AzuLoop

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- Luna Hongenaert
- Esmée Keijzer
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Acknowledgements

Abstract

The European Project Semester (EPS) is an innovative engineering capstone project semester. Currently, the programme is offered by 20 European universities, including the Instituto Superior de Engenharia do Porto (ISEP). EPS employs a learning framework based on real-world challenges, interdisciplinary projects, and multicultural and multidisciplinary teamwork. Teams are required to design solutions based on market and state-of-the-art analyses, adhere to ethical and sustainability principles, and develop and test a proof-of-concept prototype. In the spring of 2025, an EPS@ISEP team decided to address the issue of domestic water waste. The most apparent waste occurs when users turn on the tap and wait for the water to heat up, sending clean water down the drain. The designed solution eliminates this waste by redirecting water below the temperature set by the user from the shower to an additional toilet water tank. AzuLoop consists of a smart shower mixer, a water tank that adapts to existing toilet water tanks, and a few additional pipes. AzuLoop is easy to install, provides a comfortable shower experience, and reuses the clean cold shower water. During the semester, the team successfully designed, developed, and tested the AzuLoop prototype, while gaining valuable technical and personal skills through collaborative learning

Glossary

Abbreviation	Description
EPS	European Project Semester
ISEP	Instituto Superior de Engenharia do Porto
USB	Universal Serial Bus
WBS	Work Breakdown Structure

1. Introduction

1.1 Presentation

This project was completed by a team of six students, each with a different academic background.

They are presented in Table 1.

Table 1: Team Members

Akseli Järvimäki	Finland	Civil Engineering
Berta Marcó Gimenéz	Spain	Mechanical Engineering
Darius-Alexandru Ion	Romania	Industrial Informatics Engineering
Esmée Keijzer	The Netherlands	Communication and Media Design
Kristoffer Julin	Finland	Electrical Power Engineering
Luna Hongenaert	Belgium	Product Development

1.2 Motivation

We all came to ISEP with the ambition to create an innovative and impactful project. By combining our knowledge and skills, we aimed to achieve an optimal result that is not only technically strong but also provides real value. The EPS programme is supported with other courses about topics that enhance our project and make us consider different perspectives of it.

Individual motivation

- Luna - I chose the EPS programme because I often love to work in a team with students from different backgrounds because I know all the better that working in the real-world, this would be the standard. Also the hands-on approach is interesting because we learn mostly from each other and the proces of the project rather than on dry class material. I'm looking forward to step out of my comfort zone and take projects that are not in my expertise to learn new skills and face new challenges.
- Berta - My motivation to choose EPS program was broadening my horizons by working together with people from other cultures and learning from each other. Also I wanted to challenge myself by living on my own in a whole new country and having fun from people from all around Europe.
- Esmée - I chose the European Project Semester, because I am excited to work with people from different educational and cultural backgrounds. I want to experience living on my own in a foreign country, it will be a challenge to solve problems in my personal time and in the EPS project. I have to work outside of my comfort zone , because engineering has nothing to do with my main studies. This is a unique opportunity to come up with creative solutions to implement User Experience Research & Design and it is also an opportunity to learn more outside of my usual field of work.
- Darius - As an Industrial Engineering and Computer Science student, being part of the European Project Semester (EPS) in Porto at ISEP allows me to apply my technical expertise in an interdisciplinary, real-world setting. My experience with AI-based image recognition, additive manufacturing, and sustainability projects has strengthened my problem-solving, teamwork, and innovation skills. Through this program, I am enhancing my engineering knowledge, collaborating in a diverse environment, and developing sustainable solutions that align with my passion for electric propulsion and mobility technologies. EPS is a perfect opportunity to bridge my academic background with practical industry challenges while growing as an engineer and global team player.
- Kristoffer - I chose the EPS program because it seemed like a convenient way, to combine courses with a project, and then apply the knowledge from the courses to the actual project. Another reason why is to learn how to work in a multicultural environment, and learn how to work in a multidisciplinary field.

- Akseli - I chose the EPS program because it offers a structured way to merge theoretical learning with practical project work. It also provides a great opportunity to apply course knowledge to real-world challenges. Another key reason was the chance to gain experience in a multicultural and multidisciplinary work environment.

Project motivation

Beyond our personal motivation to participate in the EPS project at ISEP, we are strongly driven by our chosen topic. Smartifying everyday objects can be very diverse, but we see it as an opportunity to use our technical skills and knowledge on a topic that inspires us and that is challenging enough to work on an entire semester on it. We want to deliver a project we can be really proud of.

We started with identifying the design focus, namely sustainability. This way we are able to contribute to environmental improvements in our own way and set a clear goal for this project. Water consumption in everyday households stood out for us as an issue that we are able to understand, extremely relevant all over the world and it is tangible enough to contribute to a solution. Water usage is something we deal with daily on both environmental and financial terms. We hope with just a few adjustments in the daily household, we can contribute to reducing unnecessary water waste with just a small addition or transformation to an already existing object.

By tackling this problem we are not only creating a solution, but we are also raising awareness and encouraging others to consume water in a responsible way. This challenge offers an opportunity for us to gather our technical skills and knowledge to create something meaningful and make a real difference in the way we interact with essential resources.

1.3 Problem

Water waste is a widespread issue. A study by Water Practice and Technology estimates that approximately 20 % to 50 % of all usable water is lost due to leaks, poor infrastructure, or inefficiency. Household water waste ranks as the second largest contributor to this problem, following agriculture. One significant yet often overlooked source of household water waste is the water lost while waiting for the shower to reach the desired temperature **[Bassey James, 2025]**.

This type of waste, known as warm-up waste, varies depending on the household's plumbing system and the distance between the water heater and the shower. In cases where the heater is not located near the shower, it can take up to 60 seconds for hot water to arrive. If one assumes an average wait time of one minute, approximately 5.6 liters of clean water is wasted per shower. In a household of four people showering daily, this amounts to 24.4 liters per day or 8.906 liters per year **[Evolve Technologies, 2025]**.

Beyond water waste, this also translates into financial loss. In Portugal, the cost of water is 0.001 7 € per liter, meaning that a family of four could save around 15.14 € per year by simply redirecting and reusing this cold water instead of letting it go to waste **[TPN, 2024]**.

Reducing warm-up waste is not only beneficial for household expenses but also has a significant environmental impact. Although 71 % of the Earth's surface is covered in water, only 3 % is freshwater, and just 0.5 % is accessible for human use. The less water people waste, the smaller the strain on water resources and wastewater systems. Additionally, minimizing wastewater discharge helps reduce the introduction of harmful chemicals into natural bodies of water such as rivers, lakes, and oceans, protecting aquatic ecosystems and biodiversity **[4]**.

1.4 Objectives

Our goal is to develop a simple yet effective system that significantly reduces household water waste, potentially decreasing shower water consumption by up to 10 %. Instead of letting cold water run down the drain while waiting for the shower to heat up, our system will redirect it to an extra tank above the toilet, allowing it to be reused for flushing.

The product is a separate device that is installed between the water mixer and the showerhead. It includes a temperature sensor, a microcontroller, and two solenoid valves: one that directs water to the showerhead when the desired temperature is reached and another that redirects cold water to the toilet tank when it is not warm enough yet. The extra tank above the toilet has a float sensor that measures the water level to make sure if the stored water can or should be used to flush the toilet.

By applying this product, the team wants to minimize water waste while the user doesn't has to change their daily behaviour or make too much effort. The process is completely automated, which makes water management and sustainable behaviour effortless.

1.5 Requirements

Specify here the identified and mandatory requirements the solution has to fulfil

User interaction:

- Safe to use around water.
- Easy to use, intuitive.
- Possibility to personalize user settings.
- Make the user aware of their actions.

Interior:

- Usable water saving system
- Energetic efficient

Exterior:

- Attractive design.
- As small as possible.
- In harmony with the surroundings

Others:

- Budget friendly
- Ecologic

1.6 Tests

The main objective of building a prototype is to test the product's functionality. Prototype functional testing is a crucial step to validate if the product can be brought into real life. To guarantee the best result and experience for the users, the team will conduct several tests on the prototype.

- Structural test:To verify the structural adequacy and integrity of the water tank under hydrostatic pressure loads, a comprehensive stress analysis will be performed using SOLIDWORKS Simulation. The tank will be subjected to 30L water capacity (equivalent to 1,720 Pa maximum pressure at the bottom) through nonuniform pressure distribution simulation. The analysis will evaluate von Mises stress concentrations, particularly at critical locations such as base-wall junctions and corner regions where maximum stresses occur. Material yield strength will be compared against calculated maximum stresses to ensure a minimum safety factor of 2.0. Displacement analysis will verify that wall deformations remain within acceptable limits. The structural test passes if maximum stress values stay below material yield strength with adequate safety margins, and if no excessive deformation or structural failure occurs under the specified hydrostatic load conditions.
- Software test: To make sure the components and their connections are well planned, the team will simulate the software test first with Tinkercad.Afterwards, the testing of all input values will be done, the water level switches, the temperature sensor, and the potentiometer. Making sure values are similar to reality. Mapping the potentiometer so it represents the temperature values correctly. Checking if the valves can be controlled through the relay through the microcontroller. Making sure the valves are activated at the right time based on said temperature , and the level of the tank.
- Electrical test: Test the electrical components of the system, and the automation (in this case the microcontrollers switching properties), relays, and solenoid valves. In this case the test will be done by applying both a 5 and a 12 voltage from the power supply to the electrical components, 5 V will be applied with jumper cables, and the solenoids will be tested by applying 12 V from the relays switches by using a cable with fast connector terminals. How the team determines whether the electrical test passes or not is based on the functionality of the relays and solenoids, If the solenoids and relays work (the relay pulls & the solenoid opens), the test passes, If not, the test automatically fails.
- Real quality prototype test: Testing the complete product's functionality as fully assembled, and in a normal working environment, in order to make sure that it complies with our quality standards. Here both the software and the electrical parts go through another test phase, simultaneously with the hardware test to make sure it withstands the affecting stress caused by water pressure, this test will be done by mounting the water hoses to a water mixer with a threaded connector, the team will gradually increase the water pressure to make sure it withstands the requirement. How the team determines whether the Real quality prototype test passes or not is based by the system's whole functionality (Software & electrical test & stress test combined). The Real quality prototype test passes if the electrical test passes as announced on the electrical test part, and the Software test passes as announced on the Software test part. Also the pipes and their connectors should withstand 3 bar water pressure without any leakage from pipes or pipe fittings. If the prototype does not meet these requirements it does not pass the test and automatically fails.

With these tests, the team will conclude whether the product is viable or should be redesigned. The team's aim is to ensure a good product with good quality, in this case the test will be completed by installing our product to a water mixer, from where the team can regulate the warm/cold water distribution and therefore test the sensors and switching properties, as well as make sure our product withstands the affecting water pressure.

1.7 Report Structure

Chapter	Description
1 Introduction	Team and problem introduction

Chapter	Description
2 Background and Related Work	Research and analysis on the current solutions for the chosen problem
3 Project Management	Planning method and structure that will be followed by the team
4 Marketing Plan	Marketing strategy developed by the team to launch the project successfully
5 Eco-efficiency Measures for Sustainability	Sustainable and ecological concerns considered in the project
6 Ethical and Deontological Concerns	Ethical and Deontological concerns considered in the project
7 Project Development	Report of the progress and development of the solution
8 Conclusions	Conclusions the team gets from the final solution
9 Bibliography	List of information sources

2. Background and Related Work

2.1 Introduction

In order to have an overview of the actual market and solutions to the problem, it is fundamental to do a state-of-the-art research.

Below there's research on different products that help solve the problem of water wasting, and some projects that help spread awareness of water being a finite good and solutions to the problem.

Finally, the comparative analysis helps define the current solutions' areas of action and identify their weaknesses and strengths.

2.2 Concepts

Some concepts that help understand the main problem and the proposed solution are:

- **Water flow** It's defined by the volume of water moving through a specific area or point during a period of time.
- **Valve** It's a device that controls, regulates or directs the flow of a fluid by opening, closing or partially obstructing passageways.
- **Water consumption** It's the quantity of water used by people, agriculture, and industries for daily activities like cooking, drinking, farming, and manufacturing
- **Environmental crisis** An actual serious problem affecting nature, caused by the human impact that harms ecosystems and threatens life on Earth resulting in climate change and species extinction.

- **User awareness** Knowledge and understanding by people about how their actions affect resources such as water, with the aim of promoting their responsible and sustainable use.
- **Safe water** It is the kind of water which is drinkable or suitable for personal hygiene, without representing any risk to health.
- **Greywaters** This is wastewater from domestic or office uses that does not contain fecal contamination, such as that coming from showers, toilets, washing machines or sinks.
- **Water reuse** The process of treating and repurposing wastewater, stormwater, or graywater for beneficial uses
- **Water recycle** The process of treating wastewater to remove impurities so that it can be reused for the same or different purposes, reducing water waste and promoting sustainable resource management. While water reuse generally refers to using treated water for various applications, water recycling emphasizes the process of purification and **returning water to a system** for continued use.

2.3 Products

In this section you can find a research on some of the products that are already on the market which address water waste in households:

Shower Timer (See figure 1)

The user sets a shower time and how many showers a day should be available. When the user presses the start button, the shower timer starts counting back; when the time is off, the shower water is also cut off until the next available shower period. It is designed for domestic and commercial use in Australia. A regular shower uses between 8L and 15 L per minute, so considering a 13 min shower at 12 L/min, it would be using 156 L. If the shower length was reduced to 6 min, it would save 84 L.

When it’s on it consumes less than 10 W, and when it’s not in use it consumes less than 2 W. So this solution helps to avoid unnecessary long showers, compromising the user’s comfort, but improving the customer's finances.

Figure 1: Shower Timer **[Aquaflow Distributors, 2025]**

Flow and temperature meter connector (See figure 2)

Device that measures the temperature and water flow, so users are more conscious about the energy and water usage. It is a connector to place in the shower head cord with a display that shows the temperature and the water consumption in real time. It has an LED frame around the display that changes colors from green to red depending on the water consumption, so the user knows when they are wasting too much water.

Furthermore, it works without any battery thanks to a dynamo, so it doesn't increase energy consumption.

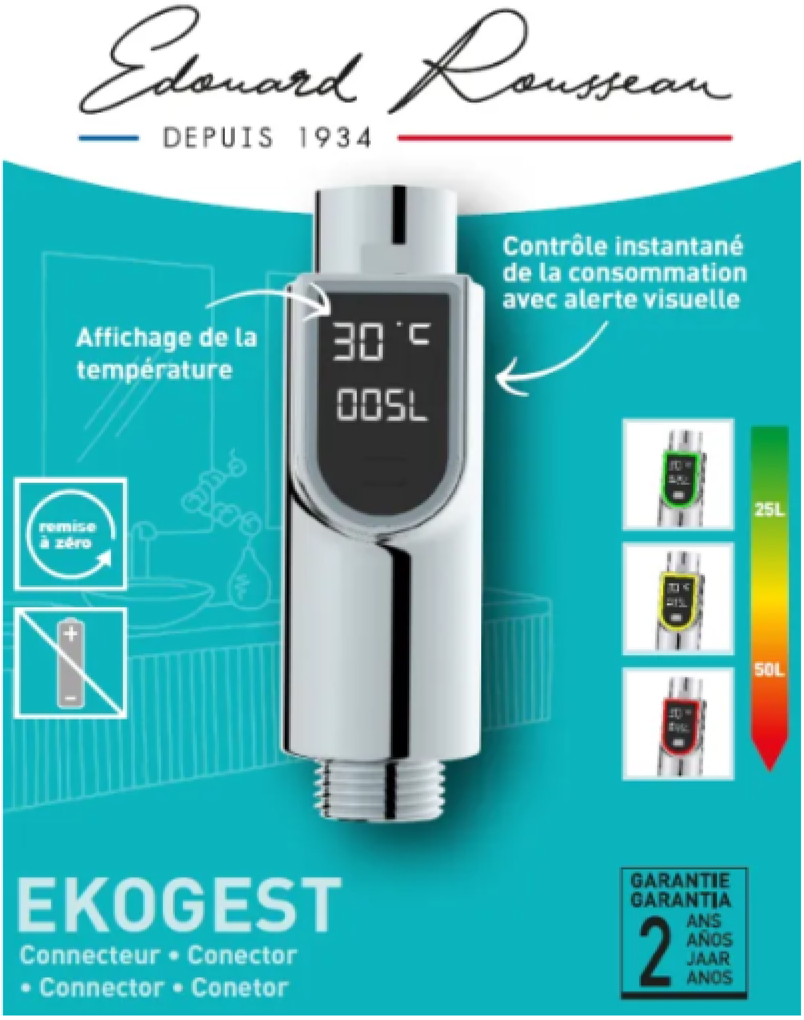

Figure 2: Ekogest flow and temperature meter **[Eduard Rousseau, 2025]**

Shower regulator (See figure 3)

A flow regulator is a device that is installed between the shower head and the hose in order to control and limit the flow of water. Its main purpose is to reduce water consumption without compromising a comfortable and enjoyable shower. This device incorporates a small opening or valve mechanism that restricts the water flow. Some models use rubber or plastic diaphragms that adapt to the water pressure to maintain a constant flow rate, while others have fixed orifices that allow up to a certain volume of water per minute.

Flow regulators can be found in different capacities, usually between 14 L/min and 6 L/min.

Figure 3: Shower Regulator **[savewater, 2025]**

Faucet aerator (See figure 4)

Faucet aerators are small attachments that screw onto the tip of a faucet, they are a type of water flow regulators. They help control water flow by mixing air with water, creating a smooth, non-splashing stream. Because of their compact design, aerators blend with the faucet, making them hardly noticeable at first glance.

Like shower flow regulators, faucet aerators come in different flow rate options from 14 L/min to 4,5 L/min, allowing customers to choose how much water is restricted.

Figure 4: Faucet Aerator **[stickq, 2011]**

WOTA box (See figure 5)

WOTA Box is a portable water reuse system that enables water use even with no water supply. More than 98 % of wastewater is reused, delivering safe and reliable water anytime, anywhere.

This product is designed to solve the problem of not being able to bring water in emergency situations or outdoor events. Although it actually needs a power supply source.

WOTA BOX removes more than 99.99 % of viruses and bacteria using four types of filters (one sediment, two activated carbon and one RO membrane), deep ultraviolet rays and chlorine disinfection.

This product relies on AI to monitor and control the quality of the clean water and system and notifies the user when there's any problem or need for maintenance.

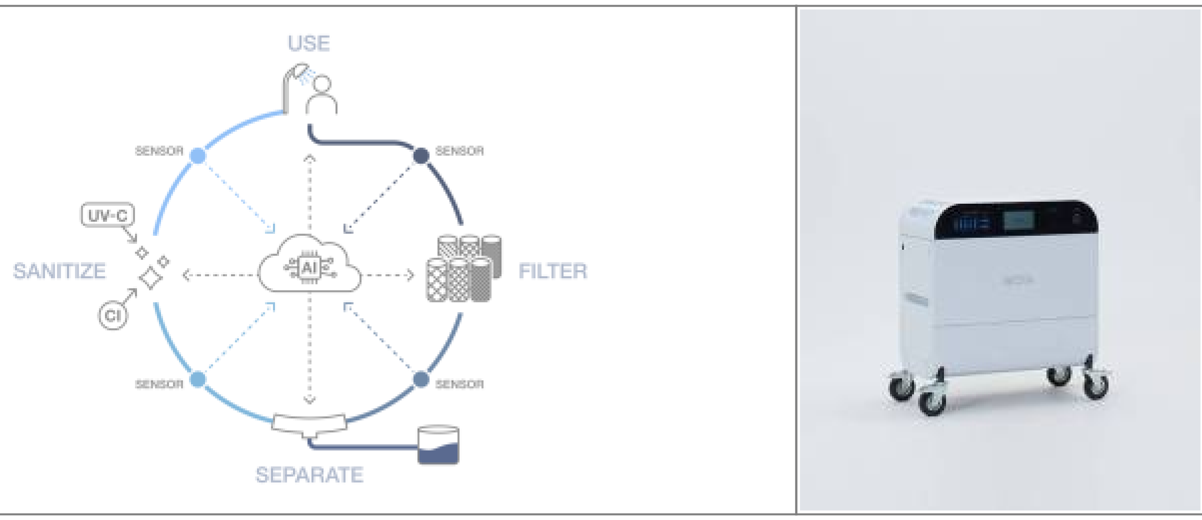

Figure 5: WOTA box **[WOTA, 2023]**

Toilet with integrated sink (See figure 6)

The solution described below is an accessory to put over the toilet tank, although there are other similar solutions, which are a toilet with an integrated sink. The purpose of this accessory is reusing the waste water from washing hands for flushing the toilet. It's designed to be easy to install.

It also addresses the issue of kids not remembering to wash their hands after using the toilet, and with its touch-free faucet, it breaks the chain of germs. Likewise, it is very suitable for small spaces since the sink room is not needed anymore in the bathroom.

Figure 6: Sink positive **[Ecobuildingproducts, 2025]**

Water Flow Kit (See figure 7)

The kit can be connected to an existing faucet or pipeline, allowing the user to track their water usage accurately. This kit enables real-time monitoring of the water consumption. It can also monitor water temperature and flow.

It has been designed for an easy installation so that the user can do it themselves by just attaching the sensors to the chosen pipeline or faucet and connecting the kit to the home assistant system via Wi-Fi.

The user can also set up alarms or notifications for a certain level of water consumption in order to prevent careless water waste.

Some of the product limitations are the ability to connect only up to two flow sensors, only allowing to track water consumption in two different locations. And also, it’s designed for indoor use, and it’s not recommended for outside use.

Figure 7: WaterFlow Kit **[WaterFlowKit, 2025]**

2.4 Projects

Water impact awareness campaign

Some associations and agencies have launched campaigns to raise awareness of water misuse, giving users some tips to save water in their daily lives such as EPA(United States Environmental Protection Agency), WaterWiseEU, EPAL (Grupo de Águas de Portugal).

Hydraloop [Hydraloop, 2025].

This project from the Netherlands and Belgium offers products to recycle waste water from the shower, purifying it and bringing it back to the system. It reduces the water use by 25 % - 45 %.

Grey Water Action [Grey Water Action, 2025].

This project, from a collaborative of educators and the California Department of Water Resources, leads people on grey water systems in order to reuse it in irrigation systems.

One Drop Foundation [One Drop, 2025].

It's a nonprofit foundation that is organizing water-saving initiatives worldwide to guarantee safe access to water for different communities.

2.5 Comparative Analysis

Figure 2 shows a comparative analysis of all products and projects that are related to what the team wants to achieve.

Table 2: State of the art comparative analysis

Product	Cost(€)	Way of saving water	Quantity of saved water	Personalization	User awareness	Smartness	Design
Shower Timer	193.94 - 354.16	Turning off the water after the time set by the user	84L(calculated for a 6min shower and a regular shower being 13min at 12 L/min)	The users set their own time	It helps the user be aware of how long they take to shower	Timer connected to the water outflow	Simple, not really attractive
Flow and temperature meter connector	20.89	It only saves water if the user wants to	None	None	It makes the user aware of using to much energy or water	Temperature and pressure sensor displayed in a screen	Attractive, very modern
Shower regulator	9.90	Limits the water flow in the shower	26L (calculated for a 13 min shower at 10 L/min, compared to a same time shower but at 12 L/min)	None	The user can be not aware at all	No smart components	Good, small and simple
Faucet aerator	7.36	Mixes water with air, reducing water flow in faucets	9 to 6 L/min	None	The user can be not aware at all	No smart components	Good, small and simple
WOTA box	Full disaster shelter package around 30.60	Recycling water	Reuse 98 % of the water	None	The user just has to be aware if the box notifies them of a problem	Sensors and AI to monitor and control water quality	designed for emergencies
Water Flow Kit	54.99	The user can set alarms for any quantity of water they find excessive, and that way reduce the use	It saves as much water as the user is willing to	The user sets their limits and receive all the data from their household	It makes the user fully aware of their water and energy consumption and gives them tips on how to save money, energy and water	Smart device connected to an APP	-

2.6 Summary

Based on this study on the state of the art, the team decided to focus on recycling water from the shower.

