The Ecodome

A connected Greenhouse

Preface

In this report I write about my internship at the company VE-Sønderjylland. I have started this internship 01/02/2016 and ended it 30/06/2016. During this internship I worked a lot to improve my skills and gained a lot of new knowledge. This was the first real project where I basically had to structure everything myself. To make it a good project I needed to put a lot of effort into it and it worked out just fine in the end.
Here I would really like to say thank you to Søren and Karin which let me do this project in this internship and also Werner Kiwitt from artefact gGmbH where I could work in a border crossing collaboration between the companies. The goal with this collaboration was to get another dome build at artefacts' ground to show people visiting the Powerpark what an intelligent greenhouse could look like. It was a pleasure to work at artefact and meet a lot of new people and friends.

Also I would like to thank my supervisor Jan that he always was there to help and if I got stuck he guided the way.
Then there is also Michael, Jens Peter and Arne who put a lot of effort and strength in to building the dome and the interior. Without them the dome would probably not have gotten that beautiful.

X O. Rottscholl

Ole Rottscholl
Mechatronics Student

Table of content

Project formulation

Project background

The goal with this internship was to build a greenhouse dome in collaboration with the Sønderborg commune and kær landsby lav which will host a huge scout camp in 2017. There will be about 40000 scouts attending this camp and they will be camping around Sønderborg for one week. The dome itself should be used to harvest some sprouts of weeds and vegetables. The project itself was to make this dome "smart" or "intelligent". The ideal solution would be to just have to plant the seeds and then the greenhouse does everything else until they need to be harvested.

Problem formulation

Making the greenhouse water the plants when needed and keeping the temperature at constant 25-28 degrees Celsius and a humidity of max. 80% was the initial task to solve. Doing so would require some sort of microcontroller and some sensors like moisture, temperature and light indicators.

Requirements & Delimitations

Requirements

- Temperature max. 28° C
- Temperature min. 3° C
- Humidity below 70%
- Soil at a certain moisture level
- Use a microcontroller
- Programming using Arduino

Delimitations

- Since the dome was getting funded by Kær landsby lav there needed to be kept track of the budget.
- Part delivery sometimes could take up to 4 weeks when ordered from China.
- Use only Arduino code

My task as an intern:

As an engineering student I had to take care of all the calculations during the internship. Also looking for parts on the internet and finding the right ones to use. Also designing and sketching was part of this internship as well as working with electronics. Furthermore the dome had to be build where I needed to help as well but the part that would take most time and effort was the programming part where I basically had to figure out myself since no one else knew how to do it. This, though was the part I struggled with the most and I really had to improve and find a way to write a working code. Since we actually were two interns in the beginning the task itself was also a lot bigger than expected but I saw it as a challenge and to improve my skills. Sometimes the challenge was quiet big and I think with more time a better result can be achieved.

Company system

In the company I was working for were actually just three people involved. The chef, Søren, who has an electronic background and if I had questions in electronics he was the one to help me. Then there is Karin his wife who was taking care of the budged and kept track of my working hours. Michael is employed by Sønderborg Commune and is working at the place. He is the one I needed to talk to when I had to get something build. All Mechanics was his working area. My supervisor, Jan, worked in collaboration with my company for this project and we had a meeting every Friday. If I had questions I could not get an answer for I was allowed to go to the University and find my answer there.

My working time was Monday to Friday from 8.00 – 16.00. Also every first Saturday a month there was something called “Socialt Samvær” where people that was part of the foundation “Vedvarende energy Sønderjylland” were meeting and could talk and have fun. In the beginning it took a while to get fill 8 hours a day of working since there wasn’t too much to do and the structure of my working day was not really clear. First after three weeks or so I finally got a clear structure in my day of working. It would start out with that I should be at the university from 8.00 to 10.00 so I could do some research, ask questions if needed or do some electronics. From 10.00 on I should be at my working place. I could have a small chat with my chef and talk about previous successes and the plans for the day. After that I could go to my desk and do some further research or calculations or do some testing. At 13.00 there was a small lunchbreak where Søren, Michael, me and sometimes Karin could have a small break and get some food. People in the foundation could come by at any time and could have a little break too. After the lunchbreak there was additional time to do some testing or research. Then at 15.45 there was a small chat with my chef about what was done today. On every Friday I had a meeting with my supervisor from the work and I had the opportunity to ask him some questions. If there was something to do he stayed and we worked together on a problem. At 16.00 the working day was over.

