A sustainable solution to grow aromatic plants in small houses – An EPS@ISEP 2017 Project

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ABSTRACT

This paper presents the development process of a sustainable solution to grow aromatic plants in small houses. The solution is called The GreenHouse and it's meant for people who live in small houses or city apartments and want fresh, home grown aromatic plants but don't have the time or space to grow them. The solution is intended to be sustainable and fit in a modern world where people are concerned with eating healthy, fresh food. Research and discussions within the group were done to develop the product. The existing solutions for growing fresh food in industrial and domestic applications as well as marketing, sustainability and ethical topics were researched and discussed. This way it was possible to set the requirements The GreenHouse should have to fit its purpose. The GreenHouse is semi automatic and doesn't require much interaction from the customer. It has two covers, one winter cover and one summer cover, that will be changed depending on the season and weather. Solar energy and rainwater are used to enable the aromatic plants grow, making this a sustainable system. The support is adaptable and made to fit different types of bars so it can be hanged on balconies or windows.

CCS CONCEPTS

• Social and professional topics → Sustainability; **• Applied computing → Collaborative learning**;

KEYWORDS

Project-based Learning, Collaborative Learning, Sustainability, Greenhouse

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1 INTRODUCTION

Eating good and healthy is a hot topic these days. People are more and more concerned with what they eat and drink. Because of this trend, the demand for fresher and healthier food is bigger than ever. Most of the time global supermarkets don't supply food that is fresh enough for this new generation of foodies. So, if people want this really fresh and healthy food, they have two choices: buying it in bio or local market, or cultivating it themselves [5].

It was with this second option in mind that the Pingun team (team 4) of the EPS@ISEP 2017 embraced the "The GreenHouse" project, especially at those who have an active and busy life, so they don't have time for cultivating this fresh food.

This paper was written within the European Project Semester at ISEP. The project is a whole semester, done in group. The group consists of four to six different students with different nationalities and educational backgrounds. This paper describes the most important parts of the project developed by team 4 at ISEP.

The GreenHouse lets the consumer grow aromatic plants in a bright and limited space, perfect for city apartments and small houses. Its features help protect plants from the sun and rain in the summer and keep them warm in the winter while leaving them light. Thanks to its rainwater collector, The GreenHouse can irrigate plants automatically.

The aim was to make a semi automatic greenhouse that is specially built for people who live in apartments or small houses with balconies. The GreenHouse will allow growing and cultivating aromatic plants almost independently.

To better explain the scope and development of The GreenHouse project, this paper is structured in three sections. Starting with the research and discussions on existing solutions for growing food in industrial and domestic applications as well as discussions on marketing, sustainability and ethical topics. This way it was possible to define the needed requirements for The GreenHouse. Afterwards the solution, The GreenHouse and its features are described. Finally,

Table 1: Advantages and disadvantages of scientific greenhouses

Advantages	Disadvantages
Preserves rare plants	Presence of plants only
Educational purpose	No trade in plants
Scientific research	Expensive
	Long maintenance time

a conclusion is given with a summary of the main points as well as a future recommendation to further this project.

2 SATE OF THE ART

A greenhouse is a structure intended for plants growth with a specific controlled atmosphere (temperature, humidity, light…). It is used to project a faster growth of plants or in some countries where the climate is not appropriate, to correspond to the needs of the plants. It also permits to have vegetables and fruits all year long and not just for a season. There are two types of uses: industrial or domestic. Moreover there are a lot of different possibilities to build a greenhouse, and a lot of different possibilities to make it work [16].

This chapter describes the current existing technologies to cultivate plants. For each type of cultivation technology,a description as how they work, which type of functionalities they have, and what their specific purpose is, is presented.

After the description of all the different types of cultivation technologies, a comparison of all their functionalities is included to sustain the chosen type for The GreenHouse.

2.1 Existing greenhouses

2.1.1 Scientific and touristic greenhouses. The purpose of The New York Botanical Garden is to collect a large variety of plants that come from different continents to study them but also to exhibit them in one place. This way tourists or locals can enjoy the scarcity of plants and school's may visit it for an educational purpose [14].