Inspired by the WOTA box technology, the final product could be a redirection from the shower waste water to the house water system. The problem with this kind of project is purifying the water and the maintenance the system would need. There's where another solution comes up; the project could be focused on the clean water that goes to waste before actually showering, just because it's too cold. Inspired by the water flow kit, the solution could track the temperature of the water and only let it run when it's warm enough. That way there wouldn't be any need for filters or chemicals, and the not-warm-enough water would go back to the boiler.

Also inspired by the toilet with integrated sink, another solution would be redirecting the cold water or the shower waste water to the toilet tank instead of the boiler, and as a result, saving energy.

3. Project Management

This chapter will address the topic of project management. It will present a comprehensive overview of the practical aspects of project management, including key elements such as stakeholders, costs, procurement, scope, and time. Project management is a crucial part of the project since it ensures the formation of a highly organised team. This, in turn, leads to the successful completion of a project that aligns with the needs of stakeholders, meets the desired scope, and provides team members with a good view of what is going on.

3.1 Scope

The team designed a system using a microcontroller that continuously measures the temperature of the input water from the boiler. If the temperature is below an input (, the water is automatically divert to a storage tank instead of being wasted. This stored water is later used to flush the toilet, giving it a second life and reducing overall water consumption. The following chapter defines the project's boundaries by outlining the overall project scope (Figure 8), detailing the work required to achieve each.

In order to effectively manage the project scope, the work will be further divided into the different deliverables that the team has to hand over in the wiki expressed in this work task breakdown structure:

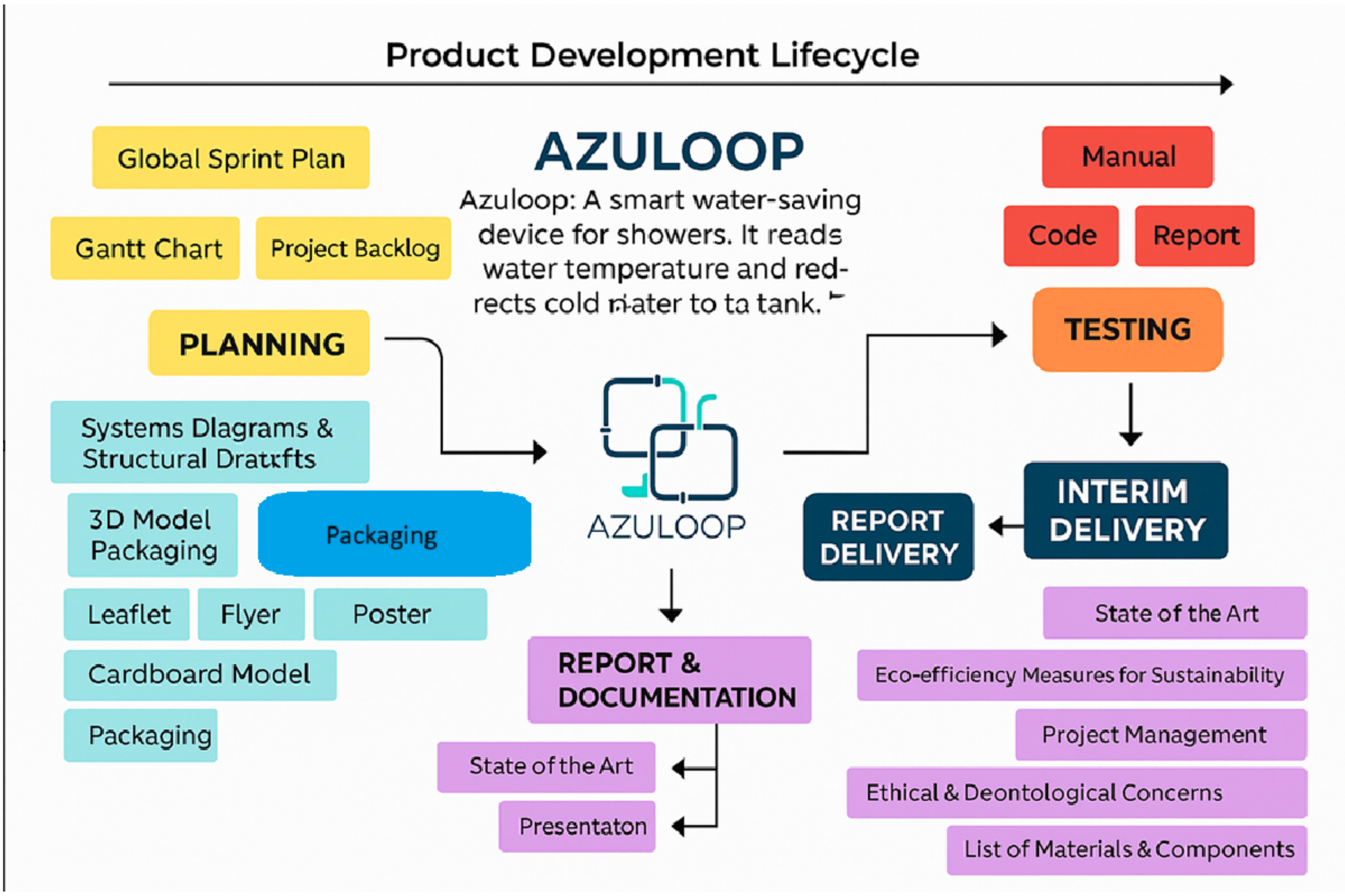

Figure 8: Project WBS

3.2 Time

The EPS teams have to complete a list of milestones (See figure 3).

Table 3: Project Milestones

Date	Description
2025/03/01	Choose and share the team's top 3 preferred project proposals
2025/03/12	Upload the “black box” **System Diagrams & Structural Drafts**
2025/03/15	Define the **Project Backlog** , **Global Sprint Plan, Initial Sprint Plan** and **Release Gantt Chart** of the project
2025/03/19	Upload the **List of Components and Materials (what & quantity)**
2025/03/26	**System Schematics & Structural Drawings** to the wiki (Deliverables) and do the **cardboard scale model** of the structure
2025/04/06	**Interim Report and Presentation**
2025/04/10	Interim Presentation, Discussion and Peer, Teacher and Supervisor feedbacks
2025/04/15	**3D model** video
2025/04/29	Final **List of Materials (local providers & price, including VAT and transportation)**
2025/05/02	Refined Interim Report (based on Teacher & Supervisor Feedback)
2025/05/14	**Packaging solution** and Report
2025/05/28	Results of the **Functional Tests**
2025/06/15	**Final Report, Presentation, Video, Paper, Poster and Manual**
2025/06/18	Final Presentation, Individual Discussion and Assessment

2025/06/25	Update the wiki, report, paper with all suggested corrections
	Hand in to the EPS coordinator a **printed copy of the poster, brochure and leaflet**
2025/06/26	Hand in the **prototype and user manual** to the client

3.3 Cost

The total cost of those components is **912.42 €** and that would just be for one unit of the product. Also, the team is composed of a staff as seen in the table with salary budgeting **[Glassdoor, 2025]**. Since the project lasts 5 months, the total budget for the staffs salary will be **76000 €** (See Table 4). Furthermore, there's a set budget for the prototype of 100 € which is the budget this EPS project should adjust to. (See Figure 9).

Components and material

	Quantity	Price per piece	Shipping	Total
Micro controller	2x	€11,75	Farnell €14,99.	€23,50
Valve Normally Closed	2x	€119,18	Digikey €18	€238,36
Valve Normally Open	2x	€233,74	Digikey €18	€467,48
Temperature sensor	1x	€5,35	PTrobotics €5,66	€5,35
Float level sensor	2x	€2,94	Digikey €18	€5,88
Power source	1x	€14,95	Digikey €18	€14,95
Relay	3x	€1,23	PTrobotics €5,66.	€3,69
Voltage regulation	1x	€0,38	Digikey €18	€0,38
Case through injection molding (18,7cmx13,3cmx11cm)	1x	€31	Estimated €3	€31
Bluetooth shield	2x	€9,72	Farnel €14,99	€19,44
Male push-in fitting G3/8-10mm	5x	€3,89	RS components €6,95	€19,45
Female push-in fitting G3/8-10mm	1x	€8,09	RS components €6,95	€8,09
Male ⅜-M3/8	4x	€1,38	Casa Peixoto €free	€5,52
T pipe fitting	2x	€0,89	Leroy Merlin pick up in store	€1,78
Bulkheid G3/8	5x	€13,51	RS components €6,95	€67,55

Figure 9: Component list

Table 4: Salary budgeting

Role	Monthly Salary (estimated)	Total Cost (5 months)
Project Manager	3000 €	15000 €
Electrical Engineer	2500 €	12500 €
Mechanical Engineer	2500 €	12500 €

Role	Monthly Salary (estimated)	Total Cost (5 months)
Sales Manager	2800 €	14000 €
Sales Person	1800 €	9000 €
Design Engineer	2600 €	13000 €
Total salary budget		**76000 €**

3.4 Quality

The team has documented quality metrics that apply to the project deliverables, associated thresholds and how they should be reviewed (See Figure 5 and 6).

Table 5: Product quality

Metrics	Description	Threshold	Reviewing method
Material durability	Housing should be waterproof and resistant to any minor impacts	Doesn’t let water in through the joints, and its lifespan is a minimum of 10 years	Impermeability testing and stress testing
Energy efficiency	Uses as little energy as possible	Max 45W in worst-case scenario	Energy consumption testing
Temperature sensor performance	Precision in sensing the water temperature	User input temperature with max ±2ºC deviation	Temperature sensing test
Valves and programming performance	Valves open or close pipes entryway as programmed	No errors; when the water is warm enough, the program makes the shower head valve open and close the toilet tank valve	Usage test
Maintenance and repairability	Components should be easy to replace or repair	Non-dangerous components should be easy to replace without specialized tools	Maintenance test
Eco-efficiency and sustainability	The product must align with sustainable engineering principles explained in Chapter 5	The product helps to improve the environment, and at its life end, its components can be recycled or reused	Lifecycle assessment

Table 6: Documentation quality

Metrics	Description	Threshold	Reviewing method
Clarity	It is easy to understand everything that's explained in the document	No confusing information or writing	All the team members read the documents to make sure it can be understood easily
Good spelling	The words can be read without any confusion	No orthographic or grammar mistakes	Run the texts through a spell checker
Completeness	The documents contain what the deliverable asked for	All necessary information is included in the documentation	Team members verifying

Metrics	Description	Threshold	Reviewing method
Accuracy	The reader can trust the information written on the documents	There's no fake information source	Ensure that information provided in the documentation is accurate and up-to-date

3.5 People

People participating in a project can cause a high risk of unpredictability, that is why it is important to organize and delegate tasks among all the parties & team members involved in the project. This particular section outlines the key individuals and groups involved in the project, and describes their roles, responsibilities, and contributions to the project .

The key to successfully delegating tasks is to keep in mind the following aspects of the group members:

- **Skills and Expertise:** Knowing the skills and capabilities of the team members is fundamental when assigning tasks, so that the outcome can be the best possible.
- **Roles and Responsibilities:** In order to avoid confusion and overlap, it is important to define the roles and responsibilities of each member and make sure that the tasks align with that.
- **Availability and Workload:** Equity is a synonym of fairness. When talking about workload, it is important to make sure no team member is overburdened to prevent burnouts.
- **Interest and Motivation:** Assigning team members tasks they are interested in will improve their engagement and productivity in the project.
- **Collaboration and Team Dynamics:** Sharing tasks should promote teamwork and collaboration, so in order to get that, it is necessary to know how team members work together.

Azuloop doesn't have any project manager, resulting in that all team members have the same responsibility among project management, and following the scope. See on the table 7 the roles and responsibilities of the different individuals and groups involved in the project.

Table 7: Roles and Responsibilities

People	Role	Responsibility
ISEP	Sponsor	Accept project deliverables. Support Economically
Akseli Järvimäki	Team member	Participate in defining change resolutions. Evaluate the need for scope changes and communicate them to the rest of the team and the EPS coordinator as necessary
Berta Marcó Giménez	Team member	Participate in defining change resolutions. Evaluate the need for scope changes and communicate them to the rest of the team and the EPS coordinator as necessary
Darius-Alexandru Ion	Team member	Participate in defining change resolutions. Evaluate the need for scope changes and communicate them to the rest of the team and the EPS coordinator as necessary
Esmée Keijzer	Team member	Participate in defining change resolutions. Evaluate the need for scope changes and communicate them to the rest of the team and the EPS coordinator as necessary
Kristoffer Julin	Team member	Participate in defining change resolutions. Evaluate the need for scope changes and communicate them to the rest of the team and the EPS coordinator as necessary

Luna Hongenaert	Team member	Participate in defining change resolutions. Evaluate the need for scope changes and communicate them to the rest of the team and the EPS coordinator as necessary
Maria Benedita Malheiro	EPS coordinator	Organize and facilitate scheduled control meetings. Facilitate scope change requests.
EPS Coaches	Supervisors	Supervise and guide the team through the process
Professors	Advisors	Advise the team through their acknowledgement. Provide resources and knowledge
Target Group	Costumers	Communicating their needs
Suppliers	Supplier	Supply components
Retail Stores	Distributors	Sell the product

3.6 Communications

The team documented how they will manage communications and meetings, which communication channels they use, etc.

Guideline for meetings

Meeting agenda

The Meeting Agenda will be uploaded to the wiki page at least 1 day in advance of the meeting. The Agenda should identify the topics to be discussed or addressed during the meeting.

Meeting minutes

Meeting minutes will be uploaded to the wiki page within the same day as the meeting. Meeting Minutes will include the status of all items on the agenda, along with new agreements discussed in the meeting.

Meeting chair person

The Chair Person is responsible for uploading the Meeting Agenda and leading the meeting. This role will change each meeting, letting all team members lead the meeting, usually according to the expertise of each one of them.

Note taker

The Note Taker will change every meeting, just like the Chair Person. The Note Taker is responsible for documenting everything discussed in the meeting and using those notes to complete and upload the Meeting Minutes.

Time keeper

Usually the time keeper will be a professor. Its responsibility is to help the team adhere to the time limit, letting the Chair Person know when they are approaching the end of their given time.

Communications matrix

In the matrix is stated what types of communication the team used, the objective, medium, frequency, audience and deliverable of those communication types (See figure 8).

Table 8: Communications matrix

Communication type	Objective	Medium	Frequency	Audience	Deliverable
Kickoff meeting	Introducing the team members. Decide on a topic for the project.	Face to face	Once	Team members	None
Control meetings	Review status of the project. Report the status of the project including activities, progress and issues.	Face to face	Weekly, every Thursday morning	Team members and project supervisors	Meeting Agenda, Meeting Minutes, Week report
Project team meeting	Discuss and develop project issues	Face to face	As needed	Team members	Jira update

Communication tools and means

- Microsoft Teams: It is the most used tool by the professors and supervisors to upload information and resources.
- Outlook: It is the medium through which the formal communication that needs to be fast is sent.
- WhatsApp: It is the most used mean for fast communication with the team members. The team uses it daily and communicates issues that need to be solved quickly.
- Jira: It is the main tool for project management; the team uploads their progress, completes the sprint reports, and is used for knowing and communicating the tasks and scopes.

Communication approaches

The team documented how they communicate with the stakeholders (See figure 9).

Table 9: Communication approaches to stakeholders

People	Role	Approach	Frequency
Akseli Järvimäki	Team member	F2F	5x/week
Berta Marcó Giménez	Team member	F2F	5x/week
Darius-Alexandru Ion	Team member	F2F	5x/week
Esmée Keijzer	Team member	F2F	5x/week
Kristoffer Julin	Team member	F2F	5x/week
Luna Hongenaert	Team member	F2F	5x/week
Maria Benedita Malheiro	EPS coordinator	Weekly meetings & email	1x/week
Professors	Advisors	Classes or email	2x/week

Suppliers	Supplier	Email & phone	2x/week
Retail Stores	Distributors	Email & phone, also F2F	2x/week

3.7 Risk

The risks associated with this project can be divided into three categories: technical risks, installation risks, and safety risks. Each of these has the potential to affect the reliability, usability, and safety of the system. Below we describe each risk type, its potential impact, and suggest ways to mitigate them. (See Figure 10).

Technical risks

-Sensor failure: Could result in incorrect water routing, leading to cold water going to the shower or overflowing the toilet reservoir.

-Microcontroller failure: May cause total system malfunction, stopping valve control and logic execution.

Response:

-Use reliable, tested components.

-Add redundancy or a manual override if possible.

-Perform regular software and hardware testing.

Installation risks

-Compatibility issues: The system might not fit all shower or toilet models.

-Water leaks: Poor installation or connector mismatch could result in leaks.

Response:

-Provide detailed installation guides.

-Use standard fittings and connectors.

-Test prototypes on different fixture types.

Safety risks

-Melting or overheating: If the case or components are made of unsuitable material or poorly ventilated.

-Electrical hazards: Risk of shock if 230V components are exposed or wiring is incorrect.

Response:

-Use flame-retardant, waterproof housing.

-Make sure to let a professional to the installing.

-Separate high and low voltage components properly & keep metallic parts grounded to protect from touch voltages in case of grounding faults.

-Ensure compliance with electrical safety standards (e.g. CE marking, IP classing, LVD).

Procurement

-Delayed component delivery: may cause timeline delays, and project cancellations. -Quality issues: May cause timeline delays, and project cancellations. -Limited availability: May cause timeline delays and project cancellations. -Cost fluctuations caused by market change: Exceedings of budget.

Response:

-Select reliable suppliers -Keep in mind backup suppliers -Order early -Lock component prices with contracts with suppliers

Communication

-Unclear communication between team and stakeholders: Can lead to wrong decisions being made. -Poor communication between team members: Can lead to project task overlaps as well as missed deadlines -Poor documentation: Can lead to important details being neglected/forgotten

Response:

-Use Jira as a project management tool -Take meeting notes -Set clear deadlines -Hold briefings to make sure everyone is well informed

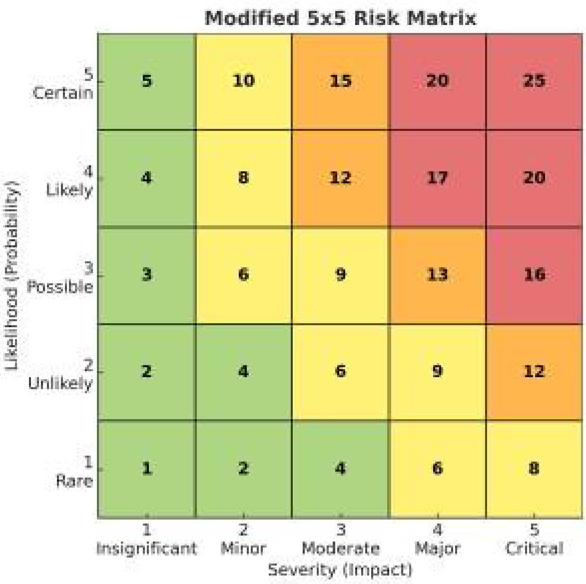

Figure 10: Risk Matrix

Risk level definition

1-4 = Low risk

- Minimal impact on project outcomes.
- Issues can be managed easily without disrupting timelines or budgets.
- Usually requires routine monitoring only.

5-9 = Medium risk

- May cause moderate delays or increased costs.
- Could affect some project deliverables or quality.
- Needs planned mitigation and regular review to avoid escalation.

10-15 = High risk

- Likely to cause significant disruption or cost overruns.
- May impact core functionalities or safety.
- Requires immediate mitigation efforts and close management attention.

16-25 = Critical risk

- Threatens overall project success and safety.
- Can cause severe financial loss, legal issues, or safety incidents.
- Demands urgent, comprehensive mitigation and contingency planning.

Possibility & Impact

- The possibility factor of a risk matrix is defined from 1-5, where 1 indicates very unlikely, and 5 very likely.
- The impact factor of a risk matrix is also defined from 1-5, where 1 indicates very low impact, and 5 very high impact.

Risk assessment See the risk assassment the team made below (See figure RiskAssassment).

Table 10: Risk Assessment Matrix

Type of risk	Risk	Possibility (1-5)	Impact (1-5)	Risk Score (PxI)	Risk Level	Mitigation Strategy
Technical	Sensor failure: Incorrect water routing	3	4	12	High	Use reliable sensors, use counter-acting valves to have a 'standard position', regular testing
Technical	Microcontroller failure	2	5	10	High	Use reliable microcontroller, use of water protected casing
Installation	Compatibility issues with fixtures	3	3	9	Medium	Clear documentation, test on multiple models, adaptable fittings
Installation	Water leaks from poor installation	3	4	12	High	Quality connectors, detailed guides, installation testing
Safety	Melting/Overheating due to poor materials	2	4	8	Medium	Flame-retardant materials, good ventilation

Type of risk	Risk	Possibility (1-5)	Impact (1-5)	Risk Score (PxI)	Risk Level	Mitigation Strategy
Safety	Electrical hazards (shock risk)	2	5	10	High	Professional installation, separate voltages, follow safety standards, use waterproof casing
Procurement	Orders not arriving on time	2	5	10	High	Choosing trusted vendors, with good stock
Procurement	Components not available in stock	3	5	15	High	Choosing alternative vendors with fast delivery times
Communication	Miscommunication	4	4	16	High	Clear roles in the group, as well as briefings to make sure everyone is informed

3.8 Procurement

The project's procurement plans have been based on a list of external sources of webshops for the components. Due to the wide variety of needed components we decided on purchasing the components from different websites. Since the procurement is an important part, there is also a need to define rules regarding the suppliers, time limits, and the possibility of locking a price contract with the selected suppliers, another important thing to keep in mind is to also have trusted backup suppliers in case the primary suppliers stock runs out.

The valves are going to be acquired from Digikey due to their good high quality selection of products.

The procurement strategy is based on table 11, in which are stated primary suppliers as well as back-up suppliers.

Table 11: Primary as well as backup suppliers

Component	Digikey	PTRobotics	Farnell	RS Components	Leroy Merlin	Foxschandlery	Factory Made	Fruugo	Time Requirement	Cost (€)	Quantity
Valve NO	Primary		Backup						2–5 days	626.86	2
Valve NC	Primary		Backup						2–5 days	184.72	2
Copper pipe					Backup	Primary			2–5 days	6.82	1
Microcontroller		Primary	Backup						2–5 days	11.75	1
Float switch	Primary	Backup							2–5 days	2.28	2
Relay	Backup	Primary							2–5 days	3.69	3
Temperature sensor	Backup	Primary							2–5 days	5.35	1
Voltage regulator	Backup	Primary							2–5 days	7.32	1
T pipe fitting					Primary	Backup			2–5 days	1.78	1
Male push-in fitting				Primary	Backup				2–5 days	11.67	3
Female push-in fitting				Primary	Backup				2–5 days	24.27	3
Bulkhead G3/8				Primary	Backup				2–5 days	27.02	2

Component	Digikey	PTRobotics	Farnell	RS Components	Leroy Merlin	Foxschandlery	Factory Made	Fruugo	Time Requirement	Cost (€)	Quantity
Thread adapter				Primary	Backup				2–5 days	22.17	3
Case							Primary		7 days	31.00	1
Protective corner tape					Backup			Primary	2–5 days	17.95	1

3.9 Stakeholders Management

Stakeholder management refers to the identification, analysis, engagement, and continuous communication with individuals or organizations that can affect or be affected by the project. Effective stakeholder management is essential to ensure that the project runs smoothly, meets expectations, and achieves its goals within the required scope, time, and budget. (See Figure 11).

Key Stakeholders in Our Project:

Team members

-Responsible for designing, prototyping, testing, and reporting.

-Key for innovation, decision-making, and implementation.

-Regular internal meetings to align progress and resolve issues.

