Report

CoffeeMush

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Acknowledgement

Glossary

Table 1 contains all abbreviations and their meanings.

Table 1: Glossary

Abbreviation	Description
ABS	Acrylonitrile Butadiene Styrene
AC	Alternating Current
AI	Artificial Intelligence
API	Application Programming Interface
CAD	Computer-Aided Design
CE	Conformité Européenne (European Conformity)
CEO	Chief Executive Officer
DB	DataBase
DC	Direct Current
dB	Decibel
EC	European Commission
EPS	European Project Semester
EU	European Union
GB	Gigabyte
GPIO	General Purpose Input/Output
HEPA	High Efficiency Particulate Air
HTTP	Hypertext Transfer Protocol
HTTPS	Hypertext Transfer Protocol Secure
I2C	Inter-Integrated Circuit
IO	Input/Output
IP	Internet Protocol
ISEP	Instituto Superior de Engenharia do Porto
ISO	International Organization for Standardization
KB	Kilobyte
LCA	Life Cycle Analysis
MP	MegaPixels
MQTT	Message Queuing Telemetry Transport
NSPE	National Society of Professional Engineers
PBI	Prioritize Backlog Items
PC	Personal Computer
PESTEL	Political, Economic, Social, Technological, Environmental, Legal
ppm	parts per million
RAM	Random Access Memory

Abbreviation	Description
RH	Relative Humidity
ROHS	Restriction of Hazardous Substances Directive
SWOT	Strengths, Weaknesses, Opportunities, Threats
TCP	Transmission Control Protocol
TV	Television
UART	Universal Asynchronous Receiver/Transmitter
USB	Universal Serial Bus
Wi-Fi	Wireless Fidelity

1. Introduction

Welcome to the exciting project dedicated to the creation of an innovative kitchen mushroom grower! In an era where thinking about sustainability and environmental responsibility is crucial. Today's environmental challenges are forcing a reconsideration of how waste is managed, in particular coffee waste resulting from everyday habits. It is in this context that this project was born, which aims to make an efficient composter accessible to everyone. The aim is to make the product of the composter useful.

This first chapter will introduce the project of CoffeeMush. Firstly the team will be presented in the next paragraph. Then the motivation, problem, objectives and requirements of the project are explained in the following sections. After that the functional tests that need to be done to test the prototype of the product will be explained. Finally, the project planning and structure concludes the introduction.

1.1 Presentation

This project was done by a group of 6 engineering students from different study fields and countries in Europe. The table 2 underneath presents team 1 who worked on CoffeeMush for the European Project Semester.

Table 2: Group presentation

Name	Origin	Background
Hugo Boulay	France	Mechanical Engineering
Nils Kötting	Germany	Mechanical Engineering
Noor Stapel	The Netherlands	Civil Engineering
Miro Heller	Belgium	Electromechanical Engineering
Roberto Lupo Agache	Spain	Computer Science Engineering
Vinyet Sorribas Sort	Spain	Mechanical Engineering

1.2 Motivation

The team made two collective choices: the individual choice to join the European Project Semester (EPS) in Porto and the teamwise choice for the subject 'kitchen composter'. The choice for the EPS was made by every individual of the team because of collective reasons. First of all to broaden personal horizons by learning about different cultures, languages and environments. Secondly because the project is conjoined with students from different engineering backgrounds. Because of this everyone can learn a lot from eachother on technical aspects. Besides, the project is the biggest each teammember has ever done, which comes with new challenges and in the end results in skills like management-, teamwork- and communicationskills. Lastly our choice for Porto specificly is because the program specifies on projects contributing to the environment. Unlike other EPS programs, there is even a whole subject on environment.

The choice for the subject 'kitchen composter' was driven by a teamwise passion for preserving the environment and embracing a sustainable lifestyle. These are the key reasons fueling our commitment:

1. Waste Reduction: The mission is to significantly cut down the organic waste reaching landfills. Transforming coffee waste into compost helps shrink the carbon footprint and reduces the environmental impact of the daily waste.

2. Eco-Responsibility: The project revolves around raising awareness about eco-responsibility. Promoting the use of CoffeeMush, it aims to raise collective consciousness about the crucial role that individual choices play in the conservation of the planet.

3. Production of a useful product: The compost generated by kitchen composter bins nowadays inside the kitchen is mostly a useless product that cannot be used for further production of plants or food. That is because needed conditions for composting cannot be provided in a house without loosing commodity. The intention is to establish a sustainable cycle by reusing coffee waste for environmentally friendly agricultural practices.

4. Production of oyster mushrooms: Within the composting process, the machine manages to control and offer the best conditions for oyster mushrooms to grow. Those are actually the ones helping with the composting process besides being so delicious.

5. Learning and Awareness: Composting isn't just about waste management; it's an opportunity for education and interaction. The project, the seek is to educate the community on sustainable practices and encourage simple actions that positively impact the environment.

In conclusion, the motivation is rooted in the belief that every small action counts. The creation of this kitchen composter is a contribution to safeguarding nature for the generations to come.

1.3 Problem

The kitchen composter is a solution to a daily problem in today's society. This problem is that a lot of organic waste is not reused, only about 5 % **[Erlantz Lizundia, 2024]**. The aim is to contribute to society by making composting more accessible. The kitchen composters on the market today are quite good, but they are expensive and the product they make is not a fertiliser or otherwise useful. These aspects will be studied and developed to find a solution.

Another problem is how to grow mushrooms as quickly as possible. After focusing the project on a mushroom composter, it became clear that fresh coffee waste and a minimum amount of coffee waste were needed. This amount is around 200g. An average family generates about 9 grams of coffee waste per day (assuming a family of 3-4 people and that each member drinks one cup of coffee per day)**[Sara Sahai Marwah, 2021]**. Therefore, an average family as it is known in our society cannot reach such quantities. This is why the product is targeted at large producers of coffee waste, such as restaurants, cafeterias, hotels or schools.

1.4 Objectives

The goal is clear: to develop a practical and innovative way to transform organic waste into a valuable resource. The composter goes far beyond being a simple container; it embodies the commitment to a sustainable lifestyle, waste reduction, and environmental education.

Why Composting? Beyond waste management, composting provides a unique opportunity to actively contribute to the preservation of the environment. By making this process available to everyone, a virtuous circle is created, turning food waste into a natural fertilizer that benefits the soil.

Although being good, traditional kitchen composters oftenly use to have some limitations. While they aim to compost organic waste, they can be slow, requiring patience as materials decompose. Moreover, there is a need for careful consideration of what is added, as certain items can disrupt the process or attract pests. In terms of sustainability, many regions already offer city-wide organic waste collection services, reducing the necessity for individual composting efforts, especially for those without access to a garden.

Recognizing these challenges, a more innovative approach was sought that would not only address the shortcomings of traditional composting but also provide a tangible benefit. Rather than limiting the project to pre-composting organic waste, a solution was considered that would harness the process to produce a valuable product. This gave rise to the idea of using coffee waste for a dual purpose: composting and mushroom cultivation.

By utilizing coffee waste as the substrate for mushroom growth during decomposition, the smart kitchen composter offers a unique advantage. Not only does it efficiently manage organic waste, but it also transforms it into a resource for cultivating nutritious and flavorful mushrooms **[Florent Awedem Wobiwo, 2018]**. This dual-purpose approach not only enhances the composting process but also provides a practical and rewarding outcome, aligning with sustainability goals while offering a compelling solution for households seeking to minimize waste and maximize resource utilization.

1.5 Requirements

As the composter takes shape, it is crucial to meet the project criteria and use them to guide the work. Let's look at what these requirements mean for the project:

1. Acquire, store, and share monitored data: The system is intended to be intelligent and communicative. It will not only collect and store data efficiently but also make it easier for all involved to understand and exchange information about the composting process.

2. a. The budget is 100€ for the prototype. This budget must not be exceeded.

b. Use low-cost local hardware solutions: Affordability is important. The aim is to select equipment that is not expensive, to ensure that our composting solution is affordable for everyone. Sustainability must be accessible to all.

3. Use open-source software: It is committed to teamwork and transparency by using open-source software. This choice not only invites others to contribute but also allows the team to continuously improve and adapt as needed.

4. Adopt the International System of Units (NIST International Guide for the use of the International System of Units): Consistency is key. Adhere to internationally recognized measurement standards to ensure that the project communicates information clearly and consistently.

5. Comply with Directives: The following standards will be followed in order to ensure that the project is up to standard:

- Machinery Directive (2006/42/EC 2006-05-17): Prioritise safety in the design and use of machinery.
- Electromagnetic Compatibility Directive (2004/108/EC, 15-12-2004): Addressing electromagnetic interference.
- Low Voltage Directive (2014/35/EU 2016-04-20): Ensuring the electrical safety of our equipment.
- Radio Equipment Directive (2014/53/EU 2014-04-16): Efficient use of the radio spectrum.
- EU ROHS Directives: Choosing environmentally friendly and safe materials.

These are not just checkboxes; they are guiding principles. By paying attention to these criteria, not only do the technical standards are complied with, but also a sustainable, compliant and user-friendly composting solution is created.

6. The device should be sustainable. This can be realized in the use of the material, the use of power consumption and making the product recycleble and long-lasting.

7. The outcome of the device must be usefull.

8. The device should be automatic, smart and easy to use.

1.6 Functional Tests

To make sure the product will work before it is brought onto the market, functional tests need to be done. For this, a prototype of the product will be made. The prototype will be tested on how well the mushrooms grow according to plan. Besides that, the sensors will be controlled and checked if any additions need to be made. Lastly, the app functions need to be checked. This can be done by checking if the information from the app corresponds with the actual status of the mushrooms in the product.

The functional tests of the prototype consist of:

1. Sensor testing: Check if the AHT20 sensor receives information on the temperature and the humidity of the environment inside the box. Detection if there is water available in the water tank or not by the water float sensor.
2. Hardware testing: See if the fan will blow if the climate is too humid and if the valve from the water tank will open if the climate is too dry.

3. Software testing: Check if the data of the AHT20 and the water float sensor will be transmitted to the application. So that the user will be able to read all of this information. If the user wants to receive a picture of the mycelium growth, the ESP32-CAM will be able to make the picture and send it to the application.
4. Alarm testing: Send a notification to the user if there is no water available in the water tank. When it is not possible to regulate the temperature and the humidity inside the box properly, this will indicate that the composter is not located in a good environment.

For further information, please refer to Chapter 7 concerning the development of the prototype.

1.7 Project Planning

It is important to plan ahead for good teamwork and the best results for the project. This is done by project planning in Jira. In this program, different sprints are made for different weeks. In these sprints multiple tasks are made and assigned to different team members. In this way it is made sure that all team members take part in the project equally. This process is shown in Figure 1.

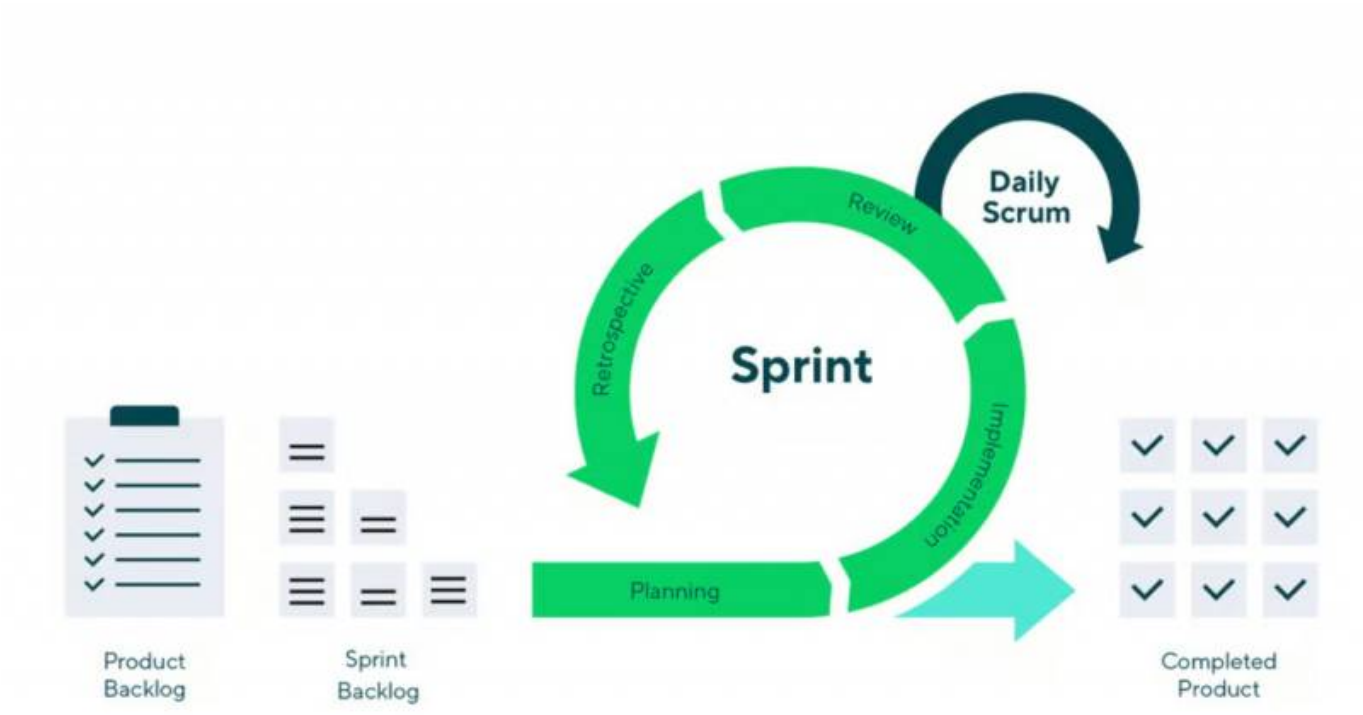


Figure 1: Scrum metodology

1.8 Report Structure

The following Table 3 shows the report structure and a brief description of the content.

Table 3: Report structure

Number	Task	Description
1	Introduction	Introducing what this project is going to look like.

Number	Task	Description
2	State of the Art	Explanation of the current kitchen composters on the market and background information.
3	Project Management	Overview of how the project was managed.
4	Marketing Plan	Explanation of the plan for putting our product on the market.
5	Eco-efficiency Measures for Sustainability	Explanation of the sustainable aspects that need to be taken into account in our project.
6	Ethical and Deontological Concerns	Explanation of the ethical and deontological aspects that need to be taken into account in our project.
7	Project Development	Explanation of the way the project was evaluated.
8	Conclusions	Concluding the main aspects of the project and the final product.
9	Bibliography	List of sources used.

2. State of the Art

2.1 Introduction

This chapter covers the state of the art of kitchen composters and mushroom growers. The first paragraph is about the different composting methods. This paragraph shows the different composting concepts that are available. The next paragraph is about the kinds of kitchen composters and mushroom growers that are now on the market. Then, the best conditions for growing mushrooms are defined. Finally, this chapter will be ended by concluding the findings on the topics. The problems that are seen in the kitchen composters of today are pointed out and translated to aspects that need to be present in this project.

2.2 Composting methods

Nowadays, there are different composting methods that convert organic waste into compost. The most common are the following:

1. Open Air Composting: This method is considered warm composting and consists of piling organic waste on a surface that is in the open air. When little waste is used and little compost is generated, some people call it cold composting as this compost does not accumulate the same amount of heat.

2. Direct Compost: This is probably the oldest method. This method consists of digging a hole in the

ground and putting the waste in the ground. The big disadvantage of this method is that the waste takes a long time to decompose unless it is chopped up.

3. Tumbler Composting: This method consists of putting the waste into a tumbler and turning the tumbler every day or every few days. The traditional method is to turn it by human power, but some mechanised systems are available that facilitate turning.

4. Worm Farm Composting: This method involves adding worms to organic waste, which aid in its decomposition. The worms produce concentrated excrements with lower nutrients and lower nitrogen compared to other composting methods, which makes it a good option. It also keeps rats away from the compost.

Worm Types

- South Australia Red Worms (Lumbricus rubellus) and Tiger worms (Eisenia fetida) under ideal conditions they rapidly reproduce 8 to 1500 worms
- Pontoscolex corethrunus or the Pheretima group
- Fishing worms are not good for composting.

5. EMO Composting: Also known as Effective Microorganisms, it is a method where Bokashi is mainly used. Bokashi is a process that, like traditional composting, converts organic matter into a nutrient-rich compost that improves soil quality. The main difference with traditional composting is that the input material is fermented by specialised bacteria, not decomposed. This method is generally used indoors and in order to filter unpleasant smells. There are some that use a carbon filter.

6. Combination Composting: Also known as Compost Composting Compost, it is a method that uses all composting methods. It does this by combining the 4 methods explained above: open composting, direct composting, vermicomposting and EMO composting. The major advantage is that all kitchen waste can be composted.

7. Commercial Composting: This method consists of mixing the waste with materials such as sawdust, pine bark, sand, ferrous sulphate and sometimes ammonia sulphate, all mixed together. It is mixed every 3 or 4 days and is ready in 6 weeks. It is made in large quantities. As it is commercial compost it does not have many nutrients but it is cheap.

8. Mechanical composting: This method involves using electricity to generate sufficient heat for composting and content rotation. The result is obtained in 24 hours and is semi-composted waste, so further composting will be required beforehand. **[Vickib, 2023]**.

2.3 Composting concepts

Currently, there are different types of kitchen composters on the market. These come in different shapes, sizes, and can even be designed for certain food waste to create plant-specific fertilizers. This paragraph shows the different concepts that are available or developed at the moment.

1) Modular composter - ORRE

This kitchen composter is built from modules, seen in Figure 2 below. Thanks to these modules, it takes up little space and allows a huge volume of waste to be processed. A built-in fan, which pushes the air inside, guarantees good oxygenation for the compost (it is important that the correct

processes take place), and the carbon filter prevents unpleasant odors.

Figure 2: Modular composter - ORRE **[Adam Szczyrba, 2020]**

2) Tea-Composter - SHiBUi

This kitchen composter is specifically designed for tea waste, as the tea grounds are natural, organic matter, they increase nutrient levels and improve soil quality as they decompose. It is designed to be for household use since around 80 % of the total tea produced in India is consumed by the domestic population. The idea of this composter is to create a small ecosystem and since plants are in direct benefit, including them in the design as a part of a complete cycle. This cycle can be seen in Figure 3.

Figure 3: Tea-Composter - SHiBUi **[Ayushi Rawat, 2018]**

3) Automated exotic mushroom growing - Fancom

Cultivating exotic mushrooms is a delicate balancing act. For years, the demand for exotic varieties of mushrooms has been growing, driven by the increasing trend of eating healthy and natural food.

Oyster mushrooms, Enoki and Shiitake are a few examples of popular exotic mushrooms. These variants can be cultivated with the help of automated mushroom-growing systems.

Nowadays there exist some machines that automatically create the optimal cultivation conditions for mushrooms with a computer. It also takes the outside conditions into account. The system for growing exotic mushrooms continuously monitors important climate parameters such as substrate, air temperature, humidity and CO_2-percentage. It always ensures the correct balance. If any abnormalities are detected, the computer will respond rapidly, but, at the same time, gradually. The result is a stable climate with hardly any fluctuations in the cultivation conditions. Users can benefit from higher production and better quality.

One example of these automated machines is the *fancom* machine, which can be seen in Figure 4.

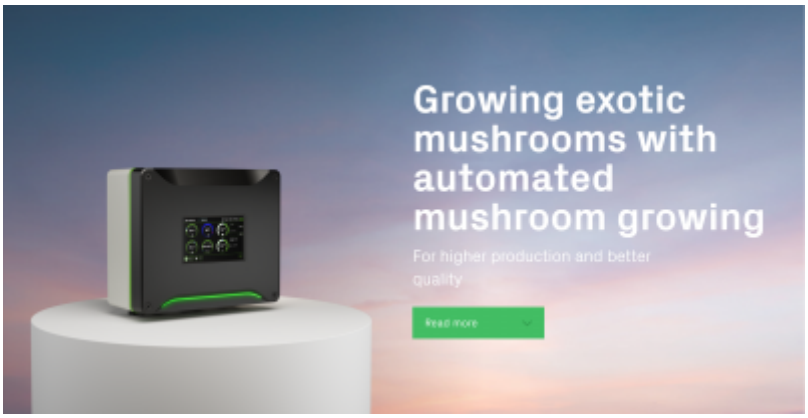


Figure 4: Fancom machine **[Fancom, 2024]**

2.4 Kinds of kitchen composters

This paragraph explains the different composters and their advantages and disadvantages. In this way, they can be compared to each other and the important aspects of this composter can be defined.

1) Reencle composter

This composter works silently 24 hours a day, so there is no need to wait until you are finished with the previous food scraps. You simply take out the fertilizer when it looks full. The composter can be seen in Figure 5 below. A 3-layer filter system guarantees odor-free composting. This composter is equipped with a non-contact motion sensor, can survive in high acid and high salinity environments, and operates quietly below 28 dB. This sound is exceptional for an actuator.

Figure 5: Reencle composter **[Hamni Flexible, 2024]**

2) Mill

The composter from the brand ‘Mill’ is a modern composter, which looks like a futuristic bin, as seen in Figure 6.

Figure 6: Mill composter **[Mill Industry, 2024]**

This product has a high price: 939 €. This makes it mainly accessible to the high financial class. Another disadvantage is that the product can be used as a chicken food, but not for any other use.

The advantages of Mill are the leak of sound and smell and the composting time. The sound (42 dB) and composting time (2.5 hours) are low. The smartness and smell are quite good as well. Though compared to other smart kitchen composters this is developed about the same. The smell is minimized by odor filtration, in which the filters have to be renewed every year **[Mill Industry, 2024]**.

3) Lomi

The kitchen composter from Lomi is less expensive than Mill, but still quite a lot: 599 €. It is smaller than the one from Mill, but the smell, time and smartness is about the same. A picture can be seen in Figure 7.

Figure 7: Lomi composter **[Pela, 2024]**

A disadvantage of this product is that the product that comes out of the composter is useless concentrated compost. So the user needs to still throw away the waste. Besides that, the time it takes to compost is about 12 hours, which is really long compared to the first to products **[Pela, 2024]**.

4) Foodcycler

The Foodcycler kitchen composter is quite similar to the kitchen composter from Lomi. The exterior looks similar as well. It can be seen in Figure 8.

Figure 8: Foodcycler composter **[Foodcycler, 2023]**

However, this product shows some more advantages: the price is lower and the compost time is shorter. The price is 500 € and the compost time is 5 hours. The only aspect that is less than the other products is the smartness: this product is more traditional and does not show innovative aspects like short compost time or a filtration system **[Foodcycler, 2023]**.

5) Skaza

This product, which can be seen in Figure 9, is the cheapest of all composters that are compared in this chapter. Though it is not that smart and innovative. A big disadvantage that comes with this is the long time it takes to compost. The composting time is 2 weeks for this product, which means that when the user fills the composter one day, the user cannot use it for the next two weeks **[Amazon, 2024]**.

Figure 9: Skaza composter **[Amazon, 2024]**

6) Beyondgreen

This product is the cheapest of these 6 products after Skaza: 409 €. All natural foods can be composted, like the other products. Beyondgreen has a lot of disadvantages though. First of all, the compost time is quite long: 1 week. Furthermore, the product is a useless compost that cannot be used for any other functions. Thirdly, the smell sound and smartness is not of high quality. There are no measures taken to improve this, compared to the traditional way **[beyondGREEN biotech, 2024]**, **[Richard Baguley, 2022]**.

Figure 10: Beyondgreen composter **[beyondGREEN biotech, 2024]**

7) Mella Mella is a system for mushroom growing specifically. There are three different boxes, in which three different types of mushrooms can be grown. The product can be seen below in the figure 11.

Figure 11: Mella mushroom grower **[Jill Sherman, 2023]**

The user has to install the device and select the humidity and fan speed. After this, the user has no actions that need to be done, apart from filling the water tank once a week. The smell and noise are minimized, though not zero. There is always a background noise and the process takes long, which is a disadvantage. The smell is minimized by fans, which reviewers say works well. The device is quite smart, it regulates the humidity and airflow, but it does not have an app that shows you how long until the mushrooms are done **[Jill Sherman, 2023]**.

8)Shrooly This device is quite similar to Mella, though a little smaller. There is only room for one type of mushroom to be grown. This can be seen below in the figure 12.

Figure 12: Shrooly mushroom grower **[Ben Coxworth, 2022]**

Though mostly different spores are added, so some kind of mixture arises. The input is not waste, but a product from Shrooly, called pods. This is similar to Mella. The pods can grow one to three batches of mushrooms. A disadvantage is that these pods need to be bought for every use of the device, they cost 12 € per pod **[Ben Coxworth, 2022]**.

In the Table 4, the six different kitchen composters and the two mushroom growers are compared. They are compared on the aspects ‘cost’, ‘waste input’, ‘product output’, compost time’, ‘smell’, ‘sound’ and ‘smartness’. Cost, compost time and sound can mostly be measured in quantity with units, but sometimes there is no quantity known.

Table 4: Comparison of kitchen composters

Name	Cost [€]	Waste / Input	Product output	Compost time	Smell	Sound [dB]	Smartness
Reencle	585	Natural food	Grasscompost	2 h	Filter system	28	Smart sensors
Mill	939	Natural food	Chickenfood	2.5 h	Filter system	42	Smart sensors
Lomi	599	Natural food	Useless concentrated compost	12 h	Filter system	‘quiet’	Smart sensors

Name	Cost [€]	Waste / Input	Product output	Compost time	Smell	Sound [dB]	Smartness
Foodcycler	500	Natural food	Useless concentrated compost	5 h	Filter system	‘quiet’	No additional aspects
Skaza	90	Natural food	Useless compost	2 weeks	No system	0	No additional aspects
Beyongreen	409	Natural food	Useless compost	1 week	No system	Not quiet	No additional aspects
Mella	447	Bought product	Mushroom	2 weeks	No system	Not quiet	No additional aspects
Shrooly	419	Bought product	Mushroom	2 weeks	No system	Not quiet	No additional aspects

2.5 Conditions for growing mushrooms

Mushrooms are mostly grown in buckets with holes for ventilation and oxygen. They are grown by combining coffee grounds with mushroom spawn and water. The coffee ground needs to be heated (60-80 °C) to kill organisms first. This does not need to be done if the coffee was already heated for making a drink. Afterward, it should be cooled to room temperature. Only after that can you add the mushroom spawn to the coffee ground, the optimal temperature for this is room temperature (18-24 °C). It takes two weeks to colonize the spawns, in this time they should be in the dark to prevent fruiting. During this period, you also need to maintain a humidity of 85-95% for growing oyster mushrooms **[Drew Swainston, 2023] [Desiree Vilar, 2023]**. The coffee ground must be completely colonized by the spawns to start fruiting. The coffee cannot be older than 24 hours, otherwise mold will start growing on it. At the end of the growing cycle, the composted grounds can be used to enrich the soil for your own plants **[Elliot Webb, Niall Cullen, 2023] [Adam Sayner, 2023]**.

2.6 Conclusion

The kitchen composters that are on the market nowadays show some problems. This can be concluded from the table 4. This project aims to solve these problems in order to make the purchase of kitchen composters more attractive. It is of interest to clarify those problems to be able to solve them.

First of all the product that comes out of the composters that are on the market nowadays are not fertilizers. The products are dried and compact, but not really useful to fertilize plants or grow food. The Mella and Shrooly grow mushrooms, which is a useful product. The disadvantage of them is that the input needs to be bought at their company, it is not waste from people themselves.

Second, kitchen composters are quite expensive these days, and it is difficult to get rid of the composter's leftovers. Due to the high costs, it is not accessible for lower-class citizens. Next to that, it is hard to sell the additional products people create by using the composter to local services. These two aspects could be combined to find a problem: selling the product of the composter can make the composter financially more accessible.

Based on this state-of-the-art study, the team decided to adopt techniques to obtain the best

conditions for mushrooms so that they can be grown as quickly as possible. The smart device must be sustainable, affordable and innovative. Multiple factors had to be taken into account: the noise, smell, size, method, prize and product of the composter. From the research on the state of the art, it can be concluded that the price is really high (about 500 €) for a smart kitchen composter. Another aspect to note is the composter product: the usefulness of this product is, in most cases, not so high. It is often compost that cannot be used, for example, to grow new food. Often it is waste or animal food. This is something the team wants to take into account for the project. It would be good if the product is a type of food that can be eaten or used in the kitchen. The mushroom-growing devices that are on the market now need input products that need to be bought from their company. CoffeeMush thrives to make mushrooms from actual waste, which contributes to the environment and affordability.

In the next chapter, the project will be managed to be able to perform the tasks within the project as good as possible. The management chapter shows how the project is tackled, how the tasks are divided and how the product and project will be finished on time for the deadline with the best results.

3. Project Management

3.1 Scope

In order to be more precised about the scope of the project than in the introduction, from a project management point of view, the following objectives are to be achieved, also illustrated in Figure 13:
- Initial research: First of all, initial research has to be done to find out the state of the art. At this point, the marketing analysis can be started, which will provide new strategies to innovate by following ethical and sustainable ideas.
- Project Planning: Once the product has been defined, the development process begins to be planned, taking into account the milestones of the project as a whole.
- Design on the final product: Whole schematics drawings and materials specifications regarding the physical creation of the final product. This will be followed by the 3D model, the product video presentation, paper, poster and manual.
- Design and creation of the prototype: Which has to be actual proof that the product works. It starts with a simple cardboard model, and ends with a functional prototype connected to the server and an android device with the app installed.
- Final Report and Presentation: As it follows it contains all the required documentation on the development process as well as the presentation of the main parts.

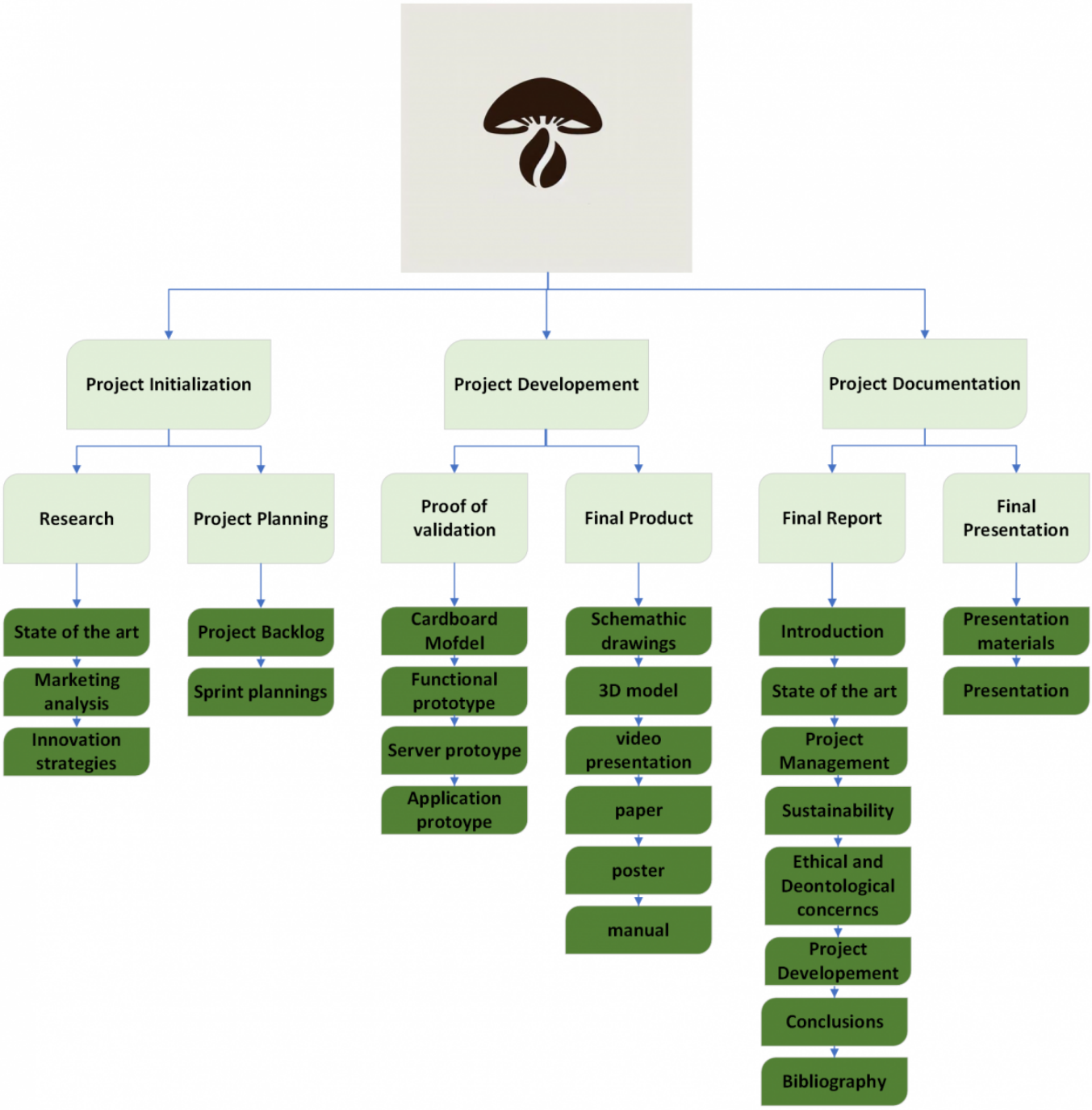


Figure 13: Project scope scheme

3.2 Time

Table 5 shows the deadlines the team has set for the project.

Table 5: Deadlines

Task	Deadline
Blackbox	2024-03-06
System Diagram	2024-03-06
Structural Drafts	2024-03-06
Project Backlog	2024-03-08
Global Sprint Plan	2024-03-08
Release Gantt Chart	2024-03-08

Task	Deadline
List of Components and Materials	2024-03-13
System Schematics	2024-03-20
Structural Drawings	2024-03-20
Cardboard scale model	2024-03-20
Interim Report	2024-04-07
Presentation materials	2024-04-07
3D model video	2024-04-17
Final List of Materials	2024-04-23
Refined Interim Report	2024-04-30
Packaging solution	2024-05-15
Functional Tests	2024-05-28
Final Report	2024-06-16
Final Presentation materials	2024-06-16
Video	2024-06-16
Paper	2024-06-16
Poster	2024-06-16
Manual	2024-06-16
Final Presentation	2024-06-20
Suggested corrections	2024-06-25
Prototype and user manual handing	2024-06-27

3.3 Cost

Regarding the project costs, the workers' salaries and the budget are considered for the materials used. Other costs such as goods or services used, like workspace, electricity, and others, are not taken into account. Thank you though, to ISEP for allowing the team to use them.

Therefore, the average cost of hiring an engineer in Portugal amounts to 2217 € **[Glassdoor, 2024]**. Taking into account that the team consist of 6 workers for 5 months and adding the 100 € budget, the total cost is 66.610 €.

3.4 Quality

Considering that the project can be splitted in different independent parts, the quality metrics to be applied for each of them will be specified.

3.4.1 CoffeeMush Quality

The metrics are shown here in terms of the physical product itself:
- Durability: Ensure that the composter is built to last and withstands regular use over time.
- **Functionality:** Verify that the composter effectively converts coffee waste into mushroom growth and fertilizer.
- **Ease of Use:** Assess how user-friendly the composter is, considering factors like setup,

maintenance, and harvesting.
- **Safety:** Ensure that the composter is safe to operate and doesn't pose any risks to users or the environment.
- **Environmental Impact:** Measure the environmental benefits of the composter, such as reduced waste and sustainable mushroom production.
- **Material Quality:** Evaluate the quality of materials used in the composter's construction for longevity and eco-friendliness.

3.4.2 Documentation Quality

The metrics are shown below taking into account all the project documentation (including the Report, schematic drawings, documents, user guides…):
- **Clarity:** Ensure that documentation (user manuals, assembly guides, etc.) is clear and easy to understand.
- **Completeness:** Verify that all necessary information is included in the documentation, covering setup, usage, troubleshooting, and maintenance.
- **Accuracy:** Ensure that information provided in the documentation is accurate and up-to-date.
- **Consistency:** Maintain consistency in language, formatting, and terminology throughout the documentation.
- **Accessibility:** Ensure that documentation is accessible to all users, including those with disabilities, by providing alternative formats if needed.

3.4.3 Marketing Quality

Metrics relating to all marketing and promotional material (including logo, slogan, brochure, promotional video…) are shown in this section:
- **Brand Identity:** Assess the alignment of branding elements (logo, slogan) with the product's value proposition and target audience.
- **Visual Appeal:** Evaluate the aesthetic quality of promotional materials, including videos, images, and graphics.
- **Message Effectiveness:** Measure the effectiveness of marketing messages in communicating the product's benefits and unique selling points.
- **Engagement:** Monitor audience engagement metrics (views, likes, shares) for promotional content across various platforms.
- **Consistency:** Ensure consistency in branding and messaging across all marketing channels and materials.

3.4.4 Android Application Quality

At last but not least, all the metrics for the android application are defined:
- **Functionality:** Ensure that the app functions as intended, providing all necessary features and capabilities.
- **Performance:** Evaluate app performance in terms of speed, responsiveness, and resource usage.
- **User Experience** (UX): Assess the app's user interface design and navigation for ease of use and intuitiveness.
- **Compatibility:** Verify that the app is compatible with a wide range of Android devices and operating system versions.

- **Security:** Ensure that user data is secure and protected against unauthorized access or breaches.
- **Bug-Free:** Monitor and address any bugs or issues reported by users through regular testing and updates.

3.5 People

In every project, an intricate network of stakeholders plays a pivotal role, each with varying degrees of influence and significance. The success of any project depends upon a comprehension of the involved people and their roles. Within this particular project, a diverse array of stakeholders contributes to its advancement and ultimate fruition.

At the forefront stands the dedicated project team, serving as the driving force behind the development of the prototype and the overall progress of the initiative. Charged with the task of translating vision into tangible reality, this team wields a profound impact on the project's trajectory and outcome.

Further contributing to the project's evolution are the esteemed educators from EPS, whose invaluable feedback and financial support are instrumental in guiding its course. Endowed with a wealth of knowledge and experience, their input not only enriches the project's development but also ensures its alignment with educational objectives and fiscal feasibility.

In addition to these stakeholders, suppliers also play a crucial role in the project's success. Suppliers provide the necessary materials, components, and resources essential for the project's execution. Their reliability, quality of products, and timely delivery directly impact the project's progress and outcomes. Building strong partnerships with suppliers fosters collaboration and ensures a smooth flow of materials, contributing to project efficiency and effectiveness. Thus, acknowledging and nurturing relationships with suppliers is paramount for achieving project goals and delivering value to stakeholders.

Finally, customers must be taken into account. Their importance lies in their indirect but substantial influence. Ultimately, our product responds to their needs, so their satisfaction is essential to our success. Without them, our efforts would lack meaning and viability.

3.6 Communications

At the core of the communication strategy lies the primary channel: the WhatsApp group, which serves as a dynamic hub for instantaneous communication among team members, transcending geographical barriers and facilitating seamless collaboration regardless of the locations. This platform enables the team to swiftly disseminate vital information, share updates, and address pressing matters in real-time, fostering agility and responsiveness in the operations.

Furthermore, the interactions extend beyond the virtual realm, finding meetings in the classroom environment. Given the frequency of the face-to-face encounters, the opportunity is taken to participate in daily discussions and meetings during the breaks between classes. This in-person communication not only promotes team cohesion but also ensures alignment and clarity in the collective project work.

While WhatsApp serves as the primary communication channel, other digital platforms are also leveraged to enhance collaboration efforts. Microsoft Teams plays a key role as a centralised

repository for storing essential documents and files, facilitating access and sharing among team members. In addition, Jira's collaboration capabilities integrate communication into task workflows, forcing the team to discuss tasks once they are completed. This ensures complete documentation and promotes transparency, allowing team members to stay informed and engaged throughout the project lifecycle.

3.7 Risk

Risk management is a proactive approach to anticipating and addressing potential challenges, whether positive or negative, that may arise during a project. It involves identifying, assessing, and prioritizing risks to develop strategies for mitigating adverse impacts and capitalizing on opportunities. By continuously monitoring and controlling risks throughout the project lifecycle, teams can adapt swiftly to changing circumstances. Key components of risk management include:
- Risk Identification: Continuously identifying potential risks throughout the project lifecycle to anticipate and prepare for potential challenges.
- Risk Evaluation: Assessing the likelihood and potential impact of identified risks on project outcomes, both quantitatively and qualitatively, to determine appropriate mitigation strategies. Probabilities and time frames (long, medium or short term) are also considered.
- Risk Handling: Developing strategies to address both negative risks (threats) and positive risks (opportunities). For negative risks, efforts may focus on avoidance, mitigation, or transferring the risk to other parties such as insurance companies. Positive risks may be exploited, enhanced, shared, accepted, or ignored depending on their potential benefits.
- Risk Monitoring and Control: Continuously monitoring and controlling identified risks throughout the project to ensure that mitigation strategies remain effective and to respond promptly to any changes or new risks that may arise.
By systematically managing risks, teams can enhance their ability to navigate uncertainties and increase the likelihood of project success in an ever-changing environment. Table 6 shows the main risks that are considered for the project.

