Sustainable Food Production Through Vermiponics | Report

Authors:

- Ana Mendes
- Elena Victoria Tatuc
- Fien Joos
- Jakub Wyka
- Kris Petrevski

Acknowledgements

Glossary

Abbreviation	Description
C-U	Control-Unit
EMC	Electromagnetic Compatibility
EPS	European Project Semester
EU	European Union
GHG	Greenhouse Gas
IoT	Internet of Things
ISEP	Instituto Superior de Engenharia do Porto
LAN	Local Area Network
LVD	Low Voltage Directive
OE	Order of Engineers
PBI	Project Backlog Item
PSS	Product Service System
RED	Radio Equipment Directive
RFID	Radio-frequency Identification
ROHS	Restriction of Hazardous Substances
SEO	Search Engine Optimization

Abbreviation	Description
SWOT	Strengths Weaknesses Opportunities Threats
USB	Universal Serial Bus
WBS	Work Breakdown Structure
LCA	Life Cycle Assessment

1. Introduction

The European Project Semester (EPS) is a one semester programme offered by different universities throughout Europe, including Instituto Superior de Engenharia do Porto (ISEP). The main idea of the programme is to provide students with the experience of working together in an interdisciplinary and international team of 3-6 students and hopes to foster the kind of team-working skills sought after by employers. The goal is to design and develop a new product by combining each other's knowledge and skills. In this first chapter of the report, the members of our team are presented and the topic of the project is elaborated.

1.1 Presentation

This team, which is part of the European Project Semester (EPS) at Institutio Superior de Engenharia do Porto (ISEP) during the spring semester of 2021, consists of five students from different countries and fields of study. These students will combine their knowledge and skills in order to work together towards the same goal, which is stimulating sustainable food production by designing a smart vermiponics system for city buildings.

Our scientific backgrounds are shown below in Table 1.

Table 1: Information about team members

Name	Country	Field of study
Ana Mendes	Portugal	Biomedical Engineering
Elena Victoria Tatuc	Romania	Industrial Design
Fien Joos	Belgium	Product Development
Jakub Wyka	Poland	Mechanical Engineering and Applied Computer Science
Kris Petrevski	Macedonia	Information and Communication Sciences for Business and Management

Team 2 is presented in Figure 1, during an online meeting.

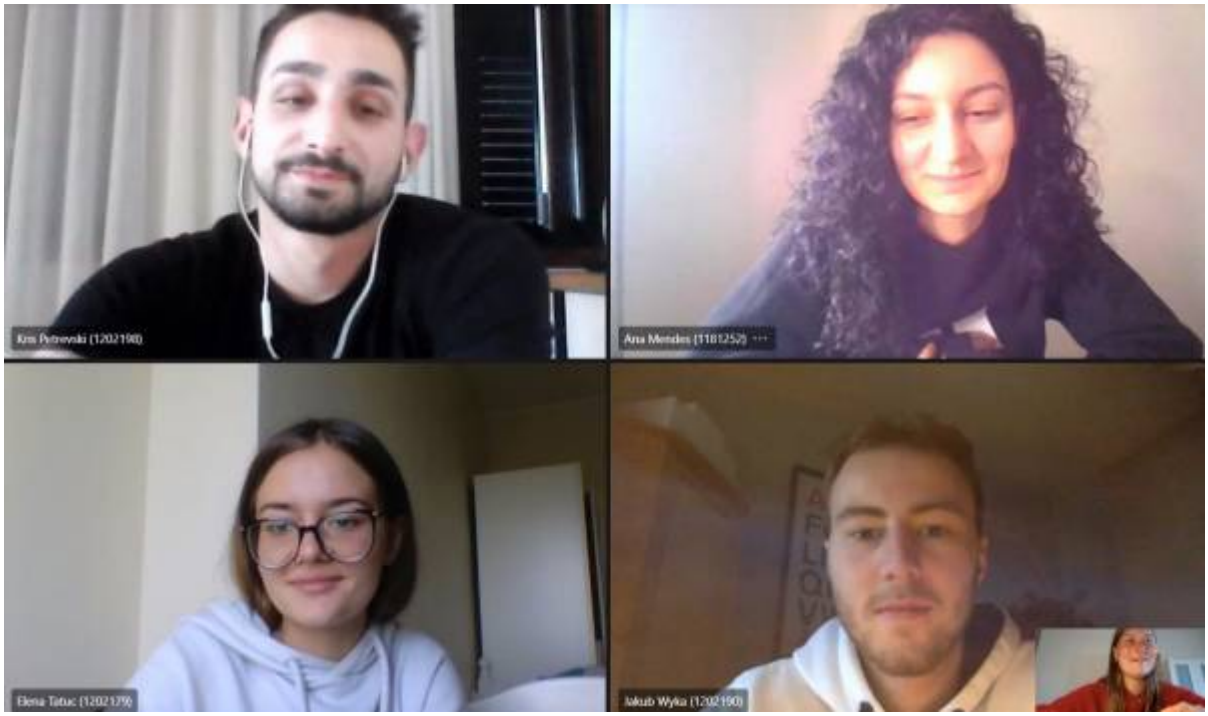

Figure 1: Team 2 members

1.2 Motivation

The team members of team 2 have chosen to participate in the EPS programme because of multiple reasons. First of all, we are all keen to gain new experiences and to broaden our horizon by stepping out of our comfort zone and take on this new challenge. Secondly, we want to explore new academic fields and new cultures, and working together in an international and multidisciplinary team is a great opportunity to do this and to learn from each other. Next, the scientific, as well as the social aspects of the project appeal to us. Finally, we aim to improve our English as well as learn to look at the design process from different points of view.

We believe that participating in the EPS programme will be enriching in many ways. We want to develop a project that inspires and connects the members of our team. The vermiponics system is an interesting topic, as it can contribute to a more sustainable environment, which is an urgent need in today's society.

1.3 Problem

As the world's population grows, the demands for increased food production expand, and as the stresses on resources such as land, water and nutrients become ever greater, there is an urgent need to find alternative, sustainable and reliable methods to provide this food. The current strategies for supplying more produce are neither ecologically sound nor address the issues of the circular economy of reducing waste **[1]**.

Food production relies on the availability of resources, such as land, freshwater, fossil energy and nutrients, and current consumption or degradation of these resources exceeds their global regeneration rate. The concept of planetary boundaries aims to define the environmental limits within which humanity can safely operate with regard to scarce resources.

As reflected in the UN’s Sustainable Development Goal 2, one of the greatest challenges facing the world is how to ensure that a growing global population, projected to rise to around 10 billion by 2050, will be able to meet its nutritional needs. To feed an additional two billion people by 2050, food production will need to increase by 50 % globally. Whilst more food will need to be produced, there is a shrinking rural labor force because of increasing urbanization. At the same time, food production will inevitably face other challenges, such as climate change, pollution, loss of biodiversity, loss of pollinators and degradation of arable lands. These conditions require the adoption o-f rapid technological advances, more efficient and sustainable production methods and also more efficient and sustainable food supply chains.

In short, the global population is rapidly growing, urbanizing and becoming wealthier. Consequently, dietary patterns are also changing, thus creating greater demands for greenhouse gas (GHG) intensive foods, such as meat and dairy products, with correspondingly greater land and resource requirements. But whilst global consumption is growing, the world’s available resources, i.e. land, water and minerals, remain finite. Thus, a major global challenge is to shift the growth-based economic model towards a balanced eco-economic paradigm that replaces infinite growth with sustainable development.

In this context, aquaponics has been identified as a farming approach that, through nutrient and waste recycling, can aid in addressing both planetary boundaries and sustainable development goals, particularly for arid regions or areas with non-arable soils. Aquaponics is also proposed as a solution for using marginal lands in urban areas for food production closer to markets.

Whilst aquaponics may be considered in the mid-stage of development, there are a number of allied, novel methods of food production that are aligning alongside aquaponics and also which can be merged with aquaponics to deliver food efficiently and productively. These technologies include algaeponics, aeroponics, aeroaquaponics, maraponics, haloponics, biofloc technology, and vermiponics.

In our project, the focus will be on vermiponics, which uses worm casts of mainly red wriggler worms also known as tiger worms (Eisenia fetida or E. foetida) to provide nutrients in a hydroponic system. Allied to the vermicomposting, we will include a 'keyhole garden' design in our product. It should be noted that vermiponics is in its infancy and mainly practiced by hobbyists and in research laboratories. This is why it is interesting to explore the possibilities of vermiponics.

1.4 Objectives

The main objective of this project is to develop a modular vermiponics system for residents of a city building. This objective involves designing the product and building and testing a prototype. In the designing phase, our main concerns will be related to the modularity of the system and the smartification of the vermiponics. Sustainable production techniques are already considered during the design phase. Concerning the building phase a list of materials will be needed and close attention will be paid to assembling the components in order to secure the relationship between every layer of the vermiponics (the water, the worms and the plants). Finally, testing the product is essential. Our objective of this phase is to have a working prototype and see actual results.

1.5 Requirements

The requirements of the project include:

- Mandatory adoption of the International System of Units;
- Using open-source software and technologies;
- A maximum budget of 100 €.

Functional requirements:

- Modularity (multiple configurations possible/ multiple sizes,…);
- Low energy consumption (even without any source of energy the system must be able to operate);
- Easy installation and maintenance (design for assembly and disassembly);
- Recyclable components.

Standard requirements:

Comply with the following EU Directives:

- Machine Directive (2006/42/CE 2006-05-17);
- Electromagnetic Compatibility Directive (2004/108/EC 2004 12 15);
- Low Voltage Directive (2014/35/EU 2016-04-20);
- Radio Equipment Directive (2014/53/EU 2014-04-16);
- Restriction of Hazardous Substances (ROHS) in Electrical and Electronic Equipment Directive (2002/95/EC 2003-01-27).

1.6 Envisaged Tests

A set of functional and performance tests are required in order to verify the operation of the system. These tests are described in table 2.

Table 2: Functional and performance tests

Condition	Expected result
Temperature and humidity sensor to ensure an optimal environment for the eco-system.	Microcontroller processes the information from both sensors and notifies the user when any adjustments need to be made.
Light sensor to track the movements of the worms.	Microcontroller processes the information from the sensor and provides information about the position of the worms.
pH sensor to measure collected rainwater (avoid acid rain coming in to the system).	Microcontroller processes the information from the sensor and warns the user when the rain water can’t be used.
IoT platform communication.	The online platform receives values from the microcontroller.

Condition	Expected result
Mobile application displaying information.	The app displays the information according to the data sent by the microcontroller.

1.7 Report Structure

The following table contains the main eight chapters of the report, with a small description of each of them.

Table 3: Report structure

	Title	Description
1	Introduction	Presentation of the team members, of the project purpose,objectives and requirements.
2	State of the art	Identification of previous knowledge about smart products.
3	Project management	Overview of the progress in the Agile management and SCRUM.
4	Marketing plan	Identify the main target group and strategies to introduce our product in the market.
5	Eco-efficiency Measures for Sustainability	Measures to implement to make the product as sustainable as possible.
6	Ethical and Deontological Concerns	Analysis of the ethical challenges related to vermiponics.
7	Project Development	Next steps to be done in order to build the prototype: concept, architecture, components, materials, prototype.
8	Conclusions	Summary of our project so far and future work.

2. State of the Art

2.1 Introduction

The general theme ‘smartification of everyday objects’ was the starting point for this project. Before the actual topic of our project was chosen, a study was made about the history and current market of smart products. By gaining insights into this market segment, a better decision could be made on where to innovate and for which object added value could be created through smartification.

The Fourth Industrial Revolution (Industry 4.0) is the automation of normal manufacturing and industrial practices, using smart technology. This Industry gained an increasing amount of attention over the years, and there has been a significant demand for more complex and technological

developments **[2]**.

Hoffman and Novak **[3]** define smart products as products that “interact and communicate with themselves and each other – and with humans – on an ongoing basis by sending and receiving data through the Internet that is stored and organized in a database.” In summary, smart products have:

1. ‘Sensors’ that collect data about the environment, and answer to physical or chemical stimulus. They can monitor and react to human or/and environmental behavior. The most common sensors measure temperature, humidity, movement, light, and sound;
2. ‘Actuators’ that are controlled by a Control-Unit (C-U) and activate an action based on the data collected by the sensors. They usually respond by converting the source's energy into mechanical motion, and can be categorized depending on the type of motion they present and
3. ‘Network connectivity' which is the process of connecting different parts of a network to one another. This can be achieved via Wi-Fi, Bluetooth, Radio-Frequency Identification (RFID), Local Area Network (LAN), and others.

The three main features of smart products are intelligence, ubiquity and autonomy. The smart products market is heterogeneous and has many segments (health, smart home, mobility, lifestyle, etc.) and several economic actors (multinationals such as Google and Apple or new start-ups offering innovative products) **[4]**.

2.1.1 Markets and Contexts

A smart product can be categorized into one or more contexts. The main contexts/categories of these products are:

1. Smart cities: dealing with congestion, energy waste, improving quality of life.
2. Smart home: control appliances, lights, thermostats, and other devices with network connectivity.
3. Health: smart medical devices, monitor and transmit data in real time, connecting doctors with patients.
4. Mobility: multimodal capability that bundles many transport options.
5. Lifestyle: these include smart textiles, gadgets, etc.

2.1.2 Consumers' Resistance

The continuous growth of Internet of Things (IoT) carries challenges and ethical issues, such as: lack of human control, doubts about the utility and added value of the product (perceived uselessness), perceived price, difficulty of usage, privacy and security concerns, and perceived novelty. The consumers' resistance manifests itself in three forms - rejection, postponement, or opposition -, and the understanding of these manifestations is important for the success of smart products, reducing the risk of failure **[5]**.

2.2 Research Projects

Tobias Mittag et al. **[6]** studied the recurring smart services and their implementations for manufacturing companies. The selection of ten case studies allowed them to find out the main features of smart products/services and their implementation. To identify the recurring elements, they did a comparative analysis, selecting the recurring functions of the case studies: Product Monitoring, Analytics, Alerting, Communication, Provide Information. Furthermore, this research enhances the importance of creating an overall solution that meets the requirements from the market as customers expect/demand certain services (Market Pull).

Soumitra Chowdhury et al. **[7]** did a systematic literature review to answer the question “What are the value creating features of smart product service systems in industrial firms?”. A Product Service System (PSS) is an integrated product and service that delivers value for the customers and product manufacturers. Smart PSS refers to the incorporation of smart digital technologies in design and delivery of PSS.

In 2019, Pai Zheng et al. **[8]** conducted a study on Smart PSS, its key aspects, challenges and future perspectives, of which they concluded that their findings could be summarized into three different aspects - Technical aspect, Business aspect, and Social and Environmental aspect.