Research

The idea of having a greenhouse that can keep the plants watered is not a new idea. It exists in the big greenhouses in Holland already where they grow tomatoes. In the big greenhouses they have a watering pipe above the plants that, when plants need water they would spray water onto the plants. Also using it in private greenhouses a lot of people used Arduinos before to make their greenhouse smart.
Using the search word “garduino” or “smart greenhouse” in google gives a lot of examples of projects some people did in their spare time or even as their final year project.
Many of those garduino project are just used for small greenhouses or just some boxes but not for a big 38 m2 dome. But getting inspiration by those project was great to see what is possible and what is harder to do. If there is a lot of time and knowledge in programming a connection with the internet is possible to always see what the current state of the greenhouse is or apply some growing light to minimise the time from planting the seeds to eventually harvesting the plants.

How different all the ideas are, they all have some things in common. They all need to have some sensors to control different aspects of the greenhouse. There are always these crucial things like temperature and humidity as also the moisture in the soil which have to be controlled. And all this will the need to be connected to a controller.

There is a project on the internet found on the webpage Instructables.com where a person has uploaded his fully working Arduino based growing box[1]. In this example there is a lot of good information how to operate a greenhouse using Arduino. It gives a good overview which sensors are suitable and how to control everything with the microcontroller. The example has implemented more than just temperature/humidity and soil sensor but also a floating sensor, a buzzer and a CO2 sensor. Furthermore there are some relays to turn on and off heater, lamps and fans implemented.

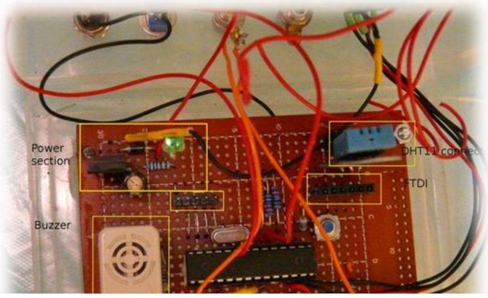

Abbildung 1 Arduino for Greenhouse, Garden or Growbox: Construction
http://www.instructables.com/id/Arduino-for-Greenhouse-Garden-or-Growbox/step13/Arduino-for-Greenhouse-Growbox-or-Garden-The-CO2-s/

[1] http://www.instructables.com/id/Arduino-for-Greenhouse-Garden-or-Growbox/?ALLSTEPS

There are a lot more smart greenhouses out in the world. Another one does not even have to use soil to grow plants. There is a company called Netafim that is specialized on providing creative greenhouse planning and design. They provide customers with different kinds of upgrades for their greenhouses like control systems or heating systems[2].

They have developed a technology that makes plants grow in greenhouses without using soil a basement for the plants. Instead they use a substrate either inorganic or organic to grow the plants directly from the substrate. The inorganic substrate consists of volcanic ash, pumice and vermiculite whereas the organic substrate consists of coco peat moss, composts and other organic mixtures. Using this method, growing plants out of a substrate, does involve a good knowledge about some physical and chemical aspects as air/water ratio, pH and mineral content to get enable an optimal growing platform for the plants.
Netafim are using a lot of different sensors and equipment to determine the water requirements of the plants. The growth and the development of the plants are effected by the water and nutrient application which mean a better control of water and substrate will give a better plant. To accomplish that they use light sensors and tensiometers[3] and much more to make the plants grow as fast as possible. [4]

To be able to keep the greenhouse at a temperature that is ideal for the plants to grow Netafim came up with two different methods. One of them would transport hot water through steel or aluminium pipes to heat up the greenhouse uniform. Through radiation the temperature around the pipes would increase. This method will be controlled by a central system computer.
The other method uses Hot air where a burner would produce heat and will blow the warm air into the greenhouse.

The process Netafim is working with is interesting but also really hard to accomplish in an internship of 6 month. Therefor there will have to be found different solutions for growing plants and be able to control their growing process. Searching the internet for alternative watering methods.

Abbildung 2 Perl Hose http://www.seyboth.de/shop/images/product_images/popup_images/Perlschlauch%204.jpg

The most common watering systems in many greenhouses are perl hoses. They are easy to connect to a watering pump and do their job pretty good. I got the inspiration to use the perl hoses by finding a YouTube video[5] that showed that it is fairly easy to water big areas with these pipes by using a single watering pump as supply. The general problem with using pipes with small holes are that they at one point might congest and no water is flowing out. In a lot of forums on the internet people have been complaining that these perl hoses actually aren't the best because they are known to congest over a certain time but in the end those are the most common watering pipes which would also be used in the greenhouse we were building. Another problem that have to be solved it the temperature control. As we got from the problem formulation the temperature must not get above 28 degrees Celsius. In most common small greenhouses that would be found in most gardens at home there will be one window and one door. This is most likely enough to get the temperature down if needed. In our dome though we have 38m2 and getting the temperature hold on a constant level is not easy. In some greenhouses people rely on having two or even three windows and a big ventilator in the top to circulate the air and through the windows get new air into the greenhouse.
Keeping the control of the temperature does not only mean how to cool it down but also what