The building is organized with eleven glass pavilions that are all open on the inside. The structure of this house is made with glass and metal. To provide shadow, some parts of the glass are grounded. Each pavilion house has a different group of plants representing various weather conditions found around the globe.

The Conservatory is a grand victorian-style crystal palace made up of eleven interconnected glasshouse galleries. The center piece is a glass dome that features a large collection of the world's palms under glass. The other ten glasshouse galleries are arranged in pairs on either side of the Palms of the World Gallery, each one displaying a different natural habitat and offering visitors an environmental tour around the world.

Table 1 includes the advantages and disadvantages of this system.

2.1.2 Industrial greenhouses. These allow growing plants massively in order to sell them. This type of greenhouses may be formed into three categories: low technology, medium technology, hight technology.

Table 2: Advantages and disadvantages of low technology greenhouses

Advantages	Disadvantages
Sustainable	Sales restricted geographically
No pollution	No mass culture
Biological food	Only seasonal plants

Table 3: Advantages and disadvantages of medium technology greenhouses

Advantages	Disadvantages
Large production	Cooling provinence
	Pollution of the sea with plastic wastes

Low technology greenhouses use low technology to grow vegetables thus contributing to being sustainable and eco-friendly. For cold winter, Eliot Coleman, a grower specialist in low technology greenhouse production wrote a book titled "Winter Harvest Handbook" explaining how it is possible to grow plants without technology during winter with a cold house [4]. The purpose for Eliot Coleman is to expand the production season using other method than technology.

This type of greenhouse has a tunnel or igloo shape with metallic skeleton and plastic cover. They have poor ventilation but their structure is relatively inexpensive and easy to erect.

To protect the vegetables a plastic cover is necessary and it permits to keep the warmth in the soil. This double protection also allows the relative humidity to increase, protecting the plants against frost.

To control the plants growth, Eliot Coleman explains in the methods and tricks to improve the growth of plants without using technology. These include the construction and maintenance of greenhouses, planting schedules, crop management and harvesting practices [3].

Table 2 contains the advantages and disadvantages of this system.

Medium technology greenhouses have a tunnel or igloo shape with metallic skeleton and plastic cover.

Plants don't touch the soil - they grow from bags filled with oven-puffed grains of white perlite stone. Chemical fertilizers are drip-fed to each plant from a wide computer-controlled vat.

Table 3 contains the advantages and disadvantages of this system.

The Dutch Venlo greenhouse is the most popular of the greenhouse structures and a perfect example of a hight technology greenhouse. Its characteristics are adapted for growers and suppliers [12].

The Venlo greenhouse has a simple structure. It is composed by a basic steel structure and an aluminum roof system which requires low-maintenance [13].

Due to excessive ground production in the Netherlands, groundwater has been polluted, which forced producers to remove their crops from the soil. New irrigation systems had to be found. The hydroponic system was one solution. This system is based on the growth of the plant. Gutters are suspended from the structure of

Table 4: Advantages and disadvantages of high technology greenhouses

Advantages	Disadvantages
Big varieties of products	Expensive
Big production	

Table 5: Advantages and disadvantages of greenhouses in gardens

Advantages	Disadvantages
Fresh food	You need a garden with space
You can grow your own plants	Plants need maintenance
	It is expensive

the greenhouse, mineral wool carpets are placed on the gutters as a hydroponic medium. The plants are hydrated by a drip irrigation system where water is collected by the gutter. Excess water with minerals is collected in a drainage tank to eradicate all possible diseases. In many cases, the drained water is treated by a UV sterilizer with enough energy to destroy harmful bacteria and viruses.

Table 4 contains the advantages and disadvantages of this system.

2.1.3 Domestic greenhouses. Greenhouses in gardens have a medium size, that is to say consumers can't put it inside the house but they can put it in the garden. A large amount of plants can be grown while controlling the atmosphere.

Greenhouses in gardens have two types of shades: the first one is tunnel like in Figure 20 and the second one is the same shape and size as a garden shed. The tunnel is made with a wooden or metal structure and covered with transparent plastic. The second shape is also made with a wooden or metal structure and covered with plastic or glass. They have a door and windows for the aeration. The wooden or metallic parts are the skeleton of the greenhouse. The plastic or glass part covers the structure to keep the warm and let through the light needed for the growth of plants.