Muztoba Khan and Thorsten Wuest **[9]** focused on the importance of upgradable PSS, but this logic can be applied to smart products as well. The shorter innovation and product development cycles make consumers dispose of conventional products before the end of their useful lives, that even if the product was considered sustainable, this life-shortening practice, takes away that aspect. Making a product/system upgradable is the right path to approach this problem, because as new technologies for product development arrive, one could still take advantage of those, but with the original product/service they bought.

The following table compiles the most important aspects and features of smart products/services according to the different studies mentioned above.

Table 4: Research projects

Project	**Theme**	**Main Features**	**Business**	**Design**	**Manufacturing**	**Usage**
Building blocks for planning and implementation of smart services based on existing products [10]	Smart products/services and their implementation	Product monitoring Analytics Alerting Communication Provide information	'Use-oriented' business model	Involvement of users in the process	Building blocks Use available data about the system to keep improving it	Monitoring Optimization Service support
Smart Product-Service Systems in Industrial Firms [11]	Smart PSS features for added value	Digital resource integration with customers Connect capability Analytic capability	Use generated data to improve customer relationship and PSS redesign	Boundary spanning Dynamic capabilities	Manufacturers have to find ways to exploit digitalization to meet current needs of the digital era	Remote monitoring to reduce machinery breakdowns
A survey of smart product-service systems [12]	Key aspects of PSS	Digitalization capabilities (connect, analytic, intelligence) Co-creation	Business model Digital platform Value co-creation Circular economy	Adaptable design Service innovation	Planning Process control	Remote monitoring Reconfiguration Reuse Remanufacturing Recycling at 'end-of-life' stage

Project	Theme	Main Features	Business	Design	Manufacturing	Usage
Towards a framework to design upgradable product service systems [13]	Importance of upgradable PSS	Customization Modularization	Upgradable systems provide a better and continuous relationship with customers	Flexible design to allow rearrangements during the use phase in accordance with the customer's requirements, while maintaining minimal structural change	Integrated development of product and service	Collect data about the usage behavior and taking customer feedback into account

From this analysis it is possible to say that **monitoring** is a common and important usage feature, mentioned in each project, to improve the relationship with the customers. Other key aspects to retain are that this relationship with customers should be open and truthful, as the company should provide information about the design and manufacturing stages, as well as service support during the usage stage. Furthermore, the products should be **reusable**, and/or **recyclable** products that actually add value, and the **modularization** and **customization** help creating **upgradable** services/products for greater longevity.

2.3 Commercial Projects

The commercial projects/products are vital in the comparative process of the first research steps, to oversee what is already available on the market, to analyze the qualities and downsides of the products, and to conclude on which features the team's product should compile, and some issues that could be solved with said product.

The next table contains a smart object/product for each context/market mentioned previously, with its description, main features, market, price, and an evaluation of sustainability (environmental, economic, and social) and ethics.

Table 5: Smart objects

Product	Context	Description	Main Features	Sustainability	Ethics	Market	Price (€)
Bigbelly	Smart cities	Smart waste and recycling system	Solar powered Sensor-equipped Real-time communication	Environmentally sustainable	Very respectful of ethical issues	Municipalities and cities governors	*Not specified*
Wi-Fi Plug	Smart home	Intelligent plug	Wi-Fi connection Energy efficient Measurement of electricity consumption Timer to turn on/off	Environmentally and economically sustainable	No issues reported	Everyone who wishes to keep track of their energy consumption and people who forget	9.99 - 14.00

Product	Context	Description	Main Features	Sustainability	Ethics	Market	Price (€)
8sense by Beurer	Health	Device that vibrates when back posture is not correct or when the person is in the same position for too long	Real-time feedback 14-day memory “8sense” app Lithium-ion battery	Not very sustainable (materials, production)	Ally to preventive health, avoiding back problems	For everyone who desires to correct their posture/maintain it correct	100.00
MaaS Made Easy	Mobility	Software for easy access to smart mobility (for transport operators, municipalities and corporations)	Flexibility Integration Cost-effective Route planner Real-time transit data	Sustainable for the environment, the economy, and the community	Privacy data issues can be found due to vulnerabilities of the system	Everyone can benefit from smart mobility strategies	*Not specified*
Smart Watch	Lifestyle	Sports watch	12 sports modes GPS Heart rate monitor Acceleration, Geomagnetic, Air pressure, Ambient light sensors Bluetooth 5.0 App 14-day battery life	Unsustainable production, but sustainable for the community to monitor vital signs, exercise, etc.	Can be an ally for preventive health Vulnerabilities of system can be found (potential threat to users) Misused data will also cause bad influence and the companies are not transparent on the usage of personal data	Suitable for everyone	25.00 - 450.00

2.4 Sustainable Food Production Systems

The demands for increased food production caused by the world’s population growth mentioned in section 1.3 (previous chapter) directed the focus of the project to the urban areas, where 55 % of the world’s population lives currently, and is expected to increase to 68 % by 2050 **[14]**. After evaluating the existing market of smart products, the theme of the project is sustainable food production systems.

2.4.1 Aquaponics

Aquaponics is a food production system. It's an energy and cost-efficient way to grow plants and vegetables. Aquaponics is based on a system that uses a symbiotic relation between plants and fish. The main process that occurs in this system is that bacteria convert fish waste into plant food. The plant feeds on this and purifies the water. Fish waste can turn into plant food through the process of the 'nitrogen cycle': fish waste contains ammonia (this can not be absorbed by the fish, as it is toxic) so bacteria convert the ammonia to nitrate. Two types of bacteria are necessary to do this - the first bacteria (Nitrosomonas) converts ammonia to nitrite, and the second bacteria (Nitrobacter) converts nitrite to nitrate **[15]**.

Figure 2 illustrates what an aquaponics system generally looks like.

Figure 2: Aquaponics system **[16]**

Advantages of aquaponics [17]:

- No artificial fertilizers/ other agricultural fertilizers: obtain high-quality, chemical-free food that is safe for human health;
- Saves 95 % water compared to cultivation methods;
- Production is completely independent of the weather and climate;
- Energy savings of up to 70 % can be achieved compared to traditional horticulture;
- Plants have constant access to nutrients which allows them to grow faster (e.g.: lettuce can grow in 1 month compared to the 'normal' 2 months);
- The aquaponics system does not use large, environmentally damaging agricultural machinery.

2.4.2 Vermiponics

As more research on aquaponics was conducted, it became clear that there are valid arguments as to why aquaponics maybe an ecologically minded and economically viable option. However, currently, the vast majority of aquaponic systems are simply not sustainable **[18]**. It turns out that there are a lot of alternatives, like vermiponics, that represent theoretical and technical progress towards sustainable primary production.

Vermiponics is a novel way to grow plants that uses the nutrients from worm castings (specifically from worm-tea) to grow plants in a soil-less (or hydroponic) environment. Vermiponics is similar to aquaponics (which is also soil-less) but instead of the nutrients being provided by fish waste that is broken down by bacteria, the nutrient solution in vermiponics is made from worm-tea instead. Worms can create an effective organic fertilizer for plants, as they decompose organic matter and food scraps. This process is called **vermicomposting**. The result of this process is compost tea/worm-tea, that serves as a non-toxic alternative to chemical fertilizer **[19]**.

The following image illustrates what a vermiponics system generally looks like.

Figure 3: Vermiponics system **[20]**

Several reasons that justify vermiponics being more sustainable than aquaponics are listed below **[21]**:

- Vermiponics does not require equipment for heating or cooling because operating range for vermiponics is 7-32 °C. An aquaponic system with Tilapia, for example, has operating temperatures between 21-32 °C which often creates a need for climate control and/or greenhouse;
- Vermiponics does not require filtration systems. Solids are not a problem for worms and the microbiome, and plant roots remove excess solids when the plants are harvested;
- Vermiponics does not need large stock tanks for fish. Fish tanks take up 10-100x more space than vermiculture systems;
- Fish food is grown with conventional agriculture (land-intensive and water-intensive) so the complete footprint for aquaponics is quite large. Vermiponics has no additional land use, as nutrients come from food waste that would otherwise end up in a landfill;
- Nutrient density of vermiponics solution is approximately three times that of aquaponics;
- Worms are far more robust than fish, as it is easy for fish to die from disease or system

malfunction (loss of temperature control, oxygen, circulation, nutrient toxicity). The only way a worm population will die is if the vermiculture system gets below 1.7 °C or above 37.8 °C, which is very unlikely to happen.

2.4.3 Permaculture and Keyhole Gardens

Permaculture is an approach that integrates land, resources, people, and the environment to mimic the natural systems with no waste loops **[22]**. The following figure sums up the concept of permaculture and other aspects associated with it.

Figure 4: Permaculture **[23]**

At this point, there are a few solutions that respect the approach of permaculture. One of these, is the African keyhole garden, which was designed by CARE in Zimbabwe during the mid nineties to encourage people to grow their own food. A keyhole garden is a round garden bed with a compost pile in the middle. The garden has a notch in the front, so gardeners can easily add to or turn over the pile. It also has a drainage layer, a soil layer, and a planting area, which combine all the necessities that plants need to grow and thrive **[24]**.

Figure 5: Keyhole garden

2.4.4 Conclusion

To sum up, it is obvious that the systems involving vermiponics and/or vermicomposting are the most sustainable for food production. Furthermore, it is also clear that imitating natural systems is the most ethical, energy efficient, and sustainable approach. After plenty of discussion and consideration, the team decided to implement a system that consists of a simple modular 'keyhole garden' structure, with a composting basket in the center. The team considers this is an interesting product to smartify, as variables such as temperature, and humidity are important to monitor, and a tracking device could add value to the system.

2.5 Related Solutions

2.5.1 Subpod

Subpod is an in-ground compost system, as seen in figure 6, that turns food scraps, paper, coconut peat into rich compost. Over time, the worms living in it provide the nutrients from the compost to the garden soil, helping the plants thrive **[25]**.

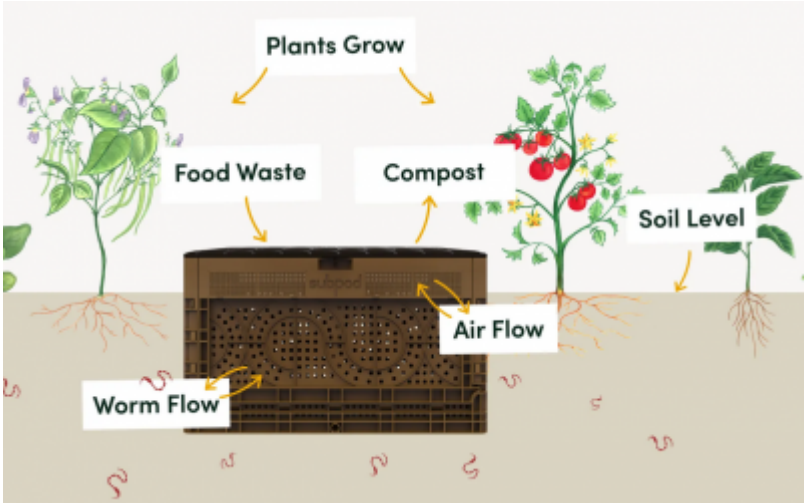

Figure 6: Subpod **[26]**

2.5.2 Biovessel

The BioLad and Engineering/Design studio 'BIONICRAFT' is dedicated to biological research, conservation and innovation. Through biological observation and experiment, they designed the 'BIOVESSEL'. The BIOVESSEL is “an ecosystem powered by food waste”, as their slogan states, that aims to deliver nature to urban homes composting food waste for a sustainable lifestyle **[27]**.

Figure 7: Biovessel **[28]**

2.5.3 Urbalive

Urbalive provides different options for indoors and outdoors: from simple vermicompostors (“Worm Farm”) to farming systems (“Indoor Planter” and “Outdoor Planter”) **[29]**.

Figure 8: Urbalive **[30]**

2.5.4 Comparison

Table 6: Comparison between related solutions to the project

Product	Price (€)	Pros	Cons
Subpod	~300	Different sizes Provides everything needed for composting	Price Availability for outside the United Kingdom is conditioned Mainly recommended for outdoors
Biovessel	~200	Small, portable Great for the inside Appealing design (can be seen as decoration)	Price Little space for plants (fits only one) No information available after 2018
Urbalive	100-160	Portable Modular They sell individual trays Cheaper Solutions for both indoors and outdoors Self-watering	The worm tea production and plant production have to be done in separate places/products, and this way it becomes more expensive (~260 €)

As seen in table 6, indoors food production is conditioned in both products analyzed. Subpod is perfect for outside (gardens, backyards, etc.), while Biovessel is idealized for the inside, but only for vermicomposting, as it has no space for food production, given the size of the product. Urbalive would be more interesting if everything was combined in one product (plant production and vermicomposting). Therefore, the combination of greater space for plant production with an appealing design is something that has not yet been achieved in the vermicomposting market.

2.6 Summary

Nowadays, endless smart products can be found on the market, with different applications. These objects are divided in five main contexts/markets: smart cities, smart home, health, mobility, and lifestyle. There are common features for these markets, including remote monitoring, digitalization, and adaptability. Furthermore, people look more and more for products on which they can have a say on, on which their opinion matters, and having customers' loyalty and trust is important for companies.

Based on this study of the state of the art, the team decided to adopt the following strategies: manufacture a modular/reconfigurable product with connectivity; develop a product that adds value and that answers to the existing problem of sustainable food production in today's society; choose the

most sustainable production strategies and materials possible; be communicative with customers, and open about the manufacturing process and materials used. Therefore, the team will develop a smart modular 'keyhole garden' structure, to fulfill the need for sustainable food production techniques as the world's population grows.

3. Project Management

3.1 Scope

Properly defined scope allows to estimate costs and the time required to finish the project. It helps to determine tasks and distribute all resources. After defining the main goal of the project we improved the planning by simple hierarchical structure consisting of all tasks and products that are needed to be done in order to successfully finish the project. By the means of Work Breakdown Structure (WBS) we divided our scope into 6 sections: Initial, Design, Interim, Executive, Test and Final. Multiple tasks create each stage.