[2] https://www.netafim.com/Greenhouse_Technology/Intro
[3] https://en.wikipedia.org/wiki/Tensiometer_(soil_science)
[4] https://www.netafim.com/Greenhouse_Technology/irrigation_nutrition
[5] https://www.youtube.com/watch?v=imxKFAfE70Y

happens when it is winter and it actually needs to be heated up if plants should also grow in winter. There needs to be anything that can store the heat gathered on the day to give it back when needed during night.
A lot of people consider using a heating pump in winter which is an obvious solution. But having a heating pump installed means having a high power consumption during the winter month. If it would be possible with the heat gathered over the day to store it in water or stones this could be possible to store the energy until it is needed[6]. There exists a concept where people have been using a stone layer for storing the excessive energy generated by the sun in stones to safe the heat and release it again if needed during night. They used a fan to suck the air through the stone layer and thereby heating up the stone and also cooling down the air. The stones will then layer by layer start to heat up until when it is night the process will then turned around. Then the temperature in the greenhouse is colder than the stones and the fan would start to turn in the other direction.

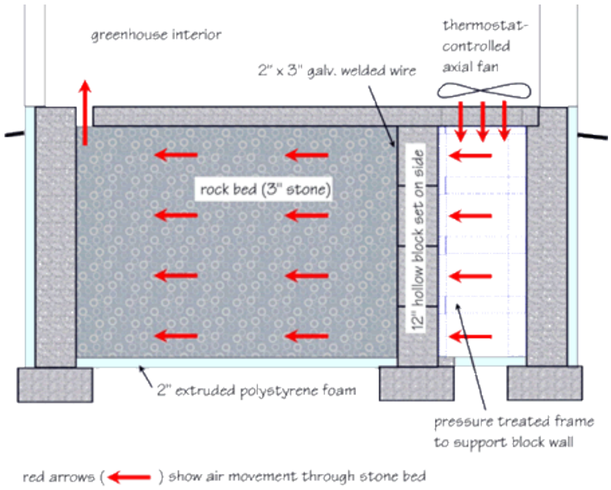

Abbildung 3 Stonelayer example http://people.umass.edu/caffery/greenhouse/heatstorage.html

From all the different shapes of greenhouses why did my company choose a dome shape? Well the dome shape itself has a bigger surface to collect the suns energy during the day. Other standard greenhouses are directed such that the long side are directed to south since there would be most sun over midday. But having a dome will always have one side facing the sun so it would use the suns energy more efficient. The shape makes the greenhouse easier to heat up and allows better ventilation[7]. Also it is some sort of eye catcher.

Concept Design

My company is also part of an association called “Vedvarende enegy Sønderjylland” which mean when they want to build this dome it should also be most likely build very eco-friendly. We wanted to use recycled materials to save money.

During the first weeks of the internship there wasn’t really too much to do since the dome project itself had to be accepted from the Sønderborg commune. The first steps in the design phase were to do some calculations about the size of the dome and how to use the interior space for later use. The idea of having high beds for easier use was been decided already pretty early. Having high beds has also some good advantages when it comes to protect the plants from mice and it would also give some space under the bed itself.

Since I first had to do some research about how to have and use a greenhouse it took some time to figure out how exactly to keep the temperature controlled in the dome? During the “social samvær” at the first month of my internship I have been talking with people about how to manage to keep the temperature constant. Having a heat pump that would also work as a dehumidifier could be a good solution. So I have been looking into some heat pumps and looked at their functions.
It would be really easy to just have a box sitting somewhere in the greenhouse working like, when it is too cold the cold air would be sucked into this box and be heated up by an internal heater. Then when the air is too hot it would cool down the air by letting the air flow across an internal heatsink. The downside of using a dehumidifier and heat pump is that these boxes are really expensive. They can easily cost up to 2000-3000 DKK.

[6] http://people.umass.edu/caffery/greenhouse/heatstorage.html
[7] http://www.solardome.co.uk/domestic/dome-uses/greenhouse/

At one point my supervisor got the idea about using stones as an energy layer and also make it a dehumidifier at the same point. Since we agreed on using high beds the stone layer could be placed below to and would take no extra space. After doing some research about stone layers and doing some calculations about pressure drop across a certain layer of stones it was proved working in theory and had to be tested in a real setup. If this would work as expected it could be a more ecological solution than a bought dehumidifier.

Kozeny-Carman equation

$$\frac{\Delta p}{L} = \frac{180\mu}{\Phi_s^2 D_p^2} \frac{(1-\epsilon)^2}{\epsilon^3} v_s$$

$$\Delta p - pressure\ drop$$

$$L - total\ height\ of\ the\ bed$$

$$\mu - viscosity\ of\ the\ fluid$$

$$\Phi_s - Sqhericity\ of\ the\ particles$$

$$D_p - Diameter\ of\ the\ related\ spherical\ particles$$

$$\epsilon - porosity\ of\ the\ bed$$

$$v_s - superficial\ \text{'empty tower'}\ velocity$$

Porosity, ϵ

Fine Sand: 0.25 - 0.50 →0.40 assumed for calculations

$D_{fine\ sand} = 0.06mm - 0.2\ mm$ → 0.1 mm assumed for calc.