The watering can be manually but also automatic like with a fogger or drip irrigation. It depends on the consumer's budget budget and the free time for hobbies. Drip irrigation system allows a continuous irrigation of the greenhouse thanks to a system of pipes to dispose at the feet of your crops. The system is controlled by a thermostat that provides the amount depending on the ambient temperature. You must connect the watering system to a water inlet or to a rainwater collector. The amount of water can be adjusted individually by planting.

To isolate the inside, bubble wrap is used. To bring shade the consumer can use a shade net. Finally there exist several types of heating: electric heating, heating oil, fans and heating table with electric heating cable.

Table 5 contains the advantages and disadvantages of this system.

Thanks to this research, the team had a better idea of what a greenhouse was. For the project, the first requirements chosen was to build a domestic greenhouse with an automatic irrigation system. However, the team would like to target a different type of audience than those with a garden, and would like to offer the opportunity for people living in cities to grow their own plants. That is why the research is extended beyond the greenhouses.

Table 6: Advantages and disadvantages of indoor allotment

Advantages	Disadvantages
It takes small space	Maintenance needed
Own plants	Only three pots
No need for garden	

Table 7: Advantages and disadvantages of AeroGarden

Advantages	Disadvantages
Low maintenance	Only AeroGarden products
5 times faster growth than soil	Power outlet needed
You can grow anything	
LED lights are low cost	
No need for land to use	
No mounting when receiving	

2.2 Cultivation possibilities in a small space

2.2.1 Cultivation without technology. Indoor allotment is a miniature garden with three pots that the consumer can put inside on the kitchen and grow small plants like aromatic plants. There is no technology so all gardening is done by the consumer as for a real garden [11].

Table 6 contains the advantages and disadvantages of this system.

2.2.2 Cultivation with technology. Aerogarden is a little greenhouse reserved for indoor use in a kitchen. The Aerogarden permits to grow five times faster than to put the vegetables in normal soil. This way the consumer can grow any plant (within the limit of plants proposed by the brand), at any time of the year and without much maintenance. It automatically creates optimal conditions for the plants by turning grow lights on and off to simulate the sun, and reminds the consumer when to add water and nutrients [1].

It informs the consumer when he has to add water, nutrients and turn on the light. The reservoir provides the root system with an abundant balance of oxygen, water, and nutrients to enable plants to grow five times faster than when grown in soil.

Concerning the lighting system, it provides high performance, energy efficient around 30.00 W LED lighting for plants. This garden tailors the light spectrum to help plants thrive, concentrating daylight white LED lights for fast growth, blue LED lights for bigger yields, and red LED lights for more flowers and fruit.

Table 7 contains the advantages and disadvantages of this system.

2.3 Conclusion

After the research in the state of art, the team decided that The GreenHouse would be a mix between Aerogarden and the domestic greenhouse. It would be a semi-automatic greenhouse that can be put on balconies. The first and most important requirement was that it could work in winter and summer in different environments. A specific cover for winter and for summer would be made to provide this use in different environments. It had to be multifunctional. The GreenHouse concentrates on domestic use. It would be made especially for small size aromatic plants. The interaction with the customer should be as little as possible. It would have an automatic irrigation system. The GreenHouse would be powered by batteries or solar energy, this way a socket is not needed nearby. After the general requirements of The GreenHouse were set it was time to take a look at how the project would be managed and controlled.