Project Supervisor (EPS Coordinator)

-Provides guidance, feedback, and ensures academic requirements are met.

-Acts as a communication link with the institution and faculty.

-Reviews deliverables and gives approval for project milestones.

ISEP / Hosting Institution

-Offers resources such as laboratory space, tools, and technical support.

-Ensures a safe and professional learning environment.

-Provides deadlines, academic structure, and evaluation criteria.

Clients / End Users

-Potential beneficiaries of the solution (e.g. homeowners, building developers, facility managers).

-Their needs influenced the design choices (e.g. water-saving functionality, usability).

-Feedback was considered during the initial design phase.

Technical Advisors / Mentors

-Offer domain-specific expertise (e.g. plumbing, electronics, automation).

-Help troubleshoot technical challenges and validate solutions.

-Occasionally consulted throughout the development process.

Suppliers / Manufacturers

-Provide components (e.g. valves, microcontrollers, relays).

-Delivery time and product quality affect project schedule and functionality.

Stakeholder Group	Role in Project	Interest	Power	Engagement Strategy
Team Members	Development, implementation	High	High	Fully involved in all phases
EPS Supervisor	Academic guidance, quality assurance	Medium	High	Frequent reviews and feedback
ISEP (Institution)	Resource provider, institutional oversight	Low	Medium	Periodic updates on progress
End Users (Clients)	Benefit from system functionality	High	Low	Considered during design, testing impressions
Installers / Technicians	Responsible for real-world setup	Medium	Medium	Clear documentation and install instructions
Suppliers	Provide hardware components	Low	Low	Early communication and specification checks

Figure 11: Stakeholders overview

Engagement Strategy:

-Weekly team meetings and progress reviews.

-Midterm and final presentations for feedback from ISEP faculty and peers.

-Email and face-to-face communication with mentors and supervisors.

-Documentation and progress updates via shared platforms (e.g. Google Drive, Teams).

-Prototypes and testing results shared for validation before final implementation.

Risk Mitigation Related to Stakeholders:

-Regular communication to prevent misunderstandings or delays.

-Clear role distribution and responsibilities among team members.

-Early involvement of advisors to validate design feasibility.

-Continuous feedback loops to ensure alignment with stakeholder expectations.

3.10 Project Plan

The team has a global sprint plan (See figure 12).

Table 12: Global Sprint Plan

Sprint	Start	Finish	Working days
1	27 february	5 march	3 days of availability
2	6 march	12 march	5 days of availability
3	13 march	19 march	5 days of availability
4	20 march	26 march	5 days of availability
5	27 march	2 april	5 days of availability
6	3 april	9 april	5 days of availability
7	10 april	16 april	5 days of availability
8	17 april	23 april	0 days of availability
9	24 april	30 april	3 days of availability
10	1 may	7 may	2 days of availability
11	8 may	14 may	3 days of availability
12	15 may	21 may	5 days of availability
13	22 may	28 may	5 days of availability
14	29 may	4 june	5 days of availability
15	5 june	11 june	4 days of availability
16	12 june	18 june	5 days of availability

The team got a project backlog in the briefing, which they should finish by the end of the semester (See figure 13).

Table 13: Project Backlog

PBI	Title	Status
A	Define project	Done
B	System diagrams and structural plans	Done
C	Project Backlog	Done
D	State of the Art	Done
E	Gantt chart	In progress
F	System Diagrams and Drafts	Done
G	Global sprint plan	In progress
H	List of Components and Materials	Done
I	Schematics and Structural Drawings	Done
J	Design development	Done
K	Interim deliverables	Done
L	3D model and video	Done
M	Interim Report and Presentation	Done
N	Functional Testing	Done
O	Packaging solution	To do
P	Poster	To do
Q	Folder and manual	To do
R	Brochure and Leaflet	To do
S	Prototype	Done
T	Video	To do
V	Final report	To do
W	Upload Final Deliverables	To do

PBI	Title	Status
X	Final presentation	To do
Y	Final Review and Submission	To do

Table 14: Sprint Plan

Sprint	Task	Duration (d)	Responsible	Involved
1	A	2	All	All
2	B,C,D	3	All	All
3	E,F,G,H	5	All	All
4	I,J	3	All	All
5	B,F,O	5	All	All
6	L,K	2	All	All
7	H,K,L	4	All	All
8	O,P,R,S	4	All	All
9	B,I,S,H	5	All	All
10	J,S	3	All	All
11	J,N,S,Q	4	All	All
12	J,L,S,P	4	All	All
13	S,L,M	5	All	All
14	S,L,V	3	All	All
15	N,S,V,Q	3	All	All
16	N,S,T,X	4	All	All

Table 15: Project Progress Register

Sprint	PBI	Responsible	Involved	Status
1	A	All	All	Done
2	B,C,D	All	All	Done
3	E,F,G,H	All	All	Done
4	I,J	All	All	Done
5	B,F,O	All	All	Done
6	L,K	All	All	Done
7	H,K,L	All	All	Done
8	O,P,R,S	All	All	Done
9	B,I,S,H	All	All	Done
10	J,S	All	All	Done
11	J,N,S,Q	All	All	Done
12	J,L,S,P	All	All	Done
13	S,L,M	All	All	Done
14	S,L,V	All	All	Done
15	N,S,V,Q	All	All	Done
16	N,S,T,X	All	All	In progress

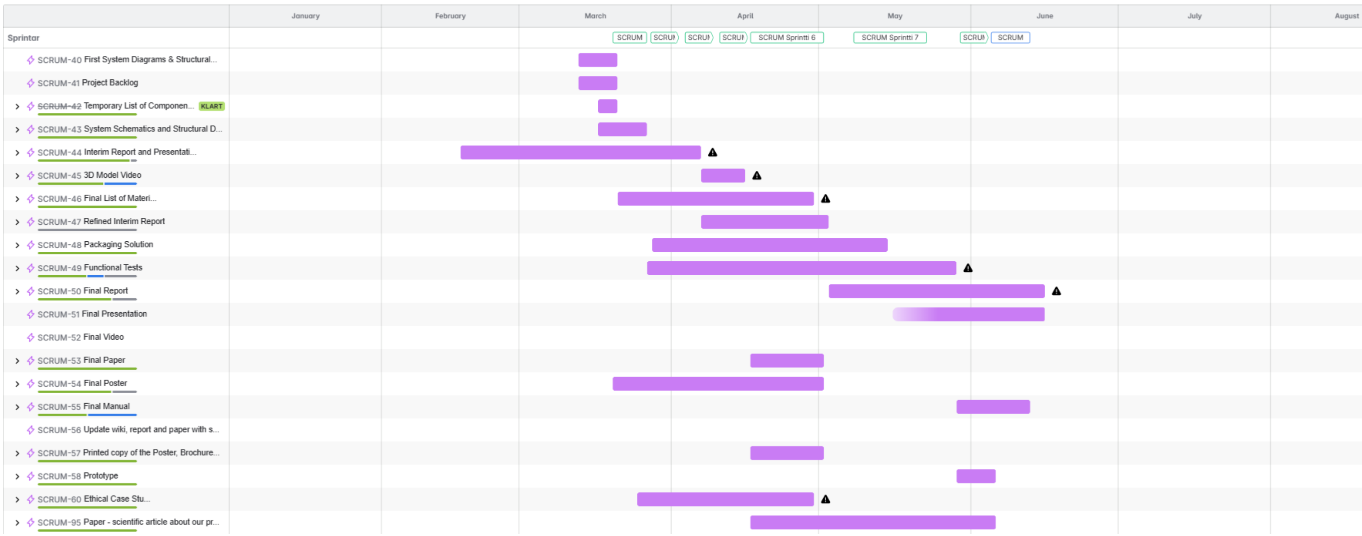

Figure 12: Sprint overview

3.11 Sprint Outcomes

3.11.1 Sprint 1 – Team Formation and Problem Exploration

During the first sprint, the team focused on team building and brainstorming. They explored various everyday problems and discussed ideas on how technology could help improve daily life. One recurring theme was the waste of clean cold water while waiting for hot water in the shower. This led to ideas about how water consumption could be reduced in households.

Sprint 1 – Burnup chart (See figure 13)

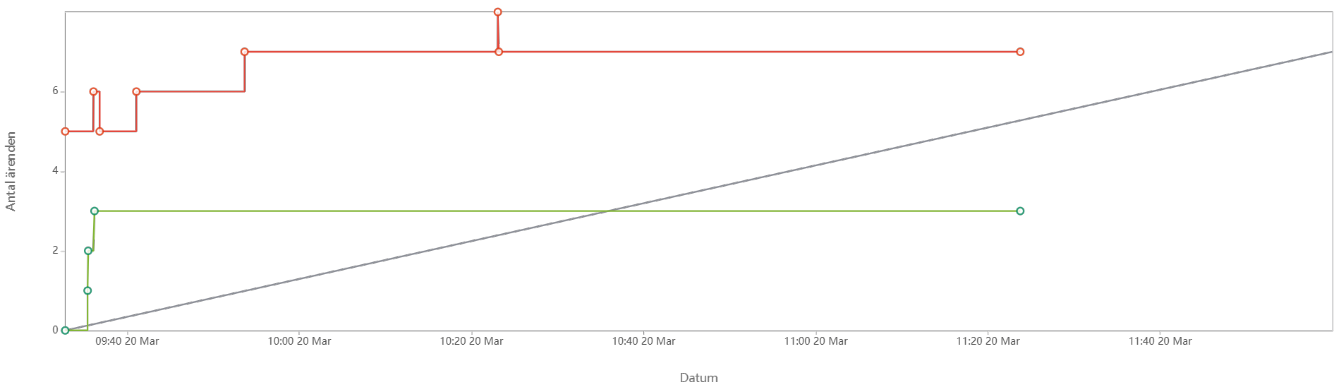

Figure 13: Burnup chart 1

Sprint end status: The project was succesfully defined, and all of the tasks were completed successfully. Planned velocity for this sprint was 7 tasks, and achieved velocity was 7 tasks.

3.11.2 Sprint 2 – Concept Development

In the second sprint, the team deepened their understanding of the water waste issue. The initial idea was to capture the cold water that runs before hot water arrives in the shower, and somehow reuse it. One early idea was to return the cold water to the boiler. The team began to research water flow, temperature sensors, and basic plumbing systems to assess feasibility.

Sprint 2 – Burnup chart (See figure 14)

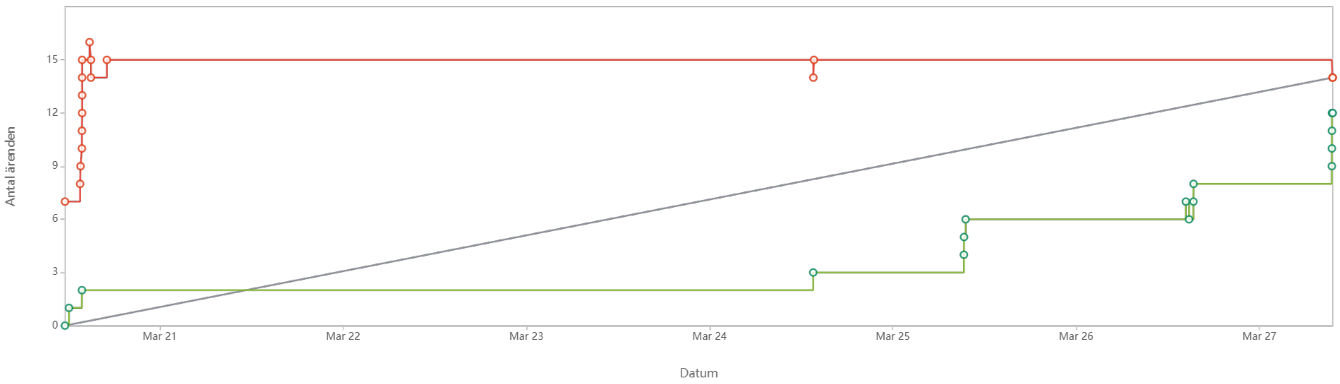

Figure 14: Burnup chart 2

Sprint end status: The making of initial system diagrams, structural plans were started, and the project backlog as well as the state-of-the-art analysis was completed. Planned velocity for this sprint was 15 tasks, and achieved velocity was 15 tasks.

3.11.3 Sprint 3 – Solution Decision and Naming

During the third sprint, the team made a key decision: the cold water would be routed to the toilet flush tank instead of being wasted. This concept combined simplicity and functionality. The project got the name “AzuLoop”. The focus then shifted to identifying necessary components, such as valves, sensors, and control logic. The team also started drafting basic system diagrams.

Sprint 3 – Burnup chart (See figure 15)

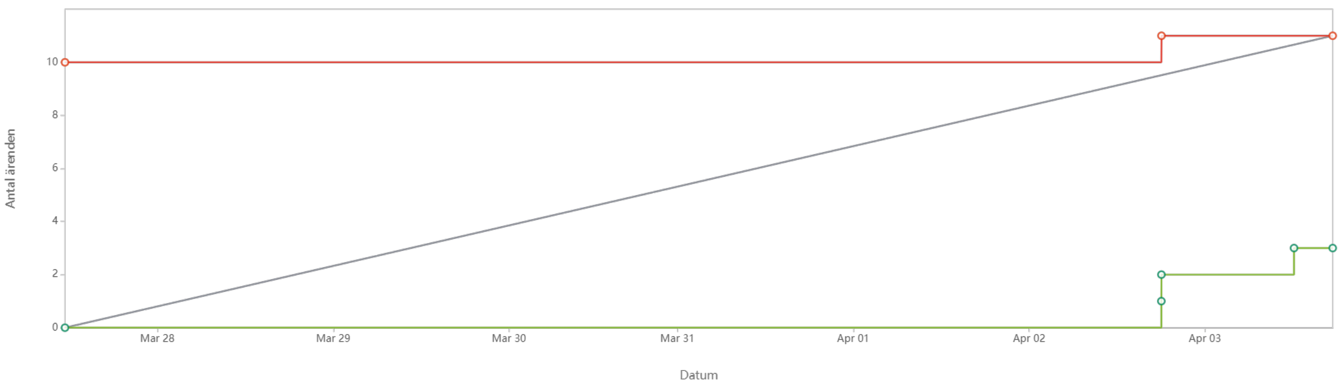

Figure 15: Burnup chart 3

Sprint end status: The gant chart, global sprint plans were all completed. Planned velocity for this sprint was 13 tasks, and achieved velocity was 13 tasks.

3.11.4 Sprint 4 – Design Development and Component Collection

In the fourth sprint, the team refined the system design and created electrical diagrams. They confirmed how the logistics will work and finalised the list of components.

Sprint 4 – Burnup chart (See figure 16)

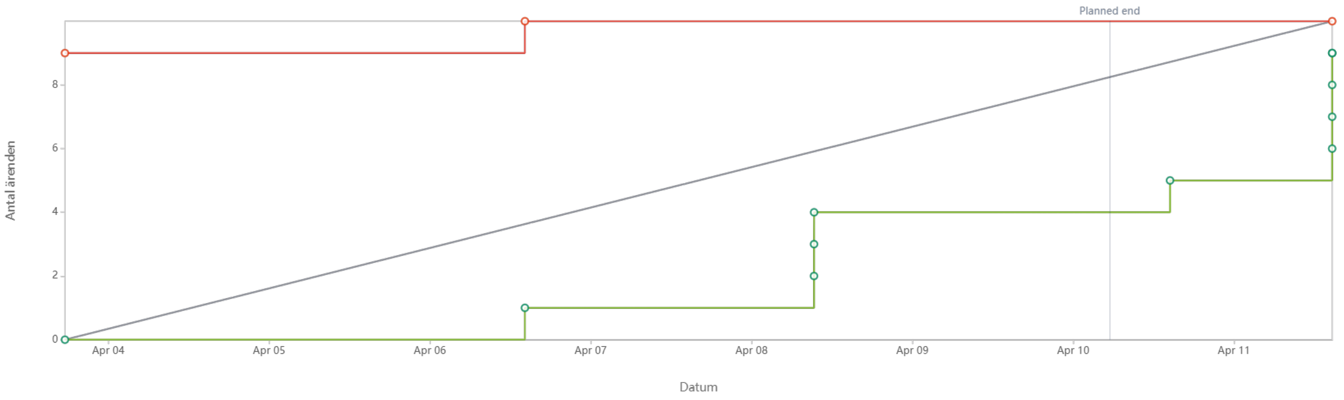

Figure 16: Burnup chart 4

Sprint end status: Schematics and structural drawings were completed for the time being, the team also started thinking about the designing. Planned velocity for this sprint was 10 tasks, and achieved velocity was 10 tasks.

3.11.5 Sprint 5 – Redesigning and rethinking

In the fifth sprint the team changed the product. They decided to redesign and create a product to redirect the cold water from the shower to the toilet tank. Also the cardboard model was done, which helped to get a visual image of the actual product. The team updated the components list for the prototype.

Sprint 5 – Burnup chart (See figure 17)

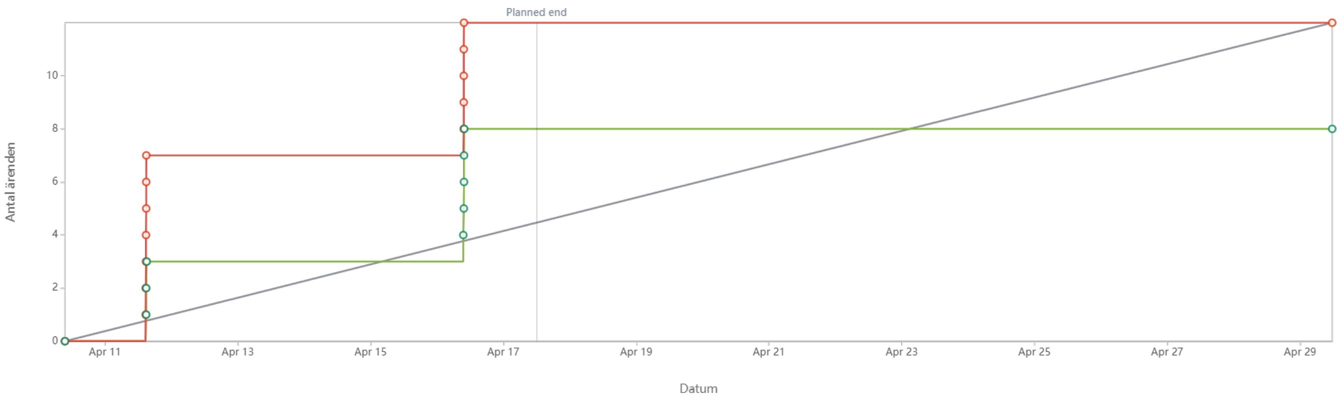

Figure 17: Burnup chart 5

Sprint end status: New revisison for the system diagrams and schematics were completed after receiving feedback about the current version. Planned velocity for this sprint was 12 tasks, and achieved velocity was 12 tasks.

3.11.6 Sprint 6 - Refining the interim report

In the sixth sprint, the team made the 3D model for the product, and started refining the interim report as asked. They also calculated the product cost and the expected cost of operation.

Sprint 6 - Burnup chart (See figure 18)

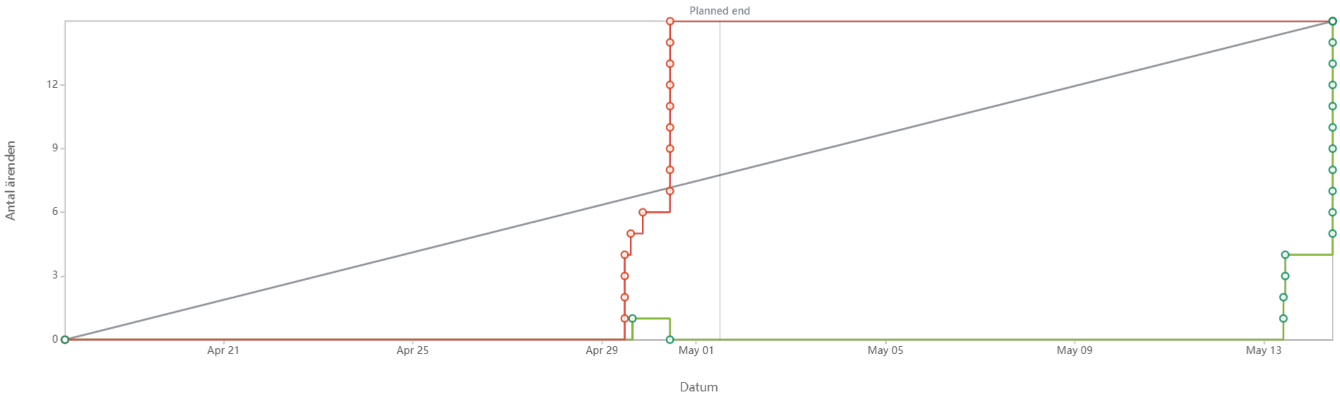

Figure 18: Burnup chart 6

Sprint end status: The initial interim deliverable tasks were started. Planned velocity for this sprint was 15 tasks, and achieved velocity was 15 tasks.

3.11.7 Sprint 7 - 3D modeling and component joining & electrical connection

During the seventh sprint finished the final component list for the product, finalised the interim report and improved the cost calculation.

Sprint 7 - Burnup chart (See figure 19)

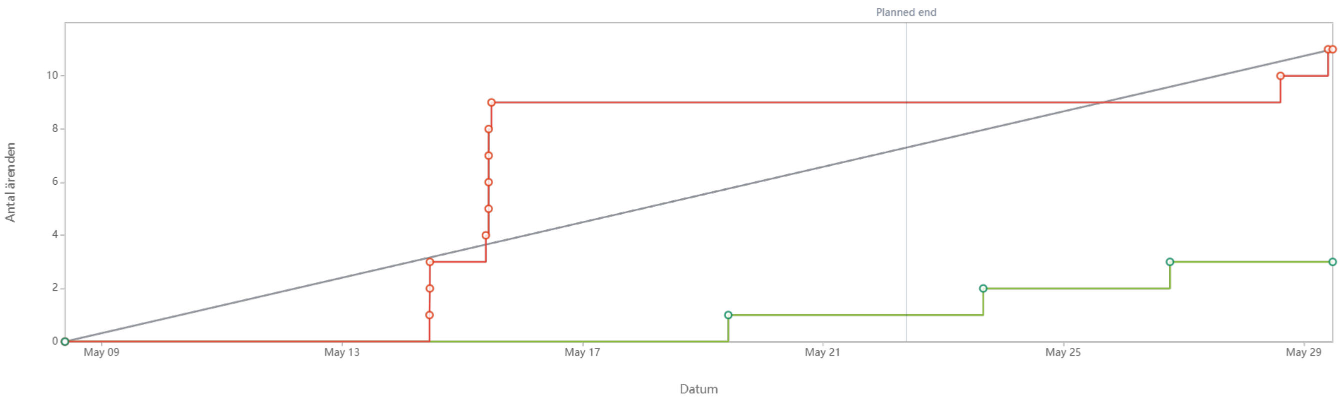

Figure 19: Burnup chart 7

Sprint end status: The research of components and materials for the prototype were started, interim deliverables were prepared, and the 3D model and video were completed. Planned velocity for this sprint was 11 tasks, and achieved velocity was 11 tasks.

3.11.8 Sprint 8 - Graphic & Packaging design

In the eighth sprint the team uploaded the leaflet and the poster, the first paper abstract version and the proposed packaging solution.

