HyGrow
Aquaponic System

PRODUCING FOOD IN EVERY POSSIBLE ENVIRONMENT

University of Vaasa FINLAND

NOVIA UNIVERSITY OF APPLIED SCIENCES

ALEKSANDRA NAYDENOVA
MEI RAMADA QUEROL
TIJE KUIJPER
TIMO VAN ROJE

TOBIAS EKFORS

EPS PROJECT AUTUMN 2021

Hygrow Aquaponic Greenhouse

“Producing food in every possible environment.”

Vaasa (Finland), 16 December 2021, Version 2

Authors

Aleksandra Naydenova	aleks.naydenowa@gmail.com	+31 6 14 49 18 29
Mei Ramada Querol	meiramada@gmail.com	+34 6 38 24 06 31
Tije Kuijper	tije@me.com	+31 6 34 66 04 94
Timo van Roje	t.v.roje@gmail.com	+49 157 87 99 36 84

Coach and client

Tobias Ekfors (coach)	tobias.ekfors@novia.fi	+35 85 059 270 35
Mikael Ehrs (client)	mikael.ehrs@novia.fi	+35 84 478 055 36
Roger Nylund (coordinator)	roger.nylund@novia.fi	+35 85 052 722 81

Preface

This Final report presents an Aquaponic System on the roof of Technobothnia, written by four students participating in the EPS programme at NOVIA University of Applied Sciences. This programme is designed for students mainly from the engineering field, but students from the business and management field are also welcome. The EPS is offered at 18 different universities in Europe. The projects at Novia UAS are mainly in the fields of sustainability and energy. The EPS is not only about results but also about working in an intercultural and interdisciplinary team.

Today, climate change is a very sensitive issue. Therefore, it is important to take countermeasures and minimise the carbon footprint. Often food is imported from far away, which leaves a large carbon footprint, and often a lot of water is needed for production, where there is already a general water shortage. Thus, with our project, we want to make it possible to produce food sustainably and locally. Our team want every interested person can use the Aquaponic System. Therefore, we aim to make the system as easy to use as possible.

We would like to thank our supervisor Tobias Ekfors for his assistance. He gives us useful tips and advice for our work. Furthermore, we would like to thank Mikael Ehrs, our client, he supports us with good feedback for our ideas and how to work on the project. Moreover, we want to thank Hans Linden, who helped us with all technical questions we had. A special thanks goes to the previous EPS groups who have already worked on our project. Their work and recommendations helped our team to familiarise themselves with the topic and steer the project in the right direction.
Without Novia UAS and Roger Nylund as EPS coordinator, our team would not be able to work on this great project and have such great experiences. We would like to thank Sebastian Dalaholm, who provides us with equipment and helped us to get access to the roof. Finally, a big thanks to the AI, Robotics and Big Data-project, who sponsored the budget for our project.

Vaasa, December 2021
Aleksandra Naydenova
Mei Ramada Querol
Tije Kuijper
Timo van Roje

Summary

The goal of the project is to realize an aquaponic system that provides the best conditions for the growth of plants and fish. In addition, the system should be automated. This should be done in a user-friendly way, so that even beginners are not overwhelmed with it. To draw attention to our project, a concept will be developed to inform people and students about the project. Finally, the methods for project management will be explained and working in an international team will be evaluated.

To make this possible, the team worked further on a greenhouse with an Aquaponic system, which was built by the previous EPS team. During the project, some structural changes were made to the aquaponics system. For example, the whole system was redesigned and insulated to create the best possible conditions for the plants and fish, as well as to increase energy efficiency.

Sensors were installed for automation, providing important data on water and air quality. Furthermore, a user-friendly interface was created, which provides all important data in a simple and clear way and historical data is recorded. Automations were added to allow the system to operate as autonomously as possible.

For public relations, several posters were created, which are for promotional purposes. In addition, a website and Instagram page were launched to reach people on a digital level as well.

Lastly, the teamwork was evaluated over the duration of the project. This showed that the team worked very well together over the course of the project and that each of the team members took away a lot of positive abilities from working in an international team.

Table of Contents

1 Introduction

The purpose of this chapter is to introduce the aim of the Aquaponics system Greenhouse project, the involved stakeholders, in relation to their needs and motivations. The abovementioned project is being carried out by the Novia University of Applied Sciences in Vaasa, Finland, in cooperation with AI Robotics project and the University of Vaasa.
The Hygrow project have been previously followed through by two other European Project Semester groups, laying the foundation of a working Aquaponics system. Nevertheless, throughout the Autumn semester 2021, we as a team have strived for the full automation of the Greenhouse, in relation to finding an interactive mean of educating people on the importance of introducing sustainable farming systems to our homes, thoroughly covered in the Final report.

1.1 Stakeholders

In this part, the different involved stakeholders are elaborated.

1.1.1 Novia University of Applied Sciences

Novia University of Applied Sciences is situated in the west of Finland. It is the largest Swedish-speaking University in Finland with over 4000 students and 300 personnel. The history and traditions of the UAS goes back to 1813. Novia University offers multidisciplinary higher education with a practical orientation. The school trains students to become experts and developers based on the requirements of working life. High quality degrees provide students with a proper platform for their future careers. (Novia UAS, n.d.)

1.1.2 University of Vaasa

The University of Vaasa is as the name states also located on the west coast of Finland. It consists of 4 schools for research and teaching: management, accounting and finance, marketing and communication, and of technology and innovations. The school has over 5000 students and more than 450 personnel. (University of Vaasa, n.d.)

1.1.3 Sponsorships

Hygrow project has been sponsored by few extra companies, more specifically Svenska Kulturfonden, AI Robotics och big data, and UPC Print.

1.2 Mission, vision, and goals

In this paragraph, the mission, vision, and goals are described. The focus for the mission and vision is long-term, beyond the end of the project. The goals are created to be reachable by the end of the project.

1.2.1 Mission

"To create an understandable self-sustained climate independent Aquaponic System for producing food in every possible environment."

It is a long-term mission. Focussing on the endpoint where this project (EPS Autumn '21) part of is. It is the idea of the future of the Aquaponic Greenhouse. With the concept of an Aquaponic Greenhouse, it would be possible to make a producible Aquaponic

Greenhouse to let every individual be able to grow food in every environment. That is a mission where the EPS Autumn ’21 group is part of.

1.2.2 Vision

“Giving every home the possibility to produce food.”

Climate, geography, and prosperity have influence on the production of food. An Aquaponic Greenhouse takes this away and gives every household the opportunity to grow food. That is what Hygrow Aquaponic Greenhouse contributes to.

1.2.3 Goals

The project is divided into four goals. The four goals are each focussing on the profession of one of the members of the group. On this way, everyone can develop themselves for their own profession.

1.3 The Team

The Hygrow project consists of a multi-cultural team, with team members coming from the Netherlands, Germany, Spain and Bulgaria, each of them bringing a unique perspective into the project. Furthermore, a diversative environment have been created, due to each member’s varied educational background, with expertise in the fields of Chemical Engineering, Industrial Design, UX Design and Project Management.

The benefits of working in such international team is unutterable, as so team members will have the incredible opportunity to combine their competences and skills, with the purpose of achieving the final goal, that have been stated at the start of the project.

Table 1: Team Competences

Field of expertise	**Project members**
Biochemical Engineering	Timo van Roje
Electrical / Electronic engineering	Timo van Roje
Project Management	Tije Kuijper
Marketing	Aleksandra Naydenova
Public Relations	Aleksandra Naydenova
Industrial Design	Mei Ramada Querol
Accounting	Tije Kuijper

2 The Aquaponic System

The aim of this chapter is to define the aquaponic system and all its components. This section is divided into six paragraphs. The first paragraph is about explaining what an aquaponic system is, followed by another paragraph about the initial conditions of the system and the choice of the ecosystem for the project. The third paragraph is related to the process of rebuilding the house. Subsequently, the fourth paragraph describes the initial Aquaponic System and possible problem scenarios, including their respective solutions, while the fifth paragraph describes the conducted process with improvements in the Aquaponic System. Finally, a summary of the five paragraphs has been made together with recommendations for upcoming groups.

2.1 What is the Aquaponic System?

An aquaponics system is a combination between aquaculture and hydroponics, meaning that both plants and fish live together in a synergy circular environment. Different techniques are available for the Aquaponics system: nutrient film technique, media bed and deep-water culture.

2.1.1 Nutrient Film Technique (NFT)

This method consists of placing the plants in a tube, through which water and nutrients can circulate smoothly from the fish tank to the filter tank and then being pumped into the plants. The roots will grow downwards looking for nutrients in a foam medium, allowing oxygen to flow through the small holes in the foam and thus reach the plants (Figure 1).

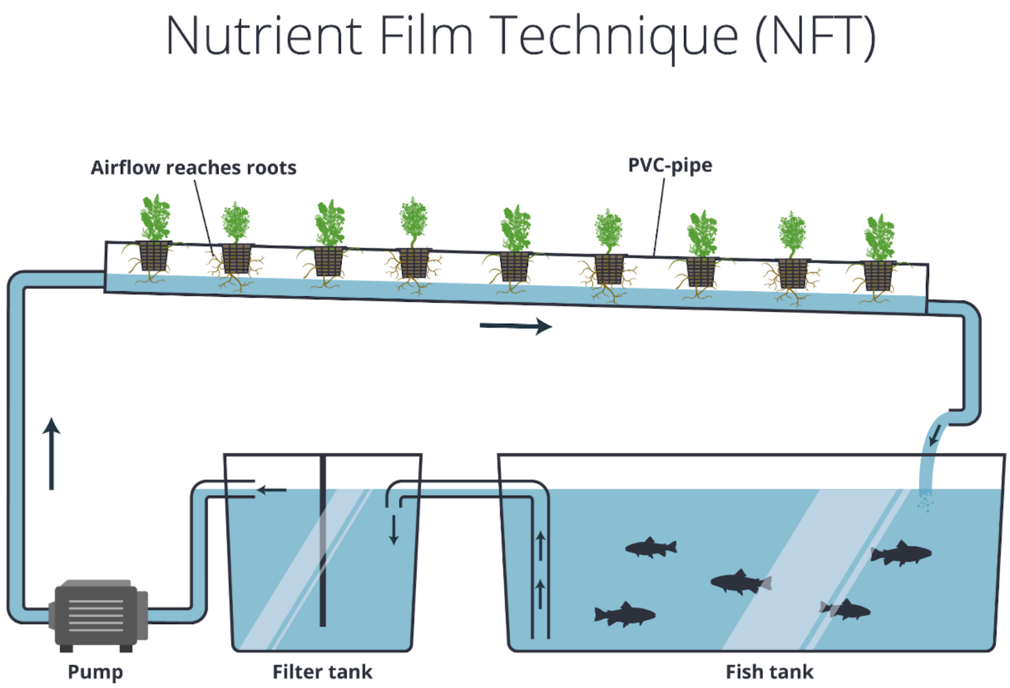

Figure 1: Nutrient Film Technique (Verheyen, 2019)

2.1.2 Media Bed

This system requires plants to grow in a tank filled with a media, usually gravel, perlite or Styrofoam are used, and occupied with running water underneath. From time to time the media is flooded and drained out from the fish tank to return the water into the main tank and allow the cycle to get restarted (Figure 2).

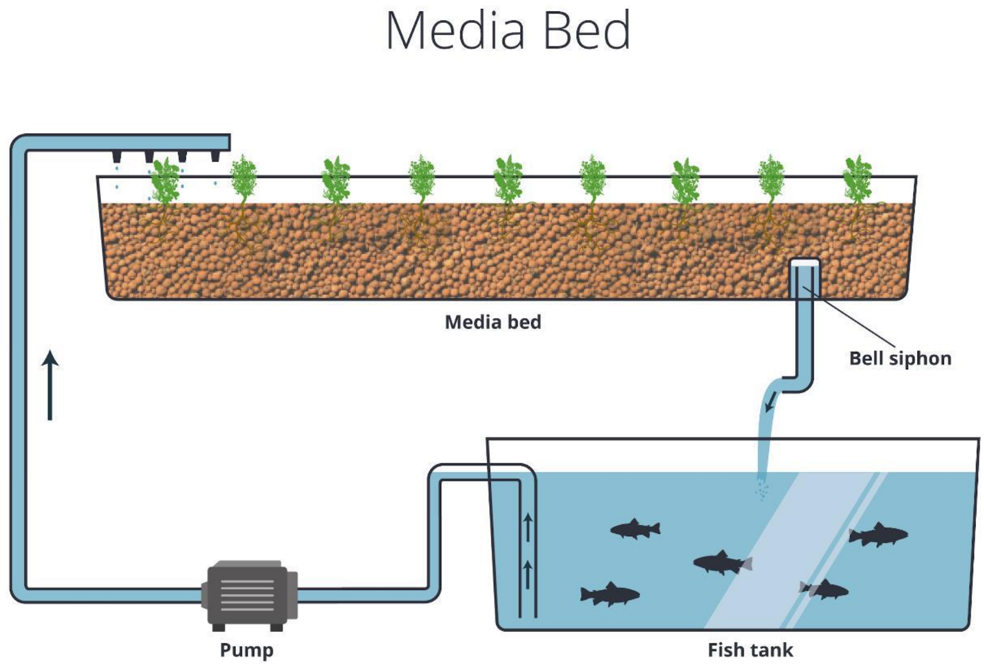

Figure 2: Media-filled bed system (Verheyen, 2019)

2.1.3 Deep Water Culture (DWC)

This technique involves the plants being located into floating rafts. Water is continually flowing from the fish tank to the separate little ponds on which the rafts are to be found, afterwards the left water drains back to the first mentioned deposit. Additional tanks should be added into the system like a sedimentation tank and a biofilter tank (Figure 3)

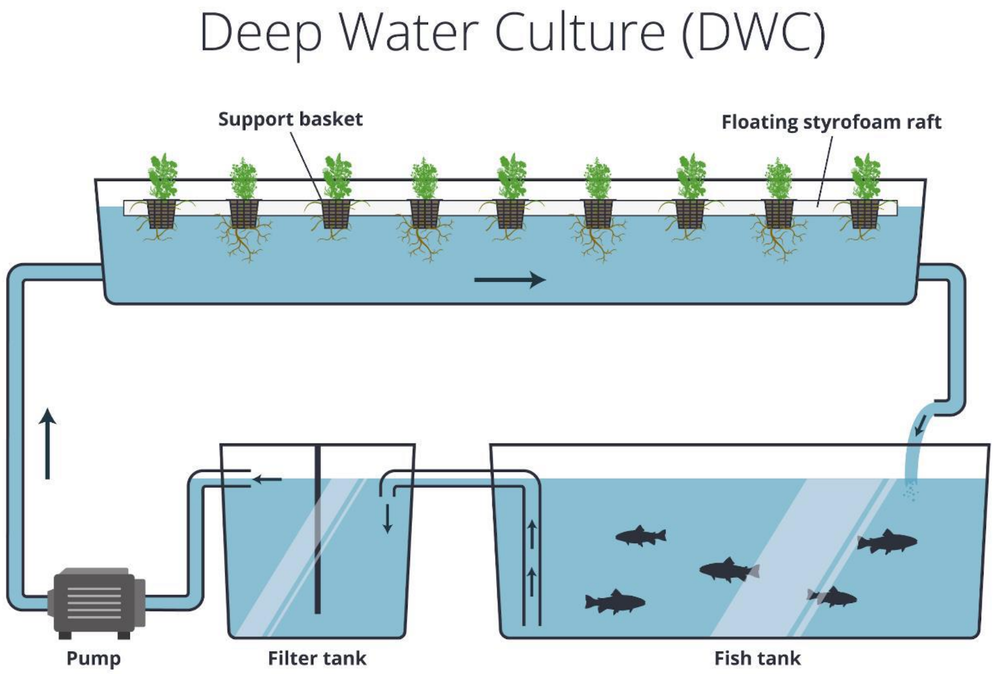

Figure 3:Deep water culture system (Verheyen, 2019)

2.2 Choice of an Aquaponic eco-system

Creating a functioning Aquaponics system requires a well-researched choice of plants and fishes, which will be presented in this chapter. Furthermore, the forthcoming results have been derived from Aquaponic System Spring Team 2020 Report (Verburgh, et al., 2020), next to individual research, with the purpose of having an up-to-date information on prices, availability, and delivery times.

2.2.1 Choice of fishes

Based on the conducted research from the previous Spring Semester group working on the project, the chosen fish for the water culture and marine, was to be consisted of the Koi carp. The reason behind this, as stated in previous research, corresponds tightly with the availability of the type of fishes in pet stores and other fish farm retailers in Finland Report (Verburgh, et al., 2020). One of the affordable and realistic options for Koi carp suppliers in Finland is the pet store "Rallen Riutta", situated close to Helsinki. However, delivery costs exceed the planned budget for fishes in the system, thus why searching for other options will follow.

The initial alternative was to purchase the fish from a local shop, to avoid the cost of shipping and handling. Following this option, extensive informative research was carried out and the necessary information was consulted with knowledgeable users of the fish.
On the basis of the information collected, it has been concluded that European Perch (Figure 4: European Perch) is the best choice for the project because they are a local fish, and their metabolism is adapted to the extreme temperature's changes in Finland.

Figure 4: European Perch (Fishing Planet, 2021)

Besides the European Perch, other marine life can be introduced to the system such as shrimps or small snails. They can be found in bigger pet stores, so their availability is broadly spread. Regarding the implementation of shrimps/snails to the eco system, one needs to consider the risk of them being eaten by the fish, next to the diseases in the aquaponics system, as the percentage is comparatively high, thus why the system will require a closer monitoring, to prevent death of the established marine life.

Based on the risk management table that the previous group of Spring 2020 has provided our team (Appendix 4: Risk Management Table Spring Semester 2020) with one could clearly notice that an overfill of waste in the tank with fishes could be a potential issue with a higher priority (Verburgh, et al., 2020). Moreover, this will be considered whenever working on the Aquaponics ecosystem.

2.2.2 Choice of plants

The other important part of the aquaponics system are the plants. Considering the recommendations from the previous team, that worked on the project, the planting process will start with soilless gardening. The plants will be sown in rockwool or any other type of media from the beginning of their growth process, with the purpose of not exposing the young plants too early to an environmental shock, which will cause a loss of small roots when transferred from soil to soilless habitat. Moreover, they will need to be kept under a lid, as this would be the most beneficial method to germinate the seeds, next to maintaining the humidity and temperature. Another important point to be considered is the deficiency of micro and macro nutrients, such as iron, potassium, and calcium in the plants. Therefore, implementing nutrition to the soil, would prevent the created eco system from failure.

After doing an extensive inventory of the materials left from the previous groups (Appendix 3: List of materials from previous group), available packages of herbs/vegetables were found, which are the following:

- mint
- parsley
- spinach

For the scope of this project, the plants that will be taken into consideration will be the aforementioned, with the given flexibility of adding other types of plants, such as lettuce and rucola, in order to create a more diverse selection of plants. Another reason behind this would be due to the fact that as stated in previous report: "Monocultures are often not very sustainable as they do not require a wide range of nutrients, that can quickly become depleted as well as be more susceptible to diseases, which can be fatal in such a closed environment." (Verburgh, et al., 2020, p. 152).

2.3 Rebuilding the house

In this chapter the state of the Greenhouse is explained along with the improvements to be made.

To improve the condition of the Greenhouse, the recommendations and comments from the previous group have been considered, alongside some details detected while checking the actual condition of the house. Below is a list of all the practical information left by the previous groups is presented:

- During winter the water is susceptible to drastically drop in temperature and cause damage to both plants and fish, therefore the isolation of the construction is recommended.
- The finding of a solar water panel can be of great help to heat the water during the coldest season.
- An easier assembled, dismountable, and better insulation solution for the walls would be double-layer plexiglass.
- A part of the roof has a slight slope, which causes water to accumulate in that area. (Verburgh, et al., 2020, p. 120).

Apart from the recommendations, several parts of the house were in poor condition after having spent 1 year without care, due to the outbreak of COVID-19 situation in Finland. The most damaged part was the PE foil walls, as they have been pierced by the sides, that happened to be strongly exposed to the wind. The fact that the walls were in a deplorable state meant that the water had entered the house and consequently some of the electronic devices had become wet and damaged. To avoid this type of situation, repairing the walls became s priority to get the house back in good condition. Another factor that needs to be considered is the electrical wiring, which was not covered or protected from water.

Having mentioned all the relevant points and knowing the mission of the project has helped the Group to agree in emphasis more in the automation rather than with the building itself. Furthermore, the final location of the project will not likely be the roof of Technobotnia. That being said, the focal point will be only on the essential part for having the system running and the goal will be to make sure that it is in a working condition, thus activities of replacement or fixing will be needed.

Subsequently, this decision has led the team to start repairing the walls and looking for possibilities of protecting the wiring system, next to providing the Greenhouse with the necessarily heating and insulation system to the main tank. Before starting any of the mentioned actions, an inventory of the objects left by the previous groups was made (Appendix 3: List of materials from previous group) the task of identifying everything that is missing and everything that is already within our reach has been made easier.

2.3.1 Repairing the walls

To procure the whole system to its old conditions, first the walls must be repaired. The entire followed procedure will be briefly explained from the moment the team analysed the situation until a decision has been made and carried out.

Pursuant to the abovementioned condition of the Greenhouse and taking into consideration the recommendations of the previous groups, double layer plexiglass sheets should be bought for the purpose of better insolation and assembly/dissemble of the whole structure. Regardless of whether this is the best option for the benefit of the house, the budget is limited, and the team has settled for not spending a large amount on the house.

An alternative that could be considered is to replace the actual PE foil with a new one and achieve protection against wind and water for a limited period. This solution will provide shelter for the fishes, plants, people, wiring system and all the items kept inside the Greenhouse.

2.3.1.1 Check what is needed

Once a plan of fixing the walls have been established, a list of the things needed has been made:

- PE foil
- Stapler
- Staples for wood
- Screws
- Electric Screwdriver
- Wood Ribbons
- Safety harness
- Scissors

2.3.1.2 *Buy materials for the repair*

No materials had to be bought as the team could find them within the leftovers from the previous groups (PE foil, Screws, Wood Ribbons and Scissors) or were provided by the Technobothnia Janitor or Tobias (Staples, Staples for wood, Electric Screwdriver and Safety harness).

2.3.1.3 *Steps followed*

To start with the procedure, a couple of steps have been taken.
Firstly, an observation was made has been conducted with the purpose of point out all critical parts of the conditions of the walls (Figure 5: Repairing the walls, view of). Secondly, understanding how the walls were built and attached to the woods. Moreover, the foil from the top has covered approximately 20cm of plastic between the rooftop and the vertical walls (Figure 6)
The next step was adding the new PE foil underneath the old one, therefore prevents the wind from damaging the parts with the most friction on the wood.
Once the foil was attached to the structure (Figure 8), the inferior part of the plastic was rolled and placed around the perimeter of the house. Finally the reparing of the walls was accomplished (Figure 9).

Figure 5: Repairing the walls, view of the previous PE foil installed

Figure 6:Repairing the walls, view of how the PE was cut

Figure 8:Repairing the walls, attaching the PE foil

Figure 9:Repairing the walls, the result

2.3.2 Protect the wiring system

In first glance, when entering the Greenhouse it was noticed by the project group that the wires in the house were well-connected and managed, however no measures were taken for protecting the cables from the weather conditions. Moreover, it was noticeable that the house was not isolated well enough, and the risk of the walls breaking up due to various reasons was foreseeable.

electric cabin with rain protection left by the previous group should be recycled (Figure 10: 3D render of the Switch cabinet used). Another point to take into account is the main power socket, as this is located outside the greenhouse protected by a cabin, but as the electricity supply must be connected at all times, the cabin is left open. This disables any protection provided by the cabin, so a remediation has to be found.