Table 6: Risks

Risk	Timeframe	Probability	Impact	Handling	Monitoring
Malfunctioning of the composter machine, leading to suboptimal conditions for mushroom growth.	Long-term	30 %	90 %	Having different kinds of sensors for monitoring such as temperature, air quality, light, pictures...	Monitoring in the app and having alerts for non logical happening things
Inadequate monitoring system in the application, resulting in inaccurate data collection or failure to send alerts.	Long-term	30 %	90 %	Making strict testing on as many use cases as possible.	Saving all things in the logs besides the application and database

Risk	Timeframe	Probability	Impact	Handling	Monitoring
Shortage of coffee waste or oyster mushroom seeds due to fluctuations in supply or unexpected demand.	Long-term	50 %	90 %	Migrate this responsibility to the user. Anyways it is offered the facility of buying/selling those through the application	Saving for each user/machine the amount of coffee waste, mushrooms produced...
Dependence on specific suppliers for essential components or materials, leading to delays or disruptions in production.	All terms	10 %	40 %	Having different suppliers options just in case	No need
Limited demand for coffee waste composters or oyster mushrooms, resulting in low sales and revenue generation.	Long-term	10 %	80 %	Accept/Be aware of coffee use and not produce more composters than needed	No need
Competition from alternative composting methods or mushroom cultivation techniques.	Long-term	30 %	70 %	Analyzing competitors and planning marketing strategies for innovation and improvement	No need
Lack of proper permits or licenses for selling compost, mushrooms, or fertilizer, hindering business operations.	Long-term	20 %	40 %	Accept/Be aware of legal conditions for each region	No need
Overestimation of project costs or underestimation of expenses, leading to budget overruns and financial strain.	Mid-term	30 %	70 %	Meticulous calculations before doing each step	No need
Difficulty in securing funding or investment for the project, limiting its ability to scale or expand.	Short/Mid-term	40 %	70 %	Being as convincing and innovative as possible	No need
Human error during the operation of the composter machine or application, resulting in production delays or errors in data analysis.	Short/Mid-term	50 %	60 %	Procuring having things done a reasonable time before the deadline	No need

Risk	Timeframe	Probability	Impact	Handling	Monitoring
Potential contamination of mushrooms or compost with harmful pathogens or toxins, posing health risks to consumers.	Long-term	20 %	90 %	Having the process as controlled as possible	Asking feedback each time a set of mushrooms are collected through the application
Accidents or injuries related to the operation of the composter machine or handling of materials.	Long-term	10 %	60 %	Designing it as carefully as possible considering users might not use it as expected	Having one department or folder with all related informations
Environmental factors such as temperature fluctuations or pest infestations affecting mushroom growth or composting process	Long-term	30 %	80 %	Designing the product as self-dependent as possible, isolate it from outside conditions being as efficient and sustainable as possible.	Monitoring which inside-machine conditions differ the most from the outside ones

3.8 Procurement

To realize this project, in addition to the deliverables already mentioned, it is mandatory to carry out a proof of concept in the form of a prototype. For the construction of the prototype the given budget is 100 €. Given the constraints imposed by limited financial resources, a strategic approach to recruitment is adopted, being cost-consciousness and selective.

In light of the budgetary constraints, the team aims to maximize the utilization of existing resources by adapting the functional prototype to incorporate the most cost-effective materials readily available. Drawing upon ingenuity and creativity, pre-existing components and materials are identified and reused to suit project requirements, minimizing cost without compromising functionality or quality.

Furthermore, a priority is the selection of electronic elements and programming languages based on the collective expertise of the team members in these domains. By leveraging the existing proficiency and familiarity with certain technologies, the risk of costly errors or inefficiencies is mitigated, ensuring optimal utilization of resources and expediting the development process.

To optimize logistical efficiencies and reduce transportation costs, the team consolidates the procurement efforts by sourcing all electronic materials from a single supplier: Digikey, renowned for its competitive pricing and comprehensive product offerings. This strategic partnership not only streamlines the supply chain operations but also minimizes lead times and enhances cost-effectiveness, maximizing the value derived from the limited budget.

For non-electronic materials, a similar cost-conscious approach is used, opting to purchase from affordable physical stores within Porto, such as Continente and Ikea. By prioritizing affordability and accessibility, the procurement strategy is optimized to ensure a prudent allocation of resources, while

meeting project requirements.

Additionally, capitalize on the resources available through the educational institution ISEP, by leveraging borrowed components to complement procurement efforts further and alleviate financial burdens.

In essence, procurement strategy represents a sensible balance between resource utilization, cost awareness and strategic sourcing, underpinned by a commitment to maximizing value and minimizing expenditure. By aligning procurement practices with project constraints and objectives, a solid foundation for success is laid, while optimizing resource utilization and mitigating financial risk.

3.9 Stakeholders Management

Defining stakeholders is a critical step in understanding the various parties involved in a project. By identifying stakeholders and their respective needs, project objectives, priorities, and resource allocation can be effectively determined. This process also aids in identifying user needs, thereby enhancing both the quality of work and the final product. According to ISO standards, stakeholders are defined as individuals or groups with an interest in the decisions or activities of an organization. In Table 7 stakeholders are listed along with their functions, interests, and levels of influence.

Table 7: Stakeholders

Stakeholder	Function	Influence	Interest
Project team member	Working on the project	5	5
Teachers	Control and guide the project	5	4
Suppliers	Supply with needed materials	2	2
Customers	Buy and use the product	4	4

By plotting the stakeholders on the grid in Figure 14, project managers can gain insight into how to work effectively with each stakeholder group. Stakeholders are often categorized into four quadrants:

High Interest, High Influence: Stakeholders in this quadrant have both a high level of interest in the project and significant influence over its outcomes. They require close communication and engagement to ensure their needs are addressed and their input is considered.

High Interest, Low Influence: These stakeholders are highly interested in the project but have limited influence over its direction. While their input may be valuable, their impact on decision-making may be minimal. It's important to keep them informed and involved to maintain their support and address any concerns they may have.

Low Interest, High Influence: Stakeholders in this quadrant have significant power to influence the project's outcomes but may have limited interest or awareness of the project. While their involvement

may be sporadic, it's essential to engage them strategically to gain their support and leverage their influence when needed.

Low Interest, Low Influence: Stakeholders in this quadrant have minimal interest in the project and little to no influence over its outcomes. They may require minimal communication and involvement unless their interest or influence changes over the course of the project.

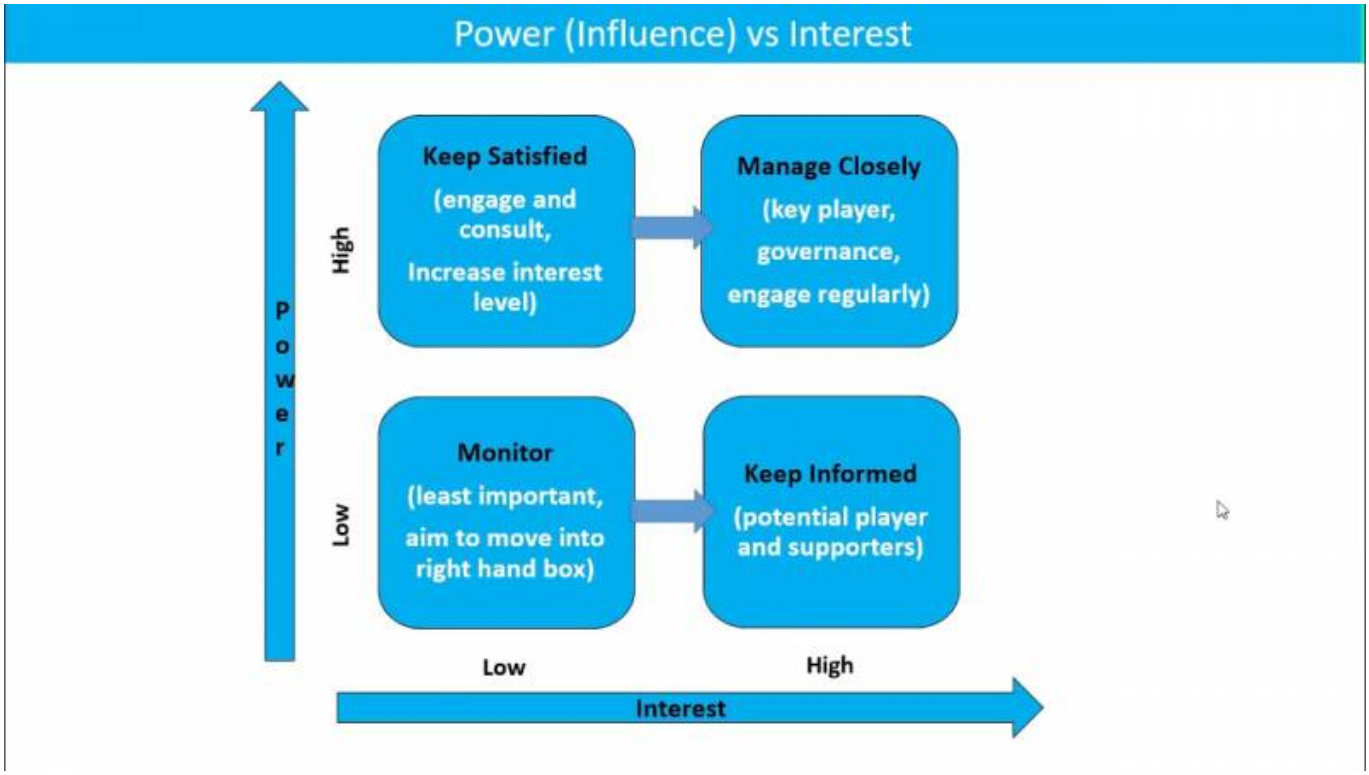


Figure 14: Interest-influence grid **[Skills Unlimited, 2021]**

3.10 Project Plan

The optimal sprint duration and plan is defined below using Global Sprint Plan Table 8.

Table 8: Global Sprint Plan

Sprint	Start	Finish	Status
1	29/02/2024	06/03/2024	Done
2	07/03/2024	13/03/2024	Done
3	14/03/2024	20/03/2024	Done
4	21/03/2024	03/04/2024	Done
5	04/04/2024	10/04/2024	Done
6	11/04/2024	17/04/2024	Done
7	18/04/2024	24/04/2024	Done
8	25/04/2024	01/05/2024	Done
9	02/05/2024	15/05/2024	Done
10	16/05/2024	22/05/2024	Done
11	23/05/2024	29/05/2024	Done
12	30/05/2024	05/06/2024	Done
13	06/06/2024	12/06/2024	Done
14	13/06/2024	19/06/2024	Doing

Sprint	Start	Finish	Status
15	20/06/2024	26/06/2024	To do

The table below shows the project backlog, including all relevant tasks/deliverables, using Project Backlog Table 9. It prioritizes all backlog items (PBI), keeping higher priority items at the top, and lower priority at the bottom.

Table 9: Project Backlog

Summary	Issue key
Sprint 8 stand-up dailies	CK-440
Product Design	CK-404
Sprint 7 stand-up dailies	CK-400
Electronic design	CK-391
Sprint 6 stand-up dailies	CK-373
Meetings	CK-368
Final List of materials - 23/4/2024	CK-366
Teachers feedback on Interim report	CK-352
Interim presentation	CK-346
Color Palette	CK-336
3D Model video	CK-319
Rail for rolling down system with stop	CK-310
Sprint 5 stand-up dailies	CK-306
Interim presentation 11/04/2024	CK-303
Sprint 4 Stand-up dailies	CK-297
Ventilation Design	CK-270
Market Analysis 03/04	CK-237
Interim Report 07/04	CK-226
Mushroom recognition model	CK-222
Manual	CK-221
Poster	CK-220
Paper	CK-219
Project video	CK-218
Final presentation	CK-217
Final report	CK-216
Functional tests	CK-215
Packaging solution	CK-214
Presentation 11/04	CK-212
Outside with solar panel	CK-211
Coffee capsules opener	CK-210
Share fertilizer/mushrooms/waste in app	CK-209
Anti-smell	CK-208
Smaller Design	CK-207
API	CK-197
Database	CK-196
Management Tasks	CK-101

Summary	Issue key
Wiki report (First idea)	CK-58
Composting process	CK-10
Cardboard Model	CK-7
Materials	CK-6
App	CK-5
“Marketing name, slogan, logo and flyer”	CK-4
First electronic design	CK-3
First design	CK-1

Below shows an identification key project deliverables (when they will be started and completed) and build a release Gantt chart. See Figure 15 for inspiration.


MAR
APR
MAY
JUN
Sprints
Tablero...
Tablero...
Tablero Sprint 4
Tablero...
Tablero...
Tablero
Tablero...
Tablero Sprint 9
Tablero...
Tablero
Tablero...
Tablero...
Tabler...
CK-10 Composting process
CK-6 Materials
CK-1 First design
CK-58 Wiki report (First idea)
CK-3 First electronic design
CK-101 Management Tasks
CK-7 Cardboard Model
CK-4 Marketing name, slogan, logo and flyer
CK-270 Ventilation Design
CK-5 App
CK-196 Database
CK-210 Coffee capsules opener
CK-197 API
CK-237 Market Analysis 03/04
CK-226 Interim Report 07/04
CK-208 Anti-smell
CK-297 Sprint 4 Stand-up dailies
CK-303 Interim presentation 11/04/2024
CK-306 Sprint 5 stand-up dailies
CK-310 Rail for rolling down system with stop
CK-319 3D Model video
CK-336 Color Palette
CK-214 Packaging solution
CK-215 Functional tests
CK-216 Final report
CK-217 Final presentation
CK-218 Project video
CK-219 Paper
CK-220 Poster
CK-221 Manual
CK-346 Interim presentation
CK-352 Teachers feedback on Interim report
CK-366 Final List of materials - 23/4/2024
CK-368 Meetings
CK-373 Sprint 6 stand-up dailies
CK-391 Electronic design
CK-400 Sprint 7 stand-up dailies
CK-404 Product Design
CK-440 Sprint 8 stand-up dailies
CK-446 Sprint 9 stand-up dailies
CK-467 mqtt
CK-486 Sprint 10 stand-up dailies
CK-489 Sprint 11 stand-up dailies
CK-490 Sprint 12 stand-up dailies
CK-491 Sprint 13 stand-up dailies
CK-492 Sprint 14 stand-up dailies
CK-493 Sprint 15 stand-up dailies
CK-519 Team building
CK-531 Prototype

Figure 15: Release Gantt chart

3.11 Sprint Outcomes

The results of each sprint are shown below. Although the initial results may not meet the desired standards due to the limited experience of the team, there are noticeable improvements as the project progresses.
In agile project management, particularly in Scrum, velocity refers to the amount of work a team completes during a sprint. It's a measure of how efficiently the team is delivering on their commitments.

Planned Velocity is the velocity that the team anticipates achieving for a particular sprint. It's based on factors such as historical data, team capacity, and the estimated complexity of the tasks or user stories planned for the sprint.

Real Velocity, on the other hand, is the actual velocity the team achieves during the sprint. It reflects the team's ability to execute their planned work within the sprint timeframe, taking into account any unforeseen challenges, dependencies, or changes that may have impacted their productivity.

Comparing Planned Velocity with Real Velocity provides valuable insights into the team's performance and helps identify areas for improvement. If the Real Velocity consistently falls short of the Planned Velocity, it may indicate that the team is overcommitting or encountering obstacles that impede their progress. Conversely, if the Real Velocity exceeds the Planned Velocity, it suggests that the team is delivering more efficiently than expected.

Analyzing this comparison enables the team to make informed decisions for future sprints, such as adjusting their capacity planning, refining their estimation techniques, or addressing any bottlenecks that may be hindering their productivity. Ultimately, the goal is to optimize the team's performance and ensure they consistently deliver value to the project stakeholders. This comparison can be seen in table 10. The x indicates that the sprints have not yet started. The team started in sprint 2. But in sprint 2 the time was not recorded, because the team only learned it in sprint 3. That's why the 0 values are shown in sprint 2 and the start of sprint 3.

Table 10: Sprint velocities

Sprint	Velocity planned	Real velocity
1	X	X
2	0	0
3	0	1 week 2 hours
4	2 weeks 30 minutes	1 week 2 days 5 hours 30 minutes
5	1 week 5 hours 30 minutes	1 week 1 day 3 hours
6	0 minutes	1 week 3 days
7	1 week 1 day 7 hours 30 minutes	3 days 4 hours
8	1 week 3 days	1 week 3 days 3 hours
9	1 week 3 hours	4 days 1 hour 30 minutes
10	2 weeks 4 days 6 hours 15 minutes	3 days 3 hours 15 minutes
11	7 hours	2 weeks 3 days 3 hours

Sprint	Velocity planned	Real velocity
12	5 hours	1 week 6 hours 30 minutes
13	2 weeks 2 days 1 hour 30 minutes	7 hours

For each sprint, a subset of items from the product backlog is selected and moved into the sprint backlog. This subset is determined during sprint planning, where the team collaboratively decides which items they can commit to completing within the sprint's time frame. The sprint backlog represents the specific set of work items that the team aims to accomplish during that sprint.

The backlog for each sprint provides focus and direction for the team, ensuring that they have a clear understanding of what needs to be done and can work towards achieving the sprint goals.

That is why for each sprint a link to the Jira filter that shows only that sprint’s task backlog is pasted, followed by the burndown chart.

A burndown chart is a graphical representation of the work completed versus the time remaining in a sprint. It typically shows the remaining effort (measured in time) on the vertical axis and the sprint duration on the horizontal axis.

At the beginning of the sprint, the burndown chart starts at the top, indicating the total amount of work remaining. As the team completes tasks throughout the sprint, the chart “burns down,” with the line trending downwards towards zero. The ideal scenario is for the chart to reach zero by the end of the sprint, indicating that all planned work has been completed.

The burndown chart provides valuable insights into the team's progress during the sprint. It helps stakeholders visualize whether the team is on track to complete the planned work or if they are falling behind schedule. If the burndown line deviates significantly from the ideal trend, it prompts the team to identify and address any issues or obstacles that may be impeding their progress. Additionally, it allows for course corrections to be made mid-sprint, ensuring that the team stays focused on achieving their sprint goals.

3.11.1 Sprint 1

No Jira data available for sprint 1

3.11.2 Sprint 2

See sprint 2 backlog in our Jira page.

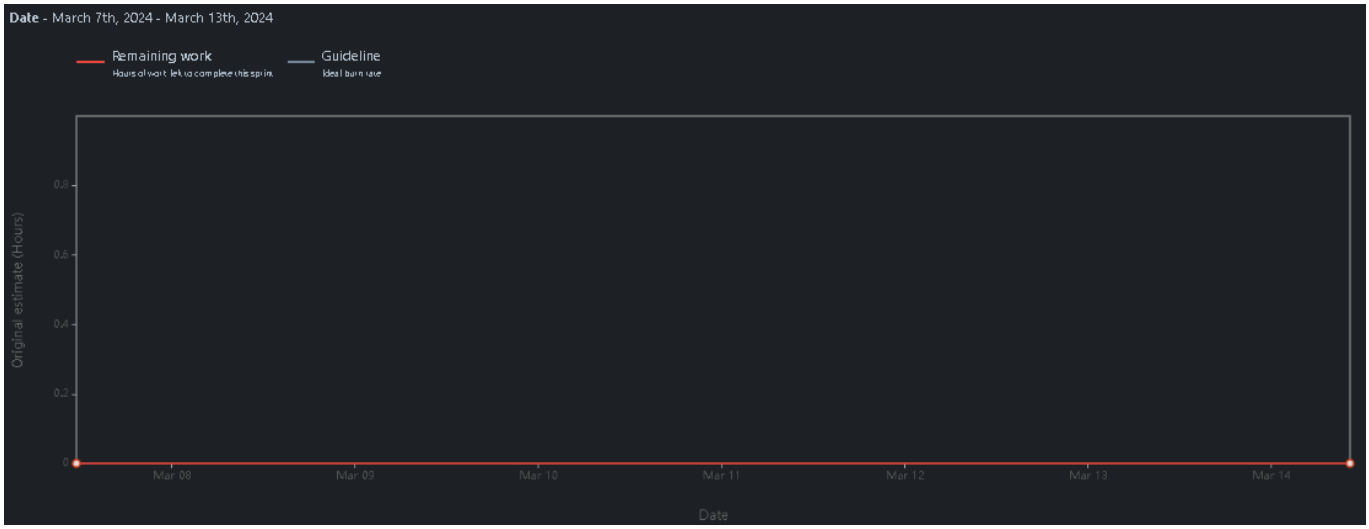


Figure 16: Burndown chart for Sprint 2

3.11.3 Sprint 3

See sprint 3 backlog in our Jira page.

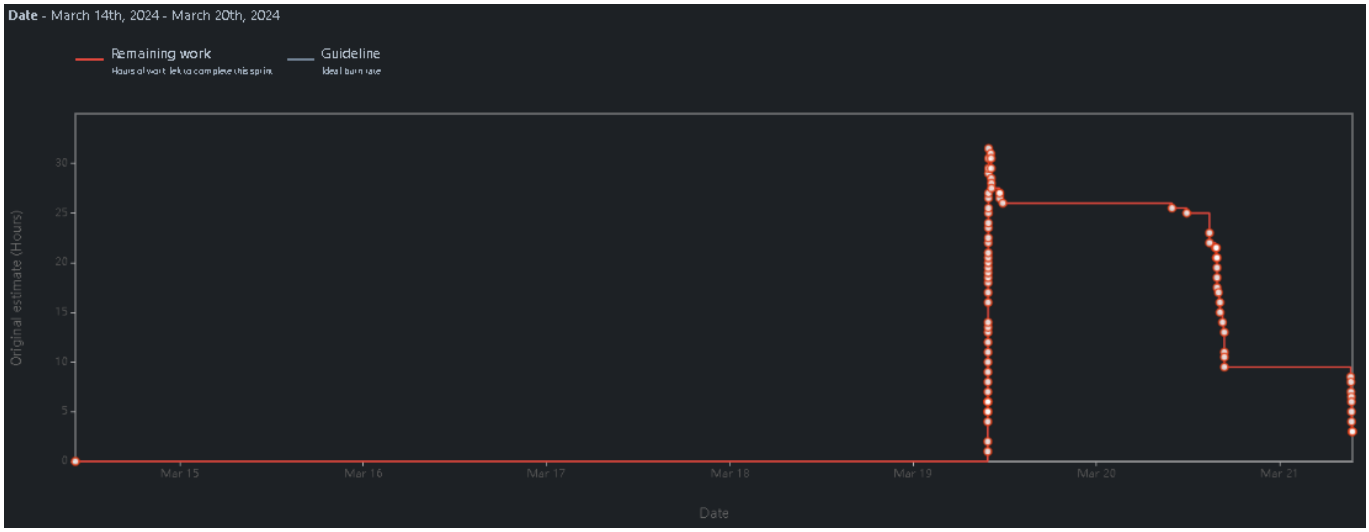


Figure 17: Burndown chart for Sprint 3

3.11.4 Sprint 4

See sprint 4 backlog in our Jira page.

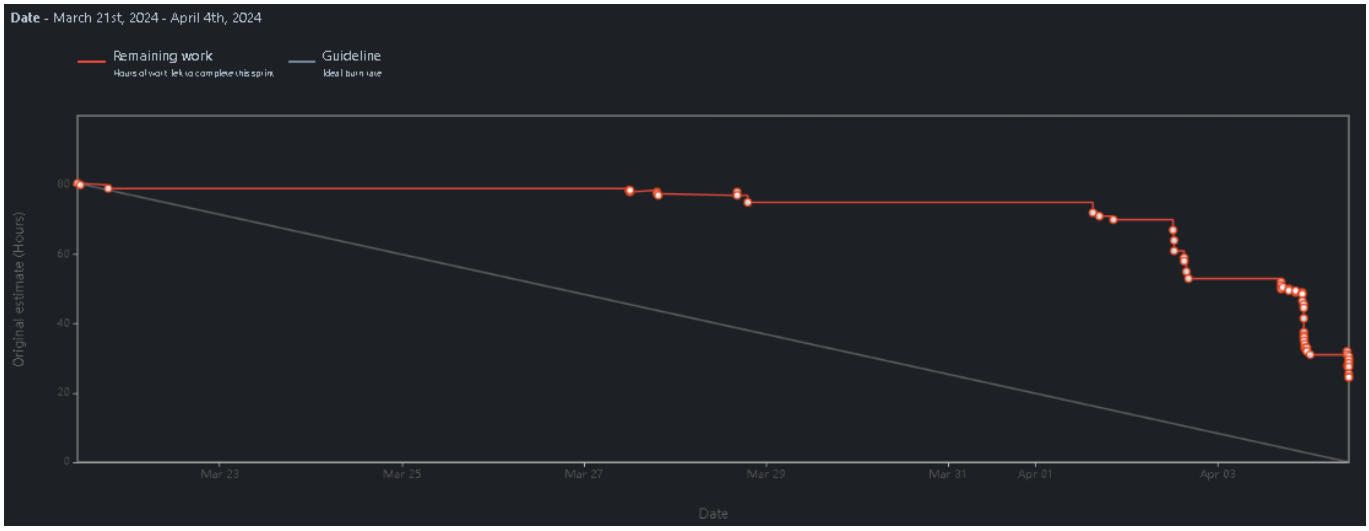


Figure 18: Burndown chart for Sprint 4

3.11.5 Sprint 5

See sprint 5 backlog in our Jira page.

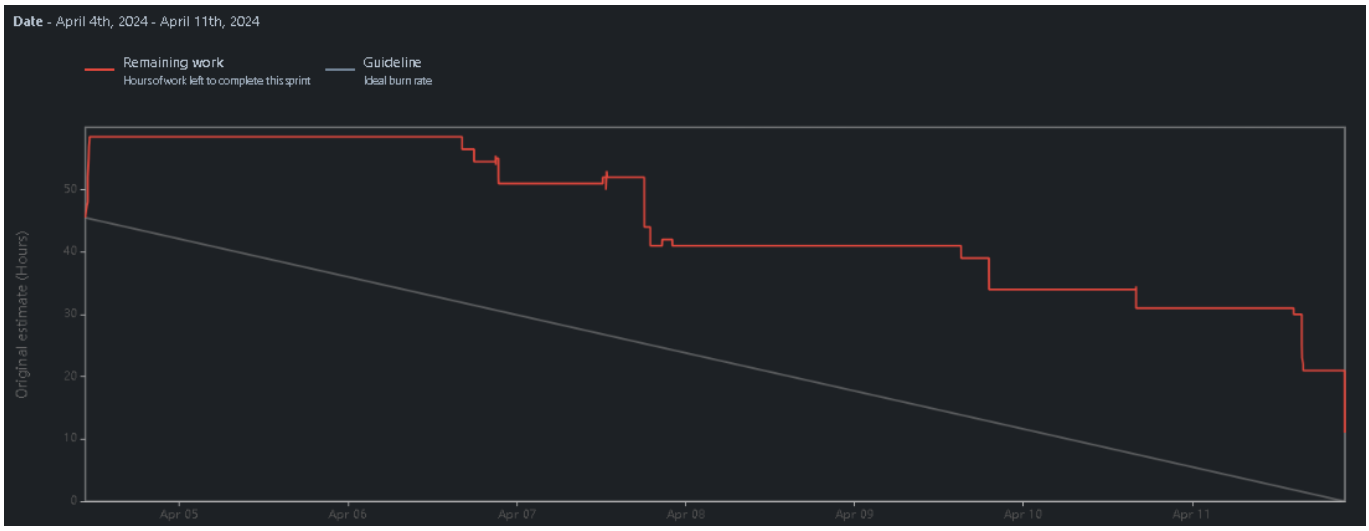


Figure 19: Burndown chart for Sprint 5

3.11.6 Sprint 6

See sprint 6 backlog in our Jira page.

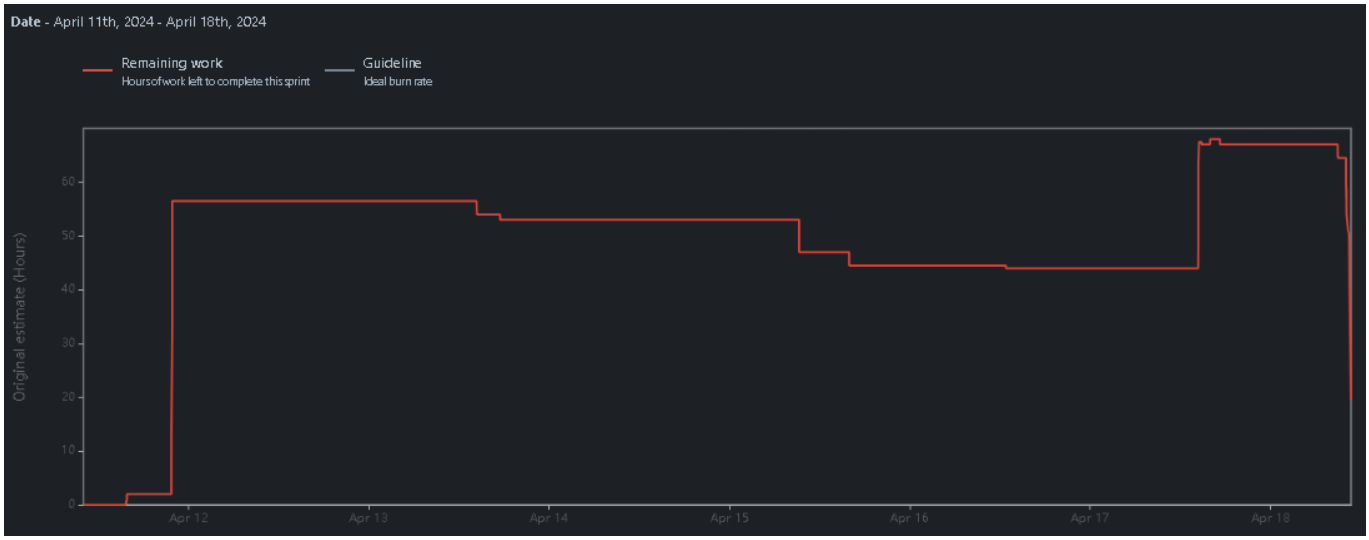


Figure 20: Burndown chart for Sprint 6

3.11.7 Sprint 7

See sprint 7 backlog in our Jira page.

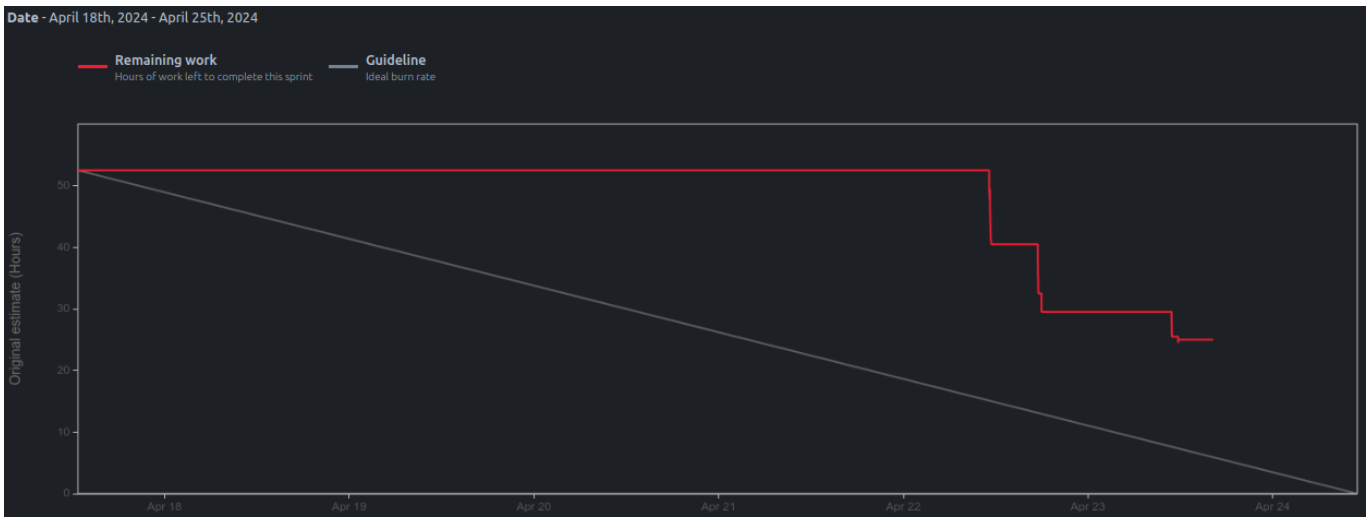


Figure 21: Burndown chart for Sprint 7

3.11.8 Sprint 8

See sprint 8 backlog in our Jira page.

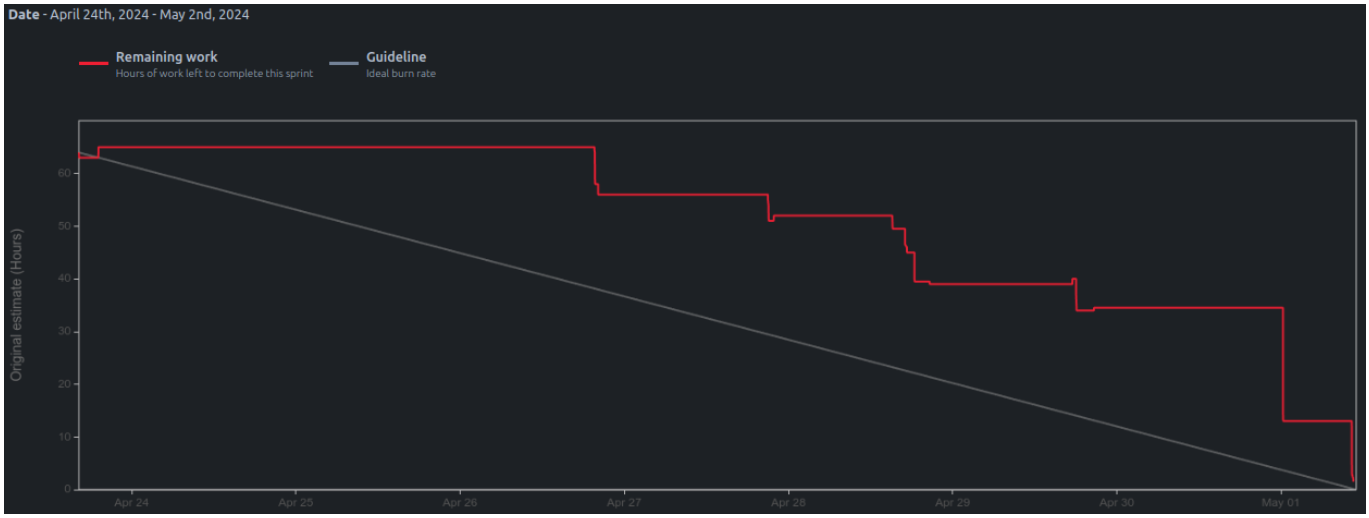


Figure 22: Burndown chart for Sprint 8

3.11.9 Sprint 9

See sprint 9 backlog in our Jira page.

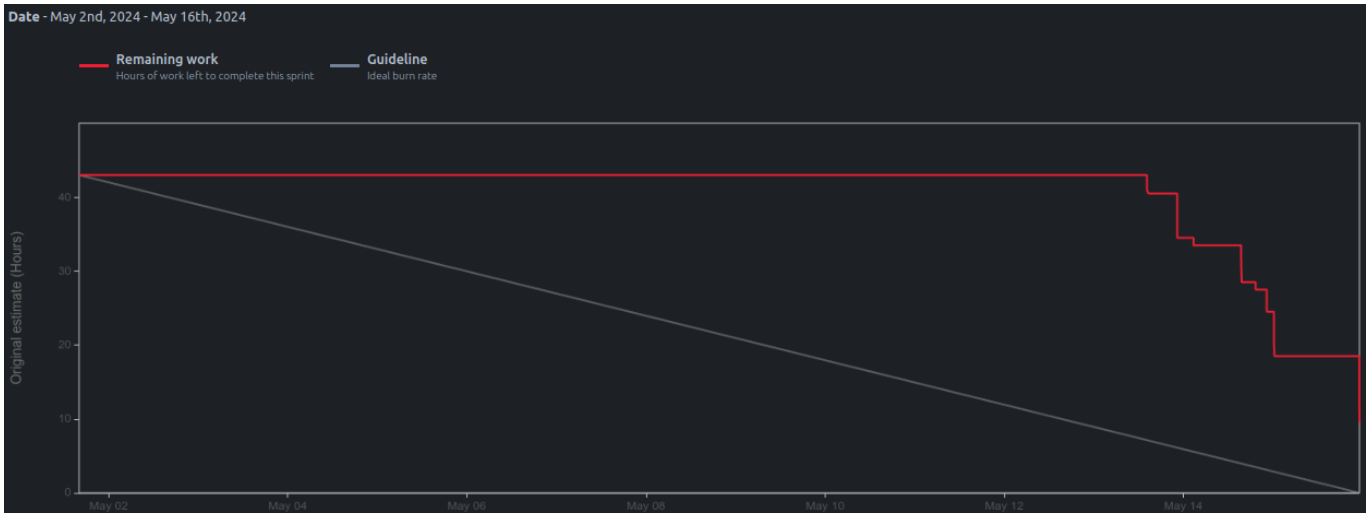


Figure 23: Burndown chart for Sprint 9

3.11.10 Sprint 10

See sprint 10 backlog in our Jira page.

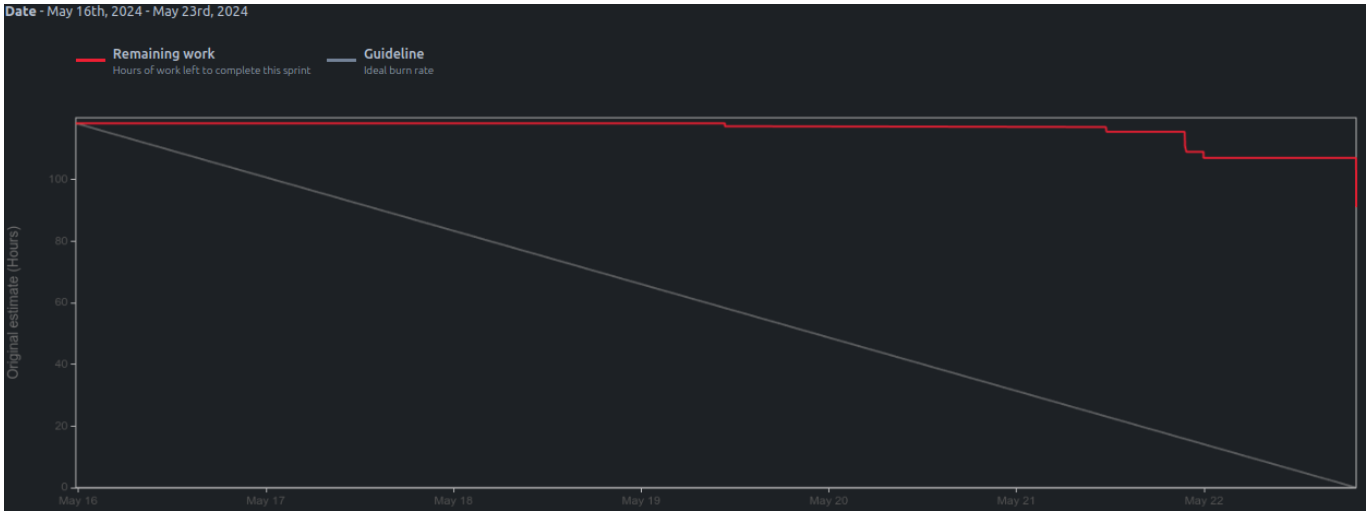


Figure 24: Burndown chart for Sprint 10

3.11.11 Sprint 11

See sprint 11 backlog in our Jira page.

