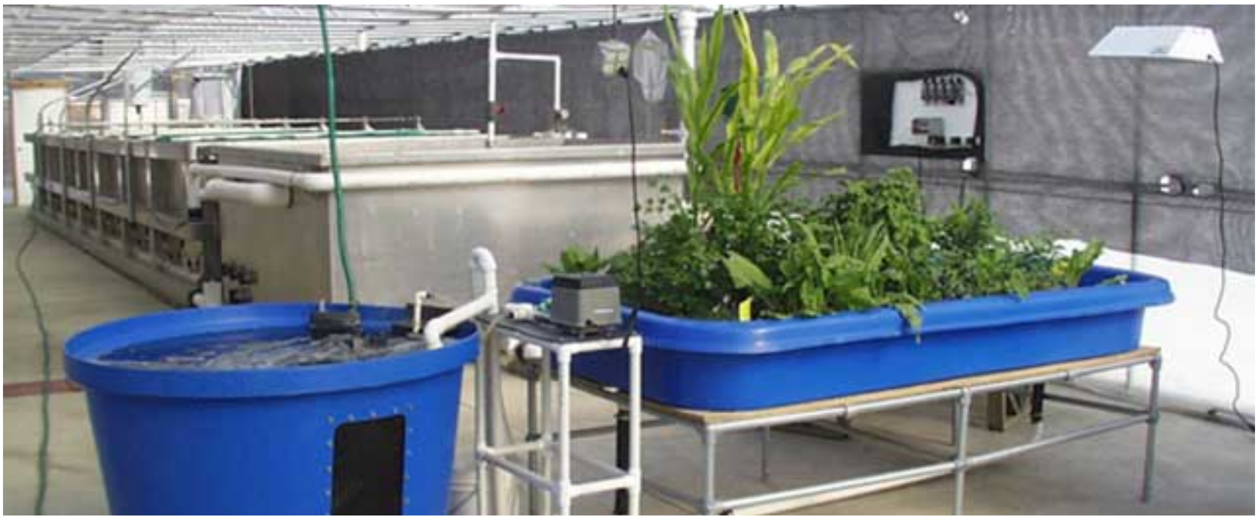
Aquaponic Greenhouse – Low energy house

European Project Semester

EPS-Project Spring 2023

Jeroen Mooijman, Lennard Uhlenbrock, Ewelina Witaszek-Faure, Matijs Vermost



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Matijs Vermost

Project:
European Project Semester, NOVIA University of Applied Sciences
Aquaponics project

Overseer:
Mikael Ehrs
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Sponsors:

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1 Abstract

Our main project for this semester's "Aquaponic Greenhouse – Low energy house" project is to improve a partially existing aquaponic system inside a greenhouse. In addition to the aquaponic system, we also have to convert the greenhouse in a low-energy house. Since the project is very complex, we are a group of 4 foreign students, who can bring a lot of knowledge from different fields of studies.

The previous groups build an insulated tank for the fish and also a greenhouse made out of wooden beams and PE foil. We can use and improve them for our project.
We start with the decision of the fish species we want to use in our aquaponic system. This selection shows us what kind of water we will use in our system, either sweet water or saltwater. And with the kind of water, we can choose plants, which we want to grow in our system.
In addition to the fish, we also need to get some experience with water quality, what we have to do to change the pH, the hardness or the temperature. We use for this purpose smaller aquariums.

The second part of the project will be the converting of the greenhouse into a low-energy house. We will bring on insulation on almost every wall, the roof and the door. One wall will be a see-through wall, to let in some light and make it more attractive.

Next to all the research and practical work, we bring in project management, for example a schedule, a WBS or also Mission and Vision.

2 Preface

Before you lies the end report Aquaponic Greenhouse – Low energy house. This document has been written to fulfil the requirements for the Spring 2023 European Project Semester. The project was one of the projects offered by NOVIA University of Applied Sciences in Vaasa, Finland.

The past four months as a project group we researched aquaponic systems, research low-energy construction and renovated and improved the rooftop greenhouse on Technobothnia. An experience none of us had ever done, but have really enjoyed.

During this semester we all were granted the opportunity to develop ourselves as a person and to improve and test our current skills, which is something we really appreciate as well as the amount of freedom given by NOVIA University of Applied Sciences and our Coash to be able to do this. Especially because before we started we were all strangers to each other from different countries and (educational) backgrounds. After a week of individual teambuilding with each other and general teambuilding and excursions with the other European Project Semester students we quickly got to know each other.

Words cannot express our gratitude to everyone from NOVIA, Technobothnia and Svenska Kulturfonden who have supported us with guidance, resources, information, and financial resources to be able to execute and bring this project to a good end. In special we want to thank our coach Mikael Ehrs who has guided and supported us tremendously, thank you for that.

We hope you enjoy reading this report and are satisfied with the produced conclusions and results,
Jeroen Mooijman (Building Master), Lennard Uhlenbrock Ewelina Witaszek-Faure, Matijs Vermost
12-05-2023

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Figures & Tables

4 Team member

- 
Ewelina: Hello, I'm 21 years old. I'm studying packaging engineering for 2 years now. I come from France and my engineering school is in Reims. I decided to join the Erasmus adventure because I really want to get out of my comfort zone. Indeed, with EPS program, I can learn about subject other than packaging. Additionally, practising English will be very helpful for my future job. Thanks to project management learnt at Novia University of Applied Sciences, my knowledges are stronger. Be here in Finland is also an opportunity to discover another culture, other people, another way to teach. I am totally fulfilled with my Erasmus stay and also, I'm grateful to take part of the aquaponic project.

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Lennard: Hey, I'm Lennard Uhlenbrock, 24 years old, my home university is the Hochschule Osnabrück in Osnabrück, Germany. I study mechanical engineering, with a specification to energy technic. Before I started my studies, I did an apprenticeship as an industrial mechanic and worked half a year after I succeeded the apprenticeship. As I heard in my home university that there is the opportunity to do an exchange in kind of the EPS program, I thought for myself that I won't get a better chance to work abroad with international team members like you do it in the EPS. So, I applied for it to get some experience in working with other nationalities but also to live for a certain amount of time in another country for my own. It is also a good opportunity to improve my English. I came to Finland because I always wanted to visit Scandinavia and now, I'm here for four months and working on the project with a nice team of international students.

- Jeroen: Hej I am Jeroen Mooijman from the Netherlands. I am 24 years young, and I study industrial engineering & management at Hz University of Applied Sciences in Middelburg, the Netherlands. I decided to join the European project semester to experience something different and to live and be in another country for some time.

- Matijs: Hello, my name is Matijs Vermost. I am 21 years old and studying energy management at the Artesis Plantijn University of Applied Sciences in Antwerp, Belgium. In my second year they told me that I got the opportunity to finish my bachelor's degree abroad. When I saw that Finland was one of the options I was immediately convinced. I was really interested to live and study in another country, and I think that this is a once in a lifetime experience. I think that you can learn a lot by living in another country with different culture and working together on a project with people with a different background.

5 Aquaponic System

At the beginning of the EPS Erasmus Mikael Ehrs presented the project: An aquaponic system and a low-energy house. This chapter is dedicated to the aquaponic system, his working principle and future plans for it.

5.1 What is aquaponic?

Aquaponics is a cooperation between plants and fish and the term originates from the two words aquaculture (the growing of fish in a closed environment) and hydroponics (the growing of plants usually in a soil-less environment). (Harlaut, 2012)

Figure 1: Aquaponic system (Miimosa, N.D)

Aquaponics operates in a closed circuit, based on a so-called balanced ecosystem. Fish, raised in a small pond, produce manure. Manure loads ammonia and organic matter into the pond water.The water "charged" of the basin is directed, via a pipe and through a pump, to the culture bins where plants are grown on a neutral substrate (clay balls, gravel, etc.) enriched with bacteria.
Bacteria transform the organic matter in the water into nutrients that can be absorbed by plants (phosphorus, calcium, iron), and ammonia (harmful to fish) into nitrate (a form of nitrogen that can be absorbed), so plants are fed.The water purified (denitrified) by the plants then returns to the fishpond. (Harlaut, 2012)

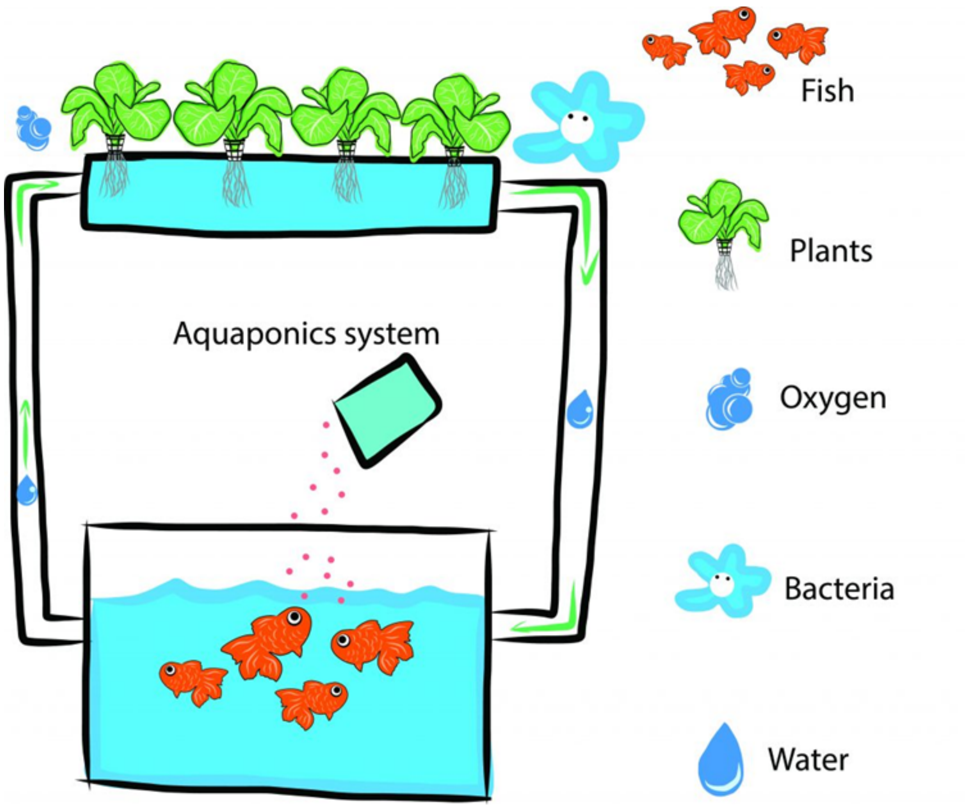
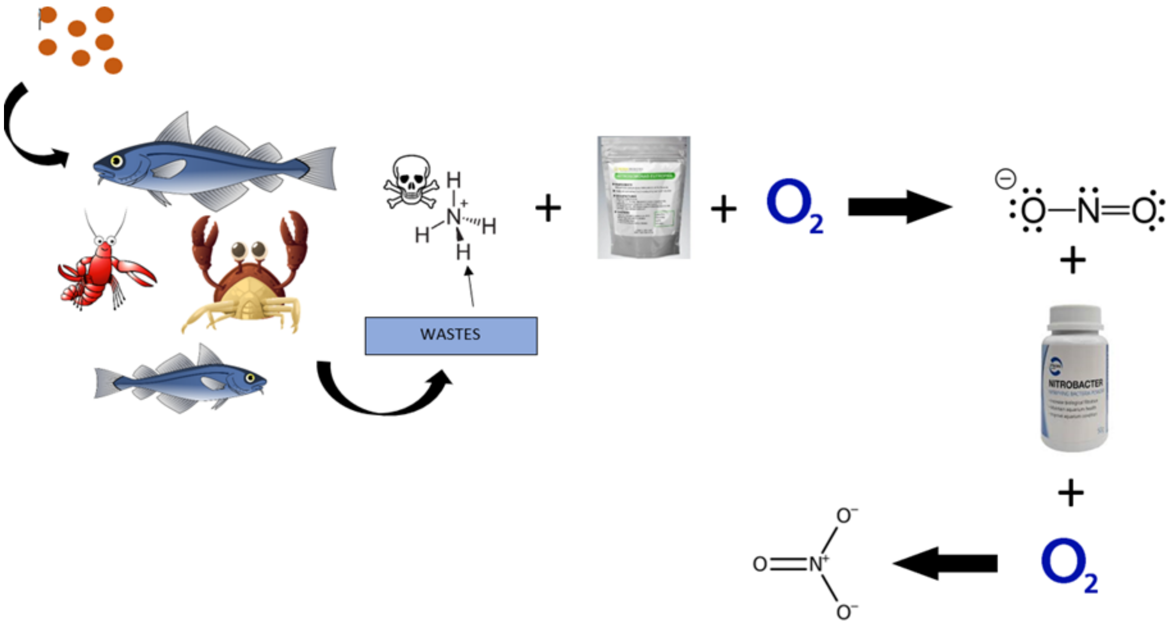


Figure 2: Example aquaponic system (The aquaponics guide, n.d.)

As the fish get fed, they poop, and the water gradually becomes filled with their ammonia-rich wastes.

It must be known that ammonia rich environment is too toxic for the species living in it. This way, we must add a nitrifying bacteria called Nitrosomonas utilizes oxygen and ammonium from the fish waste in an acid formation process. The next step in the nitrogen cycle is carried out by a different bacteria called Nitrobacter. These bacteria also need oxygen to carry out their chemical conversion. The Nitrobacter convert the nitrites to nitrates. Plants take up their nitrogen in the form of nitrates, so now this nitrate-rich water will provide the plants with what they need and that completes our aquaponic nitrogen cycle. The toxic ammonium has been removed the from the environment of the fishes, the plants receive their nitrogen fix and the bacteria just go about their day doing what they know best. (Harlaut, 2012)



$NH_4^+ + O_2 \rightarrow NO_2^- + 2H^+ + H_2O$ $\qquad$ $2NO_2^- + O_2 \rightarrow 2NO_3^-$

Figure 3: Nitrogen cycle (Harlaut, 2012)

It has a lot of benefits. It is therefore suitable for small-scale/domestic consumption as well as commercial fresh food production, particularly in communities where water is scarce.

1. Farming Benefits

- Year-Round Gardening: Because it's often protected from hard weather conditions, insects and pollution, plants can grow all the year.
- Low water use: One of the significant benefits of aquaponic growing is less water is used compared to the traditional growing method, like soil gardening. Aquaponics uses approximately 90% less water than conventional agriculture. The water is rarely changed or discarded since it's recycled repeatedly through the entire system.
- Growth: Plants grow faster in an aquaponic system than plants in soil because they access 100% natural nutrients 24 hours a day.
- Two Sources of Income: Aquaponics offers two streams of income, both fish and vegetables.

- Small Carbon Footprint: Aquaponics farming does not require farmland with fertile soil. Aquaponics can be done successfully on any land, cement, gravel, rocky surfaces, or even drought lands, which are difficult to use in conventional farms.
- Food Security / self-sufficient of living: Food security and food independence are increasingly becoming important. Aquaponics is another way of living a more self-sufficient lifestyle.

2. Nutritional Benefits

- Healthy food: because of the absence of chemical products, only natural wastes is used, the food is not contaminated by heavy metals, toxic substances etc... Moreover, it can encourage people to eat more vegetables.
- Fresh produce: For those persons who have a domestic aquaponic system at home, they don’t need to buy vegetables from supermarkets which get it from other countries.