Several solutions were proposed with the help of Hans Lindén but the one that best suits the current needs is the implementation of an external box to protect the first one. This protection will be provided by a plastic box with a hole in the lateral part (Figure 11: Simulation of the main power socket's protection). The installation of the protection was, as well installed by Hans Lindén.

Figure 10: 3D render of the Switch cabinet used

Figure 11: Simulation of the main power socket's protection

2.3.3 Provide heating system to the main tank

As mentioned above, the house is not equipped with isolation against the negative temperature, only against the water and the wind. Considering that both fish and plants need warmer temperatures for their proper development, it has been decided to install a system to heat the water in the main tank.

By using a water heater integrated in the system along with a temperature sensor, as the water circulates throughout the system, a constant warmth in the tank can be achieved at all times. Heated water will run throughout interconnections, which eventually will result in closing the loop and achieving the specified temperature. This point will be developed in forthcoming chapter 2.5 and 2.5.5.

2.3.3.1 Insulation of the main tank

In order to achieve an invariant temperature in the system, the insulation of the main tank has been considered, thus preventing the heat from dispersing so quickly and providing the fish, plants and bacteria with the exact temperature throughout the system.

Countless methods can be used when it comes to insulating, but the most common approaches for outdoors tanks are by adding materials for insulation such as insulation blanket, foam, PIR, polystyrene and rigid insulation on the tank, keeping in mind that leaving a gap between the tank and the actual insulation material used is vital for the process. For a greater protection a second layer can be added.

The Aquaponic team has decide that the use of wood as a structure and expanded polystyrene (EPS) as insulation is the best alternative due to the ease with which both materials can be obtained. All information regarding the insulation of the tank and the process undertaken for its construction can be found in the subsequent section: 2.5.

Figure 12: Expanded Polystyrene, EPS (Connor, 2019)

2.3.4 Connect electricity and Wi-Fi for the house

Electricity is a vital segment for the proper functioning of the Greenhouse, even so at the beginning there was no access to a connection point. This setback has been currently solved thanks to the help of the school, allowing the team to proceed with the plan of running the system. Electricity access point is situated outside the greenhouse, which has been protected from weather impedances (Figure 11: Simulation of the main power socket's protection).

Another issue that has arisen is in relation to the Wi-Fi connection, was that the team would have to get a personal SIM card or get access to a different network instead of using the provided host connection by Novia UAS. The team's final decision is to use a mobile connection and a 4G router.
Once all this has been solved, it will be possible to continue with the installation of all the electronic elements explained in the next section.

2.3.5 Researching for and implementing improvements to the house

Once the house has come to its old conditions, renovations will follow with the purpose of utilizing the usability of the space.
One of the biggest changes will be made to the main tank, as it will be thermally insulated from the outside. Another implementation would be to reorganize the available space and get rid of what is not used. Furthermore, it has been considered to install cameras at different angles, which would help with the tracking of the status of the house and the system in real time.
A further hindering factor in the greenhouse is the high humidity in the environment and the type of wood used for the floor, which absorbs large quantities of water and deteriorates quickly, therefore it is recommended for the next team to change the floor.

2.4 Rebuilding the Aquaponic System

Another very important segment for the project is the Aquaponic System of the Greenhouse. The purpose of this chapter is to evaluate the entire process of rebuilding the Aquaponic System from the beginning till the end of it. When talking about the Aquaponic System it is referred to the system of tanks and tubes in charge of transporting the water throughout the closed circuit.

On the basis of this chapter, the initial state of the system is described accompanied by a brief explanation of the process implemented to repair the system and some problematic scenarios are introduced alongside their possible solutions. Eventually an improvement scenario will be chosen to be carried out.

2.4.1 Initial condition

The current system consists of a set of two distinct aquaponic techniques (DWC and vertical towers) connected simultaneously to the main tank. Water flows from the main fish tank, passes through the radial flow separator, through the bio filter tank and then it is distributed by water pumps to the vertical towers and the DWC racks. The remaining water is afterwards collected in a common tank where it is sent back to the fish tank by means of another water pump.

2.4.1.1 Check what we have and need for a running system

To check the system since it was lastly used, a general restart of the system was needed. The condition of the water pumps was in order; however it must be noted that there were not enough sensors for the water level or other types of sensors that could be useful for the project. The absence of a polyurethane filter foam was also noted. Although there was a lack of specific sensors, the process of checking if the system was damaged was not compromised, however the above-mentioned sensors will be necessary for the automation part.

In this sub-section the materials required, and the plan carried out to set up the system will be analysed, followed by a summary of the conclusions drawn from the tests carried out on the system.

What do we have?

As mentioned above we have:

- all tanks
- small tubes
- large tubes
- water pumps
- trays for the planters
- 12 planters

What do we need?

The things needed are:

- 36 planters
- Water level sensors
- Polyurethane filter foam
- PH detectors
- Other detectors for checking the state of the water
- Air pump

The team has managed to 3D print all the planters and buy an air pump as well as a PH and ammonia test for controlling the current state of the water.

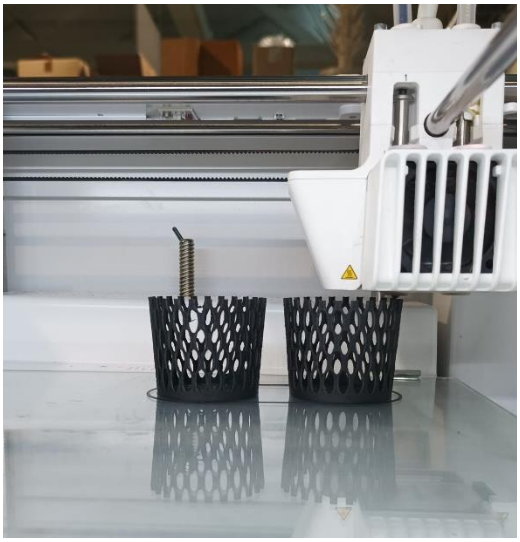

Figure 13: 3D printed planter

2.4.1.2 Create a plan to put the system together

Now that the Greenhouse is in good condition, progress is being made to assemble, test, repair and improve the Aquaponic System of the house. The first thing that was done was to check if tanks were connected, next to if there were any leaks in the system. Afterwards the water pumps were checked and made sure that they are in good working condition, and finally the water was put into the main tank, in order run a test of the whole system and its condition.

The test conducted by the team was a trial-and-error situation. Considering all the external factors, the time, and the current state of the system after a long period of inactivity, it was determined that the fastest and most efficient option was to simply start the whole system and check if it had any defects.

2.4.1.3 Testing of the system

This section will be concerning all the detected problems throughout the performance of the test of the aquaponics system. At the beginning, some leaks were detected in the connection between the main tank and the precipitation tank, and another problem was noted in the water level of the system, as some places are missing a system for preventing an overflow of the water (Figure 14). This resulted in few points of the tanks to have water below the necessary level and other with an excess of it for the correct functioning (Figure 15).

Figure 14: Testing of the system: tank that do not have an overflow system

Figure 15: Testing of the system: bio filter

Figure 16: Testing of the system: DWC Racks

2.4.2 Improve the Aquaponic System

In this section, the different scenarios created to improve the Aquaponic System will be explained. Since the aforementioned problems are mostly related to water control and leakage at the connections, this implies a complete dismantling of the system. Considering the temperature challenge mentioned in previous sections, a radical change of the system is planned. The process starts with creating different problematic scenarios for later solutions and creating a new system proposal. Different improvements will be presented, and the most successful methods will be chosen to achieve the final objective of this project.

2.4.2.1 Creating different problematic and improvements scenarios

To create the different scenarios, the focus will be put into the vertical tower systems and one of DWC racks. Another aspect, which will be considered, is the implementation of a certain type of filter for the water pumps, in relation to multiple sensors, responsible for the automation of the entire process. Finally, an installation of multiple cameras will be completed.

A crucial aspect for the system is the temperature to which plants and fish are exposed. A problematic scenario would, in the worst-case situation, mean that all the water in the system will change into a solid state. This would lead to a fatal end for the living organisms and most probably for the whole tank system, as all connections and tanks will be damaged by the expansion of the frozen water. A potential remedy to this problem would be to insulate the entire system and provide heat to it by means of a water heater. It is a simple, intuitive, and practical solution, allowing the system to become independent from the outside environment and thus, one step closer to the project's mission.

However, this solution has its shortcomings, as insulating the entire system in its current state would require a lot of material, due to the volume of the system, as well as multiple separate structures resulting in a significant number of walls, through which the heat could get lost. Hence, a change of system has been suggested, making it much simpler, next to avoiding complex geometrical shapes.

The complete insulation of the tank would also mean a considerable reduction of sunlight penetrating the tank. One option is to not insulate the tank entirety, nevertheless due to the amount of heat lost this would not be feasible. An alternative would be to replace the sunlight with artificial light. The team has come to the decision that the most reasonable solution is the latest one in view of the limited daylight hours available in Finland during the cold season. Sunlight, even if the plants have access to it, would not be sufficient to provide them with the required sun exposure.

2.4.2.2 Choose the best scenario

Taking into account all the scenarios proposed above, the best-case solution the team has come up with, is a combination of the above-mentioned possibilities. This leads to the creation of a reduced aquaponic system, capable of controlling both the temperature and the light inside the system, thus favouring the correct development of plants and fish.

2.5 New system

As noted above, the current system will be changed to raise its capabilities and achieve a closed circuit independent of the environment in which it is located.
In this section the concept of the new system will be explained, and the different design alternatives will be shown. Afterwards, one of them will be chosen and a preview of the 3D model will be presented. Subsequently, a list of the needed items will be shown and later

the process followed for the construction of the new system will be described along with the incorporation of living organisms into the system.

2.5.1 Concept of the new system

The main concept of the new system is to design a solvent circuit that is simpler than the previous one, with the goal of achieving higher performance in terms of heat loss.

On this basis, the new system will be centered on the main tank, the sedimentation tank and the biofilter tank. This means that all living organisms will be located in the main tank, i.e. plants and fish in the same space. Three designs have been produced for this purpose. The strengths and weaknesses of each are shown and briefly explained.

2.5.1.1 First design

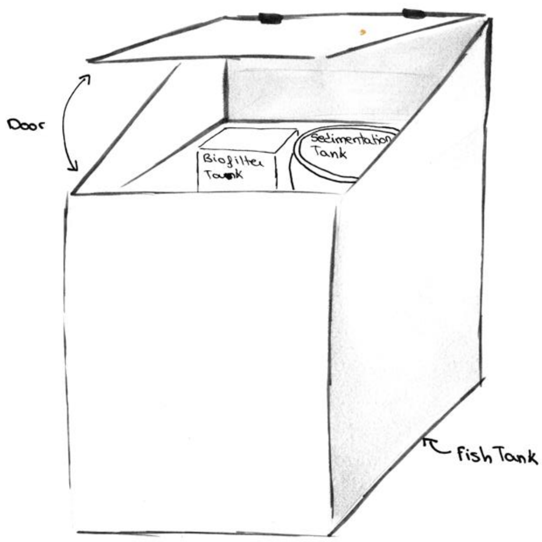

Figure 17: New system: first design

Strengths:

- All the tanks are placed together, so that the insulation volume is reduced.
- Large top door for easy accessibility.
- Sloping top to allow sunlight to enter if necessary.

Weaknesses:

- Reduced remaining space for fish and plants.
- Poor accessibility to the biofilter and sedimentation tank in case of maintenance.
- Struggling for big tank drainage.

2.5.1.2 Second design

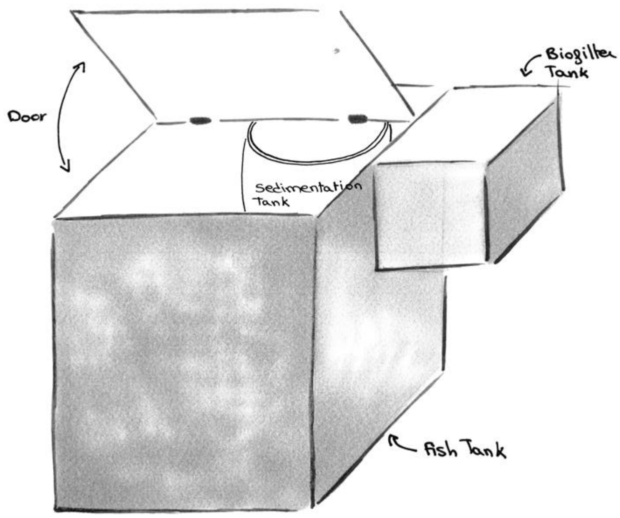

Figure 18: New system: second design

Strengths:

- Main tank and sedimentation tank are placed together, so that the insulation volume is reduced.
- Large top door for easy accessibility.
- Accessibility to the biofilter tank.
- Less water needed, thus less heating required.

Weaknesses:

- Reduced remaining space for fish and plants but not as much as the previous design
- Poor accessibility to the sedimentation tank in case of maintenance.
- Struggling for big tank drainage.

2.5.1.3 Third design

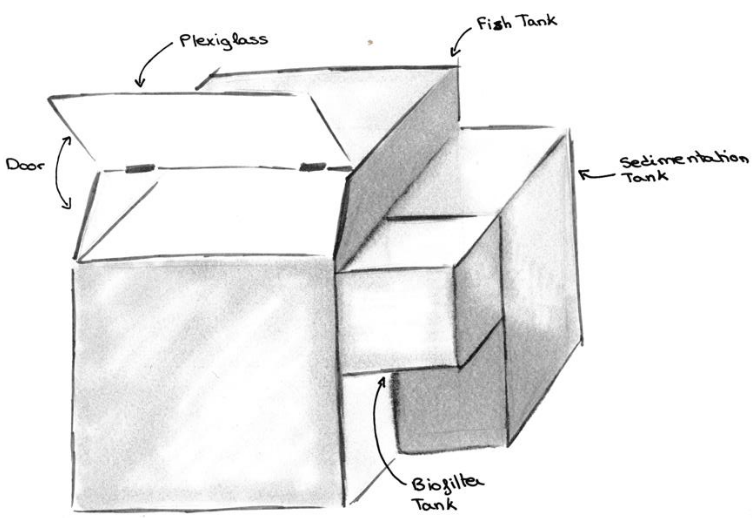

Figure 19: New system: third design

Strengths:
- Small top door for less heat loss.
- Easy access to biofilter and sedimentation tank.
- No space reduced for plants and fish.

Weaknesses:
- More material needed.
- Further space required.
- Struggling for big tank drainage.

2.5.1.4 Implemented design

The preferred design by the group is the second one, as it combines the best of the other two explained. It saves space by placing the sedimentation tank inside the main tank, and still has enough area for the fish and plants, due to the other tank being placed outside. At the same time, it saves material as one tank does not need to be insulated and it saves water by reducing the volume of the big tank.
An extra system will be added to improve water drainage in the main tank as it was a disadvantage in the three proposed designs.

In this design, the water flows from the sedimentation tank to the water heating system by means of a water pump. From this location the water circulates to the biofilter tank, ensuring a high temperature for the bacteria. Following, the water drains by gravity to the main tank and returns to the sedimentation tank.

2.5.2 3D view

This section contains a 3D view of the complete design and each of the small add-ons that complete it, thus providing a clear overview of what the final goal is. All the renderings presented in this section have been made with the Solid Works program.

2.5.2.1 Add-ons for the system

Shown in this section is a 3D version of the add-ons that collectively constitute the complete system, along with a brief description of how they function.

Insulating structure of the main tank

Figure 20: Insulating estructure of the main tank

Utility: External structure which is responsible for the insulation of the main tank. Composed with wood and expanded polystyrene.

Insulating structure of the biofilter tank

Figure 21: Insulating structure of the biofilter tank

Utility: Structure responsible for the insulation of the biofilter tank, it is shown that in the upper part the biofilter tank is located and in the lower space is meant to be for the heating system.

Hanger for cables

Figure 22: Hanger for cables

Utility: Organizing cables from the automation.

Hanger

Figure 23: Hanger

Utility: Provide additional saving space for hanging items.

Hanger for lights

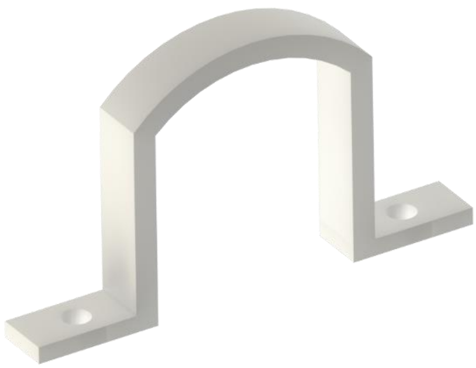

Figure 24: hanger for lights

Utility: Hanging ceiling lights.

Water drainage system

Figure 25: Water drainage system

Utility: Provides an effortless method of draining water from the tank.

Final rendering

In this section different perspectives of the final rendering of the new system will be shown:

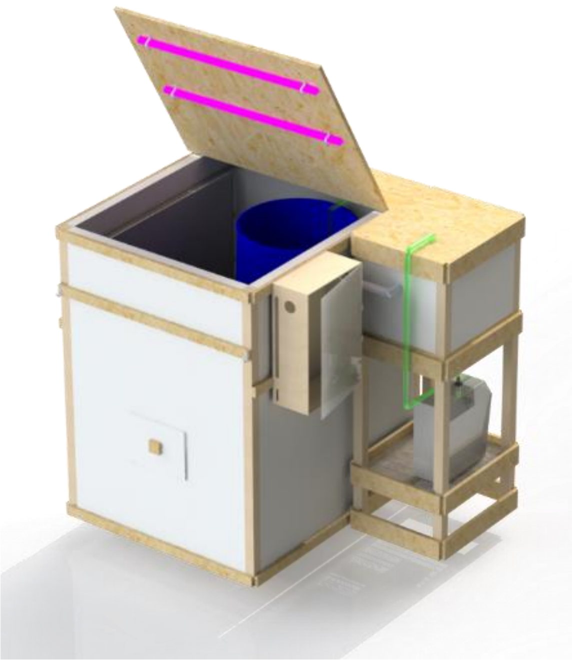

Figure 26: Final render, first view

Figure 27: Final render, second view

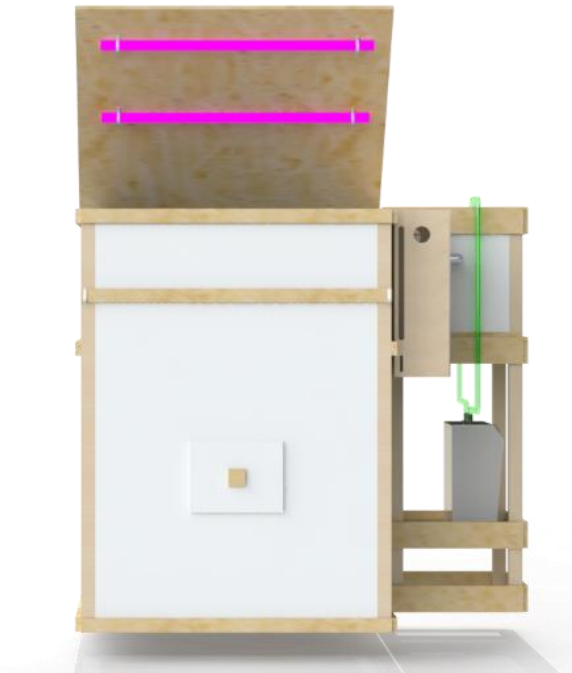

Figure 28: Final render: third view

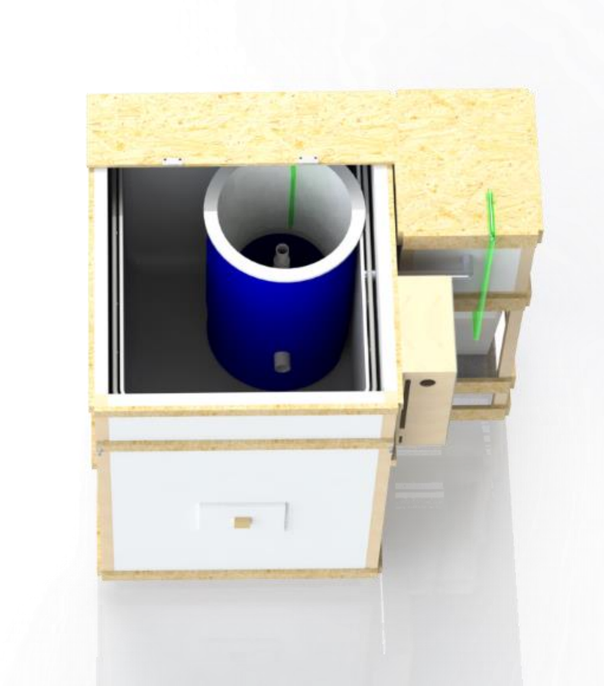

Figure 29:Final render, fourth view

Figure 30: Final render, water drainage system

2.5.3 What is needed

Following a list of all needs to build the new system is shown.

- Wood
- Silicone
- Insulating foam
- Expanded polystyrene (EPS)
- Screws
- Hinge
- Electric saw
- Electric screwdriver
- 3D printer

The team procured all the required materials, with the help of the school along with some purchases and leftovers from team members or previous groups.

2.5.4 Building the new system

The procedure of the construction of the new system is described and shown in this chapter - from planning, through inventory, to the final result. Firstly a full description is written and afterwards some images illustrating the procedures can be found.

First the design was made and following the materials to be used were determined. This decision was based on the resources available to the team and those that one could rapidly and efficiently obtain. Once the materials had been chosen, the procedure to make the corresponding measurements started, thereupon cut both the wood and the expanded polystyrene in the right proportions (Figure 31). With all the materials being cut, the following step was to insulate the main tank, including bottom, sides, and the upper part (Figure 32). Same procedure was carried out for the biofilter tank (Figure 33).

Some alterations and repairs were made to the tanks as they had some pipes that were no longer needed. These boreholes were sealed with the application of silicone (Figure 34). Everything was then put in place and water was added to the system. Finally, the lights, water pump and air pump were incorporated together before the fish were introduced to the system (Figure 35). Meanwhile all the steps described above were taking place, the parts which needed to be 3D printed were being created and ready to be placed into the system (Figure 36).

Figure 31: Team member taking measurements and cutting wood

Figure 32: Insulation of the bottom of the main tank

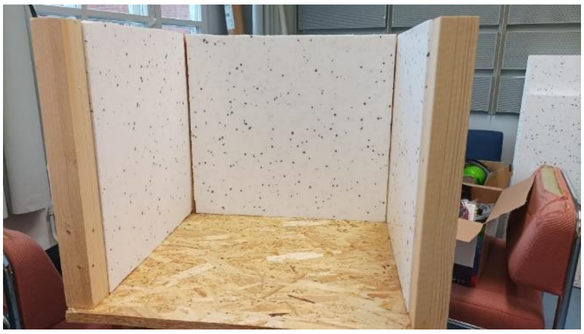

Figure 33: Insulating of the biofilter tank

Figure 34: Team member applying silicone to the sedimentation tank


Figure 35: Installation of lights

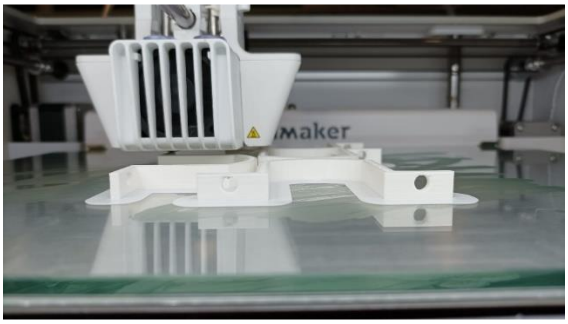
Figure 36: Printing hanger for lights

2.5.5 Living environment and its needs

To create the desired ecosystem, it is required to introduce fish and plants into the Greenhouse. The focus was on getting acquainted with the correct processes of incorporation of the fishes in the tank and the procedure followed for the germination of the plants. Information on how the plants and fish have been chosen and what has been done for this can be found in sections 2.1 and 2.2 of this document.