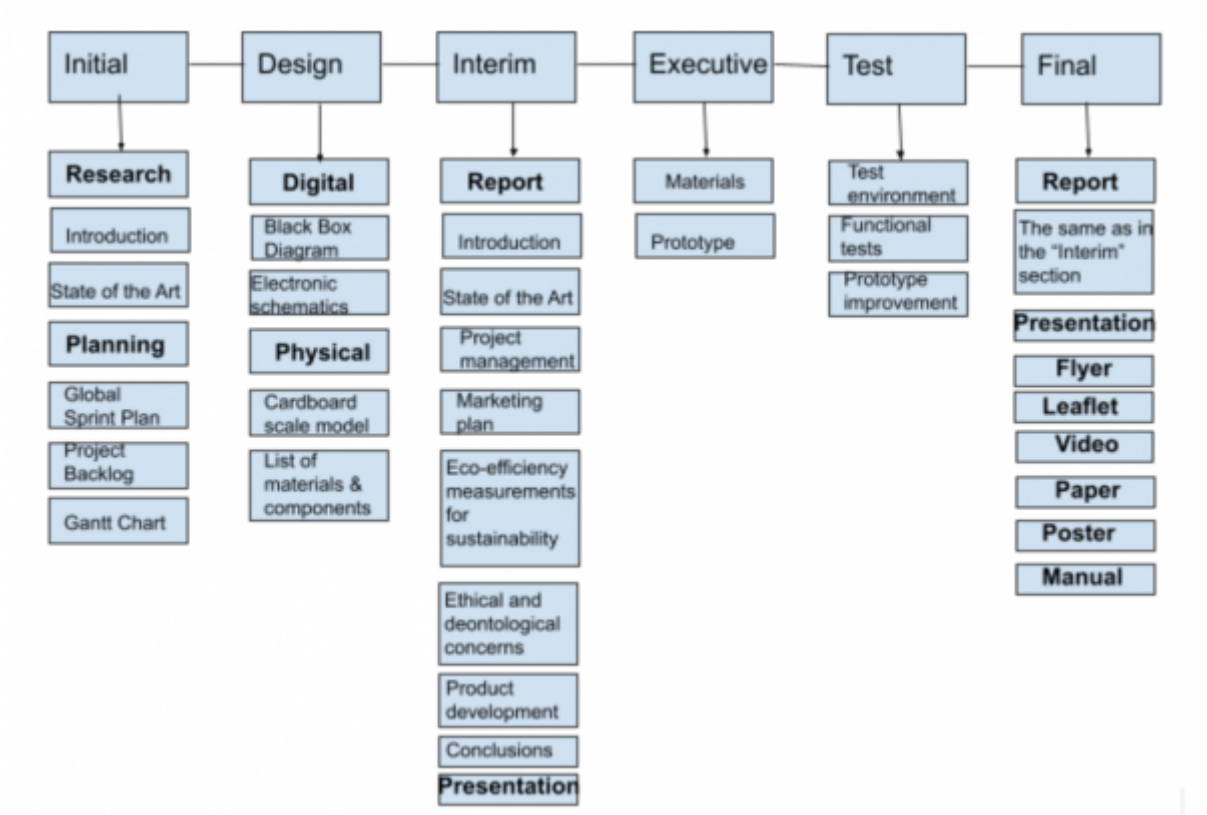

Figure 9: Work Breakdown Structure

3.2 Time

Using global sprint plan we defined our optimal sprint duration and plan our sprints until project end. Then the project backlog was created including all relevant tasks and deliverables. Based on these the Gantt Chart was produced (figure 10).

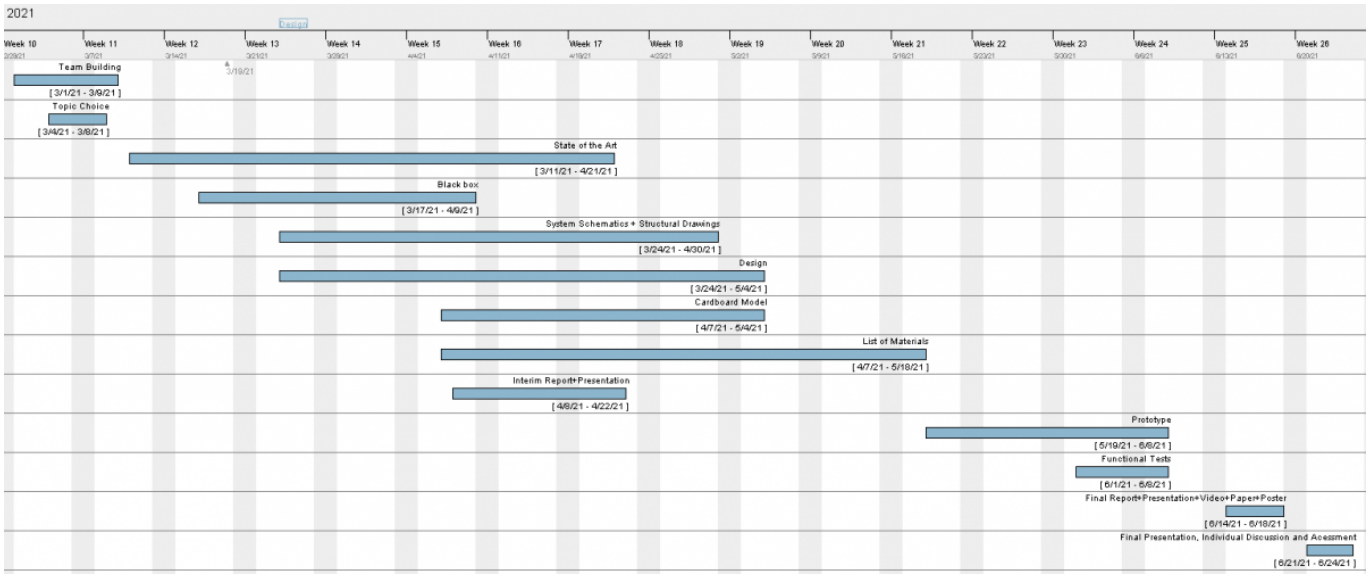

Figure 10: Gantt Chart

3.2 Cost

Document the planned vs. effective costs of your project.

3.3 Quality

Document quality metrics that will apply to your project deliverables, associated thresholds and how they should be reviewed.

3.4 People

The human resources are the key factor for project. Team members contribute to multiple task development. To help organize the work different tasks were allocated to team members. What is more the team knows who is responsible for certain task. It is visible on the table below.

Table 7: Responsibility Assignment Table

Task	**Responsible**
Teambuilding report	Ana
Topic choice	Jakub
State of art and project backlog	Jakub
Blackbox	Ana
System schematic and structural drawings + cardboard model	Fien
List of materials	Kris
Interim report and presentation	Elena
List of materials (revised): local providers & price, including VAT & transportation	Fien & Jakub
Refined design of the product	Elena & Ana
Revised interim report	Kris

Task	Responsible
Start Design	Jakub
Finalize design	Elena & Fien
Finalize design: high fidelity prototype	Kris & Ana
Upload result of functional tests	Fien
Upload final report + presentation + video + paper + poster	Jakub
Final presentation	Fien

Not only the team members are involved in the project development. These people together with the team members are called stakeholders. Stakeholder is a person such as an employee, customer, or citizen who is involved with an organization, society, etc. and therefore has responsibilities towards it and an interest in its success **[31]**.

Table 8: Stakeholders and their role

Stakeholder	Role
Team members	Students
Benedita Malheiro	EPS coordinator
Benedita Malheiro, Cristina Ribeiro, Jorge Justo, Manuel Silva, Paulo Ferreira, Pedro Barbosa Guedes	Supervisors
Ana Barata, António Arrais de Castro, Cláudia Facca, Luís Castanheira, Luís Lopes, Paulo Ferreira, Sandra Luna	Teachers

3.5 Communications

Good communication within team is essential to obtain successful project outcome. Because of pandemic situation and to ensure the good flow of information the following communication methods were introduced:

- Meetings - mainly on Zoom and Microsoft Teams
- Email - used to communicate with teachers and supervisors
- Chat - WhatsApp and Messenger groups to access quick, everyday communication between team members
- Other apps - Microsoft Planner, Microsoft OneNote, Google Drive, Canva

Table 9: Communication Matrix

What?	Why?	Who?	When?	How?
Deliverables	Develop the project	Team members	Before the deadlines	Uploading to Wiki and presenting to the supervisors/teachers
Weekly team meeting	To gain feedback	Team members, supervisors	Every Thursday	Microsoft Teams
Everyday stand-up	Discuss the work being done on previous day, set new tasks	Team members	Everyday	Microsoft Teams

What?	Why?	Who?	When?	How?
Sprint planning	Divided into team members, set deadlines and add tasks to the project Backlog	Team members	Every Monday	Microsoft Planner
Sprint review	To check the progress	Team members	Every Friday	Microsoft Planner
Brainstorming	To find new ideas	Team members	Before taking action	Microsoft Teams, WhatsApp, Messenger, Google Drive
Agenda	To pick the topics for meetings with supervisors	Team members	Every Wednesday	Wiki
Interim Presentation	To present current state of the project and obtain feedback from the supervisors	Team members, supervisors	April 22, 2021	Microsoft Teams

3.6 Risk

Risk is the possibility of loss or injury. Risk analysis and management is an important project management practice to prevent surprises during the project development. The lack on a structured risk management framework leads to:

- Incomplete impact evaluation: no knowledge of the impact on the project goals (scope, time, cost, and quality)
- Lack of transparency and communication gap between team member and outside the team.

Therefore, the implementation of such framework will provide a conscious and focused risk identification/management, the envisioned project progress with minimal surprises, an early and effective communication of project issues, and an effective team building tool.

The following two tables are related to product and project risks. The risks are evaluated through the following criteria:

- Impact, which can be low, medium or high;
- Probability, in a scale of 1 (no-very low probability) to 4 (very high probability).

3.6.1 Product Level

Table 10: Product Risks

Risk	Cause	Effect	Evaluation	Mitigation
Functionality	Problems with suppliers, lack of necessary skills	Incomplete product	Impact: high Probability: 2	Prototype development and testing, focus on evolving required skills
Performance	Wrong mechanisms	Lower sales, unsatisfied customers, bad reviews	Impact: high Probability: 2	Intensive research and testing

Risk	Cause	Effect	Evaluation	Mitigation
Design	Improper design	Lower sales because of the product aesthetics	Impact: high Probability: 3	Present different designs to different individuals and choose the most liked and efficient one

3.6.2 Project Level

Table 11: Project Risks

Risk	Cause	Effect	Evaluation	Mitigation
Team conflicts	Lack of communication	Delays	Impact: high Probability: 2	Early communication, open discussions, compromising
Lack of skills	Lack of expertise in a certain field	Delayed work, inappropriate development of tasks	Impact: high Probability: 2	Research, turn to supervisors for guidance
Time management	Wrong estimations	Delayed work, inconsistent & unfinished sprints	Impact: medium Probability: 3	Weekly sprint reviews and evaluation

3.7 Procurement

Document your procurement management strategy including make vs buy decisions, materials/services to be acquired, sources, costs, timings, etc.

3.8 Stakeholders Management

Define how you will manage stakeholders to keep them engaged.

3.9 Sprint Outcomes

Scrum is an Agile project management methodology involving a small team led by a Scrum master, whose main job is to remove all obstacles to getting work done. Work is done in short cycles called sprints, and the team meets daily to discuss current tasks and any roadblocks that need clearing **[32]**. This framework uses the following:

- **Daily stand-up**. It is an everyday meeting on which team members discuss the work being done on previous day, plan the current day and review the obstacles that have occurred. It is worth mentioning that those meeting should be carried out in standing position.
- **Sprint planning**. Every Monday, at the begging of each sprint, the team plans what will be done this week. Then the tasks are allocated to the different team members and their duration is estimated.

- **Sprint review**. Every Friday, at the end of each sprint, the team reviews the last sprint plan. The tasks are divided into completed and not completed.
- **Sprint retrospective**. Apart from sprint review the sprint retrospective takes place every Friday. It is reflected what was positive and what was negative during the last sprint. Based on these three categories are created: start doing, keep doing and stop doing.

Based on academic calendar delivered by ISEP, the number and duration of sprints were adjusted. It is shown in table 12.

Table 12: Global Sprint Plan

Sprint	Start	Finish
1	01/03/2021	07/03/2021
2	08/03/2021	14/03/2021
3	15/03/2021	21/04/2021
4	22/03/2021	28/03/2021
5	29/03/2021	04/04/2021
6	05/04/2021	11/04/2021
7	12/04/2021	18/04/2021
8	19/04/2021	25/04/2021
9	26/04/2021	02/05/2021
10	03/05/2021	16/05/2021
11	17/05/2021	23/05/2021
12	24/05/2021	30/05/2021
13	31/05/2021	06/06/2021
14	07/06/2021	13/06/2021
15	14/06/2021	20/06/2021
16	21/06/2021	25/06/2021

Project Backlog is built including all relevant tasks and deliverables. Project Backlog Items (PBI's) are prioritized, keeping higher priority items at the top, and lower priority items at the bottom. Each task has a status: To do, Doing or Done. It means that the Project Backlog is continuously updated. When the task is done it goes to the bottom of the table.

Table 13: Project Backlog

PBI	Title	Status
TR	Teambuilding report	Done
TC	Topic choice	Done
SA	State of art and project backlog	In progress
BB	Blackbox	To do
SSS	System schematic and structural drawings + cardboard model	To do
LM	List of materials	To do
IR	Interim report and presentation	To do
LLR	List of materials (revised): local providers & price, including VAT & transportation	To do
RDP	Refined design of the product	To do
RIR	Revised interim report	To do
SD	Start Design	To do
FD	Finalize design	To do
FD	Finalize design: high fidelity prototype	To do

PBI	Title	Status
FT	Upload result of functional tests	To do
FR	Upload final report + presentation + video + paper + poster	To do
FP	Final presentation	To do

Below the completed sprints are presented. As mentioned before they are weekly, based on the Global Sprint Plan and Project Backlog.

Table 14: Sprint 4 (22/03 - 28/03)

Task	Estimated duration (h)	Real duration (h)	Members involved	Status
Weekly classes	60	60	Ana, Elena, Fien, Jakub, Kris	Done
Finish and upload Blackbox to Wiki	1	1.5	Kris	Done
State of the art	2	3	Fien	Done
Make final product choice	6	4	Ana, Elena, Fien, Jakub, Kris	Done

Table 15: Sprint 5 (29/03 - 04/04)

Task	Estimated duration (h)	Real duration (h)	Members involved	Status
Define target group	3	-	Elena	Doing
Weekly classes	58	58	Ana, Elena, Fien, Jakub, Kris	Done
Research about symbiotic relations	3	2.5	Jakub	Done
Sketches	3	3	Fien	Done
Electronics schematics	2	2	Ana	Done
Finish and upload state of the art to Wiki	2	2	Kris	Done

Table 16: Sprint 6 (05/04 - 11/04)

Task	Estimated duration (h)	Real duration (h)	Members involved	Status
Detailed system schematics & structural drawing	4	-	Fien	Doing
Refine Blackbox	2	-	Kris	Doing
Weekly classes	40	40	Ana, Elena, Fien, Jakub, Kris	Done
MACOM presentation	3	3	Ana	Done
Energy & Sustainable Development presentation	2	2.5	Jakub	Done
ETHDO: choice for the case study	1	1	Elena	Done

Table 17: Sprint 7 (12/04 - 18/04)

Task	Estimated duration (h)	Real duration (h)	Members involved	Status
Upload Interim Report	50	-	Ana, Elena, Fien, Jakub, Kris	Done
Cardboard scale model	5	-	Fien, Ana	Doing
Weekly classes	55	55	Ana, Elena, Fien, Jakub, Kris	Done

Table 18: Sprint 8 (19/04 - 25/04)

Task	Estimated duration (h)	Real duration (h)	Members involved	Status
Finish cardboard scale model	5	-	Fien	Done

Task	Estimated duration (h)	Real duration (h)	Members involved	Status
Prepare interim presentation	8	-	Ana, Elena, Fien, Jakub, Kris	Done
Detailed System Schematics & Structural Drawing	15	-	Fien, Ana	Doing
Weekly classes	4	6	Ana, Elena, Fien, Jakub, Kris	Done

Table 19: Sprint 9 (26/04 - 02/05)

Task	Estimated duration (h)	Real duration (h)	Members involved	Status
List of materials	10	-	Ana, Elena	Doing
Project development	15	-	Ana, Elena, Fien, Jakub, Kris	Doing
Refine design	5	-	Fien	Doing
Weekly classes	10	9	Ana, Elena, Fien, Jakub, Kris	Done

Table 20: Sprint 10 (03/05 - 16/05))

Task	Estimated duration (h)	Real duration (h)	Members involved	Status
Leaflet (first draft)	1.5	-	Elena	Done
Introduction for Research Paper	1.5	-	Ana	Done
Power budget	5	-	Ana	Doing
Sustainability presentation	3	-	Ana, Elena, Fien, Jakub, Kris	Done
3D video	5	-	Elena	Doing
Apply teachers' feedback to report	2	-	Ana, Kris	Done
Refined interim report	7	-	Ana, Elena, Fien, Jakub, Kris	Done
Classes	17	15	Ana, Elena, Fien, Jakub, Kris	Done

3.10 Sprint Evaluations

Using Microsoft Planner and Microsoft OneNote we planned our sprints. It allowed us to review each sprint. Those tasks that were not completed were delayed for the next week until being finished.