5.1.1 Types of aquaponics

Nutrient Film Technique (NFT)

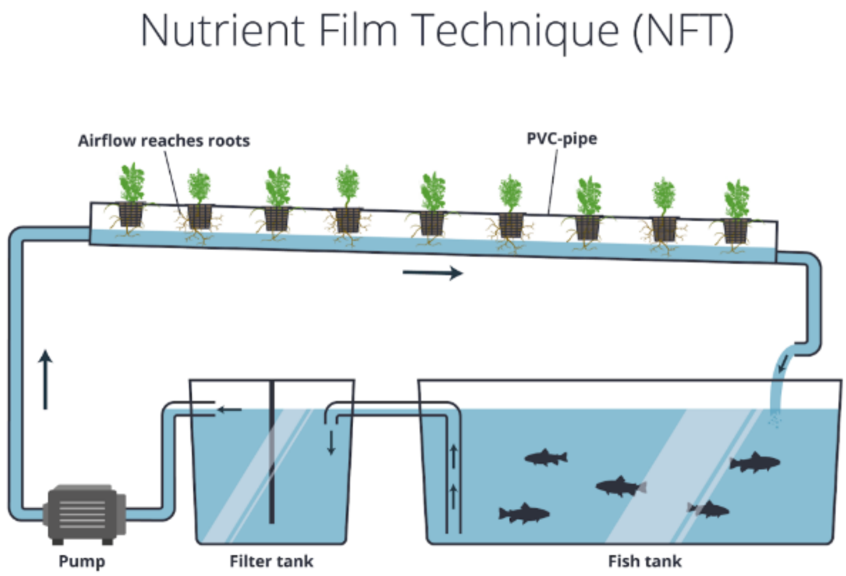


Figure 4: Nutrient film technique (Spring 2020 EPS group, 2020)

It is a method in which plants are grown in narrow gutters. A film of water continuously flows through each channel. This water film provides water, nutrients and oxygen to the roots of plants. As with the raft system, the water flows continuously from the tank into the filters, then flows into the NFT gutters where the plants are grown, then returns to the tank. In the NFT, a separate biofilter is mandatory because the necessary bacteria are not present enough in the water. (Spring 2020 EPS group, 2020)

Stength	Weakness
• Great supply of nutrients, oxygen, and water • Space efficient • Easy access • Lower labour costs • Beginner friendly • Possibility of future expansions • Constant waterflow prevents clogging and growth of algae and funguses • Easy to check how roots are growing or are there any problems	• Filter must be integrated into system • only good for leafy greens (Because of the design) • roots are not good isolated from temperature fluctuations • flow rate must be constant • power outage can ruin the culture (requires a lot of routine maintenance)

Table 1: Strength vs. weakness NFT

Media Bed

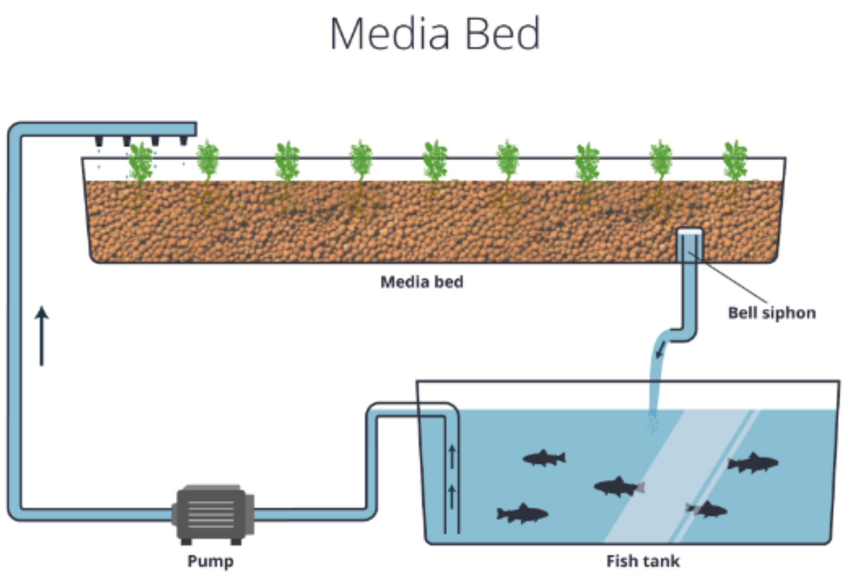


Figure 5: Media bed (Spring 2020 EPS group, 2020)

How does it work?

A media bed system uses a bin, tank or container filled with gravel, perlite, or other substrate. This bed is periodically flooded by water from the reservoir. The water then goes back into the basin. All wastes, including solids, are decomposed in the culture bed. Worms can be added to the culture bed to improve waste decomposition. This method uses the least number of components since no filtration system is required. This makes this technique very simple to use. Production, on the other hand, is much lower than the other two methods. The bed filled with supports is, in general, used when the objective is not to maximize production, in leisure facilities for example. (Spring 2020 EPS group, 2020)

Strength	Weakness
• Plants are supported by media • Media also acts as mechanical and biofilter (captures and breakdown wastes in plant bed) • Easy to operate (often used by backyard gardeners and beginners) Large root mass plants can be grown (fruit, flowering plants, vegetables and root vegetables)	• Produces less than other techniques • Not space efficient • Requires more labour hours than other techniques • On large scale, media is heavy and very expensive

Table 2: Strength vs. weakness media bed

__Deep Water Culture (DWC) or RAFT__

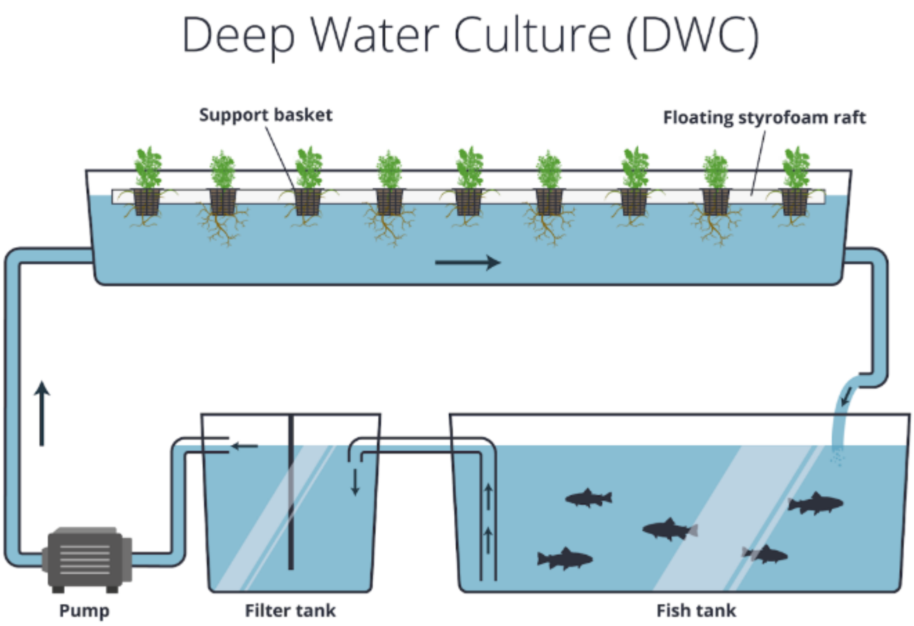


Figure 6:Deep water culture (Spring 2020 EPS group, 2020)

How does it work?

The plants are fixed on rafts (polystyrene panels floating on the surface of the water). The water flows from the fish tank, through the filtration components, into the reservoir where the plants are grown, and then back to the tank. Bacteria, used in the transformation of nitrites and nitrates, live in the tank of the raft and throughout the system. By providing a buffer volume, the additional volume of water in the tank reduces fish stress and potential water quality problems. This is one of the biggest advantages of the raft system. (Spring 2020 EPS group, 2020)

Strength	Weakness
• Large water volume reduces stress on fish, temperature is more stable • Optimizes floor space by creating a process line (highly productive) • Inexpensive to build • Can grow bigger plants than Nutrient Film Technique • Removing grown plants much easier than in Media Bed technique	• Needs a lot of energy for heating or cooling the water (large volume of water) • System needs more fish than other techniques to have enough nutrients diluted in water • Roots might not receive the right amount of oxygen (under water) • Needs supplemental oxygen • Needs external filtration

Table 3: Strength vs, weakness deep water culture

<u>Conclusions of different aquaponic methods:</u>

For choosing the right aquaponic system, all the purpose has to be summarized to do the right choice: However, different studies had been done to compare different types of aquaponic:

- Study Lennard in 2006

It has carried out a comparative study of the performance of the three systems and its conclusions are following:

The crop yield is higher on the gravel method. Deep water culture arrives in second position and last the NFT technique. For the cleaning yield, the NFT again, is less effective than the other two. However, it should be noted that this study was conducted on a 21-day period. Many agree that this is insufficient to measure long-term effects term of the three systems and the evolution of all parameters. It emerges from this study that the NFT technique is certainly the least adapted to the scale trade because it presents many constraints and disadvantages in the long term. The technique on inert substrate is effective. But the accumulation of waste could have in the long term a negative impact on the structures that will be reserved for recreational activities. At scale the rafts technique is used because it has many advantages and that the disadvantages are acceptable.

- Study Love et al (2004)

They conducted statistical studies on different techniques and travelled the world to gather information from aquaponic gardeners. Here are their results.86% use inert gravel or coconut fibre substrates. 46% use rafts. 19% use the NFC. 17% use vertical towers. Most systems are small and the scale of individuals. There are still too few commercial facilities. There are systems of vertical cultivation which allow a very important optimization of the space available. Water is reduced to its bare minimum with drip operation. This is a system generally found in urban or peri-urban areas. The technique of aeroponics has the wind in its sails and consists in spraying a very fine fog of nutrient solution directly on the roots of plants. Thus, water saving is observed but the problem of clogging the plumbing is still present.

To conclude, we know that vertical NFT and Deep water Culture are two differents systems that were already tested by others groups. The vertical NFT system has been chosen because it's yield. In fact, vertical system allow to grow more plants. However, the previous group has struggles with this kind of system. Indeed, the plants does not received enough nutriments and when one pump broke, all the water comes out from the NFT system and drown the greenhouse floor. Concerning the deep water culture, the struggles were (ask mikael why and what what the struggles of this system). Concerning our project, we still don't know which system we will used. It will depend on how much times and how much money is still left for the aquaponic system.

5.1.2 How start an aquaponic system?

1) Choice of the tank: This is the key element of your system and it plays a crucial role in the growth cycle of your plants and your fish. For easy cleaning, a conical

or flat bottom tank is good. It must be also solid, with nontoxic plastic if possible. (Harlaut, 2012)

2) Circulation and oxygenation of water: The water should be very well oxygenated and have an ideal circulation so that your bacteria and plants remain healthy. (Harlaut, 2012)

3) Quality of water: The water is one of the most important elements in the aquaponic system. The water must be watch carefully: temperature, pH, oxygen rate. (Harlaut, 2012)

Figure 7:Water Quality tester

4) Population: We must avoid too many fishes in the tank.

5) Feeding: Overeating your fish just like waste is very harmful as they can rot in your aquaponic system. Food rot causes disease and consumes a lot of dissolved oxygen.

Figure 8: Fish feed

6) Choice of plants and spacing: The choice of plants and their spacing must be judicious. It is recommended to plant vegetables with a short growth cycle such as salads and intercalate them with crops longer cycle such as eggplants, for example.

5.1.3 Parameters to control

In order to have healthy fishes, and by the way, healthy plants, it is very important to control the “chemistry” of our aquaponic system. They are the “perfect” values of each chemical compound for each part of the eco-system: (Harlaut, 2012)

Type	Temp	pH	Ammonia (mg / l)	Nitrite (mg / l)	Nitrate (mg / l)	DO (mg / l)
Warm water fish	22-32	6-8.5	< 3	< 1	< 400	4-6
Cold water fish	10-18	6-8.5	< 1	< 0.1	< 400	6-8
Plants	16-30	5.5-7.5	< 30	< 1	-	> 3
Bacteria	14-34	6-8.5	< 3	< 1	-	4-8
Aquaponics	18-30	6-7	< 1	< 1	5 - 150	> 5

Table 4: Control parameters (Harlaut, 2012)

The most important test to do, is the pH test. It will determine whether your water has an acid or basic tendency. The ideal is to have a so-called neutral pH, that is equal to 7 but it can be between 6.5 and 6.8. The importance of maintaining a good stable pH is to allow the assimilation of water nutrients by your aquaponic ecosystem, not to mention the fact that bacteria do not develop as well in extreme pH. (Harlaut, 2012)

When a bacterium enters the nitrification phase, it will release acidity. This acidity will slightly change the pH of your water which will decrease. That is why we must regularly monitor our rate in order to maintain a perfect balance. If you regularly add water to your tank, you will not have this concern. Just take a little water from the pond during your weekly waterings in the house and the garden to empty a little water from the pond and thus add as much rainwater as the pond water withdrawn. (Harlaut, 2012)

5.1.4 Technical part

As we had to do our own aquaponic system, there is the basic technical stuff to have

Materials needed	How it looks like	For what use ?	Do we have one ?
Culture bed	 *Figure 9 : Culture bed (grown by you, n.d.)*	a culture bed for growing your plants, whatever type of aquaponic system is chosen. Plants need to grow, but it must also understand that the tank must hold enough fish to provide enough nutrients for the amount of plants you want to grow.	We have a tank
Water pump	 *Figure 10 : Water pump (trees.com, n.d.)*	Enables to pump dirty water and by consequences make the water more oxygenated and cleaner	Yes
Air pump	 *Figure 11: Air pump (akvaariotarvike, n.d.)*	It is used to oxygenate water from your aquaponic system	Yes

substrate/biofilters	 *Figure 12 : substract for aquaponic system (gogreenaquaponic.com, n.d.)*	Enables the bacteria development, keep well the humidity, neutral pH to not acidify the water.	No
Bell siphon	 *Figure 13: Pipeline used for aquaponic (youtube DIY video, n.d.)<*	allows you to relieve your aquaponic pump by avoiding having to turn it on and off while creating high and low tides in your aquaponic system. The bell siphon allows to extend the life of the pump but above all to improve the growth of the plants thanks to the alternations of tides so dear to the systems of aquaponic culture	Yes

Table 5: Required starting equipment

We did an inventory about what the previous group has left. They have left the main things like pumps, aquariums, tank, biofilters, pipes... This way, we can reuse the material for our aquaponic project. However, we have to buy some material for the green house

Figure 14: old NTF system used for growing plants

Figure 15 : tank, biofilters container and bucket used for the aquaponic system

5.2 Components

5.2.1 Crayfish and shrimp species

First, we can assume that selecting the right species depends on a few factors. Indeed, we had to decide if we would use salt or sweet water. The crayfish and prawns must be edible and there must be a possibility to sell them local in Vaasa. Of course, they must be available for buying. In the beginning, our options were very limited, because there are only two pet stores in Vaasa that have quite a large selection of fish species. The first store, called Vaasan Akvaarioliike, only has a few sweet water species that can live in aquariums, however we could not use these in our aquaponic system. (Lapland WIldfish, N.D.)