3 METHODOLOGY

3.1 Project Management

To get a project to a successful end, it is important to implement project management tools to ensure that all of the appropriate skills, methods, resources and knowledge are used in an optimal way. The team started with identifying the scope of the project. With this scope it was possible to define the different tasks and deadlines. These deadlines and tasks were then arranged in a Gannt chart. The Gant chart proved to be a helpful tool to manage all the resources together with all the different tasks. If new tasks would rise the team would be able to plan them well, to be sure other tasks weren't affected by the new ones. To ensure the quality and to keep track of the budget, the team made an overview of the different types of materials and components that were needed for the prototype. When new components or materials had to be added, the team had to take a look at the quality and budget management to see if it fitted in the project. With a project, different risks can lead to big problems. To minimize these problems and try to prevent these problems from happening, a risk analysis was made with the most important risks and solutions to minimize them. Decisions in projects are made and influenced by different stakeholders in a project. It is important that every stakeholder is provided with the information they need when new decisions are made. An overview of all the different stakeholders was made so the team was able to know what the influence was of every stakeholder. This way important decisions were communicated and discussed correctly with the appropriate stakeholder. With the help of all of these managing tools the project stayed structured and didn't lose its direction to the end product.

3.2 Marketing Plan

To identify the target market, a complete market analysis was done. Out of these market analysis it was chosen that The GreenHouse was intended for young people who care about healthy lifestyle and live in cities. This was chosen because nowadays healthy eating has become really important [5]. Most of the time, in cities, people buy aromatic plants in the supermarket because it is convenient. They don't have space to have a garden and they don't have time to cultivate. Consequently, the team decided to create a product that can be put on balconies and doesn't take up much space. In The GreenHouse, the customer can grow their own aromatic plants and thus consume fresh aromatic plants for cooking. In addition, it was decided that The GreenHouse does not require much maintenance from the consumer. The irrigation method is fully automated as well as the summer cover movement. This way the consumer can enjoy his free time without having to look to much at The GreenHouse.

3.3 Eco-efficiency Measures for Sustainability

Since real sustainability is standing on three pillars (economic, environmental, social) the company is focused on all three of them [17]. The team decided to use natural resources (like wood), to design the product to be a long live product, to use as little energy as possible and the amount of unnecessary material left overs will be the minimum possible. Broken parts can be replaced and ordered, in order to reduce waste. If the costumer decided to stop using the product, it is possible to send the electronic parts back to the company (in exchange for a small sum). The company can reuse these components. The product uses mostly sun and rainwater to provide growing conditions, just little energy is needed to run the control system and the motor for the sun/rain cover. The company is part of a network of sustainable operating businesses. This leads to healthy and long lasting relationships with other companies. The sustainability aspect of the company is used for advertising, to meet the growing need of people of a green life style. The company also takes seriously the mission to increase the quality of the social environment. The product itself shall work as a catalyst for people to get in touch with nature again. The company also wants to educate people, for example, school classes. Therefore different groups are invited to the company. This shall encourage to follow their sustainable ideas.

3.4 Ethical and Deontological Concerns

In the project there were four different parts that relate to ethical en deontological concerns. These were the following Engineering, Sales and Marketing, Environmental and finally liability ethics.

For the engineering ethics the code of ethics from the NSPE (National Society of Professional Engineers) was followed [15]. Because of this code, the team made some important decisions. The wood would be treated so that it wouldn't splinter too fast and was safe for all people. Electrical components were made so that they were well protected, in the way that it couldn't electrocute anybody. Plugs and protection boxes were used to protect all the electronic parts from touching people when handling The GreenHouse. Or even when an error should happen, the current would not be to high.

The marketing and sales part was based upon the code of ethics for marketing developed by the American Marketing Association [2]. It was taken into account that everything was showed totally honest as it is. Defaults or errors with certain parts of The GreenHouse were communicated directly with all the stakeholders. A good feedback and communication system, so the team was sure that a good and respectful relation with every stakeholder was built.

In the environmental part it was important to look at the different materials and components that would be used as well as how the resources would be used in the company. The team decided that this would be an important part of the project. The company wanted to be an environmental friendly organization. That's why it was chosen to use materials as wood and cork, which are both materials that could be easily recycled.

