WATER NANO GRID

Where community engagement meets cutting edge technology

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0. Context

0.1 SDG6: Clean Water and Sanitation

The Sustainable Development Goals (SDGs), serve as a blueprint for achieving a better and more sustainable future for all. Among these 17 goals, the Sustainable Development Goal 6 (SDG6) is dedicated to ensuring the availability and sustainable management of water and sanitation for all. This goal is critical, as water scarcity, poor water quality and inadequate sanitation have a negative impact on food security, livelihood options and education around the world.

0.2 SDG6.4: Water Use and Scarcity

Within the broader framework of SDG 6, our target is the 6.4 which aims to specifically address water use efficiency and the sustainability of freshwater withdrawals.
The SDG6.4 has two primary components:

- **The Target:** By 2030, substantially increase water-use efficiency in all sectors and ensure sustainable freshwater withdrawals and supplies to address water scarcity and substantially reduce the number of people suffering from water scarcity.

- **Indicators:**
  SDG 6.4.1: Increase the water use efficiency
  SDG 6.4.2: Reduce the level of water stress

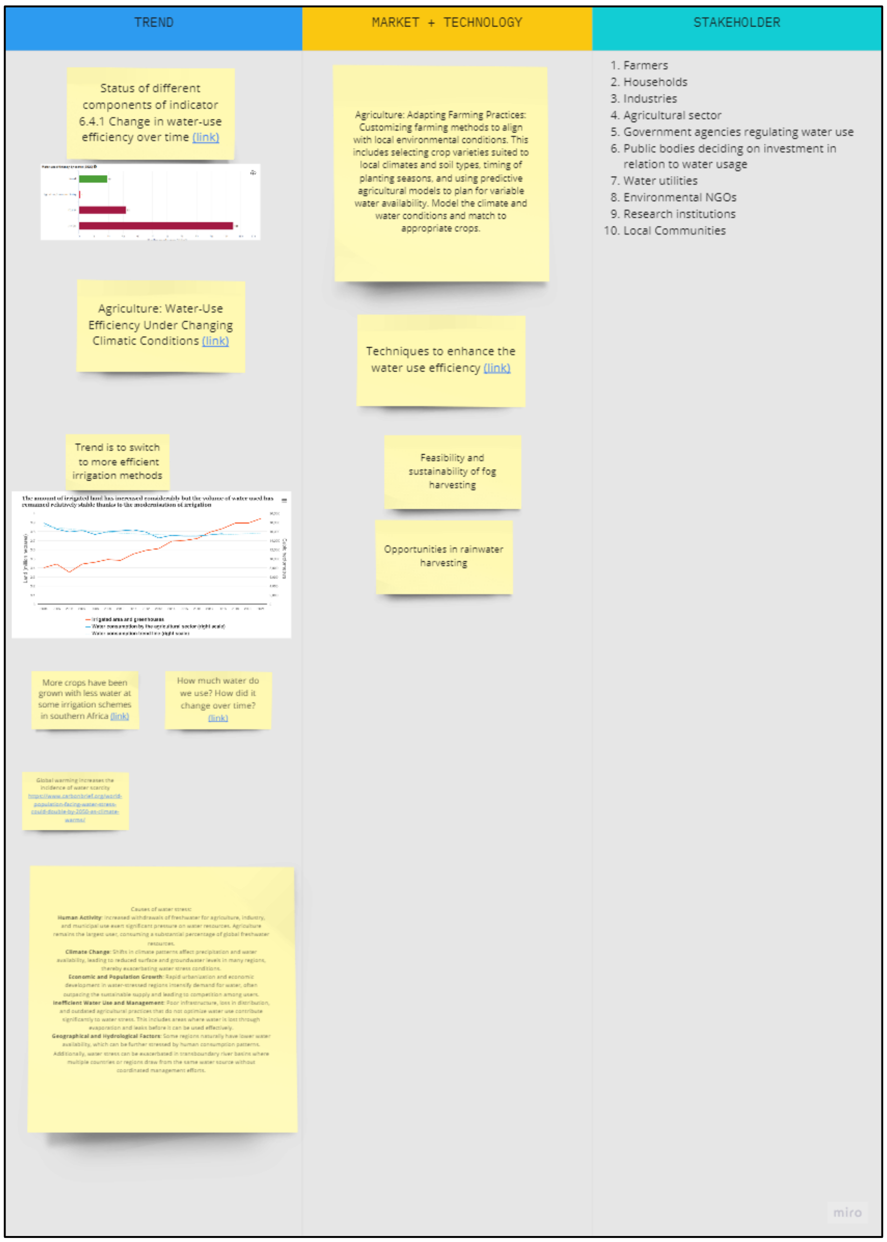
From these two indicators our projects focus on the first one (SDG6.4.1).