The second store is called Vaasan Eläinkeskus and has more species than the previous one, which gave us more options. Unfortunately, not the right species we were looking for. Moreover, we talked to the store owner, and we asked him some questions, for instance information about the availability of fishes in Vaasa. As an answer, he told us that the pet stores in Finland are having a hard time, since a lot of people are ordering products online these days. We could find other pet stores in nearby, but even though they are different pet stores, they have almost the same species. He also told us that he could give us the contact of a local fisherman, but because of some issues with finding it, we did not receive yet the contact information.

After the conversation with him, we started to search also on the internet and as a result, we have found more options. First, we were looking into web shops from Finland, and the first website we found was www.laplandwildfish.fi. In this website, river Crayfish that are caught in Lapland are being sold. Thus, this would be perfect for us, because firstly they are available, secondly, they are sweet water species and thirdly, Finnish people love to eat crayfish. The problem is that the catching season is from July till September and unfortunately, this does not match with the time we are working on the project. Other than this website, there were no more local Finnish websites. As a consequence, we extended our research to other countries in Europe.

We found Masterfish.eu, that is a web shop that is located in Germany and that has a lot of different species of shrimps. On the website, it is written that the fish only travel between 24-48h, and they are delivered within one week after the order has been placed. However, the fish need an additional stabilization period, which may result as a delay in shipment. Masterfish.eu only work with authorized delivery companies who are certified for transporting live animals, consequently the shipping is a bit more expensive (Lapland WIldfish, N.D.)

Figure 16: Shipping costs to Finland (masterfisch, n.d.)

Name	Japanese Swamp Shrimp	Red Crystal Shrimp	Red Cherry Shrimp	Japanese Swamp Shrimp (European breeding)	White Pearl Shrimp (Pregnant)
Photo					
Price (Incl tax)	€ 8,10	€10,4	€2,76	€5,59	€ 15
Size (cm)	3 - 3,5 ➔ 5cm	1 - 1,5	1 - 1,5 2 - 2,5	1 - 1,5 2,1 - 2,9	2,5 – 3 cm
Characteristics	pH level: 6-7,6 Temperature: 15° - 27°C KH: 3-10	pH level: 6-7,5 Temperature: 20° - 25°C KH: 0 - 2 dKH GH: 4 - 6 dGH TDS:100-200	pH level: 6,2-8 Temperature: 18,3° - 23,8°C KH: 3-15 GH: 4-8 TDS	pH level: 6-7,5 Temperature: 15° - 25°C KH: 4-10 GH TDS	pH level: 6-8 Temperature: 16° - 28°C KH: 3-30 GH: 3-30 TDS

www.garnelio.de is a German web shop that also delivers in Finland. The interesting thing about this one is that they sell shrimps who are already pregnant. This could may come in handy to speed up our process with the limited time we have.

www.ruinemansgroup.com This is a web shop with his origin in The Netherlands, but their products are being sold in Helsinki as well. They also provide delivery all over the world. The interesting thing about this website is that it sells crayfish. The store in Helsinki is called Suomen akvaariopalvelu oy.

Name	**Blue Florida Crayfish**	**Zebra Crayfish**	**Thunderbolt Crayfish**
Photo			
Price (tax incl, shipping excl)	/	/	25 euro
Size (cm)	2-3cm ➔ 10 – 13 cm (1-3 months)	6-8cm ➔ 15- 18cm	8cm ➔ 15-18cm (3-4 months)
Characteristics	pH level range: 7-8 Temperature: 22° - 27° C kH 4 – 6 gH 6 - 8 TDS 150 - 200	pH level: 6,5 – 7,5 Temperature: 20° - 29° C kH 6 – 15 gH 4 – 10 TDS 100 - 300	pH level: 6,5 – 7,5 Temperature: 18°- 26°C kH 3-10 gH 4-10 TDS 100-300

Finnaly, the fish shop ”akvaariolinna” has been chosen as our fish supplier. However, it can't be possible de to order fishes on the websites. Below the list of the only material that can be ordered from the website. (akvaariolinna, kein Datum)

Figure 17 : list of materials that can be bought on the website (akvaariolinna, n.d.)

Ordering species was done by phone call and mail. At the beginning, the owner, Jesse Valo send by mail the list of the crayfish and shrimps that could be edible.

Cambarellus patzuarensis	Orange Mini Mexican Crayfish (IDV-PACK)
Cambarellus diminutus	Blue Mini Mexican Crayfish
Cambarellus puer	Cambarellus puer
Cambarellus texanus	Cambarellus texanus
Cherax quadricarinatus	Blue Lobster
Cherax quadricarinatus	Blue Lobster
Cherax sp.	Red Lobster
Cherax sp.	Red Lobster
Cherax snowden	Papua Black Orange Tip Crayfish
Cherax holthuisi var apricot	Papua APRICOT Crayfish
Cherax holthuisi var extreme red	Papua EXTREME Red Crayfish
Cherax boesemani	Papua RED Boesemani Crayfish (I)
Cherax boesemani	Papua RED Boesemani Crayfish (II)
Cherax boesemani	Papua BLUE Boesemani Crayfish
Cherax lorentzi	Papua Blue Moon Crayfish

Cambarellus patzuarensis	Orange Mini Mexican Crayfish (IDV-PACK)
Cambarellus diminutus	Blue Mini Mexican Crayfish
Cambarellus puer	Cambarellus puer
Cambarellus texanus	Cambarellus texanus
Cherax quadricarinatus	Blue Lobster
Cherax quadricarinatus	Blue Lobster
Cherax sp.	Red Lobster
Cherax sp.	Red Lobster
Cherax snowden	Papua Black Orange Tip Crayfish
Cherax holthuisi var apricot	Papua APRICOT Crayfish
Cherax holthuisi var extreme red	Papua EXTREME Red Crayfish
Cherax boesemani	Papua RED Boesemani Crayfish (I)
Cherax boesemani	Papua RED Boesemani Crayfish (II)
Cherax boesemani	Papua BLUE Boesemani Crayfish
Cherax lorentzi	Papua Blue Moon Crayfish

Figure 18 : List of species that can be edable

Thanks to this list, we made a choice of shrimps and crayfish which is explained on the next paragraph.

5.2.2 Selected species

5.2.2.1 Small shrimps and guppies

At the beginning of the project, it was decided to start an aquarium. Indeed, The aquaponic project construction has been planned to end at the end of Erasmus so in the meanwhile we had to store somewhere the shrimps. At the beginning of March, some guppies fishes and little shrimps has been bought at the local pet shop. These species do not

Figure 19 : Aquqrium in the classroom

fit for our aquaponic system, but we could already get some idea of shrimp and fishes behavior.

5.2.2.2 Cherax Pulcher/Thunderbolt Crayfish

Figure 20: Thunderbolt crayfish (Wikipedia, n.d.)

The first species we selected is the Cherax Pulcher, it is a crayfish that can be found in the West Papua in Indonesia, described as the most beautiful crayfish species and it can only be found in the Hoa creek. These fishes are also called thunderbolt crayfish, rose moon crayfish or pink coral crayfish. Rocks and sand can be found in the creek where they live. It is a fast-flowing river so they can handle a fast stream in the aquarium. They required a lot of rocks in the aquarium, so they can hide from each other. Moreover, they may hurt or kill each other, therefore, enough hiding spots could reduce it. (Chucholl, N.D.)

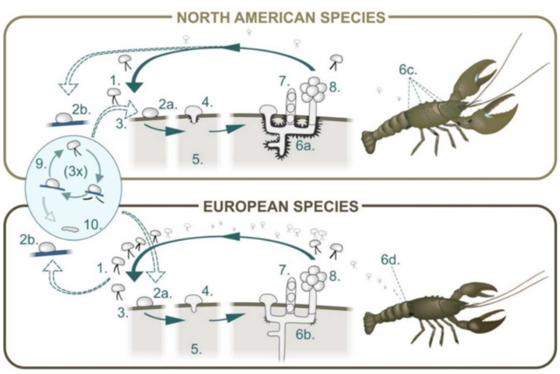


Figure 21: Scematic representation of zoospores (Viljamaa-Dirks, 3/2016)

Also, having this species of crayfish required a particular attention, because they are not immune against the crayfish plague. Indeed, crayfish plague is a disease of European crayfish species, death or even extinct of species can be caused by this disease. We know that a fungal-like water mould is responsible. During its vegetative life in the cuticle of crayfish, it infects other crayfish by producing zoospores.

Another thing to look out for is shell rot, although in most of the cases they can take care of it themselves. Every 15-25 days, the crayfish molt their exoskeleton, depending on their size. The bigger the species are, the longer the cycle takes. When they molt, they can get rid of this shell rot, but they also do it to increase in size. You can recognize that they are about to molt when their tail gets wider and looser.
Crayfish are also able to amputate their paws or claws but can regenerate these as well. Sometimes you can recognize an older claw on the nob between the fingers, this mostly does not get regenerated.

The thunderbolt crayfish is as all other crayfish edible. Only the tale gets used when served. (Tank Facts, N.D.)

Breeding: They become mature when they are 8 to 10 months old. The female carries around 50 eggs and they use their appendages to keep the eggs clean and oxygenated.

They take a lot of time to climate to the aquarium, their aquarium values:

- pH level range: 6,5 - 7.5
- Temperature range: 18° - 26°C, optimal 22 – 26° C
- kH 3-10
- gH 4-11
- TDS 100-300

Ph level found where they live is 6,6.

5.2.2.3 Amano Shrimp Japonica

The second species that we selected is the Amano Shrimp Japonica or with his scientific name called Caridina japonica. The shrimps can be found in the swamps in Japan. These shrimps are nice to have in your aquarium, they eat almost everything. They will consume leftover fish food, and detritus on the bottom of the aquarium. So they keep their habitat clean. In

Figure 22: Amano Shrimp Japonica

captivity they can live 2 till 3 years and their size can get up to 5 cm. (Aquarium care , N.D.)

The Amano Shrimp will molt his exoskeleton, in the early stage of his live this can happen every 3-4 days. It is important that you don’t take the exoskeleton out of the aquarium because they will use it as a source of food.

Specifications:

- pH 7,2-7,5
- Temperature 22,2°- 25,5°C
- kH 6-8
- TDS 200

The japonicas shrimps and thunderbolts crayfish have been chosen because of their similar water temperature: 15 to 27°C for the japonicas shrimps and 22 to 27°C for the thunderbolt crayfish. Moreover, their pH range are quite similar too: 6 to 7,6 for Japonicas and 7 to 8 for the crayfish. In addition, japonicas were quite cheap.

Figure 23 : Pictures of the shrimps when there were arrived

We received the shrimps from the Akvaariolina shop. Located in Helsinki, ordering fish is done only by calling or sending an email at the responsible person, Jesse Valo. First, he send a list of what kind of shrimps/crayfish can be eaten.

Then we choose 8 japonicas shrimps and 2 thunderbolts crayfish because of their close temperature of water and their environment's pH.

Its took around 2 weeks to received the shrimps because they had to be transported from the Netherlands (shrimps japonicas) and from Indonesia (thunderbolt crayfish). Unfortunately the crayfish were not available at first, so we received only 8 japonicas shrimps and put them in aquarium located in the EPS room.

Figure 24: Picture of the aquarium with guppies

5.2.3 Aquarium

5.2.3.1 Products

AquaSafe was applied to the water prior to introducing the shrimp. This product serves the purpose of ensuring the safety of tap water for the fish by neutralizing harmful substances, protecting their skin and fins, and promoting the overall health of the aquarium. The recommended dosage of AquaSafe is one cap per 20 liters of water, providing the necessary treatment to maintain a suitable environment for the aquatic inhabitants.(www.tetra.net)

Figure 25 : Aquasafe product (tetra aquasafe, n.d.)

5.2.3.2 Pump

The presence of a filter in the aquarium offers several advantages, including reduced frequency of water changes and increased fish stocking capacity. The filter effectively cleanses the water by removing waste and impurities. By eliminating these contaminants, the filter helps to maintain water quality and create a healthier environment for the fish. Additionally, a properly functioning filter aids in the biological filtration process, where beneficial bacteria break down harmful substances such as ammonia and nitrites, further enhancing water

Figure 26: Aquarium pump (finnish pet shop, n.d.)

conditions. Consequently, having a filter in the aquarium minimizes the need for frequent water changes and enables a higher fish population to thrive. (Editorial, 2009)

5.2.3.3 Plants and rocks


Indeed, the presence of plants in an aquarium has several positive effects. Firstly, aquatic plants can help reduce the amount of algae in the water by competing for nutrients and light, limiting the resources available for algae growth. Additionally, plants contribute to the oxygenation of the water through the process of photosynthesis, wherein they absorb carbon dioxide and release oxygen, benefiting the overall health of the aquarium inhabitants.

Moreover, plants play a crucial role in recreating a natural environment for fish. They provide shelter, hiding places, and spawning sites, which mimic the natural habitat of the fish species. This helps create a more comfortable and stress-free environment, allowing the fish to exhibit natural behaviours and thrive. (scapednature, 2019)

Similarly, rocks in an aquarium aid in reconstructing a natural environment. They can be arranged to create caves, crevices, and ledges, offering additional hiding spots and territorial boundaries for the fish. Moreover, rocks can act as a form of natural filtration by providing surface area for beneficial bacteria to colonize. These bacteria help break down organic waste, contributing to the overall filtration and maintenance of water quality in the aquarium. (Barrington, 2023)

5.2.3.4 Decoration

Aquarium decorations serve several important functions in aquatic environments. They enhance the visual appeal of the aquarium, creating an aesthetically pleasing display. Decorations simulate natural habitats, providing a comfortable and stress-free environment for aquatic life. They offer hiding places and territorial boundaries, promoting security and natural behaviour. Decorations also contribute to water quality by assisting in filtration and algae control. Overall, decorations play a crucial role in creating a vibrant and thriving aquarium ecosystem. **(Michael, sd)**

5.2.3.5 Lighting

Aquarium lighting serves as a substitute for natural light, enabling plants to undergo photosynthesis. By providing the necessary light spectrum and intensity, artificial lighting systems support plant growth and energy production. This process involves the absorption of light energy by chlorophyll, which is used to convert carbon dioxide and water into glucose and oxygen. Proper lighting duration and intensity are essential for the optimal growth and health of aquarium plants.