The last part of ethics is liability. In this part of ethics it means the company is responsible for every action it does. To be completely good with liability, the team made sure the product was made by the rules of the following EU directives:

* Machine Directive [8]
* Electromagnetic Compatibility Directive [6]
* Low Voltage Directive [7]
* Radio Equipment Directive [9]
* Restriction of Hazardous Substances (ROHS) in Electrical and Electronic Equipment Directive [10]

4 SOLUTION

4.1 General Architecture

The GreenHouse has two different covers: one for cold weather (winter cover) and another one for warm weather (summer cover). The winter cover is rigid, removable and made of a transparent foil. On the other hand, the summer cover is an automatic rotational awning cover that protects the plants from the sunlight and from the rain at the same time. The summer cover is fixed and it closes automatically leaving a space between the structure and itself. During the winter, The GreenHouse works as a traditional greenhouse. In these cold months the winter cover must be placed on top of the product to ensure that the temperature inside is warm enough. During the summer The GreenHouse works as a shade house providing the aromatic plants of a pleasant environment.

The general structure is the part of The GreenHouse which is composed by:

* The water tank
* The irrigation system
* The rain water collector
* The electronic box
* The frame
* The panels

The general structure allows containing the pots with the plants and watering them. Figure 1 shows the general structure as an exploded view. The frame is composed of wood, while the panels are made of marine plywood. The team also decided to use cork as isolation for the final product. The cork is glued to the panels. For the prototype, the cork was replaced by foam in order to stay in the budget.

The final product is sold as a kit. This means the consumer assembles the product himself. This takes no longer than thirty minutes. The frame is therefore composed of different pieces that fit together with screws. This choice was made to keep the packaging as small as possible.

4.2 Summer Cover

The summer cover is the part of The GreenHouse that requires an electronic operation. Once fixed to the assembly, this part no longer moves. It is actuated by a motor that can open or close the summer cover. Its role is to protect the plants during warm seasons. It is made with a material that reflects the sun's rays and provides shade.

When the temperature gets above 31 °C, the temperature sensor sends a signal to the control system that will activate the mechanism. The cover opens to shade the plants. However, it will not completely close the structure to prevent the plants from suffocating. It is therefore half open to let the plants breathe. When the temperature drops under 30 °C, the cover returns to its original position.

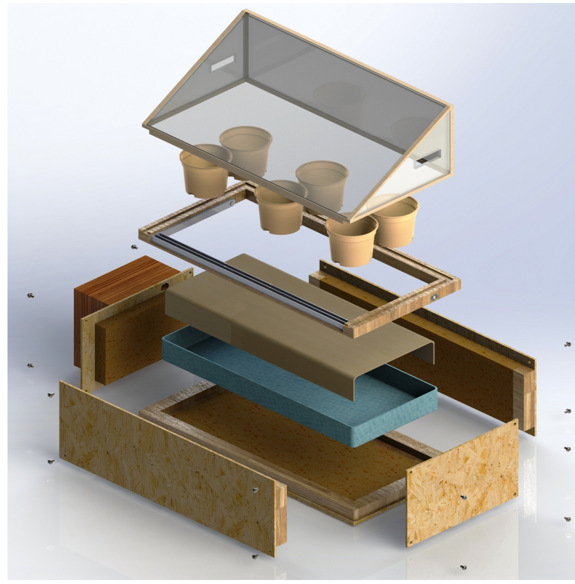

Figure 1: General structure as exploded view

The choice of these two temperatures was made to provide a hysteresis and preventing the cover from opening and closing all the time.

The second role of this cover is to protect the plants from heavy rain. Thanks to a rain sensor, it closes to protect the plants and opens when it does not rain any longer. The cover just protects the plants in case the rain is too strong and damages the leaves.

4.3 Winter Cover

The winter cover is operated manually. It is a part that can be detached from the assembly and stored during warm seasons. The customer must use it to protect the plants from the cold during the winter. The cover is made out of transparent foil and has a marine plywood frame. Thanks to the temperature sensor and a yellow LED light, the consumer is notified when the temperature is too low and therefore knows when to change the winter cover. The winter cover for the final product can be folded, in order to save space for the storage. It is made foldable with the help of hinges. The folding system wasn't applied to the prototype, because it would take too much time.