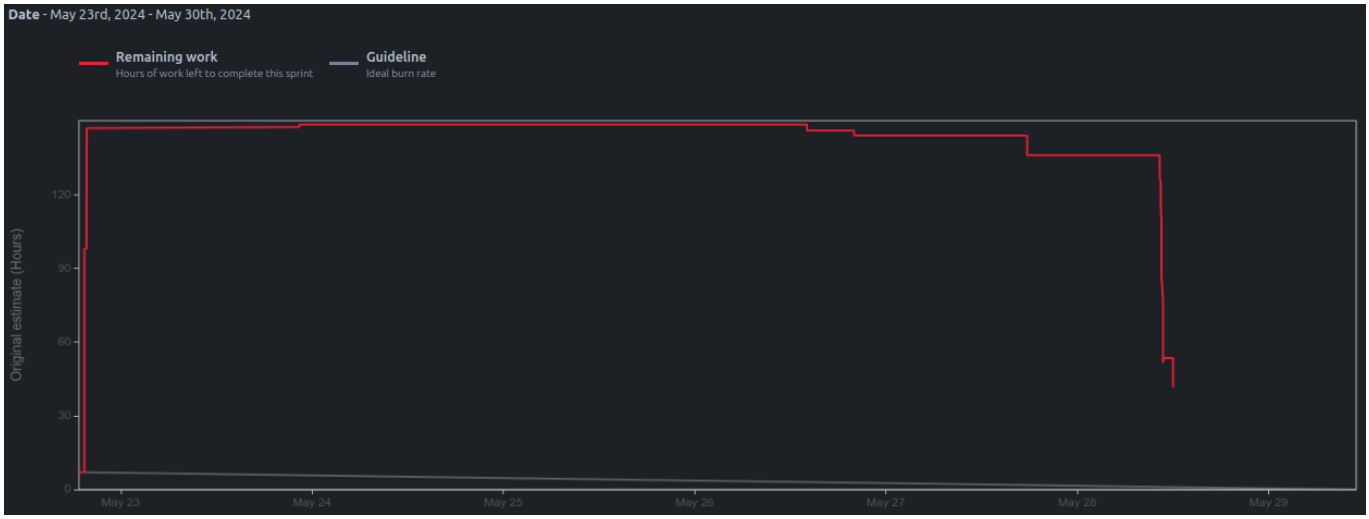


Figure 25: Burndown chart for Sprint 11

3.11.12 Sprint 12

See sprint 12 backlog in our Jira page.

Figure 26: Burndown chart for Sprint 12

3.11.13 Sprint 13

See sprint 13 backlog in our Jira page.

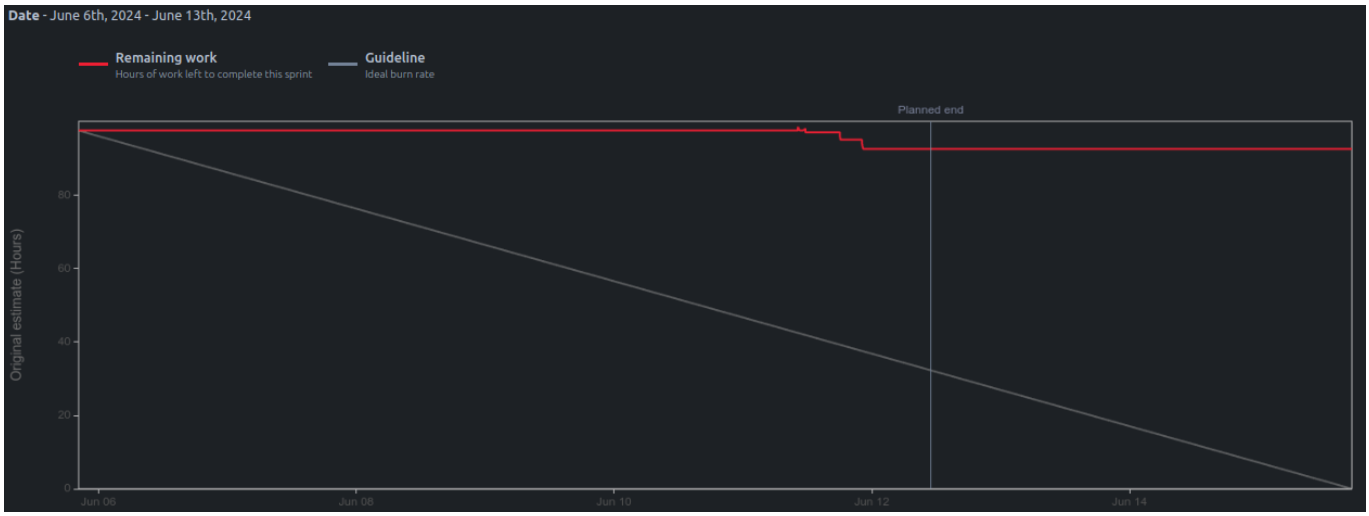


Figure 27: Burndown chart for Sprint 13

3.12 Sprint Evaluations

For the retrospectives the team does the Good/Bad/Start/Stop and Actions retrospective with metroretro.io. For each Sprint only the link to the board and a table with the stickers information are included.

3.12.1 Sprint 1

No data available for this sprint

3.12.2 Sprint 2

Table 11 contains the 2nd Sprint Board stickers.

Table 11: 2nd Sprint Board stickers

Content	Zone
Finally a nice and convincing idea	Good
We Could find a good idea	Good
We did all the things we had to do	Good
We have a better plan and finished our sprint	Good
Planning is getting better	Good
It took us quite a long time to decide for an aidea	Bad
We dont inform each other enough what we have done	Bad
We defined the tasks at short notice	Bad
Not everyone is participating	Bad
Lack of work sometimes	Bad
Assign tasks the first day of the sprint	Start
We must start imputing time to jira tasks	Start
Make clear appointments	Start
We must comment all jira tasks in order to prove we did it and make it easy for other people to find our work	Start
We must be responsible with our jira tasks (make sure all our tasks finish on done state)	Start
Show up in time / let us know if you cannot be there	Start
Give tasks to hugo	Start
We have to stop being absent in meetings	Stop
Thinking about the old composter idea (i thnik everyone already did it)	Stop
quiting classes without telling	Stop
Not havong Done tasks commented or with imputed time at the end of the sprint	Actions
Anyone who disrispects any of the follo ing rules must bring cookies	Actions
Arriving late twice (+10 min)	Actions
No Excuses	Actions
Thursday morning is the most important day. Must be there	Actions
Not telling u wont come in the group	Actions

3.12.3 Sprint 3

Table 12 contains the 3rd Sprint Board stickers.

Table 12: 3rd Sprint Board stickers

Content	Zone
Some people started using Jira propperly	Good
Finding the electronic parts and the schematics	Good
Most tasks completed	Good
The tasks are clear and organized	Good

Content	Zone
Communication	Bad
We need to work more on our tasks	Bad
A few tasks were not on the done column	Bad
Some people do more work than others	Bad
We need to think about the final design, to be able to implement everything well	Start
Say if you are not there	Start
Communicate more the progress on our tasks	Start
We have to start using the time inputs and putting tasks in the column they have to be at each time	Start
Update people on what you are doing	Start
Check each others work	Start
We have to stop letting tasks for last minute, it can affect other people work	Stop
read each other work at the end of the tasks	Actions
Update the others on our tasks	Actions
Communicate if you are not there / late	Actions
Doing Standup dailies	Actions
Assign tasks equally on Jira	Actions

3.12.4 Sprint 4

Table 13 contains the 4th Sprint Board stickers.

Table 13: 4th Sprint Board stickers

Content	Zone
We commented the standup dailies	Good
We made a good progress during the vacation	Good
everybody is contributing and is working hard on their tasks	Good
unfinished tasks	Bad
not every task is done at the end of the spring	Bad
We planned this sprint with too much work and we couldn't finish all tasks	Bad
Nothing	Bad
Strat doing more stan-up dailies	Start
Communicate if you think you cannot finish your task, you can ask for help	Start
do more reviewing on the tasks from others	Start
Get an idea of how the final design should look like	Start
Growing mushrooms	Start
ignore messages in groupchat	Stop
Doing tasks without putting them to done in jira	Stop
stop editing in the wiki when somebody else is editing it at the same time	Stop
Taking Whatsapp messages more seriously	Actions

3.12.5 Sprint 5

Table 14 contains the 5th Sprint Board stickers.

Table 14: 5th Sprint Board stickers

Content	Zone
We delivered the report	Good
Everyone was prepared for the presentation	Good
I copied	Bad
We didn‘t control each tohers work	Bad
Lot of mistakes	Bad
Improving the report	Start
Sticking to agreements	Start
Completing the daily tasks	Start
Being late	Stop
Promising thhings you dont do	Stop
Taking Whatsapp messages more seriously	Actions

3.12.6 Sprint 6

Table 15 contains the 6th Sprint Board stickers.

Table 15: 6th Sprint Board stickers

Content	Zone
More people were on time	Good
We finished the 3d video	Good
Not all tasks were finished	Bad
Communication in the whatsapp group	Bad
Checking all weork	Start
Reviewing tasks	Start
Having a leader	Start
ignoring messages in whatsapp	Stop
letting unassigned tasks	Stop

3.12.7 Sprint 7

Table 16 contains the 7th Sprint Board stickers.

Table 16: 7th Sprint Board stickers

Content	Zone
Tasks were reviewed	Good
We almost finished the writings in the wiki	Good

Content	Zone
To have a leader	Good
We started going to the lab	Good
Not comunicating the trouble in some tasks	Bad
unfinished tasks	Bad
I had unfinished tasks	Bad
finishing tasks!	Start
Being more accurate putting tasks	Start
Finishing the report	Start
stop editing the wiki without saying it in the whatsapp	Stop
Ignore whatsapp	Stop
doing tasks without marking them as done in jira	Stop
Not telling important information for the group	Stop
Meeting twice a week in stead of once	Actions
Brainstorm with the whole group for some topics	Actions
All tasks should be assigned	Actions
Finish tasks and communicate	Actions

3.12.8 Sprint 8

Table 17 contains the 8th Sprint Board stickers.

Table 17: 8th Sprint Board stickers

Improved interem report	Good
Solid report	Good
Almost all tasks were done	Good
we completed almost every task	Good
We delivered the report little bit in the limit	Bad
Not everything finished	Bad
We lost the 3D model	Bad
Working on the paper	Start
Start working on the paper	Start
Making backups for the report and other data	Start
Editing the wiki without announcing it	Stop
being late	Stop

3.12.9 Sprint 9

Table 18 contains the 9th Sprint Board stickers.

Table 18: 9th Sprint Board stickers

Improvedments on interem report	Good

Few tasks were not done	Good
We got back the 3D model	Good
We were late	Bad
imputing time on jira	Start
Editing the wiki without communicating	Stop

3.12.10 Sprint 10

Table 19 contains the 10th Sprint Board stickers.

Table 19: 10th Sprint Board stickers

The leader thing is working	Good
microcontroller from Paulo works really good, tested all the sensors and the actuators	Good
PRoces prototype and electronics	Good
microcontroller with cam does not work, in this case we will not been able to have a cam	Bad
Communication	Bad
There were some undone tasks	Bad
Finish tasks	Bad
WE did not do the monday meeting	Bad
functional test for 3D design	Start
Communicating	Start
Using jira properly	Start
Reading feedback in jira	Start
Doing more dailies	Start
working quick just to have the task done	Stop

3.12.11 Sprint 11

Table 20 contains the 11th Sprint Board stickers.

Table 20: 11th Sprint Board stickers

Functional tests	Good
We did the functional tests	Good
Unfinished tasks	Bad
Unifinished tasks	Bad
watering system	Bad
There were some tasks unfinished	Bad
finding solution for the water system	Start
doing teambuilding	Start
Finish your tasks and communicate	Start
Using jira	Start
not finishing your tasks	Stop

3.12.12 Sprint 12

Table 21 contains the 12th Sprint Board stickers.

Table 21: 12th Sprint Board stickers

teambuilding	Good
too large paper	Bad
We didn't have the paper ready on time	Bad
commenting tasks	Start
Doing tasks quickly just to put them to the done column	Stop

3.12.13 Sprint 13

Table 22 contains the 13th Sprint Board stickers.

Table 22: 13th Sprint Board stickers

Most tasks completed	Good
The tasks are clear and organized	Good
We need to work more on our tasks	Bad
Update people on what you are doing	Start
Check each others work	Start
Say if you are not there	Start
Letting tasks for last minute	Stop

3.13 Conclusion

This chapter offers a detailed overview of the project team's approach for the semester ahead. It emphasizes the importance of a well-defined assignment, accompanied by a clear problem statement, ensuring that key stakeholders are considered and project milestones are achieved through effective planning. This solid groundwork allows the team to focus on other crucial aspects of the project.

In summary, project management emerges as a pivotal element in project execution, providing essential tools for organizing work effectively. Through meticulous objective setting, deadline management, and budget adherence, the team can prioritize tasks and enhance productivity. Furthermore, thorough risk, cost, quality, and communication analyses ensure comprehensive project management, enabling swift problem resolution and transparent stakeholder communication.

Moreover, the integration of daily and weekly monitoring, facilitated by the Scrum method and Jira platform, promotes reduced stress, heightened morale, and streamlined task management, thus optimizing project efficiency.

Moving forward, the subsequent chapter will explore marketing strategies and their critical role in project success, elucidating the adopted strategy and target audience considerations.

4. Marketing Plan

4.1 Introduction

In order to bring CoffeeMush to the market in the most attractive way possible, it is first necessary to be clear about the target market on which the product is to be focused. The intention is that the product will be used in kitchens, mainly for larger households / larger kitchens in e.g. hostels, hotels or even student residences, where space is not limited. Restaurants in urban areas are not really an option, because kitchens are often very small and space is more valuable for customers than for a kitchen composter. It would also be an option for hostels where users share the kitchen or for a flat with a common area where residents of all flats can dispose of their coffee waste and grow mushrooms.

To know the kind of market that needs to be researched, the target audience needs to be clarified. For this product the target audience is people who drink a lot of coffee. The most coffee is drunk in the North-West of Europe: Finland, Sweden, Norway, Denmark, Netherlands, Belgium. This will be the market of focus, but of course all coffee lovers can use the product. These countries consume almost 10 kg of coffee per person per year **[Anonymous, 2024]**. In this group of coffee drinkers, the target persona would be the people who are open to reusing their coffee waste for growing mushrooms.

Besides that, the aim is to make the product affordable and reach a large number of people so that they can start composting their coffee waste.

Next paragraph will analyse the market on a macro- and micro level.

4.2 Market Analysis

4.2.1 Micro Analysis

In the micro analysis the value proposition is defined. The value proposition is to motivate people to reuse their coffee waste to grow mushrooms. In this way the waste does not need to be processed and the mushrooms do not need to be produced and bought outside the house. This process saves money, environment and time. Compared to the kitchen composters that are on the market already, this composter produces mushrooms, where other composters produce a useless compost product.

4.2.2 Macro Analysis

In this macro analysis, the influences from other companies and cultural institutions that influence people’s behaviour, preferences, norms and values will be discussed. This is done by the PESTEL analysis, in which all letters represent a topic that can influence the target audience on deciding to (not) buy the product. The topics are political, economic, social, technological, environmental and legal. They are explained underneath.

Political
The rules and laws from the government on the smart kitchen composter influence the target audience. When changes are made by the government, it influences behaviour of the target audience.

For example, in some countries people pay for the collection of their waste, which could motivate the target audience to reuse their coffee waste instead of throwing it away.

Economic
Economic reasons are a big motivator for people to decide on purchasing or not purchasing a product. This counts for the kitchen composter as well. The product is aimed to be cheap and thereby accessible for a large group of people.
And besides that, it accomplish the conditions to be considered as a circular economy system **[Ellen Macarthur Foundatio, 2024]**.

Social
The social topics which influence the market of smart kitchen composters are population growth rates, age distribution, labour market trends and household sizes. The household sizes correlates for example to make it financially beneficial. If a household is just one, the coffee waste is less and the costs for waste collection are less than in a household of five coffee drinking people. The social aspect of contributing to the environment is increasing. People are getting more aware of the environment and will talk about it with other people, convincing more and more people to take environmental friendly measures. This smart kitchen composter helps that as well. Besides that, nowadays mushrooms are perceived as healthy, tasty and their nutritional benefits can appeal to health-conscious consumers.

Technological
The smart kitchen composter is dependent on the technical progresses for sensors, apps and internet. An application will be made that adapts to the composter and shows the progress of the composting process. In the future, this application will have to be updated to the standards of the time. And of course the mushroom process itself can be improved from investigations in order to minimize the time or improve the efficiency.

Environmental
The smart kitchen composter is sustainable, as it reuses the coffee waste for growing the mushrooms. This may people is motivated to purchase the kitchen composter, most people in the North-West of Europe are well aware of the environmental problems and want to contribute to help the environment. And compared to other composting methods growing mushrooms on recycled waste has a lower carbon footprint compared to traditional farming methods **[Nick Robinson, 2024]**.

Legal
For the app, there are laws about privacy and security that need to be followed. Besides there are safety rules that need to be followed about electrical devices, like this composter with sensors. These rules and laws need to be researched and followed.

SWOT analysis will be done in the following paragraph, enlightening the strengths, weaknesses, oppertunities and threats of CoffeeMush on the market.

4.3 SWOT Analysis

SWOT refers to strengths, weaknesses, opportunities and threats on the market. It is crucial to consider these aspects for the kitchen composter. This will help to understand the constraints to watch out for and the opportunities to explore.

Strengths
- Reuse waste

- Save money
- Innovative
- Environmental friendly
- Local source of food
- Reaching people of lower financial classes

Weaknesses
- Quite some space needed
- Only coffee can be composted
- Mushrooms can also be grown in coffee ground without a smart device

Opportunities
- Market with potential
- People want to contribute to the environment

Threats
- Competitors
- Price sensitivity of consumers

The marketing strategy of CoffeeMush will be discussed in detail in the next paragraph.

4.4 Strategy

4.4.1 Strategic Objectives

In order to get a good market position, it is important to determine what to aim for in the market. For this, the Business Model Canvas is made an shown in Figure 28.

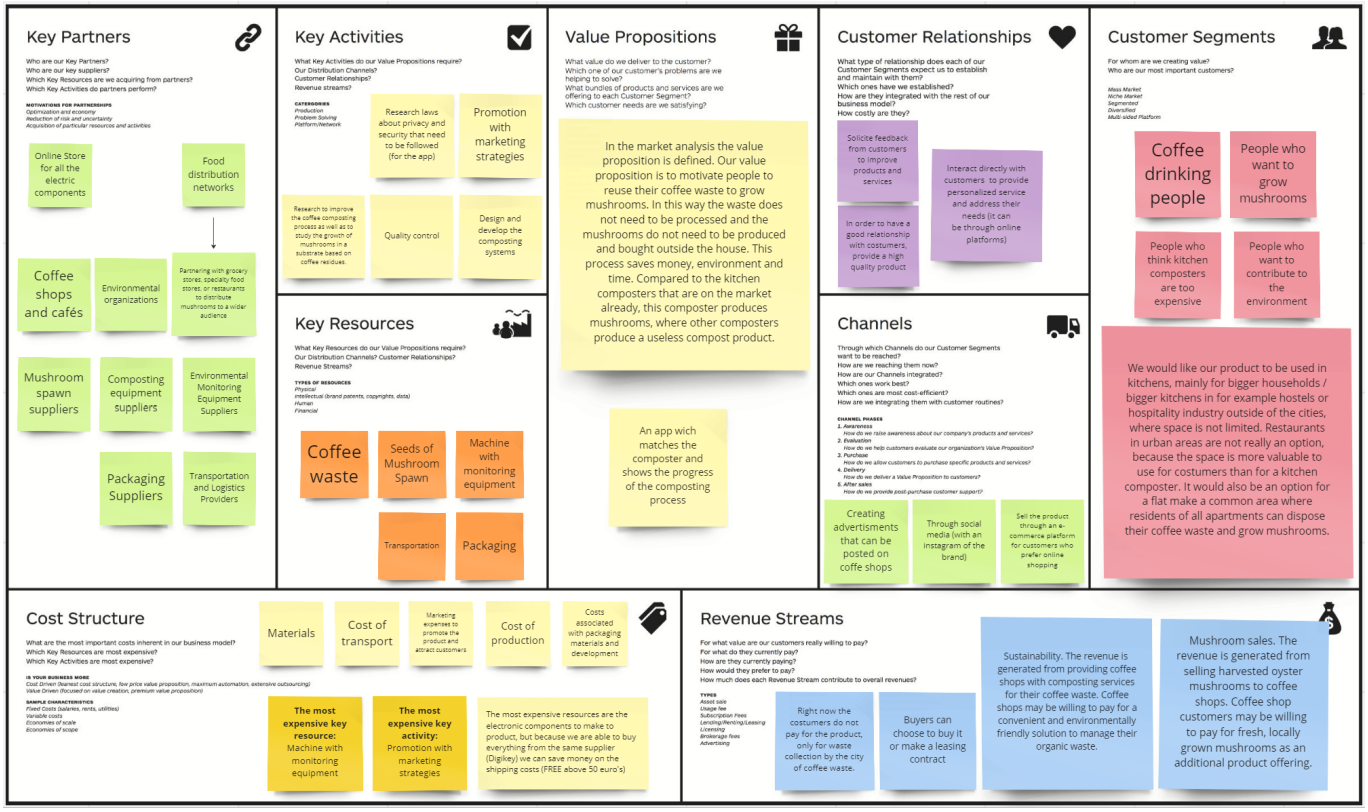


Figure 28: Business Model Canvas

4.4.2 Segmentation and Targeting

Segmentation:
In marketing segmentation the customers on the market are divided into different parts to get a clearer understanding of the customers that the products focusses on. The segmentation can be done judging on demographical, geographical, behavioural or psychological aspects. For CoffeeMush, geographical distribution holds minimal significance as the product functions effectively based on the combined demand from both northern and other regions, ensuring sustained operations. More eminent is the behaviour and demographical aspects. The customer segment that is focussed on should show a stable life, meaning that the income is steady and the household is arranged. Furthermore, the behaviour should show interest in coffee waste, mushrooms and/or composting.

Target audience:
CoffeeMush be used in kitchens, mainly for bigger households / bigger kitchens in for example hostels or hospitality industry outside of the cities, where space is not limited. It would also be an option for a flat make a common area where residents of all apartments can dispose their coffee waste and grow mushrooms. Thirdly the product could be used in big households, where there is enough space for the product. The age and income of the target audience is in a wide range. Approximately between 20 and 80 years old and an average to high income. The product is attractive for people who drink a lot of coffee, eat a lot of mushrooms, or want to contribute to the environment by processing coffee waste sustainably.

4.4.3 Positioning

CoffeeMush is a product that is different to any other product on the market. There are a lot of kitchen composters on the market, but they do not make a product that is useful for further fertilization or growth. In this way CoffeeMush distinguishes itself; the product mushrooms can actually be eaten. In addition, it is intended to stand out by making the product more accessible and less expensive. The only products that do something similar to CoffeeMush are way too expensive as pointed out in figure 29

Exploring a potential avenue, our company is contemplating the introduction of a secondary business model centered around the distribution of mushroom spawns via a monthly subscription arrangement.

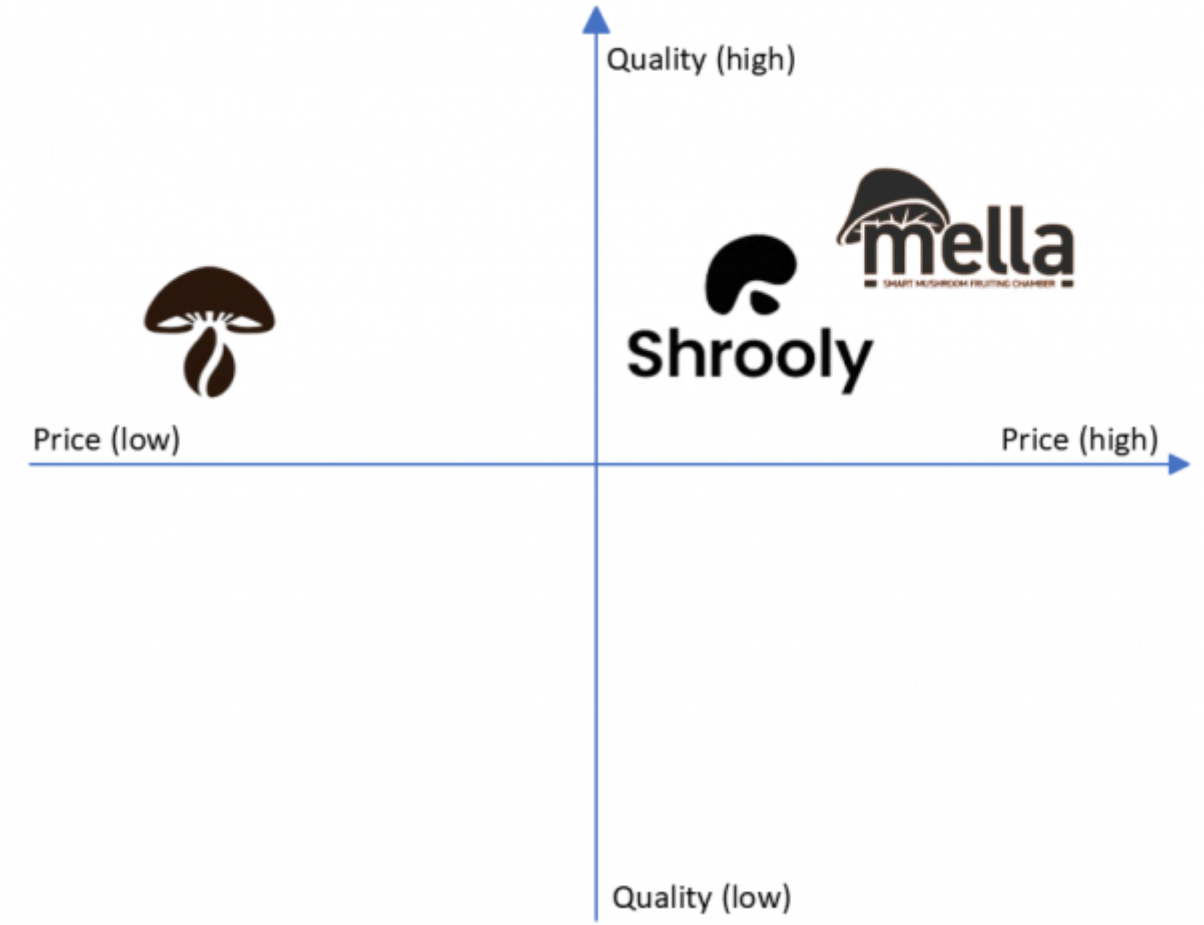


Figure 29: Positioning map

4.4.4 Marketing-Mix

In the marketing mix, the four P’s—product, price, place, and promotion—play vital roles in shaping CoffeeMush's market strategy and consumer engagement.

Product Beyond merely being an item or service, CoffeeMush embodies a sustainable solution designed to transform coffee waste into nutrient-rich compost, fostering the growth of mushrooms. By addressing the pressing needs of customers for eco-friendly waste management alternatives, CoffeeMush not only delivers convenience but also contributes to cost savings and environmental conservation.

Price While the exact pricing of CoffeeMush is yet to be determined, it is strategically aimed to undercut existing kitchen composters in the market. This competitive pricing approach ensures accessibility to a broader spectrum of consumers, democratizing sustainable practices and widening CoffeeMush's market reach.

Place CoffeeMush strategically positions itself within the realm of kitchen composters, targeting distribution channels such as electronic stores and kitchen-focused retail outlets. Furthermore, its availability through online platforms enhances accessibility and convenience for consumers, catering to diverse purchasing preferences and lifestyles.

Promotion To amplify its visibility and appeal, CoffeeMush adopts a multifaceted promotional strategy encompassing both digital and physical mediums. From engaging social media campaigns on platforms like Instagram to leveraging traditional advertising spaces such as bus stops, CoffeeMush's

promotional efforts aim to capture the attention of a wide audience and drive conversion through persuasive messaging and compelling visuals.

By intricately weaving these elements into its marketing approach, CoffeeMush not only positions itself as a market disruptor but also cultivates a strong brand identity synonymous with innovation, sustainability, and consumer value.

4.4.5 Brand

NAME OF THE BRAND

CoffeeMush

The name of the brand is *CoffeeMush*, a fusion of the words coffee and mushroom, the two main aspects of the product. It is made sure that this brandname and logo are protected by the trademark. In this way, other companies cannot take the name or logo.

COLOURS

The colours are choosen as seen in Figure 30.

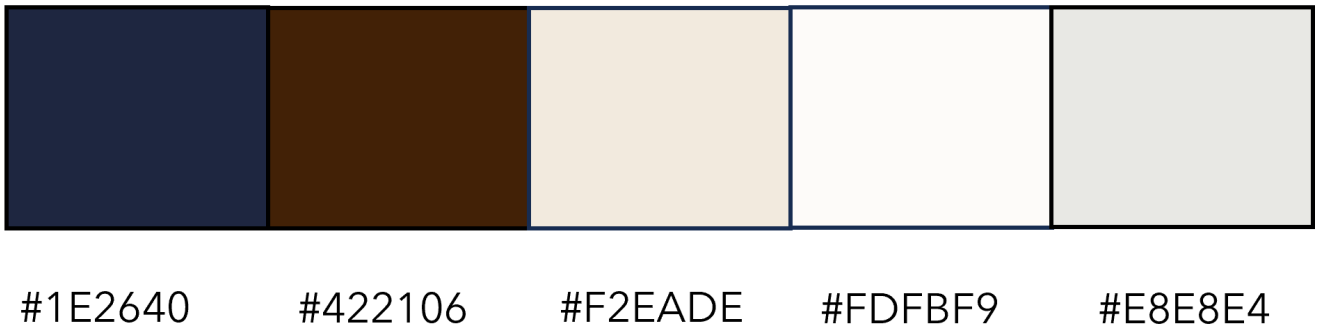


Figure 30: Colour palet

These colours are warm and match with earth colours, like the colour of mushroom and coffee (waste).

LOGO

A logo is a symbol comprised of words, images and colors to identify a brand or product. The logo of *CoffeeMush*, seen in Figure 31, is formed by the shape of a mushroom where the base is a coffee bean. This logo is designed to suggest the fusion of coffee with mushrooms, as well as the product does.

Figure 31: Logo CoffeeMush

SLOGAN

The following slogan was choosen because it is simple, catchy, positive and explains what the product is about:

Brew and renew, from coffee grounds to mushroom bliss!

FLYER

A flyer is a promotional material used to inform viewers about a brand, business or organization.

This flyer, seen in Figure 32, is designed to convey quality and sustainability, qualities that the product has. The idea was to make it simple as the composter works. The first thing one sees on the flyer is the name of the product, followed by a brief description of what it does. In the centre there is a large image showing how coffee mushrooms can be grown. The background is brown, which reminds us of coffee and mushrooms.At the bottom is the brand logo as well as the brand slogan. Finally, at the bottom right of the flyer there is a QR code in order to provide more information about the product to those who are interested.

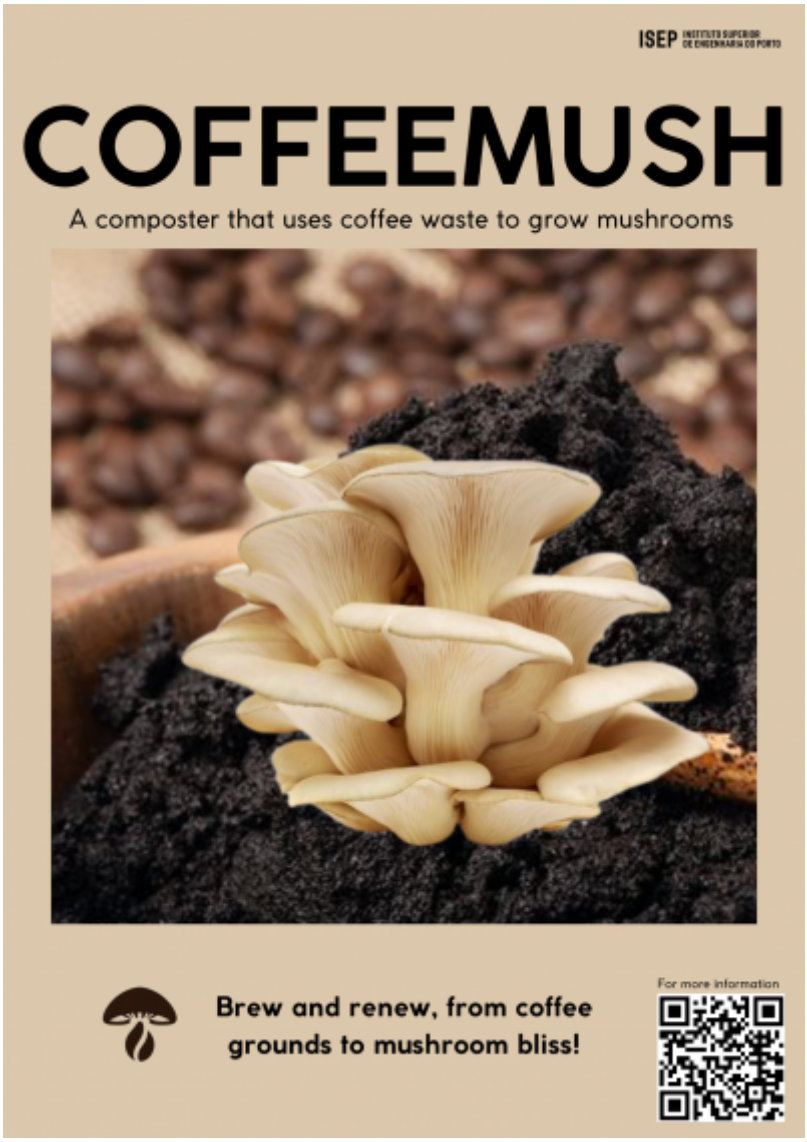
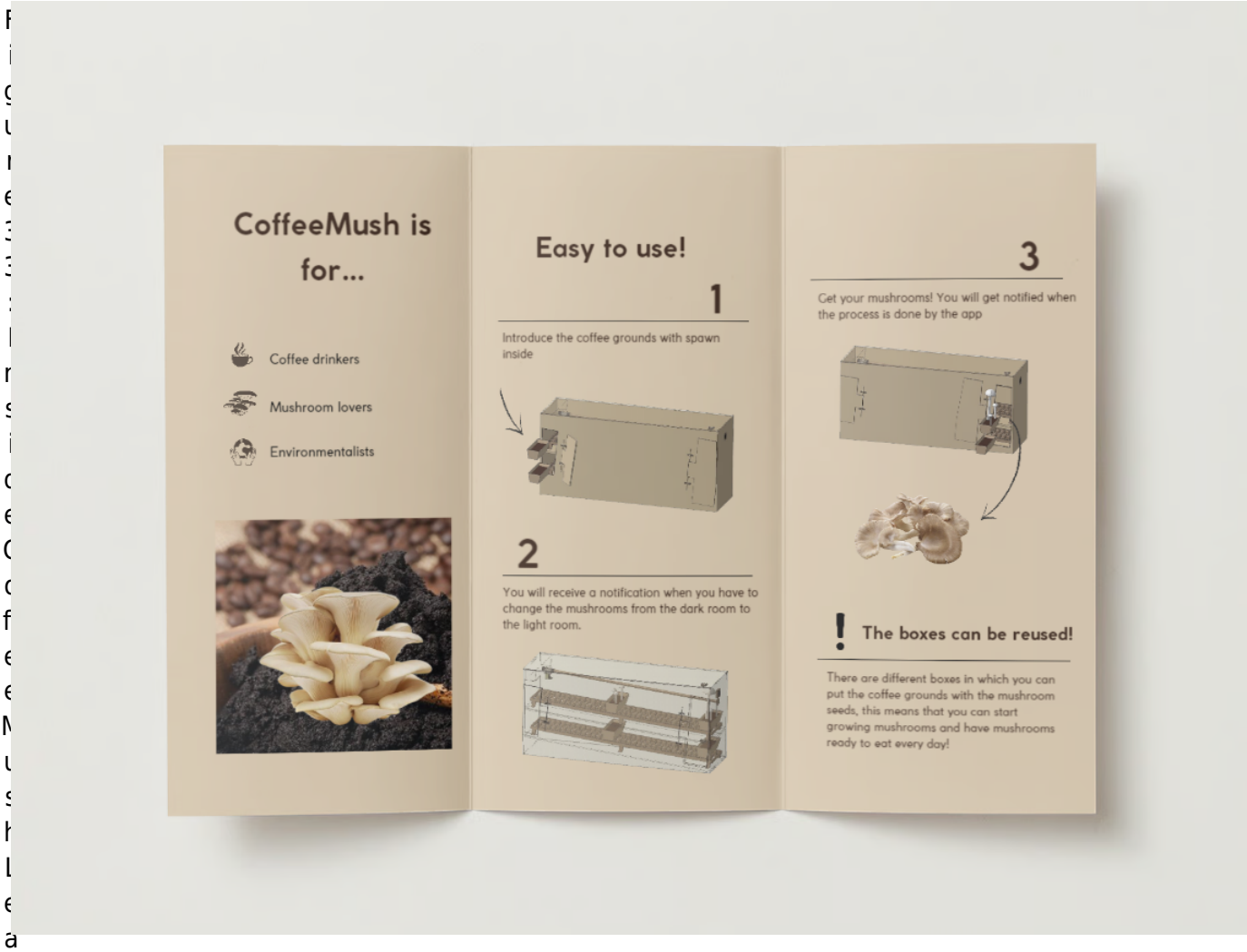


Figure 32: CoffeeMush Flyer

LEAFLET

A leaflet is a printed sheet of paper containing information or advertising and usually distributed free.

This leaflet, seen in Figure 33, is designed to communicate in a simple and visual way how to use the CoffeeMush composter. As you can see, the brand colours have been used and the same design as in the flyer has been respected. The leaflet is shown below.


CoffeeMush is for...
Coffee drinkers
Mushroom lovers
Environmentalists
Easy to use!
1
Introduce the coffee grounds with spawn inside
2
You will receive a notification when you have to change the mushrooms from the dark room to the light room.
3
Get your mushrooms! You will get notified when the process is done by the app
The boxes can be reused!
There are different boxes in which you can put the coffee grounds with the mushroom seeds, this means that you can start growing mushrooms and have mushrooms ready to eat every day!

flet

Figure 34: Outside CoffeeMush Leaflet

eeMush Leaflets

CoffeeMush Leaflets

The leaflet has been contextualised to show what it would look like in real life. The images are shown below.

Figure 37: Leaflet Contextualisation from the back

POSTER

As can be seen, the poster follows the same aesthetics as the flyer and leaflet. It has been kept simple, and the information has been distributed in a visual way.

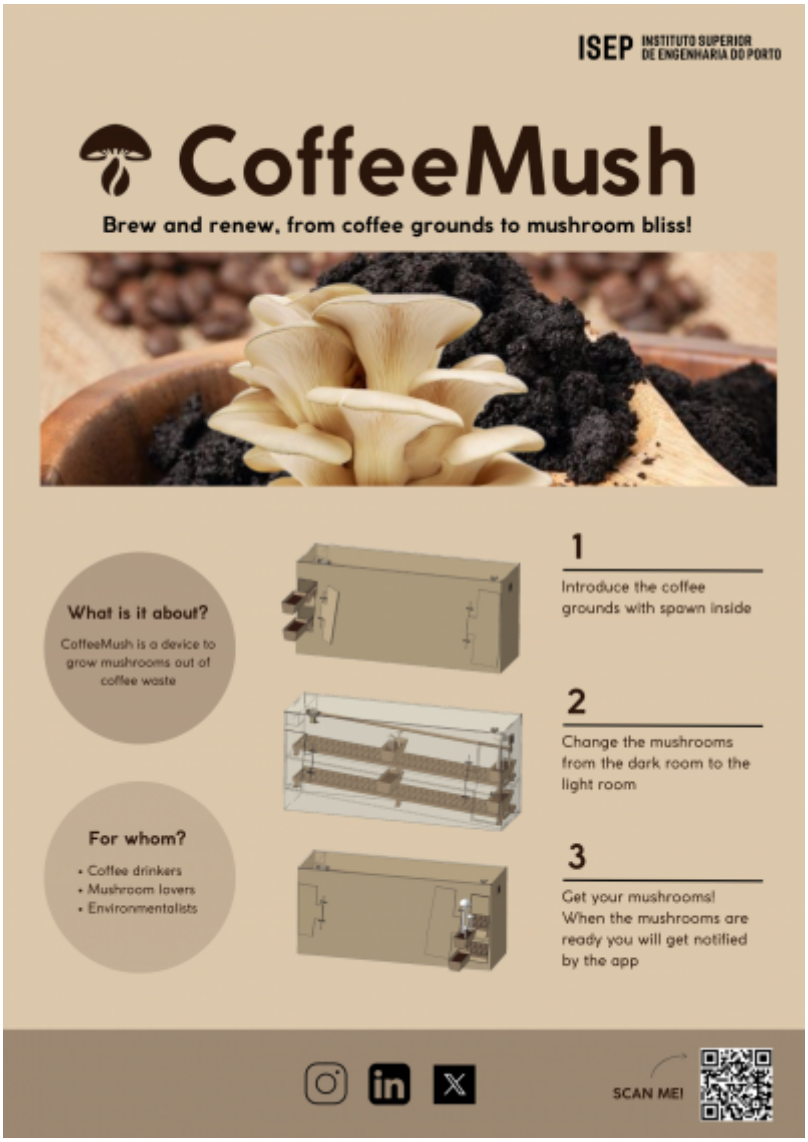


Figure 38: Poster

Follwing this, the programmes will finalize the marketing plan.