1. Frame the Problem

1.1 Initial Research

The first step we did was doing some research, to know the situation related to our topic, focusing in three relevant aspects:

- Trend
- Market + Technology
- Stakeholders



From this research the main ideas that we obtained where the following ones:

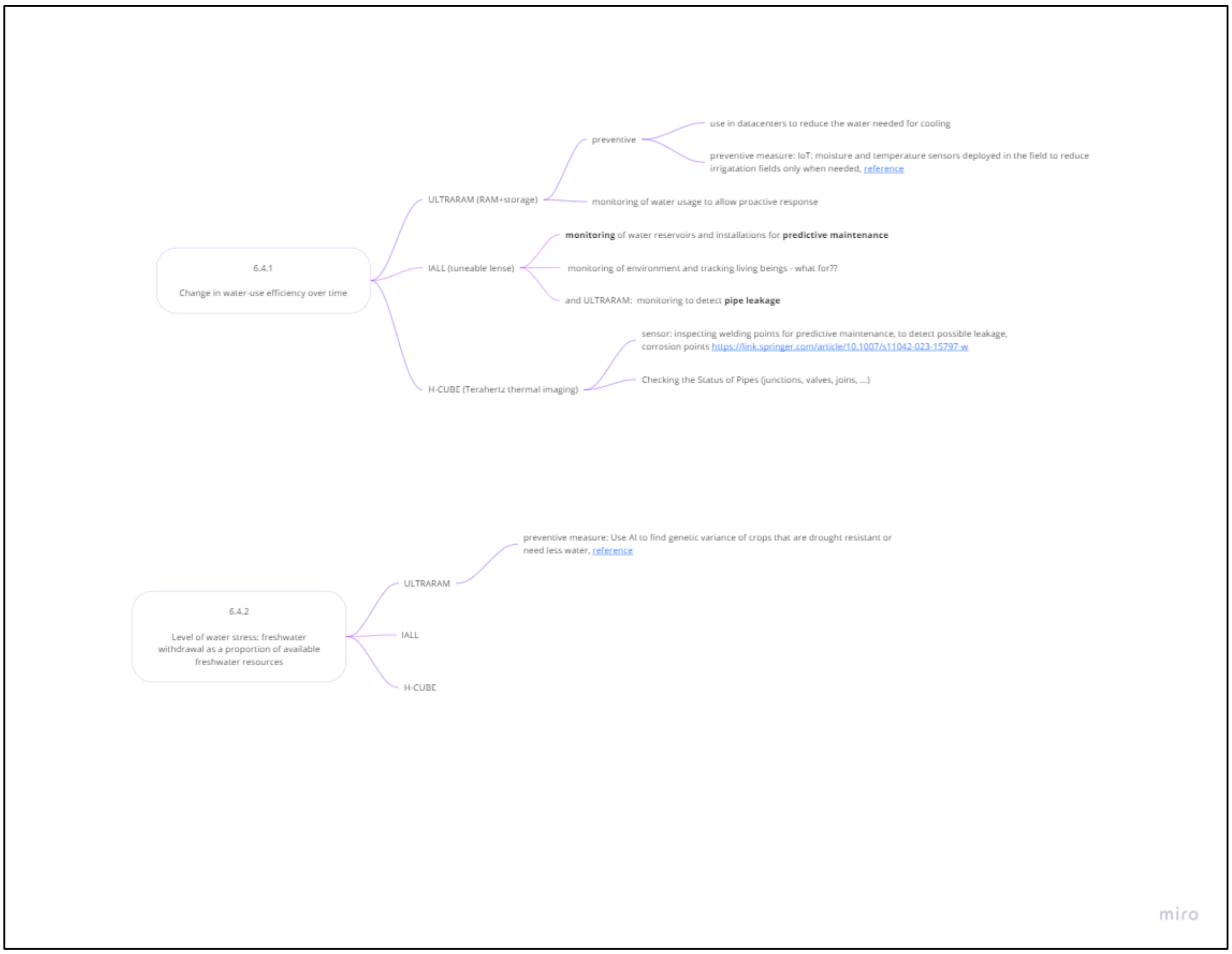
- Trend:
    - With the growing global population and urbanization, the demand for freshwater resources is escalating.
    - Climate change exacerbates water scarcity through altered precipitation patterns and more frequent extreme weather events.
    - There is a rising global emphasis on sustainable development, driving policies and initiatives aimed at improving water-use efficiency and ensuring sustainable water management.
    - Environmental awareness and the need for sustainable practices are influencing corporate strategies and consumer behaviors.
- Market + Technology:
    - Innovations in water-saving technologies, such as precision agriculture, smart irrigation systems, and industrial water recycling, are gaining traction.
    - Digital technologies, including IoT (Internet of Things) and AI (Artificial Intelligence), are being increasingly applied for real-time water monitoring and management.
    - There are three main possible sector targets where water can be more efficiently used: Agriculture, Industrial and Municipal/Domestic use.
- Stakeholders:
    - Governments and Policymakers
    - Agricultural Sector
    - Industrial Sector
    - Municipalities and Utilities
    - Non-Governmental Organizations (NGOs)
    - Technology Providers