Initially, the winter cover was a triangular prism with horizontal base and the side walls were of the same size. Because of the following reasons it was changed to a triangular prism with horizontal base but one of the sides create a 90° angle with this base:

* The triangular prism with the rectangle angle is easier to manufacture or build which makes this task simpler.
* The first model requires a central attachment point which would mean a line of shadow in the center of the greenhouse.
* The elimination of the central bar line provides of a greater sun exposure surface that is useful to help in rising the temperature of the greenhouse during the cold months.

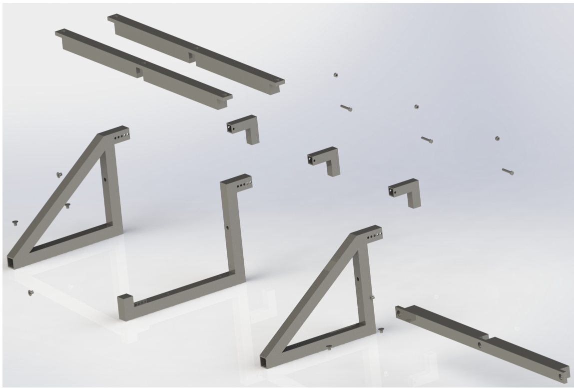

Figure 2: Assembly of support system

* 90° angle facilitates the storage of the cover allowing it to be allocated in corners and occupying less space than the initial model. It also gives space to storage things inside.

4.4 Support System

The support system which makes it possible to put The GreenHouse on the outside of the balcony is maybe the most important functionality of the product. The support holds The GreenHouse on the balcony, this way the customer doesn't lose any space inside the house. To sell the product as a kit, the supporting system comes as a bunch of small parts, which are to be assembled by the customer in an effortless way. The supporting system can be adjusted to the size of the balcony to increase the versatility of the product and to make sure that it will fit to any kind of fences or balconies. The support system is made of steel tubes stacked together by screws securing the position of these tubes. The tubes on the top of the support system allow to regulate the position when fixing it to a fence in a window or balcony, giving the possibility of opening or closing the measure depending of the size needed. All the tubes can be connected and fixed easily using screws and hexagonal nuts to make the assembling simpler and intuitive for the customer. Figure 2 shows this assembly.

When building the prototype there was limited time and budget so the best option was to weld all the tubes together avoiding the usage of all the screws and creating a fixed structure that can develop the same function as the real one but without the possibility of disassembling it. In addition, this option allowed the team to have the opportunity of experimenting in welding steel.

4.5 Irrigation System

For the irrigation system, the team decided to adopt a new method that is similar to mat irrigation. The team wanted to avoid using too much energy and tried to make The GreenHouse as automatic as possible. Because of this, the principle is the same as the mat irrigation, but the mat is made from glass fibre material. This mat sucks the water from the water tank placed at the bottom of The GreenHouse (capillary effect). This way the mat is always wet, without the need of the costumer to water it every day. Wicks are connecting the pots with the mat on the bottom. For the prototype, the wicks are going directly from the pots to the water tank, because a mat would cost to much. Figure 3 shows the irrigation system.

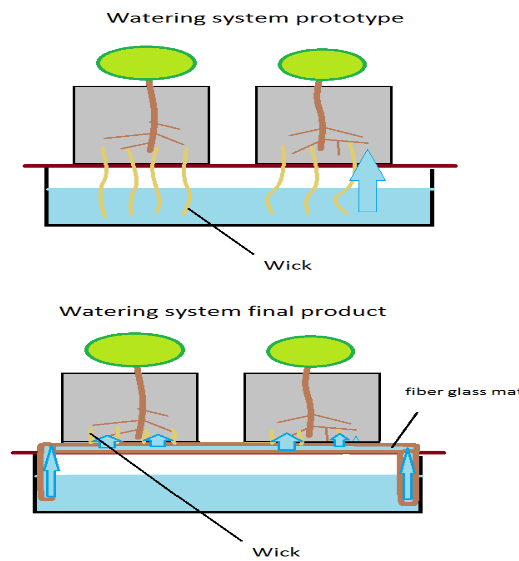

Figure 3: Irrigation System

4.6 Waterproofing

In order to make the product waterproof, the team decided to use marine plywood and a special sealing for the wood. This solution is more expensive and was not used for the prototype. The prototype is made of normal chipboard. Marine plywood is made of special water resistant wood and glued with very little gaps between the wood layers in order to prevent water from entering. The sealing for the final product gives the wood an extra protection against water and moisture. There are many sealing-products without any toxics available.