Aquarium lighting not only supports plant growth but also regulates fish behaviour, metabolism, and overall well-being. Proper lighting mimicking natural day and night

cycles helps maintain fish's physiological rhythms. It enhances the visual appeal of the aquarium, showcases vibrant colours, and promotes the growth of beneficial microorganisms and algae as natural food sources. Striking a balance in lighting based on species-specific recommendations ensures a suitable environment for fish, promoting their health and natural behaviours. (Reich, 2019)

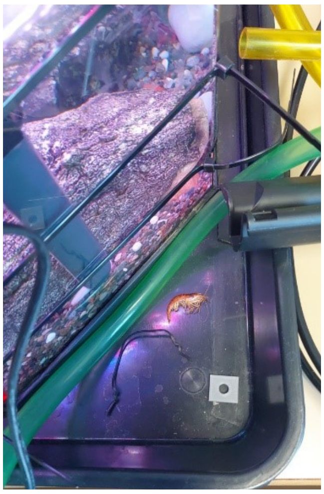
5.2.4 Observation

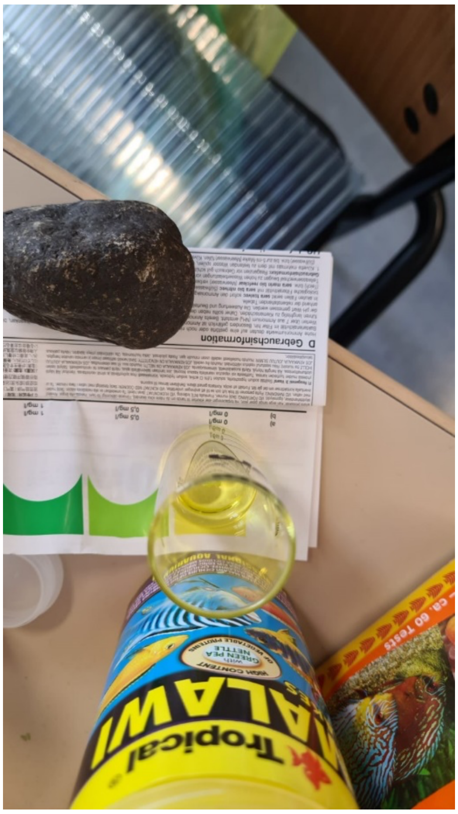
5.2.4.1 Water conditions

Regular observations were conducted to evaluate the water conditions for fish survival, and the findings consistently showed that all parameters, including pH, potassium (K) rate, magnesium (Mg) rate, remained within acceptable ranges, indicating a favourable environment for fish thriving without the need for additional products. However, due to water evaporation caused by heating to a temperature of 25°C, periodic water additions were necessary to maintain the desired water level in the aquarium.

5.2.4.2 shrimps

During the transfer of the shrimp to the aquarium, unfortunate events led to the death of three individuals. Two shrimp were found outside the tank, suggesting that they had jumped out and died. The cause of death of the third shrimp, which was found dead inside the tank, remains unknown.





It has been found that the shrimp feed on plants and algae. Therefore, in an aquaponic system, it is important to ensure that the shrimp are not near the plants to prevent plant consumption.

It has also been observed that these shrimps produce minimal waste, which can be problematic as plants require a certain amount of waste for optimal growth. To address this issue, either a larger shrimp population or the addition of other fish species to the tank should be considered to increase waste production and support plant growth.

In addition, it was observed that shrimp did not exhibit aggressive behaviour towards each other in larger tanks, unlike in confined aquariums. Therefore, the availability of sufficient space in a larger tank removes concerns about potential conflicts between shrimp populations.

5.2.5 Bacteria for aquaponic

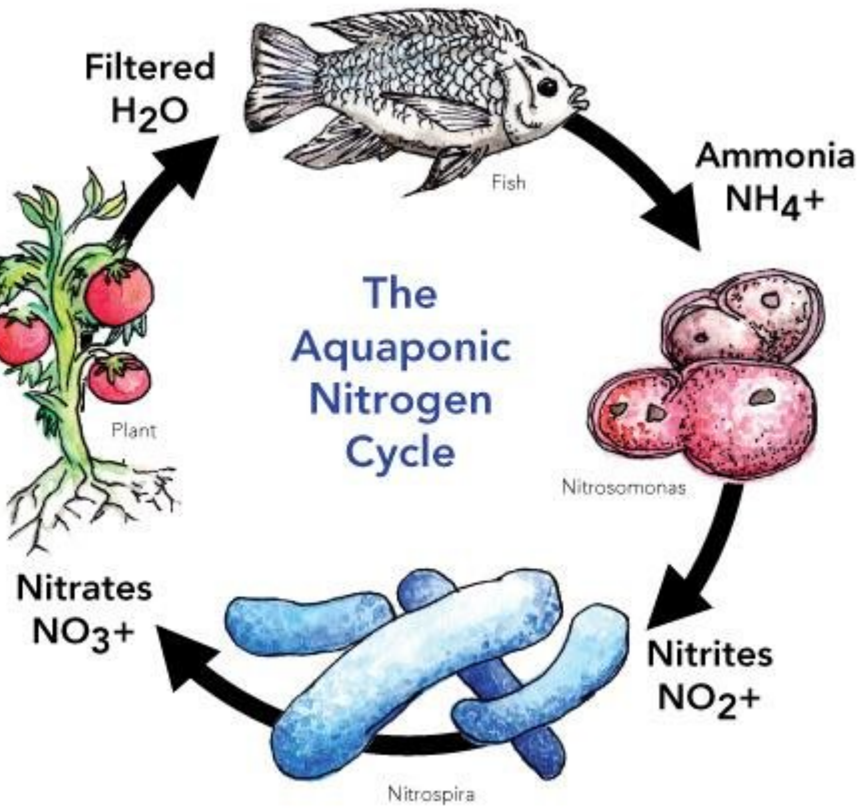


Figure 27: Nitrogen cycle (researche gate, n.d.)

In aquaponic system, the nitrifying bacteria plays an essential role. In reality, the fish waste is converted by the nitriding bacteria: waste enters the system as ammonia, then transformed into nitrates and then nitrates that fertilize the plants.

Aquaponics is a two-stage process and involves the use of two types of nitrifying bacteria:

1. Converting Ammonia into Nitrites:

Fishes produce waste which contains a lot of ammonia. Then, the bacteria called Nitrosomonas convert the waste's ammonia into nitrites.

2. Converting Nitrites into Nitrate:

Nitrites must be converted to nitrates to keep fish and plants healthy. For this process, another kind of bacteria, the nitrobacter converts the nitrates into nitrites. Plants grow rapidly when they absorb nitrates. Excessive nitrites can kill the fish.

It must be known that bacteria reproduce slow: it takes days or even sometimes month to establish a colonies. However, there are some few key parameters to help them growing. In fact, dark location, good water quality and adequate amount of oxygen. In addition, colonizing bacteria needs pH between 6 and 8.5, water temperature between 17.5° and 34° C, UV lights and high surface area where to develop. (gogreenaquaponic.com)

And Where can we buy it?

Specialized websites

Specialized shops

5.2.6 Biofilters

A biofilter is a place for bacteria to colonise. It provides a large surface area, pH, dissolved oxygen levels and the right temperature.

Biofilters are quite simple to set up and consist of a tank connected to the air pump and some substrates that provide as much surface area as possible for the nitrifying bacteria to grow on. The more surface area the bacteria must grow on, the better, as it means a more efficient nitrification process. In fact, in aquaponics, if the surface area in your grow media is not large enough for the bacteria to colonise, you need to add more surface area. Therefore, it is really advisable to have biofilters. The biofilter will be an important part of your system, ensuring that the plants have enough nutrients to grow healthy, while cleaning the water for the fish to live in. (Wallace, 2014)

DIFFERENT BIOFILTERS:

1. Moving bed filters

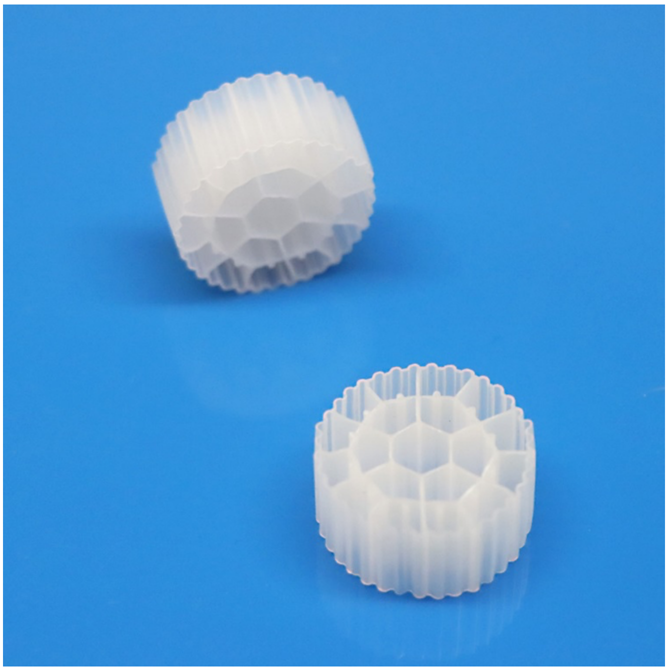


Figure 28: Moving bed filters (alibaba, n.d.)

This kind of biofilter uses pellets that moves through piping to bring surface area for the nitrifying bacteria to develop. Floating raft system is the most adapt aquaponic system which can use moving bed filters. (Wallace, 2014)

2. Static filter

These are tray-like filters that can be slid into a separate container next to the fish tank before the plants. These afford a large area for the bacteria to collect on. This filter needs to be placed after the solid filter before it attains the plants. This way, the water is filtered before reaching the plants. (Wallace, 2014)

Figure 29: Static filter (Wallace, 2014)

3. **Drip filter**

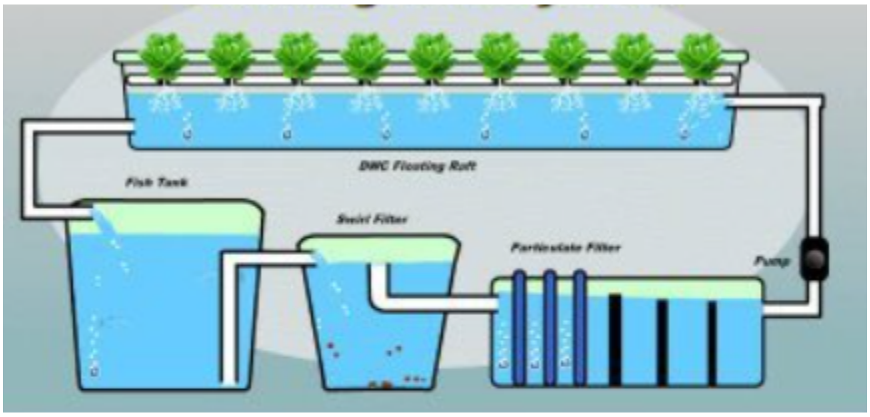


Figure 30: Drip filter (Adhao, N.D.)

This filter allows water to drop in from the top. The water passes through the filter box, full of gravel, oyster shells, or another similar bio medium with lots of surface area. This biofilter also needs to be positioned where the water is filtered before it gets to the plants. As the water moves through the filter, the ammonia is converted to nitrates before it is pumped back to the plants. (Adhao, N.D.)

5.2.7 Plants

With aquaponics, you can grow any plant you want: vegetables, flowers, leafy greens, small root vegetables, fruiting plants, herbs. Before planting your first seeds, there are some things to consider: Some plants adapt better to a smaller system, while other nutrient-hungry plants require larger systems to thrive. In this table, there is a resume of the best plants to grow in different types of aquaponic system:

Aquaponic system	Plants	Why ?
Raft System or Deep Water Culture (DWC)	There a some plants that can be grown with this kind of aquaponic : Lettuce, Basil, Kale, Swiss Chard, Cabbage, Bok Choy, Mint, Watercress....	Light-weight vegetables, Water friendly Harvest potential
Nutrient Film Technique	There a some plants that can be grown with this kind of aquaponic : Arugula, Spinach, Parsley, Dill, Strawberry...	For this kind of aquaponic system, it's better to choose some plants that avoid clogging the pipe, with shallow roots
Media Bed Aquaponics System	There a some plants that can be grown with this kind of aquaponic : Tomato, Sage, Ginger, Cucumber, Pepper...	A Media Bed aquaponics system can grow almost all plants, including plants that do not do well in other aquaponics methods

Table 6: Plant comparison

Parameters for successful plant production:

- Location: The amount of sunlight is important for growing a healthy plant. If it has been decided that the plants will grow outdoors, the plants will need to receive enough sunlight. If it is an indoor aquaponics system, it is important to ensure that the grow light can provide the light that the plants need to grow healthy.

- The type of system: A media-based system can grow almost any type of plant. However, if you're planning to build a raft system or NFT, you'll need to select plants with small root structures, such as lettuce and strawberries.

- Plant nutrient requirements: If you have a new system, plant crops with low nutrient requirements. You can always add nutrient-demanding crops such as tomatoes and other fruit crops once your system is mature or fully established.

- Space available: The space available will affect the type of aquaponics system you choose and the types of plants you grow. This is because some plants require more space than others. The space required to grow the chosen plants needs to be considered.

- Reason for growing plants: Aquaponics gardening tends to work better if you grow plants that will be eaten or used. Thinking about the purpose you want to achieve in the system will help you make a better decision about which plant to grow in an aquaponics system.

- Climate: Choose plants that will thrive in your climate. All plants have their own optimum temperature range in which they thrive. So it is best to plant only warm weather plants if the aquaponic system is in a warm location and cold weather plants if the aquaponic system is in a cold location. The temperature setting can be adjusted when growing in a greenhouse, but this will cost some extra electricity. (gogreenaquaponics.com)

Nutriments for plants:

Plants needs different nutriments like non-mineral nutriments: Carbone, Hydrogen, Oxygen. But also, mineral nutriments like: Nitrogen, Phosphor, Potassium, Calcium, Magnesium...

We can control the rate of each nutriment thanks to chemicals tests.

Figure 31: Nutriment testing ki (How to aquaponic, n.d.)t

However, even with all those criteria met, there are still risks of growing plants:

- Some insects can come from the outside of the greenhouse and eat the plants
- Some plants do not grow because of the lack of nutriments

5.2.8 Current state of aquaponic system

In the past years the aquaponics project has been running for multiple European project semesters already. In these years research has been conducted and multiple test setups already created and tested. This offers a wealth of information and conclusions we could potentially make use of in the decisions we make. The current state of the aquaponic system is a disassembled system and a lot of components we could use for our own test setup. In this chapter some of the recommendations and conclusions of previous groups are summarized, so that we can make decisions based on that.

The EPS group of the 2020 spring semester had the objective of creating a modular sustainable and flexible aquaponic system and the development of a control system. They partially succeeded in this objective. This group was able to establish a 2 m² hydroponic surface suitable for 10kg of fish. The plan was to make it a modular and flexible system, but due to time and budget constraints were not able to manage this. Next to this they were able to create a water storage system that assists in maintaining normal water levels in the system. Significant improvements were made to the water distribution model in the towers and protection against algae in the system. The concept system worked, but due to time a proper test was not conducted.

5.3 Recommendations

After their research they left with some recommendations for other groups on how to approach the project. These recommendations have been summarized in the following paragraph.

5.3.1 Sensors

In this system they made use of a lot of sensors to control and monitor the system parameters. The ideal value of and the parameters they monitored were:

Parameter	Cool water Fish	Koi Carps	Cool weather plants	Bacteria	Cold water Aquaponics	Unit
Temperature	10-24	2-30	16-25	20-30	18-22	°C
pH	6.0-8.6	6.8-8.2	5.5-7.0	6.0-8.5	6.5-7.0	-
Dissolved Oxygen	>5	>4.5	>3	4-8	>5	ppm
TAN	<1	<0.5	-	<3	<0.5	
Nitrite	<0.1	<0.25	<1	<3	<0.1	
Nitrate	<300	<60	-	<300	50	

Figure 32: Ideal system parameters (Spring 2020 EPS group, 2020)

These sensors are all connected to a raspberry PI unit that visualizes the data on a website accessible via the internet. At current time the website nor the sensors work as the system and required infrastructure has been disassembled. The components to make it work are still available and seem to be working, so when required this could be reinstated.

5.3.2 System Cycling

The previous group recommended that before living organisms can be introduced, a suitable environment must be prepared. This involves cycling the system for at least two weeks to remove the chlorine from the tap water using UV lamps, adding ammonia to the system, and adjusting the levels of ammonia, nitrites, and nitrates to recommended values before introducing the nitrifying bacteria. Once the environment is stable and the ammonia levels decrease, fish and plants can be added to the system.