2.5.5.1 Fishing

Final research has been conducted and a decision, regarding the specific fish first suggested, has been considered for this project. The fish that will be predominantly incorporated into the Aquaponic System is the European perch, due to their great adaptability to temperature changes, in addition to their availability in the Baltic Sea.
To obtain them, a fishing trip was organised with the whole group together with the project tutor. Unfortunately, the organized trip resulted in the catching only one fish, that had to be introduced to the system.


Figure 37: Team members fishing

2.5.5.2 Plants

Another point in focus, related to the Greenhouse, are the plants.

According to the research made by the previous group (Verburgh, et al., 2020) and the own resources the plants that will be used are:

- Parsley
- Romaine lettuce
- Lettuce /Salad bowl
- Winter brunette
- Red Chard
- Spinach
- Mint

The seedlings were developed in a closed place, inside special germinating homes to maintain humidity. Different types of media were tested, with the purpose of germinating the seeds, in jiffy pellet, in coconut skin and in polyurethane filter foam (Figure 38).

Figure 38: Planted seeds with different medias

Figure 39: Seeds after a week of being planted

The results showed that after a week of having planted the seeds (Figure 39), the method that has worked best is the one with pellets. Once this method was confirmed to be the most successful one, more seeds were planted through the pellet system, but not before putting a base of coconut skin in the pots, in order to avoid the maximum number of residues left by the pellets, thus preventing the water pumps from clogging (Figure 40, Figure 40).

Figure 40:Planters with the coconut skin

Figure 41: Planters with the coconut skin and the pellets

2.6 Conclusions and recommendations

In this section the conclusions of the whole point "The aquaponic system" are shown together with some relevant recommendations and suggestions for the subsequent groups. The conclusions highlight the crucial points covered in the section whilst the recommendations include all interventions that our team has not been able to carry out or achieve.

2.6.1 Conclusion

The definition of an aquaponic system has been described here along with the different techniques that can be used. Subsequently, the different fish and plants that can be used have been introduced. Additionally, an extensive explanation on the exact species used - both fish and plants, has been provided. The aforementioned species are the following: European Perch, for the fish, and spinach, lettuce, parsley, and mint - for the plants.

The process of rebuilding the walls of the greenhouse, the old aquaponic system and the implementation of a new system has also been comprehensively described. The choice of the new system has meant the installation of insulation around the entire circuit and a crucial reduction in the space available in the main tank. The construction process was then detailed with the use of wood and expanded polystyrene as the main insulation materials along with various 3D printed designs.

Finally, the attainment of fish and plants is discussed, regrettably only 1 fish has been incorporated into the system. Moreover, due to the late planting process, not all the plants have been able to fully grown.

2.6.2 Recommendations

To summarise this section, recommendations will be provided for the next group.

As mentioned before, it is advisable to change the floor of the greenhouse, due to the current wood being prone to moisture absorption, having damaging effect on it. Unluckily, when changing the PE foil on the walls of the house, the roof part was not fixed because of time- and budget-related, therefore it is suggested to improve the upper part as it has multiple holes through which water can leak in.

In the new Aquaponic system, the sedimentation tank is placed inside the main tank to save energy, in addition to reducing the volume of the needed water, however, an upper drainage system needs to be implemented in the tank for its correct functioning and for the correct maintenance of the system.

The ammonia in the water must be inspected regularly for the well-being of the fish and acted upon, as unstable levels can be caused by different factors.

Finally, it is urgent to start planting the plants and obtaining the fish as soon as possible, in order to have time to manoeuvre in case neither can be achieved.

3 Automation of the Aquaponic System

Automation has become essential in today's world and therefore the Aquaponic System should also be automated as far as possible. This makes it feasible that only a few human interventions need to take place and that the system can be monitored.

This chapter consists of four subchapters. First, the basic components of the automation system are explained, this includes both, the hardware and the software. Then the problematic scenarios of the aquaponic system are listed and explained how to react to them. Third, the physical structure of the automation system is explained. This consists of which sensors are present and how they are connected, as well as the power supply for the automation. Finally, the functions of the Home Assistant are explained, which includes the programming in Node-Red, the remote control of the system, as well as the structure and function of the two dashboards.

3.1 Hardware and Software

Automation requires various devices that communicate with each other. Hence, one need sensors that record parameters, microcontrollers and a computer that process the signals and compare them with each other. In addition, actuators are required that can intervene in the process and thus change the parameters.

3.1.1 Sensors

For the automation of the Aquaponic system, the use of sensors is essential. These are permanently installed in the system and continuously measuring the actual state of various parameters. One can differentiate sensors in two big groups, the first sensors are binary sensors, they can only transmit an on or off state. The bigger second group are analog sensors, the output is usually between different voltages or currents. Therefore, the sensors needs to be connected to a microcontroller to transform the analog output to a tangible value.

3.1.2 Actuators

The actors have a direct influence on process variables in a system. For example, a heater can increase the temperature, or a valve can regulate the flow. Thus, they are indispensable for the smooth running of the process. To control these actors, a microcontroller is needed. However, the microcontroller can only supply actuators with a voltage of 5 volts. If devices with a higher voltage must be supplied, relays must be installed which interrupt or close the circuit of a higher voltage. These relays can be controlled by a microcontroller.

3.1.3 Raspberry Pi

A Raspberry Pi is a single-board computer that runs with Linux as its operating system. The advantages of the computer are its small size, low energy consumption and it is inexpensive. For this project, a raspberry pi 4B is used, as shown in Figure 42. (Gordon, 2019)

Figure 42: Raspberry Pi 4B (Multitronic, 2021)

The Raspberry 4 is the central unit of the Automation system. it has the task of communicating with the ESP 32 board, and it is also used to run the Home Assistant software.

3.1.4 ESP 32 Board

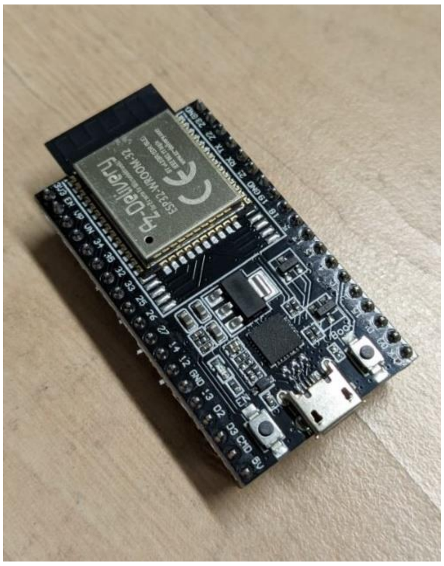

Figure 43: ESP 32

An ESP 32 is a microcontroller which provides wi-fi connection and Bluetooth. Due to the connectivity and low power consumption, it is a perfect choice for IoT applications. Moreover, the Board has several pins which can be connected to a huge amount of several Sensors. Another advantage is that it can be easily programmed through the ESPHome integration. On the Internet, many projects deal with the programming of sensors with ESPHome. This is very useful for the team because none of the members has any previous knowledge in the programming of microcontrollers.

The board has two tasks in the system. The selected sensors do not output a direct value, instead it will supply an electrical signal. No relevant information can be taken from this signal without further processing. Therefore, the sensors are connected to the ESP 32 board, which processes the signals and converts them into useful values. However, the board cannot display the values clearly, so the values are sent via Wi-Fi to the central unit, where they are processed and further analysed. The used ESP 32 Board is located in the switch cabinet next to the fish tank.

3.1.5 Home Assistant

Home Assistant is a free and open-source home automation software. It can work on different devices, in this case, Windows and Raspberry Pi. The main components of Home Assistant are various integrations that allow you to add different devices from different manufacturers. It supports Wi-Fi, Zigbee and MQTT. With these integrations, you can automate a process.

Figure 44: Home Assistant (Home Assistant, 2021)

Home Assistant has a complete user interface, which makes it easy to use and requires little programming knowledge. There is also a large community on the internet where sample codes are available. The dashboard of Home Assistant is called Lovelace and is very structured and easy to change.

The software for Home Assistant can be downloaded from the website. To install it on the Raspberry Pi, this software must be loaded to a SD card, which is then inserted into the Raspberry Pi. Once the Raspberry Pi has been started, it should be found on the network. Next, you need another computer that is also connected to the same network. The Home Assistant start interface can then be opened in the browser. Further add-ons can then be added via the user interface. The currently installed add-ons are explained below.

ESPHome

ESPHome is an add-on that allows to program and manage ESP32 based microcontrollers as easily as possible. The ESPHome supports a lot of different integrations for sensors, switches and other actuators. Connected devices are added directly to the Home Assistant user interface. (ESPHome, 2021)

TP-Link Kasa Smart

With the TP-Link integration, various devices of the brand can be implemented in the Home Assistant. The TP-Link devices need to be connected to the local Wi-Fi and then they can be integrated to the Home Assistant via this add-on. (Home Assistant, 2021)

Node-Red

Node-Red is a programming tool that allows to wire hardware devices together. It is flow-based and allows connecting a wide spectrum of nodes. A built-in library provides useful functions and allows to save templates. For this project the Node-Red program is used for the automation and for the remote control of our system. (Node Red, 2021)

Influx DB

The Influx database is an add-on which can store the data received from the sensors. This add-on also includes nodes for the Node-Red integration, which allows to import and process data from the database in Node-Red. (Home Assistant, 2021)

Motion Eye

Cameras which are connected to the running device of the Home Assistant can be integrated via the Motion Eye Add-on. It is also possible to add a card to the Home Assistant Dashboard. There is a bunch of settings, which allows to configurate the camera to your needs.

3.2 Problematic Scenarios

The aim of the automation is that the Aquaponic System requires as little human intervention as possible. To ensure this, an analysis must be made of which scenarios can occur that have a major impact on the system. In this sequence the problematic scenarios are listed and discussed.

A major risk is the leakage of water in the system. Overflowing tanks or leakages from hoses and tanks can cause considerable damage to the building. Therefore, sensors must be installed to detect overflowing tanks so that pumps can be switched off. Leakages in containers are more difficult to register, but they can be detected by an untypical change in the filling level or with a leakage sensor.

Too low levels in containers can also cause problems. If the level in containers with pumps drops, the pumps can run dry and thus damage or even destroy them. To prevent this the pump must be turned off. Also, the biofilter must always have a minimum of water so that the bacteria can work properly.

The Aquaponic system requires a temperature from about 15°C to work accurately. Therefore, a heating system is installed. If the heating system fails and the temperature drops, the bacteria conversion rate will decrease significantly. Thus, the temperature needs to be observed.

The pump must run continuously for two reasons. On the one hand, a failure of the pump would stop the supply to the biofilter and the ammonia concentration in the fish tank would increase. On the other hand, water would no longer flow through the hoses, and since temperatures are very low in winter, there is a risk that the hoses will freeze. For this purpose, flow sensors are used that measure the volume of liquid that flows through the pump per unit of time. This makes it possible to detect when a pump is not working properly.

Different sensors are also installed for the various parameters of the water to detect changes and ensure an optimal environment for the Plants and fish. Other risks are the sensors and the microcontrollers themselves, as these can also fail. In addition, there can also be a power failure, which can be caused by a general power failure or by an overload. All problematic scenarios are shown in the Table 2.

Table 2: Problematic Scenarios

Problematic scenarios	Reasons	Detection	Reaction
Pump is not working	Pump broken, Plugging, no electricity	Water flow Sensor	notification, check for plugging and pump
Overflow of Biofilter	too much Water in the System,	Binary water level sensor	Notification, check the outlet for plugging
Low level in the fish tank	Evaporation; break of the tank	Water Level Sensor (Binary, ultrasonic)	Notification, check the tank and refill water
Leakage in the system	Break of the tank, hoses defect, roof defect	Leakage sensor	Notification, check the whole system
Ammonia, nitrite value out of range	Bacteria dead; too many fish	Ammonia and nitrite sensor; Water test kit	add bacteria to the system
nitrate value out of range	too many Fish, not enough plants	nitrate Sensor; Water test kit	Notification, check the plants fish ratio
Dissolved Oxygen value out of range	High Temperature of Water, Air pumps not working	DO-Sensor	Notification
Temperature out of range	Heating defect, Too cold/warm outside	Temperature Sensor	Notification, check the heating system
PH-Value out of range	too much Ammonia; other inorganic substances	PH-Sensor	Notification, adjust the ph value with chemicals
Turbidity out of range	Too much fish food or fish wate in the System	Turbidity Sensor	Add an additional filter, change the water
Sensors broken	Various Reasons	No values of the Sensors	Notification
No Wifi connection	various reasons	No communiation with the Raspberry	Renew the internet access
No electricity	Shortage, overload, triggered RCD	No connection to sensors from the Raspberry (battery)	check the fuse

Due to our budget, it is not possible to buy a nitrate-, nitrite-, or ammonia-sensor. These sensors are using an ion-selective membrane, and these are quite expensive (Citizen sensor, 2021). Furthermore, the dissolved oxygen sensor and the oxidation – reduction potential sensor are also quite expensive. To observe the ammonia, nitrate, and nitrite concentration a water test kit is used.

3.3 Applying the Automation to the Greenhouse

This subchapter deals with the implementation of the hardware and software. It discusses how the individual sensors and microcontrollers were wired and how they were added to the Home Assistant software. Moreover, a piping and instrumentation diagram is drawn and explained. The layout of the electric and of the Aquaponic System with the sensors are shown in this subchapter.

3.3.1 Electrical Layout

This sub-chapter deals with the electrical system of the aquaponic system. At the beginning of the project, it was considered to use the existing switch cabinets and to expand them with relays and several connections. However, after long deliberations and discussions, the decision was made to not use these switch cabinets. Since none of our team members is an electrician, we are not allowed to carry out any electrical installations. Furthermore, due to the energetic optimisation of the system, new circumstances prevail.
In order to ensure the safest and most reliable operation possible, smart sockets are used instead of switch cabinets, which make it possible to control individual pumps or lights. Furthermore, they also offer USB ports that provide the power supply for the Raspberry Pi and ESP 32 board. All the electronic parts are placed in a cabinet to protect them against water and high humidity.

3.3.2 Piping and Instrumentation Diagram

This section explains the piping and instrumentation diagram (P&ID`s) of the Aquaponic System. A P&ID is a method of representing a complex system in a simplified way. Symbols are standardised and used for different parts of the system. A big advantage is that you get a very good overview of the system. Every single installed part is drawn in a P&ID. Not only the components, but also the instruments and sensors are marked there. In addition, the various product flows can be traced very well.

The P&ID in Figure 45: P&ID shows the aquaponic system with all its components. The structure of the system is shown here in a simplified way. In addition, one can see the changes to the previous succession, which can be found in the Appendix 1: Previous Piping and Instrumentation Diagram. In the new system, the sedimentation tank is now located in the fish tank. The towers and DWC have been removed from the system for energy reasons. Moreover, the water is now transported by the pump through the heater into the biofilter. From the biofilter, the water flows through the overflow pipe back into the fish tank. To ensure a sufficient oxygen supply for the fish and the bacteria a compressor is installed which pumps air directly in the water.

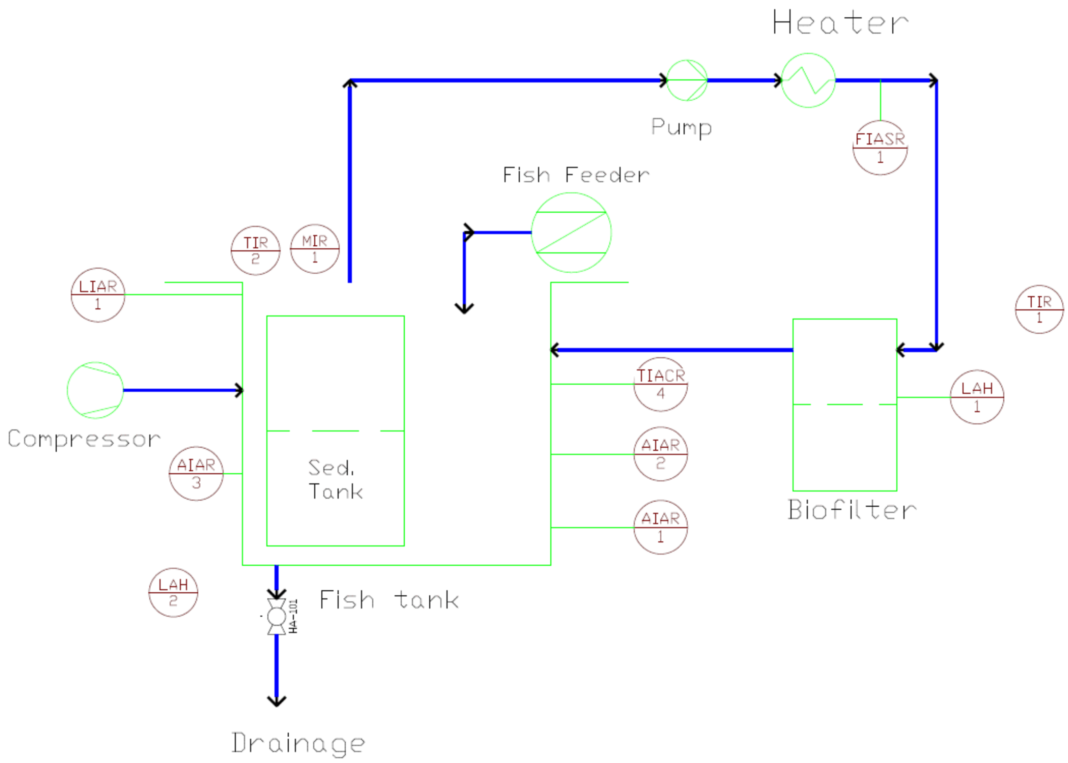

Figure 45: P&ID

In the P&ID, all the instruments are sketched in, to give an overview of which sensors are installed where and how they are linked to each other. The sensors are represented by a circle divided into 2 halves by a line. In the upper half, letters are shown that indicate the measured variable and the function of the measuring point. The first letter is the measurand and the second letter represents the function of the measuring point.
In the lower half there are numbers, so that each individual measuring point appears only once in the flow chart and thus no confusion can occur. The meanings of the letters used are explained below. (Bindel & Hofmann, 2021)

First Letters:
A - Analysis (Concentration of ammonia, nitrite and nitrate, PH-value, DO)
F – Flow
L – Level
M – Moisture
T – Temperature

Second Letters:
A – Alarming
C – Controlling
H – Upper limit
I – Indicating
L – Lower Limit
R – Recording

In the following, the individual measuring points are listed, and a description is given of the function they have.

LAH 1-2:
These sensors are binary level sensors. When a certain maximum level is reached, these sensors transmit a signal that triggers an alarm. These sensors are installed to prevent containers from overflowing. These Sensors can be used as a water leak sensor to detect a leakage from a hose or a tank. In addition, an alarm is triggered.

FIASR 1:
These flow sensors give an exact value of how much the respective pump is currently pumping. In addition, the pump is switched off if the flow is too low. This can have various causes. On the one hand, a blockage can lead to this, but it is also possible that there is no medium to be pumped or that the pump is damaged in some other way. This is to prevent further damage to the pump. At the same time, an alarm is triggered.

TIR 1 and MIR 1:
Temperature and humidity over the water surface in the fish tank are measured, indicated and recorded by these two sensors. These parameters are important for the growth of the plants.

LIAR 1:
The level of the fish tank is continuously measured, indicated and recorded by this ultrasonic sensor. A leakage of this tank represents a high risk. A drop in the filling level is to be detected and thus an alarm is triggered. The water level can change also from water evaporation.

TICAR 1:
The fish and bacteria need a certain water temperature for growing. For this purpose, a sensor is installed that measures, indicates and records the temperature. It is also used to control the heating so that there is always a constant water temperature. If the water temperature is too high or too low an alarm will be triggered.

AIAR 1-3:
These sensors are used to record various measured variables. These includes PH-value, electric conductivity, and the amount of light. They are also indicated and recorded. If a limit value is exceeded or not reached, an alarm is triggered.

3.3.3 Implementing of the Sensors and Actuators

All built-in sensors and actuators are listed below. The wiring and connecting to Home Assistant will be explained. Furthermore, the wiring to the ESP 32 board is described.

PH – Meter

For Observing of the PH- Value, a probe from gravity is used (Figure 46). These probes input voltage is 5 volts and the output is between 0 and 5 Volts. But the ESP 32 board can handle only 3.3 Volts. However, the Voltage of the output needs to be reduced. One can do this with a so-called voltage divider. The voltage divider exists of two different resistors, so the maximal voltage is reduced to 3.3 Volts.

Figure 46: PH-probe

Specifications:

Supply voltage:	5 V
Measuring Range:	PH 0-14
Temperature:	0-60°C
Accuracy:	± 0.1
Response Time:	≥ 1min

(Dfrobot, 2021)

The accuracy of the PH-meter is ± 0.1. To ensure this accuracy a calibration must be done, for these 2 buffer solutions with a known PH-Value are needed. After cleaning, the probe is dived in the first buffer solution with a PH-Value of 4, when the Voltage is stable, the corresponding voltage is noted. The same is done with the second buffer solution with a PH-Value of 7.

There is a linear dependence between the PH value and the voltage. These two points are drawn into a graph and a formula for the dependencies between the PH-value and the voltage is calculated as shown in Figure 47.
For a more accurate calibration a third buffer solution is needed. However, it was not available at the Moment. The Formula for calculating the PH value is 5.1724* voltage + 0.5345. The implementation to Home Assistant is done with the ESPHome integration.

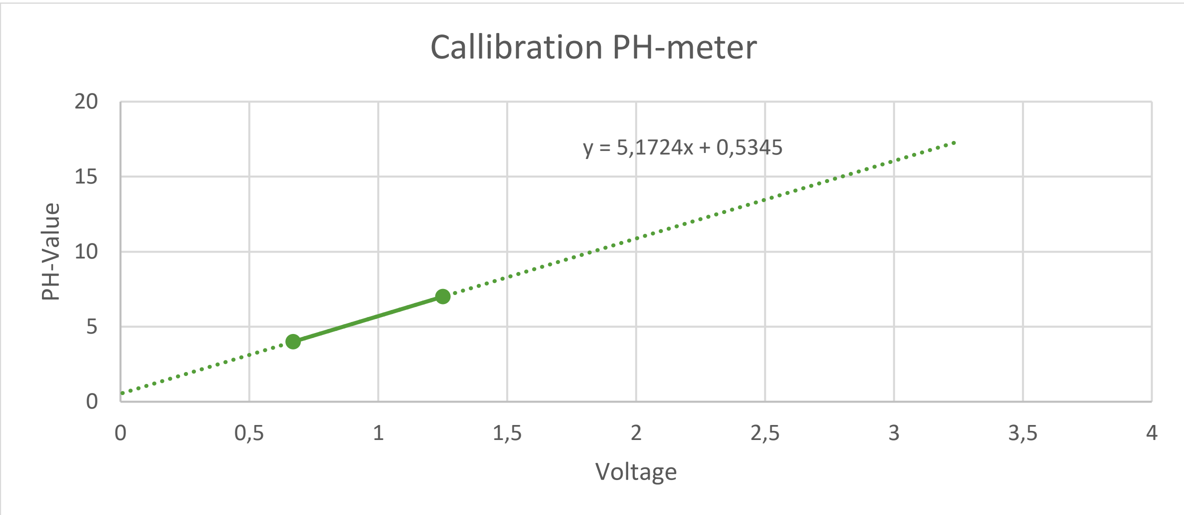

Figure 47: Calibration graph

Electric conductivity sensor

The DFR 0300 sensor from Gravity (Figure 48) measures the conductivity of the water. The sensor consists of two metallic plates with the measuring liquid between them. The conductivity of the water provides information about how many inorganic ions, i.e., salts, are in the water. These salts are mainly carbonates, nitrates, nitrites, and dissolved ammonia. A too high salt content has a negative effect on plant growth and the well-being of the fish.