1.2 Technologies First Impressions

The technologies related to the ATTRACT Project, that were presented to us where the following ones:

- H-Cube: Micromechanical Bolometers array for Terahertz imaging
- IALL: A tunable thin lens based on liquid crystals
- ULTRARAM: Ultralow-power, Non-volatile, Random Access Memory

From these three technologies, we started to do some brainstorming on possible application fields, considering the initial research done previously.



From this research the main ideas, related to each technology where the following ones:

- H-Cube
  - Sensor for inspecting welding points for predictive maintenance, to detect possible leakage, corrosion points, etc.

  - Checking the status of pipes (junctions, valves, joins, ...)

- IALL
  - Monitoring of water reservoirs and installations for predictive maintenance

  - Monitoring of environment and tracking living beings

  - Monitoring to detect pipe leakage

- ULTRARAM
  - Monitoring of water usage to allow proactive response

  - Moisture and temperature sensors deployed in the field to reduce irrigation fields

  - Monitoring in datacenters to reduce the water needed for cooling

  - Use AI to find genetic variance of crops that are drought resistant or need less water

Additionally, we asked the professors for more possible ATTRACT Project technologies.

- AHEAD: Creation of 3D-printed hydraulic components integrating fluid sensing elements
  - 3D printed smart pipe with several functions:
    - Temperature sensing
    - Heating
    - Energy Harvesting
  - Incorporates a transmitter that shares the information with a receptor

We thought that this technology could be used on pipe system monitoring installations.

1.3 Problem Definition

Using the different research, the information about the technologies and some meetings with the coaches we manage to define our problem:

There were two main problems that we manage to define with his characteristics:

- Domestic Sector Problem:
  - Tons of water used on the cities
  - 70% of the municipal water is used in the domestic area
  - The use of water on the households can be optimized without the active intervention of the user

- Agriculture Sector Problem:
  - Is the sector where more water is used
  - The old irrigation systems use the water very inefficient, and a lot is wasted
  - With the nowadays technology a huge improvement can be done, feasible and viable

From these two main problems, we framed several *How Might We Statements*:

Water Re-circulation

- How Might We implement water-recirculation systems in old residential buildings to improve water efficiency without extensive renovations?
- How Might We leverage the Attract technology to achieve that?