4.5 Marketing Programmes

4.5.1 Programmes

The product program contains for main aspects that need to be focussed on. First of all the product development: the CoffeeMush device will undergo comprehensive development and testing to ensure optimal performance and user satisfaction. Automating the composting process and streamlining mushroom cultivation is a must, without losing, of course, any accuracy on the project functionality.

Next to that, the team should focus on customer experience. Central to the program’s approach is a focus on delivering exceptional customer experiences. From intuitive setup instructions to robust support resources, the product is designed to ensure that every interaction with it is positive, simple and enriching.

Thirdly, market expansion should be done through advertising. To maximize the reach and impact, a strategic advertising campaign will be implemented. By using social media and print (leaflets, posters,

flyers) advertising, awareness of CoffeeMush among a broad audience will drive interest and engagement with our product. This advertising effort will showcase the benefits of CoffeeMush and position it as a must-have solution for eco-conscious consumers.

Lastly, partnership with supermarkets is important. Strategic partnerships with supermarkets will be forged to amplify the product's visibility and accessibility. Through collaborative agreements, CoffeeMush will be prominently featured and promoted within supermarket chains, increasing brand exposure and driving sales. By leveraging the existing customer base and distribution networks of supermarkets, CoffeeMush's presence in the market will be expanded and new customer segments will be captured.

Through these pillars, this program represents the project’s commitment to innovation, sustainability, and customer satisfaction.

4.5.2 Budget

To promote CoffeeMush and to make sure the customers can be reached according to the marketing program, money is needed. To calculate this budget, table 23 below is made. The expenses are estimated for the first year in which CoffeeMush comes onto the market. The cost for a social media manager in Portugal is 250 € per month on average **[GlobalPixal, 2024]**. That is 3000 € for one whole year.

Table 23: Budget marketing

Expense	**Cost [€/year]**
Flyers	80
Posters	200
Leaflets	100
Social media	3000
Total	3380

4.5.3 Control

To ensure optimal results from a marketing plan, it is essential to implement monitoring controls that track its progress. These controls continuously evaluate the plan's actual performance against projected outcomes, facilitating adjustments based on the analysis of marketing data. This can be done by taking care of the three following aspects **[George N. Root III, 2019]**.

- Consumer feedback: Marketing endeavors aim to influence consumer behavior and drive product or service adoption. One crucial control mechanism involves gathering customer feedback through various channels such as online polls, surveys, or direct interviews. This feedback informs adjustments to the marketing strategy based on consumer preferences and perceptions. For instance, if feedback reveals dissatisfaction with a recent feature like making it mandatory to have an account, it is prudent to remove or revise it accordingly.
- Sales analysis: Sales metrics, including units sold, revenue generated, and profitability, serve as key indicators of a marketing plan's effectiveness. Comparing actual sales data to projected targets provides insights into market response and identifies areas for improvement. For

example, if sales within the intended target market are below expectations, further research is conducted to understand customer behavior and preferences. Analyzing demographic sales breakdowns may reveal shifts in target audience dynamics, prompting adjustments to the marketing strategy.

- Advertising profit: Monitoring the marketing budget is crucial to maintaining financial health and maximizing returns. Controls such as tracking print advertising expenses, trade show travel costs, and market research expenditures help manage spending while optimizing profitability. By meticulously scrutinizing expenses, businesses can identify areas of overspending and make informed decisions to ensure budget adherence and resource optimization.

4.6 Conclusion

The marketing chapter has provided valuable insights into the potential of the product. Through segmentation and targeting research, clarity on the target audience and the purpose behind developing the solution is gained. This collective understanding fuels the team's determination to deliver a successful product to the market. The target audience is large, chasing individuals who are committed to global sustainability and have coffee drinkers in their households (not necessarily those who drink coffee themselves, but those who live with coffee waste producers). The marketing strategy, embedded within the marketing mix, integrates product development, pricing strategies, strategic placement, targeted promotions, and compelling brand messaging.

To effectively reach the diverse audience, the following is used: TV, social media, and print advertising channels, including leaflets, posters, and flyers. The goal is to capture the attention of the audience and highlight the benefits of CoffeeMush.

Furthermore, marketing control will be implemented to measure and evaluate the effectiveness of the marketing initiatives.

Moving forward, the next chapter will focus on ensuring the sustainability of this project, which is a priority in this team’s mindset.

5. Eco-efficiency Measures for Sustainability

5.1 Introduction

Sustainability is of high importance in the modern days. It means to satisfy existing needs, without eliminating the needs of future generations. This correlates with the 17 sustainable development goals (SDG’s) from the United Nations. They address poverty, hunger, good health and well-being, quality education, gender equality, clean water and sanitation, affordable and clean energy, decent work and economic growth, industry, innovation and infrastructure, reduced inequalities, sustainable cities and communities, responsible consumption and production, climate action, life below water, life on land, peace, justice, strong institutions and partnerships. Eco-efficiency generates more value through changes in technology and processes, while reducing resource use and environmental impact throughout the life of the product or service. It also applies to all aspects of the business, from purchasing and production to marketing and distribution **[Hari Srinivas, 2024]**.

Today, more than 90% of CEOs say that sustainability is fundamental for success. Evidence of the

modern CEO's state of mind is seen in how much attention companies are putting toward their sustainability strategies. Also, a recent report published by Shelton Group reveals that it's important for brands to take a stand on social issues. In fact, not only do consumers support corporate activism (86% want companies to stand for social issues) but also that 64% of them are likely to buy from such companies **[Shelton, 2024]**. According to Nielsen's 2015 Global Corporate Sustainability Report, 66% of consumers would spend more on a product if it came from a sustainable brand. Up to 73% of the surveyed millennials had a similar view. And according to Horizon Media's Finger on the Pulse study, 81% of millennials expect companies to declare their corporate citizenship publicly **[Simonetta Lein, 2018]**.

Because CoffeeMush is a new project, it is really important to take the different sustainable aspects into account. The aim is to be a sustainable brand, one that has successfully integrated environmental, economic and social issues into its business operations. Responsibility should be taken by affecting the different aspects as positive as possible.

Sustainability goes beyond environmental care, it involves four main aspects - environmental, economic, social and product life cycle - each of which must be taken into account for a true sustainability strategy. That is why this chapter is divided into these 4 sections: The environmental, where the importance of the environmental impact on society as well as on everyday life is shown. The economic, where all aspects of sustainable economy are examined, including the different possibilities that can be implemented.The social, where it is reflected how the composter is designed to be an inclusive and sustainable product. And at last but not least, the life cycle analysis, where the life cycle of the composter is studied.

Most SDG's come back in one of these paragraphs in this chapter.

5.2 Environmental

The environmental influence of products is of high importance nowadays. Due to the lack of responsibility of human beings, the environment is being destroyed. By using natural resources, emitting greenhouse gasses, and polluting nature. If this keeps up, the earth will heat up, there will be more flooding and human lives will be at risk. That is why it is important to be careful with the environment and to take it into account in everything one does. For the product, it is important to try to reduce negative influences on the environment. This is achieved by using sustainable materials, minimizing transport, reusing and recycling.

In the project, the aim is to use sustainable materials. A material is sustainable if the amount of CO_2 used to produce it is as low as possible. This is the case, for example, with recycled materials.

Pollution is a serious problem for both the environment and human health. Think of all the plastic litter that fills the oceans and the chemicals that litter the soil and water. It is causing the disappearance of wildlife, weakening ecosystems and damaging the health and livelihoods of communities.

People are starting to agree that businesses need to be more eco-friendly. That means not just cutting down on greenhouse gases but also making less trash, saving resources, and looking after biodiversity. Using stuff like recycled plastics, plant-based materials, and wood from responsible sources can really help businesses be kinder to the planet.

Plus, there are cool new ways to deal with waste, like turning coffee leftovers into mushroom food. Instead of throwing things away, it is about finding ways to reuse them and make them useful again. It is about being smart with resources, reducing waste and helping the environment while doing good

business.

It also reduces environmental pollution by reusing coffee waste to grow mushrooms. Traditionally, the coffee waste would have been thrown away and the soil for growing mushrooms would have to be produced and purchased separately. With this new way of using coffee waste to produce mushrooms, the amount of transport is minimized, fewer new products have to be produced and the waste does not need to be processed. This reduces the amount of CO_2 emissions.

5.3 Economical

Economical sustainability means that the price of the product matches the time the product fulfills its purpose. This has a relation with the following SDG's concerning economic growth, industry, innovation, reduced inequality, responsible production and consumption. For CoffeeMush the materials and transportation methods are the biggest economical influences.

Additionally, investing in innovation and finding creative solutions to economic challenges can pay off in the long run. For example, developing new ways to reuse coffee waste for mushroom cultivation not only reduces waste but also opens up new revenue streams and business opportunities. This kind of forward-thinking approach can lead to economic growth and resilience in the face of changing market conditions.

In addition, by promoting responsible production and consumption practices, one can reduce waste and minimize environmental impact, which can ultimately lead to cost savings and greater efficiency. Companies that prioritize sustainability often find that they can reduce their operating costs over time by optimizing the use of resources and minimizing waste generation.

The materials need to be obtained from a variety of places. The coffee needs to be collected from big coffee producers like coffee companies, restaurants or schools. This is most economically friendly if the coffee waste can be collected close to the kitchen composter. The aim is to collect the waste locally and possibly the mushrooms can be sold/exchanged there as well. This keeps the economic influences as low as possible.

Other materials for the composter need to be ordered at multiple companies. This makes it difficult to make them economically more sustainable, as prices are quite standard. The goal is to collect most materials from local companies.

The transport of the materials, the coffee, the spawns and the mushrooms needs to be limited to make it economically sustainable. This is done by exchanging, buying and selling efficiently. For example, if a school does not do anything with their coffee waste. The neighbors with a lot of space could collect the coffee and when they produce a lot of mushrooms, the school canteen could use it for their food. This could be compromised by some money or free food/coffee for the neighbors in the school.

5.4 Social

Social sustainability involves no poverty, equality, peace, justice and quality education. This product could contribute to those social aspects. For example, people can get a composter if they have a lot of coffee waste. If they do not need the mushrooms, they can sell them (locally) and make money out of it.

The CoffeeMush composter is not just about growing mushrooms, it is about making a real difference in people's lives. It is designed to be affordable and easy to use, so anyone, no matter their background, can get on board with sustainable living. By giving a practical way to deal with their coffee waste and grow their own mushrooms, CoffeeMush is making green living accessible to everyone. And that is not just good for the environment; it is good for building a more inclusive and welcoming community too.

To contribute to quality education, the composter could be part of a learning class in schools. To teach children how to grow mushrooms from coffee waste. Schools usually have a lot of coffee waste and the mushrooms can be used in the canteen or to teach children to cook.

5.5 Life Cycle Analysis

Life cycle analysis (LCA), also known as life cycle assessment, is an essential tool to support sustainable development decision-making. According to the US Environmental Protection Agency, LCA is a tool for assessing the potential environmental impacts of a product, material, process or activity **[Allan Astrup Jensen, 1997]**.

In the following, the life cycle of the CoffeeMush composter is defined:

1. Procurement:

Standardised parts will be purchased for use as well as recyclable materials (aluminium, plastic and glass).

2. Production:

Transforming the raw materials into components combining the components to create the kitchen composter. Everything will be manufactured in the same factory to reduce logistical complexities, minimise transport costs, and reduce environmental impact by reducing energy consumption and transport emissions.

3. Treatment:

As far as the treatment of materials is concerned, sustainable and environmentally friendly treatments will be used. Therefore, chemical treatments will be avoided as they can emit toxic substances that pollute water and soil, and can emit toxic gases and residues.

4. Assembly:

The product is designed to be assembled quickly and easily.

5. Packaging:

The packaging will be sustainable. To achieve this, it's designed to have a second use after its primary function, which is transport, has been completed. It is also designed to be made from recyclable materials.

6. Transport:

The transport of the composter to retailers or consumers will be done by truck. It will be efficient in order to reduce gas emissions from vehicles. This efficiency will be achieved by using shorter routes;

by grouping multiple deliveries in a single vehicle to reduce both costs and emissions associated with transport; and by using hybrid or electric vehicles in order to reduce fuel consumption and emissions.

7. Use:

Installation and use of the composter in the kitchen. Some maintenance and operation may be necessary, adding new mushroom and coffee grounds.

8. End of its useful life:

When the product has reached the end of its useful life, it can be easily disassembled and its parts can be recycled by throwing them into the corresponding recycling bins.

5.6 Conclusion

A compact and efficient design has been chosen for the composter. The aim is to have something that does not take up too much space and at the same time is easy to use and accessible. This design choice not only makes our composter user-friendly but also helps minimize our environmental footprint by using fewer materials.

In terms of materials, Priority is given to recycled and sustainable options for the construction of the composter. By opting for materials like recycled plastics, the aim is to keep CO_2 emissions low during production, aligning with our commitment to sustainability.

When selecting the components for the device, make sure to choose durable and recyclable options. This ensures longevity and minimizes environmental impact throughout the composter's lifecycle, reflecting our dedication to sustainability and responsible waste management.

Apart from sustainability, ethics is an important aspect to take into account. In the next chapter this topic will be researched, analyzed and applied to CoffeeMush. Ethics of engineering, sales and marketing, environment and liability are taken into account.

6. Ethical and Deontological Concerns

6.1 Introduction

Ethics is a branch of philosophy that explores the complexities of human behaviour, especially how individuals interact within society. It seeks to understand the reasoning that underlies the moral judgements, investigating the concepts of right versus wrong **[Government of Canada, 2015]**.

Deontology, on the other hand, is a specific ethical theory within the field of ethics. It emphasizes the importance of adhering to rules to delineate between right and wrong actions. It is often associated with the philosopher Immanuel Kant, who espoused the view that ethical conduct adheres to universal moral laws, exemplified by maxims like “Do not lie” and “Do not steal.” The simplicity of deontology lies in its application: adhering to rules and fulfilling one's duty. This approach harmonizes with the human innate sense of ethical behaviour, making it easily understandable and relatable.

To ensure ethical integrity and adherence to deontological principles in the project, it is thoroughly

examined from several perspectives. As a result, the following sections are structured: first, engineering ethics, with the priority given to the fulfilment of engineering duties. Secondly, guidelines for sales and marketing ethics are established, outlining clear boundaries to keep activities within acceptable parameters. In addition, a focus on environmental ethics is integrated, in particular within the sustainability section. And finally, responsibility is seen as a crucial aspect to to take into account.

6.2 Engineering Ethics

Ethics and engineering are interconnected disciplines, engineers are held to the highest standards of honesty and integrity. Their work directly influences the quality of life of society collectively. Engineers are expected to stand up for the principles of honesty, fairness, justice and equity, while prioritising public safety and welfare. However, the specific ethical standards governing engineering practices may differ from country to country, and some nations lack a formal written code of ethics. CoffeeMush is mainly focused on the North-West European market, although it is also designed to reach the whole world.

The *National Society of Professional Engineers' (NSPE) code of ethics* outlines the standards of ethical behavior engineers should follow in their professional lives. Those are divided in 3 groups, the follow ones:

I. Fundamental Canons

Engineers, in the fulfillment of their professional duties, shall:

1. Hold paramount the safety, health, and welfare of the public.
2. Perform services only in areas of their competence.
3. Issue public statements only in an objective and truthful manner.
4. Act for each employer or client as faithful agents or trustees.
5. Avoid deceptive acts.
6. Conduct themselves honorably, responsibly, ethically, and lawfully so as to enhance the honor, reputation, and usefulness of the profession.

II. Rules of Practice

1. Engineers shall hold paramount the safety, health, and welfare of the public.
2. Engineers shall perform services only in the areas of their competence.
3. Engineers shall issue public statements only in an objective and truthful manner.
4. Engineers shall act for each employer or client as faithfulagents or trustees.
5. Engineers shall avoid deceptive acts.

III. Professional Obligations

1. Engineers shall be guided in all their relations by the highest standards of honesty and integrity.
2. Engineers shall at all times strive to serve the public interest.
3. Engineers shall avoid all conduct or practice that deceives the public.
4. Engineers shall not disclose, without consent, confidential information concerning the business affairs or technical processes of any present or former client or employer, or public body on which they serve.
5. Engineers shall not be influenced in their professional duties by conflicting interests.
6. Engineers shall not attempt to obtain employment or advancement or professional engagements by untruthfully criticizing other engineers, or by other improper or questionable

methods.

7. Engineers shall not attempt to injure, maliciously or falsely, directly or indirectly, the professional reputation, prospects, practice, or employment of other engineers. Engineers who believe others are guilty of unethical or illegal practice shall present such information to the proper authority for action.
8. Engineers shall accept personal responsibility for their professional activities, provided, however, that engineers may seek indemnification for services arising out of their practice for other than gross negligence, where the engineer's interests cannot otherwise be protected.
9. Engineers shall give credit for engineering work to those to whom credit is due, and will recognize the proprietary interests of others **[National Society of Professional Engineers, 2019]**.

The standards underline the significant influence that engineering has on the world and its people. It is therefore essential to ensure that engineering contributions are both beneficial and ethical. Engineers should be committed to fundamental principles, professional guidelines and personal commitments to uphold the highest standards of safety and integrity.

6.3 Sales and Marketing Ethics

Sales ethics as well as marketing ethics are essential to have a responsible business. Sales ethics refers to a set of behaviors that ensure that every lead, prospect and customer is treated with respect, fairness, honesty and integrity. It means that a salesperson gives priority to the people to whom they sell, respects their decisions and opinions rather than imposing their agenda on them.

When thinking long-term, ethical sales behaviour makes sense: it builds loyalty and trust with customers because it does the right thing for them. What is the result? Higher customer spend, more engaged employees and lower company operating costs. By adopting an ethical approach to sales, a clear statement is made: the intention is to sell to customers who want to buy the product or service rather than to sell by any means necessary. So ethical sales can take the whole company to the next level. By integrating ethical culture into CoffeeMush's business, the foundation is laid for customer loyalty, higher morale among sales reps and the marketing team, and even sustainable growth.

To make that happen, it's necessary to take the following steps:

1. Always be honest about the impact the product makes.

Many customers will never do business with a company again after just one negative experience. These unhappy customers may also overload the customer support department with complaints and refund requests.

2. Avoid attacks on competitors.

Underestimating competitors will not enhance your reputation in the eyes of potential customers. On the contrary, it may give the impression that you are dishonest and unethical.

In essence, the focus should be on making the product stand out in terms of quality, rather than denigrating competitors.

3. The "Serve, don't sell" approach is recommended.

The sales process is fundamentally about supporting buyers in making informed decisions. According

to Liston Witherill, creator of the “Serve Not Sell” method, this approach takes the pressure off salespeople to drive sales.

The “Serve Without Selling” method consists of different stages that can be followed sequentially:

- **Fit:** Define the perfect customer by taking into account demographic and psychographic factors such as job title, industry, company size, beliefs, key issues and previous experience.
- **Discovery:** Identify the potential customer's personal and organisational pain points, understand why change is needed now, determine their goals, objectives and motivations.
- **Offer:** Present solutions suited to the potential client's pain points and objectives, demonstrate how assistance can be provided, offer examples of similar past clients, provide options for collaboration and answer any questions.

To conclude, the idea is to generate a customer network made up of people and businesses that can truly benefit from the offered product, creating mutually beneficial relationships.

From the customer's perspective, the goal is that the product can make a real difference to their life or business. From the company's point of view, the aim is to have loyal customers who are satisfied with CoffeeMush and that this leads to an ethical and honest relationship **[Pipedrive, 2024]**.

6.4 Environmental Ethics

The field of environmental ethics concerns human beings’ ethical relationship with the natural environment. Environmental ethics examines the moral relationship of human beings to nature, following the growing awareness in the 1970s of environmental threats from technology, industry and population growth **[Alasdair Cochrane, 2024]**.

As commented in the sustainability chapter, worsening environmental pollution and the depletion of natural resources underline the urgency for companies to take immediate action to protect the environment. Companies that adopt an environmental ethic are known to be more valuable within their industry. By fulfilling their environmental responsibilities, they also put pressure on other companies that are reluctant to do the same. For these reasons, it is vital that the team takes into account the environmental impacts of the product, whether direct or indirect. For this reason, certain measures will be taken, which are as follows:

- Recycled and recyclable materials will be used.
- The composter will be manufactured in factories that have a regulation of the pollution that is emitted
- The parts that are purchased from suppliers and are standardised, will be purchased from companies that have environmental ethics in mind and act in accordance with their products.
- The product will be designed to be easily recyclable.
- Sustainable packaging will be designed. To achieve this, it is intended to be designed in such a way that it has a second use after the end of its main function, which is to transport. It is also intended to be made of recyclable materials.
- Transport and distribution will be efficient in order to reduce greenhouse gas emissions from vehicles. This will be done by using shorter routes; by grouping multiple deliveries in a single vehicle to reduce both costs and emissions associated with transport; and by using hybrid or electric vehicles in order to reduce fuel consumption and emissions.

6.5 Liability

Responsibility are those principles that the company defines as an ethical and trustworthy corporation. The team CoffeeMush is committed to working according to the principles listed below:

- **Environmental impact:** Take into account the ecological footprint left behind. Decisions should always be made from an environmental perspective. Actions can be taken such as using recyclable materials.

- Human rights: Consider and respect human rights. Produce in factories that respect minimum salaries, safety measures and do not exploit women and children.

- Safety standards compliance: In order to guarantee a safe product for consumers. This can be achieved through quality controls.

- Consumer instructions: Users must be provided with accurate information about the product. This includes instructions for use and appropriate warnings.

- Ethics: The company is committed to comply with the ethical guidelines explained in the previous sections.

- Data privacy protection: The data will be handled carefully and making sure that it doesn't fall in to the wrong hands. Data privacy protection will be given high importance to protect costumers.

There are also some directives from European Comission that must to be followed and taken into account to ensure that the product is safe and also to avoid lawsuits in case of an accident. Those directives are as follows:

- **Machinery directive [2006/42/EC.]:** (17 May, 2006) Is one of the main legislations of health and safety for machinery. Regulates the potential dangers that a human may experience when using a machine. This directive ensures a high level of protection for EU workers and citizens. **[European Comission, 2006]**
- **Electromagnetic Compatibility (EMC) Directive [2014/30/EU.]:** (26 February, 2014) Refers to all electrical devices that are interconnected or interfere with each other when they are close. This direction keeps all side effects under control and guarantees that electrical and electronic equipment does not generate electromagnetic disturbances and is not influenced by them. **[European Comission, 2014]**
- **Low Voltage Directive (LVD)[2014/35/EU]:** (20 April, 2016) Covers health and safety risks in electrical devices with a certain voltage: 50 and 1000V for alternating current; 75 and 1500V for direct current. **[European Comission, 2016]**

CoffeeMush is firmly committed to responsible ethical business conduct. By following the principles and regulations outlined above, the company shows itself to be trustworthy and reliable. By focusing on environmental impact, human rights, safety compliance and consumer instructions, CoffeeMush works to ensure that its products not only achieve high quality standards, but also make a positive contribution to society and the environment.

6.6 Conclusion

The intersection of ethics and engineering points to the profound responsibility of engineers in determining the wellbeing of society. Standing up for honesty, integrity and ethical conduct is essential, although standards may vary from country to country. For CoffeeMush, targeting the North West European market while still aspiring to a global reach requires embracing rigorous ethical principles, as defined by the National Society of Professional Engineers (NSPE). These principles underline the great influence of engineering and the imperative to ensure ethical and beneficial contributions.

This chapter has identified the ethical needs to be addressed unconditionally and has defined the actions that will be taken in order to ensure this. For ethical engineering, the engineers of the team will strictly follow the code of ethics, as they have a huge impact on the world and on people. However, specific ethical standards and practices may differ from country to country. Sales and marketing ethics are essential for responsible business. The decisions and opinions of consumers will be respected rather than imposing the need and purchase of the product. In the environmental field, it is essential to take measures to respect the environment in product development. This is why the aim is to use recyclable materials, which will be tested to ensure that they are product safe and that they comply with regulations. Last but not least, liability has been focused on environmental impact, human rights, safety compliance, consumer instructions, and data security. To ensure liability, European Commission directives will be strictly followed to ensure that the product is safe.

In the following chapter it will be discussed how the team has been organised for the execution of the project, as well as the methodology that has been followed for the development of the product.

7. Project Development

7.1 Introduction

In this chapter, the development of CoffeeMush is explained. The requirements for this project are organized to five main aspects. Firstly the data needs to be acquired, stored and monitored for communication about the composting process. Secondly, the hardware solutions should be affordable and local. Next to that, the software should be open-source to become a transparent company towards the user. Fourthly, the International System of Units is used for consistency. Lastly the directives are an important standard in the whole project.

These requirements are reached by taking them into account in the whole design process. In the next paragraph the ideation of the project will be discussed. After that, the concept is explained of the composter itself. Thirdly, the design is explained by the structure, smart systems, packaging and manual. External programs are used for this, as well as tables and pictures to give a better view on the project. Lastly the prototype with hardware and software is shown

7.2 Ideation

The beginning of this project was a lot of brainstorming and discussing. At first the team wanted to make a kitchen composter for all organic waste. Composting food waste is a natural process that takes really long before the product can actually be used again. The market does not show many devices which can do this efficiently. Besides the budget is really high for composters like this. CoffeeMush thrives to make a useful product from actual waste. There are some coffee growing devices on the market, but their input is a product that needs to be bought from the company before

the device can be used. So the options for developing a kitchen composter show some challanges.

As the team wanted to focus on making the product affordable and sustainable, the idea of using only coffee waste to produce mushrooms came up. The idea of CoffeeMush had many advantages and piqued our interest. The idea is to use coffee waste and combine it with mushroom seeds to grow mushrooms in a couple of weeks. To do this, the seeds must be in the dark for the first week and in the light afterwards. It is also important to use coffee residues that are no more than 24 hours old, so collect them periodically and make separate components for each 24 hours.

7.3 Concept

The concept is shown in Figure 39

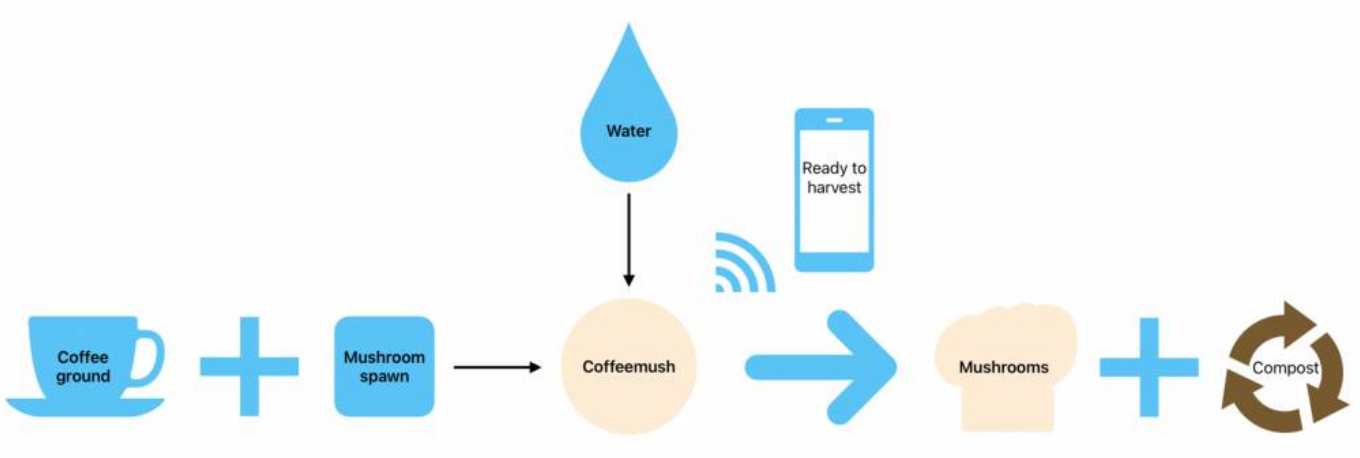


Figure 39: Concept CoffeeMush

The concept behind CoffeeMush is to build an affordable, sustainable and low power device that automatically grows edible mushrooms from coffee grounds while composing. The product consists of two main parts, a dark room for mycelium growth and a light room for ideal fruit growth. Both growth chambers contain small boxes, in which the mushrooms grow. The user needs to place coffee grounds and mushroom spawn in one of the small boxes and place it into the dark room of the device. Then the plug is plugged in and everything else, such as watering and ventilation, is done automatically. All the user has to do, is wait for a notification from the app, that the mycelium is ready for the light room and place it there. The actual mushroom will then begin to grow. When the mushrooms are ready to be harvested, the user will receive another notification on their smartphone. It is also possible to check the approximate time when the next boxes will be ready, or to see and be notified when the water needs to be refilled. Adding coffee grounds is very flexible. The user can do it every day with fresh coffee grounds and harvest the mushrooms every day, or for example collect the coffee grounds once a week from a local cafeteria, school, etc. and harvest the mushrooms once a week. The coffee grounds should not be more than 24 hours old to ensure good mushroom growth. Once the mushrooms have been harvested, the substrate can be returned to the light room for a second growing cycle. Finally, the decomposed remains can be used to fertilise the plants. After cleaning the box in a dishwasher or with water and disinfection, the process can be repeated.

7.4 Design

7.4.1 Structure

The first drawing of the ideas can be seen in Figure 40.

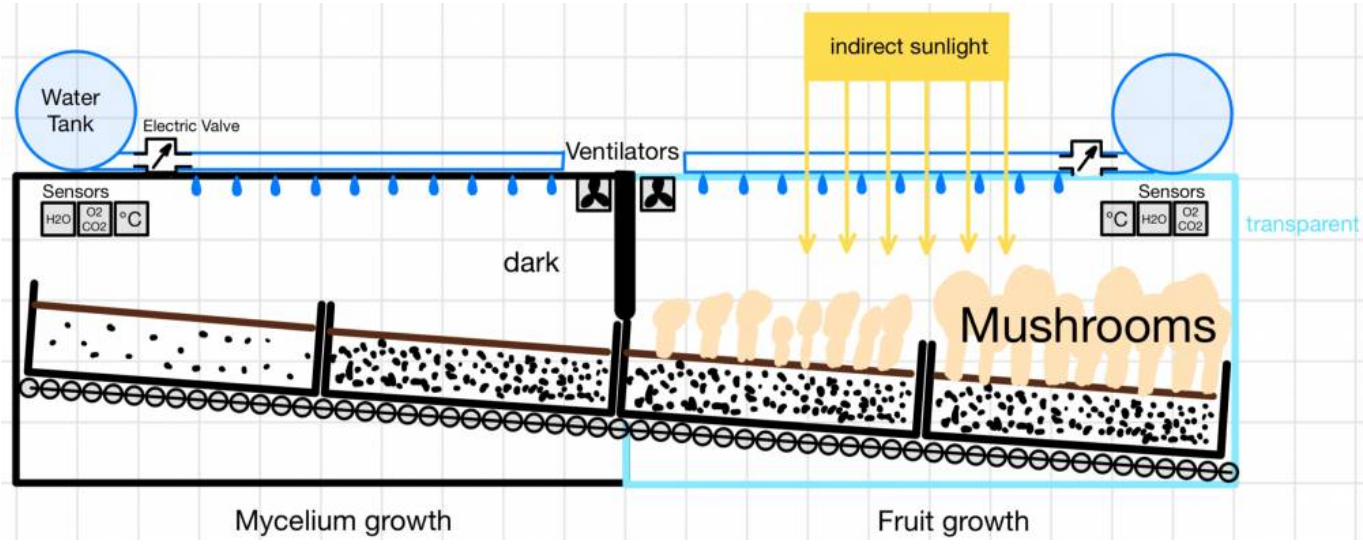


Figure 40: First drawing

The main idea was to build a device that reuses coffee grounds to grow edible mushrooms, while composing the coffee grounds. For the development of the mushrooms there should be a dark room for the mycelium growth and a light room for the fruit growth, because these are the ideal conditions. After the mycelium growth is finished the small boxes need to move to the light room. To avoid energy consumption, the boxes are on a roller conveyor and move because of gravity. The sensors should check the humidity, air quality and temperature and by opening a valve on the water tank or turning the ventilation on it is possible to have an impact on the climate in the device. The water tanks are on top of the chambers to avoid the use of a pump.

To improve the product a second drawing was made to optimize the function and to keep the price as low as possible. In Figure 41 you can see the second drawing.

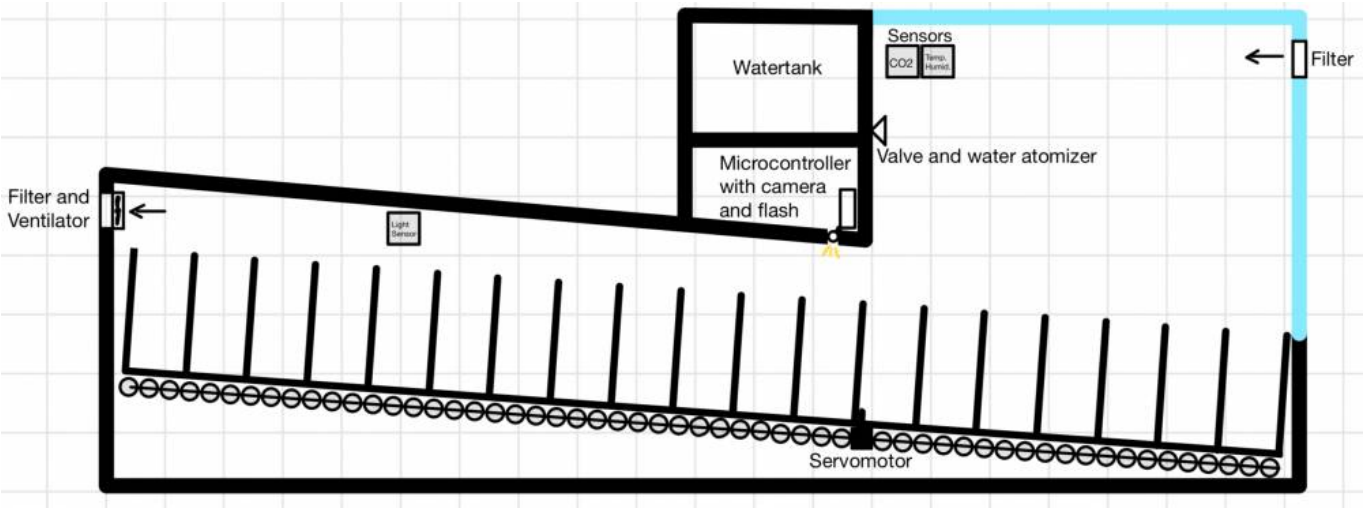


Figure 41: Improved drawing

To achieve the full potential of reusing coffee waste, growing mushrooms and getting fertilizer it should be possible to add your coffee grounds and harvest mushrooms every day. For that reason there are 12 boxes in the dark room and 7 boxes in the light room, because the mycelium growth takes 12 days and the fruit growth 7 days under ideal conditions **[Carmen Sánchez, 2009]**. To avoid

the movement of the boxes too early in the light room, for example when the boxes with coffee grounds are only added every second day, there is a camera and a servomotor added. The camera takes a picture and a trained AI can tell if the mycelium is ready for the next chamber. Then the servomotor moves and makes the way for the box to go down and blocks the way again before the next box can pass.

After the first ideas, a cardboard model was made, as can be seen in Figure 42.

Figure 42: Cardboard model

This model was then transformed into a 3D model, as can be seen in Figure 43.

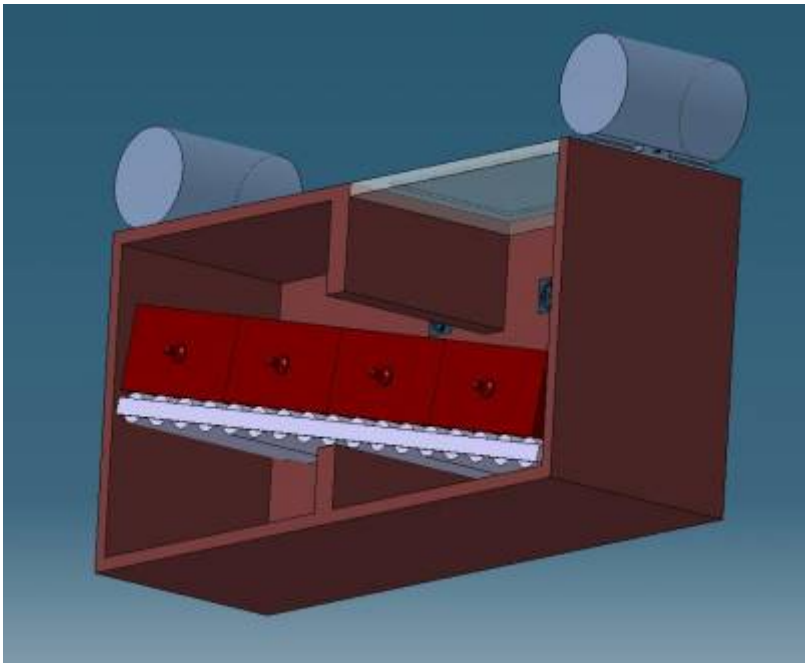


Figure 43: First 3D model

After the first iteration, some adjustments were made, resulting in a new 3D model, as shown in Figure 44, 45 and 46. The format of the first box was designed to use the coffee grounds only once. However, it turned out that the coffee grounds could be used twice. So the idea of repeating this process was added to the previous design, resulting in a new format. The new CoffeeMush consists of two levels: the dark room and the light room. It can be filled with 14 boxes on each level, allowing the

mushrooms to grow twice! A hole was made in the second level so that air could flow into the first, keeping all the mushrooms in the best condition. The only inconvenience with this new design is that when the mycelium is ready, it has to be moved by hand from the dark to the light room. An ESP-32CAM was also added to allow the mushrooms to be seen in both the dark room and the light room. The current format of the small boxes was not good. They were much too high and this would prevent the mushrooms from growing properly. It was decided to look into the problem. The first thought was to get boxes of the same size but with holes in the sides. This allowed the mushrooms to grow everywhere. But because there is no space between the boxes, the mushrooms would have difficulties in growing. But if it had holes, it would need a system to create that space, which would increase the size of the already large product, in addition to requiring complete control of the roller conveyor. The second thought was to reduce the height of these boxes, which would allow the mushrooms to grow well, while eliminating all the problems of the previous solutions. So it was decided to go with this second proposal. Here is the structure, made up of a large box, a glass part, the small boxes, the doors, the roller conveyors and all the sensors needed for the composter to work properly. The first two doors, on the left and right, are used to load and unload the small boxes of coffee and mushrooms. The third door allows access to the water tank, which is connected to the valve. The roller conveyor allows the small boxes to be moved forward by gravity. The main purpose of the glass part is to let the light through, but it also allows you to see the progress of the mushrooms.