Figure 48: EC sensor

Specifications:

Supply voltage:	3-5 V
Output voltage:	0-3.4 V
Measuring Range:	0-15 ms/cm
Temperature:	0-40°C
Accuracy:	± 5%
Probe lifetime:	> 0.5 year

(Dfrobot, 2021)

This sensor must also be calibrated before use in order to obtain an accurate result. The tolerance of this sensor is ± 5% of the measured value. A two-point calibration is also carried out. First, the sensor is immersed in a buffer solution that has a conductivity of 1.413 ms/cm. The outgoing voltage is measured and noted. Then the probe is immersed in a solution with a conductivity of 12.88 ms/cm and the voltage is noted again. Since the voltage is also linearly dependent on the conductivity, a linear correlation is carried out and this results in the following formula for calculating the electrical conductivity:
7.2576 * voltage + 0.0341.

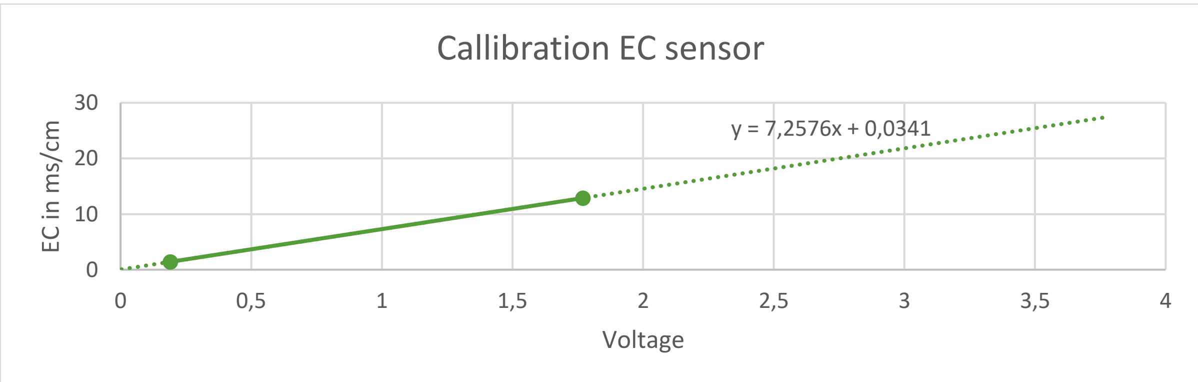

Figure 49: Calibration EC sensor

A major disadvantage of this sensor is that it should not be continuously in the water, as this shortens the life of the probe. Therefore, it is advised to use the sensor only for a short time to measure the electrical conductivity. (Dfrobot, 2021)

Ultrasonic sensor

The HC-SR04 Sensor (Figure 50) is ultrasonic sensor, which can measure the distance between the sensor and an object or in this case the Water surface. There are two pins for the measuring on the sensor, one pin triggers the transmitter for the ultrasonic sound. The second pin is the receiver pin, which detects when the echo of the sound is received. These pins are connected to the ESP board and there the time between the sending and receiving of the signal is determined. With the speed of sound and the travel time the distance between the sensor and water surface is calculated. (Sparkfun, 2021)

Specifications:	
Supply voltage:	5V
Measuring Range:	0.02m – 4m
Measuring Angle:	15°
Accuracy:	3mm

Figure 50: Ultrasonic Sensor

3.3.3.1 Aqara Temperature and Humidity Sensor

To measure the temperature and the humidity in the fish tank an Aqara sensor (Figure 51) is used. These values are important for the growth of the plants. The communication protocol of the Sensor is Zigbee. Thus, we are using a USB stick which is plugged into the Raspberry PI which allows us to connect Zigbee devices.

Specifications:	
Temperature range:	-20°C – 50°C
Humidity range:	0-100%
Accuracy:	3%
Communication Protocol:	Zigbee
Battery lifetime:	2 years

Figure 51: Aqara Temperature and Humidity (Aqara, 2021)

3.3.3.2 Aqara Water Leak Detector

In order to detect leakages in the system a water leak sensor from Aqara (Figure 52) is installed. On the backside of the sensor are two electrodes which are measuring the conductivity between each other. Due to the fact that water conduct electricity, it gives an alarm when there is a current between these two electrodes. The Communication Protocol is Zigbee and is connected as the other Aqara sensor.

Specifications:

Temperature range:	-10°C – 55°C
Communication Protocol:	Zigbee
Battery lifetime:	2 years

Figure 52: Aqara Water Leak Detector (Aqara, 2021)

3.3.3.3 Water Flow Sensor

In order to check if the waterflow is high enough, a YF-S201 (Figure 53) sensor from the company gravity is used. These sensors are Digital Sensors, that means the output is either high or low. For calculating the Waterflow the number of changes is counted. 1 liter corresponds to 460 square waves of the Signal. This Sensor is also implemented though the ESPHome integration. (Dfrobot, 2021)

Water flow range:	1-30 l/min
Voltage Range:	3,5 – 12 V
Accuracy:	± 5%
Water flow formula:	1L = 450 waves
Humidity range:	25% - 95%

Figure 53: Water flow sensor

3.3.3.4 Automatic fish feeder

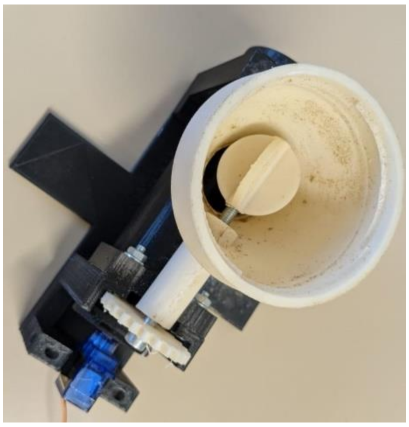

Figure 54: Fish feeder

The purpose of the automation is that the system will need as fewer human interactions as possible. Therefore, an automatic fish feeder (Figure 54) is installed. For fish food sticks are used, but this leads to a big problem because the sticks are getting stuck in the screw conveyor. To solve this, another solution is needed. A program was made which will turn the conveyor screw aback for one second after 3 seconds of the normal direction. In this way the stuck pellets can rearrange themselves and the feeding process can go on. However, in this way it is very difficult to program how much pellets will come out the feeder after a certain time.

3.3.3.5 Temperature Sensor

For obtaining of the water and the outside temperature we are using two ds18b20 Dallas sensors (Figure 55). The sensor is crucial for the regulation of the water temperature. These are the specification of the sensors:


Figure 55: Temperature sensor

Temperature Range:	-55°C to 125°C
Supply Voltage range:	3.0 to 5.5 volt
Accuracy:	± 0.1°C
Query Time:	750 ms

(Adafruit, 2021)

3.3.3.6 Heating System

To grow the plants properly, they need at least a temperature of 15°C. The bacteria starting to convert the ammonia to nitrate at a temperature from about 8°C however, the rate is quite low at this temperature. To convert sufficient ammonia a higher temperature is needed, so it is considered to heat the water up to 15 °C. A water heating from Bosch (Figure 56)with a power of 1800 watts is installed to the System. The Heating will be controlled via the AOFO Power strip.

Voltage:	220-240 volt
Power:	1800 watt

Figure 56: Heating

3.3.3.7 AOFO Power Strip

The AOFO Power Strip (Figure 57) has four sockets which can be turned on and off separately. Moreover, it contains four USB ports, these are used to supply the Raspberry Pi, ESP 32 and the 4G router with power. Over the strip the Heating, pump, and light will be controlled.

Figure 57: Aofo Power Strip

Specifications:

Voltage:	250V
Max current:	16 A
Max current USB:	3 A
Wi-Fi:	2.4 GHz
Max Load:	4000 W

The implementation to home assistant is done with the Tuya integration, which is an external cloud service and the smart life app which is available in the Play Store. Due to this reason, the sockets aren`t turned on and off directly. It takes some time until the Home Assistant registers the state of the Sockets.

3.3.3.8 TP-Link HS 100 WI-FI

The TP-Link HS 100 WI-FI is a smart plug that is used to connect and disconnect a power connection. Furthermore, the current power consumption, voltage and current can be measured.

Figure 58: TP-Link HS 100 WI-FI (TP-Link, 2021)

Specifications:

WI-FI:	2.4 GHz
Operating temperature:	0-40°C
Humidity:	5-95%
Voltage:	100-240V
Max. Load:	3680W

For implementation in the Home Assistant, you also need a smartphone and the Kasa Smart App, which is available in the Play Store. After the smart plug has been plugged in, it can be found in the app and added to the local network. It can then be added to the Home Assistant user interface and included in the Dashboard. The Plug can now be switched on and off from the UI of the HA (TP-Link, 2021)

3.3.4 Wiring of the sensors

This section deals with the wiring of the sensors to the ESP 32 board. The board is plugged on a solderless breadboard. All the sensors can be easily plugged in the breadboard and are so connected to the ESP 32. The sensors are connected by one wire to the power supply, one to the ground and one or two wires to the particular pin on the ESP 32 over the breadboard. The structure can be found in Figure 59.

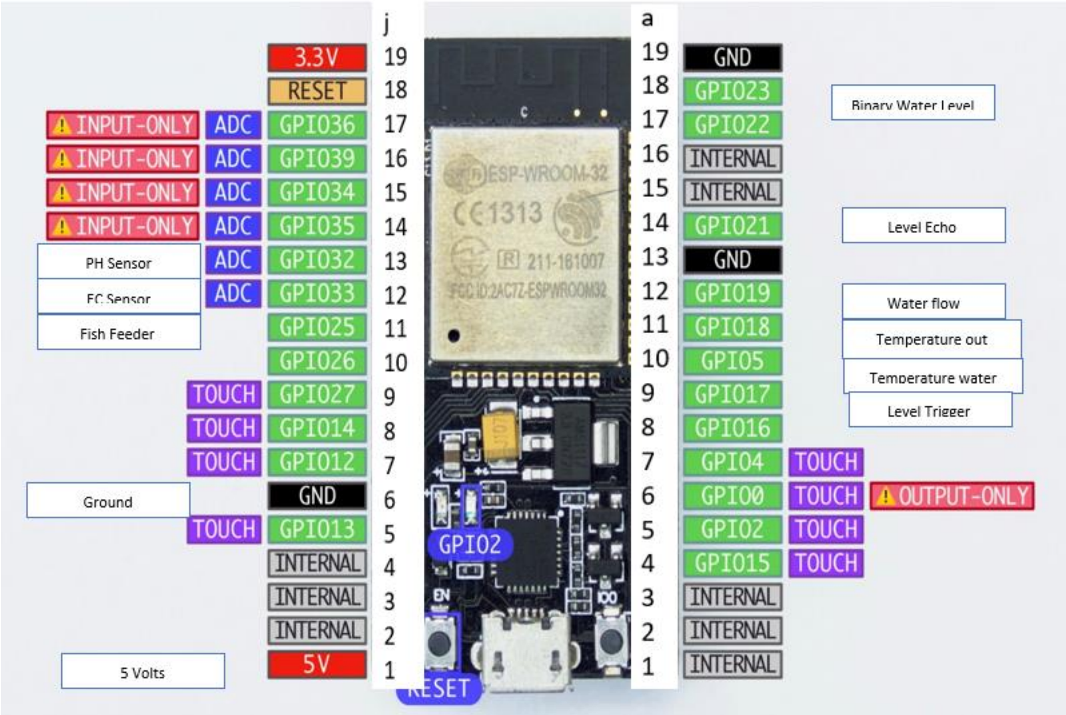

Figure 59: Structure ESP 32 (ESPHome, 2021)

3.4 Functionality of Home Assistant

This chapter explains the functionality of the Home Assistant. At first the concept of our remote control is clarified. In addition, the functions of the automation in node red are described and explained. Finally, the creation of two dashboards for observing the system is described at the end of this section.

3.4.1 Remote Control

This subchapter explains the remote access to the Home Assistant. It has an easy-to-use and clear user interface, but it is only accessible in the local network, therefore a connection to the 4G router is necessary to access the user interface. But especially for our system, it is important to enter to the Home Assistant from outside the network. There are several ways to gain remote access. Two different methods are explained below.

The first option is to use the Home Assistant's cloud service from Nabu Casa. This is a simple method to get remote access to the Home Assistant. One need only to create a user for the Home Assistant and everything else is setup automatically. However, this cloud costs 5$ per month and due to the wishes of our costumer, it was decided to use a different option which is free. (Pyranski, 2021)

The Team decided to realize the remote access with Telegram instead of the Nabu Casa cloud. Node-Red has an integration which allows to receive and send messages from a chat. In this case a group chat with all the Team members is crated. This Group includes a Telegram bot. Via the chat all Team members can ask for a status report of the system and then all relevant information's are sent automatically to the chat. All alarms are also sent in this group. You can also ask for specific parameters by sending a message with "/" followed by the corresponding measured variable, in the chat. Further functions can be found in the chapter 3.4.2.

3.4.2 Programming

When all sensors and actors have been implemented, functions must be added. They will give information on what should happen when the parameters are outside the tolerance range. To make this possible, the software Node-Red is suitable, which enables flow-based programming.

Heating control

The flow for the temperature control is shown in Figure 60 . This flow was created in Node-red. At a temperature of 15.1°C, the heating is switched off. If the water temperature falls below 15°C, the heating is switched on again and the water is heated up. Furthermore, it contains an alert when the temperature is either too high or low which will be explained more in the chapter Error handling.

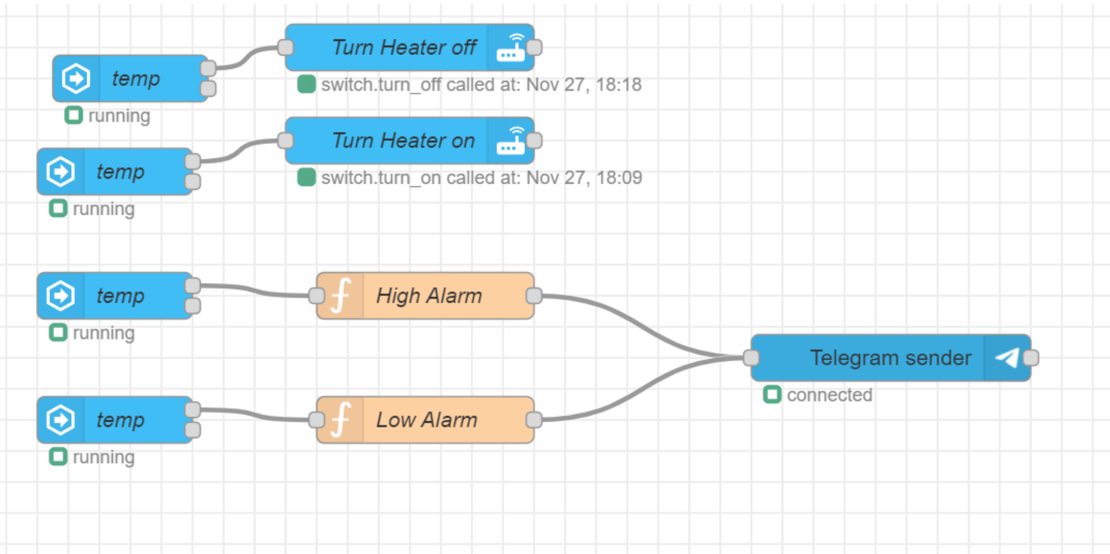

Figure 60: Heating control

Light control

The Plants in the Aquaponic system need lights for 16 hours per day. Due to the insolation of the tank, no sunlight can reach the plants. Thus, lights are installed inside of the tank. These lights are turned on and off automatically. Therefore, a timer in Node-Red is programmed, which turns the lights on at 6:00 in the morning and 18:00 off in the evening, so the plants have 16 hours of light per day.

Error handling

The plants and the fish need certain parameters of the water, to ensure an optimal grow. Therefore, an alarm message is sent to the Telegram chat when the PH-Value drops below 6.3 or rises over 7.3. If this happens additional liquids need to be added to the water. The temperature should be around 15°C. However, faults can also occur in the heating system. If the temperature exceeds a value of 18°C or falls below a temperature of 13°C, an alarm message is sent Telegram. Moreover, if the water leak detector is triggered, an alert is sent to the Chat. There are more alerts integrated in the Home Assistant and are listed in Table 2: Problematic Scenarios. On this way the operator of the system is Immediately informed when something went wrong in the Aquaponic system and can take counter measurements to avoid a bigger failure of the system. An Alarm message can look like the Figure 61: Alarm message.

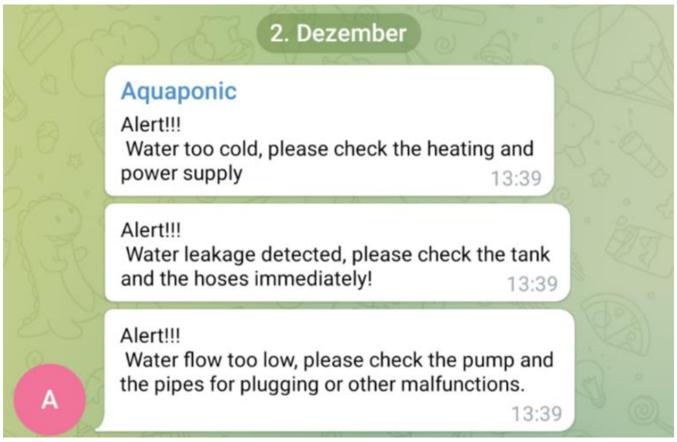

Figure 61: Alarm message

Telegram

As already explained, Telegram is used for the remote control for the Home Assistant. One feature is that all values are sent to the group via the Telegram bot when requested. To do this, the command "/report" must be sent to the group. Then an output is set in Node-Red, which searches out the respective values from the InfluxDB database. The text is generated in a function, supplemented with the values, and sent to the group with the help of the bot. The current, maximum, and minimum values of the last 24 hours are sent. Furthermore, it is shown which devices are currently switched on. In addition, a command is added, which allows to receive only a small report with the most important information. The report looks like the message in Figure 62. Furthermore, the lights, heating and the pump can be turned on via telegram. To do so, a message with a slash "/" the name of the device followed by an underscore and the function on or off is send to the group chat. There is a bunch of different commands which can be send to the group chat which will trigger a reaction. To keep an overview of the possible commands, "/commands" can be send to the chat and the bot will send a list with all of these commands (Figure 63). A single click on the command in the list will send the command. The Node Red programme can be found in the handover package.

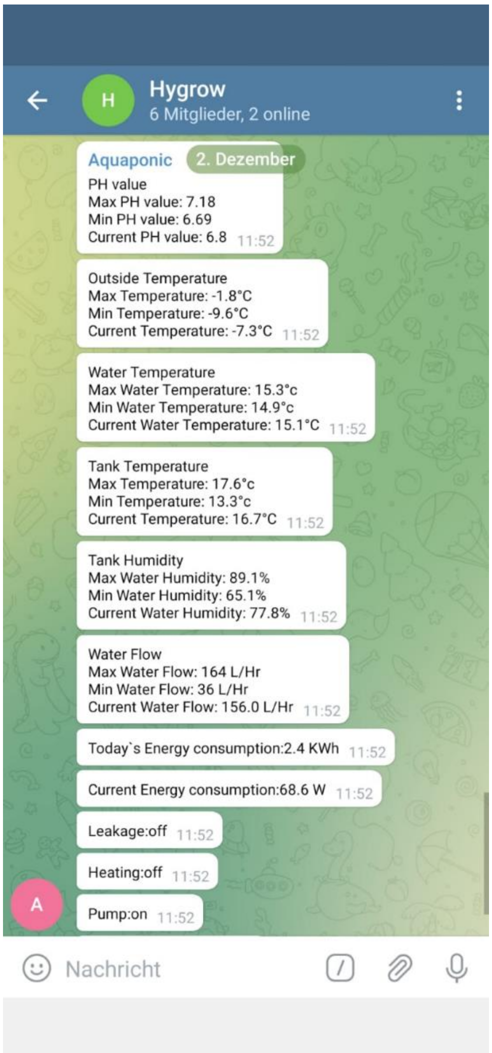

Figure 62: Telegram Report

Figure 63: Telegram commands

3.4.3 Dashboard

In order to show the user all important data at a glance, Home Assistant offers the possibility to create an individual dashboard, which can be changed according to personal preferences. For our system, 2 different dashboards were created.

Dashboard 1

The first version of the dashboard can be seen in Figure 64. Here, all current data from the sensors are displayed. In addition, a graph with the data from the last 24 hours is displayed. If you want more data about the sensor, you can also access the history by clicking on the sensor card. The lights, pump and heating can also be switched on and off via the dashboard. Furthermore, the current power consumption and the consumption on the day are shown. To get a view into the tank, a camera has been installed and card has been added to the dashboard.

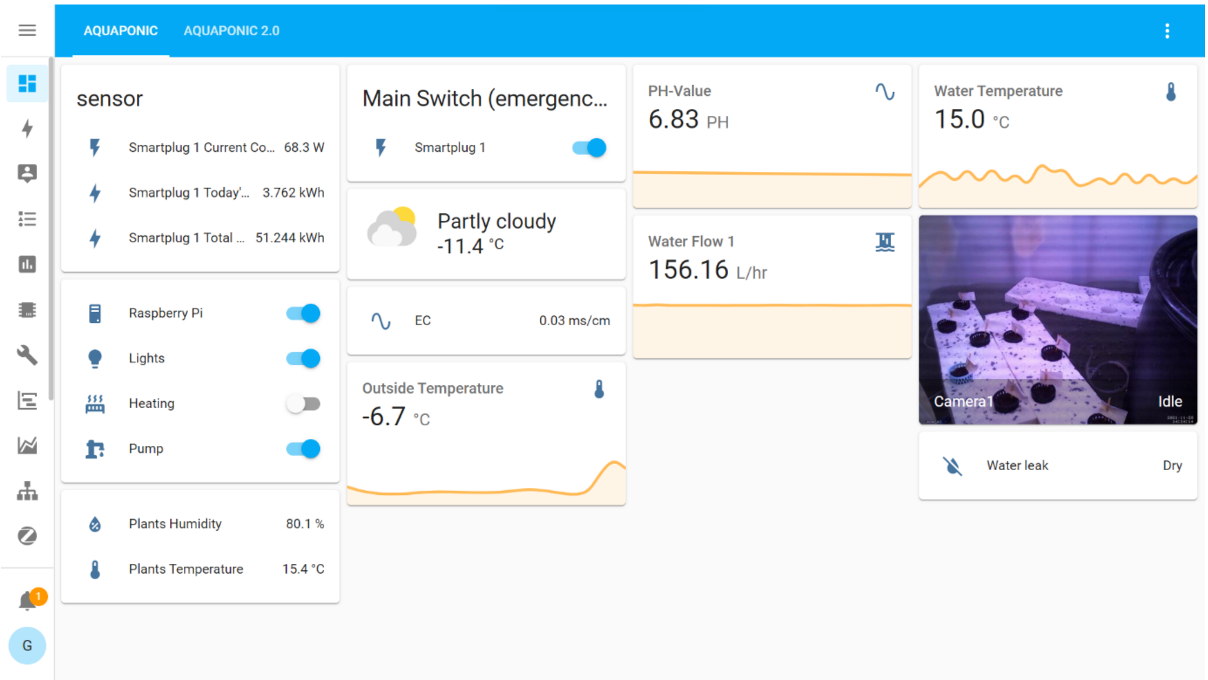

Figure 64: Dashboard 1

Dashboard 2

The base for the second Dashboard is a render of a 3D-model the Aquaponic System. All of the important equipment is included in this image and the icons for the devices are placed directly in the image. With a click on the icons, the devices are turned on or off and the colour changes to yellow for on or blue for off. With a long click on the icon, a tab will be opened with more detail about this entity. The current data from the sensors are also shown in the dashboard. A tab will open with more details about the sensor, which includes a historical graph, when you click on the value of the entity. This dashboard needs to be programmed in a yaml file and it is not possible to implement the camera to the dashboard.