The positive sides as for now are final project choice and good teamwork. Thanks to this we can focus on goal, which is clearly stated. We would love to develop a sustainable vermiponics combining it with a water collecting system with good design using efficient materials. We are looking forward to create a 3D model prototype based on sketches. In further steps it is necessary to take into consideration marketing aspects such as branding of our product, ethical ones as well as established budget. Unfortunately there are also negative sides. One of them are online meetings which result in poor interpersonal contact and difficulties in decision making.

3.11 Summary

Provide here the conclusions of this chapter and introduce the next chapter.

4. Marketing Plan

4.1 Introduction

Creating a marketing plan is critical for any business. Developing a marketing plan will help us think about the purpose, buyer personas, budget, methods, and deliverables for each campaign. We'll be able to keep on track with a campaign, notice what works and what doesn't, and measure the effectiveness of our brand strategy if we have all of this information in one place.

The focus of our strategy will be to ensure that Wormify meets client needs and develops long-term and profitable relationships with those clients. To do this, will develop a flexible strategy able to adapt to changes in customer perceptions and demand.

The business environment is a marketing term used to refer to the circumstances and forces that influence a company's capacity to establish and maintain effective customer connections. In this chapter, the first step in achieving this goal is to identify micro and macro factors.

Second, we will conduct an honest and comprehensive SWOT analysis of our marketing strategy document, looking at our strengths, weaknesses, opportunities, and threats. We will perform market research on existing customers to get a more accurate picture of our reputation in the marketplace.

The third step is to identify the strategic objectives by using SMART methodology. Specific and measurable objectives define the success of a project or initiative. Fourth, we will visualize Wormify in relation to the market and competition. Fifth, we will focus on 4P’s of the marketing mix to decide how to take the new offer to the market and to test our marketing strategy. The final focus will be on the budget and strategy control to ensure that the marketing objectives are attained.

4.2 Market Analysis

A market analysis is an in-depth examination of a market within a particular sector. We will investigate the dynamics of your market, such as volume and value, potential consumer segments, purchasing habits, competition, and other important factors, with this report.

Knowing the market environment will enable us to foresee our current position and establish the potential position of our product on it.

Looking at the environment, a distinction can be made on three levels: macro, meso and micro.

Macro – contextual level

The contextual level consists of ‘global forces’, such as: economic development, demographics, politics, technological developments and social developments.

Meso – transactional level

The transactional level consists of ‘market forces’, such as: suppliers, supply and demand, distribution, competitors and strategic alliances.

Micro – organizational level

The organizational level includes factors that handle the firm's internal climate. Think about: vision, mission, strategy, resources, processes, products and services.

Looking at each level's factor will help the Team understand the situation prevailing on the market. **Figure 11** presents components of business environments.

Figure 11: Business environments

Having the information from the market analysis will help us strengthen our market position, minimize investment risk, meet customer needs and demands while staying ahead of the competition. Therefore, we can prepare a valuable product in a more accurate way.

Competitive Matrix

A competitive matrix is a technique for industry analysis that analyzes the attributes of different brands in your market sector to determine their differences, strengths, and weaknesses. This data assists you in identifying your unique competitive edge and prospects for business growth.

We will use a competitive matrix in a form of a chart that lists each competitor along with a list of their features and benefits. **Table 21** shows the differences between the Wormify composting system and other similar products.

Table 21: Wormify competitive matrix

	Urbalive Strengths (+) Weaknesses (-)	**Subpod Strengths (+) Weaknesses (-)**	**VermiGo Strengths (+) Weaknesses (-)**	**Biovessel Strengths (+) Weaknesses (-)**	**Wormify Strengths (+) Weaknesses (-)**
Target Markets	Indoor kit made to compost kitchen bio waste – usually used in households, classrooms, offices (+)	Designed for high and low-volume food waste producers across the globe (+)	Designed for vertical gardening to eliminate home food waste (+)	Meant for beginners that like minimal design and ease of usage (+)	In-garden composting system meant for individual or community use (+)
Product	- Self watering feature (+) - Suitable for home application (+) - Red Dot design award (+) - Least functionalities (-) - No in-built sensors (-)	- No smell, no pests (+) - Quick assembly process (+) - Both outdoor and indoor usage (+) - Stable temperature - 9KG composting capacity per week (+) - Compact design (+)	- Activated carbon filter (+) - Collector for vermicompost and nutrient tea (+) - Wall mountable (+) - 3KG processing capacity per (-) - Modular and extendable (+)	- Easy to use (+) - Moisture Sensor (+) - pH Level Sensor (+) - Sprayer (+) - Designed for indoor usage (+) - Odorless (+)	- Compact and modern design (+) - Moisture sensor (+) - Temperature Sensor (+) - pH Level Sensor (+) - Connectivity with phone app (+) - Odorless (+) - 6KG composting capacity per week (+) - Modular and extendable (+)
Price	Lowest retail price (-)	Higher retail price (-)	Unknown retail price (?)	High retail price (-)	Unknown retail price (?)
Place	Online shop: less advertising, using online retailers	Kickstarter and Indiegogo at the beginning then transitioned to online shop. Dedicated to social media marketing, creating brand awareness and publicity.	Does not sell at the moment – it is in a stage of launching	Same as Subpod	Same as Subpod
Promotion	- Active on Instagram but limited to Polish market (-) - Facebook not active (-)	- Facebook and Instagram activity creating brand awareness (+) - Modern website (+)	- Not active on Facebook or Instagram (-) - Website is outdated (-)	- Active on Facebook (+) but not on Instagram (-) - Website is too cluttered (-)	- Modern website is in process of making (+) - Social networks; to target modern farmers (+)

	Urbalive Strengths (+) Weaknesses (-)	**Subpod Strengths (+) Weaknesses (-)**	**VermiGo Strengths (+) Weaknesses (-)**	**Biovessel Strengths (+) Weaknesses (-)**	**Wormify Strengths (+) Weaknesses (-)**
(Potential) Competitive Barriers	Inferior product (-)	Superior product (+); not many smart functionalities (-)	Currently a concept and not a physical product yet (-)	Complete product (+); Lots of functionalities (+)	Medium product (-); Community must use it to see its effects (-); Creation of garden community (+)

4.2.1 Problem Statement

Vermicomposting is an eco-biotechnology that employs earthworms in the decomposition of organic matter. Given global pro-environmental politics, it could be regarded as an interesting eco-innovation in biowaste management. As a result, it is perfectly suited to the circular economy concept, turning different types of organic waste (domestic and industrial) into renewable energy sources or “biosoils.” It also acts as an alternative to other waste management approaches that are considered unfriendly to the environment. Several different types of organic waste, such as by-products from various industries, have recently been proposed as substrates in the process. Some beneficial properties of vermicompost make it an interesting product for agriculture, gardening, and remediation of polluted areas. Vermicomposting on a large scale is necessary to effectively and globally solve the waste disposal problem.

4.2.2 Internal Analysis

7S Model of McKinsey for internal analysis

In order to prepare an analysis on our Team – we have decided to take advantage of the 7S McKinsey model as a framework. The model can be applied to many situations and is a valuable tool to improve the performance of your organization or to determine the best way to implement a proposed strategy. The specific layout of the McKinsey model is shown in **Figure 12**. 7S McKinsey model examines the factors internal to the organization that can affect its success. It is therefore a useful way of identifying strengths and weaknesses as part of a SWOT analysis.

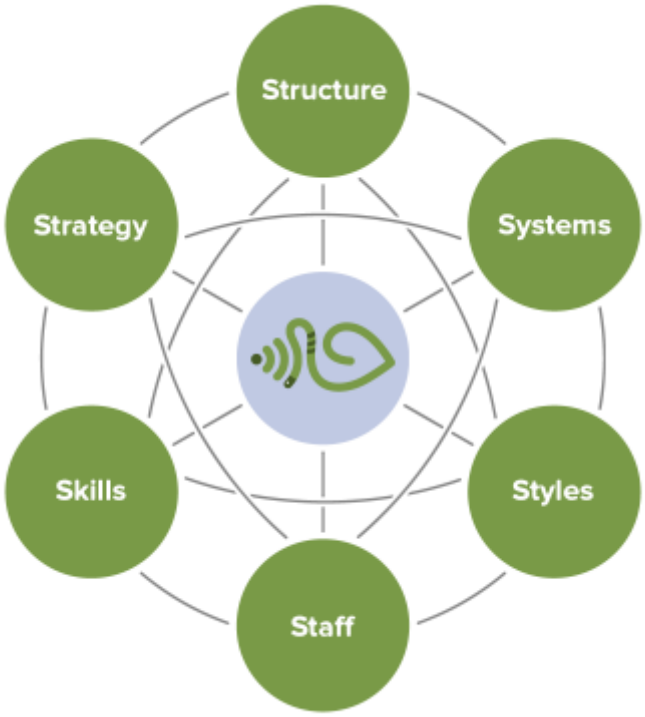

Figure 12: 7S McKinsey model

Strategy – the aim of the company and how the organization intends to increase its competitive advantage

Teams generate new knowledge in an organization by combining the explicit and tacit knowledge of individual team members. Team leaders who appreciate implicit knowledge will significantly increase the efficiency of individual interactions and group cohesiveness.

Structure - division of activities; integration and coordination mechanisms

As team members are active in making decisions, they develop a professional and personal interest in the company and its overall performance. This contribution contributes to improved efficiency as participants are actively involved in different aspects of the project and wish to see their efforts succeed overall. This not only helps with project completion but also simulates a real-world work scenario.

Systems - the main and secondary tasks that are part of the day-to-day operations of the company

Monitoring is critical because it allows the team to ensure that you are meeting your objectives. It also demonstrates that you are performing to the highest level you believe is possible. This assists you in determining ways to improve your results. The project managers are often kept up to date on the team's results.

Skills - the human capital of the organization's skill set and capabilities

The team is composed of members who are dependent on each other, work towards interchangeable achievements, and share their expertise in a specific field. Ana Mendes: Biomedical Engineering; Elena Victoria Tatuc: Industrial Design; Fien Joos: Product Development; Jakub Wyka: Mechanical Engineering and Applied Computer Science; Kris Petrevski: Information and Communication Sciences for Business and Management.

Each of us is comfortable with using most project development and research tools towards project completion.

Staff - the team’s core competencies and distinctive capabilities

Identifying and organizing work around each team member's specific strengths and skills ensures enhanced team member performance and commitment, as well as increased efficiency, which contributes to a successful project. It's no wonder, then, that cultivating a strengths-based organizational culture is regarded as critical to the future of work.

Style - key groups' typical behavior patterns, such as managers and other professionals

Team’s work is organized by using the Scrum method. In Scrum, the development team is self-led, and every member works together to complete each sprint. The members of the development team agree on how to better complete the deliverables.

Shared Values - what engender trust and link the team together

We collaborate to achieve shared goals by developing relationships based on mutual respect, constructive communication, and trust. We achieve our goals by self-motivation, resourcefulness, and the ability to change as we go. We go above and beyond to add value to the project and our customers. To achieve our goals, we use both our individual and collective abilities.

4.2.3 External Analysis

The environmental determinants research takes into account three aspects of the environment: the macro-environment, and meso-environment. Furthermore, we will use PESTLE to provide a deeper understanding of industry, alertness to risks, and a method to exploit opportunities. We'll go through each in greater detail.

4.2.3.1 PESTEL Analysis

PESTEL analysis is a strategy for reducing business risks. We can obtain useful advantages by investigating the Political, Economical, Social, Technological, Legal, and Environmental factors. These benefits aid in the concept process, product creation, product launch, content marketing strategies, and other factors that contribute to success. PESTEL analysis will assist the Team in considering a wide range of influential factors that may influence the success or failure of our product.

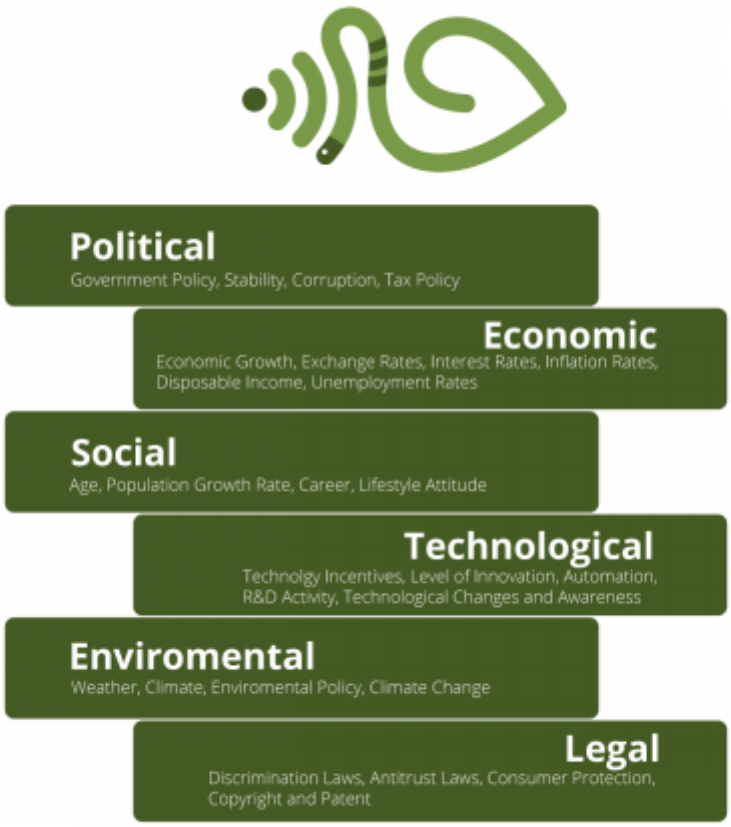

Figure 13: PESTLE model

- **Political**

The product does not have any political impact, thus this category is not relevant for our project.