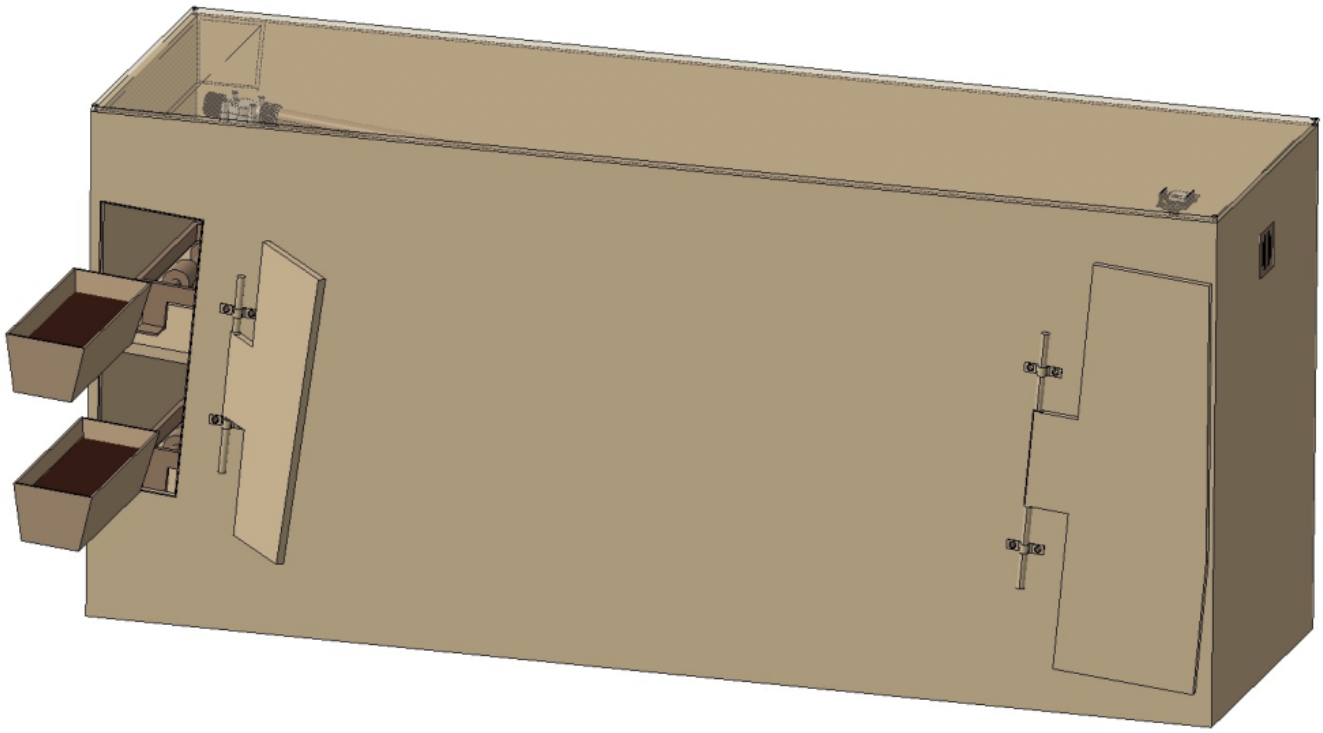


Figure 44: 3D model 1

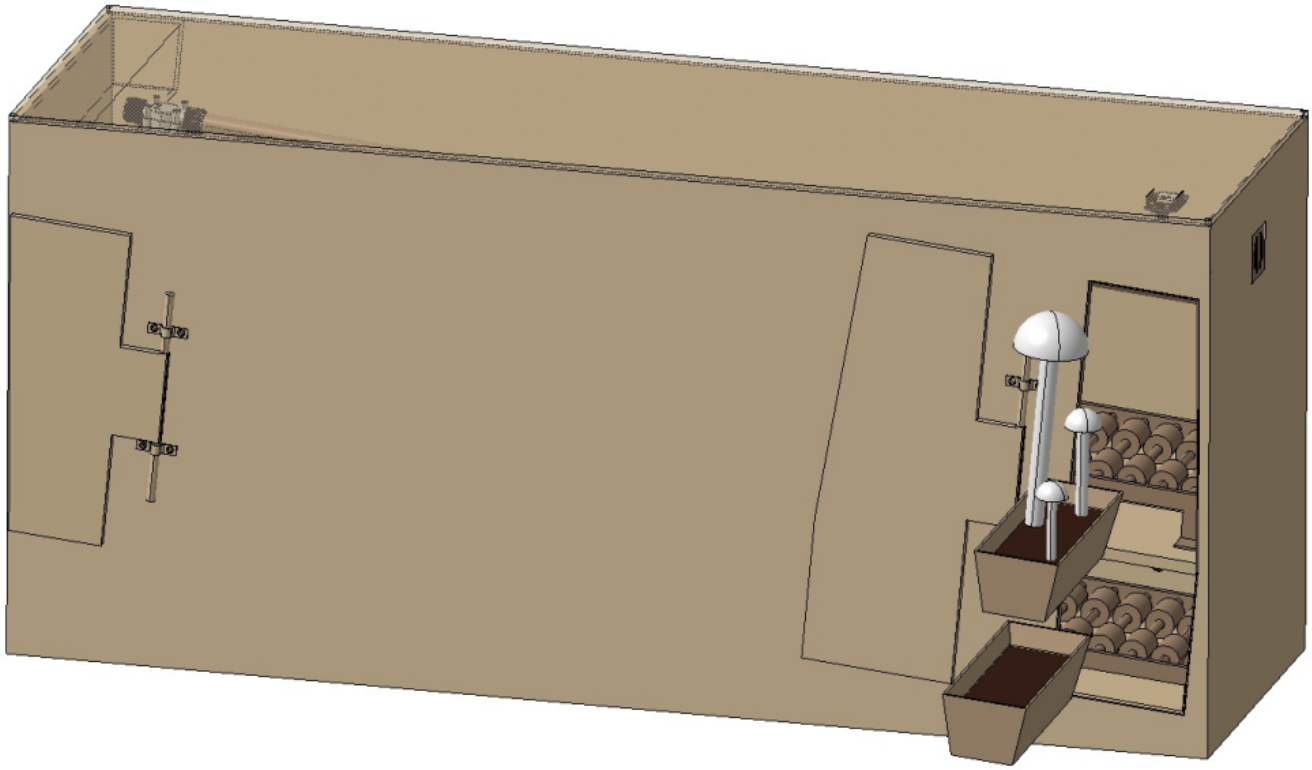


Figure 45: 3D model 2

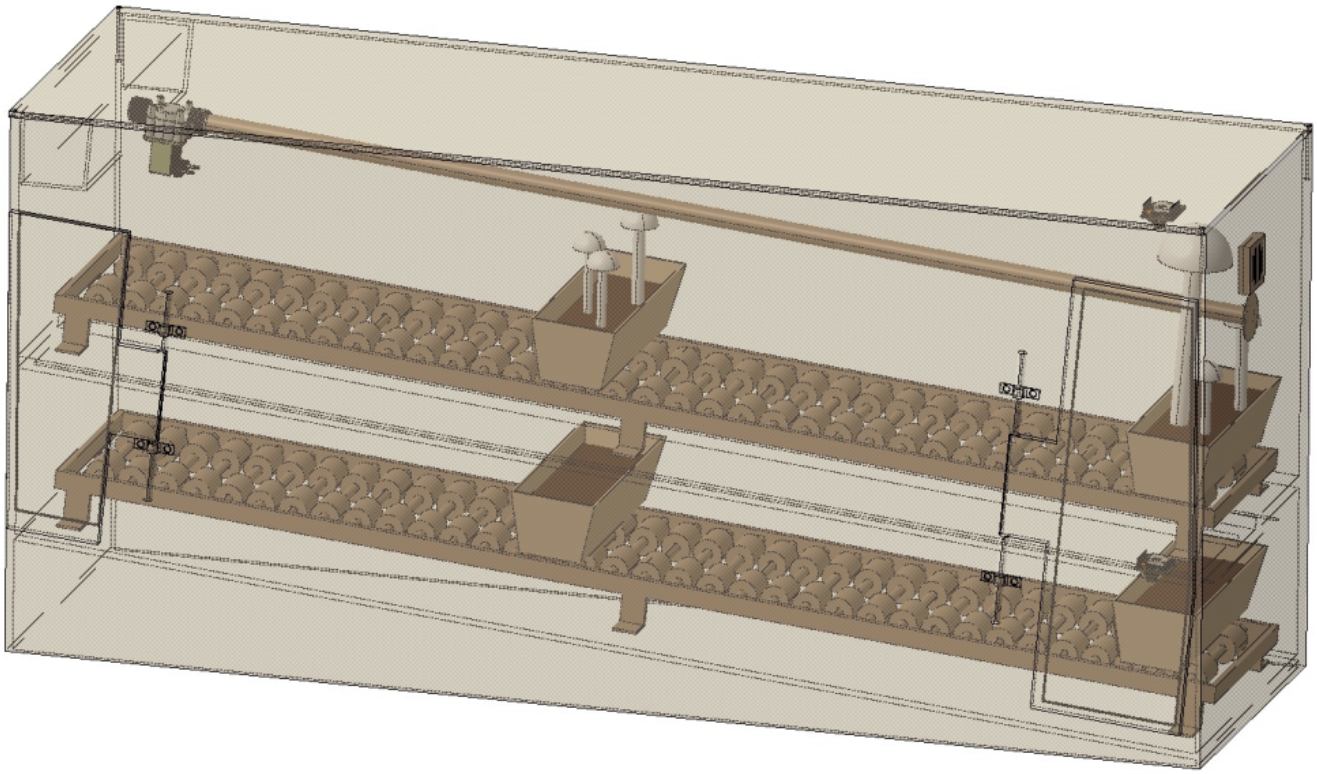


Figure 46: 3D model 3

7.4.2 Plans

Table 24: List of plans

Page Number	Name
7	Axe
6	Glass

Page Number	Name
5	Box
4	Door
3	Big door
2	Big box
1	Composter

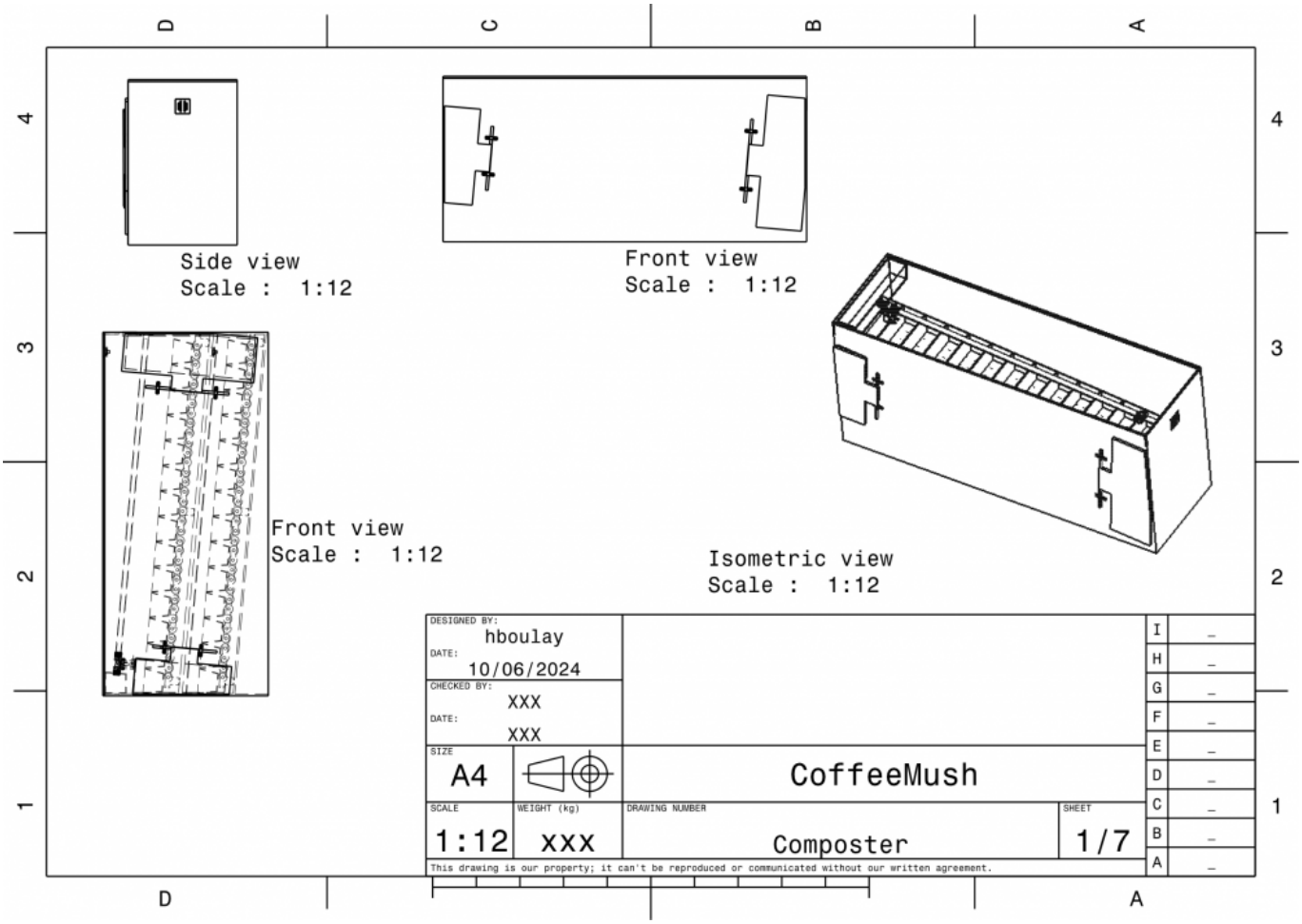


Figure 47: Composter

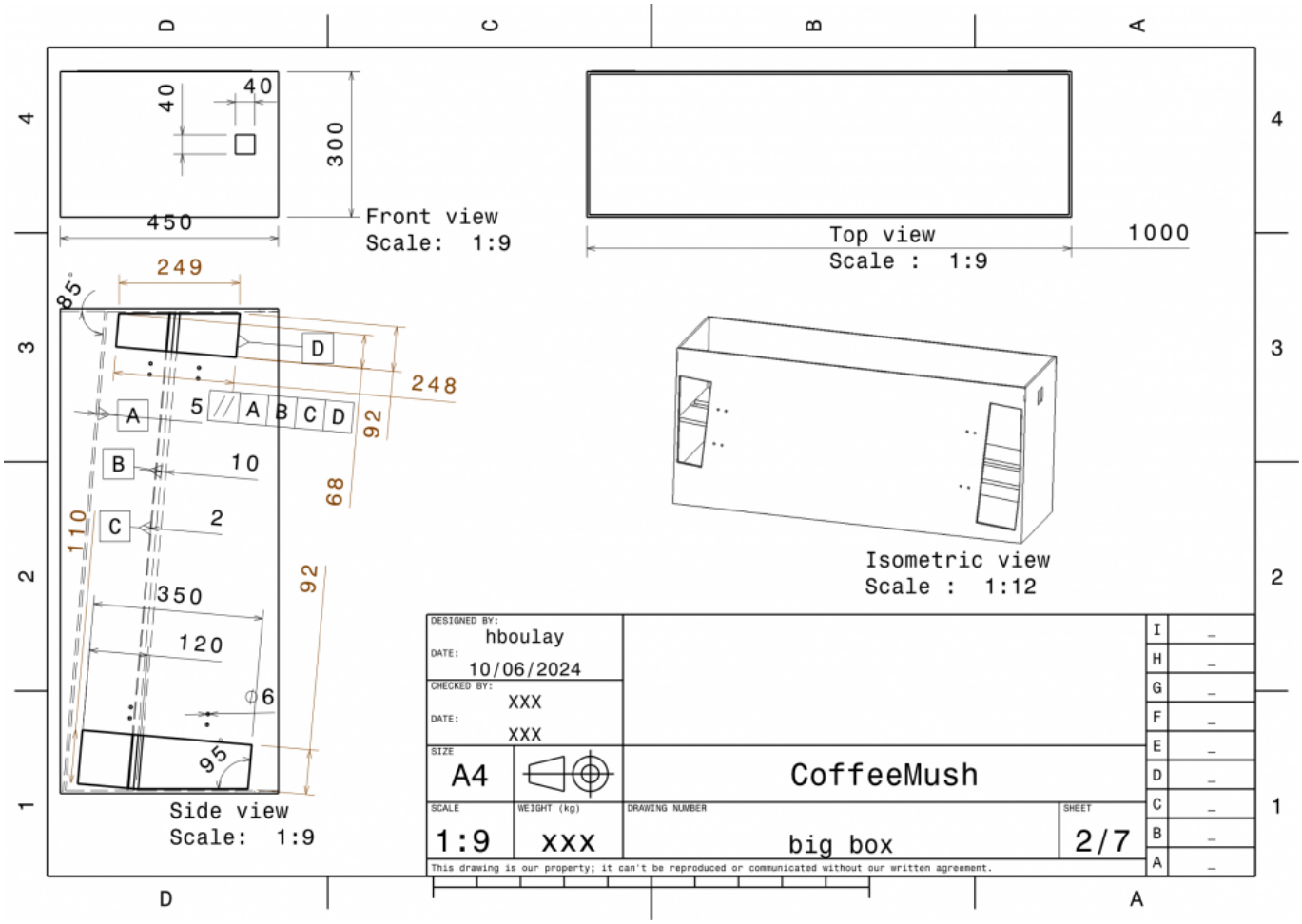


Figure 48: Big Box

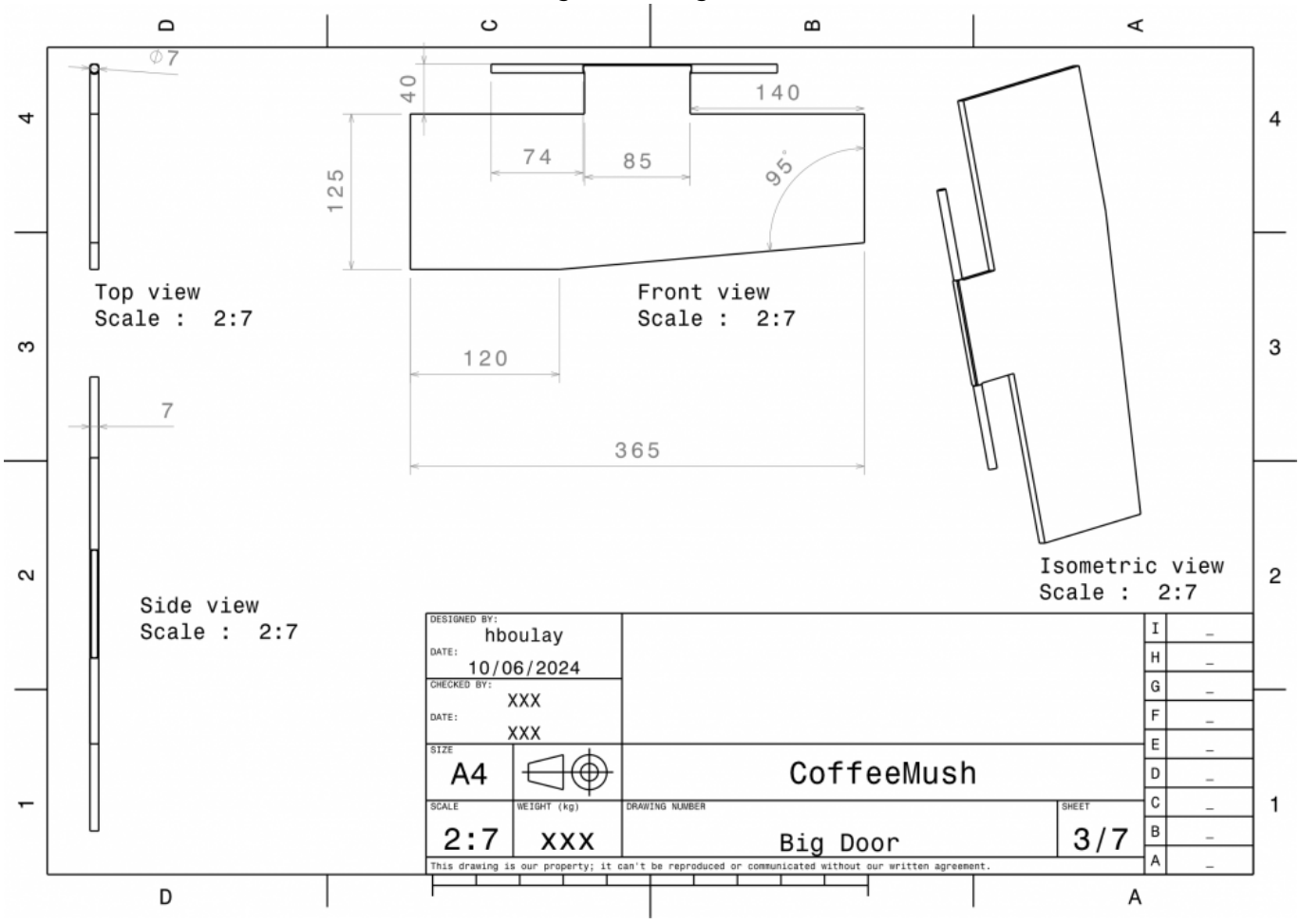


Figure 49: Big Door

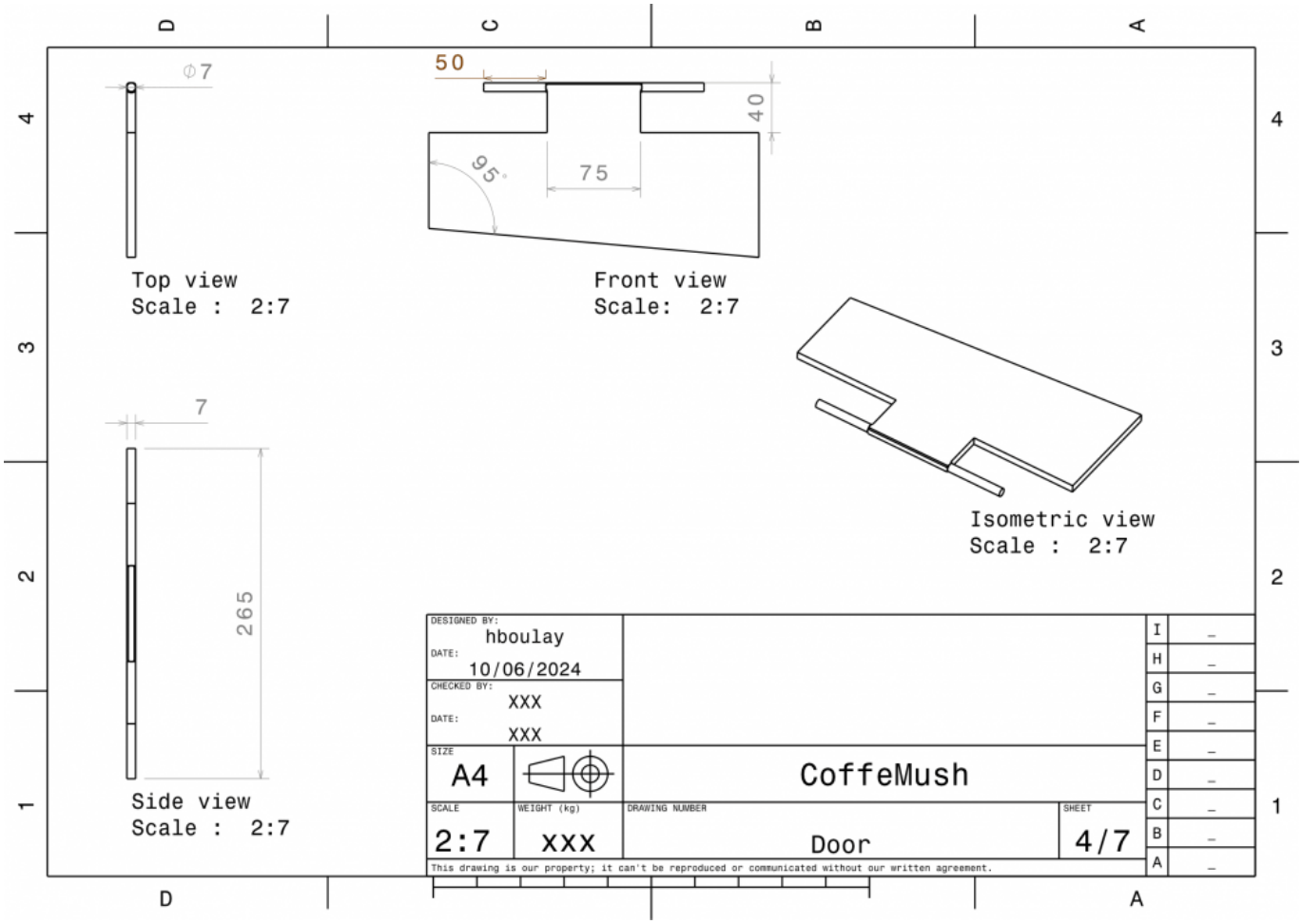


Figure 50: Door

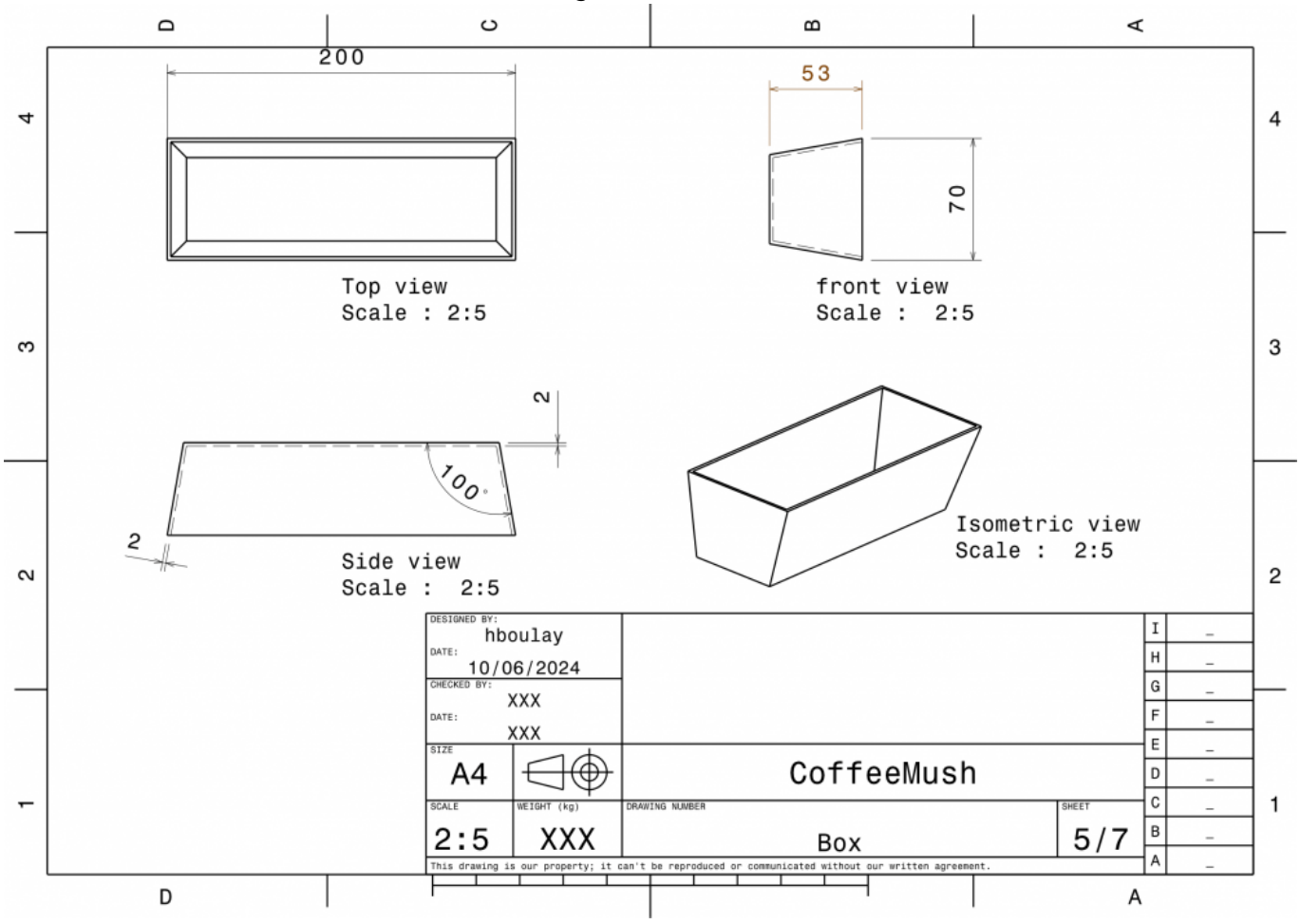


Figure 51: Box

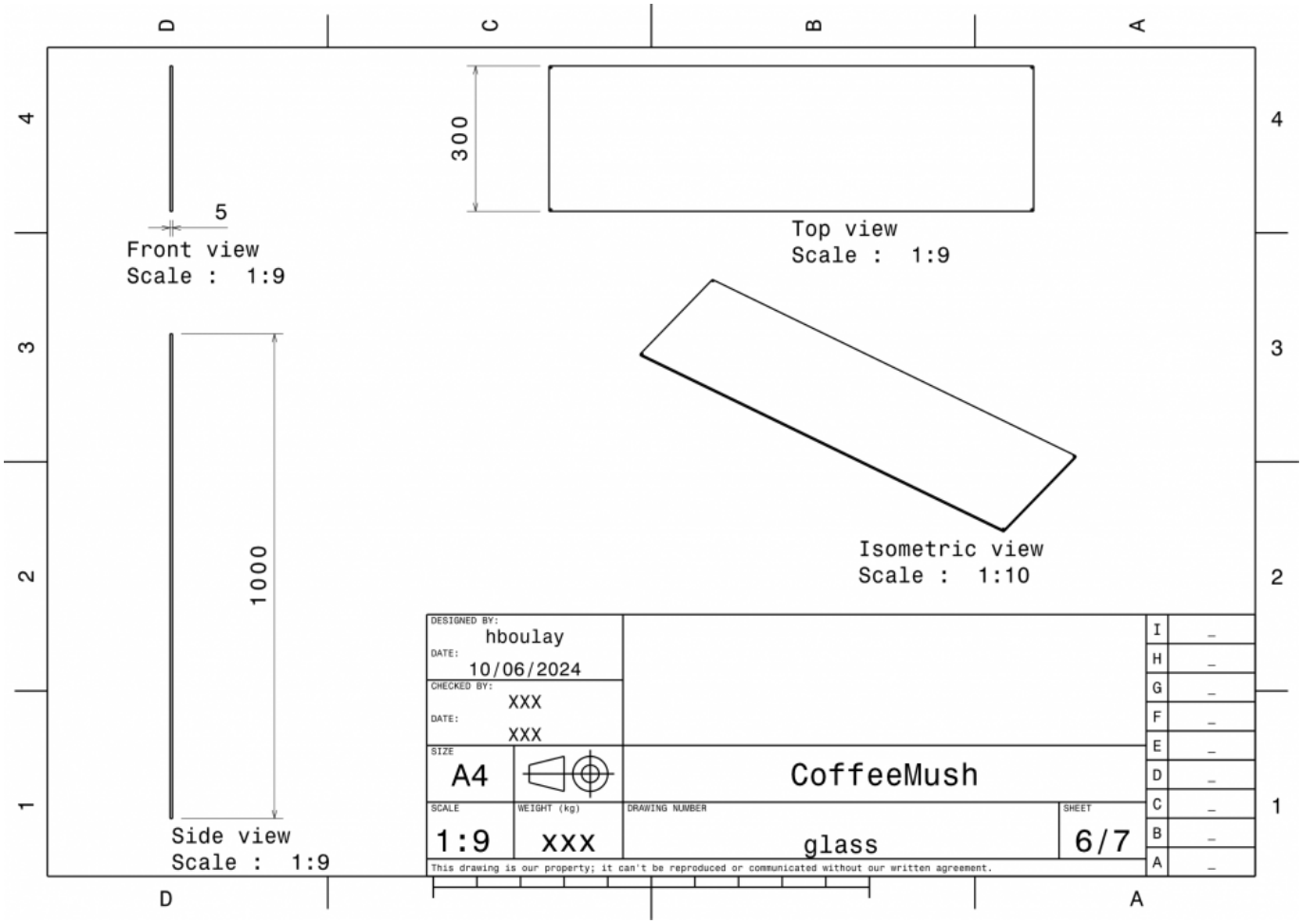


Figure 52: Glass

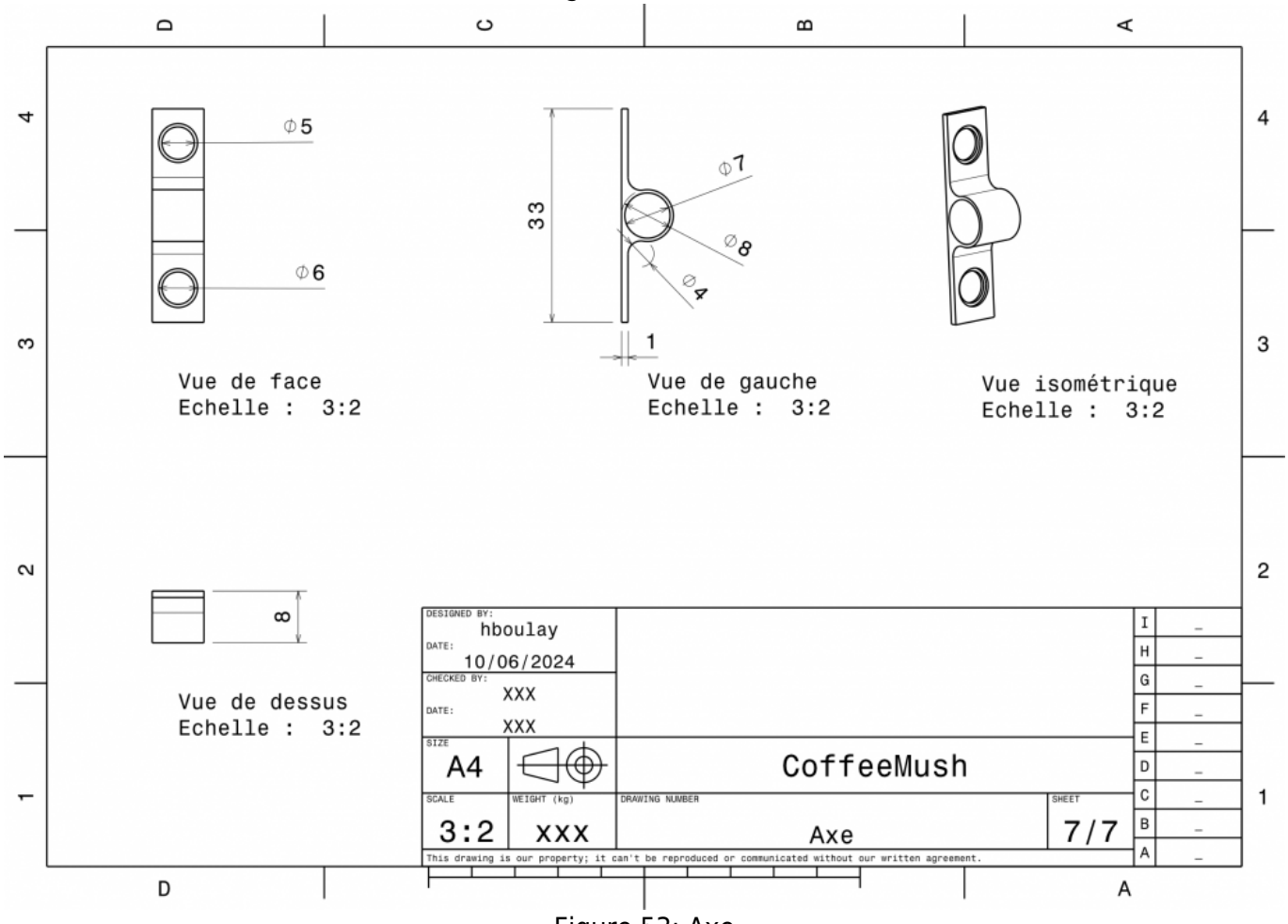


Figure 53: Axe

7.4.3 Ventilation

Ventilation is crucial for several reasons:

1. Air Circulation: Proper air circulation helps distribute heat, humidity, and fresh air throughout the grower, creating an optimal environment for mushroom growth.

2. O_2 Regulation: Mushrooms require O_2 for growth. Good ventilation ensures that there's enough fresh air containing O_2 for the mushrooms to thrive.

3. Humidity Control: Ventilation helps regulate humidity levels by removing excess moisture from the grower, preventing the growth of mold and ensuring the ideal moisture content for mushroom growth.

4. Temperature Regulation: Ventilation can help control the temperature inside the grower, preventing it from becoming too hot or too cold, which can negatively impact mushroom growth.

5. Preventing Contamination: Proper ventilation can help prevent the buildup of harmful gases and contaminants that can inhibit mushroom growth or lead to disease **[Melanie Andromidas, 2019]**.

7.4.4 Filter

Using both HEPA (High-Efficiency Particulate Air) and carbon filters offers several benefits:

1. HEPA Filter: HEPA filters are highly effective at capturing airborne particles, including spores, dust, and other contaminants. Using a HEPA filter helps maintain a clean and sterile environment inside the grower, reducing the risk of contamination and ensuring the health and purity of the mushrooms being grown **[U.S. Environmental Protection Agency, 2024]**.

2. Carbon Filter: Carbon filters are excellent at absorbing odors and gases. Carbon filters can help eliminate any unpleasant odors produced during the growing process, creating a more pleasant environment for growers and preventing the escape of strong mushroom odors into surrounding areas **[Breathe Naturally, 2023]**.

3. Combined Protection: By using both HEPA and carbon filters together, you can achieve comprehensive air filtration, ensuring that both particulate matter and odors are effectively removed from the air inside the grower. This helps maintain a clean, healthy, and odor-free environment conducive to optimal mushroom growth.

4. Smart Control: In the device, the ventilator is integrated with sensors and automation technology to monitor air quality and adjust filtration levels as needed. This ensures that air filtration remains efficient and effective, providing continuous protection against contaminants and odors without the need for manual intervention.

Overall, the combination of HEPA and carbon filters in the device contributes to improved air quality, reduced contamination risk, and enhanced growing conditions, ultimately leading to higher yields of high-quality mushrooms.

Using two HEPA/Carbon filters, one for incoming air and one for outgoing air, helps ensure maximum efficiency and effectiveness of the filtration system and also guarantees that no bad odors can escape or external contaminants can enter, even when the ventilator is turned off.

7.4.5 Components

Alternative parts

In Table 25 are alternative CO_2 sensors.

Table 25: Alternative CO_2 sensors

Sensor	STC31	SCD30	XENSIVTM PAS CO_2	MHZ-19	MHZ-1311A	MHZ-14B	UNITENSE U91010001
Manufacturer	Sensirion	Sensirion	Infineon	Winsen	Winsen	Winsen	UNITENSE
Measurement	CO_2, Temperature, Humidity	CO_2, Temperature, Humidity	CO_2	CO_2	CO_2	CO_2	CO_2
Measurement Range	400-2000 ppm, -20 °C to 70 °C, 0-100 % RH	400-2000 ppm, -20 °C to 70 °C, 0-100 % RH	400-5000 ppm	0-2000 ppm	0-1000 ppm	0-5000 ppm	400-5000 ppm
Accuracy	CO_2: ±(30 ppm + 3 % of reading) Temperature: ±0.3 °C Humidity: ±3 % RH	CO_2: ±(30 ppm + 3 % of reading) Temperature: ±0.3 °C Humidity: ±3 % RH	CO_2: ±(30 ppm + 3 % of reading)	±(50 ppm + 3 % of reading)	±(50 ppm + 5 % of reading)	±(50 ppm + 5 % of reading)	± (50 ppm + 5 % reading)
Power Consumption	8.6 mA (typical)	23.0 mA (typical)	6.1 mA (average)	80.0 mA (typical)	60.0 mA (typical)	35.0 mA (typical)	26.0 mA (typical)
Communication	I2C	I2C, UART	I2C, UART	UART	UART	UART	UART
Response Time	< 30 s (typical)	< 30 s (typical)	< 5 s (typical)	< 60 s (typical)	< 60 s (typical)	< 60 s (typical)	< 40 s (typical)
Dimensions	15 x 15 x 7 mm	35.8 x 23.8 x 7.7 mm	24.4 x 12.7 x 10.5 mm	33 x 20 x 13 mm	43 x 25 x 16 mm	43 x 25 x 16 mm	41.5 x 36 x 26.3 mm
Price [€]	59.33	47.97	25.56	71.90	75.59	75.59	26.39

The team chose the XENSIVTM PAS CO_2 sensor because it doesn't use a lot of power. Easy to connect it to the ESP32-CAM. Available on the supplier digikey, to avoid having to pay more for transportation. Accurate and still affordable.

