-assessment functioning	

	insufficient (4-5)	sufficient (6)	More than Sufficient	Good (8)	Excellent (9)
Functioning in company The student can………./I can…………					
Communicate effectively			v		
Work in a structured way			v		
Work in a team			v		
Apply knowledge			v		
Analyse problems			v		
Develop solutions			v		
Apply solutions			v		
Make a founded advice			v		
Personal competence development The student can…………/I can……………					
Advisory grade of the company supervisor **(final assessment only)**					
1. (see PDP internship)					
2. (see PDP internship)					
3. (see PDP internship)					
Advisory grade of the company supervisor **(final assessment only)**					

Name student: MD Tahsinul Islam	Name Hanze supervisor: Tamizh Munuswamy
Name company supervisor: Wouter Swart Ranshuysen	School: Hanze University Date: 30/10/2020
Filled in : O company supervisor : O intern	Signature: 
Concerns: O midterm evaluation functioning O final evaluation/-assessment functioning	

	insufficient (4-5)	sufficient (6)	More than Sufficient	Good (8)	Excellent (9)
Functioning in company The student can………./I can…………					
Communicate effectively		v			
Work in a structured way		v			
Work in a team		v			
Apply knowledge		v			
Analyse problems		v			
Develop solutions		v			
Apply solutions		v			
Make a founded advice		v			
Personal competence development The student can…………/I can……………					
Advisory grade of the company supervisor **(final assessment only)**					

1. (see PDP internship)					
2. (see PDP internship)					
3. (see PDP internship)					
Advisory grade of the company supervisor **(final assessment only)**					

FINAL EVALUATION, To be filled in by INTERN AND COMPANY SUPERVISOR

Name student: MD Tahsinul Islam	Name Hanze supervisor: Tamizh Munuswamy
Name company supervisor: Wouter Swart Ranshuysen	School: Hanze University Date: 17/12/20
Filled in : O company supervisor : O intern	Signature: Tahsinul Islam
Concerns: O midterm evaluation functioning O final evaluation/-assessment functioning	

	insufficient (4-5)	sufficient (6)	More than Sufficient	Good (8)	Excellent (9)
Functioning in company The student can………./I can…………					
Communicate effectively				v	
Work in a structured way			v		
Work in a team		v			

Apply knowledge			v		
Analyse problems				v	
Develop solutions				v	
Apply solutions			v		
Make a founded advice			v		
Personal competence development The student can…………/I can……………					
Advisory grade of the company supervisor **(final assessment only)**					
1. (see PDP internship)					
2. (see PDP internship)					
3. (see PDP internship)					
Advisory grade of the company supervisor **(final assessment only)**					

Name student: Tashin Islam	Name Hanze supervisor:
Name company supervisor: Wouter Swart Ranshuysen	School: Hanze University Groningen Date: 19-1-2021
Filled in : V company supervisor : O intern	Signature: W Swart Rc
Concerns: O midterm evaluation functioning V final evaluation/-assessment functioning	

	insufficient (4-5)	sufficient (6)	More than Sufficient (7)	Good (8)	Excellent (9)
Functioning in company The student can………./I can…………					
Communicate effectively			x		
Work in a structured way		x			
Work in a team			x		
Apply knowledge			x		
Analyse problems		x			
Develop solutions			x		
Apply solutions			x		
Make a founded advice		x			
Personal competence development The student can…………/I can……………					
Advisory grade of the company supervisor (final assessment only)					
1. (see PDP internship)			x		
2. (see PDP internship)			x		
3. (see PDP internship)			x		
Advisory grade of the company supervisor (final assessment only)	7				

11.7 Assessment Form Final Report

To be filled in by COMPANY SUPERVISOR AND HANZE SUPERVISOR

Name student: MD Tahsinul Islam	Name Hanze supervisor: Tamizh Munuswamy
Name company: EnTrance	Name company supervisor: Wouter Swart Ranshuysen

Assessments criteria	**To be filled out by company supervisor**					**To be filled out by Hanze supervisor**				
	insufficient	**sufficient**	**more than sufficient**	**good**	**excellent**	**insufficient**	**sufficient**	**more than sufficient**	**good**	**excellent**
Orientation phase										
Orientation on tasks, assignment, problem										
Orientation on company										
Plan										
Grade (1-10) weight = 20%										
Technical content										
Structured approach										
Usability										
Theoretical foundation										
Technical level										
Grade (1-10) weight = 40%										
Final report										
Problem analysis										
Approach assignment Theoretical foundation										
Clear introduction, abstract, conclusions										
Clear and correct structure										
Correct spelling and language										
Grade (1-10) weight = 40%										
To be filled out by internship administration	Signature company supervisor					Signature Hanze supervisor				
	Advised grade:					Grade lecturer:				