- **Economic**

Vermicompost production is also an ‘economically productive’ process as it ‘reduces wastes’ and consequently saves landfills space. Construction of engineered landfills incurs 20 to 25 million US dollars upfront before the first load of waste is dumped. Over the past five years, the cost of landfill disposal of waste has increased from 29USD to 65USD per ton of waste in Australia. (add source)

Earthworms turn a ‘negative' economic and environmental value commodity, ‘waste,' into a ‘highly positive' economic and environmental value product, ‘highly nutritive organic fertilizer' (brown gold), which improves soil fertility and farm productivity to generate ‘safe food' (green gold) in farms. Vermiculture has the potential to preserve the global ‘human sustainability cycle,' which entails processing food in farms from food and farm waste.

- **Social**

Life Cycle Assessment (LCA) demonstrated that vermicomposting performed satisfactorily in terms of global warming and eutrophication potential while dumping the vermicompost produced could lead to increased eutrophication. However, this is still much lower than the eutrophication caused by untreated manure dumped openly.

- **Technological**

The product is based on advanced vermiculture technology that transforms organic waste into value-added environmentally friendly goods that can increase soil fertility and productivity on a large scale.

- **Legal**

Over 4500 unregulated composting/vermicomposting operations are estimated to be present, posing a risk to soils and groundwater. The vast majority of these small scale operations (approximately 95%) are vermicompost producers on a small scale. There are only 15 managed and legally permitted vermicomposting plants, and the number of plants producing legally authorized vermicompost is currently limited to 15. This number needs to increase for Turkey to become a leading producer of vermicompost by 2023 **[33]**.

- **Environmental**

Earthworms are natural recyclers. They play an important role in breaking down organic matter and fertilizing the soil simply by feeding and pooping on a regular basis (about 1.5 times their body weight a day). The worm cast that comes from the other end is rich in nutrients and bacteria that are beneficial to plants. Scientists discovered that worm casts contain up to five times the amount of key nutrients found in the surrounding soil.

4.3 SWOT Analysis

Using a SWOT analysis as a strategic tool brings the whole team together, facilitates involvement in the implementation of the company strategy, and promotes shared awareness of key issues affecting your performance. Creating a SWOT Matrix does not necessitate advanced training and is relatively inexpensive, save for the time of those involved. The acronym SWOT stands for Strengths, Weaknesses, Opportunities, and Threats, and we will use SWOT analysis to evaluate these four facets of the market.

SWOT analysis is presented in **Figure 14** for Team Analysis and **Figure 15** for product analysis.

4.3.1 Team SWOT Analysis

Figure 14: Team SWOT Analysis

4.3.2 Product SWOT Analysis

Figure 15: Product SWOT Analysis

Practical recognition of the SWOT analysis's weaknesses and threats is the first step toward countering them with a comprehensive and innovative collection of strengths and opportunities.

4.4 Strategic Objectives

Strategic goals are statements that suggest what is crucial or essential in your organizational strategy. In other words, they're targets that allow the team to understand their strategic goals and to decide if their plan is successful and well implemented. As a result, we've agreed to use the SMART approach to set targets.

SMART is an acronym that stands for Specific, Measurable, Achievable, Realistic, and Timely. Therefore, a SMART goal incorporates all of these criteria to help focus our efforts and increase the chances of achieving the end goal.

Table 22: SMART Table

Letter	Factor
S	simple, sensible, significant
M	meaning, motivating, memorable
A	agreed, attainable
R	reasonable, realistic and resourced, results-based
T	time-based, time limited, time/cost limited, timely, time-sensitive

General mission and vision strategic objectives:

Economical strategic objectives:

- To contribute to global ecological economic recovery, a profitable and sustainable method of producing high-quality organic goods, as well as a stable and optimistic agricultural outcome, is to be achieved.
- We want to have a stake in this market by pursuing a strong role in Portugal. Our aim is to contribute to the national economy by rising the export rate further with each passing day.

Customer/Learning strategic objectives

- Our goal is to educate the public, individuals, companies, and organizations about the benefits of compost and to recycle organic materials from landfills to generate soil for community-based agriculture projects.
- We want to ensure the production of nutritious food in a healthy manner in order to help future generations survive in a healthier world.
- We imagine a world in which government, corporations, families, and individuals work together to sow the seeds of the community so that we can shift our perception of our “waste” stream.

Environmental Strategic objectives

- We envision a world in which everyone disposes of food waste and compostable materials in an environmentally responsible manner, and landfills are never an option.
- We imagine a world in which “waste” is regenerated into living soil, curing the Earth and nourishing our gardens, bodies, and souls.

Transforming Soil. Transforming Lives. Transforming Our Communities.

4.5 Segmentation

To divide properly a broad market into small segments comprising of individuals who have similar needs, requirements, and interests the process called Market Segmentation has to be done. Three main categories are taken into considerations:

- Geographic segmentation
- Demographic segmentation
- Psychographic segmentation

4.5.1 Geographic segmentation

The target market for vermiculture is Southeastern Europe, more precisely – countries that are self-sufficient in terms of agricultural food. According to all economic estimates, the application of vermicompost to grains, fruits, and greenhouse vegetables are more profitable than traditional compost in Turkey conditions **[34]**. Farmers should consider, however, that the advantages of vermicompost are not only plant-nutritional but that the disease resistance attributed to vermicompost decreases the cost of chemical pesticides as well.

4.5.2 Demographic segmentation

The main factors affecting this part are:

- **Income** – the citizens whose average monthly salaries are at least at the satisfactory level and actually who live in countries that are favorable for farming.
- **Occupation** – we assume that the clients whose professions in everyday life are connected with agriculture and farming are more likely to buy a vermiculture system due to their specific job than other consumers.
- **Education** – greater acceptance of vermicompost by farmers may come with more education and an understanding that sustainable farming also protects the environment.

Variables such as age, gender, religion, or race are not included in the demographic segmentation process since they do not influence the demand for our product.

4.5.3 Psychographic segmentation

Clients may be divided into different groups based on:

- **Social class** – consumers from the middle and higher class are assumed to be much more interested in the potential purchase of Wormify.
- **Lifestyle and personality** – clients whose jobs and lifestyles are already deeply connected with agriculture, as well as an awareness that implementing such a system will provide employment opportunities by protecting the environment, augmenting crop production when used as a fertilizer supplement, and assisting in the maintenance of ecological balance.

4.6 Strategy/Positioning

Earthworm and vermicompost markets are expanding, representing a worldwide growth in interest in vermiculture and vermicomposting. Based on our marketing research, we have chosen to concentrate on companies, organizations, and governments all over the world (Business to Business - B2B), with a secondary focus on individuals who want to divert their household waste from the waste stream and recycle it into worm castings on-site (Business to Customer - B2C).

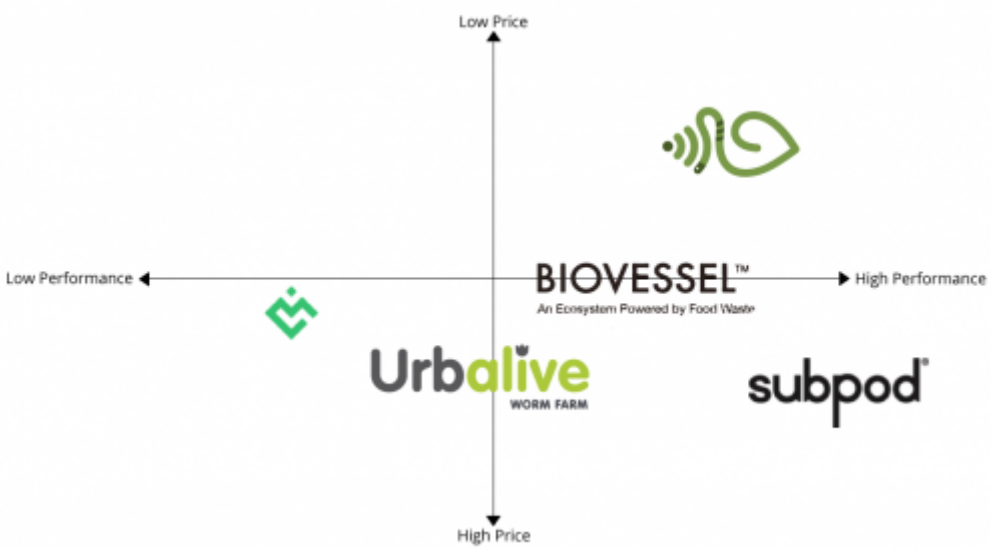

Figure 16: Positioning map 1

Figure 17: Positioning map 2

Team has decided to break into the bio marketplace with a unique and cost-effective product named Wormify. Knowing the benefits that Wormifybrings to the table, we will further analyze it as a product. An effective positioning strategy considers the strengths and weaknesses of the team, the needs of the customers and market and the position of competitors. The purpose of a positioning strategy is that it allows the team to spotlight specific areas where they can outshine and beat their competition.

During the project semester, we collected different proposals to find a good and suitable name for our vermiculture project. Towards the beginning of the project, a survey was created in which the possible brand names were divided into the two groups “closed-loop” and “sustainable/local” in order to find out which brand name and which group was preferred.

In the end, we received three possible brand names with the following order:

1. **Wormify**
2. **Rootry**
3. **SMOV** *(smart, modular vermiponics)*

The team has decided to go with the Wormify. We also did research on the WIPO (Word Intellectual Property Organization) to verify that the brand name is not already registered. This ensured us that we can use Wormify as a name for our project.

Figure 18: Logo

As for the logo - the goal was to design a logo that’s mostly related to organic foods. That’s why we decided to go with green as predominant color in our logo.

4.7 Adapted Marketing-Mix

Using a marketing mix is an ideal way to help ensure that ‘putting the right commodity in the right spot,...' occurs. A marketing mix is an important tool for determining what a product or service may deliver and how to prepare for a successful product offering. The marketing mix is most widely implemented using the four Ps of marketing: price, product, promotion, and place. These four groups, however, correspond to four other, more practical marketing pillars: the 4 C's.

Figure 19: The 4 C's

The first C in this marketing mix is the **customer’s** wants and needs. The first C, rather than focusing on the product itself, focuses on filling a void in the customer's life. This marketing strategy is critical for companies who want to better understand their consumers. It is much easier to build a product that will serve your customer once you understand them. Since the consumer makes the purchasing decision, he or she is the most important resource in any marketing campaign.

The second C in this marketing mix is **cost**. Price is just a small part of the total cost of purchasing a commodity from a consumer. It is important to assess the total cost – not just the price – of the commodity to the consumer. Cost does not only involve the price of the item, but also items like the time it takes the consumer to get to your place in order to purchase your product, or the cost of gas to get them there. Cost may also involve the value, or lack thereof, of the product to the consumer.

The Third C within this marketing mix is **convenience**. In the 4Ps marketing strategy, convenience is equivalent to “location.” These two, however, are diametrically opposed. The term “place” simply refers to where the product will be sold. This marketing technique is far more customer-focused when it comes to convenience.

The fourth and final C in this marketing mix is **communication**. Communication is often important in business marketing; without it, the four Cs will be ineffective. Interaction between the buyer and seller is needed for communication. We will execute this marketing technique by using social media.

The four C's of marketing can be extremely useful in any marketing campaign. This strategy requires

marketers to thoroughly understand their target audience before developing a product. This approach necessitates coordination from start to finish and starts with knowing what the consumer wants and needs from your product.

4.8 Budget

Marketing budget applies to all expenses associated with marketing, advertisement, public relations, promotions, and everything else that falls under the broad umbrella of 'marketing' on a daily basis, such as Google AdWords, social media, print ads, sponsorships, collateral, and events.

There are many benefits that come from having a designated marketing budget;

1. Gives you a good sense of direction for managing your marketing activities.
2. More accurately allocates limited financial capital.
3. Serves as a foundation for evaluating real outcomes. How much you invested and how much you got from a specific marketing channel.
4. Ensures your success! If you know how much money you have to invest, you'll have a better idea of which marketing channels to pursue in order to optimize your marketing ROI.

A marketing budget details all the money a company plans to spend on marketing-related programs over the quarter or year. Marketing budgets may include expenditures such as paid ads, supported web material, new marketing personnel, a registered blog domain, and marketing automation software.

As a startup, and due to limited resources, we have decided to spend our marketing budget mainly on social media, building a website, Instagram, LinkedIn and Facebook pages, and also Facebook Business Ads that expand to Instagram Business Ads. The team is also interested in Search Engine Optimization (SEO) enhancement as a way to bring the organic audience to our website funnel, therefore driving more revenue for paid advertising. The product marketing budget allocation is summed up in **Table 23**.

Table 23: Marketing Budget Allocation

Web Marketing	
Online advertising creative	100
SEO	150
Facebook Ads	200
Instagram Ads	100
Website Development / Updates	200
Google Ads	200
Advertising	
Print advertising	250
Television advertising	400
Radio advertising	300
Banner advertising	300
Total	**- 2200 EUR**

4.9 Strategy Control

Whenever there is a bottleneck in the business – we need to first identify the cause and then run a Plan-Do-Check cycle to improve the specific area that is causing problems. PDCA cycle is an iterative process for continually improving products, people, and services. It became an integral part of what is known today as Lean management. The Plan-Do-Check-Act model, represented in **Figure 20**, includes solutions testing, analyzing results, and improving the process.

Figure 20: PDCA cycle

1. **Plan:** Recognize an opportunity and plan a change.
2. **Do:** Test the update. Carry out a small-scale analysis.
3. **Check:** Examine the exam, evaluate the outcomes, and identify what you've learned.
4. **Act:** Take action based on what you learned in the study phase.

4.10 Summary

Based on this market analysis, the team decided to create Wormify- a modular, in-garden composting system meant for individual or community use. It uses the movement of worms and microbes across the garden bed to disintegrate waste and enrich the soil, which then becomes ideal for growing nutrient-dense food.

Wormify is for waste warriors who want to reduce waste, enhance soil, and grow food without generating vermin, odors, or making a mess. Wormify accomplishes this by using naturally occurring worms and microbes in the surrounding soil. Wormify is an effective and low-maintenance solution for any organic waste, including lawn and garden waste, paper, and even clothes.

Using Wormify is much easier than any other form of composting. The Wormify is embedded in the vegetable garden and has top vents that rise above the ground. The machine is stocked with live worms, castings, and starter content. After six days, food and other waste may be thrown into the

box, which has an aerator method for mixing. After that, the box is left for 10 days to allow composting to occur. The finished, rich compost soil is then removed and used in the garden.