5.3.3 Fish

The previous team had difficulty finding fish for their aquaponics system. Rainbow trout or carp were considered, but these turned out to not be a good fit. However, due to the closure of the Helsinki region, they were unable to order fish and plan to buy them as soon as the system is running. Additionally, they mentioned that other marine life, such as shrimps or small snails can be introduced to the system because they are usually available in pet shops.

5.3.4 Plants

The team states that they encountered problems with young plants not developing strong root systems because they did not use an appropriate starting medium. They suggest using rockwool from the beginning to avoid exposing young plants to environmental shock and losing small roots when transferring from soil. They also highlight the importance of plant nutrition, including providing most of the necessary micro and macro elements through the aquaponic system, but noting that deficiencies in iron, potassium, and calcium are common due to their low content in fish feed. Because of this it is recommended to supplement iron with chelated iron and adding calcium and potassium in the form of hydroxides or carbonates, which also serve as a system buffer. The concentration of inorganic elements should be monitored by the controlling system.

5.3.5 Hydroponics

The previous team recommend buying a new batch of polyurethane filter foam for an enlarged aquaponic setup, as the team did not have sufficient budget to buy plant foam themselves. The previous team purchased the foam from a company in Germany, and longer delivery times should be expected due to the availability of this product. Next to this, they also suggest buying a few more Styrofoam sheets for the rafts in the DWC system as the expansion of the system requires additional rafts.

5.3.6 Flexibility

The current aquaponic system is not flexible nor modular. Increased flexibility can be achieved by changing the piping to a more flexible material with valves.

5.3.7 Lighting

The previous team did not focus a lot on lighting during their project. Because of this the lighting could be drastically improved if more time is spent on this. They explain that the current system could greatly benefit from installing additional LED lighting and programming those accordingly.

Because of the lack of time and budget, this part of the project has been withdrawn. However, the media bed aquaponic system can be advised for the next group who will hold this project. Indeed, the media bed system is a type of aquaponic which did not take much place. Because of the small surface of built low energy house (9 m2), it is better to “compact” things together. Concerning the plants that can be grown in the future, it is advised to grow salad. In fact, the salad can be eaten by restaurant’s clients which go eat to the university’s restaurants.

6 Greenhouse

In this chapter will be an explanation of an actual greenhouse, a low-energy house and what happened to make out of a greenhouse a low-energy house.

6.1 What is a greenhouse? What is the purpose?

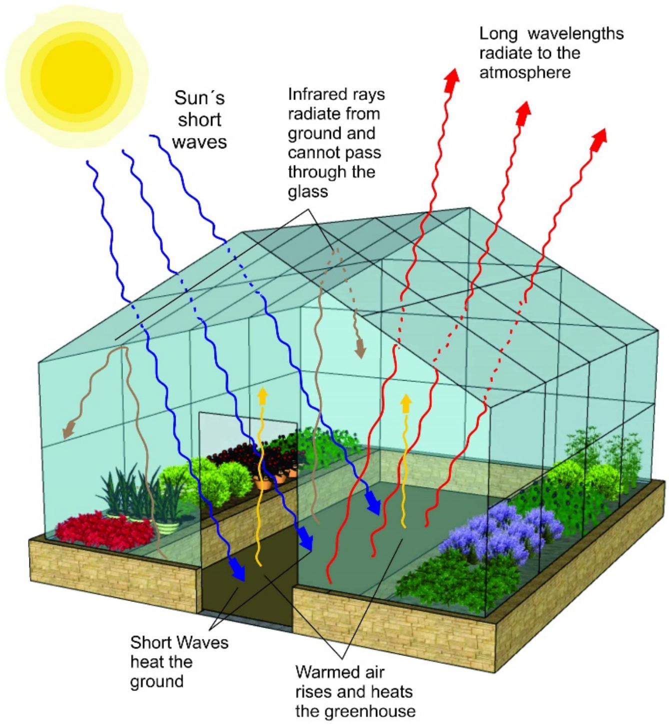


Figure 33: Greenhouse illustration

A greenhouse is a structure, typically made of glass or plastic, that is designed to allow sunlight in while trapping heat inside, creating a warm and controlled environment for growing plant.

The primary purpose of a greenhouse is to provide a controlled growing environment that can extend the growing season, protect plants from harsh weather conditions, and improve plant growth and yield. By controlling temperature, humidity, light, and other environmental factors, greenhouse growers can optimize plant growth and improve the quality and quantity of their crops.

Greenhouses are commonly used in commercial agriculture, especially for high value crops such as flowers, fruits, and vegetables. They are also used by hobbyists and home gardeners who want to extend the growing season or grow plants that are not suited to their local climate. Additionally, greenhouses can be used for scientific research and experimentation, such as studying the effects of different environmental factors on plant growth. (Petruzzello, 2023)

6.2 Current state rooftop greenhouse

During the 2020 spring semester the EPS group build a greenhouse on the southern part of the Technobothnia roof in Vaasa, Finland. The choice for this location was because on this location there is minimal disturbance from trees, building and other obstacles resulting in maximum sunshine. The available space on the roof was limited, so the greenhouse had to be compact and efficient with usage of space. These constraints made way for a 2,6m x 2m (5,2m²) building area. Various standard greenhouse designs were considered.

Figure 34: Greenhouse location

They went with a frame build from wood, the floor constructed from OBS panels and covered the walls in plastic foil. The group did not insulate the greenhouse due to budget constraints making the greenhouse very cold and difficult to heat to an acceptable temperature. In the research conducted before they started building they looked and all in- and external factors like the seasons and that will act on the greenhouse. At current time the greenhouse has fallen in slight deterioration, likely caused by the lack of insulation. The OBS panels have drastically deteriorated.

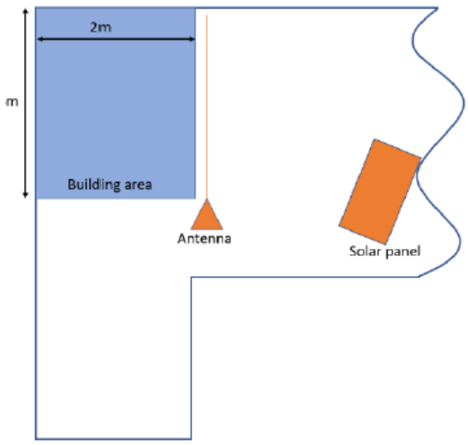


Figure 35: Rooftop building area

Due to budget constraints the previous EPS group was not able to build the greenhouse the way they had wanted to build it. In the given handover package, they have recommended us to insulate the greenhouse, because it is not protected from the elements at this moment. During the winter the temperature is far below zero for most of the season, because of this the fishes and plants are very susceptible to freezing. Next to this the previous group recommends replacing the foil they installed with double layer of plexiglass as it has a far greater thermal insulator than the current foil. This would make it easier to regulate the internal temperature of the greenhouse. Finally, the group recommends to add a steeper slope to the roof, as currently water accumulates on the roof. This can potentially cause a very dangerous situation for people inside the greenhouse.

6.3 What do we want to do with the greenhouse?

The second part of the project is to convert the exiting greenhouse into a low-energy house. That means insulation has to be installed to keep as much heat inside as possible.

6.3.1 What is a low-energy house?

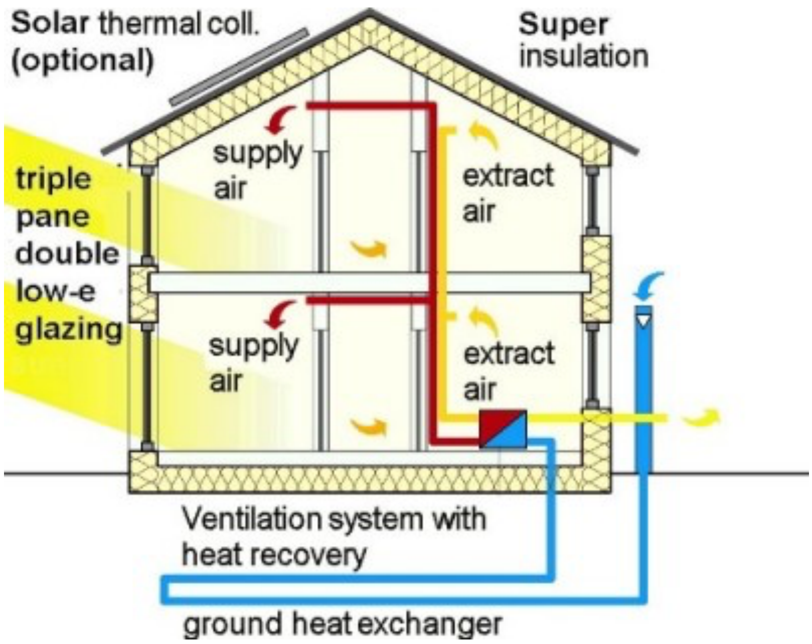


Figure 36: Low-energy house example (Wikipedia, n.d.)

Low-energy houses are typically constructed with high-quality insulation and energy-efficient windows and doors to minimize heat loss and gain. They may also incorporate energy-efficient mechanical systems, such as heat recovery ventilation and solar thermal panels to further reduce energy consumption and costs.

A low-energy house may also incorporate passive solar design principles, such as orienting the building to maximize solar gain in winter and shading it in summer to reduce cooling needs. Additional, low-energy houses may incorporate renewable energy sources, such as solar panels and wind turbines to generate electricity and further reduce energy consumption.

Overall, a low-energy house is designed to operate with significantly lower energy consumption than a conventional house, resulting in lower energy bills and reduced environmental impact. The use of high-quality insulation, energy-efficient technologies and renewable energy sources are key features of a low-energy house. (Hanse redaction, N.D.)

6.3.2 Basic calculations of heat loss

Wall	[m^2]
A1	5,844
A2	1,956
B	8,573
C	5,964
D1	3,403
D2	5,51
Roof	9,616
Floor	9

θ_{Winter}	-22°C
θ_{Indoor}	5°C
delta_θ	27 K

Insulation	W/(m^2*K)	Thickness [m]
Glass wool	0,2	0,175
EPS	0,800	0,05
Cell sheet	3,1	0,1
Glass window	1,3	
Plastic foil	80	0,005
Plexiglass	5,6	0,003
OSB	2,838	0,012

Insulation	A1	A2	B	C	D1	D2
Glass wool	31,6 W	10,6 W	46,3 W	32,2 W	18,4 W	29,8 W
EPS	126,2 W	42,2 W	185,2 W	128,8 W	73,5 W	119,0 W
Cell sheet	489,1 W	163,7 W	717,6 W	499,2 W	284,8 W	461,2 W
Glass	205,1 W	68,7 W	300,9 W	209,3 W	119,4 W	193,4 W
Plastic foil	12623,0 W	4224,96	18517,7 W	12882,2 W	7350,5 W	11901,6 W

	EPS	Plexiglas
Roof	207,7 W	1453,9 W

	EPS	OSB
Floor	192,5 W	683,0 W

	Combined
Before	69636,9 W
After	1408,0 W

Figure 37: Heat loss calculations

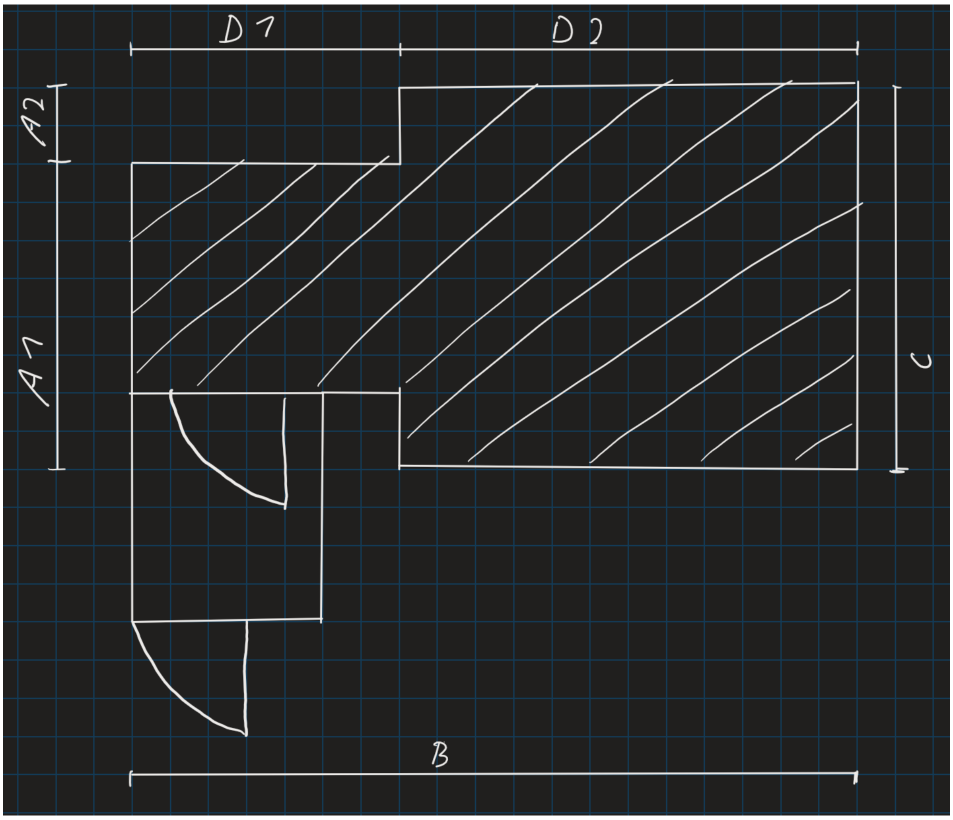


Figure 38:Groundplan low-energy house

As evident from our calculations, maintaining a temperature of 5°C in the greenhouse during the winter without any insulation requires a significant amount of heat. To calculate this, it was assumed a coldest temperature of -22°C, which is the average during the winter months.

The red market values in our analysis represent the greenhouse without any insulation, while the green market values represent the current state after improvements. It is evident that the insulated low-energy house requires only 1,41 kW of heat, which is approximately 1/50th of the 69,64 kW needed previously to maintain a temperature of 5°C when the outside temperature is -22°C.

It would be possible to further reduce the amount of required heat by using glass wool for all walls, roof, and floor. However, due to a limited budget and the requirement of a see-through window to make the low-energy house more appealing and allow natural sunlight inside, the low-energy house was built with EPS and Cell sheet plates as see-through.

These calculations represent an ideal environment, with an airtight greenhouse/low-energy house and other factors such as convection or the shape of the walls were not taken into account.

7 Chosen Materials

Prior to the commencement of the construction project, it was necessary to make informed decisions regarding the selection and procurement of appropriate building materials. Following thorough discussions, careful consideration of pricing and availability, the following materials were ultimately chosen: 50 mm thick EPS insulation plates for use in the walls, roof, and floor.

Figure 39: EPS plates used for insulation (Byggmax, n.d.)

The outside will be covered by metal sheet plates, to protect the insulation and the inside against the weather like rain, strong wind and also against the sun. These plates are modular and can be easily mounted with screws. The chosen measurements of them are 1100 mm x 2500 mm.