In Table 26 are alternative Temperature and Humidity sensors.

Table 26: Alternative Temperature and Humidity sensors

Feature	DHT11	AM2320	SHT30	AHT20
Measurement Range	0 °C to 50 °C, 20 ~ 80 % RH	-40 °C to 80 °C	-40 °C to 125 °C, 0 ~ 100 % RH	-40 °C to 85 °C, 0 ~ 100 % RH
Accuracy (Temperature)	±2 °C	±0.5 °C	±0.2 °C	±0.3 °C
Accuracy (Humidity)	±5 %	±3 %	±2 %	±2 %
Response Time	1 s	5 s	< 8 s (Typical)	< 8 s (Typical)
Output Type	Digital	I2C	I2C	I2C
Supply Voltage	3 V - 5 V	3.1 V - 5.5 V	2.15 V - 5.5 V	3.3 V - 5 V

Feature	DHT11	AM2320	SHT30	AHT20
Power Consumption	< 2.5 mA (Active)	< 1 mA (Active)	< 1.5 mA (Active)	23 µA (Measure)
Dimensions	15.5 x 12 x 5.5 mm	15 x 13 x 5 mm	59 x 26.3 x 13.4 mm	25.4 x 17.8 mm
Price [€]	4.61	3.64	8.25	3.46

The sensor AHT20 will be used in the project. It can be used on the breadboard and consumes the least power which is sustainable. It delivers a high accuracy in measuring the temperature and humidity.

In Table 27 are alternative camera modules.

Table 27: Camera modules

Feature	ESP32-CAM	Raspberry Pi + Camera Module
Wireless Connectivity	yes	no
Programming language	C/C++	Python
Image sensor	OV2640 2 Megapixels	multiple version 8 Megapixel
RAM	built-in 520 KB+external 4MPSRAM	2 GB, 4 GB or 8 GB
IO port	9	40
Power Consumption	Turn off the flash: 180 mA at 5 V, Turn on the flash and adjust the brightness to the maximum: 310 mA at 5 V, Deep-sleep the lowest power consumption can reach 6 mA at 5 V, Moderm-sleep: up to 20 mA at 5 V, Light-sleep: up to 6.7 mA at 5 V	160 mA (0.8 W) – 350 mA (1.7 W), depends on the Pi Model
Integration	microcontroller	microprocessor
Price [€]	10.53	13.95

The reason to choose the ESP32-CAM it consumes less power. Which is more sustainable. Only 8 IO ports out of 9 should be used. This will be enough for the ESP32-CAM. It is cheaper and easy to use.

In Table 28 are alternative light sensors.

Table 28: Alternative light sensors

Feature	Adafruit TSL2591	Adafruit TSL2561	Photocell
Interface	I2C	I2C	Analog
Measurement Range	188 µlx - 88 klx	0.1 lx - 40 klx	0.1 lx - 10 klx
Output Resolution	16-bit	16-bit	N/A
Supply Voltage	3.3 V - 5 V	2.7 V - 3.6 V	3.3 V - 5 V
Power Consumption	0.4 mA (active)	0.24 mA (typical)	1 mA
Operating Temperature	-30 °C to +80 °C	-30 °C to +80 °C	-30 °C to +80 °C
Package	Surface Mount	Surface Mount	Through Hole
Dimensions	18.0 x 16.3 mm	16.3 x 18.0 mm	5 mm (0.2“) diameter

Feature	Adafruit TSL2591	Adafruit TSL2561	Photocell
Price [€]	6.41	5.49	0.88

The sensor Adafruit TSL2561 is used for safety checks if there is no damage inside the dark room, where the light will be possible inside the dark room. The sensor was also used during the technical workshop class, The same sensor is therefore used so that it can be reused from school. In Table 29 are alternative water level sensors.

Table 29: Alternative water level sensors

Feature	Water Float Switch	Water Detection Sensor
Measurement Parameters	locally	40 x 16 mm
Working temperature	0 °C to +70 °C	+10 °C to +30 °C
Operating/release time	0.6ms/0.1ms max	N/A
Output Type	Analog	Digital
Supply Voltage	< 10.0 V	3-5 V
Working current	< 1 A (Active)	< 20 mA
Dimensions	off-state: from 6.0 to 13.7 mm, on-state: from 4.0 to 9.0 mm	62 x 20 x 8 mm
Price [€]	6.10	1.95

For measuring the water level, a water float switch is the best option. As it is rust-resistant, it can be purchased at the local store in Porto. In this case, transport costs and transport time can be avoided. The water detection sensor is cheaper, but the problem here is that it may detect condensate and be able to rust, so it may lose accuracy.

In Table 30 are alternative solenoid valves.

Table 30: Alternative solenoid valves

Valve	ROB-10456	SWT133B2B	1528-2003
Operating Pressure [PSI]	2.90 ~ 116.03	2.90 ~ 116.03	3.00 ~ 116.00
Mechanical Life [Cycles]	1.000.000	200.000	50.000.000
Weight [g]	121.11	114.31	122.02
Supply Voltage [V]	12	12	12
Connection Method	Threaded 3/4” NPT	Threaded 1/2“ BSP	Threaded 1/2” NPS
Price [€]	8.26	7.85	6.42

ROB-10456 valve is chosen because it has the most suitable connection, even if it has a shorter mechanical life than the other one.

In Table 31 are alternative servomotors.

Table 31: Alternative servomotors

Valve	SER0006	SER0043	1528-4326
Torque - Rated [mNm]	156.9	156.9	156.9
Voltage [V]	4.8	4.8 ~ 6	3 ~ 6
Price [€]	3.34	3.69	5.49

SER0006 valve is chosen because it is the cheapest and still has all the requirements needed for the product.

Table 32 shows the selected materials.

Table 32: Selected materials

Material	Quantity	Price [€]	Link
Recycled ABS	14.1 kg	16.92	https://aojiangplastic.en.made-in-china.com/product/XdhtGMPxbyYi/China-Recycled-ABS-Plastic-Scrap-ABS-Resin-Plastic-Raw-Material-Prices.html
Greencast® GS recycled clear acrylic	0.3 m^2	11.45	https://shop.pyrasied.nl/en/product/recycled-acrylic-greencast/
Hinge thin galvanized plate 60×35 mm	3	3.63	https://www.leroymerlin.pt/produtos/ferragens/ferragens-para-moveis/dobradicas-para-moveis/dobradica-chapa-fina-zincada-60x35-mm-15040326.html
100 screws 2.5X10MM	1	3.41	https://www.leroymerlin.pt/produtos/ferragens/ferragens-de-fixacao/parafusos/100-parafusos-pozidriv-2-5x10mm-14676536.html
Carbon Filter Material	1	13.93	https://www.leroymerlin.pt/produtos/cozinhas/grandes-eletrodomesticos/acessorios-de-eletrodomesticos/filtro-de-coifa-de-carbono-nedis-compativel-com-universal-indicador-de-substituicao-cortavel-88662276.html
HEPA Filter Material	1	9.35	https://www.amazon.es/dp/B094R6ZGFP
Total Price		58.69	

The recycled materials are more expensive then non recycled, but are worth the price for sustainability.

In Table 33 are the electric components listed.

Table 33: Electric components Digikey

Index	Quantity	Part Number	Manufacturer Part Number	Description	Unit Price [€]	Price Prototype [€]	Price with VAT [€]	Link
1	2	1568-1511-ND	PRT-12794	"JUMPER WIRE M/F 6"" 20PCS"	1.94	1.94	2.38	https://www.digikey.pt/en/products/detail/PRT-12794/1568-1511-ND/5993859
2	2	1568-1512-ND	PRT-12795	"JUMPER WIRE M/M 6"" 20PCS"	1.94	1.94	2.38	https://www.digikey.pt/en/products/detail/PRT-12795/1568-1512-ND/5993860
3	1	BKGS-830-ND	GS-830	"BREADBRD TERM STRIP 6.50×2.13"""	6.65	6.65	8.17	https://www.digikey.pt/en/products/detail/GS-830/BKGS-830-ND/5231309
4	1	493-12567-1-ND	UVK1H010MDD1TD	CAP ALUM 1 UF 20 % 50 V RADIAL	0.22	0.22	0.27	https://www.digikey.pt/en/products/detail/UVK1H010MDD1TD/493-12567-1-ND/4328648
5	1	490-9258-1-ND	RDER72J104K4M1H03A	CAP CER 0.1 UF 630 V X7R RADIAL	0.83	0.83	1.02	https://www.digikey.pt/en/products/detail/RDER72J104K4M1H03A/490-9258-1-ND/4772420
6	1	497-1443-5-ND	L7805CV	IC REG LINEAR 5 V 1.5 A TO220AB	0.54	0.54	0.66	https://www.digikey.pt/en/products/detail/L7805CV/497-1443-5-ND/585964
7	1	Q855-ND	3025013-06	CABLE A PLUG TO MCR B PLUG 6'	3.41	3.41	4.19	https://www.digikey.pt/en/products/detail/3025013-06/Q855-ND/4341884
8	1	1528-1386-ND	368	ADAPT TERM BL 2POS TO 2.1 MM JCK	1.85	1.85	2.27	https://www.digikey.pt/en/products/detail/368/1528-1386-ND/5629434
9	3	CF14JT10K0CT-ND	CF14JT10K0	RES 10k Ω 5 % 1/4 W AXIAL	0.09	0.09	0.22	https://www.digikey.pt/en/products/detail/CF14JT10K0/CF14JT10K0CT-ND/1830374
10	2	FQP30N06FS-ND	FQP30N06	MOSFET N-CH 60 V 30 A TO220-3	1.41	1.41	1.73	https://www.digikey.pt/en/products/detail/FQP30N06/FQP30N06FS-ND/1055132
11	1	448-EVALPASCO$_2$MINIBOARDTOBO1-ND	EVALPASCO$_2$MINIBOARDTOBO1	CO_2 SENSOR XENSIVTM	25.56	-	31.55	https://www.digikey.pt/pt/products/detail/infineon-technologies/EVALPASCO$_2$MINIBOARDTOBO1/14560477
12	1	1N4001-TPMSCT-ND	1N4001-TP	DIODE GEN PURP 50 V 1 A DO41	0.19	0.19	0.23	https://www.digikey.pt/en/products/detail/1N4001-TP/1N4001-TPMSCT-ND/773688
13	1	1568-1365-ND	ROB-10456	SOLENOID VALVE ONEWAY FREE HANG	8.26	8.26	10.16	https://www.digikey.pt/en/products/detail/ROB-10456/1568-1365-ND/5684378
14	1	1738-DFR0602-ND	DFR0602	ESP32-CAM 2 MP WIFI+BT AI-THINKER	10.53	10.53	12.95	https://www.digikey.pt/en/products/detail/dfrobot/DFR0602/10385116
15	1	1738-SEN0527-ND	SEN0527	AHT20 TEMP AND HUM SENSOR	3.46	3.46	4.26	https://www.digikey.pt/pt/products/detail/dfrobot/SEN0527/18069260
16	1	259-1790-ND	HA40101V4-1000U-A99	FAN AXIAL 40X10MM 12VDC WIRE	3.42	4.20	4.20	https://www.digikey.pt/en/products/detail/sunon-fans/HA40101V4-1000U-A99/6198728

Index	Quantity	Part Number	Manufacturer Part Number	Description	Unit Price [€]	Price Prototype [€]	Price with VAT [€]	Link
17	1	2882-15DYS812-120100S-2-2.5-ND	15DYS812-120100S-2-2.5	AC/DC WALL MOUNT ADAPTER 12V 12W	7.72	7.72	9.49	https://www.digikey.pt/en/products/detail/ideal-power-ltd/15DYS812-120100S-2-2-5/12818243
18	1	485-1918	1918	LIGHT SENSOR ADAFRUIT	6.05	-	6.05	https://pt.mouser.com/ProductDetail/Adafruit/1918
19	1	1738-1385-ND	SER0006	SERVOMOTOR 4.8 V	3.34	-	4.10	https://www.digikey.pt/en/products/detail/dfrobot/SER0006/7597224
20	1	FLOODSW1		WATER FLOAT SWITCH	6.10	6.10	7.50	https://www.aquario.pt/en/product/velleman-sensor-de-nivel-de-agua---normalmente-aberto-floodsw1
Total Price (*FREE Shipping)					**97.48**	**62.28**		

FREE Shipping: The total price is based on the cart summary from the website Digikey, the team will spend above 50 € so that is the reason why money can be saved on shipping costs.

7.4.6 Smart System

7.4.6.1 Hardware

In this paragraph, the black box diagram in Figure 54 is made to show all the functions of the kitchen composter. After that tables for hardware components are shown. Thirdly, the detailed schematics are drawn.

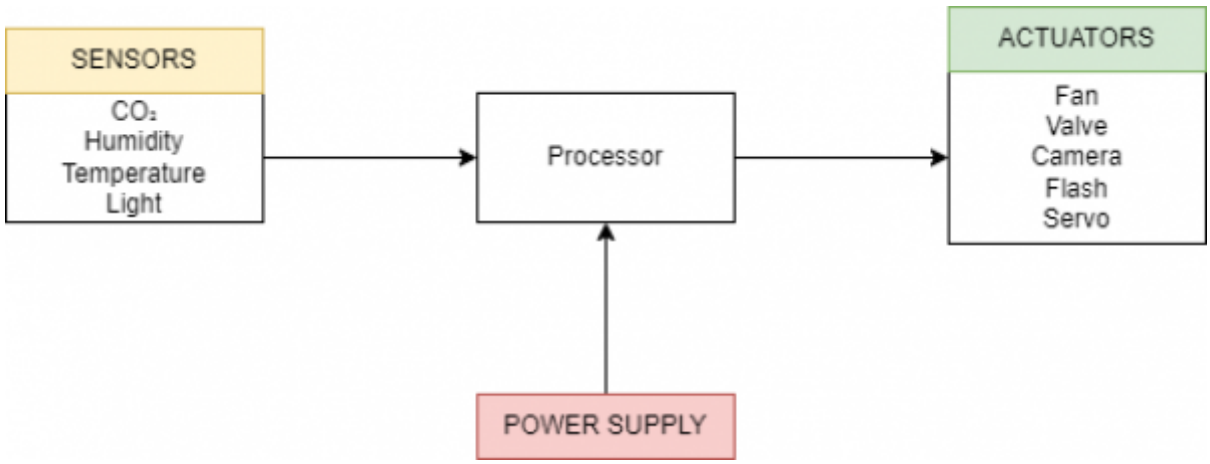


Figure 54: black box

1. Input of coffee leftovers: the input for the composter is only used coffee leftovers with mushroom spawn that you mix in the coffee leftovers to create an evenly spread of mushroom spawn
2. In the system there are some sensors that are needed to monitor the mushroom environment.

- CO_2 sensor: This sensor checks CO_2 level inside the light and dark room.
- Temp & humidity sensor: During the process, the temperature and the humidity will be constantly checked in the light room and the dark room of the machine. When there is too much humidity or the temperature is too high, the fan turns on to ventilate. When the air is dry, the ventilator turns off and the sprinklers will be activated.
- Light sensor: This sensor will be placed in the dark room, it will check that there will not be external light that comes into the darkroom of the mushrooms.
- Water float switch: It will notify the user to add water to the water tank.

3. All these sensors will send data to the processor so that the processor can send signals to the right actuators.

- Fan: The fan will turn on when the humidity is too high and also if the air quality inside the box will not be good.
- Valve: When the soil of the mushrooms is too dry, the valve will open so that the water from the water tank can go into the water tubes to give some drops of water to the soil of the mushrooms.
- Camera: The camera will see if there are mushrooms or not, it will be placed inside the light room because the lightroom will be the last phase of the growing mushrooms. The camera will send the picture to a trained AI to be able to detect the mushrooms.
- Servo motor: This motor will give the bucket access if the AI detects mycelium growth in the dark room.

4. A power supply is needed to power up every processor and also the sensors and actuators that are connected to the processor.

The detailed schematics are shown in the following Figure 55.

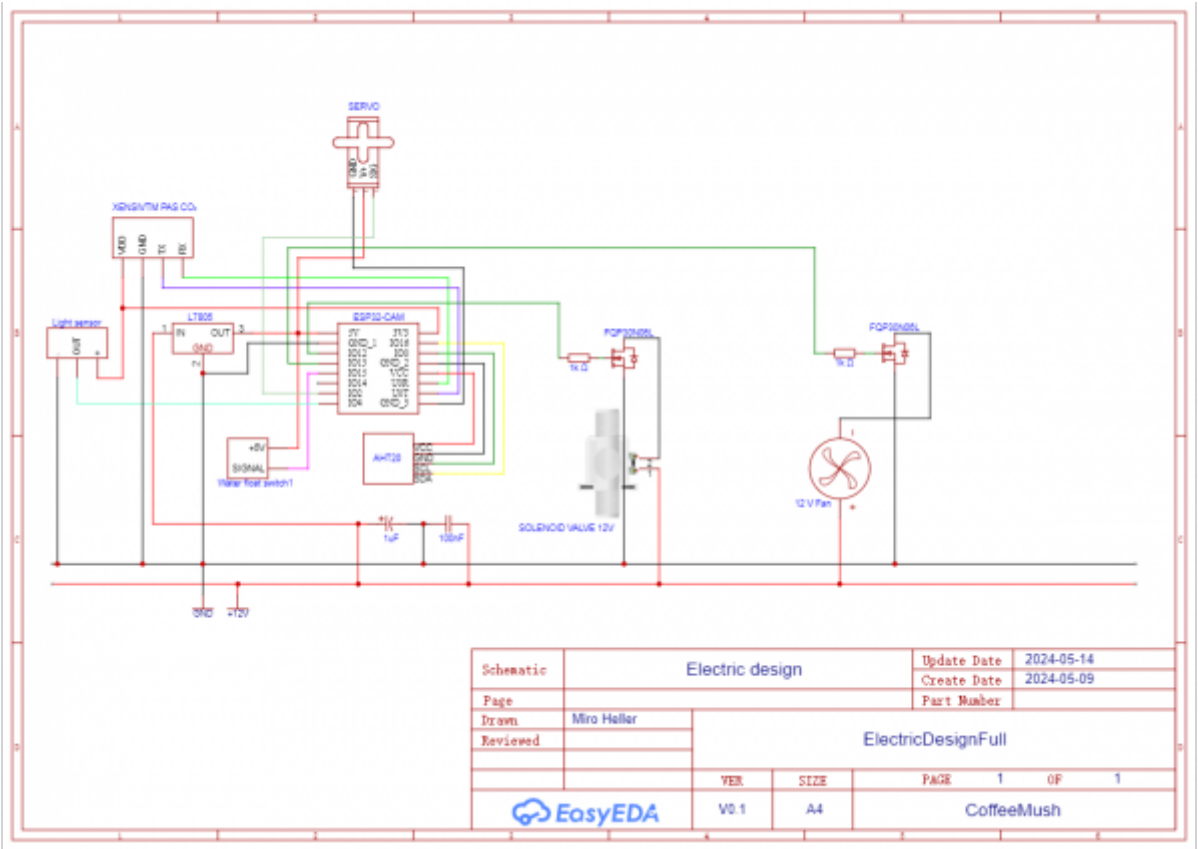


Figure 55: electric schematics

Adding an extra power supply

Ceramic Capacitor 100 nF

When adding an external voltage supply it is important to add a capacitor because it helps to stabilize the voltage supplied to the ESP32 by providing a low-impedance path for high-frequency noise. This ensures a stable voltage supply to the ESP32 because it is sensitive to voltage fluctuations given by the external supply. A capacitor is also used with a value of 100 nF because it is typically used for microcontrollers like the ESP32.

Electrolytic Capacitor 1 uF/50 V

The capacitor is used to make the input voltage smoother and it is also used to store electric energy.

It ensures a more stable and consistent power supply during load changes and for low-frequency fluctuations. 1 uF is enough to stabilize and buffer the power supply of the ESP32.

Voltage regulator (5 V)
It regulates the input of 12 V from the power supply to 5 V for the ESP32. The microcontroller normally operates with 3.3 V but lowering it to 5 V will be still safe to use for the microcontroller.
By using this voltage regulator, it is important that the regulator will not overheat and to may use a heatsink to prevent it from overheating.
The power dissipation of the voltage regulator can be calculated with the following formula **[bitsmashed, 2010]**:

$$P_{D} = (V_{I} - V_{O}) \times I_{O}$$
Where:

- P_D is the power dissipation
- V_I is the input voltage, in this case it will be 12 V that will be provided from the power supply
- V_O is the output voltage, the ESP32-CAM works on 5 V which is why the voltage regulator will have to regulate it to 5 V.
- I_O is the load current drawn from the regulator. The microcontroller operates on 310 mA if you turn on the flash and adjust the brightness to the maximum, so this will be the maximum current that is drawn from the regulator, but in reality it does not draw that amount of current continuously.

$$P_{D} = (12 \, \text{V} - 5 \, \text{V}) \times 310 \, \text{mA} = 2.17 \, \text{W}$$

2.17 W will be dissipated, and the max amount of power dissipation that the L7805 can handle is 15 W. So in this case it can be concluded that there is no need for a heatsink.

These components are used to regulate the high voltage to a safer lower voltage to be able to operate it on the microcontroller ESP32. The ceramic capacitor will stabilize the high-frequency noise while the electrolytic capacitor stabilize the low-frequency noise of the external power supply. The external power supply will convert the 230 V from to outlet to 12 V. While 12 V is still too dangerous to use for the ESP32, must be added a 5 V voltage regulator to be able to operate it more safely for the microcontroller.

Adding a 12 V solenoid valve

MOSFET (30N06L)
It is a transistor that will be controlled by the microcontroller to switch on/off the valve, the MOSFET is a high-power switch because the valve operates on 12 V, but this type of MOSFET is used because it ensures more safety for high voltage spikes.

Resistor 1 kΩ
There is a 1 kΩ resistor connected between the gate and the microcontroller, it helps to protect the microcontroller from excessive current.

Adding a 12 V Fan

Ground-side switching
MOSFET switches the ground connection of the fan. It can help to avoid potential issues with voltage drops or noise. By switching the ground connection, the voltage across the MOSFET is lower.

Isolation and safety
The positive side of the side is connected directly to the power supply. This provides isolation between the higher voltage of the power supply and also the microcontroller ESP32.

Resistor 1 kΩ
There is a 1 kΩ resistor connected between the gate and the microcontroller, it helps to protect the microcontroller from excessive current.

Adding a 4.8 V Servo motor

Voltage regulator
The servo motor works on 4.8 V which is not necessary to connect it with the 5 V voltage regulator. However, this connection can give some more stability and regulation, reducing noise and fluctuations in the power supply.

Power Budget

The power budget was calculated in Table 34.

Table 34: Power Budget

Component	**Voltage (V)**	**Current (mA)**	**Power Consumption (mW)**
XENSIVTM PAS CO_2	3.3	6.1	30.0
AHT20 Humidity & Temp Sensor	3.3	23.0×10^{-3}	75.9×10^{-3}
Light Sensor Adafruit 485-1918	1.0	5.0	5.0
Servo Motor 4.8 V	4.8	500.0	2400.0
ESP32-CAM	5.0	310.0	1550.0
12 V Fan	12.0	31.7	380.0
Solenoid Valve Oneway Free Hang	12.0	150.0	1800.0
Water Float Switch	3.3	1000.0	3 300.0
Total Power Consumption			**9 465.1**

It can be seen that all the components will consume a total power of around 10 W. That is why a power supply that can deliver 12 W should be chosen.

7.4.6.2 Software

For the project development, it's chosen to implement an Android application. This application needs different parts to work as it follows a cloud system communication. The four main components in this scheme are the composter itself, the API, the database and the Android app. Each of them communicates with one another following the scheme in Figure 56.

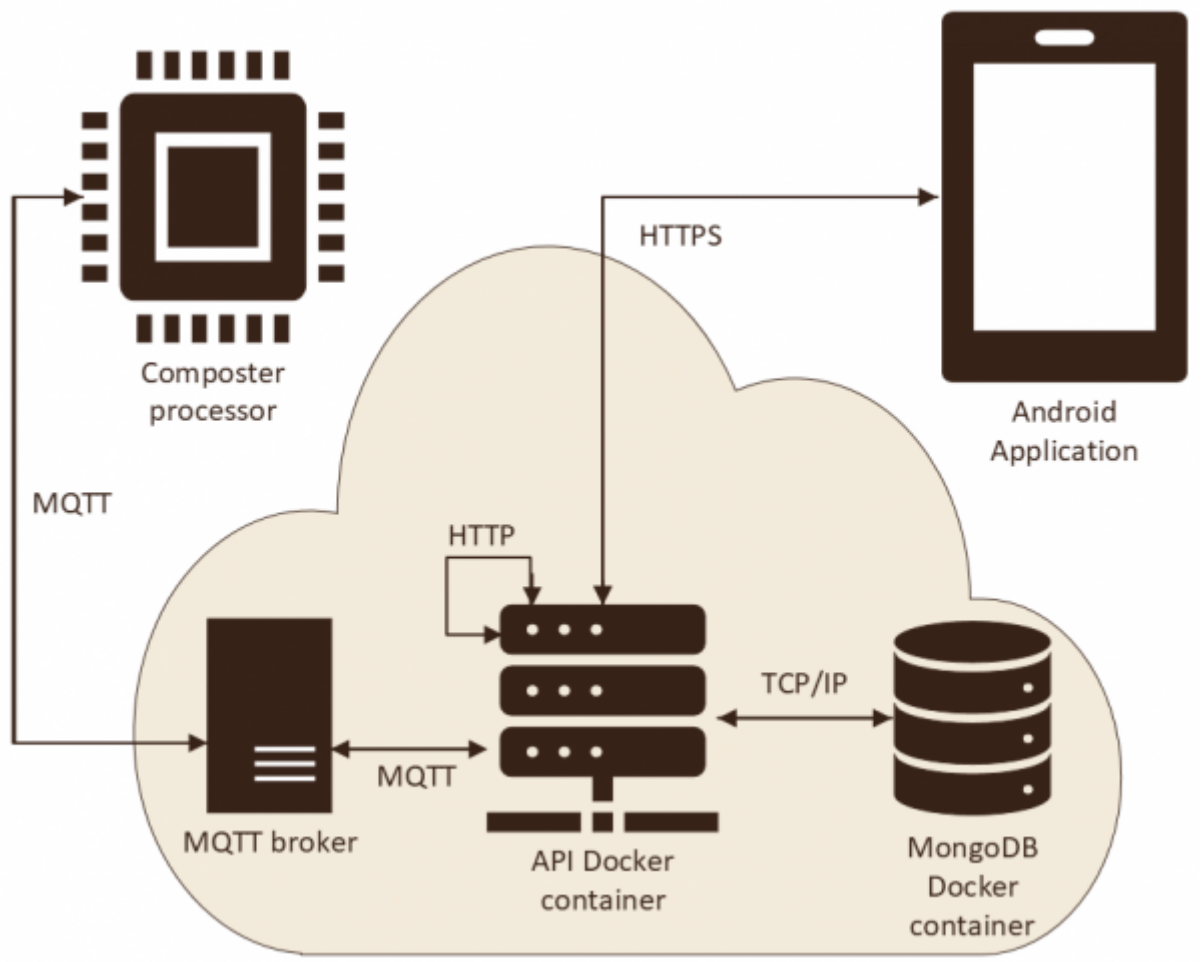


Figure 56: Communication architecture

All the code used in this project can be found in the git repository.

7.4.6.3 Composter software

The code developed for the prototype (smart device and apps) is described here using code flowcharts. The Figure 57 illustrates it.

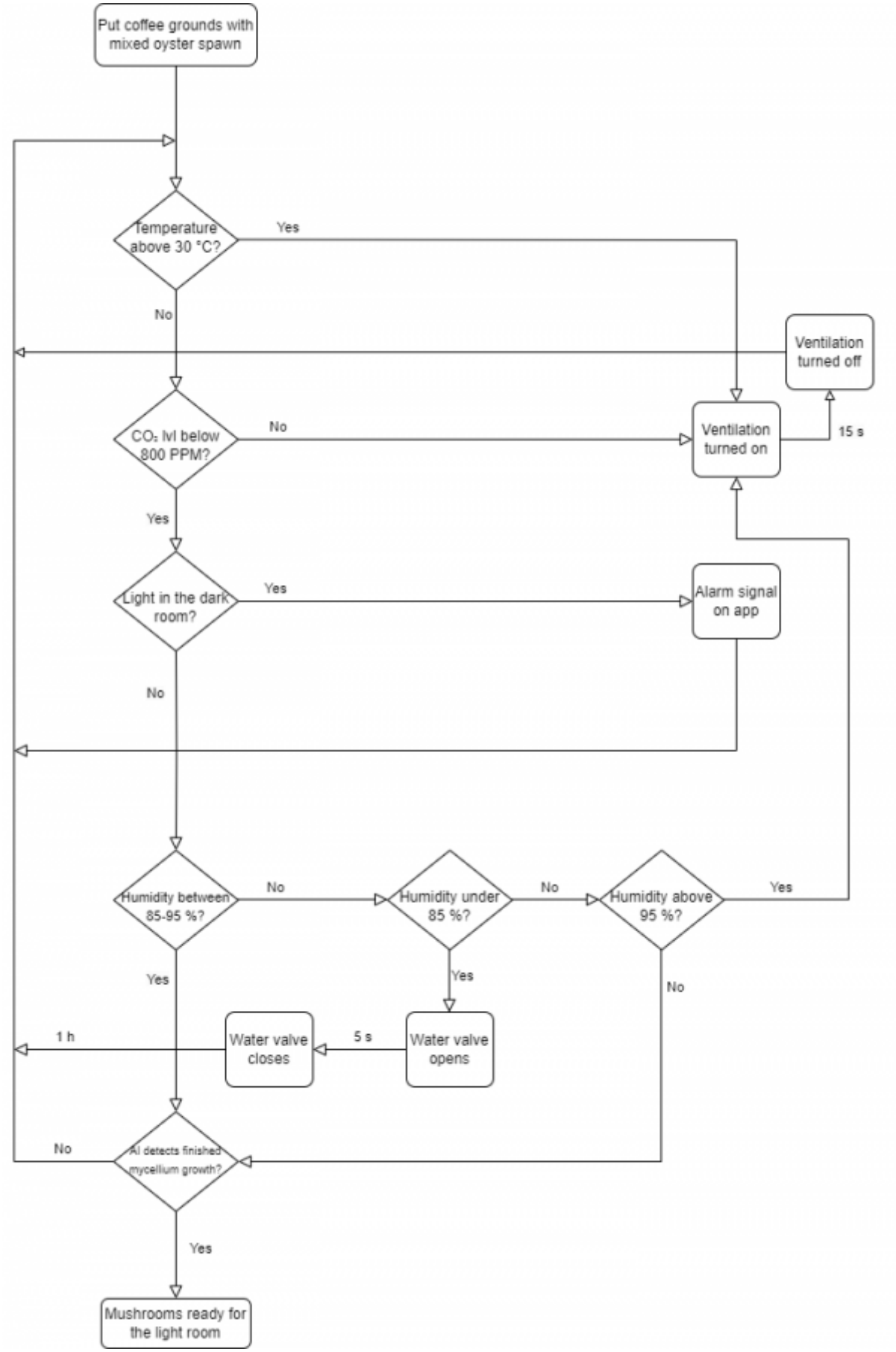


Figure 57: Flowchart

When the coffee grounds have been added to the machine, the machine will check for changes in the environment and will furthermore interact with these changes.
First, it checks the temperature if it is above 30 °C or not. If it is above 30 °C ventilation fan is to be

switched on so it can add some fresh air to the mushrooms. After it has been ventilated it will check again if the temperature is dropped or not. If this cycle repeats itself a couple of times the user will get notified that the environment where you put the mushrooms is too hot to be cooled down.
Then the CO_2 sensor will check the value of CO_2 inside the box. When the CO_2 level is higher than 800 ppm, then the ventilator will ventilate to decrease the CO_2 level.
The light sensor will work as a safety feature. This sensor is placed in the dark room. Here there must be no light inside the dark room. If the sensor detects light, the user will get notified to check if there is somewhere a hole or damage in the dark room.
The humidity sensor will check if the humidity in the air inside the box is between 85-95 %. First, it will check if it is under 85 %, if yes. The water valve will open up to provide some water to increase the humidity. Then the valve closes and waits for around 1 h so that the environment will have the time to change and to avoid that it will give for example every 5 min water to the mushrooms. If the humidity is above 85 %, it will check if the humidity is above 95 %. If yes, the ventilation will be turned on for around 15 s. If not, the camera will check using AI if there is mycelium detected. If yes, the bucket with the mycelium will go to the light room with the help of gravity and the servo motor, that will pass it through.

7.4.6.4 API

The API, together with the database and the mqtt broker are the components of the server. Each component is separated in different docker containers, the reason is that with docker containers there is better portability, maintenance and isolation. The API's function is basically to act as an intermediary between the database and the other elements (whether the app or the CoffeeMush). Inside the server, there is an API running. This API is made with Python and uses the flask framework. This is due to the simplicity of the language and the velocity one can start an API with flask. The ease with which one can create an API with flask what was made the team choose it for this framework. All the code is uploaded in the Github, table 35 describes all the endpoints programmed.

Table 35: API endpoints

Api Endpoint	Description	Type	Pre	Post
/login	Checks if credentials for authentication are correct and returns a valid jwt token for the user	GET	Valid email and password	Valid token
/register	Creates a user if possible with the data provided	POST	Valid mail, password and user information	Creates the user and returns a valid token
/connection	Creates or edits a connection between the CoffeeMush device and the application android device. It is done using the identifier qr code from the device	POST	CoffeeMush identifier, events configuration and authentication token	A new connection is created between the CoffeeMush device and the application device with the specified configuration
/connection	Deletes a connection between android application device and Coffemush device	DELETE	CoffeeMush identifier and authentication token	There is no connection between the CoffeeMush device and the application device

Api Endpoint	Description	Type	Pre	Post
/event	Mushroom device notifies mqtt broker of event, it communicates it to the API and the API decides whether it has to notify any devices or not	POST	event	Event is stored and devices are notified if needed
/data	The application asks for the data of the connected device and the API returns this data	GET	token	Return of data of Coffemush devices connected to this application

7.4.6.5 Database

For the database, the aim is to use a MongoDB database inside a Docker container. The reason for that is that non-relational databases are more scalable and flexible. So it's possible to put additional information, or even if it's not possible to complete information at a time, one can add it later.
This is the database structure the team is going to use considering the current version of the application: The following information is available for each user:
- Name
- Surname
- Gmail
- Address (Street, PC, City, Country)
- Phone number * Products: A list with the mushroom composter ids one user has, so each user can have more than one.
From each composter, there is the following information:
- Sensors: A list of sensor types that contain historical measurements. For each measurement, there is also a date, time and id:

1. CO_2
2. Humidity
3. Temperature
4. Composting_processes: There is a record of the composting processes the composter had. That means each time a new box of coffee is introduced the program adds a new composting process. For this process, it is measured the start and end time in each epoch, the environment measurements, and the pictures. So with this information is possible to improve the product. And also some feedback from the client on the application of the result mushrooms.

7.4.6.6 Android application

The Android application is the software that allows the user to control and monitor its CoffeeMush. Figure 58 shows the use cases the application has. Except for the login and register all use cases require a verification token as a parameter. It can expire and it is unique for each user. And if it is not valid the API cannot complete the use case.

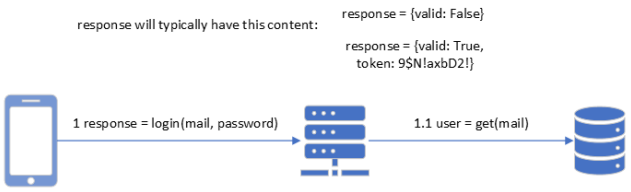
The first use case is the login. The user types the mail and password so that the application can send it to the API. The API checks if all is correct and returns a verification token if it is.

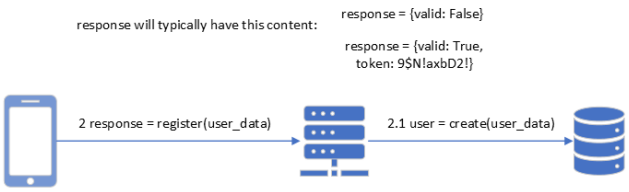
For the registration, the application sends all needed information, and if it's correct it stores the new user in the database. Otherwise, it returns an error message with the motive of failure.

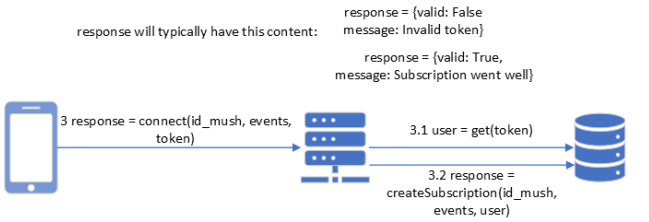
For this use case, the user scans the QR in its CoffeeMush and the application sends the ID to the API. If possible the user gets subscribed to all CoffeeMush events. The next one just removes the subscription. And the following one allows editing the events that the user is subscribed to.

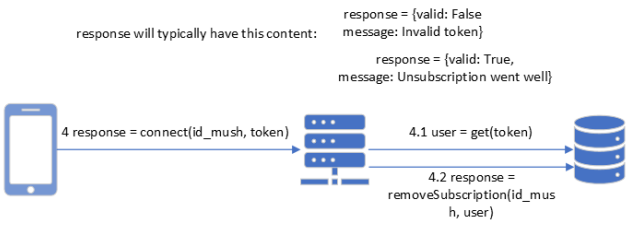
The next use case starts from the CoffeeMush, each time happens an event it notifies the broker, which notifies the API. And the API makes sure to store the event and notify whoever needs to be notified.

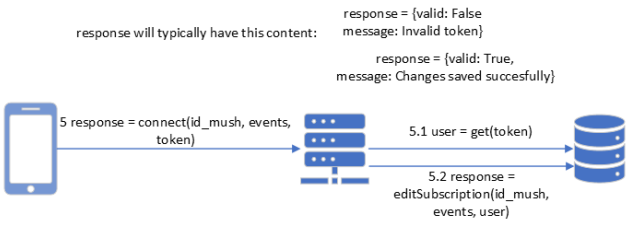
The last one allows the user to see some statistics and monitored data of its CoffeeMush considering given options.

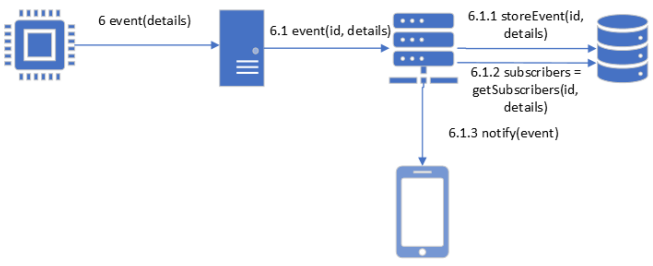

response will typically have this content:
response = {valid: False}
response = {valid: True, token: 9$N!axbD2!}
1 response = login(mail, password)
1.1 user = get(mail)


response will typically have this content:
response = {valid: False}
response = {valid: True, token: 9$N!axbD2!}
2 response = register(user_data)
2.1 user = create(user_data)


response will typically have this content:
response = {valid: False message: Invalid token}
response = {valid: True, message: Subscription went well}
3 response = connect(id_mush, events, token)
3.1 user = get(token)
3.2 response = createSubscription(id_mush, events, user)


response will typically have this content:
response = {valid: False message: Invalid token}
response = {valid: True, message: Unsubscription went well}
4 response = connect(id_mush, token)
4.1 user = get(token)
4.2 response = removeSubscription(id_mush, user)


response will typically have this content:
response = {valid: False message: Invalid token}
response = {valid: True, message: Changes saved succesfully}
5 response = connect(id_mush, events, token)
5.1 user = get(token)
5.2 response = editSubscription(id_mush, events, user)


6 event(details)
6.1 event(id, details)
6.1.1 storeEvent(id, details)
6.1.2 subscribers = getSubscribers(id, details)
6.1.3 notify(event)


7 getData(token)
7.1 user = get(token)
7.2data = getData(user)

Figure 58: Use cases

APP DESIGN

Once all the user stories have been defined, the application is designed. It looks as follows:

The first thing the user will see when opening the application will be a screen inviting him/her to log in with the account. In case the user does not have a profile created, he/she will be invited to create one. As shown, there will also be the option to log in as a guest without creating a user.