The underlying message of Wormify is, ***'Feed the soil, feed the world'***.

The following chapter focuses on the company's long-term sustainability. This allowed the team to see which eco-efficiency initiatives can be implemented in order to make the business and product more sustainable.

5. Eco-efficiency Measures for Sustainability

5.1 Introduction

Sustainability is a strong concept how has the value to keep us healthy as a society. The "Brundtland Commission" (the duty of this commission is to connect countries to pursue sustainable development together) released its final report, Our Common Future, which defines sustainable development as: "a development that meets the needs of the present without compromising the ability of future generations to meet their own needs." **[35]**.

These days, most of organizations are seeking to attain sustainable development through assessing green performance and the main criteria is Eco-efficiency. Eco-efficiency is an improved measure of sustainability because it connects environmental impacts directly with some kind of economic performance and it works as a valuable tool to approach sustainable development **[36]**.

The integration of vermiponics technology in vertical farming can be a suitable and sustainable alternative for the futuristic urban farming methods. According to **[37]**, vermiponics is a more environmental friendly technique like hydroponics, since the vermiwash comprises large amounts of plant nutrients, amino acids and humic acids for plant growth.

In order to find lasting well-being, all dimensions of sustainability, illustrated in **Figure 21**, environmental, economical and social, must be considered together.

Figure 21: Pillars of Sustainability

5.2 Environmental

The importance of environmental sustainability is to improve the quality of human life while living within the carrying capacity of the earth's supporting ecosystems **[38]**. Therefore, this affirmation leads to a main question about how humans should change the way they live in order to secure a sustainable life for themselves and future generations.

Our project intention is to solve the enormous food waste problem by composting it in a worm environment with water added to keep everything moist. The liquid form of vermicomposting products such as, vermiwash and vermicompost extract, is suitable to be used as a foliar spray for crop plants which can serve as biofertilizer and biocontrol agents. Therefore, the system has the potential to improve the urbanized food production and decrease the food waste.

One fact about the food waste problem is that 33% of all food produced is lost or wasted, making up more than 50% of global landfill waste. The results of the study suggest that roughly one-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons per year. Producing food that will not be consumed leads to unnecessary CO_2 emissions in addition to loss of economic value of the food produced **[39]**.

5.3 Economical

According to **[40]**, economic sustainability refers to practices that support long-term economic growth without negatively impacting social, environmental, and cultural aspects of the community. We understand that choosing sustainable materials for our design will impact the environment in a positive way and also that sustainability means longevity. Therefore, our product will be designed

with materials that can stand the test of time. The main components for building the system are bars in combination with connectors. The bars will have two dimensions, the big ones will be as long as a standard size we can find and also will be twice or thrice the size of the small ones. The connectors are all the same shape and same size which makes it easy to produce them. Material loss will be minimized which identifies the innovative potential to combine sustainable practices, technology, and money saving.

5.4 Social

This pillar is „a process for creating sustainable successful places that promote well-being, by understanding what people need from the places they live and work. Social sustainability combines design of the physical realm with design of the social world – infrastructure to support social and cultural life, social amenities, systems for citizen engagement, and space for people and places to evolve.” **[41]**.

One of the abilities that this project has is to bring people together through the rooftop community garden. The neighbors can create an environment that is focused on health, wellness, and education for all of those who are interested in quality of life and social respect. This urban farming has benefits such as, reduce carbon emissions, increase local economic growth, increase public health, and improve food security.

Few studies have explored that the “community gardens can improve gardeners general health, lower their obesity rates or depression, and improve mood or satisfaction with life. These health benefits may derive from the restorative capacity of nature, aesthetic experiences, improved social relationships, emotional connections, political engagement, provision of sense of freedom, encouragement of physical activity, or reshaping the nutritional environment” **[42]**.

5.5 Life Cycle Analysis

Life cycle analysis is a technique for assessing the environmental aspects associated with a product over its life cycle. The most important applications are:

- Analysis of the contribution of the life cycle stages to the overall environmental load, usually with the aim to prioritize improvements on products or processes;
- Comparison between products for internal use **[43]**.

To describe the process we need to get through the different stages of a product’s life, such us, from raw material extraction through materials processing, manufacture, distribution, and use. In this ecodesign wheel the final stage is recycling, here we need to optimize the end-of-life systems in order to approach infinity recycling.

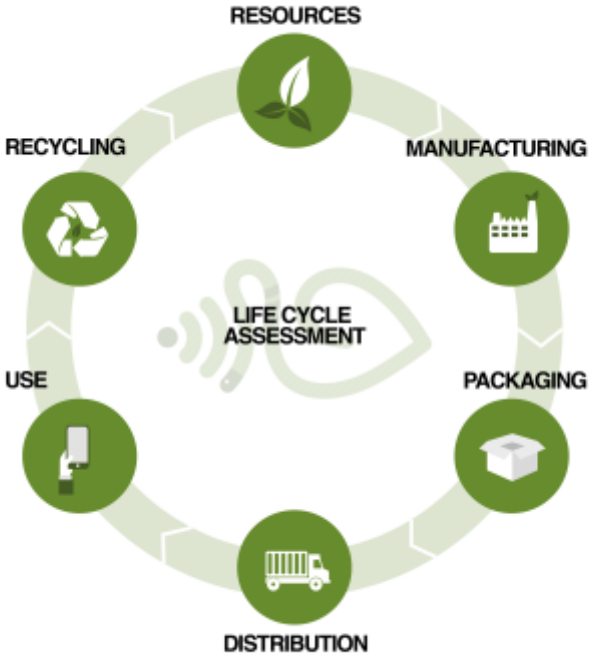

Figure 22: Life Cycle Assessment

Resources

To reach an optimal level of recycling for our design, we need to use organic, recyclable, renewable, non-toxic and reusable materials.

Another solving would be to work with other shops in the area to see if they can use the excess materials and see if they have any we could leverage in exchange. At the same time, we will verify their sustainable value.

Regarding the electronic components such as sensors and signal transducers, will have as many green materials included as possible.

Green materials come in many forms. They can range from degradable circuit boards and organic electronics to metals that are infinitely recyclable and reusable. Organic and inorganic materials can both be considered green, depending on the type of material and how it is implemented. On the inorganic side, aluminium is considered a 'green metal' due to its recyclability and incredibly long lifespan. Aluminium is known as the 'green metal' and 'the best eco metal' due to the fact it has a virtually infinite lifespan. It can be recycled repeatedly without losing any quality **[44]**.

Besides doing well-being for the planet, greener materials often accomplish the same performance as their cheaper, non-green alternatives. If quality is equal, the smart way is to market the greener materials used in the product. Consumers are becoming more responsive about how their investment affects the environment and manifest the environmental benefits of sustainable materials will often result in higher sales.

Manufacturing

The overall goal of this stage is to minimize negative environmental impacts. One solution would be to increase energy efficiency, for instance, minimizing energy use in production or use renewable energy consumption; some options can include sunlight, wind, rain and waves.

The performance of optimized production methods and operations continuously can be improved by reducing the production steps. As well, producing less pollution and emissions will help the earth and also retain the working environment cleaner and safer. In a company, sustainable manufacturing not only generates more sustainable products, but will also increase social and environmental benefits.

Packaging

Our packaging for the product will reach and optimal level of sustainability by using less material, one that can be recycled. As well, the packaging will be designed in order to reuse it in the same or similar application.

The Sustainable Packaging Coalition offers the following 8 criteria for packaging to be considered sustainable: **[45]**

- Is beneficial, safe & healthy for individuals and communities throughout its life-cycle.
- Meets market criteria for performance and cost.
- Is sourced, manufactured, transported, and recycled using renewable energy.
- Optimizes the use of renewable or recycled source materials.
- Is manufactured using clean production technologies and best practices.
- Is made from materials healthy throughout the life cycle.
- Is physically designed to optimize materials and energy.
- Is effectively recovered and utilized in biological and/or industrial closed-loop cycles.

Multiple studies have indicated that consumers are interested in sustainability factors when choosing which brands to do business with. Being more sustainable can help acquire more customers and raise loyalty.

Distribution

A clarification is that our product will be delivered at first in the place of origin. Some of the key things that our distribution industry can do is to promote a more sustainable way. While many companies continue to rely on trucks that emit harmful fumes, our distribution company have switched to clean idle trucks. These vehicles allow drivers to idle their engines without having to worry about dirtying the environment in the process **[46]**.

Another strategy would be CO_2 footprint reduction through detailed analysis of logistics and transport emissions, integrating operational performance, calculating the footprint of the building stock and machines, and making recommendations for reduction levers. Further, including more environmentally friendly logistics packaging solutions, as well as reusable, with economic and environmental business cases and assistance in setting up **[47]**.

Use

The design is smartly conceived to have as long and resisting life as possible. Because the product is

completely designed for disassembly, as all parts can easily be replaced. This extends the life cycle of the product as well as the recyclability.

Most of all, the product also includes a rainwater system that is collecting the run-off from a structure or other surface in order to store it for later use.

Recycling

One of the main strategies regarding the end of our product life is the concept of reverse logistic, transforming by-products or waste materials into new materials or products of better quality or for superior environmental value.

This reverse logistics business model benefits both the consumer and the environment as it considers the whole lifecycle of the product, helps to improve product reliability, and avoids the need for consumers to replace broken consoles unnecessarily through an efficient collection, repair and return process **[48]**.

Including eco-labelling and guidance on how to recycle and dispose, also using prepaid return shipping labels will minimize negative environmental impacts.

5.6 Summary

The study case of *eco-efficiency measures for sustainability* offered the group a deeper understanding of how the product can change in a positive way the life of people living in multiple comumnities.

Based on environmental assessment, our vermiponic garden system will be a long-lasting design in order to embrace quality and answers to existing issues of sustainable food production. At the same time, the earthworms are living in a healthier environment. After the vermicomposting process, the chemical fertilizer, called as worm-tea, which contain valuable nutrients, are beneficial for corp plants. Fertile soil that has a rich supply of compost will feed the garden soil and help the plants grow.

Nowadays, most of the products are focused only on sustainable materials and production, we aim that our product will pursue more than that. Our team will struggle to integrate all three dimensions of sustainability into this product which already has an environmentally friendly cycle.

Further, we will discuss about ethical and deontological concerns, this topic has the most direct connection with the concept of sustainability.

6. Ethical and Deontological Concerns

6.1 Introduction

Deontology is commonly referred to as a concept that suggests if actions are good or bad according to a clear set of rules. The actions that comply with these rules are considered ethical, while others

are not **[49]**. Therefore, ethical and deontological concerns are exceptionally important and pay a major role influencing today's society. Companies must take each of these concerns seriously to succeed, and to have a positive image. If the opposite happens in the era we are currently living, it is of high probability that social media speeds up the spread of the news, reaching the whole world extremely fast and making a negative impact on the company.

The present chapter identifies the four main ethical and deontological concerns related to the project, which are engineering, sales and marketing, environmental, and liability. The analysis of these topics is essential and each concern must be respected for the project to succeed and have a positive impact on society.

6.2 Engineering Ethics

There are many Codes of Ethics regarding engineers, and the following duties of this profession were taken from the Portuguese "Order of Engineers (OE)" Code of Ethics and Deontology **[50]**.

Duties of the engineer for the community (Article 141 of OE Statutes):

1. Have a good preparation, in order to perform his duties competently and contribute to the progress of engineering and its best application in the service of Humanity;
2. Defend the environment and natural resources;
3. Ensure the safety of performing staff, users and the general public;
4. Oppose the fraudulent use, or contrary to the common good, of their work;
5. Look for the best technical solutions, considering the economy and the quality of the production or the works they design, direct or organize;
6. Fight and report practices of social discrimination and child labor, assuming an attitude of social responsibility.

Duties of the engineer for the employer and the client: (Article 142 of OE Statutes)

1. Contribute to the achievement of the economic and social goals of the organizations in which they are integrated, promoting increased productivity, improving the quality of products and working conditions with the fair treatment of people;
2. Provide their services with diligence and punctuality so as not to harm the client or third parties, never abandoning, without justification, the jobs entrusted to them or the positions they perform;
3. Not disclose or use professional secrets or information, especially scientific and techniques obtained confidentially in the exercise of their functions, unless, in conscience, they consider that the requirements of the common good may be at risk;
4. Only be payed for the services they have actually provided and taking into account their fair value;
5. Refuse to collaborate in jobs whose payment is subject to confirmation of a predetermined conclusion, although this circumstance may influence the setting of remuneration;
6. Refuse compensation from more than one person interested in their work when there may be conflicts of interest or if there is no consent of either party.

Duties of the engineer when working: (Article 143 of OE Statutes)

1. In their professional associative activity, they must strive for the prestige of the profession and impose themselves for the value of their collaboration and for an irreproachable conduct,

always using in good faith, loyalty and exemption, whether acting individually or collectively;
2. Oppose any unfair competition;
3. Use the utmost sobriety in the professional announcements they make or authorize;
4. Not accept jobs or perform functions that exceed their competence or require more time than they have;
5. Only sign opinions, projects or other professional works of which they are the author or collaborator;
6. Issue their professional opinions with objectivity and exemption;
7. In the exercise of public functions, in the company and in the jobs or services in which they carry out their activity, act with the greatest posture, in order to prevent discrimination or disregard;
8. Refuse their collaboration in works on which they have to comment in the exercise of different functions or that imply ambiguous situations.

Reciprocal duties of engineers: (Article 144 of OE Statutes)

1. Objectively evaluate the work of their collaborators, contributing to the collaborators' professional appreciation and promotion;
2. Only claim the copyright when the originality and the relative importance of their contribution justify it, exercising this right with respect for intellectual property of others and with the limitations imposed by the common good;
3. Provide colleagues, whenever requested, all possible collaboration;
4. Not damage the professional reputation or professional activities of colleagues, nor let their work be underestimated, and should, whenever necessary, appreciate them with elevation and always safeguarding the dignity of the class;
5. Refuse to replace another engineer, only doing so when the reasons for that replacement are correct and giving the colleague the necessary satisfaction.

To sum up, the following table shows the most important aspects from the four articles analyzed.

Table 24: Main ethical engineering concerns

Target	**Principle(s)**
Environment	Protect natural resources
Community	Guarantee safety and health
Employer and Client	Act faithfully
Self	Perform in areas of their competence\\Refuse work beyond their capabilities and/or time
Colleagues	Be fair and supportive

Engineers have the enormous responsibility of complying with a robust code of ethics, and, furthermore, work on increasing the quality of life of not only their customers, but of society as a whole. They must conduct themselves responsibly, and ethically to guarantee their good reputation and the added value of their occupation to the public.