Stones: 0.25 - 0.40 → 0.25 assumed for calc.

$D_{stones} = 63mm - 200mm$ → 100 mm assumed for calc.

Coarse gravel: 0.25 – 0.40 → 0.35 assumed for calc.

$D_{coarse\ gravel} = 20mm - 63mm$ → 40 mm assumed for calc.

Sphericity, *Φ*

0.7 → assumed for calc.

Height of bed, L

1 meter

Viscosity of air, μ

@ 50°F → $\mu = 1{,}787 * 10^{-5} \frac{kg}{ms}$

Calculate v_s:

$$\Delta T * c_p = specific\ energy$$

$$\Delta T = 2°K$$

$$c_p\ air = 1.005\ \frac{kJ}{kg\ K}$$

$$specific\ energy = 2 * 1.005 = 2.01\ \frac{kJ}{kg}$$

Calculate $\dot{m}$:

$$\dot{m} = \frac{25kW}{2\ kJ/kg} = 12,5\ kg/s$$

Calculate Q:

$$\rho_{air} = 1,2\ kg/m^3$$

$$Q = \frac{\dot{m}}{\rho_{air}} = \frac{12,5\ \frac{kg}{s}}{1,2\frac{kg}{m^3}} = 10,4\ \frac{m^3}{s}$$

Calculate v_s:

$$v_s = \frac{Q}{A} = \frac{10,4\frac{m^3}{s}}{38m^2} = 0,27\frac{m}{s}$$

Calculate the pressure drop: Coarse Gravel (D=4cm)

$$\frac{\Delta p}{L} = \frac{180\mu}{\Phi_s^2 D_p^2}\frac{(1-\epsilon)^2}{\epsilon^3}v_s$$

$$\Delta p = \frac{180\mu}{\Phi_s^2 D_p^2}\frac{(1-\epsilon)^2}{\epsilon^3}v_s * L$$

$$\Delta p = \frac{180 * 1,787^{-5}}{0,7^2 0,04^2}\frac{(1-0,35)^2}{0,35^3}0,27 * 1 = 10,9Pa$$

$v_s\ changes\ with\ the\ different\ height\ of\ the\ stone\ bed\ the\ air\ will\ need\ to\ flow\ through.$

If v_s is 1 m/s then the final result would not be 10.9 Pa but something around 40 Pa.

Sketches

With ongoing process there needed to be done some sketches of how the interior of the dome could look like. The agreement on high beds have been made, but how many of them and how big should they be. In the dome there are ten sides where one of them is reserved for the door. Also it could be nice to have some space besides the door to place a locker for the electronic devices and a watering tank. The high beds should also be symmetrical placed around the centre to get a nice looking greenhouse. I made some initial sketches to show how the beds could be placed in the dome. The boxes at the ends of the high beds would be to store the fans. This concept would also allow to have the temperature sensor for every fan hidden away and would also hide the wires going from the box to the controller board. But this boxes would also have to be build and cost some more money that might not fit into the budget. With this in mind the sketch had to be redesigned slightly to get another solution.

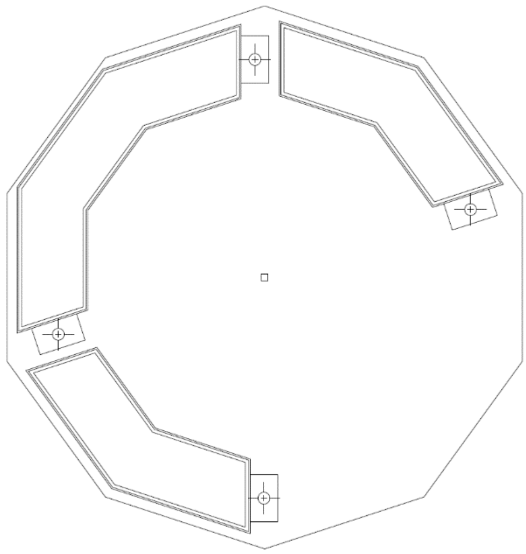

Abbildung 4 Initial sketch of the high beds seen from above

In the final design there were made some minor changes. The angles of the high beds were changed to be on a 90 degree angle for easier building. Also the boxes from the initial design were scrapped and put into the high beds ends. The fan sits now in a covered area in the sides of the beds. The space between the high beds can now be used as storage.

With this design the dome is symmetrical around the entrance and looks decent.

The Software used for designing is called NX.