Sprint 8 - Burnup chart (See figure 20)

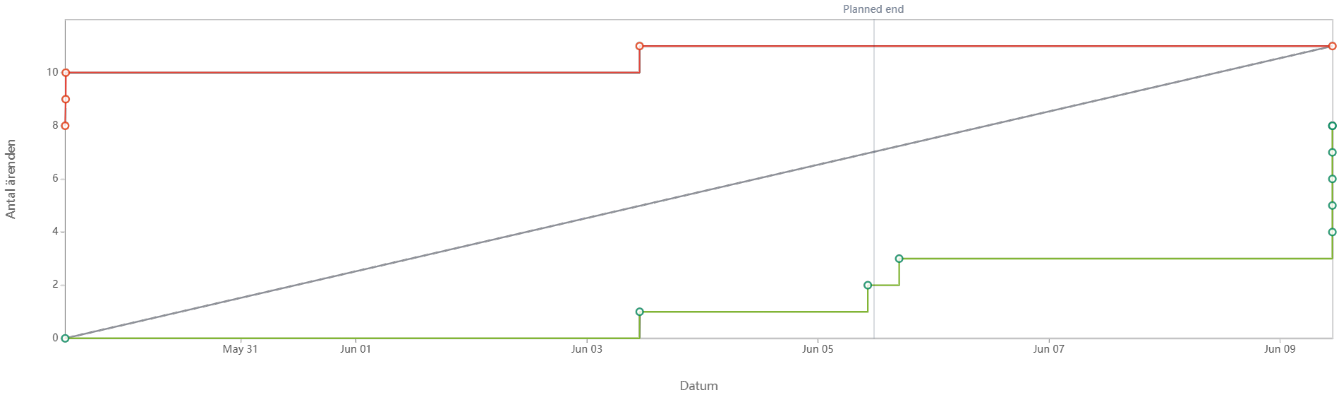

Figure 20: Burnup chart 8

Sprint end status: The packaging solution, poster, brochure, and leaflet were developed. Planned velocity for this sprint was 11 tasks, and achieved velocity was 11 tasks.

3.11.9 Sprint 9 - Project planning for prototype

During the ninth sprint, the team successfully managed to plan the prototype's hardware and software configuration and also managed to order the parts for it before Easter break.

Sprint 9 - Burnup chart (See figure 21)

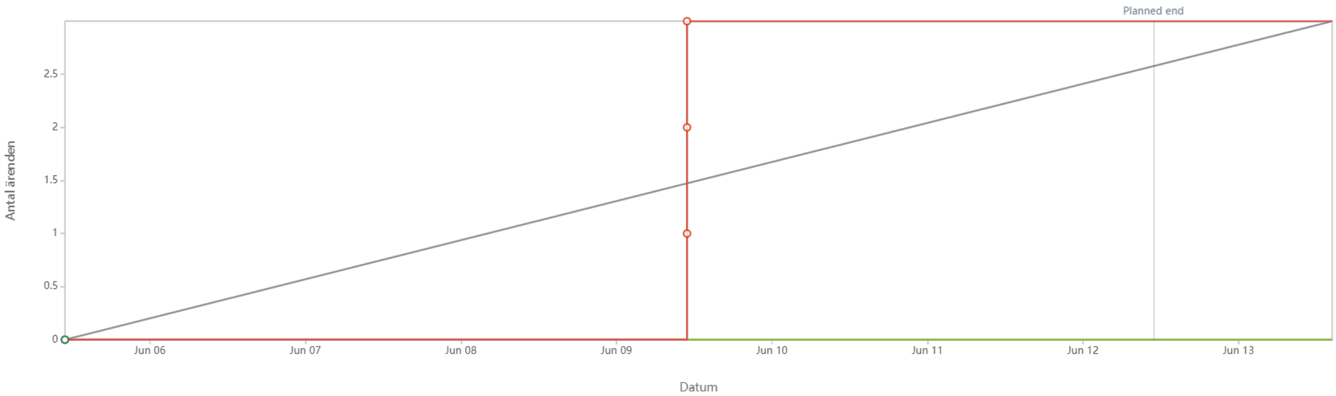

Figure 21: Burnup chart 9

Sprint end status: System diagrams and schematics and were controlled for the prototype, and the list of components and materials were all refined and completed again.

3.11.10 Sprint 10 - Prototype & scientific paper

During the tenth sprint, the team started assembling and soldering the components they had and they started coding the prototype. Because of the missing components they were a little behind with the prototype assembling. The first and second chapter of the scientific report were also submitted, for sprint 10 there is no burnup chart available.

Sprint end status: Design development continued after new feedback, and we did some more research and building of the prototype.

3.11.11 Sprint 11 - Prototype & scientific paper

During the eleventh sprint, the team assembled the components of the prototype (pipes and electrical components), but they had some problems with the coding and electronic components. For sprint 11 there is no burnup chart available.

Sprint end status: The team managed to assemble the hardware for the protoype, but ran into setbacks with the coding of the microcontroller.

Sprint end status: Functional testing of the electrical components and pressurization test of the system was done, and the manual was made.

3.11.12 Sprint 12 - Prototype & scientific paper

During the twelfth sprint the team started doing technical documenting work regarding the prototype, the team did not yet receive a functioning powersupply, and therefore we could not achieve much further progress. For sprint 12 there is no burnup chart available.

Sprint end status: The team managed to successfully complete the technical documenting work, but ran into setbacks regarding the malfunctioning powersupply.

3.11.13 Sprint 13 - Prototype & scientific paper

During the thirteenth sprint the team continued the report writing, as well as doing correction work for the report, the microcontroller also got damaged presumably by overvoltage or overcurrent, causing further delays with the functional testing part.

For sprint 13 there is no burnup chart available.

Sprint end status: The team managed to do significant progress with the coding as well as report corrections, but ran into a setback with a malfunctioning microcontroller, and therefore could not proceed with the prototype development.

3.11.14 Sprint 14 - Prototype & scientific paper

During the fourteenth sprint, the team received a functioning power supply and we managed to complete the assembly of the prototype, but they had a problem with the thermostat for the water distribution controlling, and therefore we couldn't complete all of the functional tests. For sprint 14 there is no burnup chart available.

Sprint end status: The team managed to get a new microcontroller and do the programming, but we ran into a setback with the thermostat, otherwise everything was going as planned.

3.11.15 Sprint 15 - Assembly of prototype and functional testing

During the fifteenth sprint, the team successfully managed to fix the microcontroller and the temperature measurement, after which the prototypes functional tests were succesfully completed, the team also managed to do significant progress with the scientific report writing.

For sprint 15 there is no burnup chart available.

Sprint end status: The team managed to successfully get the prototype working, and successfully completed the functional tests with success, also the scientific report was completed.

3.11.16 Sprint 16 - Report writing and completion of final deliverables

For sprint 16 there is no burnup chart available.

Sprint Evaluations

Sprint 1:

Positive: Good communication and open idea exchange within the team.
Negative: It took time to agree on which problem to focus on.
What to improve on: Early team alignment is essential for smooth progress later.
Start doing: Align early on the main problem to solve.
Stop doing: Waiting too long to reach consensus.
Keep doing: Encouraging open communication and idea sharing.

Sprint 2:

Positive: Solid concept development and active engagement in discussions.
Negative: We had some mixed opinions on what we should work on.
What to improve on: Let everyone know your opinions.
Start doing: Clearly express and explain individual opinions.
Stop doing: Avoiding disagreement—differences can lead to better solutions.
Keep doing: Actively participating in team discussions.

Sprint 3:

Positive: A clear technical direction was established, and the project got its name, AzuLoop.
Negative: As a team everyone agreed that some are working more than others and the work should be more balanced.
What to improve on: Work better as a team. Communication should be a lot better within the whole group.
Start doing: Assign tasks more fairly and communicate expectations.
Stop doing: Letting workload fall unevenly across members.
Keep doing: Defining direction and making big decisions as a team.

Sprint 4:

Positive: We successfully gathered the necessary parts and had better communication.
Negative: Workload was still unbalanced even though having better communication.
What to improve on: More documenting, more communication and teamwork. Balance the workload.
Start doing: Document work and decisions more thoroughly.
Stop doing: Assuming others know who’s doing what.

Keep doing: Working on improving communication.

Sprint 5:

Positive: We successfully managed to create the 3d-model.
Negative: Workload was unbalanced.
What to improve on: More open communication, more briefing.
Start doing: Hold regular briefings to keep everyone updated.
Stop doing: Letting communication drop between work sessions.
Keep doing: Making steady technical progress.

Sprint 6:

Positive: We successfully managed to plan and order parts for the prototype.
Negative: Workload was unbalanced.
What to improve on: More direct communication, as well as more briefing, in order to prevent misunderstandings.
Start doing: Use more direct communication and clarify roles.
Stop doing: Relying on assumptions instead of briefings.
Keep doing: Making clear progress on the prototype.

Sprint 7:

Positive: We successfully managed to finish all the tasks within the deadlines.
Negative: We had to correct several times a task that could have been correct the first time.
What to improve on: We should improve teamwork and communication.
Start doing: Double-check work and give early feedback.
Stop doing: Rushing tasks without review.
Keep doing: Meeting deadlines consistently.

Sprint 8:

Positive: We successfully created a packaging solution and poster for the product.
Negative: Workload was unbalanced again.
What to improve on: Try to help when other teammates have a big workload.
Start doing: Offer help to overloaded teammates.
Stop doing: Working isolated from the team.
Keep doing: Delivering high-quality outputs on time.

Sprint 9:

Positive: We made the deadline for ordering the components for the prototype.
Negative: Didn't get far with the wiki page.
What to improve on: Keep working on the report even when the deadline isn't close.
Start doing: Allocate time to documentation early.
Stop doing: Postponing wiki/report work until the last minute.
Keep doing: Meeting operational deadlines.

Sprint 10:

Positive: We started working and planning the prototype and managed to work on the scientific paper.
Negative: We didn't get all the components needed for the prototype so we didn't get far with it.
What to improve on: Planning next steps ahead.

Start doing: Plan further ahead to avoid delays.
Stop doing: Relying on last-minute solutions for essential parts.
Keep doing: Advancing both practical and theoretical aspects.

Sprint 11:

Positive: We came far with the prototype and finished the tasks the teachers asked us to do.
Negative: Not all the team members were here.
What to improve on: Work on the project even when we are at home or on vacation.
Start doing: Stay engaged even when remote or on vacation.
Stop doing: Letting physical absence mean disengagement.
Keep doing: Completing assigned tasks and building the prototype.

Sprint 12:

Positive: We got some documentation work done. Negative: Not all team members were here, not all of our components were working. What to improve on: Work on the project even when we are at home or on vacation. Start doing: Stay engaged even when remote or on vacation, start backup -planning. Stop doing: Letting physical absence mean disengagement. Keep doing: Completing assigned tasks effectively and always take notes.

Sprint 13:

Positive: We got a lot of documentation work done. Negative: Microcontroller failed, causing further delays. What to improve on: More open delegation of tasks within the group. Start doing: Plan further ahead to avoid delays. Stop doing: Relying on last minute-solutions for essential parts. Keep doing: Documentation work.

Sprint 14:

Positive: We successfully managed to assemble the rest of the hardware for the prototype, and do pressurization and electrical tests. Negative: Workload was unbalanced, malfunctioning sensor. What to improve on: More open delegation of tasks within the group. Start doing: Start doing documentation work if there is nothing else to do. Stop doing: Let work tasks pile up. Keep doing: Work with the prototype.

Sprint 15:

Positive: We successfully finished the prototype and got the functional tests completed with success, also we got a lot of piled up documentation work done. Negative: We let a lot of documentation work pile up, Not all team members were attending. What to improve on: Keep on doing documentation work if there's nothing else to do. Start doing: Taking notes in order to remember the sprint progress details, work on the project even when we are at home or on vacation. Stop doing: Let background work tasks pile up instead of progressing forward little by little. Keep doing: Working with documentation, Keep open team discussions.

Sprint 16:

Positive: Negative: What to improve on: Start doing: Stop doing: Keep doing:

3.12 Summary

This chapter explains how the team manages their project from the start. The goal was to develop a simple and efficient solution to reduce cold water waste in households. To do this, they applied basic project management tools to organize the work, divide responsibilities according to group members skills, and track the progress.

The team started by clearly defining the scope of the project and the resources available. An estimation of the time needed was made, considering the costs of components, and making sure the right people were assigned to different tasks. Each team member contributed to the work based on their own strengths and background.

Risk management was also an important part of the process. The team identified possible issues early on such as technical failures, installation problems, or safety concerns. This helped for better preparation and avoiding surprises during development.

The team also paid attention to stakeholders, including users, supervisors, and suppliers. Understanding their roles and expectations helped to focus on what matters most and make better decisions during the project.

As the work progressed, the team created technical plans, adjusted our design according to needs and feedback, and gathered the necessary parts. Communication within the team is super important, it makes the work smoother and more efficient.

In the end, good planning, teamwork, and clear goals helped to stay on track and keep the scope focused.

In the next chapter, the team focuses on the marketing strategy of AzuLoop.

Ultimately through applying the agile project management principles and distributing the work between the team members the team finally managed to successfully make the prototype work during sprint number 9.

4. Marketing Plan

4.1 Introduction

How will AzuLoop introduce and grow as an innovative product in the market? This chapter will explain the strategies and tactics.

The purpose of this plan is to provide a clear overview of AzuLoop’s marketing approach, taking into account the current market environment and the project’s objectives. It includes an analysis of the market, an evaluation of AzuLoop’s strengths and weaknesses, opportunities and threats, the chosen strategy with segmentation, targeting, and positioning, as well as the marketing mix, branding, marketing programs, and control mechanisms.

4.2 Business Idea Formulation

The core of the AzuLoop project is addressing water waste caused by people letting cold water run down the drain while waiting for warm water during a shower. The business idea presents a solution in the form of a device that is installed between the water mixer and the showerhead. This device measures the water temperature and stops the flow to the showerhead until the desired temperature is reached. This idea aligns with the marketing concept, which focuses on identifying and fulfilling customer needs as effectively as possible. Instead of wasting the cold water, it is redirected to an additional tank above the toilet reservoir where it will be used to flush the toilet. This means that water only comes out of the showerhead when the desired temperature is reached and no cold water is being wasted through the drain.

4.3 Business Model

The Business Model Canvas (BMC). See Figure 22. Is a strategic tool used to visualize and analyze how a business creates, delivers, and captures value. It provides a structured approach to developing and refining a business model by breaking it down into nine key building blocks:

Value Creation:

- Value Proposition: The main value the business offers to customers.
- Customers: The different groups of people the business serves.
- Channels: The ways the product or service reaches customers.
- Customer Relationships: How the business interacts with and retains customers.

Operations:

- Key Activities: The essential tasks required to run the business.
- Key Resources: The assets needed to operate successfully.
- Key Partners: External organizations that support the business.

Finances:

- Revenue Streams: The ways the business earns money.
- Cost Structure: The main expenses required to operate.

By using the BMC, businesses can identify strengths, address weaknesses, and make informed decisions to improve efficiency and growth.

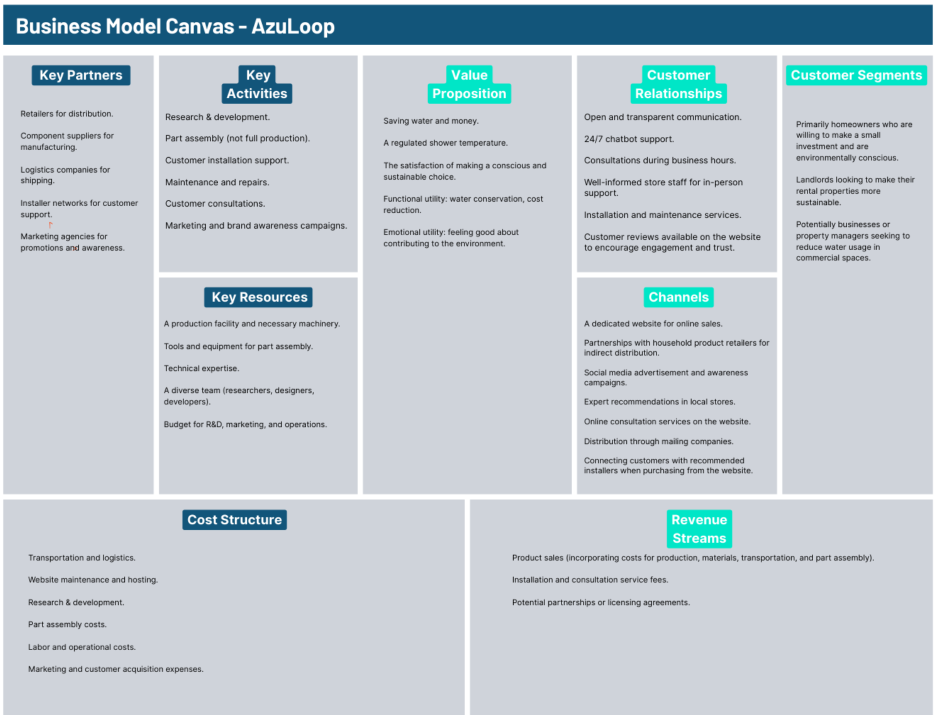

Figure 22: Business Model Canvas

4.4 Market Analysis

Macro Environment (PESTEL Analysis)

- Political: Many governments are introducing regulations to promote water conservation and sustainability. Some provide financial incentives or tax benefits for installing water-saving products, which could make AzuLoop more attractive to buyers. For instance, in the United States, the IRS offers tax credits for certain energy-efficient home improvements, including water-saving technologies. From 2023 through 2032, homeowners can claim a tax credit of up to 30 % of qualified expenses, with a maximum annual credit of 1 200 USD for energy-efficient property and certain home improvements **[IRS, 2025]**. EPA's WaterSense program funds projects that install low-flow showerheads and faucets **[Ever Flow Bidets, 2025]**.
- Economic: Rising water costs encourage consumers to look for long-term savings. AzuLoop offers a cost-effective solution by reducing water waste, making it a valuable investment for homeowners and businesses **[Joe Eaton, 2023]**.
- Social: Awareness of environmental issues is increasing, and more consumers are prioritizing sustainability in their purchasing decisions. Younger generations, in particular, are willing to invest in eco-friendly home solutions **[Xebina Hasnee, 2025]**.
- Technological: Advances in smart home technology and water recycling systems provide opportunities for AzuLoop to integrate with existing innovations, improving product appeal and functionality **[Rusé, 2025]**.
- Environmental: Climate change and water shortages are pushing governments and individuals to adopt water-saving solutions, making AzuLoop a relevant and timely product **[Sanjana Gajbhiye, 2025]**.
- Legal: Regulations requiring water-efficient systems in homes and businesses are becoming more common. Future legal requirements may further increase demand for products like AzuLoop. For example: In Australia, the Water Efficiency Labelling and Standards (WELS) scheme regulates products such as taps, toilets, and dishwashers, requiring them to meet

specific water efficiency standards. This program saves significant amounts of water annually and reduces utility costs for households **[Autralian Government, 2025]**.

Customer Segments & Marketing Personas

AzuLoop targets individuals and businesses looking to reduce water consumption and promote sustainability.

Customer Segments

- Eco-Conscious Homeowners: Individuals who prioritize sustainability and want to reduce their environmental impact while saving on water bills.
- Landlords & Property Managers: Owners of rental properties who want to increase the value of their property and attract environmentally conscious tenants.

Marketing Personas

Emma, the eco-conscious homeowner

Emma is 32 years old and has been passionate about sustainability since a very young age. She has always followed sustainability influencers on social media platforms, she reads reviews and shares her experience online. Ever since she got a steady income and bought her own house, she was constantly seeking for eco-friendly solutions in her home. She is even willing to invest in products or systems that promote sustainable behaviour, as long as they are functional and aesthetically pleasing. Although she cares a lot about the environment, she also has to combine her vibrant social life with a big workload at her job, which means that eco-friendly alternatives in her household cannot take up any more time or change her daily routine too much.

David, the smart investor

David owns a few apartments in Bonfim, an upcomming and trendy neighbourhood for young families in Porto. He is interested in sustainability, but mainly focusses on easy to install and low maintenance solutions that reduce water and energy costs over time. He is willing to invest in these kind of solutions if he could increase the value of his property and attract conscious tenants who are looking for sustainable living spaces.

Stakeholders & Retail Channels

AzuLoop will be sold through direct and retail partnerships while avoiding large online marketplaces to maintain brand control.

- AzuLoop’s Own Website: Direct sales through the official website, ensuring customer support and engagement.
- Retail Stores: In contract with home improvement and sustainability-focused stores which allows customers to view the product physically before they make the purchase.
- Retail Store Websites: Some of these partnered stores could offer AzuLoop on their own websites, this raises awareness about the brand for people who don't know AzuLoop yet.

Geographic Market

AzuLoop will target regions where costumers are more likely to invest in water-saving solutions.

- Western Countries: Europe, North America, and Australia, where plumbing standards support AzuLoop’s technology and sustainability awareness is high.
- China & Other Emerging Markets: Countries with a strong base of young, environmentally conscious consumers who are open to adopting innovative green technologies **[M. et al. Masukujjaman A. Al Mamun Y. Hong, 2024]**.

- Water-Scarce Regions: Areas experiencing frequent droughts or water shortages, where water-saving solutions are in high demand.

The competitive analysis has already been discussed in the State of the Art chapter and will be further elaborated on in the “Positioning” chapter.

4.5 SWOT Analysis

The SWOT analysis of AzuLoop identifies its strengths, weaknesses, opportunities, and threats (See figure 23).

Figure 23: SWOT Analysis

4.6 Strategy

AzuLoop's strategy is based on the STP method (Segmentation, Targeting, Positioning).

4.6.1 Strategic Objectives

AzuLoop's strategic objectives fall into three main categories:

Economic Objectives:

- Develop an efficient and sustainable product.
- Offer the best possible product at a reasonable price, based on production costs.
- Make a positive environmental impact by reducing water waste.

Customer-Oriented Objectives:

- Raise awareness about water waste and the importance of sustainability.
- Give users a high-quality product that helps them save water.
- create a user-friendly experience which includes easy installation and an automatic operation without any huge behavioural changes.

Technological Objectives:

- Create a reliable and effective device that can measure the water temperature accurately.
- Ensure the system correctly redirects water to maximize efficiency and savings.

4.6.2 Segmentation and Targeting

AzuLoop's market segmentation is based on several criteria:

- Geographic Segmentation: Focus on countries with Western-style toilets (as opposed to squat toilets) and regions where water scarcity is a pressing issue.
- Demographic Segmentation: Targeting homeowners and landlords with a stable income, aged 30 to 80, who are environmentally conscious and willing to invest in sustainable solutions.
- Psychographic Segmentation: Aiming at consumers who lead a sustainable lifestyle, aligning with values such as customer satisfaction and loyalty.
- Behavioral Segmentation: People could potentially be segmented by their behaviour on the level of awareness about environmentally changes and their willingness to adopt new technologies.

AzuLoop’s target market consists of eco-conscious homeowners and landlords within the identified geographic and demographic segments, with a strong emphasis on sustainability-minded consumers. An important subsegments are millennials because their focus on sustainability is increasing rapidly.

4.6.3 Positioning

AzuLoop positions itself as a user-friendly and highly effective water-saving solution. When AzuLoop is compared to other water saving methods, they may require active effort from the user or offer limited savings, while AzuLoop differentiates itself as a simple, automated, and sustainable solution (See figure 24).

Key Differentiators:

- No behavior change required: once installed, users save water effortlessly.
- Bundled services: AzuLoop includes installation and potential maintenance to enhance convenience.
- Direct environmental impact: immediate reduction in water waste.
- Psychological positioning: Consumers feel good about making an eco-friendly choice.

Figure 24: Perceptual map

Although AzuLoop might not save as much water as other water-saving solutions, it has the advantage that all the water coming through the showerhead is actually used. Other solutions like the shower regulator or faucet aerator mainly focus on providing a softer flow or shorter showers, but the cold water that comes out of the shower is still wasted, and in some cases, it even takes longer to reach the desired temperature.

The main differentiator of AzuLoop is its ease of use. The user does not need to worry about the installation and can confidently turn on the tap without experiencing a cold shock, simply waiting for the warm water to flow. Unlike the shower timer, water flow kit, and flow and temperature meter connector, AzuLoop requires no changes in habits or behavior. Wota Box comes closer to a system solution like AzuLoop but requires much more installation and falls into a higher price range.