Water Quality Sensing

- How Might We design a pollution and water quality sensing system that encourages community engagement and responsible water usage?
- How Might We use Attract technology to provide real-time feedback to residents about their water usage and quality?
- How Might We develop a reward system that incentivizes residents to save water in urban environments?

Water Pipes Monitoring

- How Might We utilize the Attract technology to monitor and manage water efficiency more effectively in urban/residential areas?

Smart Irrigation in Urban Gardens

- How Might We enhance water efficiency in urban gardens, or any shared green spaces?
- How Might We use Attract technology to develop predictive models that adjust watering schedules based on weather forecasts and soil moisture levels?

Smart Irrigation in Greenhouses

- How Might We optimize irrigation schedules in greenhouses using real-time data analysis?
- How Might We leverage the Attract technology for real-time sensing and analysis?

Drought-Resistant Crops

- How Might We use artificial intelligence to develop crop varieties that require less water?
- How Might We leverage the Attract technology in this process?

Increasing Industrial Water Efficiency

- How Might We facilitate the entry of water-saving technologies in industries that are traditionally difficult to penetrate?
- How Might We develop water-saving system that delivers clear benefits without the need for strict regulations?
- How Might We create compelling incentives for industries to adopt our water-saving technology?
- How Might We collaborate with industry leaders to develop water-efficient solutions that meet their sector's needs?

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But after some internal discussion, the selected How Might We statements was the following one:

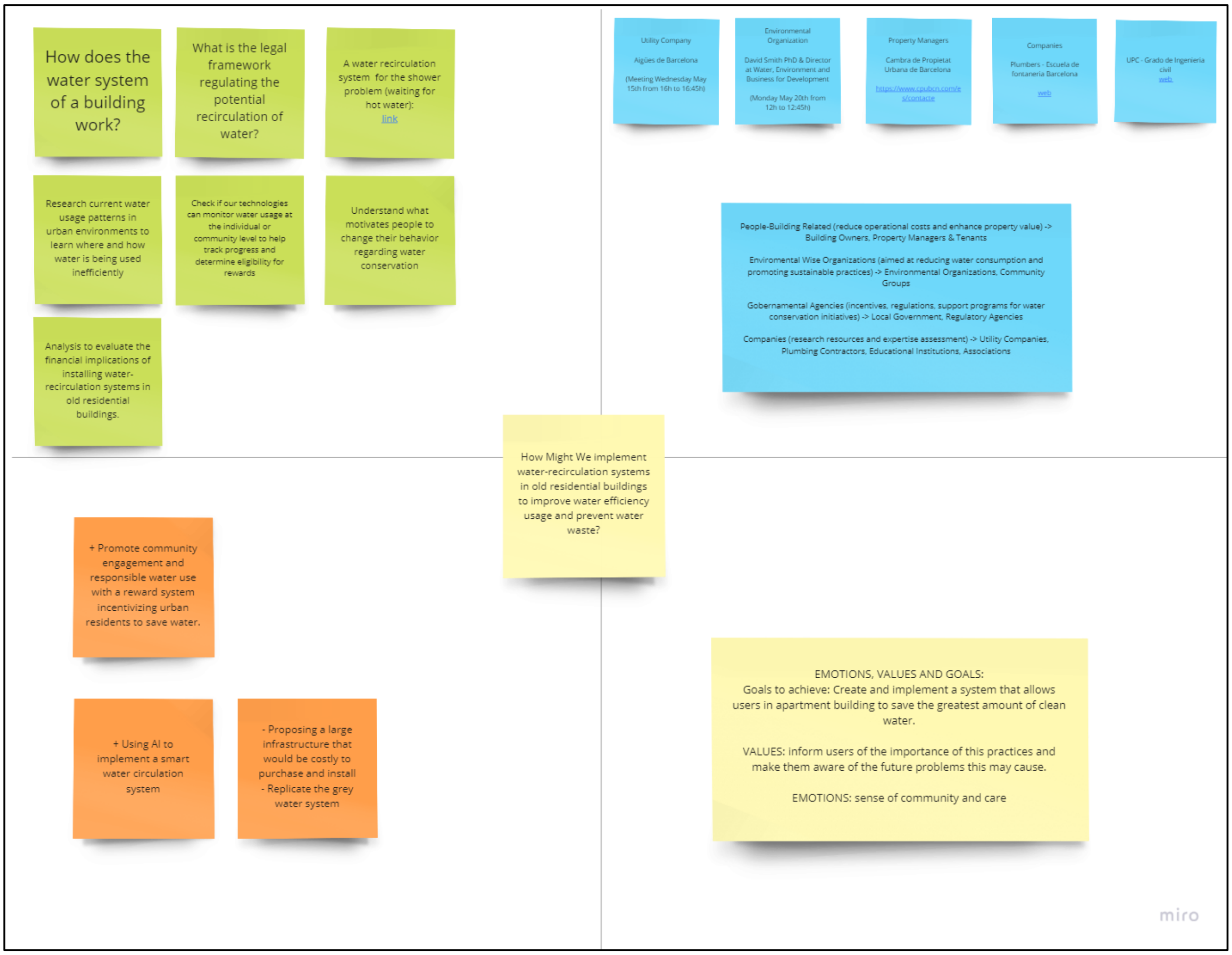
How might we implement a water-recirculation system in existing residential buildings and design a user incentive platform to improve water use efficiency?