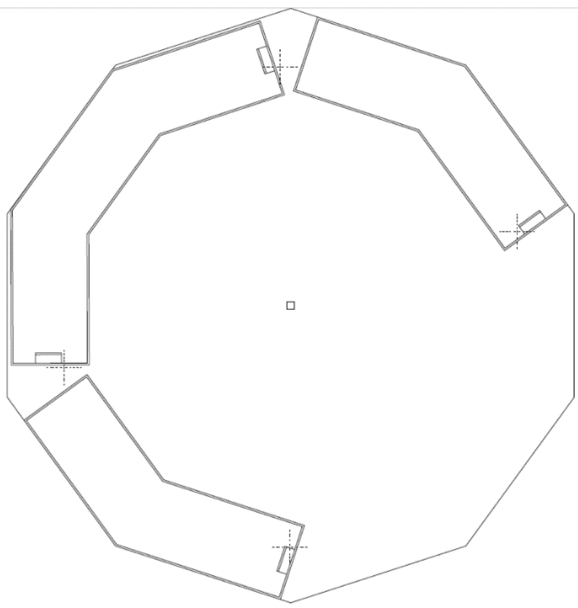

Abbildung 5: The sketches of the Final design.

Testing the Stone layer

After having the done some calculations about the Stone layer we needed to be able to test it. To do so we build a small set up using big plastic pipes with a diameter of 40 cm. We cut this pipe into two pieces of one meter length. We mounted those two pipes on a wood plate. In the plate we cut two holes to measure the airflow through the stones. Then we mounted a fan on another plate that would work a lid. When we then would turn on the fan it would blow air through the stones. With an anemometer we could then measure the airflow. We have done this test with two different sized stones. One of them were gravel stones not bigger than 10 mm in diameter. The other one were some bigger stones with a diameter of ca. 40mm. We let the fan blow in both directions and found out that the fan working better turning in one direction than in the other. This was good to find out since we needed the more efficient side to suck the air through the stones in the final set up.

The testing of both stone sizes gave the result that the bigger stones are better suited to do the job since there is more space in between the single stones. When the air is pushing on to the small stones it is almost as blowing air towards a wall since all the small stones make it really hard to find a way through the layer. This result gave a good overview of what size of stones we would need to make the layer ideal to store heat but also cool down the air going through.

The next step would be to find out what the pressure drop across the stone layer would be. To do that we needed to modify the set up slightly. We had to mount the fans below the wood plate and put a sealed lid on the top. Then we had to drill a hole into the plastic pipe a height above the stone layer. There where stones filled up to 40 cm of the plastic pipe. We build us self a manometer to measure the pressure across the stones. The manometer is angled to 45° to get a better measurement. Filling water into the manometer and marking its “zero-position” before turning on the fan to find out the difference in height when the fan is turned on. The height difference from zero position will be the change in pressure from atmospheric pressure. When blowing air through the stones the pressure is higher than the atmospheric pressure whereas when the fan sucks air out of the stones the inside of the plastic tube would create an under pressure which is lower than the atmospherics’. Doing some examples with different heights of stones would change the pressure in the manometer and give values that could be put into a graph. With a difference of 5mm in a 45° angle we have to calculate the actual height in the vertical direction which is 3.5 mm. Also 1 mm change in height equals about a change in pressure of 10 Pa. This will then be a pressure change of 35 Pa when air was blown into the stone layer.

Abbildung 7: DIY Manometer

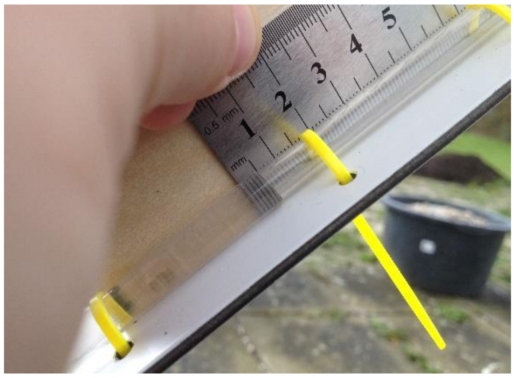

Abbildung 6: The result of blowing through the stones is about 5mm difference in height

Testing of the Dome at Powerpark Artefact

Working with a greenhouse in form of a dome requires some research about how the temperature and the humidity inside the environment of the dome changes. How will the greenhouse effect influence the different climates in the greenhouse? How high and how low can the temperature reach on a different days in a month that varies a lot in humidity and temperature during day and night.

Taking measurements in the glass dome at Artefact to test how the temperature and the humidity level changes during different days and outside conditions.