3.5 Energy consumption of the automated heating system

In this subchapter, the theoretical heat losses of the aquaponic system are calculated and discussed. Moreover, the real heat losses are calculated and then compared with the theoretical. In the end a calculation is made with the energy costs for the complete system per month.

3.5.1 Theoretical heat loss

The previous group calculated a heat loss current of 11,861 watts for the complete greenhouse at an outdoor temperature of -29°C. This heat loss is too high and requires a large heater for the greenhouse.

To make the aquaponic system more efficient, some changes have been made. This includes moving the sedimentation tank into the fish tank. Furthermore, the grow towers and the DWC are taken out of service, as they are difficult to insulate and cause a considerable heat loss. The plants are now directly floating on the water surface in the fish tank, which is almost completely closed. However, there are still holes above the water surface to ensure air circulation. Moreover, only the water is heated, so that even less energy is necessary. The fish tank and the biofilter are completely insulated to keep heat loss as low as possible.

Table 3: Theoretical heat loss

Isolated area:	9.92	m^2	Thickness isolation:	0.05	m
Bottom area	1.73	m^2	Lambda isolation:	0.036	W/m*k
Thickness OSB	0.011	m^2	heat transfer coefficient inside	12	W/m^2*k
Lambda OSB	0.13	W/m*k	heat transfer coefficient outside	23	W/m^2*k
Temperature difference (water temperature: 15°C)			Energy loss Bottom	Energy loss isolated walls	complete energy loss
5			4.47	32.72	37.19
10			8.94	65.45	74.38
15			13.40	98.17	111.58
20			17.87	130.90	148.77
25			22.34	163.62	185.96
30			26.81	196.34	223.15
35			31.28	229.07	260.34
40			35.74	261.79	297.54
45			40.21	294.52	334.73

For the new concept of the Aquaponic system, a calculation was made that shows the heat losses of the new arrangement. Therefore, the dimensions of the insulated fish tank (LxWxH: 1.1x1.3x.1.5m) and the insulated biofilter (LxWxH: 0.5x0.6x0.45m) are used to calculate the heat transfer surface, which result in a floor area of 1.73 m2 and a wall and roof area of 9.92 m2. The insulation has a thickness of 5 cm, and the heat transfer coefficient is given by the manufacturer Lackon as 0.036 w/m*K. Together with the heat transfer coefficients from the inside and outside of the insulated wall, the calculated heat loss currents are shown in the Table 3. Reference values from practice were used for the heat transfer coefficients (Schweizer-FN, 2021). A distinction was made between the walls and the roof area and the floor area of the tanks. This is since there is an OSB board on the floor surface, which provides additional insulation. Due to the low heat emission to the outside, the outside temperature is assumed for the temperature in the greenhouse.

This results in a heat loss current of 334.73 watts at an outside temperature of -30°C. This value is quite low compared to the previous amount of the heat loss. However, this value is only based on theoretical calculations. In practice, this value will be higher, because the heat losses for the hose lines were not included. Nevertheless, these should be low, as they are also insulated. In addition, there are holes in the insulation to ensure air circulation, which means that some energy is also lost. Finally, the power loss also depends on the quality of the installation. If there are still cold bridges, the losses will increase.

3.5.2 Real heat loss and comparison with the theoretical

This subchapter deals with the effective heat losses of the system. For this purpose, the power consumption of the heating element for two days is taken into account.

With the help of a function in Node-Red, the average power consumption can be displayed. This amounts to 260 watts. However, this value also includes the power consumption of the pump, the compressor, the lights, sensors and microcontroller. During the day, when the lamps are on, the power consumption without the heating is 67 watts. At night, the power consumption is 29 watts. On a daily average, the power consumption for the previously mentioned devices is 54 watts. This results in an average electricity consumption for the heating of 206 watts. It is assumed that the efficiency of the electric heating is almost 100%, so all the electric energy is converted into heat.

Furthermore, the average outdoor temperature was -9.4°C and the average water temperature 15.1°C. This results in a temperature difference of 24.5°C. Now the theoretical heat loss is calculated with this difference and results in 182 watt. This outcomes in a difference of 23.5 or expressed as a percentage 12.9%. This deviation is due to the reasons already mentioned in the chapter 3.5.1. However, a higher difference was expected, which can be attributed to the good workmanship of the insulation.

3.5.3 Cost calculation

In this chapter the energy costs are calculated for the Aquaponic system. For each month of the year the average temperature (climate-data, 2021) is used for the calculation of the energy consumption of the system. First the theoretical loss is calculated and then 12.9 % of the value are added to get the real energy consumption of the heating. Furthermore, the average energy consumption for the other devices from 54.33 watt is added and the monthly total energy consumption is calculated. The energy price for one kWh is about 0.16€ for normal households (Globalpetrolprices, 2021). It was decided to use the energy price for households because of the vision of the team: “Giving every home the possibility to produce food”. The monthly energy costs are shown in Figure 65. The costs for the system are higher in the cold months due to the heating system. In July and August, no heating is necessary, therefore the energy costs are the lowest in these months. The calculated energy cost for the whole year is about 194.35€.

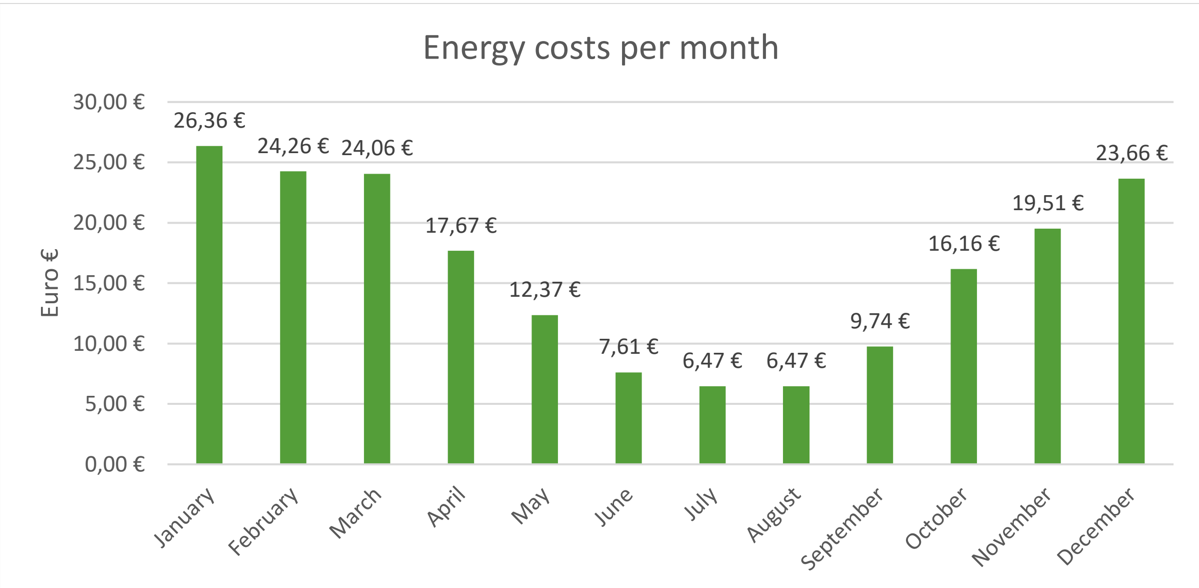

Figure 65: Monthly energy costs

3.6 Conclusions and recommendation

Finally, the conclusions and recommendations are explained in this chapter. In the conclusions are our results from the project explained. The recommendations contain advice which can be very helpful to familiarise with the topic of the automation and can help to improve it.

3.6.1 Conclusions

The tasks for the automation part were to install all the existing sensors and monitor the data from the sensors. Moreover, we should do a failure analysis to prevent catastrophic failures and overflow. In addition, it should be considered what other sensors might be useful for the system and purchased accordingly. All the data needs to be visualized in an appealing and user-friendly UI from off-side the campus. Furthermore, live pictures from the aquaponic system should be available. An additional task was to identify and separate the fish for harvesting.

During the project small but also big changes were made. The entire system had to be insulated as efficiently as possible, which also resulted in a major change in the structure of the automation. In addition, due to the reconstruction of the system, the installation of the sensors was delayed. Due to the limited budget, it was not possible to purchase sensors for monitoring the oxygen content and the ammonium content. In addition, an electrical conductivity sensor, a leak detector and a temperature sensor were purchased to obtain more data from the system.

At the end of the project, the team realized the automation from the Aquaponic system. Important sensors for observing of the water quality were installed and an attractive user interface was created, which makes all important data available at a glance. Thus, the team achieved a large part of our goals. Unfortunately, we did not succeed in making the user interface available remotely, but this problem was solved with Telegram. Due to time and budget limitations, we were not able to realize the identification and separation of the fish.

3.6.2 Recommendations

After our team, another EPS team will continue to work on the project, so we would like to share our recommendations for the next group below. These recommendations are based on our observations, problems, and experiences we had have to face during the project.

Some sensors have already been installed, but some parameters are missing to get better information about the water quality. Therefore, it makes sense to buy a dissolved oxygen sensor and, if the budget allows it, a sensor to monitor the ammonium content. The EC sensor should not be in the water for a long time. Currently it must still be used manually to test the electrical conductivity of the water. A solution here would be to realize an automatic solution as for example with a servo motor. It is also recommended to find a better solution for the fish feeder. Furthermore, the calibration of the PH and EC sensors should be done again, to ensure the accuracy of the sensors.

The user interface in Home Assistant is very user friendly and many functions can be set up without much software knowledge. This makes it also suitable for beginners. Therefore, it is recommended to continue to use and expand the existing Home Assistant. Unfortunately, the team has not managed to make the user interface available remotely, so it would be useful to research and implement further possibilities. The log in credentials for Home Assistant and other services can be found in the handover package. Furthermore, it includes more information about the automation as well as the codes in Node-Red.

4 Public relations and education

It is a well-known fact that investing in the creation of a strong, credible image for any business is a worthwhile endeavour, closely related to a successful public relations management. This is one of the reasons why the Hygrow Team will put their focus on the PR and Education aspect of the Aquaponic System Greenhouse project. Consequently, the PR Team will strive for popularising sustainable food production in home environment, by exhibiting how an aquaponics system works, next to educating people on what are some of the methods of doing so.

4.1 What did the previous group do about public relations and education?

The focus of the EPS group from Spring 2020 was spread through analog and digital advertisements. Their work was consisting of a creating a slogan, that fits the mission and vision of the project, ending up with the following two possible versions of slogans, depending on the use of context:

- **Hygrow - your sustainable and local grocery producer.** This version should be used if the project name “Hygrow” is next to the slogan, for example on a poster or flyer.
- **Your sustainable and local grocery producer.** The second solution should be used, if the logo or nothing else is next to the slogan. The slogan alone would otherwise not make a connection to our project.

Moreover, after examining the options, it was concluded that both suit the mission and vision of the current project's focus, thus why they could be used in future promotional materials, related to the Hygrow Aquaponics.

In the following paragraphs the two types of advertisements that the Spring team of 2020 will be presented as it follows:

4.1.1 Analog Advertisements:

Regarding the analog advertisements-materials, the previous EPS group worked on updating the posters, showcasing the idea behind Hygrow, creating keyrings design and merchandise clothes (Figure 66, Figure 67, Figure 69).

Figure 66: The EPS Poster Spring Semester 2020

Figure 67: EPS Promotional Poster Spring Semester 2020

The design of the keychain has been created by EPS group of Spring Semester 2020. It clearly stated the name of the project, next to its elements – the plant and fish.

Figure 68: Keychain Spring Semester 2020

The provided design of the T-shirts from the previous group can be used in presentational moments of the project, in order to clearly distinguish the Hygrow team mebers.

Figure 69: T-shirt Design Spring Semester 2020

4.1.2 Digital advertisement

Due to multiple reasons, one of it being the COVID-19 outbreak throughout the group work of the previous EPS team, the initially planned promotional materials of the Aquaponics system were not achieved. Nevertheless, the provided social media channels were displaying only the previous students and their role in the project, and certainly not presenting any information, related to how does the aquaponics system works, nor the progress that has been made throughout the different semesters.

The previously used social media channels, were the following:

- Youtube
- Facebook
- Instagram

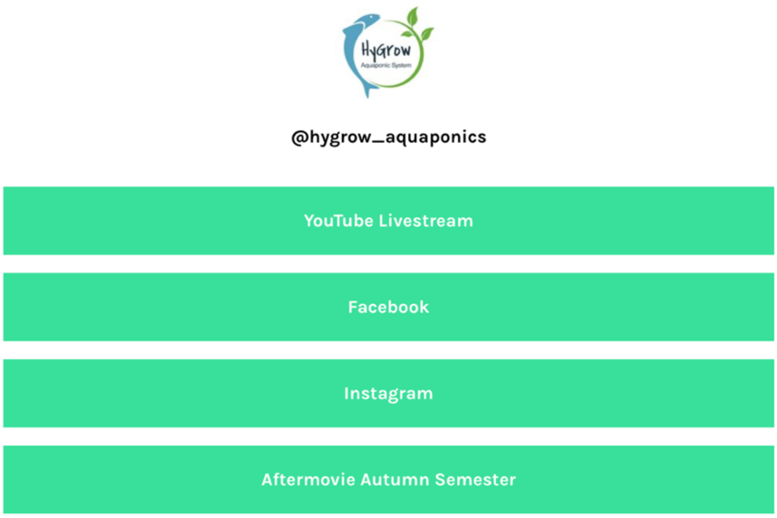

Figure 70: Social Media Channels Spring Semester 2020

Finally, the previous group created a website, with the purpose of generating and maintaining interest in the Hygrow and Aquaponic System. WordPress was the platform that was used for hosting the website and its curation of the content, regarding the project.

4.2 The creation of an educational and interactive (web)app

As topics such as sustainable farming and natural resource depletion continue to grow, understanding why aquaponics is important for the future will become more crucial for our growing population and its food demands. The idea behind the creation of the interactive (web) app has to do with finding immersive ways of involving people interested in sustainability, to take the next step and educate themselves on the existing methods of growing food anywhere. Moreover, tips and tricks on how to recreate a self-sustained greenhouse with its specifications, will be also included as part of the provided educational material.

4.2.1 Target group

For the scope of the Hygrow project, a specific target group have been considered, with the purpose of not only designing for their needs, but also working towards full client satisfaction. After an extensive research and team discussions, the following criteria of the target group has been identified:

- Age group: 18-30 years old
- Nationality: Finnish/Swedish
- Occupation: current and prospective students of Novia;
- Interest: sustainable food production, eco-friendly methods of growing herbs/vegetables, natural/organic food, vegan/vegetarian/plant-based lifestyle; DIY projects, automation

After a conducted interview with few accounted with the project Novia students, the given needs were identified:

- be able to clearly understand how does the Aquaponics system works;
- be able to visualize the system and interact with its functionality;
- to be guided through clear instructions on how to start on their own with the Aquaponics system;
- to have a list with the most suitable plants and fish for their greenhouse;
- space for questions, related to the whole system;
- know how to handle any plants/fish diseases;
- have a personalized experience, that considers their interests;
- to have a quick redirection to the actual greenhouse;
- know who is behind the greenhouse;
- to feel socially connected to the mission of an Aquaponics system;

4.2.2 Creating a prototype of the app

For the purpose of creating a prototype of the educational app, one needs to be well-aware of their target group and its needs. Moreover, the process of creation includes a brainstorm session, conducted with interested parties, in an effort to understand their behaviour, believes and wishes. Furthermore, a low-fidelity and high-fidelity prototype will be created, considering the UX/UI criteria, that will be derived from the brainstorm session with participants, falling into the main target group of Hygrow Aquaponics System.

Creative session

In order to get started with a specific design direction with the purpose of educating and popularising the greenhouse, a creative design session was organised with all teammates. For the purpose of being efficient, the used digital tool was Miro, which had the role of a visual whiteboard, where the participants can collect all their ideas in one place simultaneously (Figure 71).

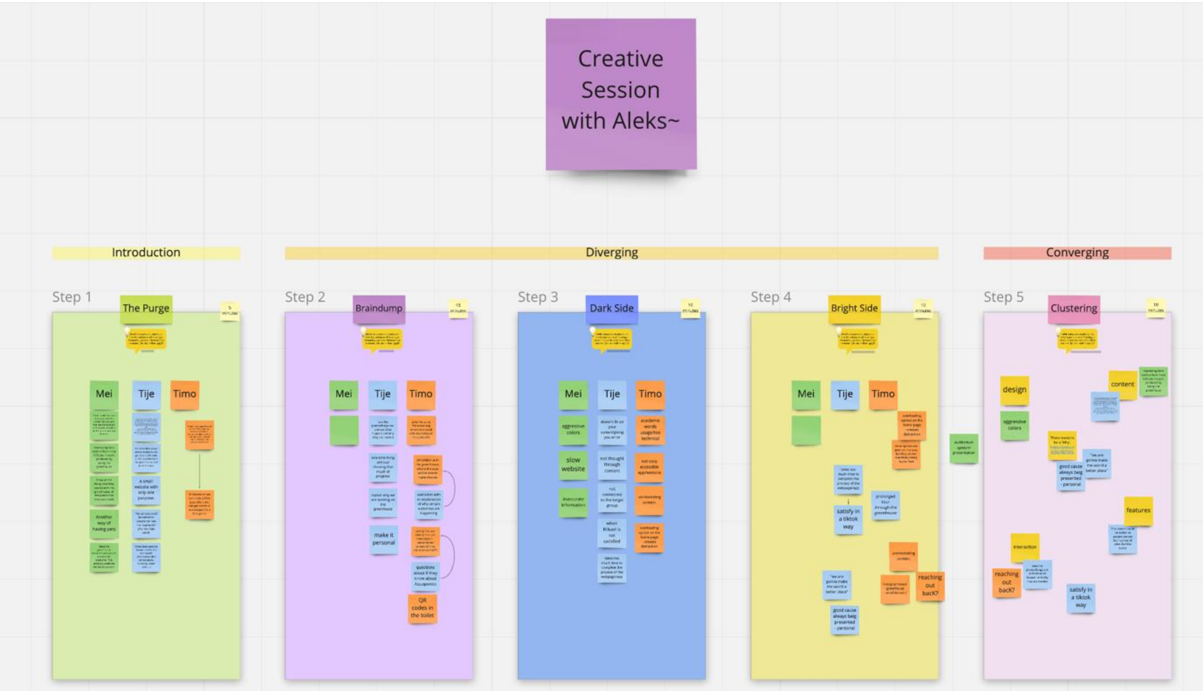

Figure 71: Creative Session with team members

Moreover, to establish a discussion and stimulate an inspiring brainstorming session, a moderator in the face of a teammate was assigned.
The meeting was split in 3 different modules, each of them following a concrete brainstorm design process. To prepare the participants with the so-needed creative space, an introduction to the topic was made, next to having them putting down all of their initial thoughts about it in the "Purge" section.

After the first module, a "Diverging" activities were implemented, with the purpose of generating as many ideas as possible.

Lastly, the previously created ideas were grouped into bigger topics, more specifically clusters. In that way the collection of ideas from the participants can be easily determining the potential design direction that the final product will have in its core.

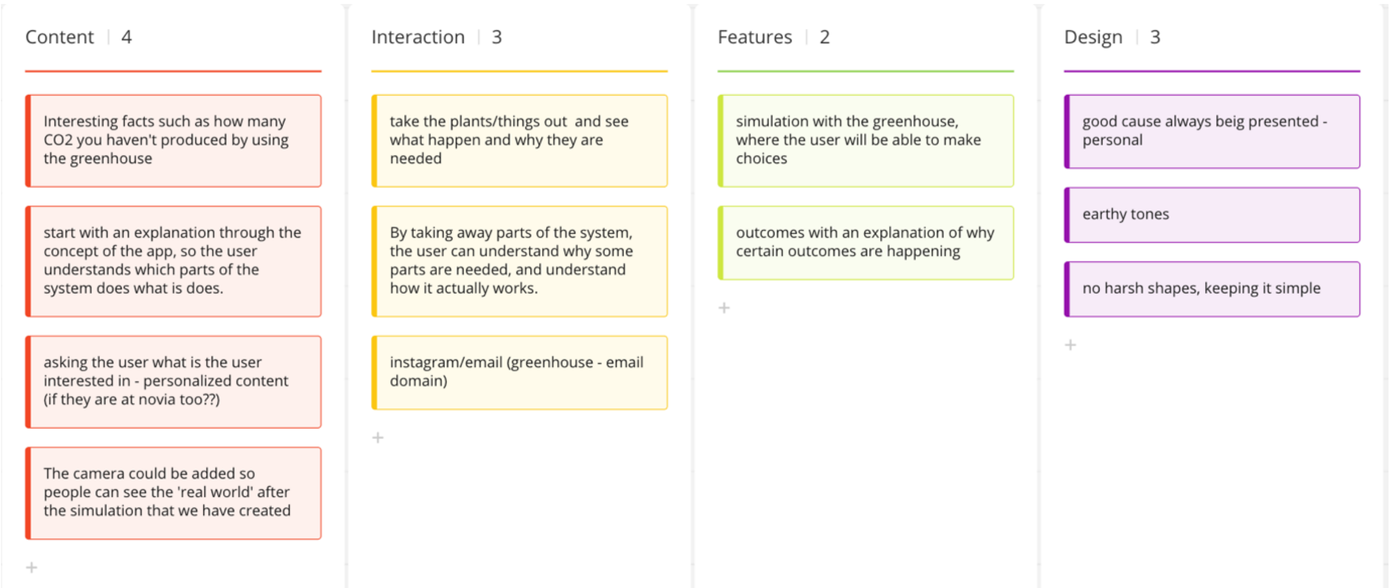

Figure 72: Results

4.2.3 Ideation process

As part of the ideation process, which includes sessions of diverging, converging and iterating, the responsible parties for this specific part of the project were tightly working with interested parties, next to the aforementioned target group. The importance of those working sessions, have to do with the satisfaction of the target group's needs, while making sure that they can continuously learn and be curious about the process of an eco-friendly, sustainable farming technique, as such as the Aquaponics system.

Firstly, a design vision was established, in order to have a clearly communicated and perpetual branding of Hygrow project. The results were visualized in a Moodboard (Figure 73), consisting of suitable typography, colour pallet, animations and design patterns and trends. A primary design direction was founded, incorporating earth tones for colours, funky round shapes, well-explanatory animations, next to bold and direct eco-friendly slogans and messages.