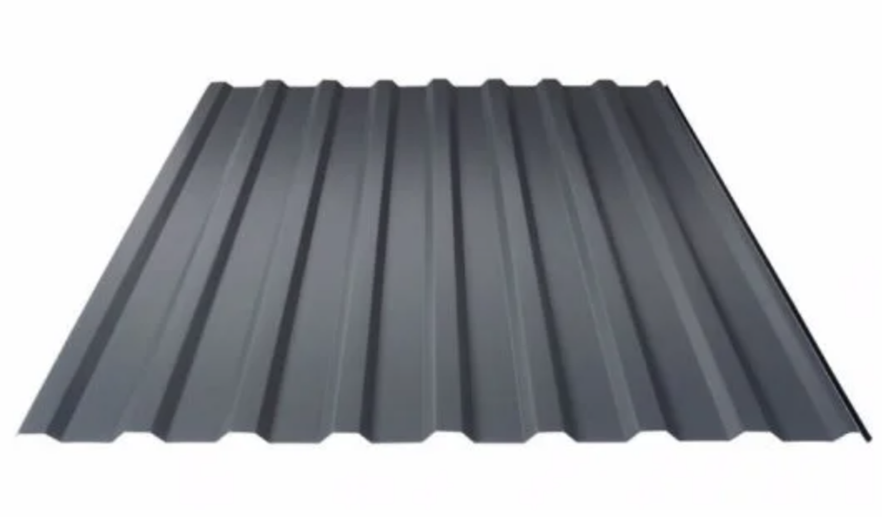


Figure 40: Metal sheet plates used for walls and roof (Byggmax, n.d.)

The sea-through wall will be made out of cell sheet plates. They let light trough into the greenhouse for some natural light. There will not be a whole sea-through wall, the west wall of the greenhouse will be covered partially with it because these plates do not insulate pretty good. The rest of the wall will be insulated like the other walls of EPS and metal sheet plates.

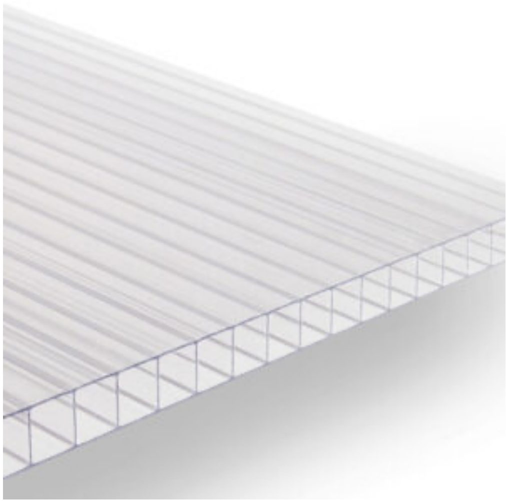


Figure 41: Cell sheet plates used for see-through wall (Kunststofforte, n.d.)

The flooring for the project will consist of the pre-existing OSB panels salvaged from the building, supplemented by a layer of tarred roof paper. The decision to use tarred roof paper was informed by its resilience in the face of water and other harsh environmental conditions, as well as its anti-slip properties. Additionally, its ease of applying it to the floor makes it an optimal choice for this project.

Figure 42: Tarred roof paper used for the floor (Byggmax, n.d.)

In order to improve the aesthetics of the interior walls and to conceal the EPS panels and wooden structure, a white foil covering was applied. The decision to use this particular type of white foil was based on its affordability and ease of installation.

Figure 43: White foil used for the inside (Byggmax, n.d.)

The materials are all available at Byggmax and have been purchased all at once at it.

8 Renovation of the greenhouse

In this chapter the whole renovation and improving process of the greenhouse will be explained, how do we reused pre-existing materials, how do we used the bought materials. These are all points that will be explained.

8.1 Inventory

Figure 44: Greenhouse at the beginning

Before starting the constructions, the main structure of the greenhouse was only made from plastic foil and wooden beams. Surprisingly it withstands winter, rain and storms. The tools and equipment for aquaponics were stored inside of the greenhouse.

Figure 45: Inventory from previous groups

Smaller parts of the Equipment like hoses were moved to the room next to restaurant Café Techno and the bigger parts, like rags for the grow towers or and unused IBC tank were moved next to the green house on the roof.

8.2 Inside renovation

Figure 46: Old floor of the greenhouse

This picture represents the stage when we took out the plastic layers from the walls.

8.2.1 Frame reconstruction

As previously noted, the primary issue with the greenhouse was a lack of insulation. The construction project began by removing sections of the old plastic foil and replacing it with new foil and EPS insulation. However, a particular corner presented challenges due to its numerous angles, which needed to be straightened to facilitate effective insulation and simplify the construction process. Accordingly, most of the old wooden beams in this area were removed and replaced with new ones to eliminate the angles and optimize space utilization. Also, these new wooden beams were painted, it was done to protect them against weather elements such as moisture and rain. This step was taken to ensure that the wooden beams remain durable and can withstand the elements for an extended period. The paint used also gave the wooden beams a fresh, new look, which added to the overall aesthetic appeal of the low-energy house. Additionally, the paint acted as a barrier against insects and fungi that could potentially damage the wooden beams. (WOOD FINISHES DIRECT, n.d.)

Figure 47: Old wooden frame

Figure 48: Painting of the wooden beams

Figure 49: New constructed wooden frame

Figure 50: Wooden frame covered with foil

The original white plastic foil was removed and replaced with a new blue plastic foil due to its extensive porosity caused by exposure to sunlight and harsh weather conditions. Together with metal sheet plates, this new foil serves to protect the interior from rain and snow. To secure the foil tightly in place, staples were utilized along the wooden beams.

Next, the EPS insulation material was cut and glued between the wooden beams. Building foam was used to glue the insulation plates in place and to fill any gaps between the EPS and the beams and to guaranty a proper insulation.


Figure 51: Cutting EPS

Figure 52: Insulation of the walls

The same process was followed for both the floor and the roof. The external layer consists of the blue foil, providing protection against inclement weather. EPS plates were inserted in between the beams, and building foam was used to secure them in place.


Figure 53: Insulation with EPS

Figure 54: Insulation of the floor

To improve the stability of the floor, the pre-existing OSB plates were placed on top of the EPS insulation. Finally, a layer of tarred roof paper was glued onto the OSB plates using a type of Kerabit glue.

It should be noted that the use of tarred roof paper as a finishing material has several advantages. Not only is it resistant to harsh weather conditions, but it also provides an anti-slip surface, making it safer to walk on. Additionally, this material is relatively easy to install and transport, making it a convenient choice for this construction project. Overall, the combination of EPS insulation, OSB plates, and tarred roof paper serves to create a durable and functional flooring system for the low-energy house.

Figure 55: Spreading glue for the tarred roof paper on the OSB plates

Figure 56: Floor of the inside

Unfortunately, the temperature on the day the tarred roof paper was applied was lower than ideal, resulting in the glue being slightly solidified. As a result, it was challenging to spread the glue evenly across the floor. However, despite this difficulty, the final result was quite satisfactory.

It is worth noting that when working with adhesives, it is essential to take into account the ideal environmental conditions for optimal performance. In the future, it may be helpful to plan for weather conditions when scheduling construction work to avoid similar issues. Despite this minor setback, the overall quality of the flooring system remains high, and the tarred roof paper is expected to provide reliable protection against harsh weather conditions.

Figure 57: Attaching of the white foil

Figure 58: Inside with white foil

After completing the construction of the walls, roof, and floor, the final step in the interior renovation was to cover the EPS insulation with a semi-transparent foil. This serves not only to conceal any foam marks or wooden beams but also to give the interior a more aesthetically pleasing appearance.

It should be noted that this is a relatively simple decorative treatment, and further decoration or stylization could be added by the next group to use the space. Depending on the desired look and functionality, additional features such as shelving, hanging baskets, or decorative lighting could be added to enhance the overall design. With a little creativity and ingenuity, the low-energy house could be transformed into a beautiful and functional space for an aquaponic system.

8.3 Outside renovation

As seen in the previous pictures, the greenhouse's original roof consisted of a plastic foil covered with cell sheet plates. However, this roof was not very strong or durable. The sheet plates had developed several holes over time, and there were some points where they were not well sealed, allowing water to seep into the greenhouse. In addition, mushrooms had begun to grow between the folds of the plastic foil, posing a potential health hazard for anyone using the space.

Furthermore, the plastic sheeting was not aesthetically pleasing, which was a concern for anyone who wanted to use the greenhouse as a functional and attractive space. Given our limited budget and construction knowledge, we decided that metal sheet plates would be a more durable and visually appealing option. Metal sheet plates are relatively inexpensive and easy to install, making them an ideal choice for our renovation project.

With the installation of the new metal sheet roof, the new greenhouse or even more the low-energy house is now more functional, attractive, and safe for use. The metal sheet plates provide better protection against the elements, prevent the growth of mold and fungi and improve the overall appearance of the space.

Figure 59: First part of the roof

8.3.1 Roof and walls

The first step in the external renovation process involved the installation of metal sheet plates on the roof. As previously mentioned, the old plastic foil was largely removed, and the roof was divided into two parts. One part was covered with a new layer of foil before the metal sheet plates were installed, while the other part received a layer of foil followed by the metal sheet plates. The same process was applied to the walls like mentioned in the part of the inside renovation. This ensured that the low-energy house was adequately protected from the elements and that any potential leaks were minimized.

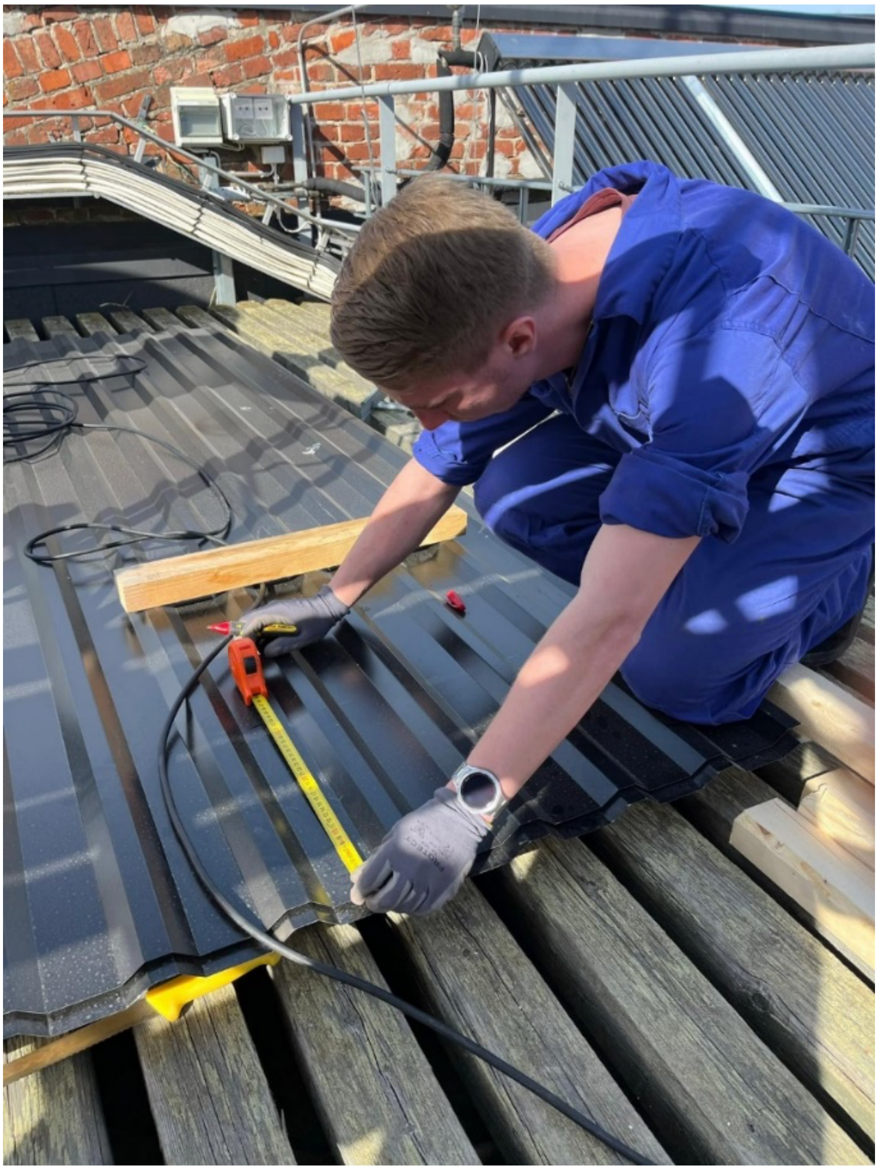


Figure 60: Preparation for cutting

Figure 61: Edge of the wall

Figure 62: South-wall of the low-energy house

Figure 63: Part of the roof of the low-energy house

The west wall and the gap between the two roof parts were covered with cell sheet plates to introduce a translucent element into the structure, allowing natural light to permeate the interior and harnessing the sun's warmth. This addition not only serves a functional purpose but also enhances the aesthetic appeal of the building. To improve insulation, two layers of cell sheet plates were used.

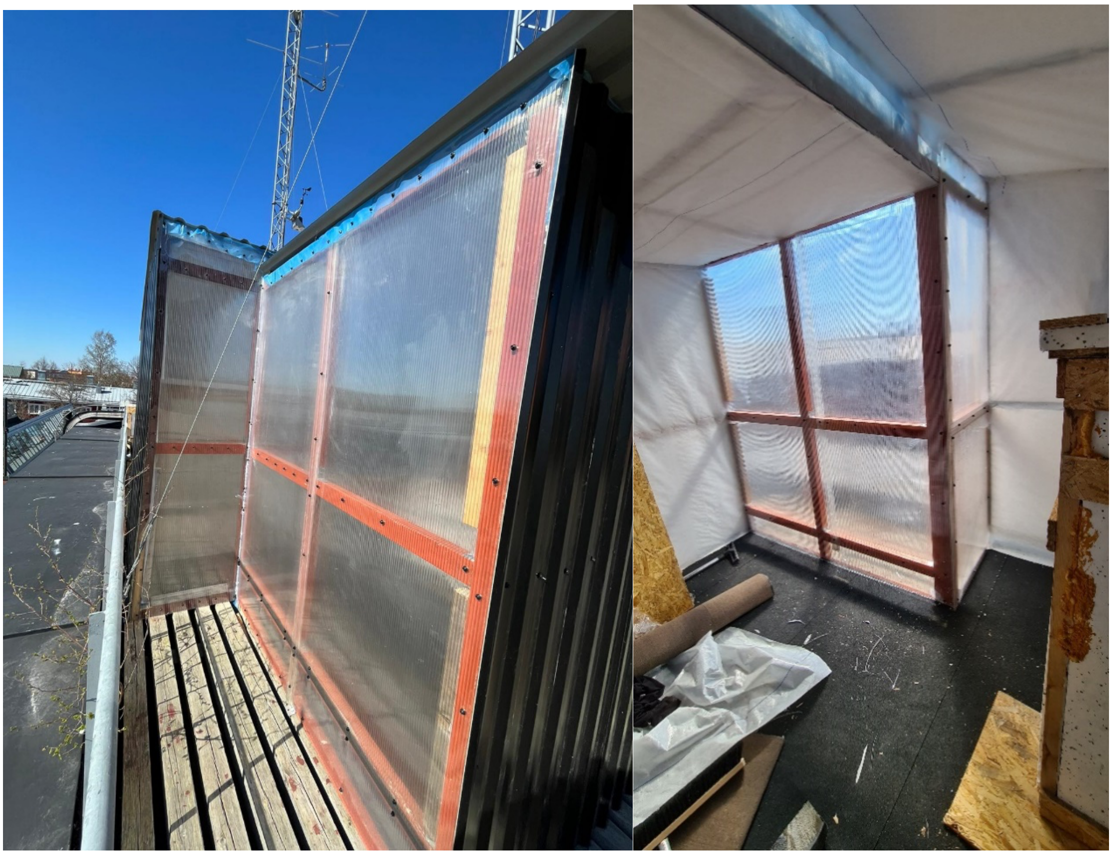


Figure 64: See-through wall outside and inside of the low-energy house

8.3.2 Entrance

The entrance of the greenhouse underwent a significant improvement from its previous state as an improvised door to a double door system. To achieve this, an additional wooden frame was constructed at the previous entrance. The outer part of the frame was covered with a combination of foil and metal sheets, while the inner part was insulated with EPS, similar to the insulation used in the low-energy house.