The products inside always has a lot of moisture trough the water tank and watering system. The team decided to use a black waterproof foil on the inside of the product. It covers the whole surface of the inside. The benefit of the foil isn't just the waterproof effect, furthermore it's easy to clean and the black colour gives an extra heating bonus in winter times trough a higher rate of absorption of the solar energy.

4.7 Water Level Warning System

The team decided to use a float sensor to check the water level on a certain (critical) point. If the water level goes lower than this point, the control system activates a red warning LED light. This red LED light informs the user about the low water level inside the water tank, so they can fill the tank manually with water. The float sensor is fed separately from the Arduino Uno. This way the float sensor is always working, even if the power switch is inactive.

To prevent rainwater overflowing the water tank, the team decided to make a hole at the top of the water tank. This way, if the water tank is to full, the water will flow out of the tank.

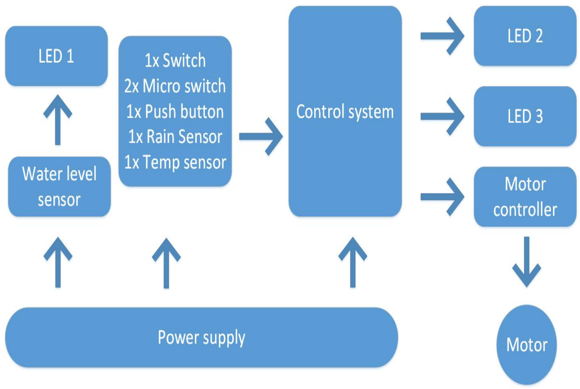

Figure 4: Black Box Diagram

4.8 Winter Cover Warning System

A yellow LED on the outside of The GreenHouse shows the user when the winter cover must be placed on the product. The temperature sensor will provide the control system with the necessary information. When the temperature drops under 5 °C, the yellow LED lights up. This means the customer must place the winter cover on The GreenHouse. The yellow LED light will keep lighting up for the time the winter cover is needed. When the temperature goes over 6 °C, the yellow LED light will stop lighting up, meaning the winter cover is no longer needed.

4.9 Electronic Connection

Figure 4 shows a simplified overview of the connection of the different electronic components. The temperature sensor and the rain sensor are connected to the Arduino Uno control system. The Arduino Uno controls the winter cover warning LED light and the motor to open or close the summer cover. A power switch is placed to power on The GreenHouse. A green LED light, lights up to show The GreenHouse is getting its power and working. A push button was added to manually open or close the summer cover in case of problems. For the control system to know if the summer cover is open or closed, two push sensors were added. These push sensors are actuated when the summer cover is fully closed or fully open.

5 TESTS AND RESULTS

5.1 Introduction

This chapter deals with the testing of the prototypes components. The testing is a really important part in the process of creating a product. It reveals technical problems which were undiscovered through the previous developing process. Furthermore gained the team additional information about some electronic components, which helped to redefine the Arduino coding. The group single tested the different main components.

5.2 Temperature Sensor Test

The temperature sensor is one of the two main inputs for the control system. The opening or closing of the summer cover is dependent on this input. It is thus important that this input is calibrated correctly. To test this accuracy, at different temperatures a thermometer (normal household mercury) was placed next to the temperature sensor to measure the difference between them. The first test was at normal room temperature, the second one in an box of ice water and the last one with a hair dryer warming up the temperature sensor and thermometer. Table 8 shows the results of this test. The first line shows the values of the thermometer, the second line of the temperature sensor and the third line shows the differnce between the two. Out of this data the team concluded that the expected difference in accuracy, of 1 °C – 2 °C, was noted. The difference is always in the positive direction. Which means the temperature sensor sensed a little bit to high. Because of this, the team decided to set the changing temperature of the Arduino, the temperature were the summer cover would open or close, a little higher. At 31 °C instead of 30 °C.