4.6.4 Marketing-Mix

AzuLoop's marketing mix follows the four P's:

Product: A tangible device installed between the water mixer and the showerhead, supported by installation and potential maintenance services. The product is designed for ease of use, water conservation, and reliability.

Price: Based on cost-based pricing, covering production, materials, transportation, and installation costs. The goal is to keep the price affordable to encourage widespread adoption.

Place: Sold via AzuLoop's own website and through retailers specializing in household products, ensuring both direct and indirect sales channels.

Promotion:

- Informative advertising to raise awareness about water waste and AzuLoop's solution.
- Emotional marketing to highlight the positive impact of sustainable choices.
- Personal selling in retail stores and through consultations.
- Trade promotions to encourage retailers to stock AzuLoop.
- Sales force promotions offering incentives to sales representatives.
- Online marketing, including social media and SEO, to boost brand visibility.
- Integrated Marketing Communications (IMC) ensures a consistent and clear brand message across all channels.

In table 16 is a breakdown of the price of the Azuloop for the customer.

Table 16: Price

Aspects	**Price (€)**
Component cost	999.60
Employee wages 14.00 €/h. (23.75 % social security)	34.65
Shipping cost for customer	50.00
Profit (15 %)	162.64
VAT	286.78
Marketing (2 %)	30.17
Total price of product for the customer	**1 564.35**

4.6.5 Brand

Figure 25: AzuLoop Logo

Identity Pillar

The Identity Pillar includes the visible and tangible elements of the brand, how AzuLoop presents itself. It consists of the identity mix: core identity, actual identity, and augmented identity.

Core Identity (Brand Name): AzuLoop's name was carefully chosen. "Azul" means blue in Portuguese and refers to the color that is most associated with water. "Loop" refers to the water recycling process of the product. "AzuLoop" is a playful creation of saying "water recycling", which is the literal function of the product.

Actual Identity (Visual Elements): This includes the logo, typography, and colors. AzuLoop's logo represents its function: two pipelines forming a loop with shower and toilet icons, emphasizing water reuse. The brand colors are dark blue (associated with water) and cyan for highlights. The typography was chosen to match the square shape of the logo, ensuring a consistent visual identity.

Augmented Identity (Additional Branding Elements):

AzuLoop is positioned as an easy-to-use, effective water-saving solution.

Object Pillar

The Object Pillar covers all marketing activities related to the brand. It consists of the core object, actual object, and augmented object.

Core Object (main exchange): The key offering is selling the water-saving device to homeowners and eco-conscious customers. The product helps reduce water waste while showering.

Actual Object (Supporting exchanges):

- Partnerships with home improvement stores as indirect sales channels.
- Suppliers and manufacturers who produce the product's components.
- Agreements with installers/plumbers to offer installation services.
- Logistics companies to handle distribution.
- The AzuLoop website, serving as both a sales platform and an information hub.

Augmented Object (Marketing Strategy):

Product: A user-friendly water-saving device with a temperature sensor and redirection system.

Price: Based on production, material, transportation, and installation costs to ensure affordability (1 564.35 € as described in table 1).

Place (Distribution): Sold through the official website and selected retail stores.

Promotion (Marketing & Communication):

- In-store sales and consultations.
- Online marketing via social media and video content.

Response Pillar

The Response Pillar covers how customers and stakeholders perceive AzuLoop. It includes the core response, actual response, and augmented response.

Core Response (Brand Positioning): AzuLoop wants to be seen as an easy and automatic way to save water while showering.

Actual Response (Brand Image): Customers should associate AzuLoop with reliability, innovation, and sustainability. The brand should have the image of a practical and advanced solution that contributes to the environment.

Augmented Response (Brand Value & Reputation):

- Brand Awareness: Marketing efforts are making AzuLoop well-known through online campaigns,

PR, and promotional materials.
- Brand Preference: Emotional branding and sustainability messaging aim to make customers prefer AzuLoop over alternatives.
- Customer Loyalty: A strong brand image, high-quality products, and good customer service help build trust and encourage repeat customers.

Managing Key Audiences:

- Customers: Environmentally conscious homeowners and landlords.
- Retailers: Stores that align with AzuLoop's sustainability values.
- Installers/Plumbers: Partners who can offer installation services.
- Environmental Organizations: Help build credibility and create awareness.
- Media: Crucial for spreading brand awareness and sustainability messaging.

4.7 Marketing Programmmes

To effectively reach and convince the target audience, there are some marketing programmes made for AzuLoop.

4.7.1 Programmes

Online Marketing:

- A visually appealing website with detailed product information and an integrated webshop.
- Social media platforms (Facebook, Instagram) and YouTube videos to showcase product demonstrations and raise awareness.
- Search Engine Optimization (SEO) to improve online visibility.

Partnerships:

- Collaborations with retailers specializing in household and sustainable products to offer AzuLoop in physical stores.
- Potential partnerships with plumbers and installation companies to facilitate setup for customers.

Public Relations:

- Engaging with media and environmental organizations to generate publicity.
- Participating in trade shows and sustainability-focused events to increase exposure.

Promotional Materials:

- Development of flyers and brochures highlighting AzuLoop's features and benefits.

Customer Service:

- Offering a 24/7 chat for consultations during office hours to answer customer questions and build trust with a specialist.

4.7.2 Budget

There is need for a well-balanced budget for the marketing programme to succeed. The priority of the marketing strategy is online marketing, strategic partnerships, public relations, promotional materials and customer service. Every part of this marketing programme contributes to the brand awareness, increasing sales and engaging with environmentally conscious consumers.

In total, there is a budget of 30 € for the marketing per product. If AzuLoop sells 150 products in one year, the marketing budget is 4 500 € which is more than enough for the listed items in table 17.

Table 17: Budget

Estimated Cost	**(€)**	**Justification**
Online Marketing	**1 800**	Focus on digital presence to increase awareness and conversions.
Website development & maintenance	500	Essential for a professional online presence with basic product info and webshop.
SEO & content marketing	200	Basic SEO implementation for visibility.
Social media advertising (Facebook, Instagram)	600	Paid ads to target eco-conscious consumers.
Video advertising (YouTube)	500	Short, high-quality video ads for product demonstration.
Strategic Partnerships	**800**	Focus on partnerships with key players in retail and installation services.
Retail collaborations	400	Key partnerships for physical presence in stores.
Partnerships with plumbers/installers	400	Collaborating with installers to reach customers directly.
Public Relations	**600**	Generate publicity and credibility through select channels.
Press releases & media outreach	200	Focused media outreach in eco-friendly press.
Trade show participation	400	Focus on one major sustainability expo for direct customer engagement.
Promotional Materials	**100**	Focus on essential promotional materials.
Leaflets & brochures	100	Distributed at key events and retail points **[360imprimir, 2025]** and **[25]**.
Customer Service & Support	**600**	Provide essential customer support while optimizing resources.
24/7 chatbot implementation	300	Automated chatbot for customer inquiries.
Live consultations & helpline	300	Staff support for complex inquiries.
Total Estimated Budget	**4 150**	

4.7.3 Control

The control phase is based on the SOSTAC model which stands for situation, objectives, strategy, tactics, action and control. This model is designed by PR Smith and is ideal for creating and controlling the marketing strategy. In this chapter we zoom in on specifically the last phase of this model where is determined if the monitoring of the progress is successful and if the predetermined goals are being reached. The control phase is all about measuring, evaluating and adjusting. Key Performance Indicators (KPIs) are predetermined, as well as the frequency and the method of the evaluation.

The important elements of the control phase are:

- Determining KPI’s such as sales figures, website visitors, social media engagement, …
- Choosing the monitoring tools such as Google Analytics, CRM-systems or social media dashboards.
- Composing a time line like a monthly report or a quarterly analysis
- Assigning responsibilities
    - Creating feedback loops to improve future actions

  [Chris Ayman, 2024].

What does this mean for AzuLoop?

First the question that should be asked is; what will be measured, which numbers are important? The answer for AzuLoop is of course the amount of products that have been sold, but also the online engagement is important. The amount of views on the website and YouTube, how many times people click on online advertisements and how many followers on social media and YouTube. The next step is to define how many times these numbers will be measured. The make sure the intervention is on time, a monthly report with the overview of the results is appropriate. How are the results being handled? If a campaign doesn’t reach enough people, the message or the channel should be changed. If it works better than expected, it will be implemented in other campaigns too. The marketing team will be responsible for keeping an eye on these numbers and adjusting the campaign when necessary.

4.8 Summary

Based on the market and economic analysis, the team decided to create a smart water-saving device intended for eco-conscious homeowners and property managers. This decision was driven by rising water costs, stricter environmental regulations, and increasing awareness of sustainability among consumers.

AzuLoop addresses a specific need: reducing water waste from cold shower runoff, which makes it especially relevant in water-scarce regions and Western countries with compatible plumbing systems.

Consequently, the team designed a solution with the following features: easy installation, automatic operation without behavior change, clear environmental impact, and energy-efficient components. AzuLoop is positioned as a simple and user-friendly product that fits into a modern, sustainable lifestyle.

It will be marketed through direct sales and selected retail partners, supported by online campaigns, partnerships, and PR, with a focus on emotional appeal and measurable impact.

5. Eco-efficiency Measures for Sustainability

Sustainability is a widely used concept that is applied by companies, organizations and politicians in various contexts. This chapter deals with specific measures to minimize the ecological footprint. An overview of the most important aspects of sustainable development and eco-efficiency. Eco-efficiency measures for sustainability provide a basis for understanding our environmental responsibility and resource efficiency.

5.1 Introduction

Sustainability has become one of the most important topics of this generation. Given the growing concerns about climate change, environmental degradation and the depletion of natural resources, both companies and consumers are looking for new ways to create and use products in a more responsible way. Sustainable development focuses on meeting the needs of the present without compromising the ability of future generations to meet their own needs. This means that we need to find a careful balance between environmental protection, social well-being and economic growth.

The United Nations developed 17 Sustainable Development Goals (SDGs). (See Figure 26). to support this global vision. These include goals like clean water, affordable and clean energy, climate action, and responsible consumption and production. Products and systems that follow these principles not only reduce their environmental impact but also contribute to a more fair and resilient society **[United nations, 2025]**.

Figure 26: SDG's **[United Nations, 2025]**

Azuloop contributes to the following Sustainable Development Goals:

- Goal 6: Ensure availability and **sustainable management of water** and sanitation for all. AzuLoop contributes by finding a new use for cold, clean water wasted in showers, ensuring that no more water is wasted.
- Goal 11: Make cities and **human settlements** inclusive, safe, resilient and **sustainable**. By implementing the AzuLoop solution in households, it will contribute to increasing the sustainability of cities and human settlements, as less water will be used or wasted.
- Goal 12: **Ensure sustainable consumption** and production patterns. AzuLoop ensures sustainable water consumption by using cold, clean water from showers to flush toilets, which would otherwise be flushed directly.

To support sustainable development in engineering and product design, two key tools are often used: eco-efficiency and life cycle analysis (LCA). Eco-efficiency is the practice of providing goods and services in a way that reduces environmental damage while maintaining economic value. It encourages the use of fewer resources and less energy to achieve the same or better results. **[Hari Srinivas, 2025]**. Life-cycle analysis, on the other hand, looks at a product's entire journey (from raw materials to disposal) to understand its total environmental impact **[P6 Technologies, 2025]**.

In developing AzuLoop, these tools and ideas are applied throughout the process. The AzuLoop is a product designed not only to help save water and energy, but also to support a circular economy through careful material choices, smart design for maintenance and minimal waste. This chapter will explore the environmental, economic and social strategies that AzuLoop is implementing to remain eco-efficient and sustainable, along with an overview of its full lifecycle impact.

5.2 Environmental

This chapter focuses on the second wing of the butterfly diagram. The butterfly diagram is a circular economy model that focuses on minimizing waste by keeping products and materials in use as long as possible. It consists of two cycles: the biological cycle (natural decomposition) and the technical cycle (maintenance, reuse, refurbishment and recycling) to extend the life of products and reduce environmental impact.(See Figure 27).

AzuLoop is an environmentally conscious product designed to reduce water waste, making it naturally appealing to users who believe in sustainable solutions like those outlined in the Butterfly Diagram. The product is developed with a focus on long-term use, minimizing waste, and optimizing energy efficiency.

- Maintenance: AzuLoop is built to last, and our team is always ready to assist with repairs if needed. Since all components are available separately, users don’t have to replace the entire product if something breaks. This extends the lifespan of the product and prevents unnecessary waste.
- Reuse: The emotional value of saving water encourages users to keep using AzuLoop instead of discarding it. Additionally, the strong ABS casing ensures that the product remains in good condition for a long time, further reducing the need for early replacement.
- Refurbish: If a user does decide to get rid of their AzuLoop, our team can collect the product, repair or replace necessary parts, and resell it at a lower price. This way, parts that are still functional get a second life, reducing overall material waste.
- Recycling: The ABS casing is fully recyclable, so when the product eventually reaches the end of its lifecycle, its materials won’t go to waste. Instead, they can be processed and reused for new products.

Besides material sustainability, AzuLoop is also designed to be energy-efficient. The system uses solenoid valves, which consume less power and are more reliable compared to motor-driven alternatives. This ensures that while saving water, AzuLoop also minimizes its overall energy consumption, making it a truly sustainable solution.

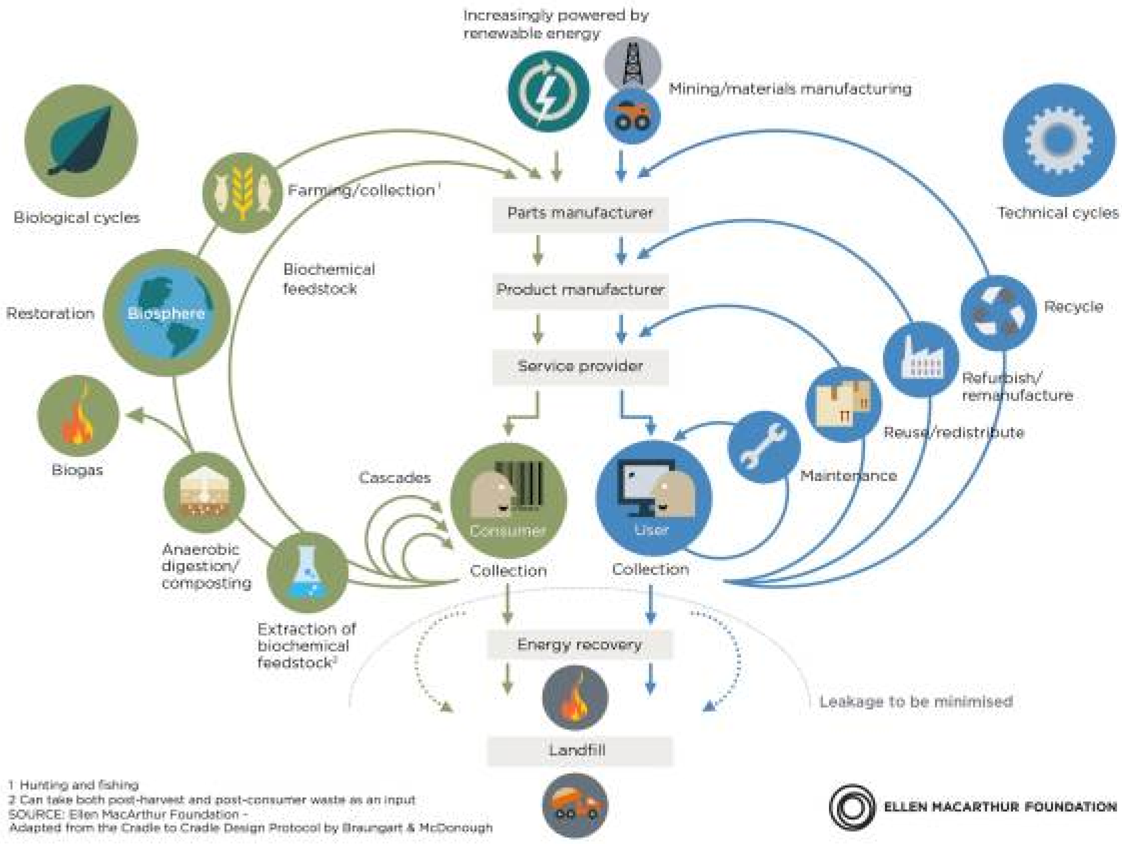

Figure 27: Butterfly diagram **[Esprix, 2025]**

5.3 Economical

AzuLoop integrates economic sustainability, ensuring that both the product and the business model are cost-effective while maintaining environmental responsibility. By using durable materials such as ABS for the casing, the product has a long lifespan, reducing replacement costs for customers and minimizing waste. In addition, standard off-the-shelf components are used for internal parts, reducing production costs and allowing easy and affordable repairs instead of complete product replacements.

AzuLoop maintenance and repairability also contributes to economic sustainability. Because individual components can be replaced separately, customers do not have to buy a completely new system if a part malfunctions. This approach not only reduces long-term costs for users, but also aligns with sustainable resource management by preventing unnecessary waste.

From a business perspective, AzuLoop ensures financial viability by offering a high-value product that appeals to both environmentally conscious consumers and cost-oriented property owners. The product's efficiency in reducing water consumption provides financial benefits to users over time, making it a worthwhile investment. By balancing sustainability with practical economics, AzuLoop ensures long-term market success while promoting responsible resource management.

5.4 Social

Social sustainability means considering how a product affects both people and the environment. AzuLoop, for example, helps to conserve water while providing many benefits to everyday life.

By reducing water waste, AzuLoop reduces household costs. A benefit that goes beyond saving money on the utility bill. With less waste, families may have additional funds to invest in other environmentally friendly products or services. This benefit is particularly important in areas where water is scarce, as the product uses it more efficiently.

The AzuLoop design also supports equity. Its affordability and sustainability make it accessible to many, including low-income households. If government funding comes into play, this benefit could be even more significant. Because the product is professionally installed, it minimizes complications for users, making it a practical choice for everyone.

Health and convenience are also part of the picture. By redirecting cold water from the shower to the toilet, AzuLoop helps avoid the sudden shock of cold water, resulting in a more pleasant showering experience. This thoughtful approach alleviates the worries of those who worry about water wastage, providing additional peace of mind.

In short, AzuLoop not only provides a more uniform and comfortable shower, but also contributes to the overall quality of life. It helps reduce utility bills, improves water use efficiency and ensures that a wider community benefits from technological innovation, all of which helps promote social sustainability.

5.5 Life Cycle Analysis

Life-cycle analysis is an important method for assessing the environmental impact of a product or service, from design to end-of-life management. It is important to determine the effect of each stage in the life of materials and components and to analyze the overall lifetime.

Life-cycle analysis is an important method for assessing the environmental impact of a product or service from design to end-of-life management. It is important to establish the effect of each life stage of materials and components and to analyze the overall lifetime.

Materials & Manufacturing

Metal Components (Copper Pipes, Metal Valves, Tanks):

- Require energy-intensive mining and processing, contributing to a high carbon footprint.
- Resource depletion and pollution are the result of metal extraction **[Solubility of Things, 2025]**.
- Metals like copper and steel are recyclable, if it is recycled this can help the environment in the long term

Plastic Components (Sensors, Plastic Tanks)

- They use less energy during manufacturing but pose environmental concerns during disposal due to microplastic pollution and lower recyclability **[Woodly, 2025]**.

Electronics (Microcontrollers, Power Supplies, Solenoid Valves):

- The semiconductor manufacturing process is resource and energy-intensive, involving rare earth elements and toxic chemicals.
- These components contribute to waste issues if discarded **[Geneva Environment network,**

2024].

Energy Consumption

Active Devices (Solenoid Valves, Digital Sensors, Power Supplies):

- Require a continuous or intermittent power supply, affecting operational efficiency.

Waste & Disposal

Recyclability

- Metals tend to be more recyclable than plastics.
- Electronic waste requires careful handling to recover valuable materials and prevent environmental contamination.

Maintenance

- Components with longer lifespans (e.g., copper pipes, tanks) may offset their initial environmental cost over time with reduced replacement frequency

Lifespan

- Temperature sensor: RTDs 10 years **[Swidget, 2023]**.
- Float switch: 20 years years **[Shon, 2023]**.
- Brass solenoid valve: 1-3 years **[Admin, 2017]**.
- Copper pipes: 20-50 years **[Epipe, 2021]**.
  - Supply power: 7-10 years **[39]**.

  The environmental impact of each component varies throughout its life cycle: metal parts such as copper pipes, valves and tanks require significant energy and resource consumption during extraction and manufacture, but benefit from long lifetimes and recyclability, thus reducing overall waste; plastic components often require less energy initially, but present disposal problems and contribute to pollution; meanwhile, electronic components such as microcontrollers, solenoid valves and power supplies incur high environmental costs during manufacture and, with shorter lifetimes, contribute to growing waste concerns.

5.6 Summary

In conclusion, this chapter shows how AzuLoop approaches sustainability by integrating environmental, economic and social aspects together with a life cycle analysis. By aligning with the principles of the Butterfly Diagram, AzuLoop demonstrates a commitment to extending product lifespan through maintenance, reuse, refurbishment and recycling. This approach not only minimizes waste, but also optimizes energy consumption, thus contributing to a reduced environmental footprint.

Furthermore, the product design and business model emphasizes economic sustainability by reducing replacement and repair costs, making it an affordable and sustainable solution for users. From a social perspective, AzuLoop improves community well-being by reducing water bills, reducing the stress related to water wastage and promoting a higher quality of life through improved showering experiences. Life cycle analysis further highlights that, despite the energy and resource demands of certain components, the long-term benefits (from sustainable materials, recyclability and efficient maintenance practices) offer a viable pathway to reducing overall environmental impact. Ultimately, AzuLoop serves as a model for sustainable innovation, effectively balancing environmental responsibility, economic practicality and social benefit.

6. Ethical and Deontological Concerns

6.1 Introduction

This chapter is about the ethical and deontological concerns of our project. In every engineering project, ethical and deontological principles play a role in ensuring responsible decision making, integrity, and accountability. These principles guide engineers in professional conduct, safeguard public trust and wellbeing. Our team has considered these values throughout the AzuLoop project.

The analysis covers five essential areas:

-Professional responsibility in engineering

-Integrity in sales and marketing

-Environmental impact

-Legal liability

-Ethical design decisions

These principles act as guiding values for responsible engineering. By addressing these aspects, we ensure that our technical solution is functional, innovative, respectful of societal values, sustainable development, and human rights.

6.2 Engineering Ethics

The team is committed to respecting engineering ethics like honesty, accuracy, and the prioritization of user safety. During the development of AzuLoop, they ensure that all technical solutions followed applicable standards and safety regulations. They also prioritize clear documentation and transparent communication within the team, ensuring that all decisions were made collectively and responsibly.

Engineers have a professional and moral responsibility to uphold public safety, health, and welfare. European engineering codes of ethics are built on the following principles:

-Integrity and honesty

-Technical competence

-Accountability for decisions and consequences

-Commitment to sustainability

-Respect for equality and human dignity

In the project, the team applied these principles by:

-Designing a system that prevents unnecessary water waste

-Implementing reliable sensor-controlled automation

-Minimizing risk of human error through intelligent logic

-Ensuring traceable and explainable system behavior

This ensures a responsible, safe, and transparent engineering solution.

6.3 Sales and Marketing Ethics

In the Azuloop's marketing and sales strategy, the team aims to provide truthful and transparent information about the product’s capabilities. Azuloop avoids misleading claims and ensures that advertising reflects the actual performance of AzuLoop, they are committed to respecting consumer rights and privacy, especially in any communication or data collection related to potential customers.

In any future commercialization or public presentation of the system, ethical marketing is essential. This includes:

-Honest communication without exaggerated claims

-Transparency about limitations and technical requirements

-Use of verified, real data in promotional materials

-Respect for consumer rights and informed decision-making

Marketing efforts should:

-Highlight true environmental benefits with evidence

-Clearly state installation and operational requirements

-Avoid any misleading visuals or claims

Following these guidelines helps build customer trust and complies with EU consumer protection laws.