The floor of the entrance area was also upgraded by laying OSB plates on top of it, which were subsequently sealed with a layer of tarred roof paper. The installation of a double door system was aimed at reducing the amount of heat lost through the entrance whenever someone entered or exited the building.

Figure 65: Entrance inside of the low-energy house

Figure 66: Entrance outside of the low-energy house

8.3.3 Instruction door removal

In the design of the low-energy house we opted for a single, fixed door. Later on in the construction of the low-energy house this was changed on request of the customer to a double-door design with the possibility to remove the doors when needed to facilitate in bringing in larger objects when necessary for future EPS groups working on this project. Next to this a removeable barrier was installed to prevent snow blocking the entrance during the winter months.

In this design the following was considered:

- In- and outside doors with frame must be removable in a non-destructive manner.
- Structural integrity cannot be altered when the doors and frames are removed.
- Create a sluice/air barrier between the doors to prevent heat escaping when opened.
- Door must be lockable
- A barrier on the front door so it can easily be opened when there is a thick layer of snow in the winter months.

8.3.3.1 Removing front-door-snow-barrier

To prevent the door getting snowed in, a removeable snow barrier has been installed. The snow barrier ensures ease of access for up to 20 centimetres of snow. If necessary, the barrier can be removed by unscrewing both metal connecting plates, marked by the black squares.

8.3.3.2 **Removing outside door**

In its original state the dimensions of the outside are (w*h) 84*200cm. When necessary to bring in objects wider than 84 centimetres the door and frame can be removed to widen it to a 130*200cm opening. To achieve this lift off hinges were used for this door, so it can be lifted out without tools. The framing around the door is fastened with metal connector plates that can be unscrewed (marked with the red circles). After that the bolts of the see-through wall on the outside must be de-bolted and the supporting cross-beam unscrewed. Once above has been done, the snow barrier must be removed.

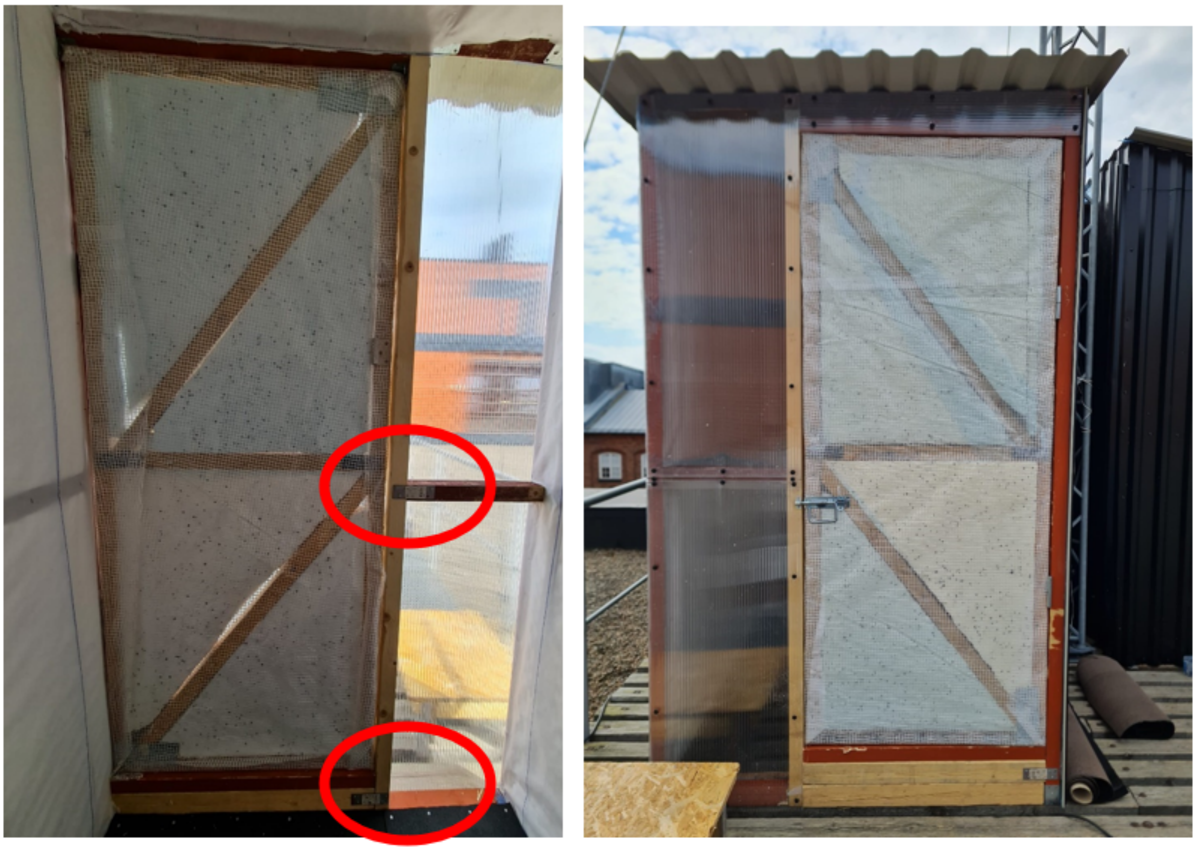


Figure 67: Instruction front door removal

8.3.3.3 **Removing inside door**

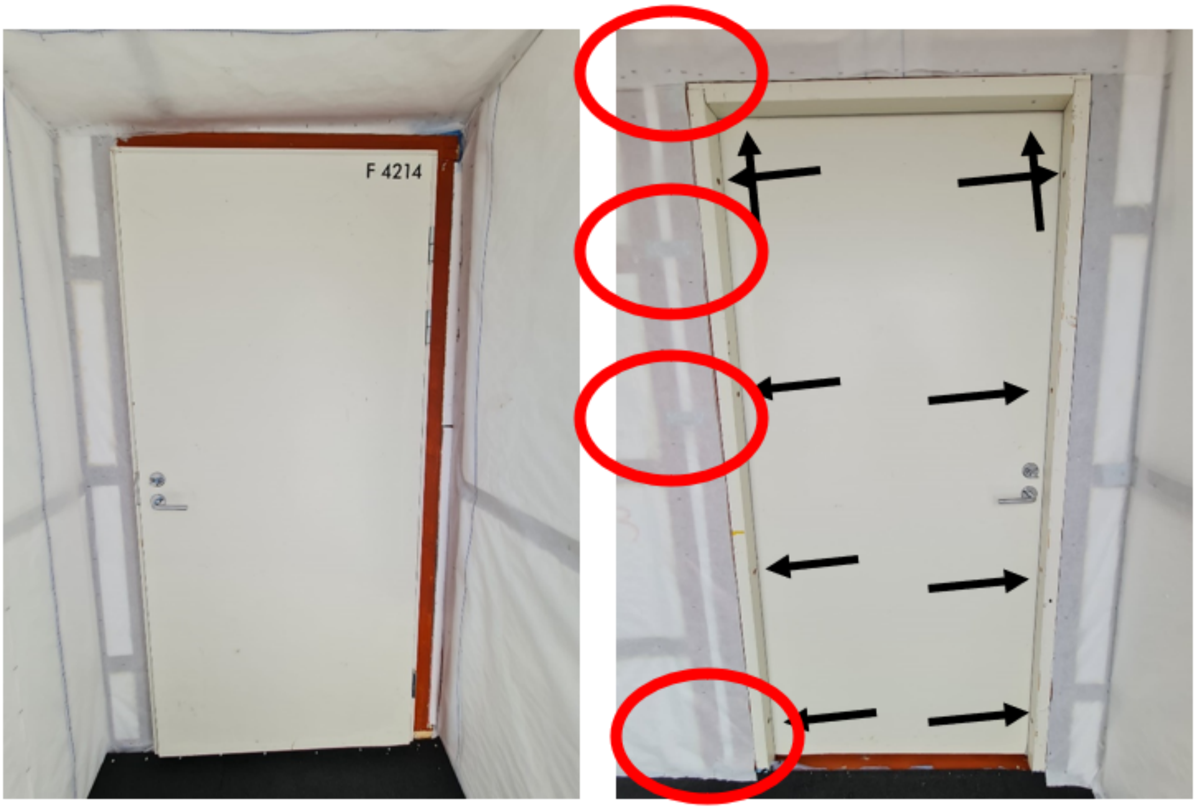


Figure 68: Instruction inside door removal

In its original state the dimensions of the inside door are (w*h) 94*200cm. This can be enlarged to a 110*200cm opening by removing the door and the doorframe. Just like the outside door, this door has been installed in such way its easily removed in a non-destructive manner to get this opening. First, the door should be lifted out of its lift off hinges. Once the door is out, the doorframe can be unscrewed by unscrewing the TX20 screws (marked with the black arrows) and taken out with care (frame can be fragile). Once the frame is out the metal connector plates can be removed, taking out the supporting beam (marked with red circles).

In the final design all considerations were made into reality. With the removable doorframes the outside door can be transformed from a 84cm wide opening, to a 130 cm wide opening. For the inside door it can be enlarged from a 91cm wide opening to a 110cm wide opening with the removal of a few screws. This opening is large enough for IBC tanks to fit through when needed.

8.4 Problems during construction

During the renovation of the greenhouse located on the roof of the Technobothnia building, the installation of metal sheet plates on the roof and walls posed several challenges. One of the primary difficulties encountered was the restriction on the use of tools that generate sparks, rendering the conventional method of hot work prohibited. As a result, the use of a tigersaw became necessary, which proved to be suboptimal for the task at hand. Additionally, the west-wall was not readily accessible, leading to a prolonged and challenging installation process for the metal sheet plates. The challenges faced during the installation process highlight the importance of careful planning and consideration of factors such as accessibility and tool restrictions in construction projects. Another challenge encountered during the renovation was the presence of a pole for an antenna near the building. Its positioning made the construction process complicated as it had to be worked around. The installation of metal sheet plates was particularly challenging, and the walls had to be carefully constructed to avoid obstruction. The team had to work with caution to ensure that the antenna pole was not damaged during the renovation process. However, with careful planning and execution, the team was able to complete the renovation successfully.

Figure 69: West-wall of the low-energy house

Figure 70: Pole of antenna

9 Project Management

As for all projects, is it important to have a clear project management in order to work more efficiently and effectively. To succeed the Aquaponic project, some project management courses were followed by all members of the team. This way, some tools were put in place for the project organisation.

9.1 Defining the project

For a successful project, a series of tasks needs to be defined to have a good overview of what are the goals and with which kind of wherewithal it had to be achieved.

9.1.1 Mission and Vision

- Mission: Try to improve a greenhouse and make a low energy house out of it, which contains an aquaponic systems.
- Vision: Developing a system to create a future where food can be produced locally and sustainable, without relying on harmful chemicals or depleting natural resources.

9.1.2 Project goals

Improve the current insulation of the aquaponic so when the heating is on, the temperature does not fall below 0 degrees Celsius.

Investigate possibilities for renewable energy and more sustainable heating to be less reliant on fossil fuels to heat the installation and keep the temperature above 0 degrees.

Have a working and improved principle of an aquaponic system with both plants and organisms.

9.1.3 Project Stakeholders

Direct	**Requirements**
Mikael Ehrs (coach)	Provide group with feedback on the project and required information
Mikael Ehrs (customer)	Provide the project team with wishes and demands on the aquaponic system design
Novia University of Applied Sciences	Provide resources & space for the project team
Indirect	
Technobothnia	Provide the project team with workspace
Tobias' team	Possible information exchange
Svenska Kulturfonden	Provide working capital & budget

Table 7: Project stakeholders

9.1.4 Project Requirements & Priorities

MUST HAVE	SHOULD HAVE	NICE TO HAVE
Organisms in the water (preferably sellable)	Good environment for the fish	Working principle
Good insulation	Protection against parasites	Automatic system
Renewable energy source (combination possibility...)		Advertisement
Vegetables that can be sold in Vaasa		

Table 8: Project requirements

9.1.5 Environment of the solution

Must be a safe environment for animal and human

Must comply to local and national laws and regulations

Must be able to withstand Finnish weather conditions

9.1.6 Project deliverables

Midterm presentation – presenting the current progress and preliminary results

End presentation – Presenting the project to the stakeholders

Project report – A report outlining the done research and booked results

Handover package – A package for the next EPS group to use

9.1.7 Project Milestones

Milestone 1: Definitive and agreed upon project charter

Milestone 2: Theoretical research completed

Milestone 3: Mid-term deliverables

Milestone 4: Working principle of aquaponic installation.

Milestone 5: Final deliverables & handover package

9.1.8 Required Resources

Work hours 24-30h/week pp

Materials 2000 euro

1h a week meeting with customer

9.2 Work Breakdown Structure (WBS)

A work breakdown structure is a project management tool that can be used to create a visual, hierarchical deconstruction of a project. In a work breakdown structure all steps of a project are outlined in a work breakdown structure, which is essential for indicating tasks, deliverables and creating work packages. (Wrike, N.D.)

A work breakdown structure is the first step in creating a project schedule. It defines all the work that has to be done and in what order it must be completed. This makes it very easy to schedule a project with a Gantt chart by incorporating the levels and task hierarchies in the schedule. In addition, it can help in preventing common project issues like missed deadlines, scope creep and cost overrun amongst other common problems. (Wrike, N.D.)

For our project we have created a work breakdown structure (Figure 73: Work breakdown structure) to break down our project into smaller, more workable work packages. This work breakdown structure was later used to develop a Gannt chart and RACI matrix for our project.

The Work breakdown structure came to life by having some brainstorm sessions. The results of those sessions are presented below.