Table 8: Temperature sensor test results

Room temperature	Ice box	Hair dryer
26 °C	0 °C	47 °c
27 °C	2 °C	48 °C
+1 °C	+2 °C	+1 °C

Table 9: Rain sensor test results

Debit	Flat (0 °)	Diagonal (45 °)
1 ml/s	Raining	Not raining
2 ml/s	Raining	Not raining
5 ml/s	Raining	Raining
10 ml/s	Raining	Raining

5.3 Rain Sensor Test

The rain sensor is the second main input for the control system. For this sensor it was important that it gave a right signal at the right amount of rain. To test the amount of water needed for the rain sensor to give a signal, the team decided to work with water sprayers. The rain sensor was put in two positions, flat and diagonal with a angle of 45°. Table 9 shows the results of this test. It was clear that if the rain sensor is put flat, the debit doesn't matter. Even with a little bit of water the rain sensor will give the signal when it's raining. When the rain sensor is placed diagonal, the debit needed was 5 ml/s. Which was a perfect debit in order not to damage the plants.

5.4 Water Level Sensor Test

Trough testing the water level sensor and the water tank, the team wanted to gain data about the volume which activates the water level sensor (can be seen as a switch) and the maximum capacity of the water tank. The team installed the water level sensor inside the water tank. the sensor was connected to the red LED light. The team filled the water tank slowly with water until the water level sensor was triggered. The water volume, which triggers the sensor, was 0.9 l. The maximum water volume was 1.2 l. It is important to remember, that the water tank is quite small, because it is part of the significant smaller prototype. The real size of the water tank

Table 10: Irrigation system test results

Wick A	Wick B	Wick C
4 mm	3 mm	7 mm
5 ml	0 ml	21 ml
120 ml	0 ml	504 ml

would be 44 cm x 22 cm x 8 cm (without volume loss, because of foil / inner structure) what gives us a maximum capacity of 7.7 l and a triggering water level of 1.8 l. Which would be a good result.

5.5 Irrigation System Test

The irrigation system is maybe the most interesting feature of The GreenHouse. Using the capillary effect in order to provide the plants with the perfect amount of water was a new concept for the whole team. Therefore an intense field study was necessary to proof the reliability of the concept. The team had three different kind of wicks to test. Wick A was assembled out of three smaller wicks, which find use for example in candles. Wick B was also a normal candle wick. Wick C was self-made and made out of a fiber glass mat. The team filled one glass with a water level scale with water and connected one wick in it. The other end of the wick went to the top. Another bigger glass, filled with tissues, was put on the top of the small one with the wick. The bigger glass minimized the effect of transpiration. The test was done with normal room temperature and air humidity. The wick started through capillary activity leading water from the small glass to the tissues on top. With the help of the water level scale of the small glass, the team could figure out, how much water went through each wick after one hour. Table 10 shows the results of this test. The first line shows the diameter of the wicks, the second line the capillarity activity in one hour and the last the capillarity activity in one day. Wick B failed the test, the capillary activity was too weak to bring the water up to the tissues. Wick C seemed to be the best solution for The GreenHouse. Wick C can lead half a liter per day to the root of a plant.

6 CONCLUSION

The main objective of this project was to develop a sustainable solution for growing fresh aromatic plants in small houses. Before starting to develop a product, a lot of research was required. For this research it was best to start with evaluating the different existing solutions to this problem. The second aspect that needed research and discussions were the different topics of project management, marketing, sustainability and ethics. Out of all this research the different requirements of The GreenHouse were set. The GreenHouse is made for people who want fresh and healthy food but don't have the time or space to grow it themselves. It has two different covers that have the right purpose depending on the weather. It is made as sustainable as possible by using recyclable materials and consuming very little energy. Because of its specific features and target it will fit right in a modern world, where sustainability and healthy eating are more important than ever. Off course a product is never completely finished. Improvements can always be made. In the case of The GreenHouse further improvement in the sustainability factor of the product can always be made. The reasearch and development done by team 4 (team Pingun) of the EPS@ISEP provides a good base to work on new sustainable products and greenhouses. For example a sustainable greenhouse for gardens, or even for industrial purposes.

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