6.3 Sales and Marketing Ethics

Companies generally enter the market with the objective to maximize sales, and, consequently, profit. To succeed in doing so, they take on tactics and campaigns to differentiate them from the competition, and catch the attention of the target audience. The fight for a place in the market can

sometimes lead to unprofessional behavior and dishonest practices. Therefore, organization support for ethical conduct is highly appreciated in sales management. The connection between sales management and business ethics is strong, given that sales managers conduct the firm's behavior and are capable of taking action to ensure customers are treated well, developing ethical values and modeling appropriate performances **[51]**.

Sam Woolfe **[52]** described ten principles of ethical marketing to improve the marketing strategy of a company, maximizing customer satisfaction and maintaining consumer trust and brand credibility.

The “Do's”:

1. Be transparent;
2. Protect consumer data and privacy;
3. Commit to sustainability and human rights;
4. Respond meaningfully to consumer concerns;
5. Maximize benefits and minimize risks.

The “Don'ts”:

1. Don't exaggerate;
2. Don’t make false comparisons;
3. Don’t make unverified claims;
4. Don’t stereotype;
5. Don’t exploit emotions.

The planning, implementation, and monitoring of a company's marketing strategy must be done with ethics in mind. This way, it is possible to achieve success and to have a solid reputation.

6.4 Environmental Ethics

Environmental concerns have been around for many decades but with the huge impact of the media, these have been brought to the spotlight in the recent years. Green marketing is the process of promoting products or services based on their environmental benefits. However, labels such as “sustainable”, “conscious” or “green” are, many times, used wrongfully and without proof. This is called **Green-washing**, giving a false impression or providing misleading information about how a company's products/services are more environmentally friendly than they actually are. Some examples of Green-washing are:

- Saying “product made **with** recycled materials”, but only a small percentage of recycled materials was indeed used;
- Irrelevant allegations saying “product does not contain CFCs” or “not tested on animals” when the product is produced in Europe - both are forbidden in Europe. This is different than “Cruelty Free”, which certifies that the brand does not sell for countries that do those tests (like China, for example);
- Using vague information with no support/proof.

These practices do not comply with Environmental Ethics and can lead to misinformation; thus the team will follow the next steps to make the product as environmentally friendly as possible:

- Maximize efficiency with minimal energy consumption;

- Use recycled materials / Recycle components;
- Maximize product life;
- Provide solutions for the end-of-life stage.

6.5 Liability

Liability is defined as “the state of being legally responsible for something”. When creating and putting a product on the market, this is a major legal aspect by which the company is protected from law suits regarding accidents caused by their product / the usage of their product.

For the EPS project, the team must comply with the following European Union (EU) Directives to avoid product liability issues:

1. **Machine Directive** (2006/42/CE 2006-05-17): concerning the danger machines may present to men, such as explosions, vibrations, radiation, finger joints, dangerous substances in flight, force limits for the operation of machines, minimum safety distance **[53]**.
2. **Electromagnetic Compatibility (EMC) Directive** (2004/108/EC 2004-12-15): intends to regulate side effects between electronic components that are connected / interface together, like electromagnetic radiation, fields in the vicinity of electronic components, etc. **[54]**.
3. **Low Voltage Directive (LVD)** (2014/35/EU 2016-04-20): concerning health and safety challenges of electrical equipment with defined limits of voltage **[55]**.
4. **Radio Equipment Directive (RED)** (2014/53/EU 2014-04-16): regulatory framework for placing radio equipment on the market, ensuring no interference and data security regulation in radio communication with other devices **[56]**.
5. **Restriction of Hazardous Substances (ROHS) in Electrical and Electronic Equipment Directive** (2002/95/EC 2003-01-27): prohibition of the use of certain substances, with the aim to protect the environment and public health **[57]**.

6.6 Summary

Based on this ethical and deontological analysis, the team chose to: focus on efficiency during the production process; work with sustainable materials; choose suppliers that are transparent regarding their products and their origin, and always have the customers and colleagues in mind in every step of the product development. The team will always be truthful and follow a path of environmental consciousness to create a product that allows for sustainable food production everywhere.

The next chapter is related to the project development, describing the process to implement the prototype (drawings, system schematics, components choice, tests, and results).

7. Project Development

7.1 Introduction

The 'Project Development' chapter describes the development of the EPS project: description of the proposed product, comparison between materials and components, system schematics, functionalities of the product, and tests and results.

7.2 Proposed Solution

The solution is based on a modular easily movable Keyhole Garden, which takes advantage of Vermicomposting to assist in fertilizing the plants. Furthermore, the system will also have a rain water collector with a filter for pollutants and a pH regulator in case the water is not safe for the environment - this way, the product will also save water when the collector has enough to provide to the system.

Figure 23: Product Design (single module)

After achieving the final design of the structure, it was important to choose the best way to connect

the modules, and figure 24 shows the different options the team went through.

Figure 24: Connector options

After evaluating different possibilities, we decided to use ropes for the prototype since it is easily accessible and not too expensive. For the actual design we would go for injection molded joints with six cylindrical entrances. The production costs will be efficient because all the connectors are the same and so only one mold will be required. The fact that the connectors all have the same shape is also an advantage when the system is being assembled. The user will not make mistakes. To conclude, it is also a sustainable option because the parts can easily be replaced without damaging the other components.

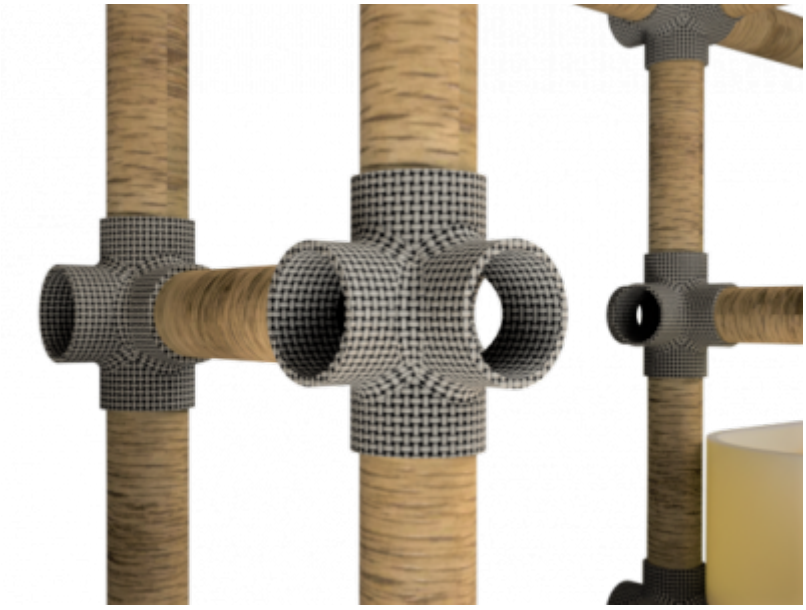

Figure 25: Fabric Connector

The following figure presents the different supporting structures. The goal of this structure is helping carry the weight of the plant and compost pot.

Figure 26: Support structure options

After evaluating these options, we again decided to use a rope structure for the prototype, for the same reasons as mentioned for the connection options, which are easy accessibility and low costs. For the actual product we would go for an aluminum plate, as shown in the right top image above. The aluminum has the advantage of being a lightweight material, as well as aesthetically pleasing.

The following picture illustrates the components for the flowerpot.

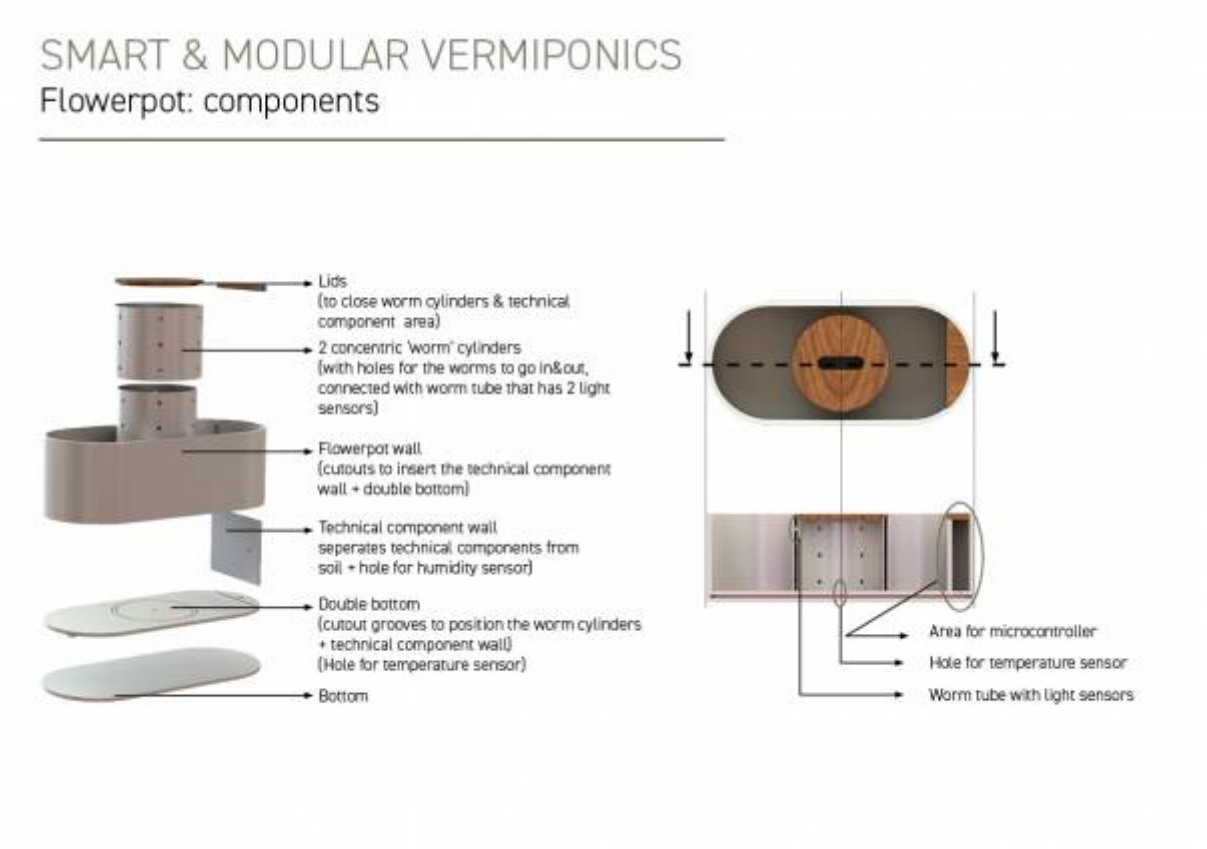

Figure 27: Flowerpot components

On the right side of the flowerpot, a closed compartment is integrated in order to protect the technical/electrical components. The keyhole garden is made of two concentric cylinders. The two cylinders will be connected with each other through tubes. These 'worm tubes' provide a passageway for the worms to go in and out the composting center. These tubes will have two integrated time-of-flight distance sensors in order to detect the movement of the worms. This way the user is able to track the worms and the direction of their movement.

Furthermore, there are two more sensors integrated in the flowerpot. One is a humidity sensor, which will measure the humidity in the soil. This way the user knows when he has to water the plants. The sensor is placed in a foreseen hole in the partition wall or "the electrical component wall". This way the distance between the microcontroller and the humidity sensor is minimized. The last sensor in the flowerpot is a temperature sensor. This sensor measures the temperature inside the composting bin. This sensor is connected with the microcontroller through the double bottom. Both sensors will be protected from humidity with a brass pipe.

Black box

To better show the functionality of the product, we drew the black box, as shown in the next image, which is a diagram with the inputs and outputs of the system.

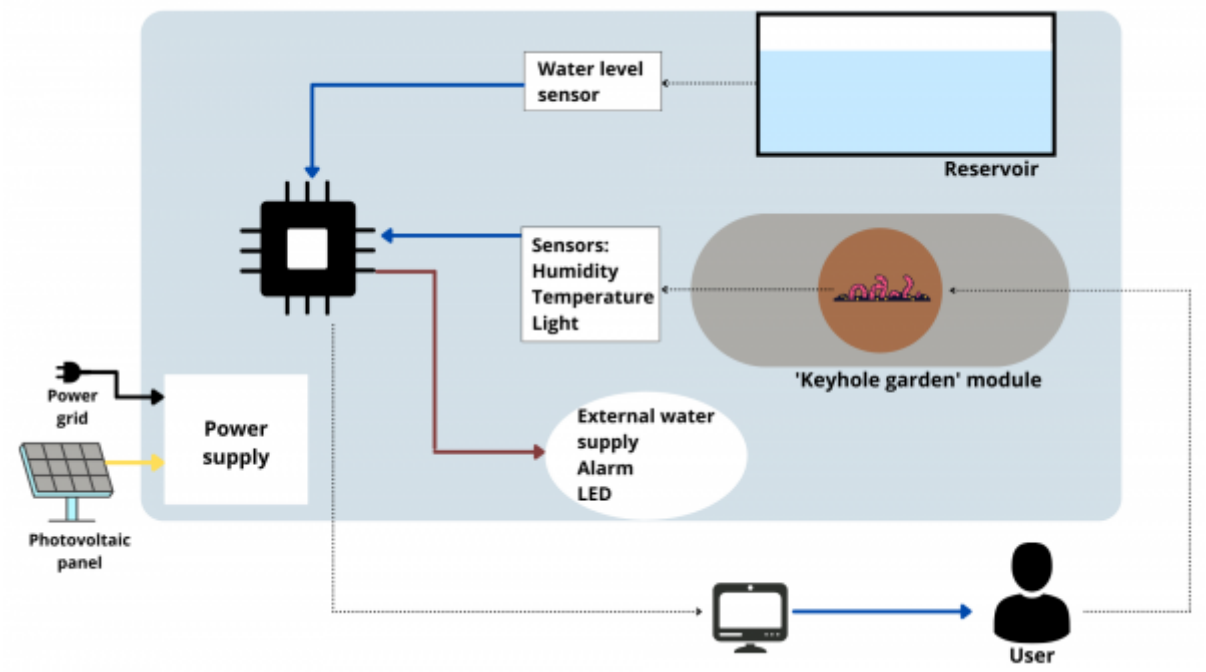

Figure 28: Black Box

7.3 Electrical Components

This topic is dedicated to the study of different materials and components necessary for the implementation of the product, in order to make a final decision of the best solution for each constituent.