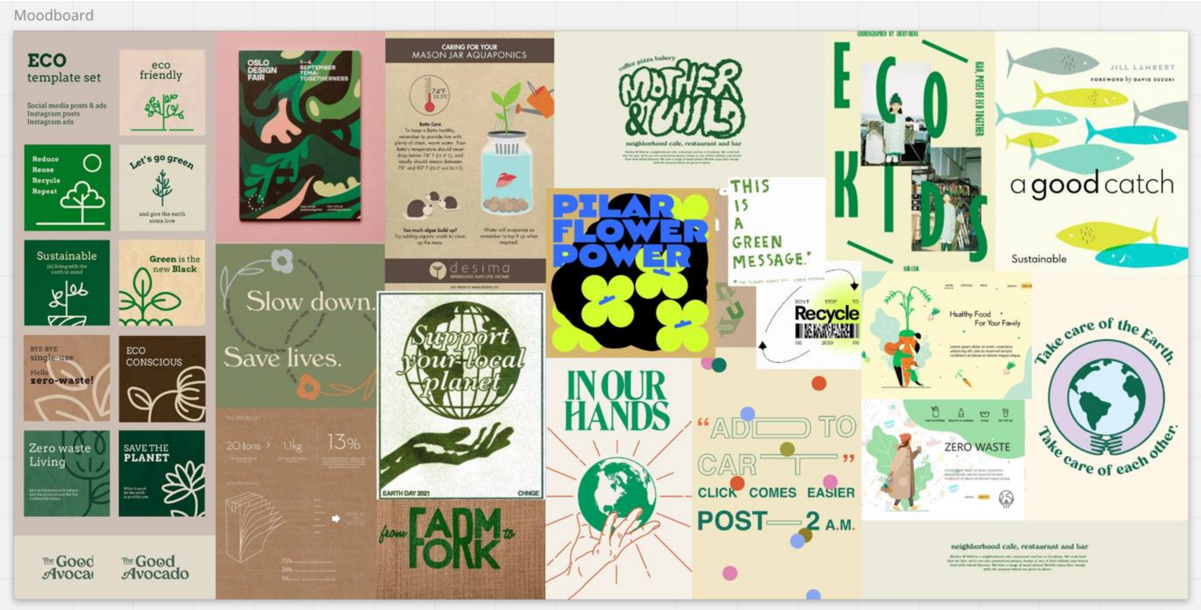

Figure 73: Moodboard

Simultaneously, a sitemap of the website was created, to be used as a guide, while designing the skeleton of the interactive web app. In it, three navigating layers have been recognized, starting with the menu of the website as part of the primary navigation, followed by the content of the secondary navigation, and finishing with the tertiary pages (Figure 74). In this way a logical structure of the website will be assured.

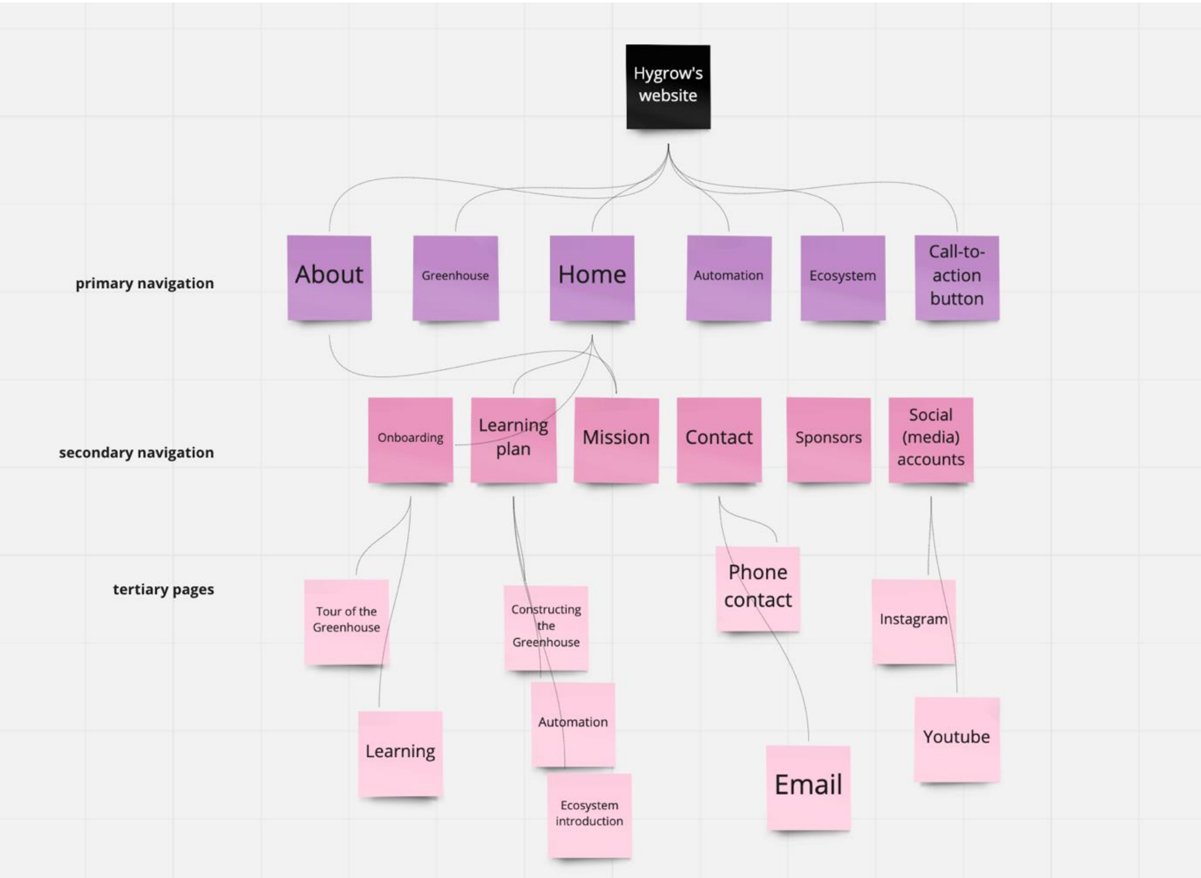

Figure 74: Sitemap Website

4.2.4 Final product and evaluation

Throughout the final stage of the creation of the interactive website, a concluding test and evaluation from the side of the target group was implemented. The procedure was used as a reassurance that the needs and wishes, stated previously by the target group, are being fully met.

The final design of the website (Figure 75) is composed of a home page, solely used as an extensive overview of the Hygrow Aquaponic System.

Figure 75: Final design of the webpage

Starting off with a clear message, helps with the expectations establishment, along the side of a clear 3D model of the current state of the Greenhouse. An encouragement to interact with the website has been created, with the help of clearly communicated "call-to-actions" button, giving users an opportunity to discover more relevant information on how to start their journey of creating a functioning Aquaponic System Greenhouse (Figure 76).

Figure 76: Call-to-action buttons

Next to that, a simplified description of a learning curve, related to the process of building, automizing and sustaining the aforementioned Greenhouse, has been included (Figure 77).

Figure 77: Learning curve

Foremost, Hygrow's mission has been presented in a form of a short promotional text. The purpose of this section has to do with the formation of a personalized content and message towards our users (Figure 78).

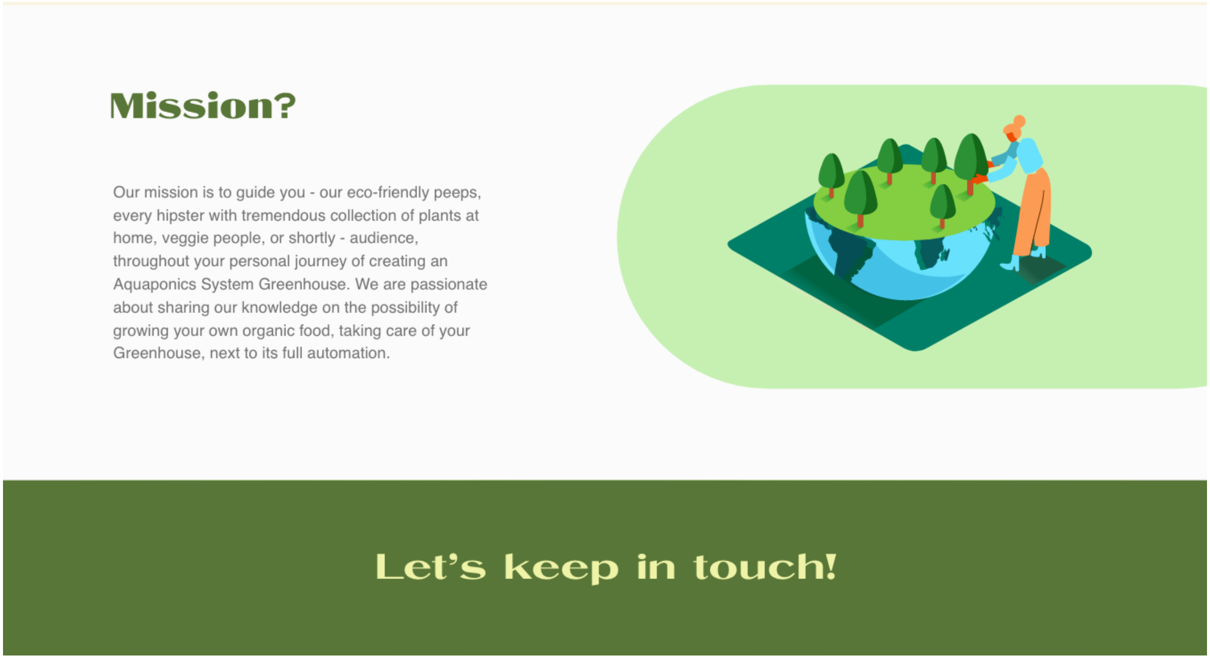

Figure 78: Personalized message

Lastly, options for further interaction with the projects' Team have been provided in the form of icons, redirecting to other platforms. A proper credentials of the stakeholders of the project have been included at the bottom of the webpage (Figure 79).

Figure 79: Credentials

4.3 Social media

For the scope of this project and the related goals, that have been stated from the very beginning, different social media channels and means will be used, in order to communicate the mission, vision, and progress of Hygrow.

Furthermore, to achieve the main objectives of these goals, the following steps will be taken and worked upon:

- Setting up social media platform accounts
- Creating content for the social media platforms
- Managing the different platforms

4.3.1 Gmail

To set up a professional image of the Hygrow project, a general email account has been made, which can be used as a mean for communicating with potential interested parties (Figure 80).

Figure 80: Gmail account of Hygrow Team

4.3.2 Instagram

The social media platform of choice is Instagram, due to its popularity among the main target group for the scope of this project. Moreover, there will be a convenient place to share updates on the status of the Greenhouse, in addition to posting educational materials, related to the system. An introduction of the teammates has been completed, and further content is to be posted (Figure 81).

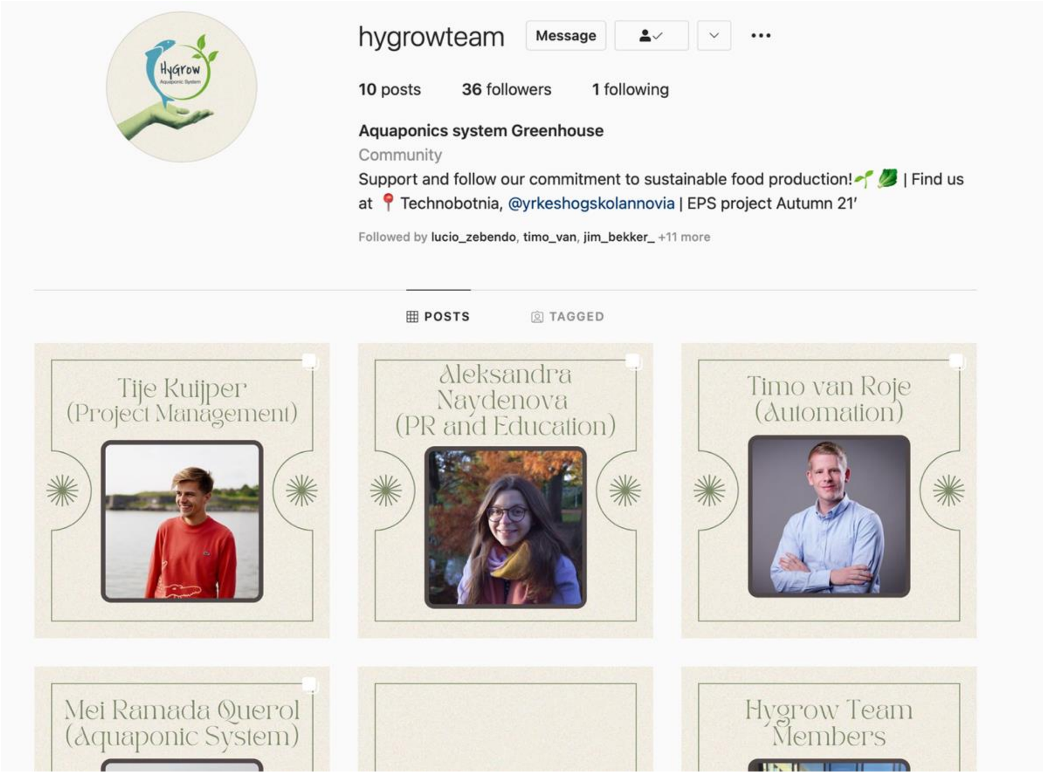

Figure 81: Instagram page Hygrow Team

4.4 Poster and stickers design

One part of the tasks related to PR, was all about designing promotional materials, more specifically posters and stickers, that can be used for advertisement purposes. The current posters and stickers can be seen in the following figures:

Figure 82: Poster 1

Figure 83: Poster 2

Ideally, the stickers will be used for promotional purposes out of the campus area of the university. This will result in a broader reach of interested parties, that would like to get acquainted with the Hygrow Aquaponics system project (Figure 84).

Figure 84: Stickers

4.5 Conclusion and recommendations

Finally, the Conclusions and Recommendations for the next EPS group are presented in this section. They have the purpose of getting prospective EPS groups accounted with the possibilities within the Educational and PR section of the Hygrow Aquaponics System Greenhouse project.

Conclusion

For the scope of this project and the initially stated goal, it can be concluded that the completion of the tasks throughout the project were successfully fulfilled. Social media presence has been established through the Hygrow's Team's Instagram page, where an introduction of the current team, next to their mission, vision, and comprehensive educational materials, can be found. Promotional materials such as posters and stickers of the project have been designed accordingly to the brand image and advertised in the university's buildings.

After a discussion during the final client's meeting, a change of direction was requested. The change that needed to be made was related to the educational part and the initial plan of having an interactive app, where users could get acquainted with the Aquaponics System specifications. Due to the fact that hosting and programming such app with a personal domain would require an immense knowledge on app development, the initial proposal of an interactive application was modified. Instead, a design proposal for a website was created, ready to be used by skilled students in the sphere of Computer Science and Web development. Regarding the content of the website, it was concluded that extensive chunks of information per each category will require a considerable amount of time, which could be invested in another direction, such as the design of the website and its functions.

Recommendations

In this paragraph, we from Hygrow team, would like to share our recommendations solely derived from our experiences, observations, and problems we have stumbled across throughout the duration of the project.

Priorly it was touched upon the idea of creating an independent from any hosting service platform website/application. The reason why it must be self-sustained hides behind the thought of handing it over to continuing with the project groups and their chance to have the creative freedom with it. Considering the prospective opportunity of implementing an interactive application with the purpose of educating people on topics related to the Hygrow project, we strongly support the further completion of this goal of ours. Additionally, our opinion has been based on the insights that we have collected throughout the research and interview part with multiple Novia students.

Another recommendation has to do with the implementation of a gamified simulation of the greenhouse and its system. Providing users with the opportunity to not only visualize, but also learn by practicing potential scenarios, based on what could happen in the greenhouse, would considerably increase the interest in acquiring knowledge and possibly getting started with the creation of their own Aquaponics System. Additionally, this idea will prevent users from making mistakes in their personally owned greenhouse and will remove the feeling of uncertainty, regarding what could be the coincidence of a given act.

Lastly, our team was provided with cameras, that were installed in strategical places throughout the greenhouse. The purpose of the installation of the cameras, was to be able to regularly update any interested party in the status of our fishes and plants. Therefore, having live updates on the activity within the greenhouse, can be another point of consideration.

5 Project Management

In this chapter, the progress of Project Management is described. This chapter is divided into two parts: the start of the project and a reflection of during the project. The first part focuses on team building and planning. The second part of this chapter shows a description of the leadership needed with an evaluation.

5.1 Beginning of the project

This part of the Project Management describes the start of the project, focussing on teambuilding, the used project management methodology, mission, vision and goals, stakeholders, Work Breakdown Structure, Responsibility Matrix, Scheduling, the Risk Assessment and finally budgeting.

5.1.1 Teambuilding

In this paragraph, the different qualities of the individual team members are described using the Belbin-test, a Team Observation Task, and the Temper self-evaluation. Every paragraph about the tests describes the individual results and the combination of the results of the different group members.

5.1.1.1 Belbin-test

In this paragraph, the results of the Belbin test are discussed. The Belbin-test is a test which is focussing on the qualities of individuals when working together with others. The test is focussing on nine different qualities. The different qualities are described in following Figure 85. (BELBIN Associates, sd)

Resource Investigator	Uses their inquisitive nature to find ideas to bring back to the team. **Strengths:** Outgoing, enthusiastic. Explores opportunities and develops contacts. **Allowable weaknesses:** Might be over-optimistic, and can lose interest once the initial enthusiasm has passed. **Don't be surprised to find that:** They might forget to follow up on a lead.
Teamworker	Helps the team to gel, using their versatility to identify the work required and complete it on behalf of the team. **Strengths:** Co-operative, perceptive and diplomatic. Listens and averts friction. **Allowable weaknesses:** Can be indecisive in crunch situations and tends to avoid confrontation. **Don't be surprised to find that:** They might be hesitant to make unpopular decisions.
Co-ordinator	Needed to focus on the team's objectives, draw out team members and delegate work appropriately. **Strengths:** Mature, confident, identifies talent. Clarifies goals. **Allowable weaknesses:** Can be seen as manipulative and might offload their own share of the work. **Don't be surprised to find that:** They might over-delegate, leaving themselves little work to do.
Plant	Tends to be highly creative and good at solving problems in unconventional ways. **Strengths:** Creative, imaginative, free-thinking, generates ideas and solves difficult problems. **Allowable weaknesses:** Might ignore incidentals, and may be too preoccupied to communicate effectively. **Don't be surprised to find that:** They could be absent-minded or forgetful.
Monitor Evaluator	Provides a logical eye, making impartial judgements where required and weighs up the team's options in a dispassionate way. **Strengths:** Sober, strategic and discerning. Sees all options and judges accurately. **Allowable weaknesses:** Sometimes lacks the drive and ability to inspire others and can be overly critical. **Don't be surprised to find that:** They could be slow to come to decisions.
Specialist	Brings in-depth knowledge of a key area to the team. **Strengths:** Single-minded, self-starting and dedicated. They provide specialist knowledge and skills. **Allowable weaknesses:** Tends to contribute on a narrow front and can dwell on the technicalities. **Don't be surprised to find that:** They overload you with information.
Shaper	Provides the necessary drive to ensure that the team keeps moving and does not lose focus or momentum. **Strengths:** Challenging, dynamic, thrives on pressure. Has the drive and courage to overcome obstacles. **Allowable weaknesses:** Can be prone to provocation, and may sometimes offend people's feelings. **Don't be surprised to find that:** They could risk becoming aggressive and bad-humoured in their attempts to get things done.
Implementer	Needed to plan a workable strategy and carry it out as efficiently as possible. **Strengths:** Practical, reliable, efficient. Turns ideas into actions and organises work that needs to be done. **Allowable weaknesses:** Can be a bit inflexible and slow to respond to new possibilities. **Don't be surprised to find that:** They might be slow to relinquish their plans in favour of positive changes.
Finisher	Most effectively used at the end of tasks to polish and scrutinise the work for errors, subjecting it to the highest standards of quality control. **Strengths:** Painstaking, conscientious, anxious. Searches out errors. Polishes and perfects. **Allowable weaknesses:** Can be inclined to worry unduly, and reluctant to delegate. **Don't be surprised to find that:** They could be accused of taking their perfectionism to extremes.

Figure 85: The different qualities following the BELBIN-test (BELBIN Associates, sd)

The group members filled out the Belbin-test presented in the classes of Team Building (Nylund, BELBIN QUESTIONNAIRE, 2021). The four individual results are shown below in the following sub-paragraphs.

Belbin-test: Combined results

The results of all the Belbin-tests are combined in Table 4 below. The best qualities of each group member are coloured green. In this way, the represented qualities in the group are visually shown. The individual test results can be found in the Mid-term report.

Table 4: Results Belbin-test (Nylund, BELBIN QUESTIONNAIRE, 2021)

Name	Coordinator	Shaper	Plant	Monitor	Implementer	Resource investigator	Team worker	Finisher
Aleksandra	9	10	12	4	9	8	12	6
Mei	5	9	17	7	5	4	21	2
Tije	14	13	3	12	11	8	5	4
Timo	8	8	9	12	10	4	7	12

The qualities which are represented by the group members are quite complete. Tije fulfils the job or coordinator, shaper and (together with Timo) monitor and implementer. Aleksandra and Mei have quite similar qualities, focussing on the shaper, plant, and team worker. Timo his qualities are mainly focussing on monitor, implementer, and finisher. The quality of the resource investigator is not well represented, so this is something the group needs to focus on while working on the project.

5.1.1.2 Team Observation Task

In this paragraph, the results of the Team Observation Task are elaborated. The Team Observation Task is a test which is focussing on the current situation of working together within the team. The test is focussing on seventeen different qualities. (Nylund, Team observation task, 2021).
In the following sub-paragraphs, the individual results are elaborated. In the last sub-paragraph, the combined results are worked out.

Team Observation Task: Combined results

The combined results of the Team Observation Task are shown in Table 5. The results are combined into one table. In that way, the total result of the group is visible. The individual test results can be found in the Mid-term report.

Table 5: Team Observation Task results combined (Nylund, Team observation task, 2021)

Statement	**1**	**2**	**3**	**4**	**5**
The team worked in mutual understanding	x	x			
The team seemed to have a common goal and clear objectives	x	x			
The team-members were committed to their tasks	x	x			
The team had confidence in everyone of its members	x	x			
The team-members were honest with each other	x				
The team-members felt secure with each other	x		x		
The team trusted each other's competence	x	x			
Communication was open	x				
The team respected all its members	x				
The team was interested in everyone's ideas	x				
Both positive and constructive feedback were given	x	x	x		
The team was emphatic towards all in the group	x	x			
The importance of cooperation was emphasized	x	x			
There was a casual, relaxed feeling in the team	x	x	x		
There was no appointed leader, but leadership was shared		x	x		
Decisions were made together	x	x			
The group was able to evaluate its own activities	x	x			

As shown in the combined results, the biggest part of the results is shown on the left side of the table (1 or 2). This shows that the team members are relatively comfortable with the team, but there is also some space for improvement in the part of shared leadership, feeling of secureness with each other, and given feedback.

5.1.1.3 Temper self-evaluation

In this paragraph, the results of the Temper Self-evaluation are elaborated. The Temper Self-evaluation is a test which is focussing on the current situation of working together within the team. The test is focussing on nine different qualities. (Nylund, Temper Self-evaluation, 2021)

Temper self-evaluation: Combined results

The combined results of the Temper self-evaluation are shown in Table 6. The table is focussing on two things. Higher ratings are shown in green, lower ratings in orange. The individual test results can be found in the Mid-term report.

Table 6: Temper Self-evaluation results combined

Name	Aleksandra	Mei	Tije	Timo
Activity	7	5	8	7
Sensitivity	4	6	6	4
Distractability	5	8	8	4
Adaptability	7	9	7	6
Steadfastness	6	3	8	8
Rhythm	6	4	7	5
Accessibility	6	7	8	7
Intensness	4	6	7	6
Mood	6	7	8	4

The results show some differences between group members. The combined results shows that all the team members are quite adaptable and accessible. Most of the group members are quite active, steadfast, have differences in moods and have a bit high feeling of intenseness. The group members have in average not a high rhythm and are not highly sensitive, some can be distracted easily.

5.1.2 Project management methodology: Agile SCRUM

In this paragraph, the used management methodology is described.

For different projects, different methodologies are used. The Aquaponic Greenhouse-project is a development project. On the beginning of the project, the greenhouse was built, and the system was ready to turn on. The goal of the project is to automize the Aquaponic System. There is no concrete endpoint which needs to be achieved, just improvements on the current system itself. This makes the project highly suitable for the usage of the project management methodology Agile SCRUM. (Ehrs, 2021)

Agile SCRUM is focussing on continuous cycles of a day to two weeks. These cycles are dominated by a particular subject, which will be delivered on the end of the cycle. The exact time a cycle will take, is not strongly planned. On this way, results will be delivered within small periods. To keep track on the progress, a tool could be used. (Ehrs, 2021)

The team chose to use Miro as a progress board. This will give visual access to the progress of the project. During the cycles, the team is describing the progress in a backlog in the form of a report. The team meets up daily to have a short conversation about the goals for that day and the progress for the different tasks. The team organizes a weekly meeting with the coach to discuss progress and results.