6.4 Environmental Ethics

AzuLoop was designed with sustainability in mind. By redirecting unused cold water to toilet flushing, the team aims to reduce unnecessary water waste in daily routines. They chose components and materials with a focus on durability and minimal environmental impact. Environmental responsibility is a central part of the choices in material selection.

The project embraces environmental ethics by minimizing water waste and using resources efficiently. The system supports:

-Reduction of unnecessary water consumption

-Reuse of cold water for toilet flushing

-Alignment with EU climate and sustainability goals

The environmental benefits of our solution include:

-Lower household water usage

-Reduced energy use related to water heating

-Smarter use of existing infrastructure (e.g., toilets)

By contributing to climate-conscious practices, Azuloop meets modern environmental responsibilities in building services engineering.

6.5 Liability

As future engineers, the team understands the importance of assuming liability for design decisions. Should the product enter the market, they would ensure that all safety standards are verified through proper testing and certification processes. Any potential malfunction would be addressed with appropriate corrective actions to protect the user and the environment.

Clearly defined liability is essential in engineering projects, especially those involving automated systems. Possible risks include:

-Sensor failure

-Relay malfunction

-Incorrect or unsafe water routing

-User misuse due to unclear instructions

The team addressed liability through:

-Risk identification during design

-Clear documentation and user guidance

-Compliance with relevant EU directives, such as the Low Voltage Directive (2014/35/EU) for electrical safety, the EMC Directive (2014/30/EU) for signal interference protection, the Machinery Directive (2006/42/EC) for automation safety, the Drinking Water Directive **[40]**

7.3.1 Structure

Initial structural drafts In the structural draft (See Figure 35). You can see the mixer of the shower on the right side. There is a pipe coming from the mixer that divides in two via 2 valves. One pipe leads to an extra tank and one pipe leads to the shower through two valves. This split takes place in the AzuLoop, our product. Before the pipes split, the water goes along a temperature sensor. After that, one pipe has a Normally Open (NO) valve that goes to the shower, so that the system can be used when there is a power outage. The valve to the extra tank is Normally Closed (NC). The extra tank on the left has two float sensors. From the extra tank there is a pipe with a NC valve leading to another valve where that pipe and a supply water pipe with a NO valve connect and lead to the toilet tank.

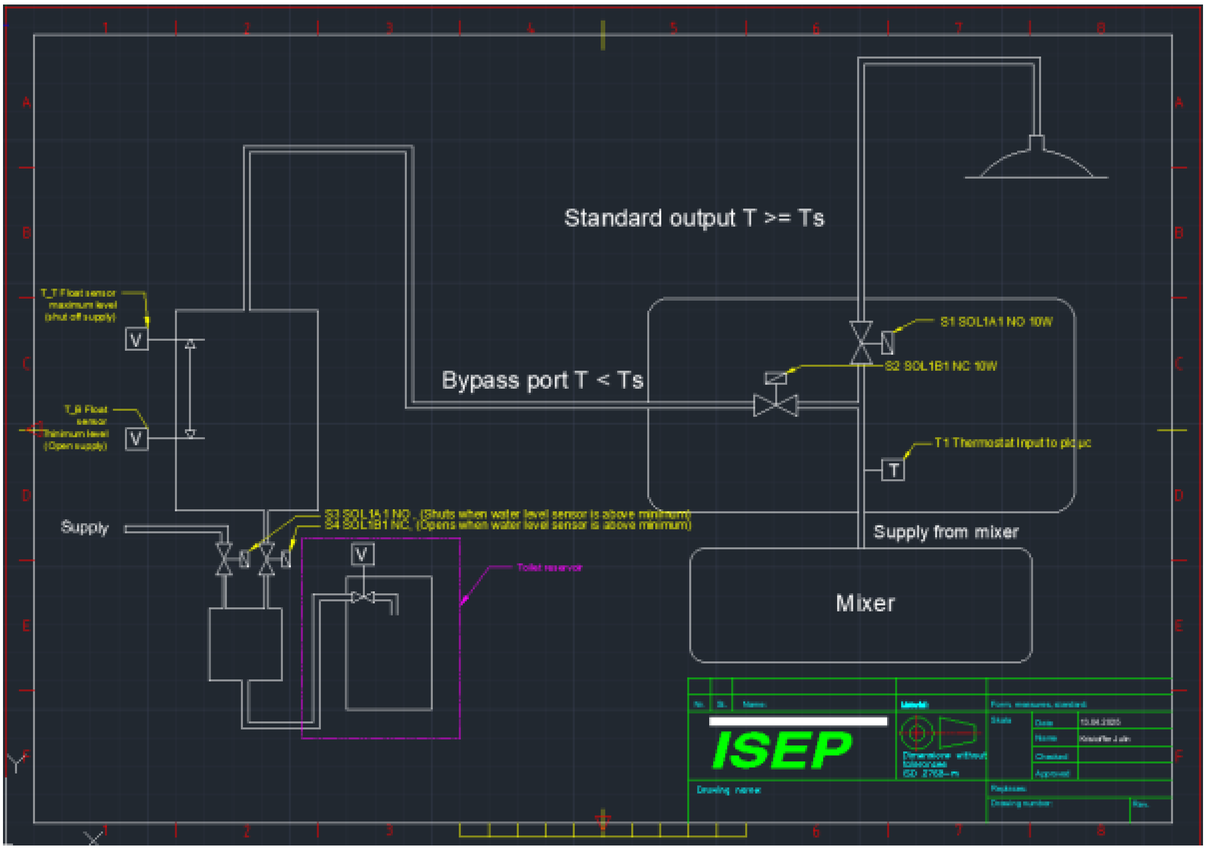

Figure 35: System Schematic

Material selection The AzuLoop consists of components. To contain the components, the product needs a case. This case will be made of glass-filled PPS with the injection-molding method. PPS has the highest steam/thermal performance, it has no water uptake in hot steam and other wet environments, it has extra stiffness and wear resistance compared to unfilled PPS. In conclusion, glass-filled PPS will withstand years of wet, hot, steamy conditions without degrading. **Colour palette** The Azuloop has a colour palette that closely relates to water, together with a bold color so the product grabs the attention of the customer (See figure 36).

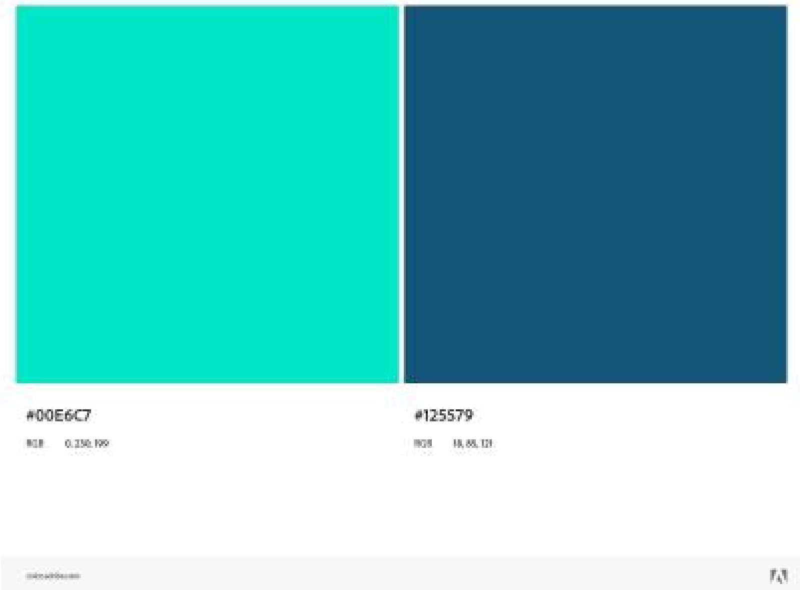

Figure 36: Colour palette

7.3.2 Smart System

== Hardware == **Black box diagram** In the black box diagram below. (Figure 37). the cold supply water on the left leads to the boiler, water mixer and a valve. The first stream of cold water gets heated in the boiler and goes to the water mixer. Here is the warm water mixed with the cold water. This mixed water flows along a temperature sensor. This temperature sensor is connected to a microcontroller that gives a signal to valves. The microcontroller and temperature sensor are powered by a power source. The temperature sensor, power source and microcontroller are contained in the AzuLoop. One valve goes to the shower head, but when the water is colder than the preferred temperature of the user, the water will be directed to an extra tank. In the extra tank there is a volume sensor that gives a signal to a micro controller when the tank is full enough (both powered by a power source). When the tank is full enough a valve will open that leads to a toilet tank. The rest of the time the main water supply valve is open, so the toilet tank always has water when no one is showering.

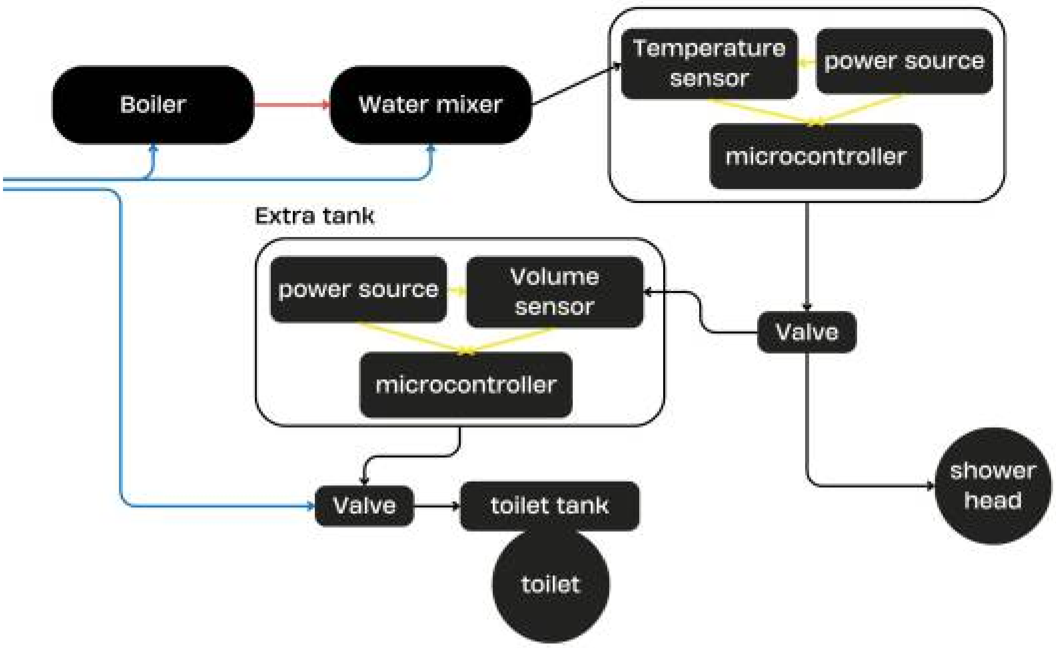

Figure 37: Black box diagram

Hardware component selection In figure 18 is an overview of the selection of the materials for the Azuloop.

Table 18: Material selection

Component	Umax (V)	Imax (mA)	Pmax (W)
1 ESP32	5	550	2.75
2 Valve	24	420	10.00
3 Temperature sensor	N/A	N/A	N/A
4 Relay coil	5	30	0.15
5 Tank	N/A	N/A	N/A
6 DC/DC Transformer	5	90	1.71

== Development Platform Selection == The following comparison evaluates development platforms suitable for embedded water management applications: ^ Platform ^ Processing Power ^ Development Complexity ^ Cost ^ Power Consumption ^ Suitability ^ | ESP32 | Dual-core 240MHz | Medium | Low | Medium | Excellent | | Arduino Uno | Single-core 16MHz | Low | Very Low | Low | Limited | | Raspberry Pi | Quad-core 1.5GHz | High | Medium | High | Overkill | | STM32 | Variable | High | Medium | Low | Complex | The ESP32 platform was selected due to its sufficient processing power for real-time control, 12-bit ADC resolution, and extensive community support. The Arduino IDE provides the optimal balance between development speed and functionality for this application scope. **Detailed schematics** The following (Figure 38) contains the electrical schematics of the AzuLoop.

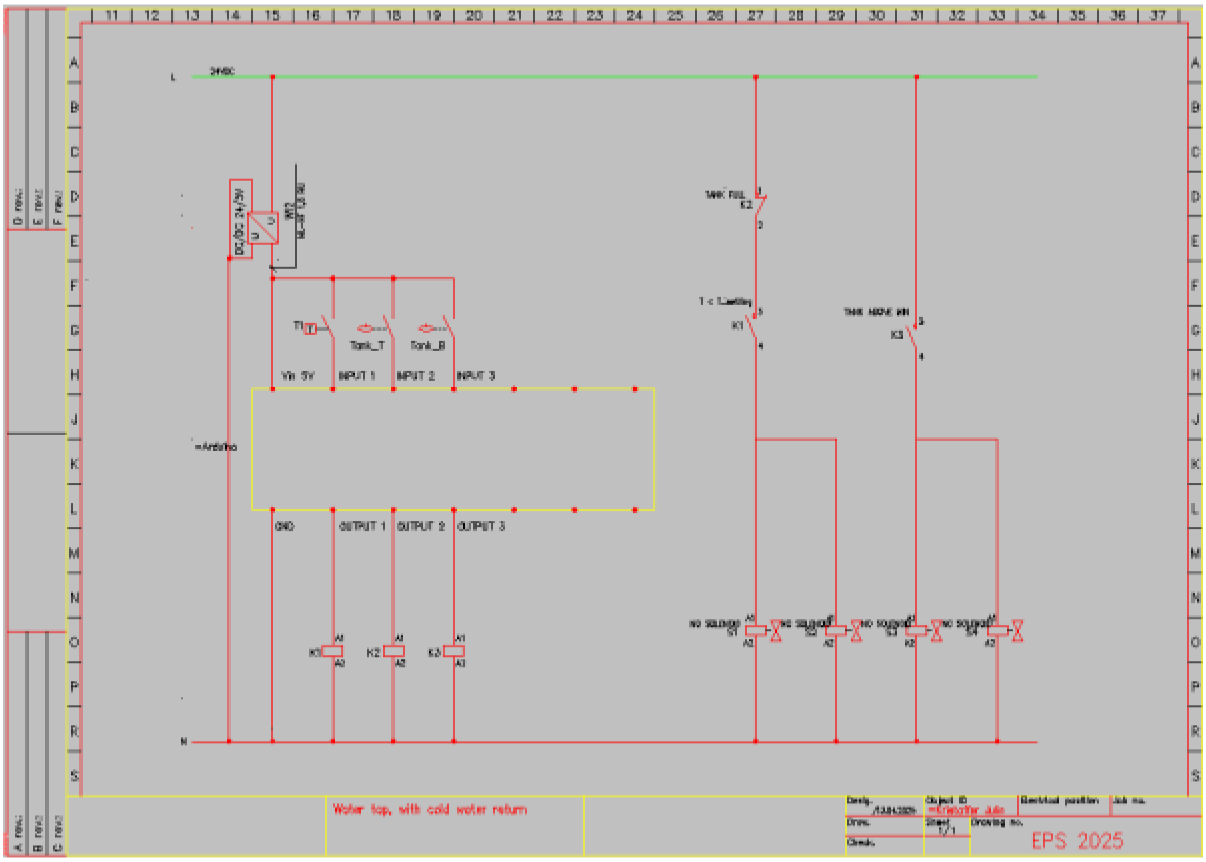

Figure 38: Electrical Schematics

Power budget Bellow are the calculations of the power the Azuloop will use. **Power consumption of our product** - **Solenoids (2)**

SOL1A1 : 10 W SOL1B1 : 10 W \begin{equation} P_s = 4 * 10 W = 40 W \end{equation} - **Relays (3)**

RSY5 : 0.15 W \begin{equation} P_r = 3 * 0.15 W = 0.45 W \end{equation} - **DC-DC converter (1)**

LM7805 \begin{equation} P_c = (U_i - U_o) * I_l = (24 V - 5 V) * 0.09 A = 1.71 W \end{equation} - **Total power consumption** \begin{equation} P_m = P_r + P_s + P_c ⇒ P_m = 0.45 W + 40 W + 1.71 W = 42.16 W \end{equation}

```
 - **Total current consumption**
```

\begin{equation} I_m = P_m / U ⇒ I_m = 42.16 W / 24 V = 1.75 A \end{equation} **Energy saving by reutilizing water (Calculated with a water cleaning power usage of 2 kWh/m^3 and a water waste of five liters per shower) = (0,002 kWh/L)** \begin{equation} P_c = 0,002 kWh/L * 5 L = 0,01 kWh \end{equation}

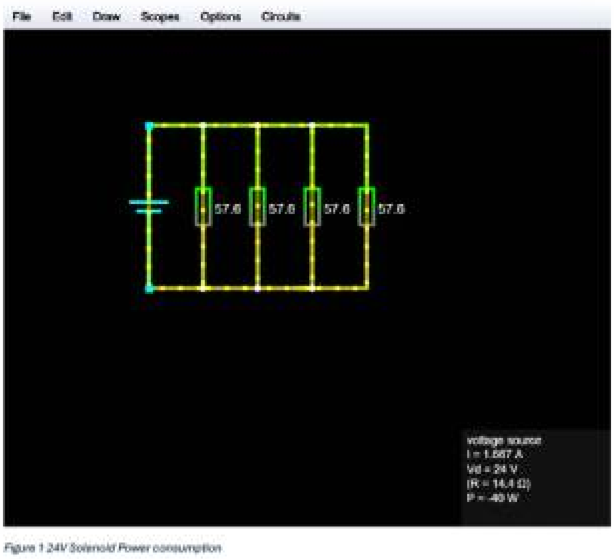

Figure 39: Power calculations 2

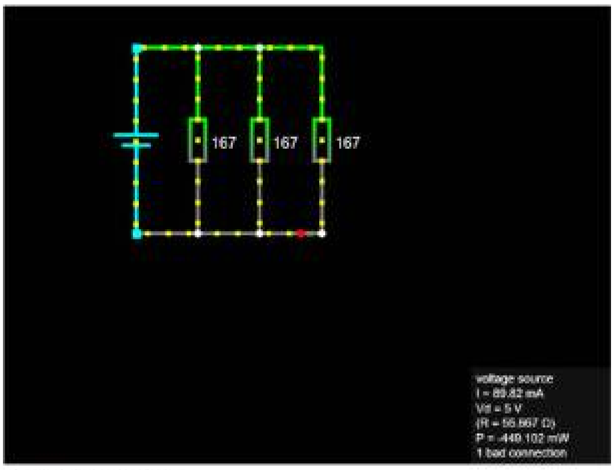

Figure 2 5V Arduino outputs to relays

Figure 40: Power calculations 3

For the user expenses we calculate with the following values: * **Electrical energy: 0.11 €/kWh** * **Expected time for warm water to arrive: 30 s = 0.5 min = 0.083 h** Energy price if everything is powered up at once: \begin{equation} Price_t = (P_m * 24 h) * 0.11 €/kWh ⇒ 0.04216 kW * 24h * 0.11 €/kWh = 0.11 € \end{equation} Normal scenario, family of four, (shower used four times/day): \begin{equation} Price_F = (P_m * 0.083 h * 4 people) * 0.11 €/kWh ⇒ 0.04216 kW * 0.083 * 0.11 €/kWh = 0.000 15 € \end{equation} Normal scenario, single person (shower used once/day): \begin{equation} Price_N = (P_m * 0.083 h) * 0.11 €/kWh ⇒ 0.04216 kW * 0.083 h * 0.11 €/kWh = 0.000 039 € \end{equation} === Software === The software differs for the prototype since there are only 2 valves and one water sensor used, the valves are both normally closed, and the microcontroller is an Arduino UNO instead of an ESP32. == Use Cases and User Stories == The smart water management system addresses several critical use cases for residential and small-scale commercial applications. Primary user stories include: User Story 1: Temperature-Based Water Conservation As a homeowner, I want the system to automatically redirect cold water to storage during shower warm-up, so that I can reduce water waste and lower utility bills. The system monitors inlet temperature and compares against user-defined setpoints to determine flow routing. User Story 2: Tank Level Management As a building manager, I need automatic tank overflow prevention and optimal filling control, so that water storage remains within safe operational limits. The system utilizes dual-level sensing to ensure adequate pressure for gravity-fed applications while preventing overflow conditions. User Story 3: System Control and Monitoring As a facility operator, I want reliable system status indication and manual control capabilities, so that I can manage the installation efficiently. The system provides local control through analog potentiometer and status feedback through operational behavior. User Story 4: Maintenance and Diagnostics As a service technician, I need straightforward system diagnostics and fault detection, so that I can quickly identify and resolve operational issues. The system provides clear operational states and failsafe behaviors for troubleshooting. == Component Architecture ==

```
 #include <OneWire.h> #include <DallasTemperature.h>
#define DS18B20_PIN 4
#define POT_PIN A0
#define WATER_LEVEL_FULL_PIN 2
#define WATER_LEVEL_MIN_PIN 15
#define USER_NO_VALVE 18
#define TANK_NC_VALVE 19
#define TOILET_PRESSURE_NC_VALVE 21
#define TOILET_NORMAL_NO_VALVE 22

OneWire oneWire(DS18B20_PIN);
DallasTemperature sensors(&oneWire);

void setup() {
Serial.begin(115200);

pinMode(USER_NO_VALVE, OUTPUT);
pinMode(TANK_NC_VALVE, OUTPUT);
pinMode(TOILET_PRESSURE_NC_VALVE, OUTPUT);
pinMode(TOILET_NORMAL_NO_VALVE, OUTPUT);
pinMode(WATER_LEVEL_FULL_PIN, INPUT_PULLUP);
pinMode(WATER_LEVEL_MIN_PIN, INPUT_PULLUP);

digitalWrite(USER_NO_VALVE, LOW);
digitalWrite(TANK_NC_VALVE, LOW);
digitalWrite(TOILET_PRESSURE_NC_VALVE, LOW);
digitalWrite(TOILET_NORMAL_NO_VALVE, LOW);

sensors.begin();
}

void loop() {
int potValue = analogRead(POT_PIN);
bool tankFull = digitalRead(WATER_LEVEL_FULL_PIN) == LOW;
bool tankMinLevel = digitalRead(WATER_LEVEL_MIN_PIN) == LOW;

sensors.requestTemperatures();
float currentTemp = sensors.getTempCByIndex(0);

if(potValue <= 164) {
setDeviceOff();
}
else {
float setpoint = map(potValue, 165, 4095, 15, 35);
controlSystem(currentTemp, setpoint, tankFull, tankMinLevel);
```

```
}

delay(1000);
}

void setDeviceOff() {
digitalWrite(USER_NO_VALVE, LOW);
digitalWrite(TANK_NC_VALVE, LOW);
digitalWrite(TOILET_PRESSURE_NC_VALVE, LOW);
digitalWrite(TOILET_NORMAL_NO_VALVE, LOW);
}

void controlSystem(float currentTemp, float setpoint, bool tankFull, bool
tankMinLevel) {
if(tankMinLevel) {
digitalWrite(TOILET_PRESSURE_NC_VALVE, HIGH);
digitalWrite(TOILET_NORMAL_NO_VALVE, HIGH);
} else {
digitalWrite(TOILET_PRESSURE_NC_VALVE, LOW);
digitalWrite(TOILET_NORMAL_NO_VALVE, LOW);
}

if(tankFull) {
digitalWrite(USER_NO_VALVE, LOW);
digitalWrite(TANK_NC_VALVE, LOW);
}
else {
if(currentTemp >= setpoint) {
digitalWrite(USER_NO_VALVE, HIGH);
digitalWrite(TANK_NC_VALVE, HIGH);
}
else {
digitalWrite(USER_NO_VALVE, LOW);
digitalWrite(TANK_NC_VALVE, LOW);
}
}
}
```

The system architecture implements a hierarchical control structure with sensor input processing, decision logic, and actuator output management. The ESP32 microcontroller serves as the central processing unit, interfacing with temperature sensors, water level detectors, and solenoid valve actuators through GPIO pins. System Integration Components: Sensor Layer: DS18B20 digital temperature sensor, dual-level float switches Control Layer: ESP32 microcontroller with 12-bit ADC resolution Actuator Layer: Normally open/closed solenoid valves for flow direction control Interface Layer: Analog potentiometer for user setpoint adjustment Power Layer: 5V/3.3V power distribution for sensors and control logic The control logic implements three operational priorities: system shutdown mode when potentiometer reads below threshold, tank overflow prevention taking absolute priority, and temperature-based flow routing for normal operation. The ESP32 platform provides enhanced ADC resolution compared to traditional Arduino implementations, enabling more precise analog input processing for improved system responsiveness.