7.3.1 Micro-controller

Table 25: Micro-controllers

Name	Description	Dimensions	Price (€)	Supplier
Arduino UNO	Processor: ATmega328P Operating voltage: 5 V Input (recommended): 7-12 V Input (limit):6-20 V Digital I/O Pins: 14 PWM Digital I/O Pins: 6 Analog input pins: 6 DC current per I/O pin: 20 mA DC current for 3.3 V pin: 50 mA Flash memory: 32 kB SRAM: 2 kB EEPROM: 1 kB Clock Speed: 16 MHz	Length: 68.6 mm Width: 53.4 mm	17.71	PTRobotics

Name	Description	Dimensions	Price (€)	Supplier
Arduino Nano	Processor: ATmega328P Operating voltage: 5 V Input (recommended): 7-12 V Input (limit):6-20 V Digital I/O Pins: 14 Analog input pins: 8 Current I/O pins: 40 mA Flash memory: 32 kB SRAM: 2 kB EEPROM: 1 kB Clock Speed: 16 MHz	18 mm x 45 mm	12.90	ElectroFun
Arduino Mega	Processor: ATmega2560 Operating voltage: 5 V Input (recommended): 7-12 V Input (limit): 6-20 V Digital I/O Pins: 54 Analog input pins: 16 Current I/O pins: 40 mA Flash memory: 256 kB SRAM: 8 kB EEPROM: 4 kB Clock Speed: 16 MHz	101.52 mm x 53.3 mm	29.90	ElectroFun
Arduino Nano 33 IoT	Processor: SAMD21G18A Operating voltage: 3.3 V Flash memory: 256 kB SRAM: 32 kB Clock Speed: 48 MHz Wi-Fi Bluetooth	18 mm x 45 mm	26.00	ElectroFun
Raspberry Pi 3 Model B	Processor frequency: 1200Mhz Storage: 1Gb Wi-Fi Ethernet USB 2.0 Bluetooth 4.1 Operating voltage: 5.0 V Supports Windows and Linux	56 mm x 85 mm Height: 17 mm	39.50	Aquario
Espressif ESP32 DevKitC-S1	Communication protocol: bluetooth, bluetooth low energy Input voltage: 3.3 - 5 V Flash memory: 4MB Operating temperature: -40 to 85 ºC	54.4 mm x 27.9 mm	18.50	ElectroFun

Name	Description	Dimensions	Price (€)	Supplier
ESP32 Battery Support	18650 charging system integrated Indicate LED inside (Green means full & Red means charging) Charging and working could be at the same time 1 Switch could control the power 1 extra LED could be programmed (Connected with GPIO16[D0]) 0.5A charging current 1A output Over charge protection Over discharge protection Full ESP32 pins break out	114 mm x 28.25 mm	18.95	BotnRoll

The micro-controller must be of low consumption, including a Wi-Fi connection module. Therefore, the ESP32 is the most appropriate option for the project. As a battery will be needed to power the system, the ESP32 with battery charging system integrated is the best controller for the project.
Consequently, the rechargeable lithium battery recommended to use with this micro-controller will be used:

Li-Ion Battery 18650

- Specifications: 3.7 V; 2200 mAh; Ø18x65mm
- Provider: BotnRoll

7.3.2 Sensors

Water Level Sensor

This sensor uses the water conductivity to determine the water level. This sensor will be placed on the rain water collector to decide if it has enough water to water the system or if it is necessary to use the building's water supply. Table 26 compares different options available on the market for this sensor.

Table 26: Water level sensors comparison

Name	Description	Specifications	Dimensions	Price (€)	Supplier

Name	Description	Specifications	Dimensions	Price (€)	Supplier
Simple level sensor	Water level sensor Depth sensor Water detection Can be used as rain sensor Compatible with Arduino, Raspberry Pi, PIC... Chemically treated plaque for durability Drilling for fixation Analogical output varies according to water level	Input voltage: 3 to 5 V Working current: <20 mA Output voltage: 0 ~ 2.3 V Operating temperature: 10 °C to 30 °C Humidity: 10 % to 90 % (without condensation) Analog sensor Detection area: 40×16 mm	60 x 20 x 8 mm	2.90	ElectroFun
Non contact water/liquid level sensor XKC-Y25-T12V	Advanced signal processing technology High-speed operation capacity No contact with liquid Easy to use and easy to install Equipped with an interface adapter that makes it compatible with DFRobot “Gravity” interface 4 levels of sensitivity	Operating Voltage (InVCC): DC 5 ~ 24 V Current consumption: 5 mA Output voltage (high level): InVCC Output voltage (low level): 0 V Output current: 1 ~ 50 mA Response time: 500 ms Operating Temperature: 0 ~ 105 ℃ Range for thickness of induction (sensitivity): 0 ~ 13 mm Humidity: 5% ~ 100% Material: ABS Waterproof performance: IP67	28 x 28 mm	12.30	ElectroFun
INOX Water level sensor		Material: stainless steel Commutation voltage: max 220 V DC Commutation current: max 1.5 A Transport current: max 3.0 A	Cable length: 30 cm Floating body length: 24 cm	14.90	ElectroFun
Liquid level sensor		Material: plastic Switch power(Max): 10 W Voltage (Max): 100 V AC Current (Max): 0.5 A AC Electric resistance: AC 1500 V / I min Temperature: -20 ºC ~ + 80 ºC	Cable length: 40 cm Float length: 85 mm	6.20	ElectroFun

The '10W Liquid Level Sensor' is small and relatively cheap compared to the other options, it works on a large temperature range and we think it is a good option for the product.

Temperature sensor

The temperature sensor will monitor the worms' environment temperature. If it detects a high temperature, the worms usually do not adapt to it so an alarm will sound. The following table compares a few options for temperature measurement.

Table 27: Temperature sensors comparison

Name	Description	Specifications	Dimensions	Price (€)	Supplier
Waterproof temperature sensor DS18B20	Capable of measuring temperature of humid environments, including underwater	Chip: DS18B20 Operating voltage: 3-5.5 V Measurement range: -55 ºC to +125 ºC Accuracy: ±0.5 °C between -10 ºC and +85 ºC 12-bits measurements (configurable) Stainless steel tip	Tip: 6 x 50 mm Cable length: 100 cm	3.70	Mauser
PT100 Temperature sensor	Thermistor	Range: -50ºC ~ 350ºC 0 ºC resistance: 100 Ω	Φ3 mm x 10 mm	11.87	ElectroFun
MakeBlock submersible temperature sensor	Environment, inside/outside water temperature	Chip: DS18B20		10.50	ElectroFun

The temperature sensor should be able to work on humid environments given the features of the product, therefore, the best option is the Waterproof Temperature Sensor DS18B20.

Humidity sensor

Although worms live in a humid environment, too much humidity may affect them negatively, so it is important to track soil humidity. Table 28 compares humidity sensors available on the market.

Table 28: Humidity sensors comparison

Name	Description	Specifications	Price (€)	Supplier
Seeed Capacitive humidity sensor	Corrosion resistant Soil humidity sensor based on capacitance changes In comparison with resistive sensors, these don't need direct exposition of electrodes	Integrated amplifier	8.49	ElectroFun

Name	Description	Specifications	Price (€)	Supplier
M5Stack Earth soil humidity sensor	The probes act together as a variable resistance. The higher the humidity in the soil, the better the conductivity between the two, so that the sensor results in less resistance and higher SIG output.	Adjustable potenciometer Analogical and digital output	4.95	ElectroFun
ITEAD humidity sensor	Used for measuring soil humidity Plug and play	Adjustable potenciometer Analogical and digital output Operating voltage: 3.3 V or 5 V DC	4.78	ElectroFun
Humidity sensor	Detects soil moisture variations, when it is dry the output turns to High and when it is humid it turns to Low	Operating voltage: 3.3 - 5.0 V Adjustable sensitivity via potenciometer Analogical and digital output LED for voltage (red) LED for digital output (green) Comparator LM393 PCB dimensions: 3.0 x 1.5 cm Probe: 6 x 2 cm Cable length: 21 cm	3.30	ElectroFun

The humidity sensor should have a high resistance to corrosion, as the 'Seeed Capacitive humidity sensor' is capacitive, it is the most resistance, and the choice for the project.

Time-of-flight sensor

The time-of-flight distance sensor will work as a tracking device for the worms. In order to find out the direction of movement, two of these sensors will be necessary to put on the tubes the worms travel through. As recommended by the supervisors, the chosen sensor is: Time-of-flight sensor.

7.4 Power

7.4.1 Power Budget

The power budget is essential to choose the right photovoltaic panel for the product.

Table 29: Power Budget

Component	I (A)	U (V)	P (W)
Micro-controller			
Total			

7.4.2 Photovoltaic panel

Table 30: Photovoltaic panels

Name	Specifications	Price (€)	Supplier
Photovoltaic Panel Poli-crystalline 10W / 12V - Cellevia Power CL-SM10P	354x251mm	15.20	Mauser
Photovoltaic Panel Silicon Mono-crystalline 20W / 12 V		22.99	Castro Electronica

7.5 Final List of Components

Finally, after comparing all the different options available, the following table compiles the chosen components and suppliers for the project.

Table 31: Materials for the prototype

Functionality	Name	Quantity	Price (€)	Supplier
Micro-controller	ESP32 Battery Support	1	18.95	BotnRoll
Water level sensor	10W Liquid Level Sensor	1	6.20	ElectroFun
Temperature sensor	Waterproof temperature sensor DS18B20	1	3.70	Mauser
Humidity sensor	Seeed Capacitive humidity sensor	1	8.49	ElectroFun
Time-of-flight distance sensor	Sensor VL53L0X	2	14.90	BotnRoll
Battery	Li-Ion Battery 18650	1	3.90	BotnRoll
Photovoltaic panel				
	Total			

7.6 Functionalities

The correct and effective functioning of the system depends on the following features:

- Keep track of the worms' health;
- Alert if temperature and/or humidity are outside specified limits;
- Use renewable energy sources;
- Use/collect rain water when available;
- Be user-friendly (minimal maintenance).

7.7 Tests and Results

7.8 Packaging

7.9 Summary

In conclusion, this smart and modular vermiponics system will be able to function on its own,

depending on the user only for providing the vegetables and food waste for the decomposing process.

8. Conclusions

8.1 Discussion

Provide here what was achieved (related with the initial objectives) and what is missing (related with the initial objectives) of the project.

8.2 Future Development

Provide here your recommendations for future work.

Bibliography

[1] Simon Goddek et al. *Aquaponics Food Production Systems: Combined Aquaculture and Hydroponic Production Technologies for the Future.* Springer Nature.
[2] M. Lopes Nunes, A.C. Pereira, A.C. Alves. Smart products development approaches for Industry 4.0. *Procedia Manufacturing*, 13, pp.1215-1222, ISSN 2351-9789.
[3] Donna Hoffman, Thomas Novak. Emergent Experience and the Connected Consumer in the Smart Home Assemblage and the Internet of Things. *SSRN Electronic Journal*.
[4], **[5]** Zied Mani, Inès Chouk. *Drivers of consumers' resistance to smart products, journal = Journal of Marketing Management.* Routledge, pp.76-97.
[6], **[10]** Tobias Mittag et al. Building blocks for planning and implementation of smart services based on existing products. *Procedia CIRP*, 73, pp.102-107, ISSN 2212-8271.
[7], **[11]** Soumitra Chowdhury et al. Smart Product-Service Systems (Smart PSS) in Industrial Firms: A Literature Review. *Procedia CIRP*, 73, pp.26-31.
[8], **[12]** Pai Zheng et al. A survey of smart product-service systems: Key aspects, challenges and future perspectives. *Advanced Engineering Informatics*, 42, pp.100973.
[9], **[13]** Muztoba Ahmad Khan, Thorsten Wuesta. Towards a framework to design upgradable product service systems. *Procedia CIRP*, 78, pp.400-405.
[14] United Nations. *68% of the world population projected to live in urban areas by 2050, says UN.*
[15] Agriculture Academy. *What is Aquaponics and How Does it Work?.*
[16] Rik Kretzinger. *Build an Aquaponic Garden with Arduino — Gardening.*
[17] Nelson Pade. *What is Aquaponics?.*
[18] Brett Roe, David Midmore. *Sustainable aquaponics.* CQUniversity.
[19] MasterClass. *How to make and use worm tea to fertilize your garden.*
[20] Julius. *Vermiponics – REGENERATE!.*
[21] Benny Thompson. *Aquaponics vs Vermiponics.*
[22], **[23]** Research Institute. *What is Permaculture?.*
[24] Keiren. *Keyhole Garden: How To Build One and 30+ Inspirational Ideas For Your Garden.*
[25], **[26]** Subpod UK. *Subpod - Below-ground composting that actually works!.*

[27], **[28]** Bionicraft. *BIOVESSEL - An Ecosystem Powered by Food Waste.*
[29], **[30]** Urbalive. *Urbalive - Live in harmony with natural principles.*
[31] Cambridge Dictionary. *Stakeholder.*
[32] wrike. *What Is Scrum in Project Management?.*
[33], **[34]** Korkmaz Bellitürk. In Turkey use-of-vermicompost. *Rice Research: Open Access*, 06.
[35] MCGILL. *What is sustainability?.*
[36] Walter Leal Filho Lisiane V. Mattos Osvaldo Luiz Gonçalves Quelhas Rodrigo Caiado. *Towards Sustainable Development Through The Perspective Of Eco-Efficiency.*
[37] GIRISH PAI SUNIT THAKUR VISHWAS SONWANE VARADA MENON ARUN MAURYA. *STUDY OF HYDROPONIC SYSTEMS AND THEIR VARIATIONS.*
[38] Marni Evans. *What Is Environmental Sustainability?.*
[39] Christel Cederberg Jenny Gustavsson. *Global Food Losses and Food Waste.*
[40] University of Mary Washington. *Economic Sustainability.*
[41] ADEC INNOVATIONS. *What is Social Sustainability?.*
[42] Helen Cole Jordi Alonso Esther Sanyé-Mengual Núria Cardona-Giralt Ferran Urgell-Plaza Ana Vazquez James Connolly Judith Cirac-Claveras Isabelle Anguelovski Margarita Triguero-Mas. *Quality of Life Benefits of Urban Rooftop Gardening for People With Intellectual Disabilities or Mental Health Disorders.*
[43] IyyankiV.Muralikrishna2017
[44] Lanna Deamer. *Top five green materials for electronics.*
[45] Big Commerce. *What Is Sustainable Packaging?.*
[46] Staff Writer. *11 Ways Green Distribution Can Be Sustainable.*
[47] Argon&Co2021
[48] HM Government. *OUR WASTE, OUR RESOURCES: A STRATEGY FOR ENGLAND.*
[49] Lara Denis. *Kant's Lectures on ethics.* Cambridge University Press.
[50] Ordem dos Engenheiros. *Código de Ética e Deontologia.*
[51] Sean Valentine. Ethics Training, Ethical Context, and Sales and Marketing Professionals' Satisfaction with Supervisors and Coworkers. *Journal of Personal Selling \& Sales Management*, 29, Routledge, pp.227-242.
[52] Sam Woolfe. 10 Principles Of Ethical Marketing. *Figaro Digital*.
[53] European Commission. *EU Machinery Legislation.*
[54] European Commission. *Electromagnetic Compatibility (EMC) Directive.*
[55] European Commission. *The Low Voltage Directive (LVD).*
[56] European Commission. *Radio Equipment Directive (RED).*
[57] European Commission. *Radio Equipment Directive (RED).*