5.1.3 Mission, vision, and goals

In this paragraph, the mission, vision, and goals are described. The focus for the mission and vision is long-term, beyond the end of the project. The goals are created to be reachable by the end of the project.

Mission

"To create an understandable self-sustained climate independent Aquaponic System for producing food in every possible environment."

It is a long-term mission. Focussing on the endpoint where this project (EPS Autumn '21) part of is. It is the idea of the future of the Aquaponic Greenhouse. With the concept of an Aquaponic Greenhouse, it would be possible to make a producible Aquaponic Greenhouse to let every individual be able to grow food in every environment.

Vision

"Giving every home the possibility to produce food."

Climate, geography, and prosperity have influence on the production of food. An Aquaponic Greenhouse takes this away and gives every household the opportunity to grow food. That is what Hygrow Aquaponic Greenhouse contributes to.

Goals

The project is divided into four goals. The four goals are each focussing on the profession of one of the members of the group. On this way, everyone can develop themselves for their own profession.

Four goals are defined:

1. Adapt the system to the needs of the fishes and plants. (Mei)
2. Automize solutions for problematic scenarios of the Aquaponic System. (Timo)
3. Educate people about growing food in every environment in an interactive manner. (Aleksandra)
4. Ensure a passed project by management of fulfilling the goals, expectations, and deadlines. (Tije)

5.1.4 Stakeholders

A stakeholder analysis was carried out to ensure that the project runs smoothly and that all parties involved are satisfied. This analysis examines how important a stakeholder is, what the requirements are and what should be paid attention to during the project. The different stakeholders and their needs are described in Table 7.

Table 7: Stakeholders Hygrow Aquaponic Greenhouse

Stakeholder	**Impact**	**Needs**	**Priority**	**Deliverables**	**Milestones**	**% time / €**
Novia	directly	innovative project to show to potential students	1. must have	Real prototype of the aquaponic house	Meeting every three weeks to discuss about this subject.	25%
		creating new knowledge	2. should be included	Calculation, presentation, report, and prototype	Weekly meeting with coach to ensure the progress.	10%
		the use of sensors in any way	1. must have	Prototype	Meeting every three weeks to discuss about this subject.	30%
Sponsors	indirectly	innovative results	3. nice to have	Report	The report on the end of this project	5%
Project group	directly	reachable goals to succeed	1. must have	Prototype and report	Check every three weeks about this subject.	15%
		following their own expertise	2. should be included	The project itself	Check every three weeks about this subject.	15%
Housing owner	directly	owner of the roof	2. should be included			
IT-department	directly	in charge of connecting	2. should be included			

In the next paragraph, the Work Breakdown Structure is elaborated.

5.1.5 Work Breakdown Structure

The Work Breakdown Structure (WBS) is shown in Figure 86. To get a better view on the text, the zoom-function of Word could be used.

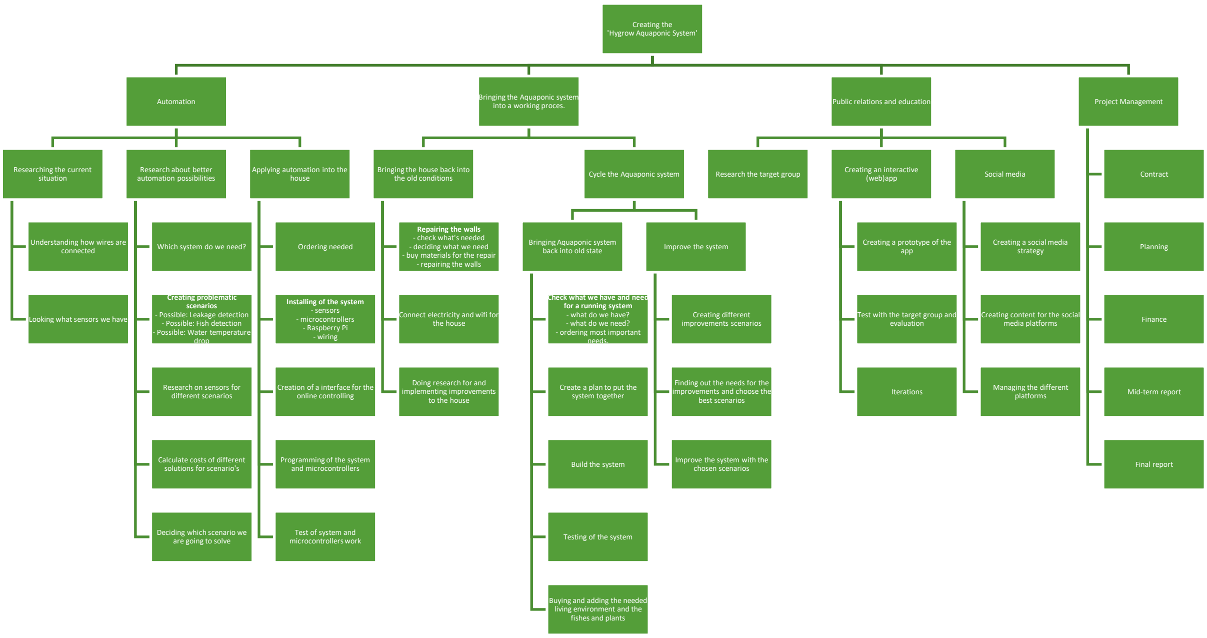

Figure 86: Work Breakdown Structure

The Work Breakdown Structure is based on the four goals. On that way, the creation of ownership for every task is easier. The Work Breakdown Structure is based on the principle that solutions are not known yet. The described process of researching, choosing the best solution and applying the chosen solutions is used frequently in the Work Breakdown Structure.

In the next paragraph, the Work Breakdown Structure is converted into a Responsibility Matrix (RACI).

5.1.6 Responsibility Matrix

In this paragraph, the Responsibility Matrix (RACI) is elaborated in Table 9. The Legend for Responsibility Matrix (RACI) is shown in Table 8 below.

Table 8: Legend for Responsibility Matrix (RACI)

Legend
Responsible
Accountable
Consulted
Informed

Table 9: Responsibility Matrix (RACI)

Creating the 'Hygrow Aquaponic System'	Aleks	Mei	Tije	Timo	Tobias	Mikael
Automation	A	I	C	R	C	I
•Research about the current situation	A	I	C	R	C	I
•Research about better automation possibilities	A	I	C	R	C	C
•Applying automation into the house	A	C	C	R	C	I
Bringing the Aquaponic System into a working process.	C	R	A	C	I	I
•Bringing the house back into the old conditions	C	R	A	C	I	I
•Cycle the Aquaponic System	C	R	A	C	I	I
--> Bringing Aquaponic System back into old state	C	R	A	C	I	I
--> Improve the system	C	R	A	C	C	C
Public relations and education	R	A	I	I	I	C
•Research the target group	R	A	C	I	C	C
•Creating an interactive (web)app	R	A	I	I	I	C
--> Creating a prototype of the app	R	A	I	I	I	C
--> Test with the target group and evaluation	R	A	C	I	C	C
--> Iterations	R	A	I	I	I	C
•Social media	R	A	I	I	I	C
--> Creating a social media strategy	R	A	C	I	I	C
--> Creating content for the social media platforms	R	A	I	C	I	C
--> Managing the different platforms	R	A	I	I	I	C
Project Management	C	C	R	A	I	I
•Contract	R	R	R	R	I	I
•Planning	C	C	R	A	C	C
•Finance	I	I	R	A	I	C
•Mid-term report	A	A	R	A	I	I
•Final report	A	A	R	A	I	I

The Responsibility Matrix is based on the Work Breakdown Structure. Since the Work Breakdown Structure is based on four personal goals, it is easy to assign the responsible person for the different tasks in the Responsibility Matrix. After a small discussion with the group members, the accountable person is assigned for every task. The consulted and informed role is assigned on a logic way.

In the next paragraph, the scheduling is elaborated.

5.1.7 Scheduling

The scheduling is done by the usage of the Gantt Chart in Figure 87. Because it is not possible to show the Gantt Chart in Word, the Excel-document is attached.

Figure 87: Gantt Chart

For every different goal, an own process is created. The several actions of the goals can be performed at the same time. The actions within the different goals can only be executed one after the other.

5.1.8 Project Risk Assessment

In this paragraph, the Risk Assessment is elaborated. The Risk Assessment itself can be found in Appendix 2: Risk Assessment in Table 11 on page 86.

In order to gain insight into the most important risks within a project, a risk inventory has been made. The focus is to be prepared for the failure of the project itself, by predicting risks. During a brainstorming session, all possible risks are listed, after which it is focused on how these risks can be detected and countermeasures are created for each risk. The impact and probability are valued with a value between 1 and 3.

Meaning of grading: Impact
1 = something we can solve by ourselves.
2 = something we need to solve with the need of external help.
3 = something we cannot solve within the project.

Meaning of grading: Probability
1 = small chance of happening (not really within this project).
2 = the chance is there; we need to be aware of this.
3 = if we don’t prepare for this, there is a big chance that this risk will occur.

After filling out the different problems, the grading is automatically changed to 1 (for 1), 3 (for 2) and 9 (for 3). On this way, the gap between the numbers increases, what helps a good interpretation of the result. To work towards the result, the impact and probability are multiplied. This multiplied number is divided by the maximum multiplied grade (9*9=81). On this way the end grade will change to a percentage, which helps with the interpretation of the most important risks.

The possible results are 100%, 33%, 11%, 4% and 1%. The most important risks to take care of are either 100% or 33%. Risks with a rate of 11% are also checked, to be sure that false graded risks are monitored correctly.

5.1.8.1 Risk Assessment of the Aquaponic System

As described above, we started with a brainstorming session. The result of this was a disorganized list of risks. To create an overview, categories are linked to these risks: Aquaponic System, Automation, Public Relations and Education and Project Management.

Practical ways of detecting problems have been added and countermeasures have been put in place. The impact and probability have been determined according to the guidelines from the previous section. The calculations have been drawn up, as a result of which seven risks emerged most strongly (score of 100% and 33%). These are the risks discussed in the next section.

5.1.8.2 The seven most important risks

In this paragraph, the seven most important risks are further described. For each risk, options have been worked out to describe measures that limit the risk. By implementing these measures, the probability of occurrence of the risk and its impact is reduced.

Risk of the Aquaponic System: No power on the roof (100%)

On the moment of writing, there is no dedicated power outlet on the roof which can be used while one of the group members is not on the roof. A new power socket will be made, but a chance is that this will not fulfil the needs of having a continuously power outlet. If the power outlet on the roof is not there or turning of unexpectedly, there is a chance it could be that bad that it is not solvable within the project. The chance that electric failure will occur on the roof, is big. That makes a score of a 3 for *impact* and a 3 for *probability*. This results in a score of 100%.
To reduce this risk, contact with the janitor is very close. If needed, he is willing to help us and get in touch with the electricity-company.

Risk of the Aquaponic System: Power outage or shortage (100%)

When the needed power is more than the power socket can handle, there is a shortage of power. Because we don’t know exactly how much power we need for heating of the system (because we need to find an inexpensive/free way for heating due to our budget), we needed to guess the amount of power needed. The chance that this power is enough, is the same as that is will not be enough. That is the moment when the system will not heat up, and there is no possibility of an Aquaponic existence. The score of 3 for *impact* and 3 for *probability*, makes a score of 100%.

To reduce this risk, we are trying to do our best to find a suitable heating system. We also asked for a power socket with enough power, and hopefully that will be enough.

Risk of the Aquaponic System: No waterflow in the system (33%)

If the waterflow in the system is turned off when needed to be turned on, there could be something broken. There is a big chance this will happen within the project (a 3 for *probability*), but the impact isn't that big (a 2 for *impact*). That makes a score of 33% following the calculations explained on the previous page.
To reduce this risk, the system is regularly checked. Within the part of Automation, the group will research possibilities to detect those failures and change things if needed.

Risk of the Aquaponic System: Pumps failure (33%)

If one of the pumps fail, the waterflow can stop at one place in the system. The water could overflow on other places, which is a risk of losing water and missing a water flow. There is a big chance this will happen within the project (a 3 for *probability*), but the impact isn't that big (a 2 for *impact*). That makes a score of 33% following the calculations explained on the previous page.
To reduce this risk, we will focus on regular checks and automation possibilities. The possibilities for automation are researched further in the project.

Risk of the Aquaponic System: Weather conditions (33%)

The weather conditions could be a problem, in combination with our budget. Cold weather conditions are hard to overcome, without money for a good heating system and isolation. There is a big chance this will happen within the project (a 3 for *probability*), but the impact isn't that big (a 2 for *impact*). That makes a score of 33% following the calculations explained on the previous page.
To reduce this risk, we will focus on finding cheaper ways of getting a heating system to prepare for cold weather.

Risk of Project Management: Limited budget (33%)

The limited budged can create big problems for the project, but we could not be sure if this will be a problem. A good heating system is the most expensive part of our expense. If our budget is limiting the creation of a good working Aquaponic Greenhouse, there is a chance we would not be able to create a working Aquaponic Greenhouse and complete our project as we want to (a 3 for *impact*). The chance is not that big, but also not that small (a 2 for *probability*). That makes a score of 33%.
To reduce this risk, we try to find cheap ways of getting our stuff. And if we need more money, we could try to find donors for our project.

Risk of Project Management: No possibility of getting fishes and plants within budget (33%)

If our budget is limiting the creation of a good working Aquaponic Greenhouse, there is a chance we would not be able to create a working Aquaponic Greenhouse and complete our project as we want to (a 3 for *impact*). The chance is not that big, but also not that small (a 2 for *probability*). That makes a score of 33%.
To reduce this risk, we could think about go and take the fishes ourselves from the sea. But that is not the best idea, because those fishes need a lot of care and expensive food. If we cannot build a good Aquaponic System, there is a chance we need to find different ways to

finish our project. A different way could be a simulation of a Aquaponic Greenhouse, instead of using the real one.

5.1.9 Budgeting of time and money

This part of budgeting is focussed on the theoretical part of the biggest costs: working ours. The working hours are shortly elaborated in this paragraph.

The combined working hours are 1.539 hours (due to the 30 ECTS each team member needs to spend to the project). Most of the time is spent to the part of Project Management, due to that everybody needs to participate in this part in the way of writing reports and evaluations. After Project Management, the building and automation of the Aquaponic System, and Public Relations and Education part are quite similar. Working together with the team members results in a lot of hours.
For those costs, we took the average price of labour in Finland and added 41% to that due to health insurance and other costs for companies. The total costs per hour per group member will be €48,36. That multiplying with the 1.539 hours, shows a total cost of €74.426,04.

5.2 Project Management during the project

The main goal of project management was to ensure that every team member experiences the best possible development with a tangible result. This is done by setting goals and monitoring them. In addition to this individual development, it was important to keep stakeholders satisfied by fulfilling agreements and delivering a suitable result. In this part of the Project Management chapter, each individual team member looks back on the project, what they learned and how they experienced it. In addition, mutual feedback was given between and discussed.

5.2.1 Reflection of the project by each team member

From the philosophy of Project Management, it is important that the collective goals and personal goals are achieved. This European Project Semester focuses on developing each individual student with a focus on achieving a positive outcome from a project. With this goal in mind, it is important to offer each individual room for group development and development of their own personal goals. Project Management has invested time in ensuring that these goals are achieved. A reflection of each group member is elaborated below.

Reflection of the project by each team member: Aleksandra

Group perspective

To begin with, having 4 group members, coming from different educational backgrounds, has been the most beneficial characteristics of the Hygrow Team. That being said, due to the scope of the project, having team members with expertise in areas such as chemical engineering, industrial design and project management have helped us cover all of the aspects of the project. Moreover, as we identified a goal per each team member in the very beginning of the project, being able to work individually in your own time and sticking to the goal has worked better than initiated, therefore I would like to adopt this strategy in my future group projects. Thanks to the personal traits of all my team members – their dedication and good working culture, we as a team established productive working atmosphere, next to having a good group dynamic. From personal experience I have noticed that having a stable group dynamic, as the one we had throughout our project, encourages me to be considerably more creative and initiative.

Personal perspective

Throughout my work in the project, I have identified two main beneficial points for my personal development. I had the unique opportunity to work closely with students from different educational backgrounds than mine, from whom I gained valuable knowledge on the topics of automation, industrial design and 3D printing. In addition to the provided class, related to project management, I had the chance to work closely with an extremely skilled project management student, thanks to whom I learned the importance of efficient task delegation and time management. Lastly, as part of my responsibility within the team, I had the freedom to better my content writing skills, in addition to practicing my graphic design skills and practical knowledge on design programs such as Photoshop, InDesign and Illustrator. Regarding my personal goal, that I have set at the very beginning and its level of difficulty, I would give it a grade of 5. The reason behind it is that I initially aimed to work on a long-term task, however due to the limited amount of time that we had to complete the project, a change of trajectory was needed. Therefore, I had to deliver a rather small product at the end, meaning that the planned workload was shorten significantly.

Reflection of the project by each team member: Mei

Group perspective

Our group has evolved positively from the beginning of the project to nowadays, considering that we are all from different backgrounds, cultures and we did not know each other before everything has turned out very well. The work among all of us is adaptable and flexible allowing all the members to organize themselves and for keeping up with the development of the project we had one or several meeting during the week for inform of any issue or advance. The weekly meetings really helped throughout all the period of the project and the fact that all the members are approachable makes it easy to ask for help in case you need something. It helped me so much with learning how to work within a "new" group of people, new experiences and also some good methodologies of working.

Personal perspective

It helped me so much with learning how to work within a "new" group of people with different points of view, personally I have had a very good experience working with the Hygrow team and with the way the project has been carried on. I feel that as a person I've learned how to interact and express my opinion better than before as well as practiced some 3D printing and carpentry. According to my goal which was taking care of the needs of plants and fish I give myself a grade of 6 because I do have achieved, along with the help of my teammates, to build a fully insulated system for a better development of both plants and fish. Unfortunately, the part of getting fish has not been as expected considering that we only have one fish and the plants that I tried to grow got stuck in the process and seem to not grow any more.

Reflection of the project by each team member: Tije

Group perspective

When the project started, I was quite nervous if I could participate in that one cool project: the Aquaponic Greenhouse. And all my teammates could be happy with this because it was all our first choice. We started setting goals, a bit chaotic at first, but later (mainly because we felt some time pressure) a little more momentum. All group members developed their own goal. My idea was to give everyone their own goal, so that each individual felt responsible for a part. Looking back, this gave a wonderful group dynamic. When the courses were finished, all the time was freed up for working on these goals. We met several times a week (as kind of stand-up SCRUM sessions), where the focus was on watching everyone's progress and seeing if anyone was in need of help. That really gave a strong sense of bonding because they weren't the most productive meetings because we got along very well. Every now and then we would meet on nights out and have a blast together. These things are the basis for a mega strong group bond, something we can be proud of. And the result really is, I am proud of what kind of development each individual has experienced. And because of everyone's developments, there is now an Aquaponic Greenhouse that has been improved on many fronts. At the end I gathered everyone together for a feedback session. And from that came the most favourable words for each other, but also parts that fellow group members can still develop. I am proud to have been able to work together in such a great group. It was truly a time I will never forget. If I am asked to do this again, I will say 'yes' with full conviction!

Personal perspective

Looking at my own development, I can say nothing else that I am happy with what I have accomplished. My personal goal was a lot of paperwork at first, but later transformed into leadership. And I really wanted to develop this skill, but it used to be scary for me to come out for it. In this project I was given the opportunity to do so, with a group of international students who all have the same goal: to have the best time of their lives. And that was quite an honour. I used some minor theories in the shaping of the project. My idea was first of all to set goals that were linked to one person. This made everyone feel responsible for their own part of a greater thing. And it worked! In addition, I thought it would be good to meet daily (or at least a few times a week) to talk about progress and if anyone could use some help. We were so aware of each other's progress and were able to help each other where necessary. We even went fishing with our teacher, which shows a wonderful personal bond between student and teacher here in Finland. I think my goal on a scale of 1 to 10 did have some challenge. But I'll put the difficulty on a 6 to 7. And I think that's a perfect number. This left room for 'the best time of my life'. And it certainly was. I've really grown in trusting myself, my social interactions with others and maybe also learned a lot about who I really am. Maybe I could have approached the leadership part more theoretically, but I think that would have given me less experience with simply executing the leadership. And I am convinced that these four months have taken me a thousand steps further. I'm going to miss it here.

Tobias, thank you for being a great coach. It was wonderful to see how much fun you enjoyed fishing with us and how much confidence you have in us. For that my biggest thanks.

Reflection of the project by each team member: Timo

Group perspective

Now, we have worked together as a team on the Aquaponics Project for four months. During this time, we went through highs and downs and learned a lot from each other. A very positive aspect was that everyone received their first preference for the aquaponics project. This motivated everyone from the beginning to make the project a success. Right from the start there was a good atmosphere in the team, everyone got along well with each other. The tasks that had to be done in the project were distributed fairly to the respective fields of study, so that everyone could show their strengths. The teamwork was very well coordinated, if there were problems, they could be discussed openly in the group and no one was left alone with their problems. In summary, we can say that there was great cohesion in the team. As a result, we achieved a good result at the end of the project with which we can all be quite satisfied. But as with every project, there were ups and downs, but as a team we were able to master all of it. What didn't go so well in this project was that we were quite slow to get into the topic at the beginning, because it is a quite complex topic. Furthermore, the atmosphere in the team was so good that productivity suffered in some cases and I sometimes had the feeling that we needed a lot of time to discuss small topics. But in conclusion I had a great time with the project team and made a great experience.

Personal perspective

During the project I personally learned a lot for and about myself. Through the group work, I have discovered my strengths and weaknesses in more detail. One skill I wanted to improve was my communication skill. This has developed positively during the project. It is easier for me to get into contact with new people and to represent my own point of view on professional topics. In addition, I was able to practically apply and deepen my professional skills during the project. By working in an international team, I learned a lot about other cultures, which was a very nice experience for me personally. Moreover, I gained experience in teamwork and I think that this project prepared me well for my future professional life, where you will work in project groups. Of course, not everything went perfectly during the project. For example, there has often been problems with my automation task. Not everything worked the way I thought it would, so it took me a lot of time to solve problems with supposedly small tasks, which was sometimes a bit frustrating. Nevertheless, in the end I achieved my set goal, which was the automation and the design of a user interface. If I had to indicate on a scale of 1-10 how challenging my task was in the project, I would give it a 6 to 7. For the automation, some things had to be programmed, but I have rather little previous knowledge in this area. Therefore, I had to do some research. However, the Home Assistant is very user-friendly, so that many functions can be done without programming knowledge. The Node-Red integration also made it very easy to program functions.

For myself, I found the time very enriching for myself, I made some new friends and had a very nice time here in Vaasa. There was a lot to discover and I look back very positively on the past 4 months. If I were asked whether I would do the semester abroad here again, I would definitely say yes.

5.2.2 Feedback to other group members

The teammates gave feedback to each other. This feedback is combined in Table 10.

Table 10: Project Management - feedback to group members combined

	Aleksandra						*Mei*						*Tije*						*Timo*					
	bad					*excellent*	*bad*					*excellent*	*bad*					*excellent*	*bad*					*excellent*
	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
Quality of the work						xxxx					x	xxx						xxxx					x	xxx
Quality of part of the report				x	x	xx				xx	xx						x	xxx					x	xxx
Project involvement				x		xxx						xxxx					x	xxx						xxxx
Bearing responsibility					x	xxx						xxxx						xxxx						xxxx
Collaborative ability				x		xxx						xxxx						xxxx					x	xxx
Fulfilling agreements					xxx	x					xx	xx					xx	xx					xx	xx
Overall rating					x	xxx					x	xxx						xxxx						xxxx

The above model was used during the feedback session at the end of the project. The above scores are not very telling, but the words spoken during the feedback session certainly were. Every group member can be sure of receiving worthy feedback, but it has been decided that it is too personal to describe in this report.