7.3.3 Packaging

Figure 41: Packaging solution

The packaging solution does not only focus on safely transporting the product, but will also be reused as a product on itself. It stays in the bathroom environment and contributes as a shower rack on your shower wall. When the customer purchases to product through our website, the transportation company will obviously provide an extra cardboard box during the transportation, but in the physical stores, the product is just directly purchased in the box. The only thing the user must do is ripping of the upper stroke by the tear-off-edge and slide the lid out of the box. Now the product can be installed and the suction-cups can be screwed on to the remaining shower rack. The loose components are arranged in ziplock bags in the cases to make the assembly easy and convenient. The tank above the toilet is much bigger, so a reusable packaging solution for this object might remain in a huge waste of material. The most convenient solution is cardboard because it is most used and it is the easiest to recycle.

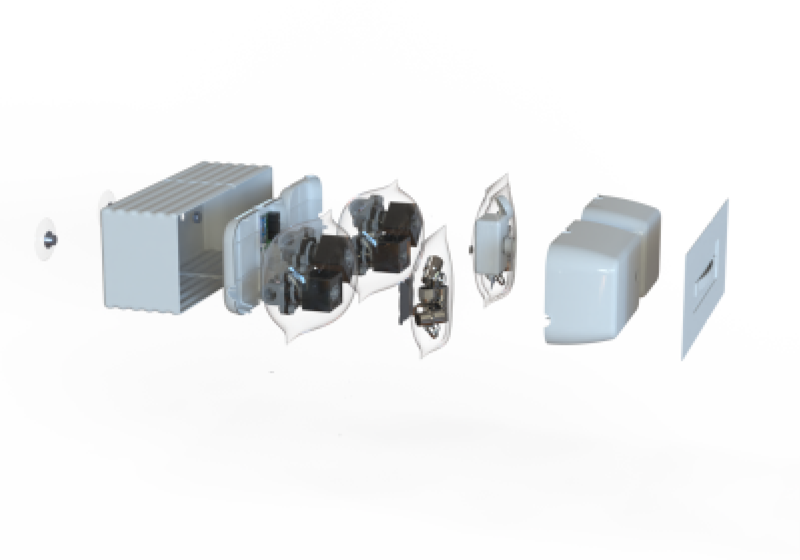

Figure 42: Exploded view packaging solution

The shower rack will be injection moulded in ABS because of it's sturdy features and water and heat resistence properties. The box is not biodegradable, but since it is designed to be reused, a second life will add much more value.

Table 19: Material selection

Material	**Recyclable**	**Durable**	**Sustainable**	**Biodegradable**	**Water- and heat resistant**
1 Recycled PMMA/Acrylic plastic	Partly large amounts end in landfills	Yes	Yes, 100 % recycled green acrylics	No	Yes
2 Recycled ABS	No	Yes	20-50 % recycled materials	No	Yes
3 Corrugated polypropylene sheets	Yes	Won't crack when bombed, good durability	No, it is derived from fossil hydrocarbons	No	Yes
4 PLA	No	Can be brittle	Made from renewable plant sugars	No	Not ideal for hot environments above 40 °C. The water resistance is adequate
5 PHA	Limited	Better than PLA	Bio-based, it has lower lifecycle impact than most petro-plastics	Yes	Short-term water resistance. Heat Deflection Temperature around 40 °C
6 Recycled polypropylene	Yes	Yes	Fossil based but recycled	No	Yes
7 ABS	No	Strong, impact-resistant, good dimensional stability	Fossil-based, not sustainable unless recycled	No	Yes

Just like the case of the system is available in different colors, so is the shower rack to fulfill every customers preferences and to blend in with their shower perfectly. The metal nobs are even pigmented in the desired color.

Figure 43: Colour variety packaging

== Load and stress simulation == To achieve this model, a lot of changes has been made. The packaging started without the side walls and a clipping lid on the box. After some load and stress simulations, it was discovered that the weight of soap would bend the shower rack almost 2 centimetres, which would lead to the soap sliding of the rack. A more stiff and sturdy material was chosen, instead of polypropylene, the rack is now made out of ABS which makes more realistic numbers out of the stress simulation. The side walls were added to evade any kind of structural risks. A force of 14,714 N was added which is the equivalent of 1,5 kilograms. After defining the the force of the gravity and the fixations the results were generated. After the adaptations every number seems reasonable, even the factor of safety has a minimum of 8; which means that the material will only start failing when the force is eight times more than we provided.

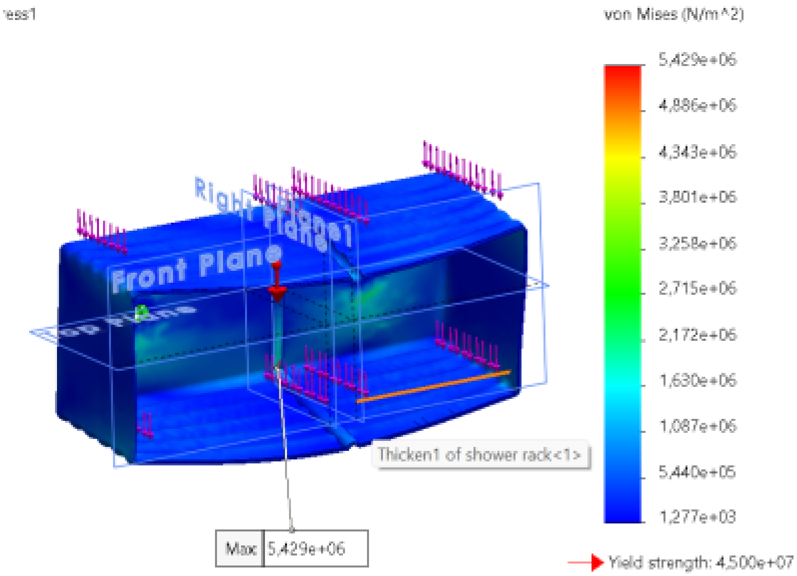

Figure 44: Maximum stress

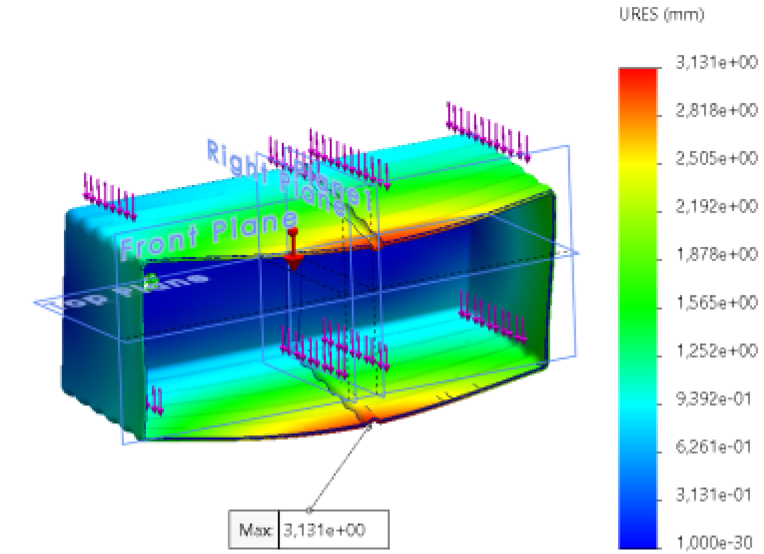

Figure 45: Maximum displacement

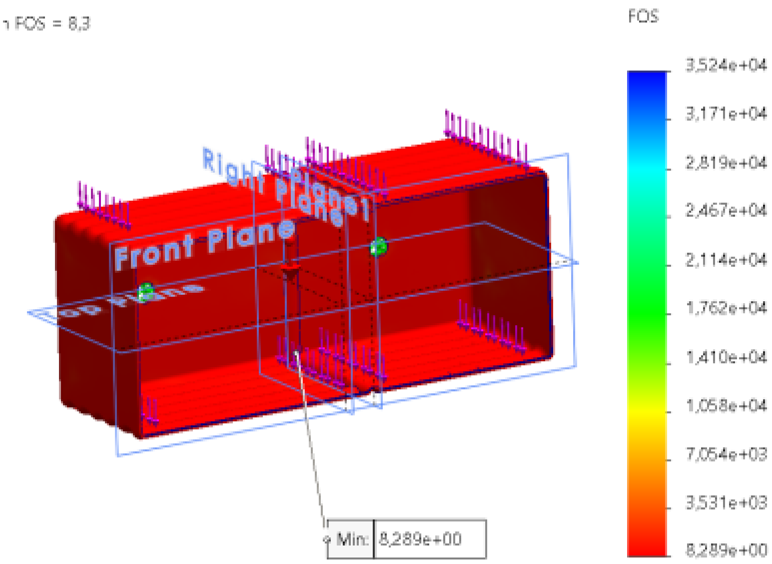

Figure 46: Minimum Factor of safety

7.4 Prototype

Prototyping is a step into bringing a product to life, and it is a crucial part of a product development process. Creating a prototype helps to have a visual and physical experience with the product in order to know if it works and what changes should be made. In this chapter, the prototype development process will be explained along with the changes in relation to the designed solution.

7.4.1 Structure

In the prototype, the team opted for a smaller water tank, to make it easier to send the water through the system and because this was available from the chemistry/biology engineering department. Also, the team chose to use plastic pipes instead of copper pipes, because it is cheaper and available at the university. The team chose to only show the functionality in the prototype, so the case is a second hand plastic box. The case is also bigger than it would be in real life.

7.4.2 Hardware

Some modifications were made to the prototype compared to the original design. The most significant change is that the valves placed after the water tank were not included in the prototype which will be part of the final product (See figure 47).

Figure 47: Labelled prototype

The prototype still demonstrates the core functionality of the system. It clearly shows how cold water is first directed into the water tank, and once the water warms up, it flows to the shower. In the final version (See figure 48) , the cold water stored in the tank would later be used for toilet flushing.

Figure 48: Final prototype on structure

Even though some components are missing from the final product, the prototype successfully shows how the temperature difference of the water controls its direction with the valves, and how the system saves water (see figure 49).

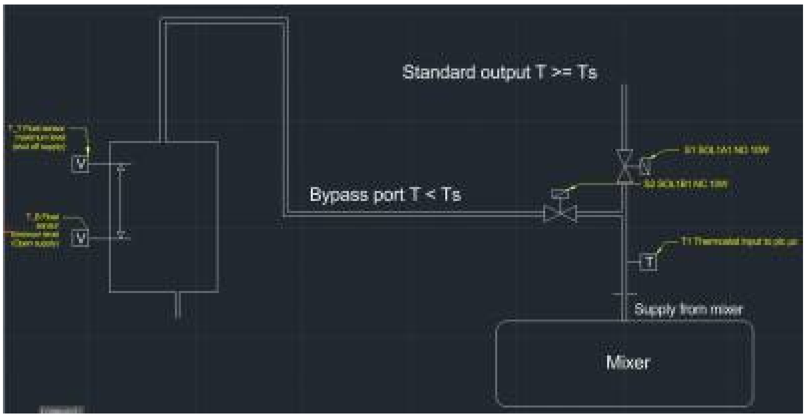

Figure 49: Schematic of the Azuloop prototype

7.4.3 Software

The prototype software implements an **intelligent water management system** using Arduino Uno microcontroller . The system utilizes **temperature-based flow control** to optimize water usage by redirecting cold water to a storage tank while allowing warm water to flow directly to the user . System Architecture The software architecture follows a **modular embedded design** with clear separation between sensor input processing, control logic, and actuator output management. The main components include: - **Temperature monitoring** via DS18B20 digital sensor - **User setpoint control** through analog potentiometer
Water level detection using float switch - **Dual valve control** for flow direction management Hardware Interface Definitions Primary Control Code:

```
#include <OneWire.h>
#include <DallasTemperature.h>

#define DS18B20_PIN 4
#define POT_PIN A0
#define WATER_LEVEL_PIN 2
#define MIXER_VALVE 8
#define TANK_VALVE 9

OneWire oneWire(DS18B20_PIN);
DallasTemperature sensors(&oneWire);

void setup() {
  pinMode(MIXER_VALVE, OUTPUT);
  pinMode(TANK_VALVE, OUTPUT);
  pinMode(WATER_LEVEL_PIN, INPUT_PULLUP);

  digitalWrite(MIXER_VALVE, LOW);
  digitalWrite(TANK_VALVE, LOW);
  sensors.begin();
}

void loop() {
  int potValue = analogRead(POT_PIN);
  bool tankFull = digitalRead(WATER_LEVEL_PIN) == LOW;
```

```
  sensors.requestTemperatures();
  float currentTemp = sensors.getTempCByIndex(0);

  if(potValue <= 4) {
    digitalWrite(MIXER_VALVE, LOW);
    digitalWrite(TANK_VALVE, LOW);
  }
  else {
    float setpoint = map(potValue, 5, 1023, 15, 35);

    if(tankFull) {
      digitalWrite(MIXER_VALVE, HIGH);
      digitalWrite(TANK_VALVE, LOW);
    }
    else {
      if(currentTemp >= setpoint) {
        digitalWrite(MIXER_VALVE, LOW);
        digitalWrite(TANK_VALVE, HIGH);
      }
      else {
        digitalWrite(MIXER_VALVE, HIGH);
        digitalWrite(TANK_VALVE, LOW);
      }
    }
  }
  delay(1000);
}
```

Control Logic Implementation The software implements **hierarchical priority control** with three distinct operational modes :

Table 20: Hierarchical priority control

Priority Level	Condition	Action	Valve State
1 (Highest)	System OFF (pot ≤ 4)	Default flow	Mixer: OFF, Tank: OFF
2	Tank Full Override	Force normal flow	Mixer: ON, Tank: OFF
3	Temperature Control	Conditional routing	Based on setpoint comparison

=== Temperature Processing Algorithm === The system utilizes the **DS18B20 digital temperature sensor** which provides accurate readings with built-in calibration . The temperature data undergoes minimal processing due to the sensor's digital output format [1]. == Temperature Reading Function ==

```
float readTemperature() {
  sensors.requestTemperatures();
  float tempC = sensors.getTempCByIndex(0);

  if(tempC == DEVICE_DISCONNECTED_C) {
    return 20.0; // Default safe temperature
  }
  return tempC;
```

```
}
```

== Setpoint Mapping Algorithm == The potentiometer input undergoes **linear mapping** to convert the 10-bit ADC reading (0-1023) to a meaningful temperature range. The implementation includes a **deadzone** for system shutdown functionality. Safety and Fault Handling == Valve Interlocking == The software implements **mutual exclusion** between valves to prevent simultaneous activation . This safety mechanism ensures that only one flow path is active at any time, preventing system conflicts and potential water hammer effects. == Sensor Fault Detection == The DS18B20 sensor includes built-in **error detection** that returns a specific error code (-127°C or DEVICE*DISCONNECTED*C) when communication fails . The software handles this condition gracefully by defaulting to a safe operational state. Water Level Override The tank full condition takes **absolute priority** over temperature-based control logic. This prevents overflow conditions and ensures system safety under all operational scenarios. Safety Logic Implementation

```
void safetyCheck() {
  bool tankFull = digitalRead(WATER_LEVEL_PIN) == LOW;

  if(tankFull) {
    // Force normal flow regardless of temperature
    digitalWrite(MIXER_VALVE, HIGH);
    digitalWrite(TANK_VALVE, LOW);
    return;
  }

  // Ensure mutual exclusion
  if(digitalRead(MIXER_VALVE) && digitalRead(TANK_VALVE)) {
    // Error condition - close both valves
    digitalWrite(MIXER_VALVE, HIGH);
    digitalWrite(TANK_VALVE, LOW);
  }
}
```

== Performance Characteristics == == Response Time == The system achieves a **1-second update cycle** which provides adequate responsiveness for residential water management applications. The DS18B20 sensor conversion time (750ms maximum) is the primary limiting factor in system response speed. == Configuration Parameters ==

Table 21: Configuration Parameters

Parameter	Value	Description
Update Interval	1000ms	Main loop cycle time
Temperature Range	15-35°C	User setpoint limits
Deadzone	0-4 ADC counts	System off threshold
Sensor Resolution	12-bit	DS18B20 precision setting

7.4.4 Tests & Results

After completion of the prototype assembly, the testing phase began with pressurization and electrical tests to verify that the assembly could withstand the expected water pressure. During the initial test, several water leakage points were identified around the pipes and fittings. As a corrective measure, the pipe fittings were sealed using a sealing compound. The electrical test was completed successfully and did not require further modifications. Following the sealing of the weak points, a second pressurization test was conducted and successfully completed. During the first two testing phases, issues were encountered with the ESP32 microcontroller. As a workaround, the microcontroller was bypassed during the electrical test by manually applying voltage to the relay coils using jumper cables. A 12V supply was connected to the relay switch, which also enabled testing of the solenoid valves. A power supply unit was used to provide both 5V and 12V outputs as required (See figure 50).

Figure 50: Prototype got manually handled. Water came into the shower tank part.

The third test included a functionality check of the microcontroller, with a focus on sensor readings, temperature setpoint control, and automated valve switching sequences, in order to validate the full software control loop. == Hardware tests == Perform the hardware tests specified in 1.6 Tests. These results are usually presented in the form of tables with two columns: Functionality and Test Result (Pass/Fail). == Software tests == Functional testing validates the core user stories and system requirements for the water management control system. Each test scenario verifies specific functionality against expected behavioural outcomes.

Table 22: Functional test results

Test Case	**Expected Behavior**	**Test Result**
Temperature Sensor Reading	DS18B20 provides accurate readings within ±0.5°C	Pass
Potentiometer Setpoint Control	Analog input maps correctly to 15-35°C range	Pass
Water Level Detection	Float switch triggers at designated fill level	Pass
System OFF Mode	Both valves remain closed when potentiometer ≤ 4	Pass

Test Case	Expected Behavior	Test Result
Temperature-Based Routing	Cold water redirects to tank when below setpoint	Pass
Tank Full Override	System forces normal flow when tank reaches capacity	Pass
Valve Mutual Exclusion	Only one valve operates at any given time	Pass

Performance Tests The table below demonstrates that our product accurately measures water temperature, enabling responsive actions based on user preferences. Here, Tw represents the actual temperature of the incoming water, while Twp indicates the temperature detected by the prototype sensor. As the water temperature changes, the sensor readings closely match the actual water temperature in real time. S1 refers to the first scenario, where the water is colder, and the second scenario shows the water after it has been heated. The sensor's accuracy is within 1°C of the actual temperature.

Table 23: Performance test results

	T_w	T_{wp}	Time
S_1	24.7°C	25°C	2 min
S_2	30°C	30.6°C	

Usability Tests System usability assessment evaluates user interaction effectiveness and operational simplicity. The potentiometer-based control interface was tested for intuitive operation. We were successfully adjusted temperature setpoints. The absence of complex user interfaces simplifies operation while maintaining full system functionality. === Structural test: Stress Calculation for 30L Water Tank (SOLIDWORKS) === The tank will be subjected to 30L water capacity (equivalent to 1,720 Pa maximum pressure at the bottom) through nonuniform pressure distribution simulation. The analysis will evaluate von Mises stress concentrations, particularly at critical locations such as base-wall junctions and corner regions where maximum stresses occur. Material yield strength will be compared against calculated maximum stresses to ensure a minimum safety factor of 2.0. Displacement analysis will verify that wall deformations remain within acceptable limits. The structural test passes if maximum stress values stay below material yield strength with adequate safety margins, and if no excessive deformation or structural failure occurs under the specified hydrostatic load conditions. Critical areas, such as the base-wall junctions and corners, were closely monitored for peak stress concentrations. The results indicated that the highest stresses are well below the material yield strength, confirming the structural adequacy of the tank design. The analysis also demonstrated that wall displacements remain minor, ensuring the tank's integrity and functionality under operational conditions. Overall, the structural test validates the tank's ability to safely contain 30L of water without risk of failure, supporting the prototype's viability for further development and real-world use. == Hydrostatic Pressure == Pressure at depth: P = ρgh ρ = 1000 kg/m³ (water) g = 9.81 m/s² h = depth (m) Max pressure at bottom: P_max = 1000 × 9.81 × 0.1753 ≈ 1,720 Pa == Simulation Steps == Model tank with above dimensions. Apply fixed restraints at base. Add gravity (-9.81 m/s²). Set nonuniform pressure load on internal faces: Use coordinate system at water surface. Pressure equation: 0x + 0y + 9810*z (z in meters from surface, downward). Mesh and run static analysis. == Analysis Results == === Factor of Safety Analysis ===

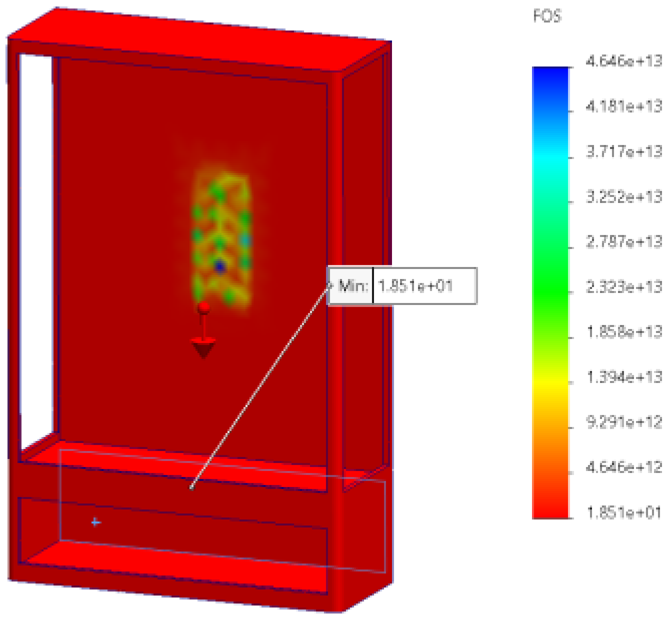

Figure 51: Factor of safety distribution

The factor of safety analysis shows exceptionally high safety values throughout the tank structure. The minimum factor of safety is 13.51, which far exceeds the required minimum of 2.0. The maximum factor of safety reaches 4.646e+13, indicating areas of extremely low stress relative to material strength. This confirms that the tank design is highly conservative and provides substantial safety margins against structural failure under hydrostatic loading. === Strain Distribution ===

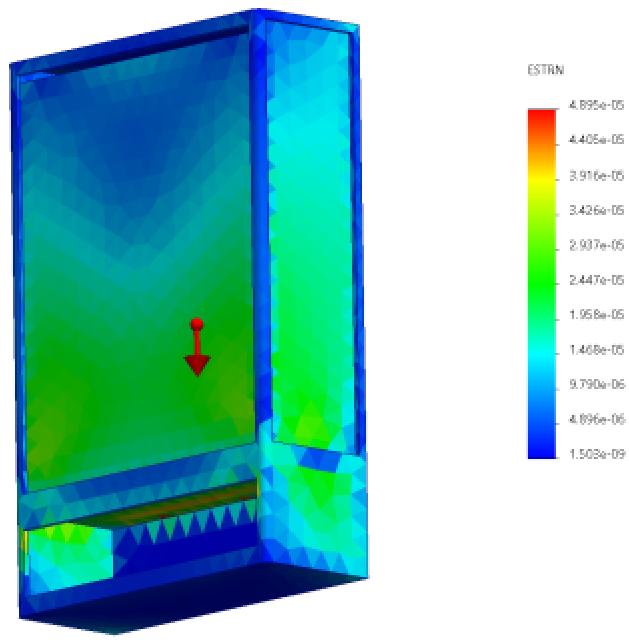

Figure 52: Strain distribution analysis

The strain analysis reveals maximum strain values of 4.895e-05 (approximately 0.00005), which are extremely small and well within elastic limits for typical structural materials. The strain distribution shows higher concentrations at the base-wall junctions and decreases toward the upper regions of the tank. The low strain values confirm that the tank operates well within the elastic range with no risk of permanent deformation. === Von Mises Stress Analysis ===