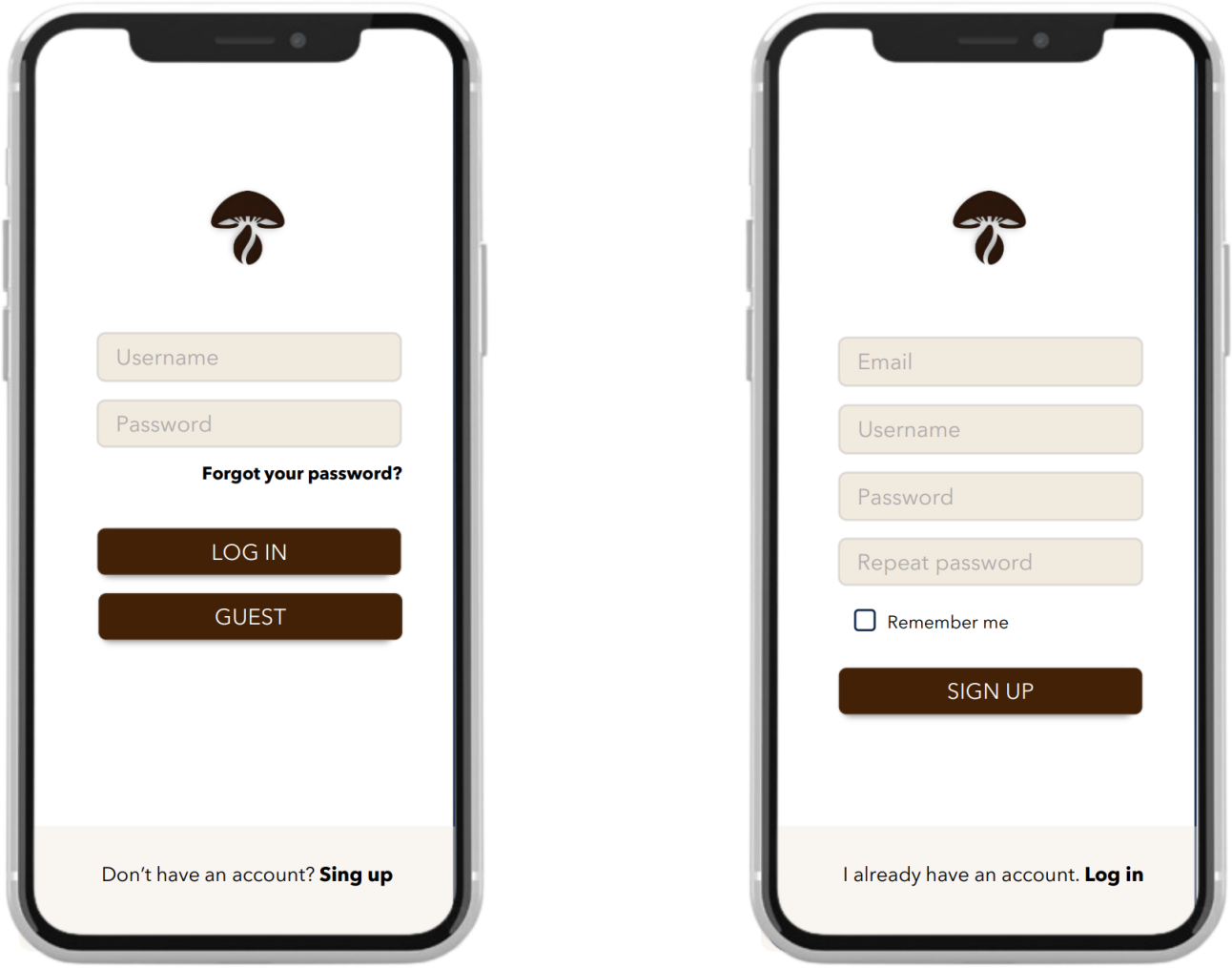


Figure 59: User creation

Once the user has logged in, he will have to connect the application to his composter. This will be done by scanning the QR code on the composter. With the app and the composter connected, the home page will appear. From the home page it's possible to access to the box control, information, general statistics, and the camera. And as you can see on the last screen, from the circular icon on the top right, if clicked, it gives the option to disconnect. If clicking on “log out”, the application redirects the user to the first screen of all, where the user is given the option to enter his or her username or log in as a guest.

Figure 60: Home page

On the main screen, when clicking on the icons, the following happens:

From the “boxes” option, a screen is reached where it's possible to see how much time is left for the mushrooms to be ready. There is also the option to mark if they have been picked.

From the “information” option, a screen is reached where it's possible to see information about temperature, humidity, CO_2 levels and amount of light. In the case that any of the measurements are out of range, this will be displayed in red, as is the case with the light indicator.

From the “camera” option, by clicking on it, a real-time photo of the dark room of the composter will appear.

Finally, when the information is being loaded, the screen will look as shown in the screen to the right.

Figure 61: App features

The application will also send notifications in case the mushrooms are ready (as shown in the first screen); and also in case it is necessary to regulate any condition of the composter, (as can be seen in the second screen).

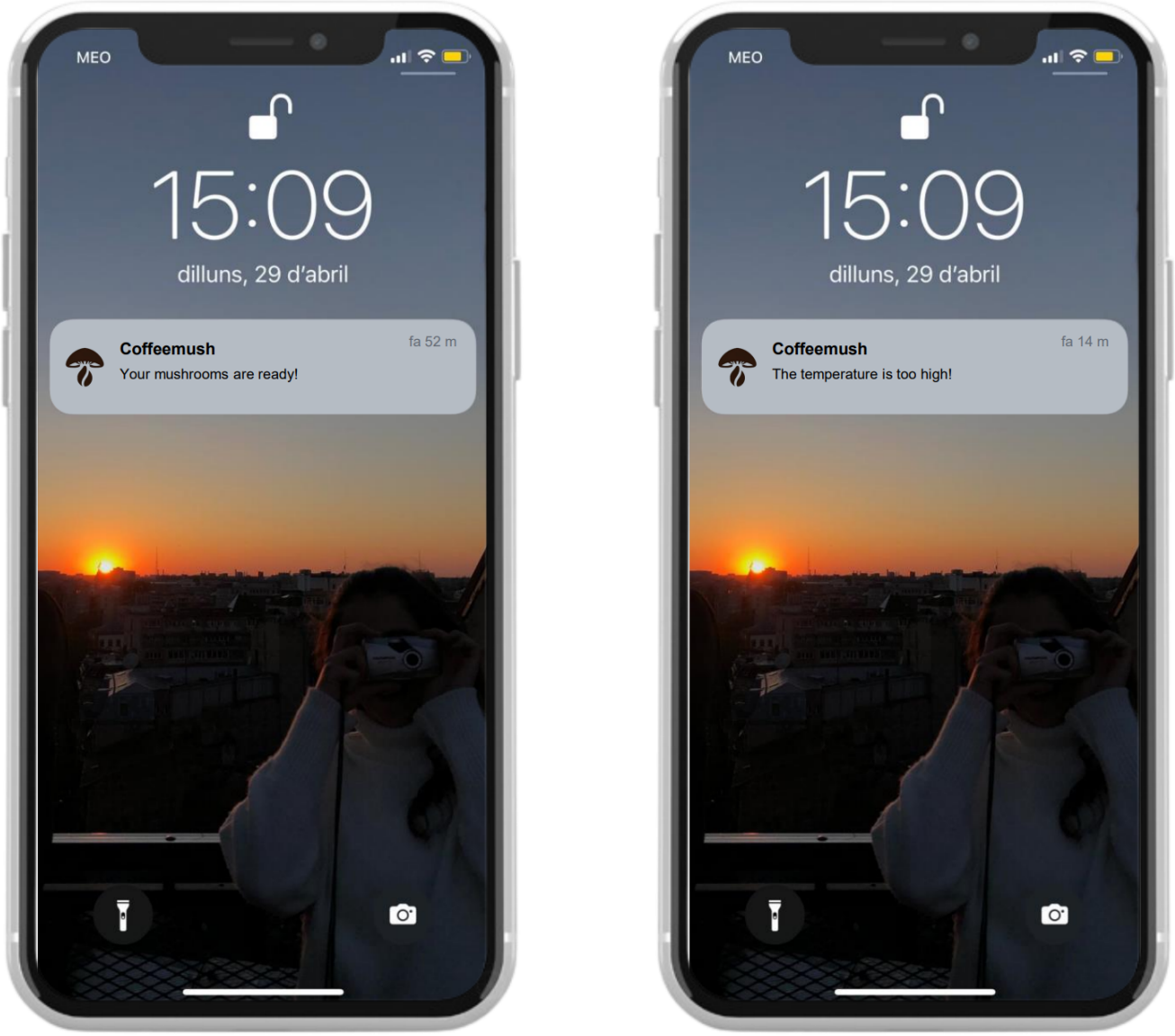


Figure 62: Notifications

7.4.7 Packaging

It is important to think about the packaging for CoffeeMush to contribute to the efficiency and sustainability of the product. The aim is to make a multipurpose packaging solution so that the package can be used after the product is packaged. In this paragraph, three different solutions will be addressed to get to the best solution for CoffeeMush.

The first packaging solution idea is using the packaging box as an extra room for growing mushrooms. Once mushrooms are grown and collected it does not mean all the coffee ground biomass is consumed, more mushrooms grow even after collecting them. That is why the extra room will be used to use the maximum amount of biomass the coffee ground has as shown in figure 63.

Figure 63: Packaging solution 1 draft

For this solution, a small change in the boxes is needed. As figure 64 shows, the small boxes can have a mechanism in which they discover their holes once they get out of one of the two first rooms, so that they discover their holes for the last room. This way, mushrooms are allowed to grow through the holes without causing any trouble inside the dark and light rooms.

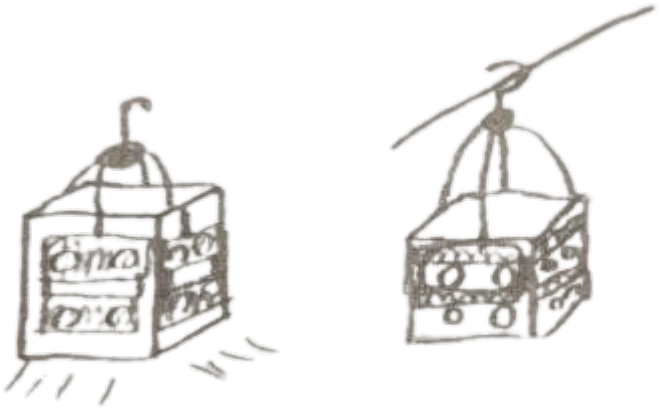


Figure 64: Packaging solution 1 drawing

A second packaging solution could be to use the packaging as material for the boxes in which the mushrooms will be grown in the composter. The package could be made from plastic, which the consumer can then fold into boxes for the mushroom growing. The package should show the folding- and tear lines. An instruction should be added, either separately or in the app or on the packaging as well. The material of the boxes cannot be cardboard but should contain some plastic, because it gets wet when the mushrooms grow. The draft and drawing for this idea are shown below in Figure 65 and Figure 66.

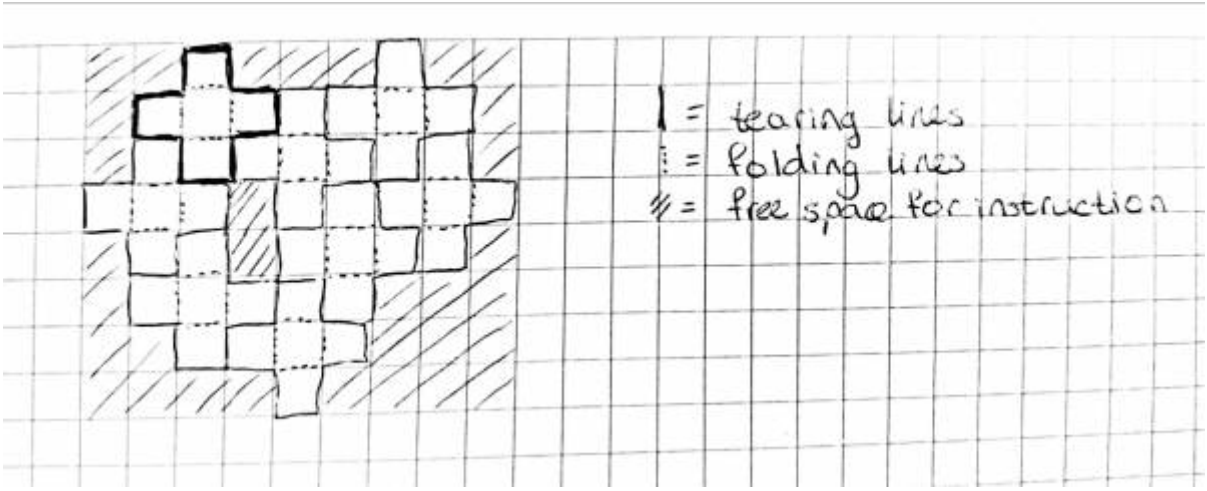


Figure 65: Packaging solution 2 draft

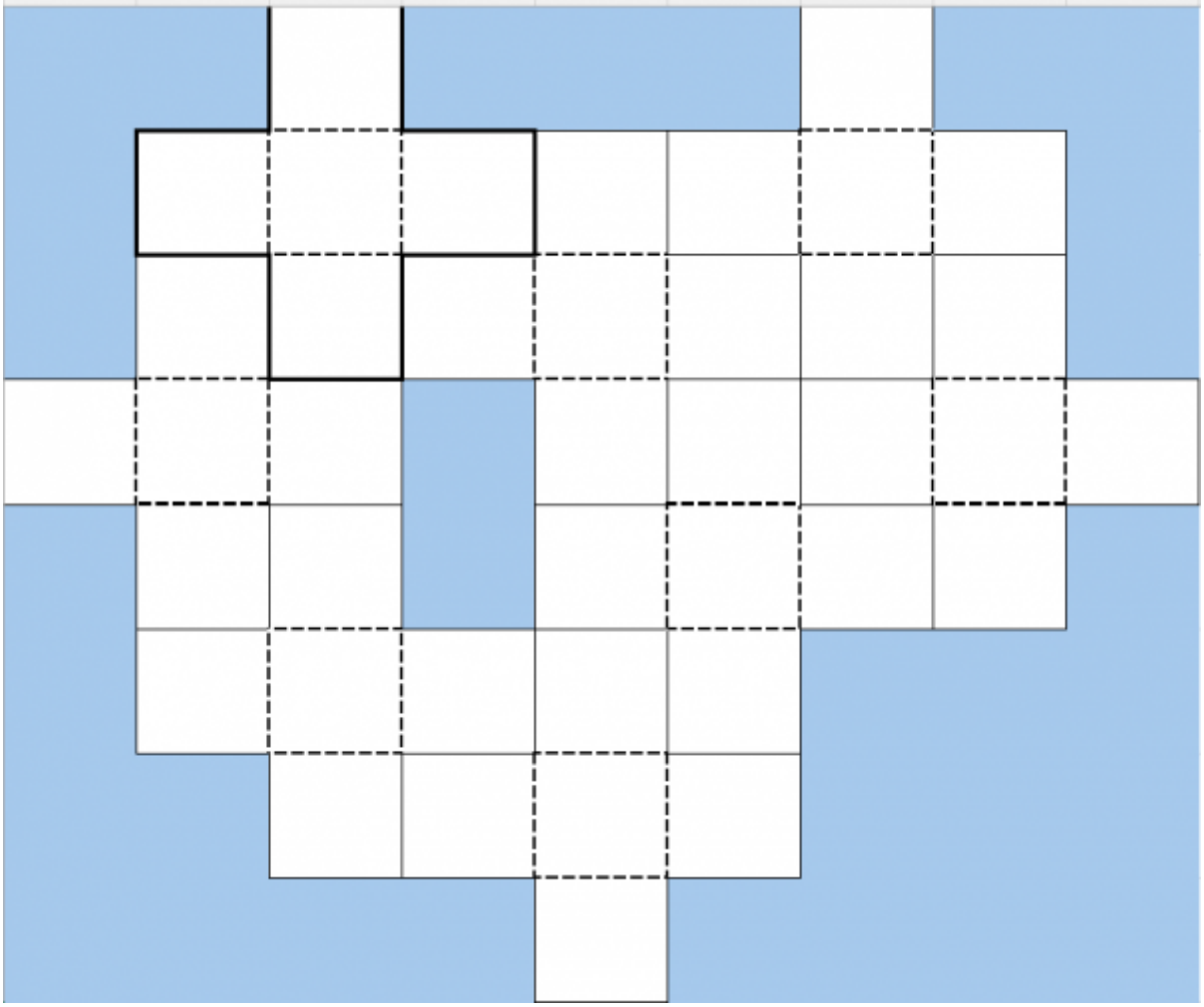


Figure 66: Packaging solution 2 drawing

Third idea:

The main idea for this packaging solution would be to have as a second life the capacity to be able to transport coffee or mushrooms from point A to point B, this avoiding the use of plastic bags which are harmful to the environment. This packaging would be waterproof and would prevent the coffee from escaping. Once you have opened it you will have access to two straps to allow the most functional transport. The draft and drawing for this idea are shown below in Figure 67.

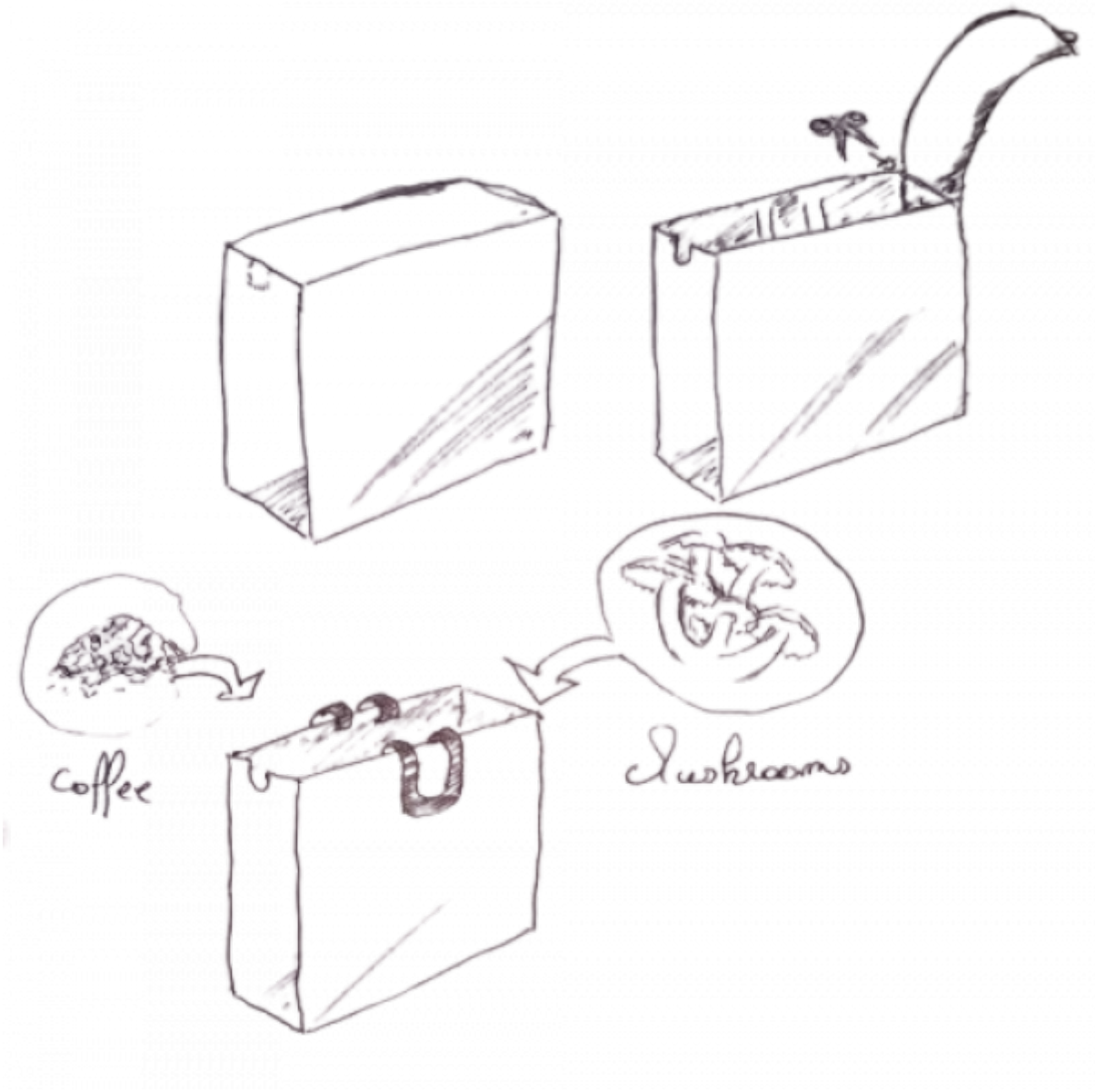


Figure 67: Packaging solution 3 drawing

Final solution

The three options were compared and analyzed, as can be seen in the Table 36. Scores 1 to 5 are given to the necessity, feasibility and how easy it is to realize for the customer. The Necessity of the product refers to how the function of the package is really useful for the customer. The necessity of number three is highest, a way to transport coffee waste and mushrooms does not come with the product. The necessity of number 2 is average. It is a more sustainable way for the boxes of CoffeeMush, but in the design there are already standard boxes. The necessity of number 1 is low, because it does not add much to the design.

The Feasibility of the product refers to how realistic the design is and how it will work in real life. The lowest score is given to the second design, because this design contains a lot of tearing and bending lines. These are quite fragile and might break during transportation. Number one has fewer of these fragile lines, but still some. Number three has the least: only a few tearing lines in the middle.

The last factor is how easy the packaging solution is to realize for the customer. This is the highest for the last one, only a couple of tears have to be made and the boxes are easily made. The first two packaging solutions contain more steps to realize, but should still be doable for everyone.

Table 36: Packaging solution

Solution	Necessity	Feasibility	Easy for customer	Total score
1	1	2	4	6
2	3	1	3	7
3	4	4	5	13

The material of the packaging will be mycelium. This decision was made because of several factors. The first one is that this material is really sustainable. It is made of biological product, which means it is easily made, never out of resource and well compostable. Besides, it is a good packaging material because it is water resistant, flame resistant and chemical free **[Mushroom pagaging by Ecovative, 2023]**. The material can be made into some form of leather, thin paper or a kind of foam. For this package it is most useful to make the box out of the foam, it protects the CoffeeMush the best. The two strips in the middle should be bendable and thus made out of the 'leather' of mycelium.

For the customer, a step-by-step-guide is made on the package: 1. Delivery of CoffeeMush in package 2. Tear at the tearing lines The box is made out of two big boxes and two long strips. The strips can be torn in two pieces. 3. Attach handles to bags The strips can be attached to the box by connecting the strips with holes to the knobs on the box. This creates a handle. 4. Bags are ready to transport mushrooms and/or coffee waste!

The design is sketched below 68:

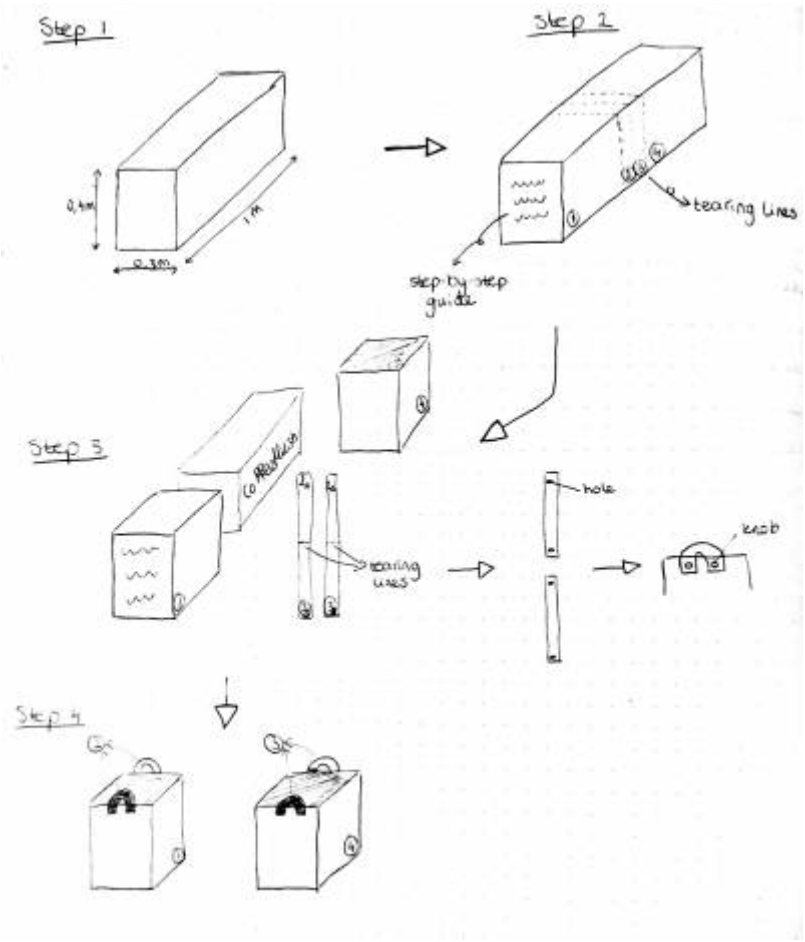


Figure 68: Packaging step-by-step design

This step-by-step guide is printed on the package of CoffeeMush. The logo and slogan will also be

printed on the outside of the package. This way they will also be visible on the boxes that are made to transport coffee waste and mushrooms.

A second version of the packaging solution was made to solve the problem of getting the device in the package or closing it around the device. Furhtermore it should be more easy for the customer to get the device out and to build the transportation boxes for coffee and mushrooms out of the packaging. The solution can be seen in Figure 69.

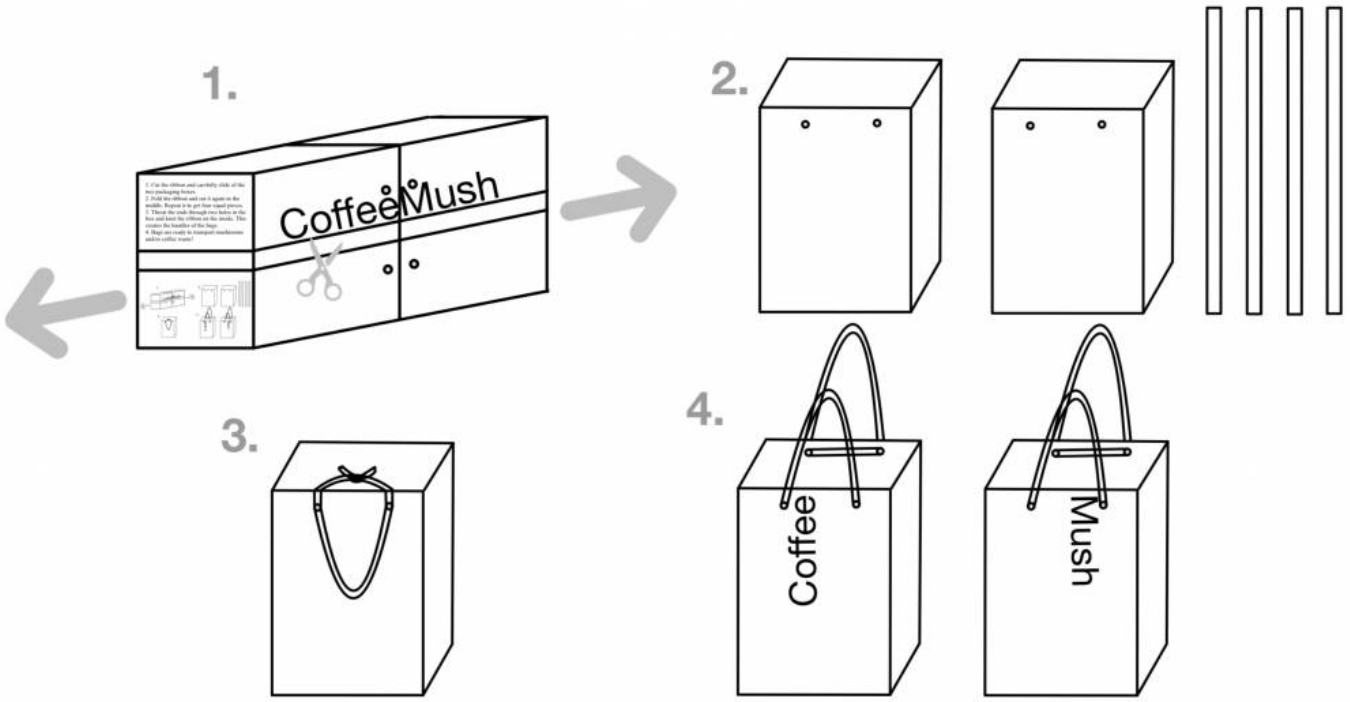


Figure 69: Improved Packaging step-by-step design

Most aspects from the first version of the packaging solution, like the materials and the printings are the same. The difference according to the other version is that there are no tearing lines and that the mycelium ribbon is used in a different way. There are to similar boxes made out of mycelium foam that are put from each side over the device to protect it. The foam is approximately 1 cm thick and made by growing the mycelium in a mole. To hold the two boxes in position and to have a material for the handles, there will be the ribbon, which is made out of the ‘leather’ of mycelium, fastened once around the entire packaging. If the customer wants to use one box for coffee grounds and one for mushrooms the name CoffeeMush will devide, that one box has written Coffee on it and the other Mush. That way the customer will not mix up the boxes. To guarantee the water resistance of the packaging, the holes for the handles could be closed with a sticker of the logo.

The step-by-step-guide for the customer is again visible on the outside of the packaging and shown in text and also pictograms.

1. Cut the ribbon and carefully slide of the two packaging boxes.

2. Fold the ribbon and cut it again in the middle. Repeat it to get four equal pieces.

3. Threat the ends through two holes in the box and knot the ribbon on the inside. This creates the handles of the bags.

4. Bags are ready to transport mushrooms and/or coffee grounds!

7.5 Mushroom cultivation

7.5.1 Modus operandi „Cultivation of Pleurotus ostreatus“

1. Inoculation:
• To obtain inoculum, the mycelium is developed on cereal grain
• Everything has to be sterile, to avoid contamination
• The resulting product is also called spawn

2. Substrate Preparation:
• There is no need to prepare the coffee grounds when using them as the substrate because they are already grinded and pasteurized, as long as they are not older than 24 hours

3. Spawning:
• Inoculate the substrate by adding spawn equivalent to 5 % of its weight
• Optionally, add a delayed release supplement (3 % to 10 % of dry substrate weight) to increase yield and size of mushrooms
• Mix everything under sterile conditions in the box

4. Incubation:
• Incubate the box for 12 to 14 days at approximately 25 °C
• Transfer the bags to the production room after the incubation period

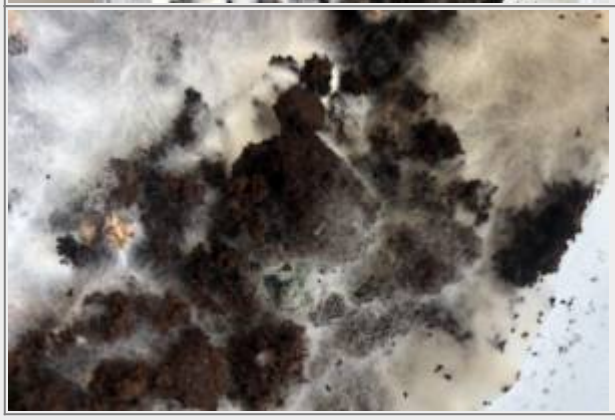
5. Mushroom Production:
• Maintain optimal temperature, moisture, and other conditions that favor fruiting

6. Harvest:
• Harvest mushrooms from the substrate approximately 3 to 4 weeks after spawning, depending on the strain, supplement usage, and temperature during spawn run **[Carmen Sánchez, 2009]**

7.5.2 Evaluating ideal growth conditions

Table 37: Mycelium growth

Table 38: Fruit growth

Day 20	Day 26
	
	
	

For this oyster mushroom growing experiment, we want to test it under different conditions such as varying the amount of water added to the coffee grounds and the different amounts of mushroom spawn added to the coffee grounds. It's also interesting to observe the duration of the mycelium growth and the fruiting growth, and to see if it's possible to grow mushrooms through spore contamination and what impact forgetting to add mushroom spawn would have.

In the day 1 picture, you can see different boxes with 200 grams of coffee grounds mixed with 5-10% of mushroom spawn. It's necessary to sanitize everything before applying the coffee grounds and the mushroom spawn to the boxes to prevent contamination. Next to the mushroom growing boxes are 2 containers with water to create high humidity, as the necessary humidity for growing mushrooms is between 85-95%. The experiment faces problems such as lack of ventilation and difficulty in controlling temperature, which can significantly impact mushroom growth and air quality, posing a risk of mold growth.

By day 4, the mycelium starts to grow, with visible white spots appearing. By day 11, these spots spread across the entire surface of the coffee grounds. Towards the end of the mycelium growth, it

becomes more apparent which ones are contaminated. It's essential for growing mushrooms that the mycelium is perfectly white; any hint of grey indicates contamination.

By day 20, the fruit growth should begin. During this phase, the mycelium boxes were placed outside the dark cabinet as they require light to grow the mushrooms. As seen in the images from day 20 and day 26, no mushrooms are visible, but there is some green-colored mold present. This contamination will affect and may even prevent the mushroom growth.

Based on these results, we can conclude that it's challenging to grow oyster mushrooms in an imperfect environment. Creating the ideal environment for mushroom growth would require a smart control device to monitor and control temperature, humidity, and provide sufficient ventilation during the mycelium and fruit growth period.

7.6 Prototype

7.6.1 Structure

The schematic in the figure below represents the prototype, which is identical to the full design except for the exclusion of the CO_2 sensor and light sensor and that only one instead of two cameras is used. In the prototype, the float switch will detect water in the water tank and send a message to the app to refill the tank. The AHT20 sensor will monitor humidity and temperature. Depending on these readings, the fan and valve can be activated. Instead of the difficult-to-obtain Mosfet 30N06L, the fan and valve are connected transistors. For a detailed step-by-step process, please refer to the explanation below the flowchart. The microcontroller ESP32 with CAM can capture images of the growing mycelium and send them to the app. For the prototype, AI detection will not be used, as training AI requires a large number of pictures and substantial time, making it infeasible for the prototype. To power on/off the device, there is a switch connected to an LED to indicate if the device is powered on.
The detailed schematics are shown in the following Figure 70.

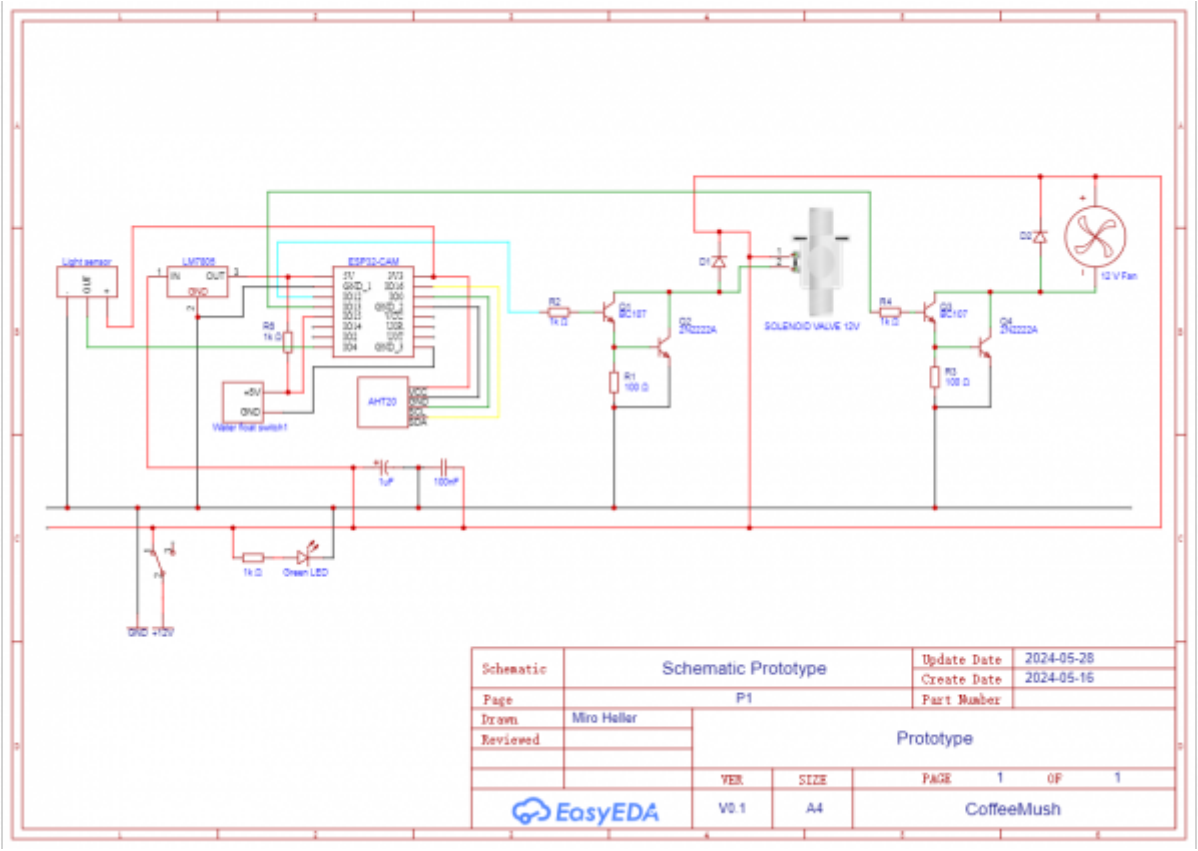


Figure 70: Electric schematics prototype

7.6.2 Hardware

For the non-electrical parts of the prototype, the white expanded PVC sheets were reused from an old project for sustainability reasons. The dimensions of the prototype are almost the same as the proposed solution, except that the length has been reduced from 100 cm to 70 cm. The small boxes are made from reused ice-cream boxes. The top is made of acrylic glass. The difference in the proposed solution is that the acrylic glass should be recycled, but this is not so easily available. Another difference is that the water tank is an ice cream box on top of the unit, instead of being integrated into the design. Figure 71 and 72 show the prototype.

Figure 71: Prototype opened doors

Figure 72: Prototype closed doors

Power Budget Prototype

The power budget was calculated in Table 39.

Table 39: Power Budget

Component	Voltage (V)	Current (mA)	Power Consumption (mW)
AHT20 Humidity & Temp Sensor	3.3	23.0×10^{-3}	75.9×10^{-3}
ESP32-CAM	5.0	310.0	1550.0
12 V Fan	12.0	65.0	750.0
Solenoid Valve Oneway Free Hang	12.0	150.0	1800.0
Water Float Switch	3.3	1000.0	3 300.0
Light Sensor Adafruit 485-1918	1.0	5.0	5.0
Total Power Consumption			**7 405.1**

Observing that all the components planned for the prototype will consume approximately 8 W in total, it is clear that a power supply capable of delivering 12 W is required. This choice is made because the consumption will be reduced without the use of a servo motor, CO_2 sensor, and light sensor.

7.6.3 Software

The software for the prototype is based on the software planned for the product. However, due to time constraints and complexity, it will be a lighter version, meaning it will not be as high-performing as originally envisioned for the application.

7.6.4 Tests & Results

Hardware tests

Table 40: Hardware Functional Tests

Functionality	**Test Result (Pass/Fail)**
Power Supply Verification	Pass
- Verify 5V output from LM7805	Pass
Light Sensor	Pass
- Output voltage changes with light intensity	Pass
Water Float Switch	Pass
- Float switch changes GPIO pin state (HIGH/LOW)	Pass
AHT20 Sensor	Pass
- Correct temperature readings	Pass
- Correct humidity readings	Pass
Solenoid Valve Control	Fail
- Solenoid valve opens/closes based on control signal	Pass
- Water flows through the solenoid valve	Fail
Fan Control	Pass
- Fan turns on/off based on control signal	Pass
Indicator LED	Pass
- LED lights up when power switch is on	Pass

Failed functionality tests:
The functionality test has revealed a failure due to the water tank being an ice cream box, and the solenoid valve's operational range being limited to a pressure range of 0.02 MPa to 0.8 MPa, equivalent to a water column with a height of 400 mm. To attain the required pressure for the water to flow through the solenoid valve upon activation, it is recommended to increase the height of the placement of the water tank in the prototype. This solution will provide the necessary pressure to ensure the proper functioning of the system.