5.3 Conclusion

In conclusion, project management during the Aquaponic Greenhouse project initially focused on group formation, project formation and reporting. The reactions to this were positive, especially from coach Tobias and client Mikael. After these components were properly established, the focus from project management changed to a focus on leadership. This leadership focused on developing the qualities of the group members as optimally as possible. This created a space where each group member was free to develop in areas where, with this experience, they can work with more confidence on an international project in the future.

Conclusion

In this conclusion progress in the field of the four stated goals has been established.

As a first goal, the Aquaponic System is optimized for the needs of the plants and fish. This was achieved by conducting research into the fish and plant species to be used. The outcome was European Perch for the fish species, and spinach, lettuce, parsley, and mint for the plants. In addition to this research, it was necessary to give the house a minor renovation with new walls and convert the Aquaponic System to a more compact insulated variant for lower energy consumption of the heating system. During all these improvements, use was made of 3D printed parts. In the end, one fish was caught, and a number of plants started growing in the Aquaponic System.

As a second goal, the automation helped to create a system that requires no human interaction except feeding the fish for a week. This has been achieved by creating catastrophic scenarios and mitigating the risks of these scenarios through the use of existing and new sensors. The resulting data was visualized in an attractive and user-friendly UI that was also accessible outside the campus. This was accomplished after obstacles such as a rigorous change to the Aquaponic System, a limited budget that prevented the purchase of some necessary sensors such as oxygen sensor and ammonium sensor. As a counterpart, several other sensors such as an electrical conductivity sensor, a leak detector and a temperature sensor have been installed that provide more information to the system, facilitating future further automation.

As a third goal, external students have been given opportunities to develop in the field of Aquaponic Systems. After brainstorming sessions and discussions with the client, an Instagram page was set up, posters were distributed and a design for an interactive web page was delivered.

As a fourth and final goal, project management during the Aquaponic Greenhouse project initially focused on group formation, project formation and reporting. The reactions to this were positive, especially from coach Tobias and client Mikael. After these components were properly established, the focus from project management changed to a focus on leadership. This leadership focused on developing the qualities of the group members as optimally as possible. This created a space where each group member was free to develop in areas where, with this experience, they can work with more confidence on an international project in the future.

In conclusion, it was a successful project in which each group member was able to successfully work out his own goal and the result is a tangibly improved Aquaponic Greenhouse in which fish can live and plants can grow for at least a week without human interaction. In addition, opportunities have been created for external students to develop. And as a last goal it can be said that the project has been successfully completed by achieving these goals with the help of project management.

Bibliography

Adafruit. (2021). Retrieved 11 23, 2021, from https://www.adafruit.com/product/381

Akvaario Keidas. (n.d.). Retrieved September 29, 2021, from Akvaario Keidas: https://akvaariokeidas.fi/en/

Aqara. (2021). Retrieved 11 27, 2021, from https://www.aqara.com/us/water_leak_sensor.html

Aquaponics Team, 2. (2020, May). *Novia.* Retrieved from http://eps.novia.fi/assets/Sidor/2/1545/Spring-2020-Hygrow-Aquaponics-Final-Report.pdf

Arduino. (2021). Retrieved from https://create.arduino.cc/projecthub/products/arduino-mkr-wifi-1010

BELBIN Associates. (n.d.). *The Nine Belbin Team Roles*. Retrieved September 23, 2021, from BELBIN Associates: https://www.belbin.com/about/belbin-team-roles

Bindel, T., & Hofmann, D. (2021). *Projektierung von Automatisierungsanlagen.* Wiesbaden: Springer Fachmedien Wiesbaden GmbH.

Citizen sensor. (2021). Retrieved 11 16, 2021, from https://citizensensor.info/nitratmesskit/#nitra4

climate-data. (2021, 03). Retrieved 11 29, 2021, from https://en.climate-data.org/europe/finland/vaasa/vaasa-6321/

Connor, N. (2019, 05 22). *Thermal-engineering*. Retrieved from https://www.thermal-engineering.org/what-is-expanded-polystyrene-eps-definition/

Dfrobot. (2021). Retrieved 11 16, 2021, from https://wiki.dfrobot.com/

Duck DNS. (2021). Retrieved from https://www.duckdns.org/abou

Ehrs, M. (2021, september 10). Scrum and Agile Project Management. Vaasa, Finland.

ESPHome. (2021). Retrieved from https://esphome.io/guides/getting_started_hassio.html

Europena Perch. (2021, 04 01). Retrieved from Fishing Planet: https://wiki.fishingplanet.com/European_Perch

Fishing Planet. (2021, April 1). Retrieved from https://wiki.fishingplanet.com/European_Perch

Globalpetrolprices. (2021). Retrieved 11 29, 2021

Google Maps. (n.d.). Retrieved September 29, 2021, from Google Maps: https://www.google.com/maps

Gordon, W. (2019, August 30). *pcmag*. Retrieved from https://www.raspberrypi.org/help/what-%20is-a-raspberry-pi/

Home Assistant. (2021). Retrieved from https://www.home-assistant.io/

Multitronic. (2021). *Raspberry Pi 4 Model B, 8 GB RAM*. Retrieved September 20, 2021, from Multitronic: https://www.multitronic.fi/fi/products/2650644/raspberry-pi-4-model-b--8-gb-ram?utm_source=vertaa&utm_medium=cpc&utm_term=%5B19919-1983476%5D%5Ba6f7af63-f97a-482a-b4d5-276bacdd9c0a%5D

Node Red. (2021). Retrieved from https://nodered.org/

Novia UAS. (n.d.). *Novia UAS*. Retrieved October 11, 2021, from novia.fi: https://www.novia.fi/novia-uas/

Nylund, R. (2021, September 8). BELBIN QUESTIONNAIRE. Vaasa, Finland.

Nylund, R. (2021, September 8). Team observation task. Vaasa, Finland.

Nylund, R. (2021, September 8). Temper Self-evaluation. Vaasa, Finland.

Pyranski, K. (2021, February 18). *Pyranski*. Retrieved from https://peyanski.com/home-assistant-remote-access

Schweizer-FN. (2021, 10 16). Retrieved 11 15, 2021, from https://www.schweizer-fn.de/waerme/waermeuebergang/waerme_uebergang.php

Sparkfun. (2021). Retrieved 11 27, 2021, from https://www.sparkfun.com/products/15569

TP-Link. (2021). Retrieved from https://www.tp-link.com/de/home-networking/smart-plug/hs100/

University of Vaasa. (n.d.). *University*. Retrieved October 11, 2021, from uwasa: https://www.uwasa.fi/en/university

Verburgh, A., Looverbosch, F. v., Lorenzoni, F., Dwenger, K., Bourras, M., Grabarczyk, N., . . . Toshev, R. (2020). *Hygrow Aquaponic System.* Novia University of Applied Sciences. Novia University of Applied Sciences.

Verheyen. (2019).

Appendix 1: Previous Piping and Instrumentation Diagram

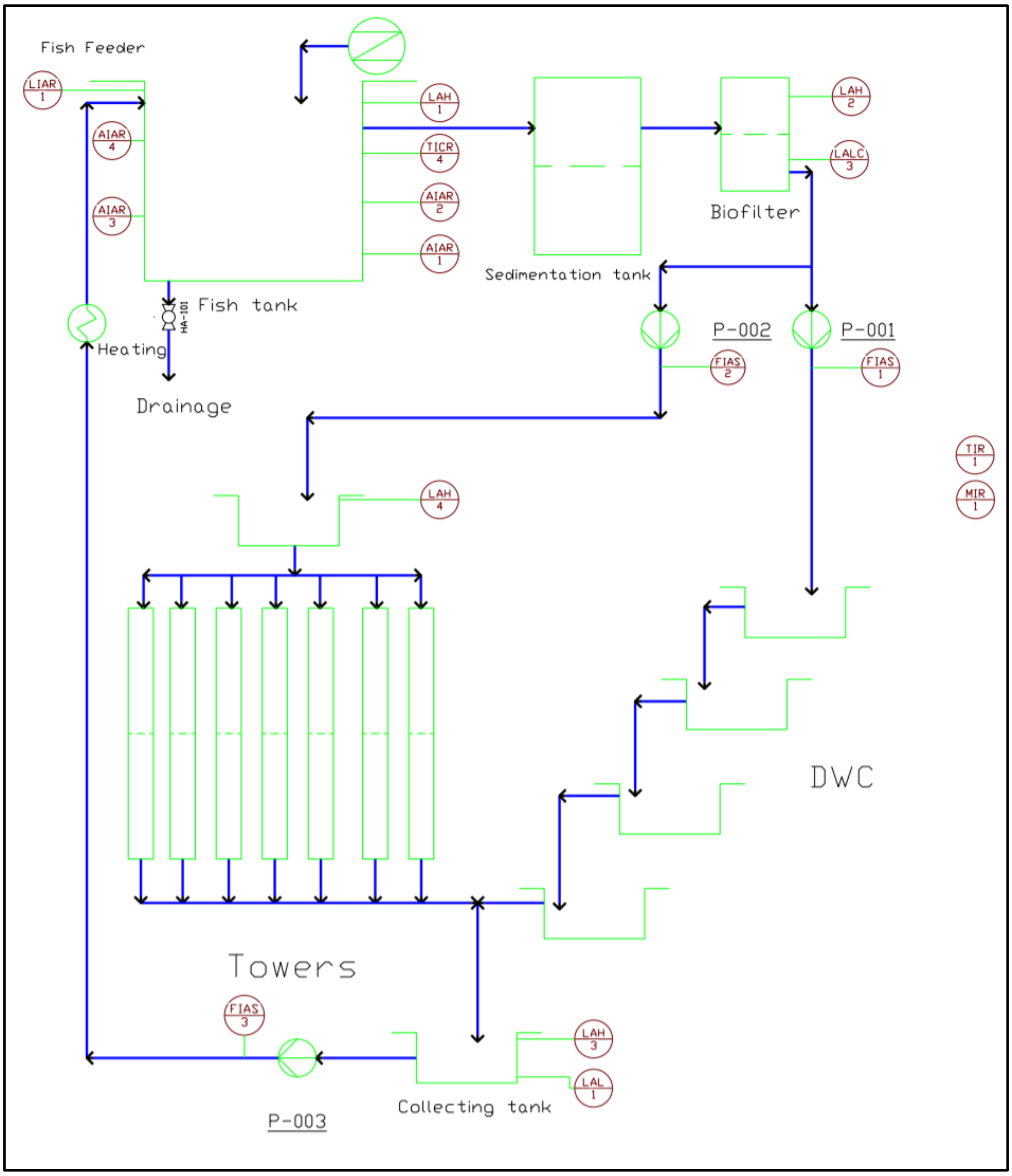

Figure 88: Piping and Instrumentation Diagram

Appendix 2: Risk Assessment

Table 11: Risk Assessment

Group	Risk	How to detect	Counteractions	Impact	Probability	Impact calculation	Probability calculation	Calculated care number
Aquaponic System	No power on the roof	System is not responding	Check electrical system beforehand, repairing it and covering it for water leakages.	3	3	9	9	100%
Aquaponic System	Power outage or shortage	Not getting responses from the system	Calculating the power needs before adding to the system	3	3	9	9	100%
Aquaponic System	No waterflow in the system	Checking the water flow	Regular check of the system	2	3	3	9	33%
Aquaponic System	Pumps fail	Regular check when turning on system	Researching automation possibilities	2	3	3	9	33%
Aquaponic System	Weather conditions	Regular check on the weather forecast	Installing heating system	2	3	3	9	33%
Project Management	Limited budget	Have a look at the provided budget	Calculating the most important costs	3	2	9	3	33%
Project Management	No possibility of getting fishes and plants within the budged	Prices being over the planned budget	Fishing, research to cheaper possibility or create a simulation instead of real-life-fishes.	3	2	9	3	33%
Aquaponic System	Dead fishes	No activity in the fish tank	Regularly checking the living condition in the fish tank	2	2	3	3	11%
Aquaponic System	Dirty water	Checking nutriens	Checking nutriens regulary	1	3	1	9	11%
Aquaponic System	Disease in fishes or plants	Checking fishes and plants	Adding fishes and plants with low disease-rate.	2	2	3	3	11%
Aquaponic System	Dying plants	Regular check on the plants	Installing lights, heating and cameras	2	2	3	3	11%
Aquaponic System	Evaporation tank empty	Checking the water level	Regular check of the system	2	2	3	3	11%

Aquaponic System	Excessive algae growth	Checking the water tank	Regularly run the system, keep the bacteria and nutrients and fishes alive	2	2	3	3	11%
Aquaponic System	Fishes and plants not getting enough nutrients	Changing colors of plants and fishes	Regular testing for nutrients	2	2	3	3	11%
Aquaponic System	Not enough food for the fishes	Testing of nutrients	Regular testing for nutrients	2	2	3	3	11%
Aquaponic System	Plants without roots	Checking the roots	Waiting with the seperation	2	2	3	3	11%
Aquaponic System	Pump tank empty	No water in the pump tank	Temporary turning of the pump of the pump tank and regulary checking the other pumps of the system.	2	2	3	3	11%
Aquaponic System	Seeds not being able to germinate	Looking at the seeds and check if they are growing	Changing the way that we are trying to make the plants.	2	2	3	3	11%
Aquaponic System	Tank breaks	Water leakage in the tank	Regular check of the condition of the tank and waterflow	2	2	3	3	11%
Aquaponic System	Water leakage	Regular check on the water level	Caulking the tanks, tightening the piping system or purchasing new tanks and implementing water level sensors to warn us of any changes	2	2	3	3	11%
Automation	Broken air pump	Fishes not getting enough oxygen	Regularly checking the living condition in the fish tank, implenenting a sensor that gives updates about the air pump	2	2	3	3	11%
Automation	Broken lights	Not having enough light in the Greenhouse/tank with fishes/plants	Checking where the problems comes from and testing out the switches	2	2	3	3	11%
Automation	Broken water level sensor	Not being able to track the water level in the fish tank	Regularly following the working conditions of the sensors	2	2	3	3	11%
Project Management	COVID-restrictions	When we are not to achieve our goals due to COVID-restrictions	Goals change as COVID measures become stricter.	3	1	9	1	11%

Project Management	Group member falls from the roof	Hear scream, poof and no sound after that while working on the roof.	Always work together on the roof and keeping safety-regulations in mind.	3	1	9	1	11%
Public Relations and Education	Not able to connect data from Greenhouse to the outside world	Website's information not corresponding with the actual data from the Greenhouse itself	Researching on possible ways to do so	2	2	3	3	11%
Public Relations and Education	Not enough capacity for managing the social media	Not taking the needed steps to complete our media strategy plan	Weighting up the needed help and strictly following the social media strategy plan	3	1	9	1	11%
Aquaponic System	Isolation on the tank is not enough	Checking water temperature	Isolate the water tank beforhand and checking of needs of isolation in cold weather	1	2	1	3	4%
Automation	Fish feeder broken	Fishes not looking healthy, sensor sends us a notification	Implementing a working sensor that gives updates on the condition of the fish feeder	2	1	3	1	4%
Automation	Lack of knowledge for implementing the automation systems	Not being able to successfully connect the system	Regular check with our coach Tobias if the actions we do are right	2	1	3	1	4%
Automation	Sensor failure	Not getting responses from the system or a sensor	Regular check of the sensors	1	2	1	3	4%
Automation	Sensor value out of range	Automation system is not working correctly	Checking if values are enough while setting up the sensors in the system.	1	2	1	3	4%
Project Management	Group member does not keep appointments	Weekly check-ups on each group member	Keeping track of each other's progress	2	1	3	1	4%
Project Management	Not reaching a deadline for studies	Not able to keep and stick to our schedule	Keeping track of each other's progress	2	1	3	1	4%
Project Management	Uneaqual expectations within the group	Talk about goals, progress and obstacles with our groupmembers	Talking about this within the weekly meetings	2	1	3	1	4%
Public Relations and Education	Educational content is not meeting the needs of the target group	Target group not interacting/learning from our content	Better research and adaption of their needs	2	1	3	1	4%

Automation	Raspberry Pi not working correctly	Not having a successful connection with live updates about the sensors	Check electrical system beforehand, repairing it if needed, check possible connection scenarios	1	1	1	1	1%
Project Management	Illness or injury of a groupmember	By informing other group members about illness of injury	Caring about COVID-restrictions within the group, helping others when needed.	1	1	1	1	1%
Project Management	Uneaqual expectations between the teachers and the group.	Detect differences in expectations in the conversations that we have with the teachers about our progress and goals	Having weekly meetings with our coach and regular meetings with the client	1	1	1	1	1%
Public Relations and Education	Advertisements not reaching enough people	Not having enough interaction	Following statistics about the website's traffic and improving the strategy based on the information	1	1	1	1	1%
Public Relations and Education	Lack of knowledge for technical parts	Struggling to create/improve the website	Getting help from other parties or the internet	1	1	1	1	1%

Appendix 3: List of materials from previous group

Table 12: General materials from previous group

Thing	Quantity	Notes	Working
Glass	1		
Cup	1		
Food fish	3	3 expired	
Fishing rod	1		
Fishing net	1		
neutral fertilizer	1		
Cleaning floor	1		
Screwdriver (set)	7		
Pliers	2		
Cutter	1		
Soldering iron	1		
Soldering tool	1		
Knife	1		
Scotch tape (black)	1		
Left back metal pieces and bolts (black tupper)	1		
Bolts 5.0x80 (blue box)	1		
PVC pipe (30cm aprox) (white)	1		
PVC pipe (30cm aprox) (grey)	2		
glue gun	1		
Silicone tube	1		
pair of gloves	1		
brush	2		
brush for dishes	1		
sandpaper p120 (little pieces)	1		
sandpaper p60 (little pieces)	1		
rubber strip	2		
plastico cilinder	2	little pieces	
Plastic wheel	2		
Conections between pipes	1	3 pipes	
	1	90º	
	1	2 pipes	
Connections between little tubes and a pipe	1		
Paint roller	1		
Tube	1	60 cm aprox.	
PP connecting pipe	1	not necesserily box	
big measuring cup	1		
bottle for watering plants	1		
S SmartStore piece of plastic	4		
plastic cilinder (different shapes)	3		
small bowl with holes and a lit	1		

Table 13: Electronic materials from previous group

Electronic things	Quantity	Notes	Working
Arduino (board Wi-Fi)	3		
Mini USB Stecker Type B	4		
Boden-feuchtigkeissensor	1		
Wasserpegelsensor	1		
Impulse switch	4		
vertikale lötpushinklemme rm - 17/23	16		
vertikale lötpushinklemme rm - 18/23	12		
VCC-RELAY.04	2		
VCC-RELAY.02	1		
Raspberry	1	Not box (Tobias)	
SD card (64gb)	1	Not box (Tobias)	
Router+cable	1	Not box (Tobias)	
Ethernet cable	1	Not box (Tobias)	
Plug extensión	1	Temporaly (Janitor)	
USB to ethernet adapter	1		
Vibration sensor	1		
Smart Wi-fi plug	1	Not box (Tobias)	
Terminal block blue 2.5smm	10		
Terminal block green 2.5smm	9		
Fuse terminal block graysih 35mm	5		
DIN RAEL CLAMP	???		
digital multimeter	1		
Circuit breaker B 1-poe (end-sleve)	~100		
digital multimeter	1		
Safety plug extension 2m Type F			
3782-PU banana plug	1		
tape cabinet clamp NK-40S	1		
heat shrink set - differnt sized	1		
releasable cable tie	~50		
3782-MU Banana plug	1		
cable ties black 2.5mmx100mm	~100		
soldering iron cable 100g	1		
vinyl electrical tape	1		
end locking piece ES35	~20		
cable ties 3.5mmx200mm	100		
connecting cable AJO.5-PU 300/5ooV	1		
connecting cable AJ1.5-SI 450/750V	1		
terminal block (kroonsteen)	10		
terminal headers gray	19		
strip cooper plate	3		
connecting cable AJO.5-MU 300/500V	1		
connecting cable AJO/5-KE 300/500V	1		
connecting cable AJO.5-TSI 300/500V	1-30m		
Plug extension 97H-MU	6		
connecting cable AJO.5-SI 300/500V	1-7m		
connecting cable AJO.5-HA 300/500V	1-7m		
power cable motor/engine cable	a lot		

red buttons (switch-spring return)	6
power cable (outside of the box) -red/yellow	a lot
insulation stripper (tool)	1
connecting cable AJO.5-OR 300/500 V0,5m	1-7m
connecting cable AJ1.5-KEVI 450/750V	1-5m
connecting cable AJ1.5-MU 450/750V	1-5m
connecting cable AJ1.5-TSI 450/750V	1-5m

Appendix 4: Risk Management Table Spring Semester 2020

Risk	how to detect	Counteractions	Priority	Probability
Water leakage from the system	Water level rapidly decreases, cracks on the tanks or piping ssytem are visible	Caulking the tanks, tightening the piping system or purchasing new tanks and implementing water level sensors to warn us of any changes	3	2
Plants death	The plants are withered	Controlling and maintaing proper humidity, temperature, water and nutrients levels	3	1
Plant disease	The plants show symptoms such as leaves yellowing, burnt spots, colour change. Pests or fungi are present on the plants.	Identifying the disease and implementing treatment such as organic insecticides, beneficial insects, polyculture. Separating infected plants from the healthy ones.	3	2
Fish death	Fish are dead	Controlling the ammonia concentration, pH, DO levels. Providing proper feed and preventing fish infections.	3	1
Fish disease	Fish behave unnaturally, lost vitality, have visible signs of disease	Identifying the disease and applying treatment, maintaining a low-stress environment, using proper fish stock density and feeding rates.	3	2
Excessive algae growth	Tanks surfaces are coverd with thick algae film, pipes are clogged with algae and fish have limited access to oxygen	Covering the tanks and piping system to prevent sunlight passing through tanks, introducing algae eaters such as koi carps, shrimps and snails	2	1
Damaged oxygenation system	Fish gulp of air from the water surface, swim less vigorously and eat less	Buying air pump and monitoring the dissolved oxygen level	3	1
Damaged sensor system	Sensor do not work or its measures are extremly out of range	Fixing or buying new sensor	3	1
Waste overfilling	The bottom of tanks is excessively covered with waste	Implementing shrimps, monitoring Total Dissolved Solids level, and frequently cleaning the system	1	1
Water pump stops working	There is no waterflow in the system	Fixing and cleaning the pump or buying a new one.	3	2
Water does not flow through vertical towers	The foam in vertical towers is dry and plants are withered	Checking the water pump, piping system and nozzles and repairing them if they stopped working	3	1
Failure of temperature control	Measuring the system temperature when we see worsened fish and plant well-being	Online monitoring and automatic control with alarm system	2	2
Rapid evaporation of water	The level of water in the system rapidly decreases	Online monitoring and automatic control with water level system. Covering the tanks.	2	1
Seedlings do not grow	The new seedlings do not germinate and grow	Adjusting lighting period, temperature and frequent watering	2	2

Priority & Probability	1-Low	2-Middle	3-High

Abbreviations

AC	Alternate current
DC	Direct current
DNS	Domain name system
DO	Dissolved oxygen
DWC	Deep water culture
EPS	European Project Semester
MQTT	Message Queuing Telemetry Transport
P&ID	Piping and Instrumentation diagram
RCD	Residual Current Device
SD	Secure Digital
UI	User Interface

Table of figures

Table of tables