ECODOME ARTEFACT

Tested was the Temperature and the Humidity of a Glass dome over the timespan of 5 Days

Temperature (°C):		Humidity (%):	
Max.	Min	Max.	Min.
44,1	- 0,6	89	32

Sunny Day at 14.00	Temperature	Humidity
	24,6	45
Cloudy day at 8.30	Temperature	Humidity
	11,4	80

Conclusion:
At this part of the year (march) the weather outside varies a lot so it is impressing to see that the temperature inside the dome will climb up to 44°C when it is maximum 16°C outside.
It might be impressing that the greenhouse effect will heat up the Dome almost three times the temperature outside but this will lead to a problem when the dome at one day should become a greenhouse.
Plants simply cannot survive the amount of heat generated inside the greenhouse and would die eventually.
This problem need to be solved with some sort of cooling system that will hold the temperature at a constant level where plants, fruits and vegetables can survive.
Also the Temperature seems to vary a lot inside the greenhouse. Where it gets really hot inside it also goes down into the negative degrees during the night, when it's cold outside.
Since most electronic components cannot sustain in a greatly changing temperature environment and would not have a big lifetime during cold temperatures there will need to be added a system that keeps the temperature during night time above a certain temperature for the electronics to survive.
Those values given above where simply taken by a thermometer that was put into the glass dome. It saved the max. and min. temperature and humidity, but it did not show how the humidity would behave at a high or low temperature. Facing this problem I wanted to build a data logger that would be able to take temperature and humidity over a timespan of a week and safe them on a SD-Card. The data logger would then also be using a LDR to track if it is day or night. Furthermore there will be a soil sensor to track the moisture of a little pot plant. To make a data logger I used an Arduino UNO and an Ethernet shield that can be put on top of the Arduino. This would then be programmed using a program which I had to write myself. It was working after a week of focussing on the data logger and was placed to take measurements in the glass dome of artefact.

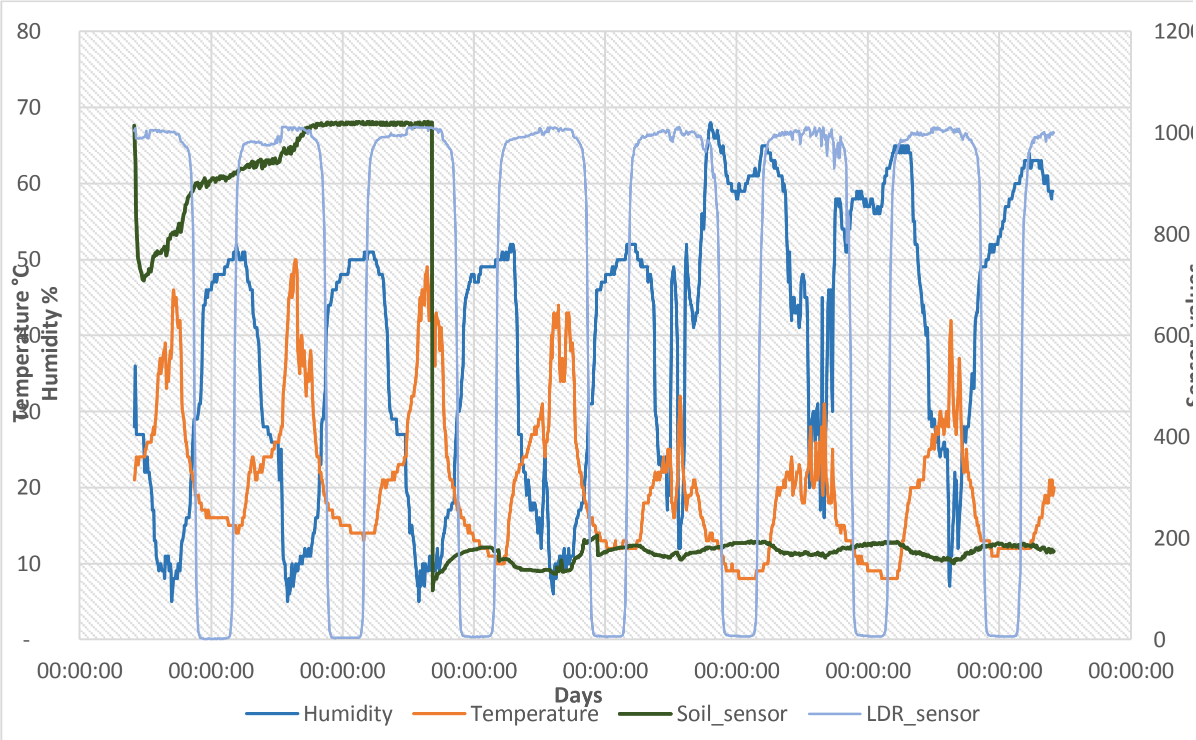

Abbildung 8 This table above shows the result of the data logger which was measurering data for 1 week. On the left vertical axis we see the scale that shows temperature and humidity, while on the right vertical axis it shows the sensor values. The values for the sensor are explained by being a 10 bit value which goes from 0 to 1023, where a low value indicates low light or wet soil. The numbers in the horizontal shows the number of days the logger was taking measurements.