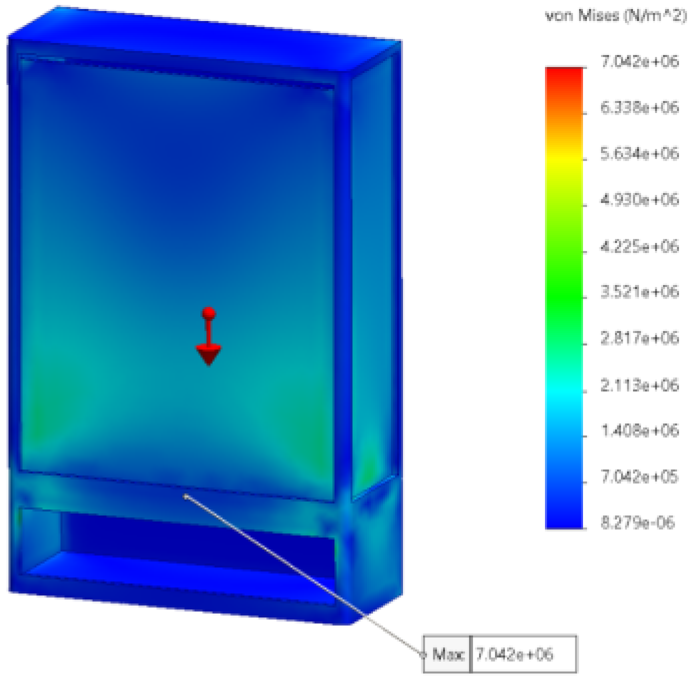

Figure 53: Von Mises stress distribution

The von Mises stress analysis shows a maximum stress of 7.042 MPa (7.042e+06 N/m²) located at the base-wall junction, as expected from the hydrostatic pressure distribution. The stress gradually decreases from the bottom to the top of the tank, following the pressure gradient. For typical structural steel with yield strength around 250 MPa, this maximum stress represents only 2.8% of the material's yield capacity, confirming excellent structural adequacy. === Displacement Analysis ===

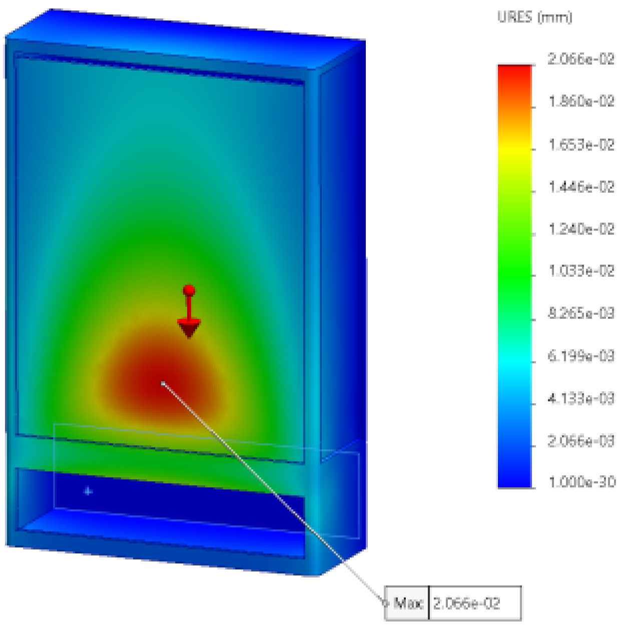

Figure 54: Displacement distribution

The displacement analysis shows maximum deformation of 0.02066 mm (2.066e-02), which is negligible for practical applications. The displacement pattern shows outward bulging of the tank walls, with maximum displacement occurring at the mid-height of the walls where bending effects are most pronounced. These minimal displacements confirm that the tank maintains its structural integrity and dimensional stability under the applied hydrostatic load. === Conclusion === The comprehensive structural analysis confirms that the tank design safely withstands the hydrostatic pressure exerted by 30L of water. All analysis results demonstrate exceptional structural performance: Factor of Safety: Minimum 13.51 (»2.0 required) Maximum Stress: 7.042 MPa (well below yield strength) Maximum Strain: 4.895e-05 (elastic range) Maximum Displacement: 0.02066 mm (negligible) The simulation results validate the tank's structural adequacy with substantial safety margins, supporting the prototype's viability for further development and real-world implementation. == Conclusion of the tests ==

Table 24: Conclusion test results

Test Type	Result
1 Hardware	Pass
2 Electrical	Pass
3 Software	Pass
4 Structural	Pass

7.5 Conclusions

The testing phase demonstrated that the prototype’s core software logic for temperature-based water redirection and tank level management functioned as intended under controlled conditions. Functional and usability tests confirmed that the system responded correctly to user input and sensor states, with reliable valve switching and safety overrides. While some limitations were observed, particularly in sensor accuracy, the results validate the effectiveness of the implemented software control strategy. These outcomes provide a solid foundation for further refinement and integration in the next development stage, where focus will shift to optimizing system robustness and expanding functionality.

7.6 Achievements

Team Azuloop has made a lot of progress in the five months they are developing the Azuloop. The main goal of the project was to develop a system that significantly reduced the household water waste, potentially decreasing shower water consumption by up to 10 %. This goal has been satisfactorily fulfilled, thanks to achieving a list of requirements. The requirements they accomplished are: **User interaction** * Safe to use around water * Easy to use, intuitive * Minimal possibility to personalize user settings **Interior** * Usable water saving system * Energy efficient **Exterior** * Attractive design * As small as possible * In harmony with the surroundings **Other** * Ecologic Unfortunately, due to scarce resources, lack of knowledge and time the Azuloop has some shortcomings: **User interaction** * There could be more possibilities to personalize the user settings. * The user might not be aware of their actions related to water waste while using the product. **Other** * The temperature sensor did not work in the final prototype. * The cost of the Azuloop is very high, due to a complex electrical system, so the price for the customer is also quite high. The customer does not save as much water to get the money they paid for the Azuloop back.

7.7 Future Development

As said in the previous paragraph, team Azuloop has made a lot of progress through the first phases of the development of the Azuloop. Unfortunately, the project only lasted one semester and the team did not have all the resources available that they needed, like time and budget. The team has some recommendations for further development: * An app to regulate the temperature and to enhance the user experience and customization of the product. * Add the water from the tap to the Azuloop system and into the extra tank. * Further research into redirecting the water to the boiler. * Make the design more invisible, for example build into the wall. * Cost/benefit optimization, for example through funding of the government so the Azuloop is affordable for everyone.. * Creating a system of water redirecting through all the house so the user can save more water and save money. In conclusion, the team agrees that the project has a very satisfactory outcome, accomplishing most of the goals and requirements, but there's still room for improvement and further development of the project. ===== Bibliography ===== *Will be added automatically by citing, in the body of the report, entries specified in BibTeX format and stored in the https://www.eps.dee.isep.ipp.pt/doku.php?id=refnotes:bib file* PS - *If you have doubts on how to make citations, create captions, insert formulas, etc. visit this page with examples and select "Show pagesource" to see the source code.*

[Bassey James, 2025] Bassey James, 2025. *Waste of Water: Figures, Causes, Impact, and Sustainable Solutions | What is Green Living? — whatisgreenliving.com.*
[Evolve Technologies, 2025] Evolve Technologies, 2025. *25% Of Shower Is Wasted Before You Ever Get In — thinkevolve.com.*
[TPN, 2024] TPN, 2024. *How much does water cost in Portugal? — theportugalnews.com.*
[4] Rinkesh. *The Effects of Wastewater and How Bad It Is For the Environment - Conserve Energy Future — conserve-energy-future.com.*
[Aquaflow Distributors, 2025] Aquaflow Distributors, 2025. *Showertimer - The innovative Australian water saving device — showertimer.com.au.*
[Eduard Rousseau, 2025] Eduard Rousseau, 2025. *edouard-rousseau.fr.*
[savewater, 2025] savewater, 2025. *.*
[stickq, 2011] stickq, 2011. *How do I make a faucet pour instead of spray? — diy.stackexchange.com.*
[WOTA, 2023] WOTA, 2023. *wota.co.jp.*
[Ecobuildingproducts, 2025] Ecobuildingproducts, 2025. *eco-buildingproducts.com.*
[WaterFlowKit, 2025] WaterFlowKit, 2025. *waterflowkit.nl.*
[Hydraloop, 2025] Hydraloop, 2025. *Hydraloop | Smart Water Recycling Systems — hydraloop.com.*
[Grey Water Action, 2025] Grey Water Action, 2025. *Greywater Action - For a sustainable water culture — greywateraction.org.*
[One Drop, 2025] One Drop, 2025. *The Foundation | One Drop Foundation — onedrop.org.*
[Glassdoor, 2025] Glassdoor, 2025. *.*
[IRS, 2025] IRS, 2025. *Energy Efficient Home Improvement Credit | Internal Revenue Service — irs.gov.*
[Ever Flow Bidets, 2025] Ever Flow Bidets, 2025. *Unlock Water Efficiency Rebates Everflow Bidets Savings — everflowbidets.com.*
[Joe Eaton, 2023] Joe Eaton, 2023. *The Surging Price of Water — aarp.org.*
[Xebina Hasnee, 2025] Xebina Hasnee, 2025. *The Increasing Popularity Of Eco Friendly Home Products: A Deep Dive Into Consumer Shifts and Market Trends — jugyah.com.*
[Rusé, 2025] Rusé, 2025. *Smart Home Trends for 2025: What to Expect in Home Automation — rusehome.com.*

[Sanjana Gajbhiye, 2025] Sanjana Gajbhiye, 2025. *Climate change is fueling a global water crisis — earth.com.*
[Autralian Government, 2025] Autralian Government, 2025. *Choose products that save water and money.*
[M. et al. Masukujjaman A. Al Mamun Y. Hong, 2024] M. et al. Masukujjaman A. Al Mamun Y. Hong, 2024. *Sustainable consumption practices among Chinese youth - Humanities and Social Sciences Communications — nature.com.*
[360imprimir, 2025] 360imprimir, 2025. *2500 Folhetos D\ípticos: 64,99\€ | Imprimir Folhetos D\ípticos Online | 360imprimir — 360imprimir.pt.*
[25] 360imprimirCartazes889x20AC
[Chris Ayman, 2024] Chris Ayman, 2024. *The PR Smith's SOSTAC® Plan: A Comprehensive Guide to Strategic Planning — thinkmarketingmagazine.com.*
[United nations, 2025] United nations, 2025. *THE 17 GOALS | Sustainable Development — sdgs.un.org.*
[United Nations, 2025] United Nations, 2025. *Communications materials - United Nations Sustainable Development — un.org.*
[Hari Srinivas, 2025] Hari Srinivas, 2025. *Sustainability Concepts: Eco-efficiency — gdrc.org.*
[P6 Technologies, 2025] P6 Technologies, 2025. *Life Cycle Assessment for Engineers: A comprehensive guide — p6technologies.com.*
[Esprix, 2025] Esprix, 2025. *ESPRIX mit Schwerpunktthema Kreislaufwirtschaft – ESPRIX — esprix.ch.*
[Solubility of Things, 2025] Solubility of Things, 2025. *Environmental Impact of Metal Production and Use | Solubility of Things — solubilityofthings.com.*
[Woodly, 2025] Woodly, 2025. *What is the carbon footprint of plastic? - Woodly — woodly.com.*
[Geneva Environment network, 2024] Geneva Environment network, 2024. *The Growing Environmental Risks of E-Waste — genevaenvironmentnetwork.org.*
[Swidget, 2023] Swidget, 2023. *Lifespan of IAQ, temperature, and humidity sensors — support.swidget.com.*
[Shon, 2023] Shon, 2023. *Water Level Relay VS Float Switch: Which One Is Best To Use? — lorentzzi.com.*
[Admin, 2017] Admin, 2017. *Solenoid Valve Maintenance - An overview — betavalve.com.*
[Epipe, 2021] Epipe, 2021. *How Long Do Copper Pipes Really Last? | ePIPE — whyrepipe.com.*
[40] EU) 2020/2184) for hygiene in water systems, and the General Product Safety Directive (2001/95/EC) for overall consumer safety. These together form the basis for CE marking. Engineers and manufacturers must share responsibility for product safety and performance.

6.6 Summary

Ethical considerations have guided the AzuLoop project at every step. From ensuring user safety to minimizing environmental impact, the team has consistently followed engineering and moral principles. The team considered ethics from multiple perspectives: -Engineering safety and reliability -Marketing transparency -Environmental sustainability -Legal compliance and accountability As a result, Azuloop: -Selected durable, energy-efficient components -Prioritized intelligent water-saving logic -Ensured the system supports both people and the planet -Designed with future compliance in mind This ethical foundation helped design a solution that uses clean water efficiently while supporting environmental, technical, and societal goals. In the next chapter, the focus is on project development.

7. Project Development

7.1 Introduction

This chapter will be a summary of the development of the project. First is the Ideation phase of the team and product explained, followed by an overview of the final concept. The concept paragraph contains the structure, smart system and packaging of the product. Next is the prototype paragraph. The main changes in relation to the designed solution will be explained for the structure, hardware and software. The tests and results will also be showed in this paragraph.

7.2 Ideation

The project started with a focus on the theme Smartifying Everyday objects. The team identified a problem and target group. After careful consideration, the team selected “Water Usage” as the problem area and decided to focus on homeowners. Two days of Design Thinking Workshops made each member contribute with a variety of ideas. The ideas were evaluated by using Dot-Voting. (See Figure 28). So that the most promising ideas were identified and prioritized.

Figure 28: Dot voting

Working from the winning ideas, the team initially came up with a system-based solution. After guidance from professors to concentrate on a product-based solution, the concept evolved into the Smart Shower Mixer (See Figure 29). This device contains a temperature sensor that monitors the water temperature. When the water is colder than the user's preferred temperature, the sensor triggers a valve to divert the water to a tank before the boiler. When this happens, the primary valve directing water to the shower remains closed. Once the water reaches the desired temperature, the system reopens the shower valve and closes the tank valve at the same time, so the pre-heated water goes to the shower. The water from the tank will be redirected to the boiler with a pump. This solution led to tweaking the target group: Environmentally conscious homeowners who own a tankless boiler.

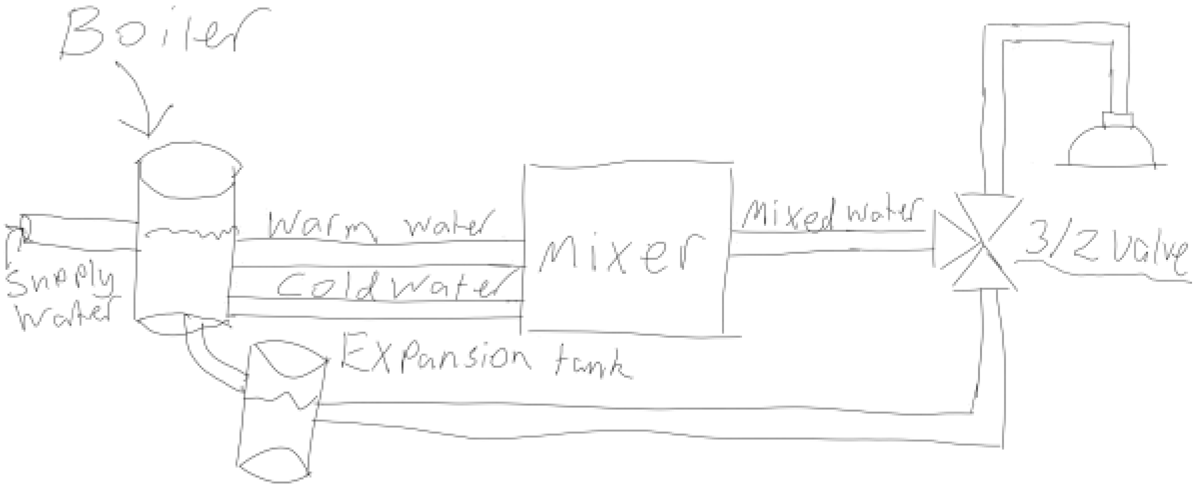

Figure 29: Boiler solution

7.3 Concept

After presenting the concept again, additional feedback led to a second version of the Smart Mixer. The cooler water will be redirected to the toilet instead of the boiler. In this version, the product takes advantage of the forces of gravity to direct the water into a tank above the toilet. Inside this extra tank there will be a water level sensor and when it measures that the water is above a certain amount, it opens a valve that directs the water to the toilet tank so the user can flush the toilet with it.(See Figure 30) The need for a pump will be eliminated, so the result is a more cost-effective and simpler product installation. The solution will be more accessible to end-users. The end users will now be environmentally-conscious homeowners who have a bathroom with a toilet and shower in the same room.

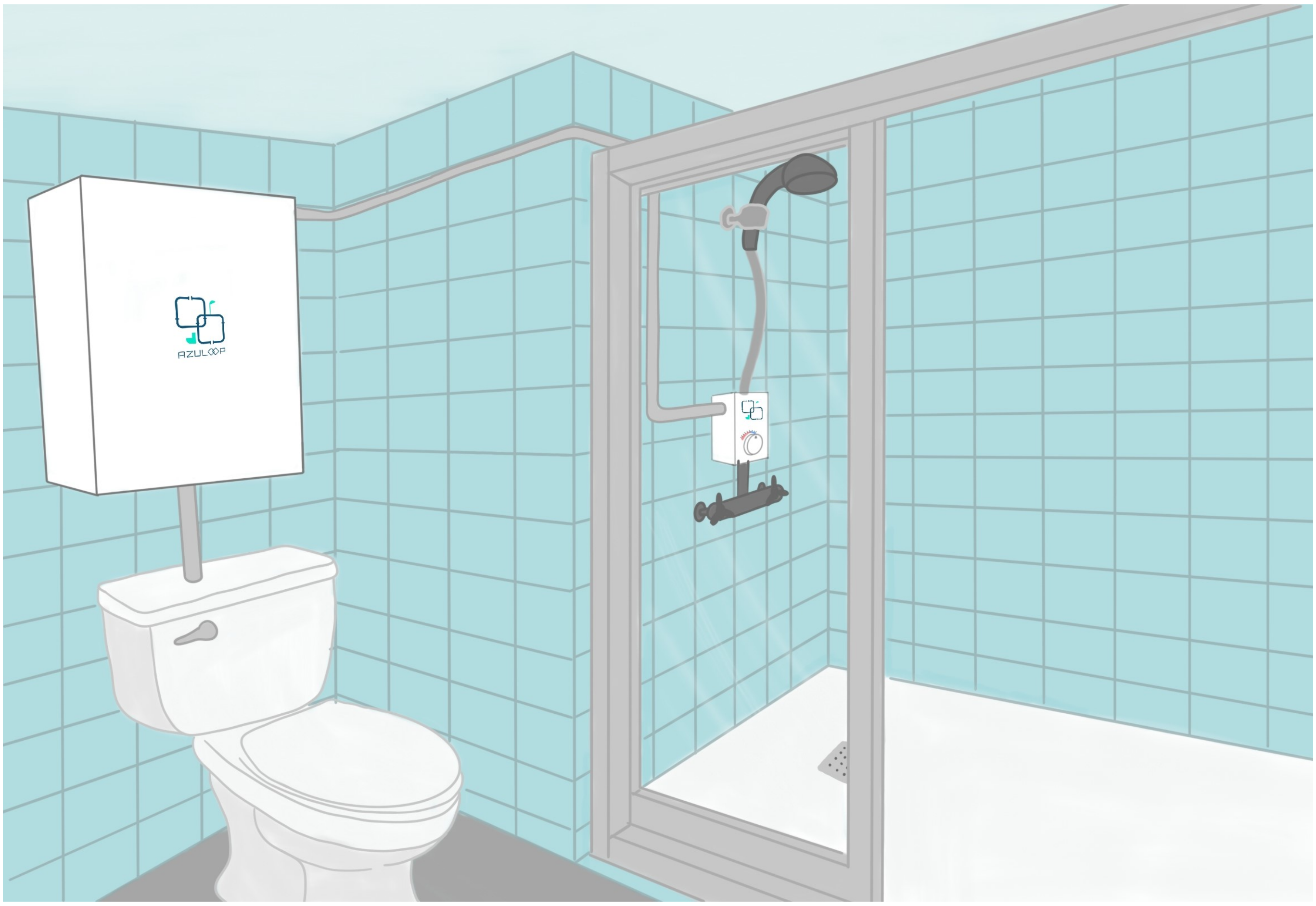

Figure 30: AzuLoop in context sketch

=== Detailing === First, the Azuloop consists of a box inside the shower (See Figure 31). Inside, there are two solenoid valves, one Normally Open, one Normally closed. Also there is a temperature sensor, a potentiometer and a micro controller.

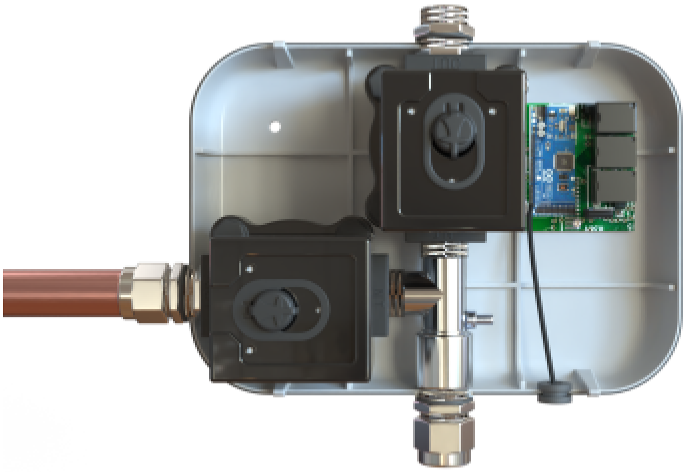
Figure 31: Shower part inside

The second part of the Azuloop consists of an extra tank above the toilet(See Figure 32). The front is see-through glass and inside are two float level sensors to measure the water level.

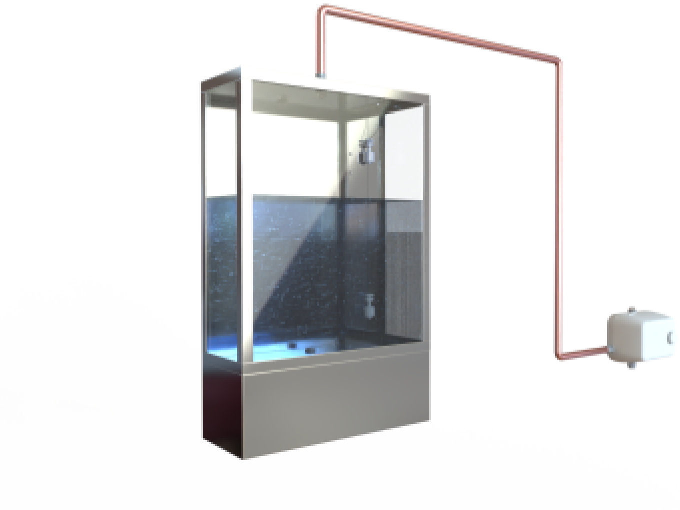

Figure 32: Complete view

In the lower back of the extra tank are two solenoid valves (See Figure 33) and connections to the micro controller.

Figure 33: Backside tank

To ensure a safe use with rounded corners of the tank without loosing the aesthetic value of the metal structure, a protective corner tape is added to the edges of the tank (See Figure 34).

Figure 34: Protective corner tape [(Protective corner tape