Stress Analysis

First, an analysis of the 3D model under expected normal loads was conducted. This includes the gravitational force of all components, a filled water tank, and 5.6 kg of substrate in the small boxes. For simplification, all electrical components and doors were removed, as they have minimal impact on stability and weight. The results of the analysis are shown in the following Figure 73.

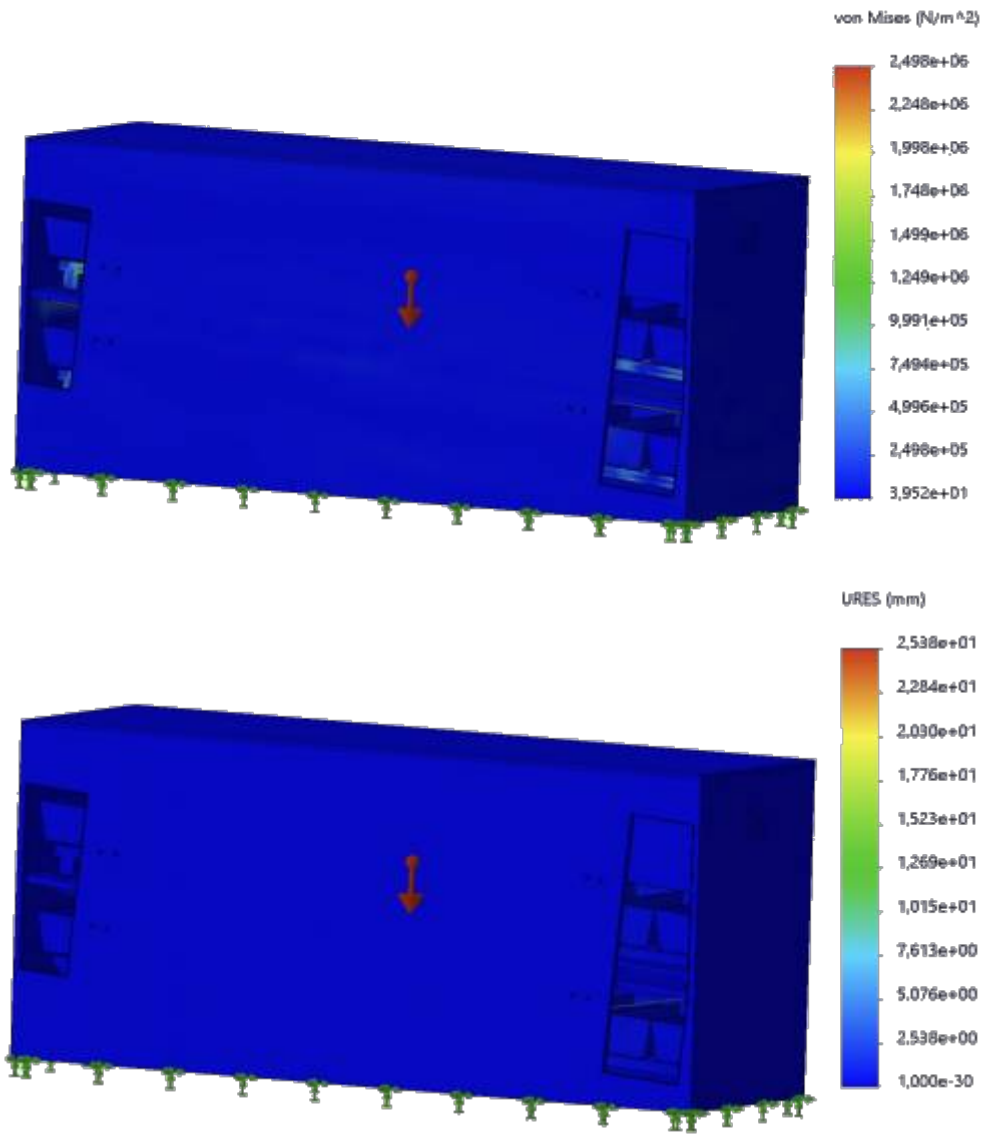


Figure 73: Stress Analysis and deformation normal load

The analysis reveals a maximum stress of 2.5 MPa. Given that the ABS material used can withstand at least 30 MPa, no stability issues are anticipated. However, it was noted that the plate intended to block light for the dark room sags by 25 mm in the middle due to its own weight. This issue will be resolved by adding some support to the upper plate. Otherwise, there are no significant deformations under normal load.

Next, the maximum possible load uniformly distributed on the device was examined. At a load of 1000 kg on the device, only a small area exceeds the maximum stress, specifically at the middle attachment of the roller conveyor to the level, as seen in Figure 74. This element will be reinforced, as it was identified as a weak point, even though such high loads are not expected.

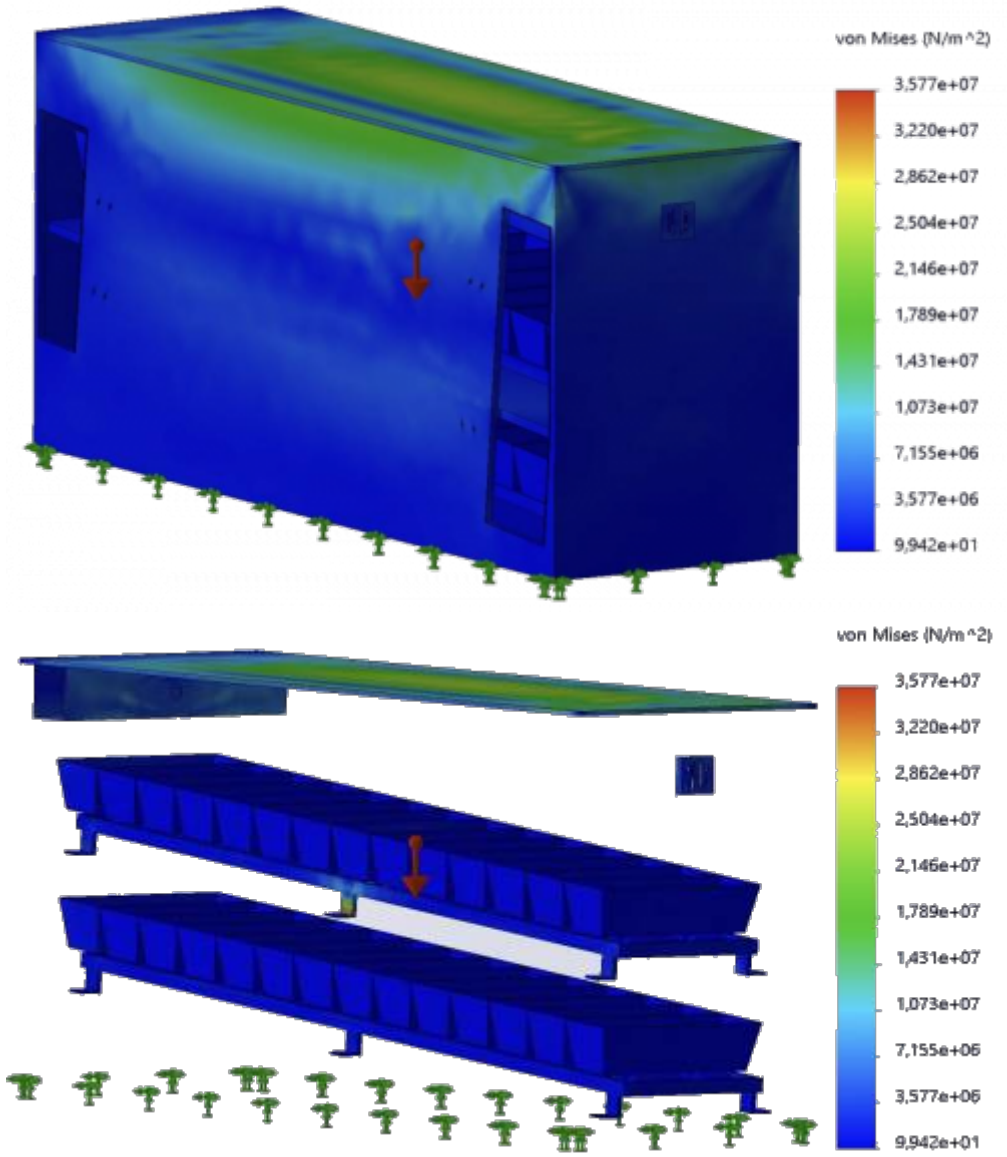


Figure 74: Stress Analysis 1000kg load on top

The deformation of the acrylic glass roof is 26 mm, which is high but acceptable for such a load. It can be seen in Figure 75 below.

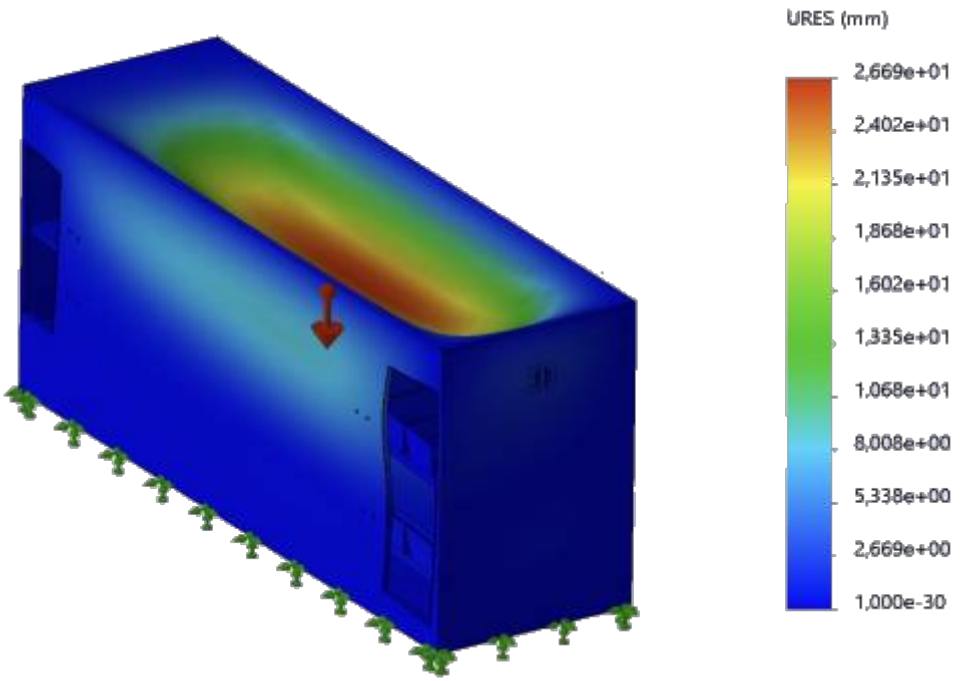
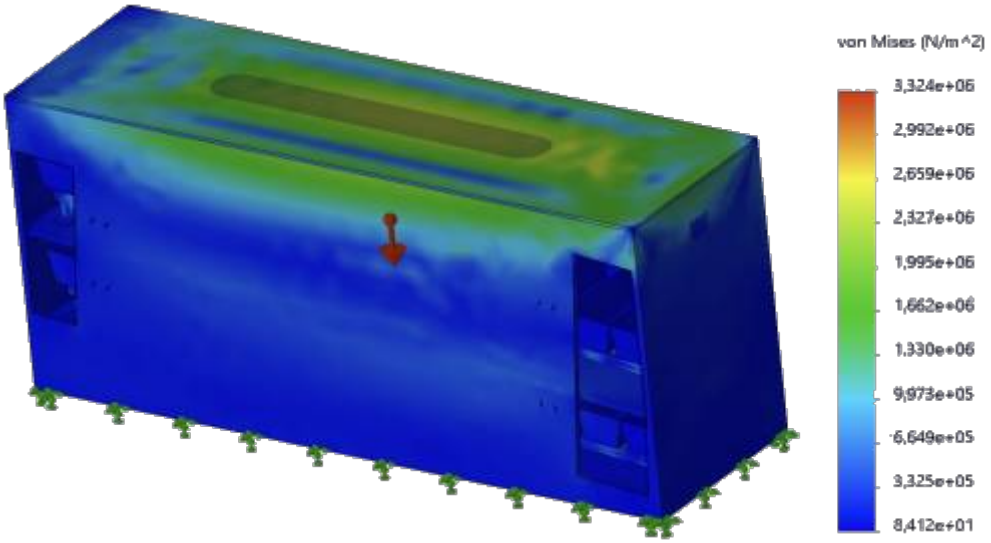


Figure 75: Deformation 1000kg load on top

A more realistic load scenario was then simulated, applying a weight of 100 kg on an area the size of a forearm on the roof. The acrylic glass is displaced downward by a maximum of 3 mm and experiences a maximum stress of 3 MPa, as seen in Figure 76.



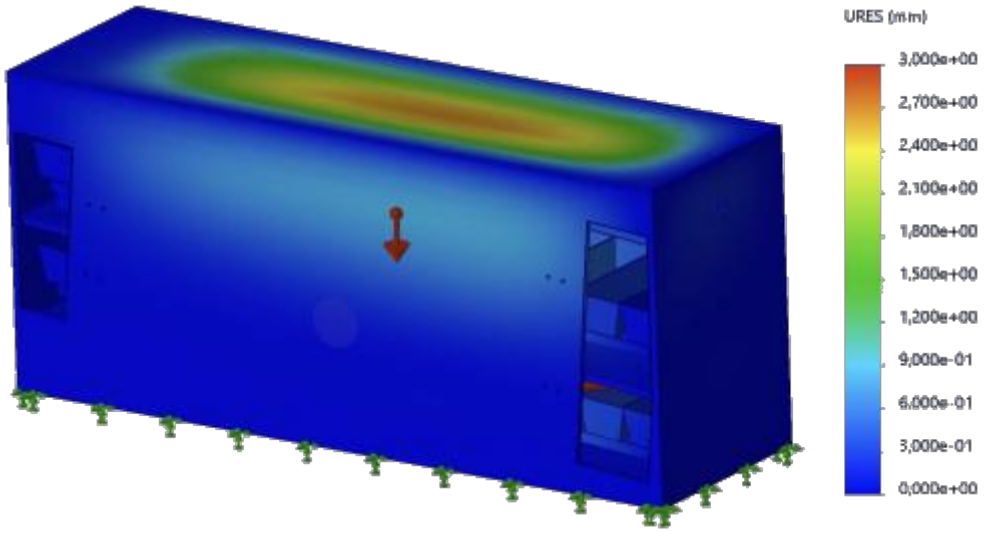
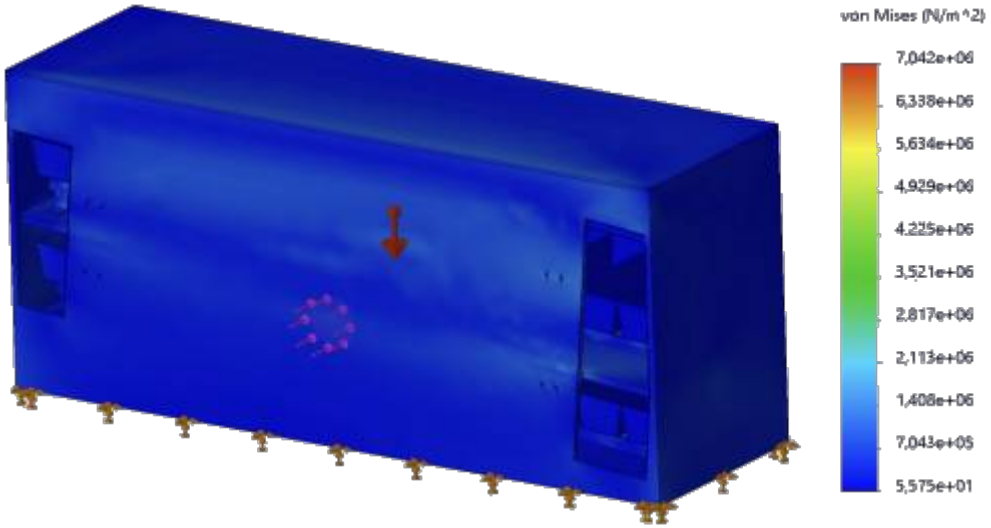


Figure 76: Stress Analysis and deformation 100 kg lean on top

Since acrylic glass can withstand approximately 70 MPa, this stress is not problematic.

Finally, a kick with a force of 1000 N against the side wall of the device was simulated. The side wall displaces by approximately 2 mm, and maximum stresses of around 7 MPa occur. The stress can be seen in Figure 77 and the deformation in Figure 78.



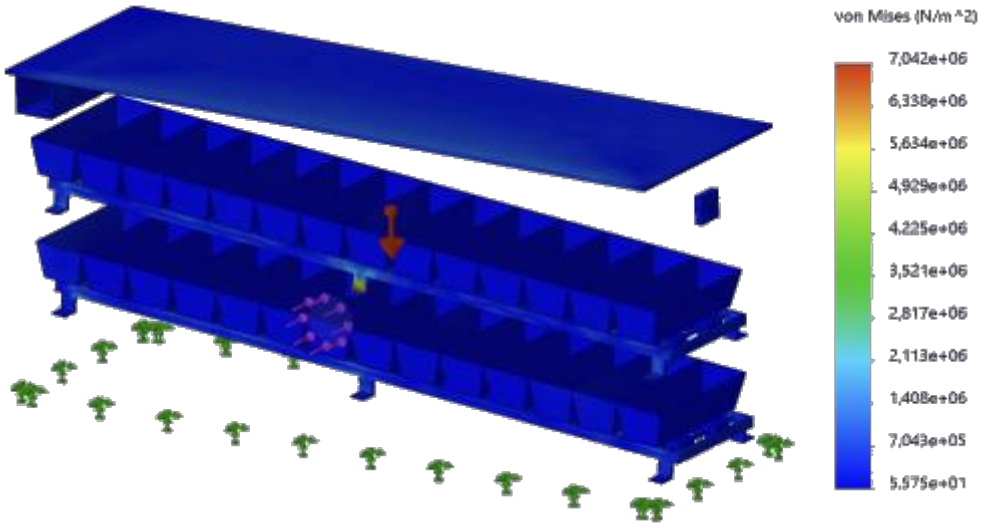


Figure 77: Stress Analysis 1000 N kick

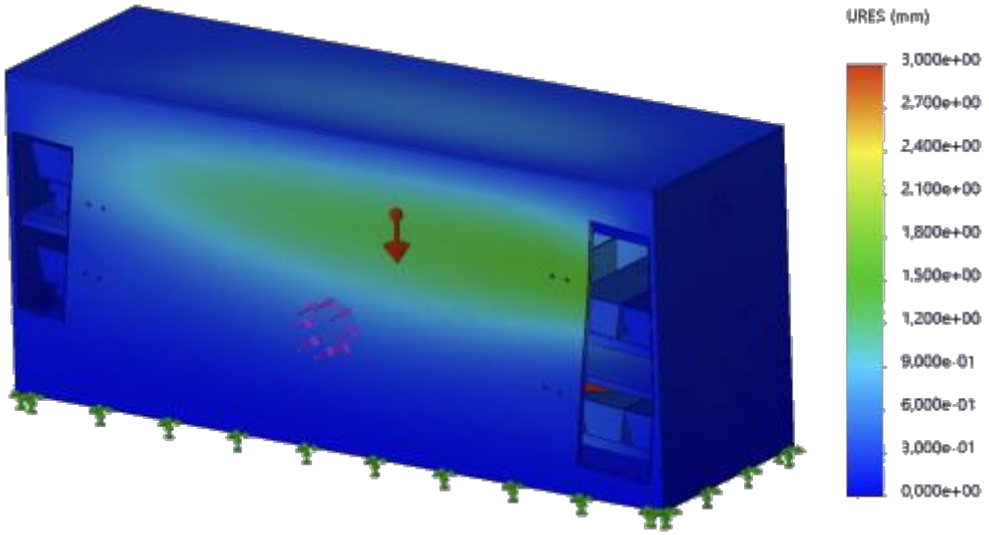


Figure 78: Deformation 1000 N kick

The maximum stress occurs again, like in the second simulation, at the attachment of the roller conveyor to the level. This again confirms the presence of a weak point and justifies the reinforcement of the component, even though the maximum allowable stress is not exceeded.

In conclusion, the analyses indicate that the product can withstand significant stresses and loads, thus meeting our durability and stability requirements. Additionally, material savings to reduce weight and cost could be considered.

Software tests

API testing

For the API testing locust was used. The testing went well, first started with 100 users doing requests, then it moved to 1000 and it finished with 10000 users. The api made no fails apart from the “Remote end closed connection without response” error which happened due to the poor capacity of the PC where the API ran for that quantity of users. Figure 79 shows the evolution of the API with user incrementation. In table 41 can be seen the final statistics for this testing.

Table 41: Api stress test statistics

Type	Name	# Requests	# Fails	Median (ms)	95%ile (ms)	99%ile (ms)	Average (ms)	Min (ms)	Max (ms)	Average size (bytes)	Current RPS	Current Failures/s
DELETE	/api/auth	4372	10	580	30000	70000	5331.13	5	83232	14.97	9.3	0
GET	/api/auth	13012	26	580	29000	69000	5129.99	5	86619	47.9	28.1	0
DELETE	/api/connection	4203	2	590	29000	70000	5047.61	4	86524	47.98	8.3	0
GET	/api/connection	12987	32	570	29000	69000	4983.86	4	86825	47.88	28.5	0
POST	/api/connection	4406	12	580	30000	67000	5145.35	5	85852	47.87	9.2	0
POST	/api/login	8401	17	570	25000	45000	3949.87	5	85006	270.72	5.8	0
PUT	/api/login	4262	9	540	26000	51000	3997.24	5	82059	163.99	4.2	0
GET	/api/user	13005	35	570	30000	72000	5248.96	5	86324	49.87	27.8	0
X	Aggregated	64648	143	570	29000	67000	4905.83	4	86825	82.68	121.2	0

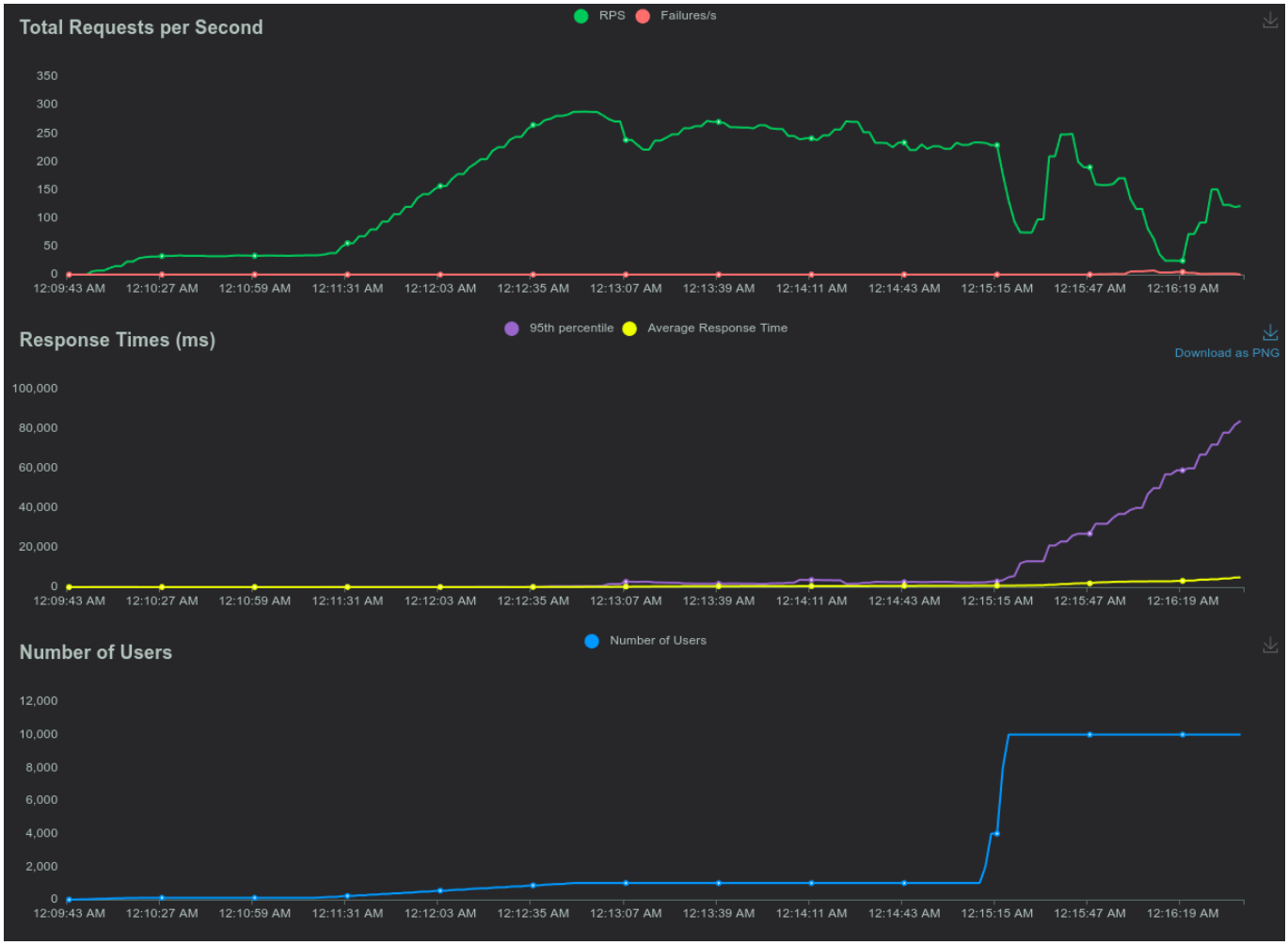


Figure 79: Api stress test

Now we are going to see how fast is the API to respond as the previous tests were more of stress tests. Table42 holds the functional and performance (exchanged data size and latency) results of the implemented API. The latency tests were made by making ten consecutive calls to each operation and calculating the corresponding average and standard deviation values. Table43 presents the load impact in the longest operation (worst case). The load tests consist in making 10, 100 and 1000 simultaneous requests to the operation with higher average latency in table42.

Table 42: API: functional and performance results

Operation	Method	Result	Size (B)	Average Latency (ms)	Latency Deviation (ms)
Check	token	GET	OK	207	6
Connect	POST	OK	332	9	7
Disconnect	DELETE	OK	334	7	3
Get	Data	GET	OK	331	6
Get	User	GET	OK	290	8
Login	POST	OK	426	21	7
Logout	DELETE	OK	245	25	10
Register	PUT	OK	315	14	1

Table 43: API: load results

Requests/Results	Operation	Method	Size (B)	Average Latency (ms)	Latency Deviation (ms)
10/10	Logout	GET	245	36	11
100/100	Logout	GET	245	28	8
1000/1000	Logout	GET	245	763	331

These results show that the app provides a friendly user experience. Mqtt broker testing
For the mqtt broker testing the mqtt-stresser tool from inovex has been used. This tool works by creating a given number of clients and a given number of messages per client. Then all clients send messages continuously and each of them report if there is any missing message. The test has been done first using 10 clients sending 150 each and the second time 100 clients sending 50 messages each. Figures 80 and 81 show the results.

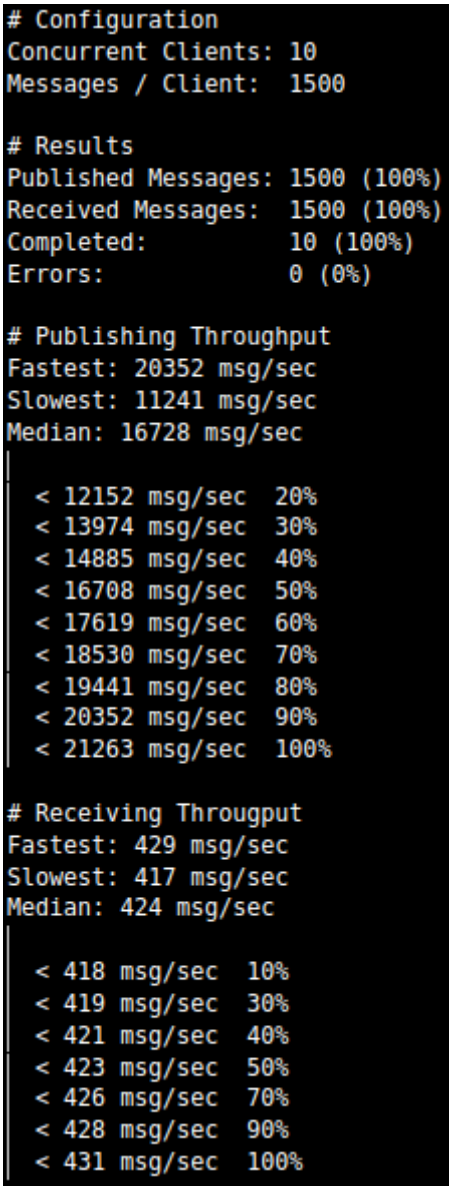


Figure 80: First mqtt broker stress test

```
# Configuration
Concurrent Clients: 100
Messages / Client:  5000

# Results
Published Messages: 5000 (100%)
Received Messages:  5000 (100%)
Completed:          100 (100%)
Errors:             0 (0%)

# Publishing Throughput
Fastest: 28229 msg/sec
Slowest: 4595 msg/sec
Median: 16921 msg/sec
|
  < 6958 msg/sec  7%
  < 9321 msg/sec  14%
  < 11685 msg/sec  31%
  < 14048 msg/sec  39%
  < 16412 msg/sec  48%
  < 18775 msg/sec  76%
  < 21139 msg/sec  94%
  < 23502 msg/sec  97%
  < 25865 msg/sec  99%
  < 30592 msg/sec  100%

# Receiving Througput
Fastest: 328 msg/sec
Slowest: 142 msg/sec
Median: 288 msg/sec
|
  < 160 msg/sec  10%
  < 179 msg/sec  20%
  < 272 msg/sec  23%
  < 291 msg/sec  64%
  < 309 msg/sec  89%
  < 328 msg/sec  99%
  < 346 msg/sec  100%
```

Figure 81: Second mqtt broker stress test

Software tests comprise: (i) functional tests regarding the identified use cases/user stories; (ii) performance tests regarding exchanged data volume, load and runtime (these tests are usually repeated 10 times to determine the average and standard deviation results); (iii) usability tests according to the System Usability Scale.

7.7 Conclusion

To conclude, CoffeeMush was developed to be a smart device that makes mushrooms out of coffee grounds and mushroom spawn. It is designed to have two separate rooms: a dark room for the mycelium to develop and a light room for the mushrooms to grow.

There are multiple sensors to keep track of the conditions and adjust if necessary. The water level sensor, CO2 sensor, light sensor, temperature sensor and humidity sensor are connected to an application. The application shows the customer the conditions and notifies if the water tank needs to be refilled for example. When the humidity is too low, the valve automatically opens and increases the humidity. Besides the sensors there is also a ventilator for circulation of the air. Additionally, there are two cameras, which can take pictures of the boxes with mycelium and mushrooms to show in the

app and to know if the box is ready to go into the light room. The boxes with coffee waste, mycelium and mushrooms move on a roller conveyor.

In the electronic circuit, the sensors mentioned in the text above are connected to power. Additionally, there are components like a regulator, capacitor, resistor and transistor are added for safety and to make sure the right amounts of power are connected.

To connect the composter to the application, there are several components needed. The composter processor is used for the API Docker container by an MQTT broker. This broker is connected to the application and to another broker: MongoDB Docker container. This last broker is to make an account in the application, where additional information like name and contacts can be saved. The packaging solution is a solution for reusing the package of the product. In the case of Coffeemush, the package is made to make two bags out of it. These bags can be made for transportation of coffee grounds or mushrooms. The bags are easily made out of the package; only the straps for the handles need to be adjusted. The material of the packaging is mycelium; a sustainable, renewable and degradable material.

The functional tests are done for the design of CoffeeMush, which finalizes the project of CoffeeMush. The next chapter will revise, conclude and dig deeper for further development.

8. Conclusions

8.1 Discussion

The project started with choosing a topic. The team decided on a smart kitchen composter, but soon realised that the products already on the market were not real composters and only allowed for a lean quality compost. State-of-the-art research made it possible to understand what was already on the market. It was important to ensure that the project was innovative, so an application was created to keep an eye on the progress from a distance. The target groups are larger households, apartment blocks, but also hostels and cafeterias with enough space. But in general, the product is attractive to anyone who drinks a lot of coffee, eats a lot of mushrooms or wants to contribute to the environment by processing coffee waste in a sustainable way.

Thanks to CoffeeMush, the customer will be able to obtain mushrooms of a quality that can be used for food, while at the same time having a very respectable use for the planet and for the wallet. Apart from a few sensors and a fan, CoffeeMush uses gravity to automatically move the coffee grounds. In addition, this product is equipped with a camera that allows the application to have a real view of what the mushrooms look like.

For the prototype part, the app, the sensors and the fan work. The only problem is that the solenoid valve does not get enough pressure to open. This could easily be solved by using a non-pressure solenoid valve. But the prototype could still be used to grow mushrooms, for example by manually watering or increasing the height of the water tank.

8.2 Future Development

CoffeeMush can be improved in several ways. Firstly, costs can be reduced by increasing sales, optimising the manufacturing process and buying materials in bulk.

Another improvement would be an additional function in the application: to communicate with people from other apps. This would make it easier to exchange, share, sell or buy coffee waste, mushrooms or mycelium.

Thirdly, the mecylium could be gotten out of the grown mushrooms, instead of buying them. This proces would have to be researched further before realising.

To increase the quality of the process, there should be a camera, a humidity sensor and a temperature sensor in the dark and light-filled compartments to separately monitor: the state of growth of the mycelium and mushrooms; the ideal humidity for the growth of the mycelium (lower humidity) and mushrooms (higher humidity); and the temperature because the dark and light-filled compartment can heat and cool differently. Finally, to regulate temperature and humidity more efficiently, there should be dedicated heating/cooling and vaporisation systems instead of the current fan and perforated tube.

9. Bibliography

[Erlantz Lizundia, 2024] Erlantz Lizundia, 2024. *Organic waste valorisation towards circular and sustainable biocomposites.* [Accessed in April 2024].
[Sara Sahai Marwah, 2021] Sara Sahai Marwah, 2021. *A COMPLETE GUIDE FOR SUSTAINABLE COFFEE WASTE RECYCLING.* [Accessed in May 2024].
[Florent Awedem Wobiwo, 2018] Florent Awedem Wobiwo, 2018. *Valorization of spent coffee ground with wheat or miscanthus straw: Yield improvement by the combined conversion to mushrooms and biomethane.* [Accessed in April 2024].
[Vickib, 2023] Vickib, 2023. *8 Methods of Composting.* [Accessed in April 2024].
[Adam Szczyrba, 2020] Adam Szczyrba, 2020. *kitchen+composter&l=36|Modular Composter // ORRE.* [Accessed in March 2024].
[Ayushi Rawat, 2018] Ayushi Rawat, 2018. *kitchen+composter&l=40|SHiBUi: Tea-Composter.* [Accessed in March 2024].
[Fancom, 2024] Fancom, 2024. *Automated growing system for exotic mushrooms.* [Accessed in March 2024].
[Hamni Flexible, 2024] Hamni Flexible, 2024. *Compostador de Fertilizante de Cocina a Jardín Reencle Prime - Plata.* [Accessed in March 2024].
[Mill Industry, 2024], **[Mill Industry, 2024]** Mill Industry, 2024. *Mill food recycler.* [Accessed in April 2024].
[Pela, 2024], **[Pela, 2024]** Pela, 2024. *Lomi classic.* [Accessed in April 2024].
[Foodcycler, 2023], **[Foodcycler, 2023]** Foodcycler, 2023. *The new foodcycler by Vitamix Eco 5.* [Accessed in April 2024].
[Amazon, 2024], **[Amazon, 2024]** Amazon, 2024. *Skaza Exceeding Expectations Bokashi.* [Accessed in April 2024].
[beyondGREEN biotech, 2024], **[beyondGREEN biotech, 2024]** beyondGREEN biotech, 2024. *beyondGREEN All-Electric Kitchen Composter.* [Accessed in April 2024].
[Richard Baguley, 2022] Richard Baguley, 2022. *Digging in the Dirt: 4 Home Composters Reviewed and Rated.* [Accessed in April 2024].
[Jill Sherman, 2023], **[Jill Sherman, 2023]** Jill Sherman, 2023. *We Tested the Mella Smart Mushroom Fruiting Chamber by FirstBuild.* [Accessed in April 2024].
[Ben Coxworth, 2022], **[Ben Coxworth, 2022]** Ben Coxworth, 2022. *Shrooly system automates in-home mushroom-growing.* [Accessed in April 2024].
[Drew Swainston, 2023] Drew Swainston, 2023. How to grow oyster mushrooms at home – 4 easy

methods for indoors and out. *Homes & Gardens*.
[Desiree Vilar, 2023] Desiree Vilar, 2023. King Oyster Fruiting Conditions (Temperature & Humidity). *BootstrapBee*.
[Elliot Webb, Niall Cullen, 2023] Elliot Webb, Niall Cullen, 2023. *How to Grow Mushrooms in Buckets.* [Accessed in March 2024].
[Adam Sayner, 2023] Adam Sayner, 2023. *Growing Mushrooms In Coffee Grounds.* [Accessed in March 2024].
[Glassdoor, 2024] Glassdoor, 2024. *How much does an Engineer make in Porto, Oporto?.* [Accessed in April 2024].
[Skills Unlimited, 2021] Skills Unlimited, 2021. *Power (Influence) and Interest Grid in Stakeholders.* [Accessed in April 2024].
[Anonymous, 2024] Anonymous, 2024. *Coffee Consumption by Country 2024.* [Accessed in April 2024].
[Ellen Macarthur Foundatio, 2024] Ellen Macarthur Foundatio, 2024. *Circular economy introduction.* [Accessed in May 2024].
[Nick Robinson, 2024] Nick Robinson, 2024. *GROWING GOURMET MUSHROOMS WHILE PROTECTING THE PLANET.* [Accessed in May 2024].
[GlobalPixal, 2024] GlobalPixal, 2024. *Find Out How Much Social Media Management Costs.* [Accessed in April 2024].
[George N. Root III, 2019] George N. Root III, 2019. *Examples of Controls in a Marketing Plan.* [Accessed in April 2024].
[Hari Srinivas, 2024] Hari Srinivas, 2024. *Sustainability Concepts.* [Accessed in April 2024].
[Shelton, 2024] Shelton, 2024. *"Brands & Stands: Social purpose is the new black.* [Accessed in April 2024].
[Simonetta Lein, 2018] Simonetta Lein, 2018. *Why Sustainable Branding Matters.* [Accessed in April 2024].
[Allan Astrup Jensen, 1997] Allan Astrup Jensen, 1997. *Life Cycle Assessment.* [Accessed in April 2024].
[Government of Canada, 2015] Government of Canada, 2015. *What is ethics?.* [Accessed in April 2024].
[National Society of Professional Engineers, 2019] National Society of Professional Engineers, 2019. *Code of Ethics for Engineers.* [Accessed in April 2024].
[Pipedrive, 2024] Pipedrive, 2024. *Sales Ethics for Next-Level Sales & Marketing Success.* [Accessed in April 2024].
[Alasdair Cochrane, 2024] Alasdair Cochrane, 2024. *Environmental Ethics.* [Accessed in April 2024].
[European Comission, 2006] European Comission, 2006. *Machinery Directive.* [Accessed in May 2024].
[European Comission, 2014] European Comission, 2014. *Electromagnetic Compatibility (EMC) Directive.* [Accessed in May 2024].
[European Comission, 2016] European Comission, 2016. *Low Voltage Directive (LVD).* [Accessed in May 2024].
[Carmen Sánchez, 2009], **[Carmen Sánchez, 2009]** Carmen Sánchez, 2009. Cultivation of Pleurotus ostreatus and other edible mushrooms. *Springer Verlag*.
[Melanie Andromidas, 2019] Melanie Andromidas, 2019. *How to Grow Mushrooms: Ventilation and Humidity.* [Accessed in April 2024].
[U.S. Environmental Protection Agency, 2024] U.S. Environmental Protection Agency, 2024. *What is a HEPA filter?.* [Accessed in April 2024].
[Breathe Naturally, 2023] Breathe Naturally, 2023. *Activated Carbon Filters: What Do They Remove from Your Air?.* [Accessed in April 2024].
[bitsmashed, 2010] bitsmashed, 2010. *Power and Thermal Dissipation.* [Accessed in May 2024].

[Mushroom pagaging by Ecovative, 2023] Mushroom pagaging by Ecovative, 2023. *Why mushroom packaging.* [Accessed in May 2024].