The table shows a clearly connection between the temperature and the humidity. As on a sunny day the temperature climbs up to almost 50 degrees Celsius the humidity would go down to below 10 %. Below you can see a small section of the excel sheet. This section shows the data from 18.00 to 22.00 o'clock in the evening. The data logger was taking measurements every 10th minute.

Hum.	Temp.		Soil	LDR		Time	
8	% ,	41	°C	815	998		18:00:00
10	% ,	42	°C	821	997		18:10:00
10	% ,	42	°C	804	986		18:20:00
9	% ,	37	°C	805	982		18:30:00
12	% ,	31	°C	823	981		18:40:00
13	% ,	30	°C	829	980		18:50:00
13	% ,	29	°C	838	977		19:00:00
14	% ,	28	°C	844	975		19:10:00
15	% ,	26	°C	857	973		19:20:00
15	% ,	26	°C	860	973		19:30:00
16	% ,	24	°C	866	970		19:40:00
16	% ,	24	°C	873	967		19:50:00
16	% ,	24	°C	876	959		20:00:00
16	% ,	23	°C	876	949		20:10:00
18	% ,	22	°C	883	920		20:20:00
21	% ,	22	°C	883	876		20:30:00
23	% ,	21	°C	886	807		20:40:00
26	% ,	21	°C	890	692	Light Low	20:50:00
29	% ,	20	°C	893	485	Light Low	21:00:00

29	% ,	19	°C	900	263	Light Low	21:10:00
29	% ,	19	°C	899	112	Light Low	21:20:00
29	% ,	19	°C	902	42	Light Low	21:30:00
30	% ,	18	°C	891	7	Light Low	21:50:00
31	% ,	18	°C	899	4	Light Low	22:00:00

When the sun goes down and the temperature in the greenhouse is falling, the humidity will increase but the amount of water in the air might actually not change too much.

Building of the dome

Eventually we got the building licence for the dome were able to raise the dome. The barebones were built on a Saturday were we invited members of the association to join. This day we were about 15 people to support building that dome and it took just a few hours to raise it. There was done some work beforehand already. Two of the association members where mechanics and helped digging the holes for the fundament. I was helping them to get the right distances to put the fundament and doing some work myself.

Abbildung 9: A picture of how we were digging out the soil to put the fundament.

Abbildung 10: Day of building the dome

With some passed weeks the greenhouse was evolving to be more of a greenhouse. We digged some of the earth from the inside of the dome to get some additional space. After that we wanted to put down some plastic foil on the ground to make a stable floor. My supervisor was sponsoring the plastic since it was some remains of an old project of his. The reason to put this plastic on the ground was to keep out the water that could be appearing from the ground because of the capillary rising moisture. Also it would save the high beds from rotting away.

Abbildung 11: Start of building the interior of the dome.

Eventually the interior high beds where finished and we could put down the stones and the soil into the high beds.

Since the centre part of the greenhouse should not be left as empty space we put down some additional beds to grow plants.

Abbildung 12: The greenhouse is almost done! The high beds are finished and the next step would be to do the wiring

The triangles which are not covered with plastic on picture 8 were left open while building the interior to keep the room cold enough to be able to work in it. Even with the opened triangles the greenhouse effect would already heat up the dome when there was a lot of sun.

Just as we were closing in on finishing the project we covered the last triangles. The next step was to do the programming for everything that should be controlled.

Prototyping:

With the dome build up the next step was to figure out what would be needed to make it smart. From the research we figured out that the watering method using the perl hoses would be a good way of doing it. But since we have three big beds and there can be a scenario where only one bed should be watered we needed to have some sort of regulating system. A valve for every bed could be a solution. Then controlling the valves and a watering pump using a microcontroller we can precisely water the bed we want to.
How does the microcontroller know when to water the beds? In every bed there are two soil sensors that keep track of the moisture in the soil. When both sensors give a value above a set value in the program the bed is considered dry and the microcontroller would give a signal to turn on the watering pump and open the valve for this specific bed.
The stone bed which should be able to keep the temperature constant would need to have some fans connected to suck or blow air through the stones. We selected some fans my chef bought from china. The fans themselves turned out pretty bad for this case since they consume a lot of energy. They run on 12 V and need 70 W. Their initial use was being a cooling fan for cars. By the time we figured out we already had ordered four so we would have to make it work with them. The fans would need to be able to run in both directions so they needed to be put on an H-bridge. However when the fans ran at 12 V they would require a lot of power which would heat up the cooling plates of the h-bridge and almost burn them over.

Also to get an overview of if the stone layer really is working out we wanted to have some additional temperature sensor close to the fan outlets. With this we can measure what temperature the air is that was sucked through the stone layer. This method is also a check if the stone layer if filled up to its maximum. When the air coming through the stones is as warm as the temperature in the rest of the greenhouse this is a sign that all the stones are heated up and we cannot cool anymore. Then we need to open a window or the door.