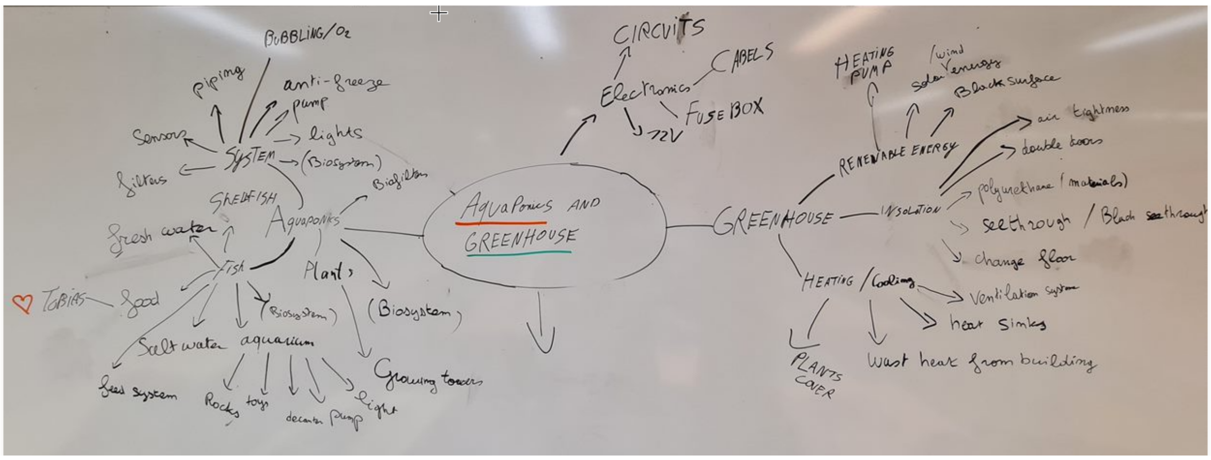


Figure 71: Mindmap

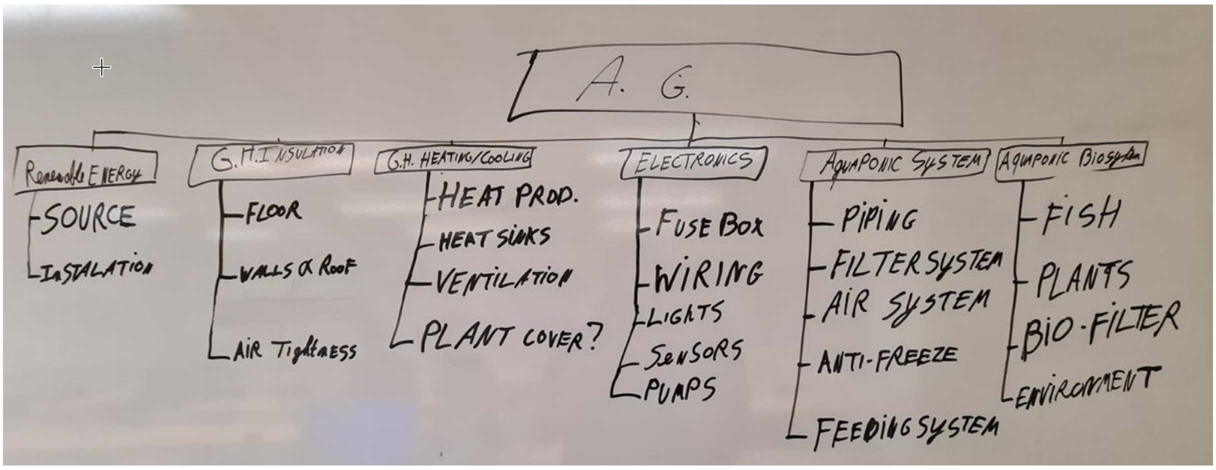


Figure 72:Draft work breakdown structure

After the brainstorm sessions and some discussion, the work breakdown structure was formulated, as shown in Figure 72.

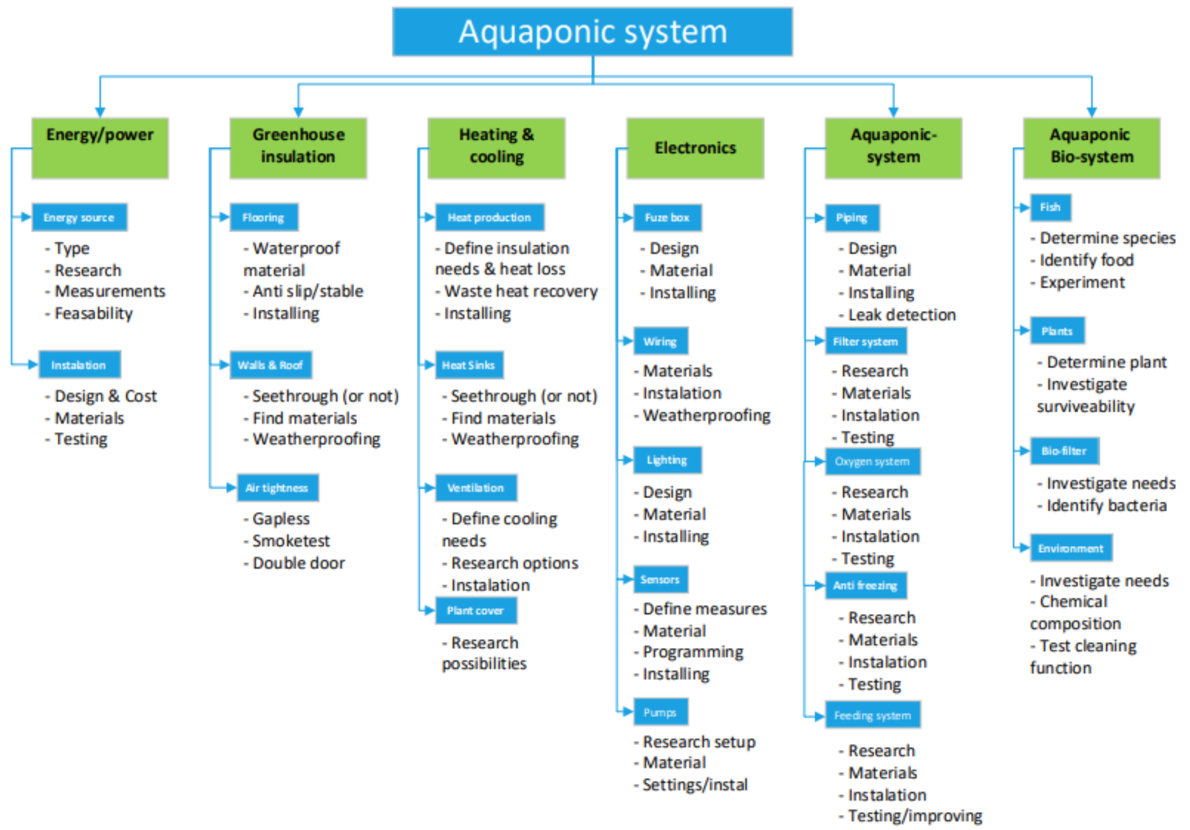


Figure 73: Work breakdown structure

9.3 Project scheduling

To bring a project to a success a large number of separate activities must be controlled and managed to not miss important deadlines. A GANNT chart is a great way to do this as it gives a clear visual on how the project is going and what important milestones for the project are.

In the GANNT chart the identified tasks in the work breakdown structure were expanded into more detail to identify the essential tasks. After identifying those essential tasks, a timescale was attached based on how long we estimate these tasks to take. The Gannt chart can be found in Appendix 1: GANNT chart.

9.3.1 Conclusion

In conclusion, the deviation from our Gannt chart can be blamed on several factors that have impacted our project's progress. First, a big impact was performed by a modification of the project scope, when it was decided to stop the development of an aquaponic system and focus our attention on building a good greenhouse. These changes to the original scope caused the timeframe, resource distribution, and task dependencies to be adjusted to account for these changes, which results in a deviation from the original Gantt chart.

Secondly, the weather conditions were not always on our side with rain and spring snow. The unpredictable weather had a negative impact on our project schedules. Unfavourable weather can impede progress, stymie workflow, and create delays. In the end this fortunately only caused a very minor deviation in the planning.

Lastly, setbacks are an inherent part of any project, regardless of its nature, length or complexity. These setbacks are not always to be blamed on internal factors, but on external factors like the weather and scope changes too. While deviating from the initial project planning can be frustrating, its key to acknowledge the dynamic process project management can ben. In the end, the project group was able to react quickly to the impactful scope change and managed to finish the project well before the deadline.

10 Budget Analysis

At the beginning of the project, the budget was 2000 euros. With this amount of money, the aquaponic system and low-energy house has to be built. Has mentioned before, an aquarium has been started. What was left from the previous group was the empty aquarium, one pump and some decorations. However, some materials had to be bought to operate 2 aquariums with some good environment to live. Below the budget analysis after buying materials and shrimps for the aquarium.

Budget analyse			
Date	**Price (€)**	**product**	Budget
17/02/2023	7,2	Aqua safe	1774,21
17/02/2023	14,3	Pumpfilter	
17/02/2023	3,9	Suction cup	
21/02/2023	20	4x shrimp	
21/02/2023	10	2x plant	
22/02/2023	4,99	Timer	
10/mrt	45,3	Pump	
10/mrt	4	Fishing net	
10/mrt	4	Airtube	
11/mrt	12,5	Delivery fee	
11/mrt	50	Thunderbolt crayfish	
11/mrt	49,6	Amano Shrimps	

Around 10% of the budget has been used for the aquarium. Then the 90 % has been used for the construction materials.

Budget analyse			
Date	**Price (€)**	**product**	Budget
17/02/2023	7,2	Aqua safe	227,43
17/02/2023	14,3	Pumpfilter	
17/02/2023	3,9	Suction cup	
21/02/2023	20	4x shrimp	
21/02/2023	10	2x plant	
22/02/2023	4,99	Timer	
10/mrt	45,3	Pump	
10/mrt	4	Fishing net	
10/mrt	4	Airtube	
11/mrt	12,5	Delivery fee	
11/mrt	50	Thunderbolt crayfish	
11/mrt	49,6	Amano Shrimps	
17/03/2023	10	Gravel and Plants	
21/03/2023	15	Aquarium Heater	
21/03/2023	4,2	Thermometer	
21/03/2023	14,4	2x Aqua safe	
4/04/2023	80,47	13x EPS Floor	
4/04/2023	359,5	50x EPS Walls	
4/04/2023	7,45	Sockets	
4/04/2023	17,98	2x Foam	
4/04/2023	45,9	2x 4.8x35 Screws (250)	
4/04/2023	831,2	16x Metal sheet plate	
4/04/2023	72,73	Metal sheet plate (big)	
4/04/2023	87,95	Sea-though wall	

As representative on the table, 70% of the budget left has been used for construction materials.

During the following meeting with Mikael Ehrs, he decided to add 1000 euros more to finish the building construction.

Budget analyse				
Date	**Price (€)**	**product**		Budget
17/02/2023	7,2	Aqua safe		21,38
17/02/2023	14,3	Pumpfilter		
17/02/2023	3,9	Suction cup		
21/02/2023	20	4x shrimp		
21/02/2023	10	2x plant		
22/02/2023	4,99	Timer		
10/mrt	45,3	Pump		
10/mrt	4	Fishing net		
10/mrt	4	Airtube		
11/mrt	12,5	Delivery fee		
11/mrt	50	Thunderbolt crayfish		
11/mrt	49,6	Amano Shrimps		
17/03/2023	10	Gravel and Plants		
21/03/2023	15	Aquarium Heater		
21/03/2023	4,2	Thermometer		
21/03/2023	14,4	2x Aqua safe		
4/04/2023	80,47	13x EPS Floor		
4/04/2023	359,5	50x EPS Walls		
4/04/2023	7,45	Sockets		
4/04/2023	17,98	2x Foam		
4/04/2023	45,9	2x 4.8x35 Screws (250)		
4/04/2023	831,2	16x Metal sheet plate		
4/04/2023	72,73	Metal sheet plate (big)		
4/04/2023	87,95	Sea-though wall		
17/04/2023	2,91	Loctite		
17/04/2023	19,2	5,0x80 screws (200)		
17/04/2023	20,6	4,0x40 screws (200)		
17/04/2023	19,2	12x 90x90 angle		
17/04/2023	22	20x 60x60 angle		
17/04/2023	163,3	wood 64,8 m		
17/04/2023	3,49	brush		
17/04/2023	3,95	stapples		
17/04/2023	6,99	tooth spatula		
17/04/2023	19,98	2x foam		
17/04/2023	134,85	3x white foil		
17/04/2023	24,43	Paint		
17/04/2023	58,95	blue foil		
17/04/2023	149,9	2x glue		
17/04/2023	189,9	2x tar paper		
8/05/2023	20,6	4,0x40 screws (200)		

8/05/2023	4,4	M5 discs (100)
8/05/2023	16,92	wood 7,2 m
8/05/2023	3,95	6x100 screws (10)
8/05/2023	9,99	foam
8/05/2023	28,35	4,8x35 Screws (250)
8/05/2023	97,3	2x Metal sheet plate
8/05/2023	175,9	2x Sea-though wall
11/05/2023	8,99	Silicon

At the end of the project was almost everything of the budget used, including the 1000€ extra.

11 Conclusion

Finally, this EPS Project was for our team a huge challenge. In fact, each member study a different field and only one member of the team has a building skill. Firstly, A lot of research had to be done about aquaponic system and low-energy houses. Secondly, as mentioned previously, managing the project was not easy and we had to adapt easily towards the unforeseen. In the end, we succeed to finish the low-energy house. Thanks to this project, our team did not just learn about a new topic: our team learn about working together. In fact, beside the scholar side, all of us learn about how to adapt towards different ways of working and habits. Each team member became more mature, organized and with a lot of new knowledges at the end of this project.

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Appendix 1: GANNT chart

Voer in cel B2 de bedrijfsnaam in.

Voer in cel B3 de naam van de projectleider in. Voer in

Begin project: Mon, 6/2/2023

Start week: 1

Task	Responsible	Start	End
Research	Project Group 3	13-02-23	9-04-23
Fish		13-02-23	10-03-23
Research species		13-02-23	6-03-23
Choose & order species		7-03-23	20-03-23
Evaluate experiment results		20-03-23	10-04-23
Plants		7-03-23	7-04-23
Research type of plant		7-03-23	10-03-23
Choose & order plants		10-03-23	17-03-23
Evaluate experiment results		17-03-23	7-04-23
Bio filters		18-02-23	10-03-23
Research possibilities		18-02-23	21-02-23
Test with fish & plants		20-03-23	27-03-23
Walls & roof			
Research materials & calculations		19-02-23	1-03-23
Choosing & ordering materials		20-03-23	27-03-23
Installing		10-04-23	12-04-23
Floor			
Research materials		17-03-23	20-03-23
Ordering materials		20-03-23	27-03-23
Installing		10-04-23	12-04-23
Energy sources			
Investigate source possibilities		17-03-23	21-03-23
Installing & testing		15-04-23	30-04-23
Evaluate results		17-04-23	30-04-23
Heat sinks			
Research feasability		21-04-23	24-04-23
Ventilation			
Researching need and possibilities		20-03-23	22-03-23
Installing & testing		22-04-23	24-04-23
Evaluate results		24-04-23	25-04-23
Plant cover			
Research feasability		2-05-23	3-05-23
Pumps			
Researching possibilities		5-04-23	7-04-23
Installing & testing		24-04-23	26-04-23
Evaluate results		26-04-23	29-04-23
Oxygen system			
Researching possibilities		5-04-23	7-04-23
Installing & testing		24-04-23	26-04-23
Evaluate results		26-04-23	29-04-23
Anti freezing			
Researching possibilities		21-04-23	24-04-23
Feeding system			
Researching possibilities		6-03-23	10-03-23
Installing & testing		26-04-23	28-04-23
Evaluate results		28-04-23	30-04-23
Testing & experimenting			
Concept aquaponic system		17-03-23	27-03-23
Choose & design concept		26-03-23	27-03-23
Test greenhouse			
Heating & cooling		25-04-23	30-04-23
Air tightness, weatherproofness, durability		25-04-23	30-04-23
Deliverables			
Mid-term report & presentation		16-03-23	16-03-23