There is one window installed in the top that will be opened and closed by an actuator. The actuator itself is a recycled one which we got from an old wheelchair. Also the window would have to be able to open and close, so the actuator itself will also needed an h-bridge for the use. The h-bridged we used were Dual H Bridge Stepper Motor Drive Controller Board Module for Arduino L298N.

Although it has two connections for motors we are only using one to not burn the h-bridge.

Now there will be a list of what we have been using of electronic components.

Component	Amount
12 V DC Fans	4
Linear Actuator	1
Watering valves	3
Watering pump	1
Temperature Sensor DHT11	5
Soil Moisture Sensor	6
H-bridges L298N	3
Power FET	4
Arduino DUE Microcontroller	1
Pushbuttons	3
Cables 230V	Min. 50 meter

There will be needed about 21 meter of the perl hoses and the same amount of regular watering pipes.

At one point during the process we wanted to have one h-bridge for each fan and the actuator. Why do we then in the final set up only have 3 h-bridges connected? Simply because we figured out that the fans already give a decent airflow when they run on 6 volt. This means when we connect the fans two by two in series they get 6 volt each to run on. This saves some electronics and also reduces the power consumption.

Furthermore there was implemented some pushbuttons on the final setup. They are needed to have some manual control of the system. Having pushbuttons for each watering system and the window gives the possibility to manually open and close the window when really needed and also open for the watering valves and turn on the water supply.

All the electronics have been set up on a board to have a nicer overview of it.

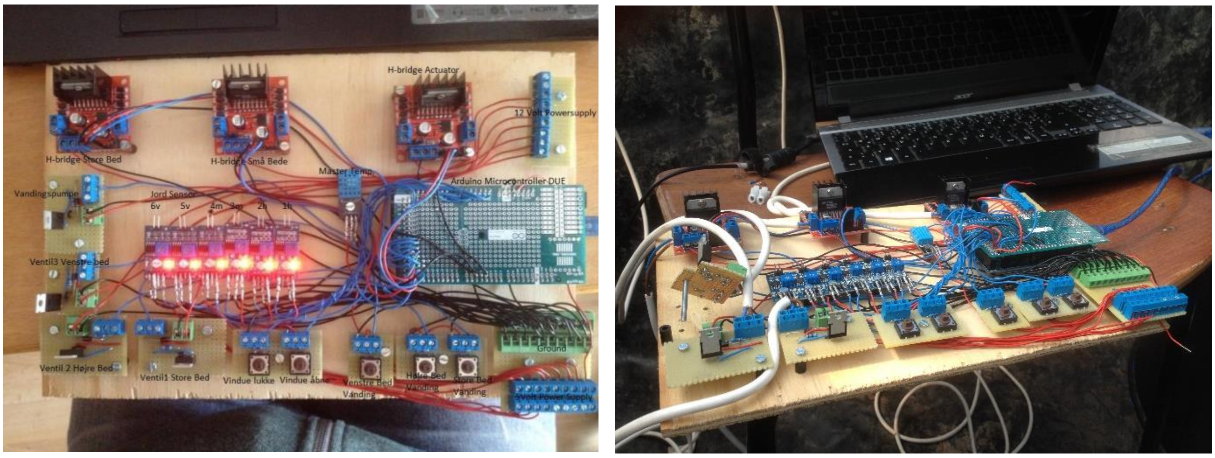

Abbildung 13: The left picture shows the electronics set up on a board. The components are named to keep track of what is what. The right picture shows the set up with the wires connected to it.

Conclusion:

Finishing up this internship I must say that this semester really helped me out in gaining new knowledge. In the beginning I was not really convinced if this project would be any god or if it would just be some “needed to be done” project. Also I kind of feared that the programming in this project would just be too much for my skill. But with the project going along I grew more and more to the task and with the first programming successes it moved into a more doable project. Starting out by looking at different codes on the internet helped my understanding of coding and helped me during my later programming decisions. Having to do all the work that would normally be spread out across a team gave me a better overview of how much work it actually is to create a good project. My focus was to get the programming running for the Eco dome and make it work. So besides finishing up the program in the last weeks I also needed to connect all the cables on a test board and in the dome. The project is really interesting and there is a lot more to improve and add onto what there already is. My chef is thinking about having the dome running off grid so it should be supplied by solar panels and maybe attach some growing light to make the plants grow faster. So the project right know is almost working as I intended it. During my final tests I had some slight problems in getting the power-FETs to work. When pushed on one of the buttons the watering valve connected should open and the watering pump should start pumping. This though was not quiet working in the last test. But the fans would start sucking air into the stone layer and cool down the air in the dome as expected.

I definitely enjoy having taken this internship and it really helped me out improving.