Aiming to solve the domestic sector problem and thinking about a feasible solution for existing building blocks, related to the re-use of water and a platform to incentivize it.

2. Frame the Solution

2.1 Vision Board

On this initial stage of framing the solution we carried out a *Vision Board of our Project*, focusing on the research, the stakeholders, the concept/ideas and the goals:



The main ideas where the following ones:

- Research:
    - Understand what motivates people to change their behavior regarding water conservation
    - Research current water usage patterns in urban environments to learn where and how water is being used inefficiently
    - Analysis to evaluate the financial implications of installing water-recirculation systems in old residential buildings

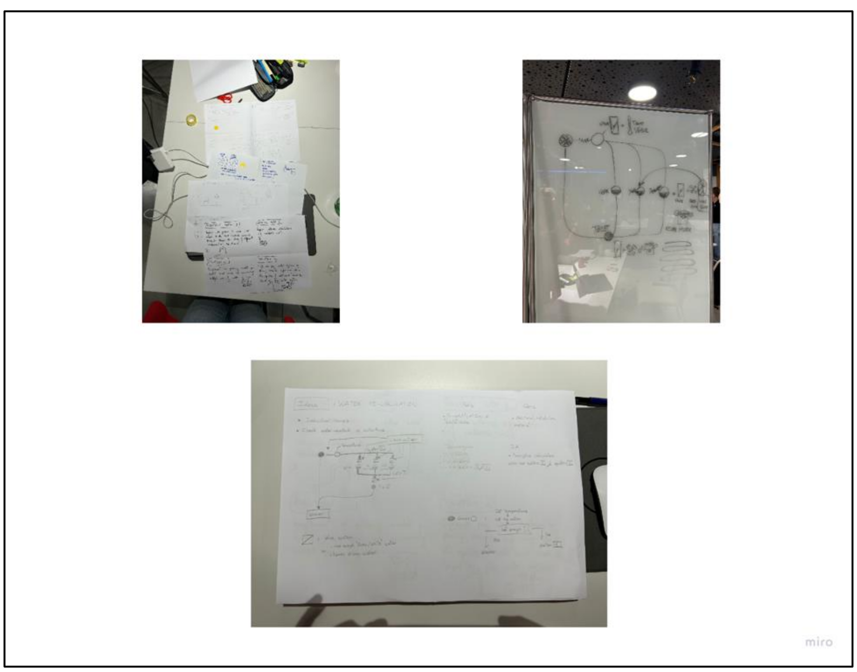
- Stakeholders:
    - People-Building Related: reduce operational costs and enhance property value
    - Enviromental Wise Organizations: aimed at reducing water consumption and promoting sustainable practices
    - Governmental Agencies: incentives, regulations, support programs for water conservation initiatives
    - Companies: research resources and expertise assessment

- Ideas:
    - Promote community engagement and responsible water use with a reward system incentivizing urban residents to save water
    - Using AI to implement a smart water circulation system

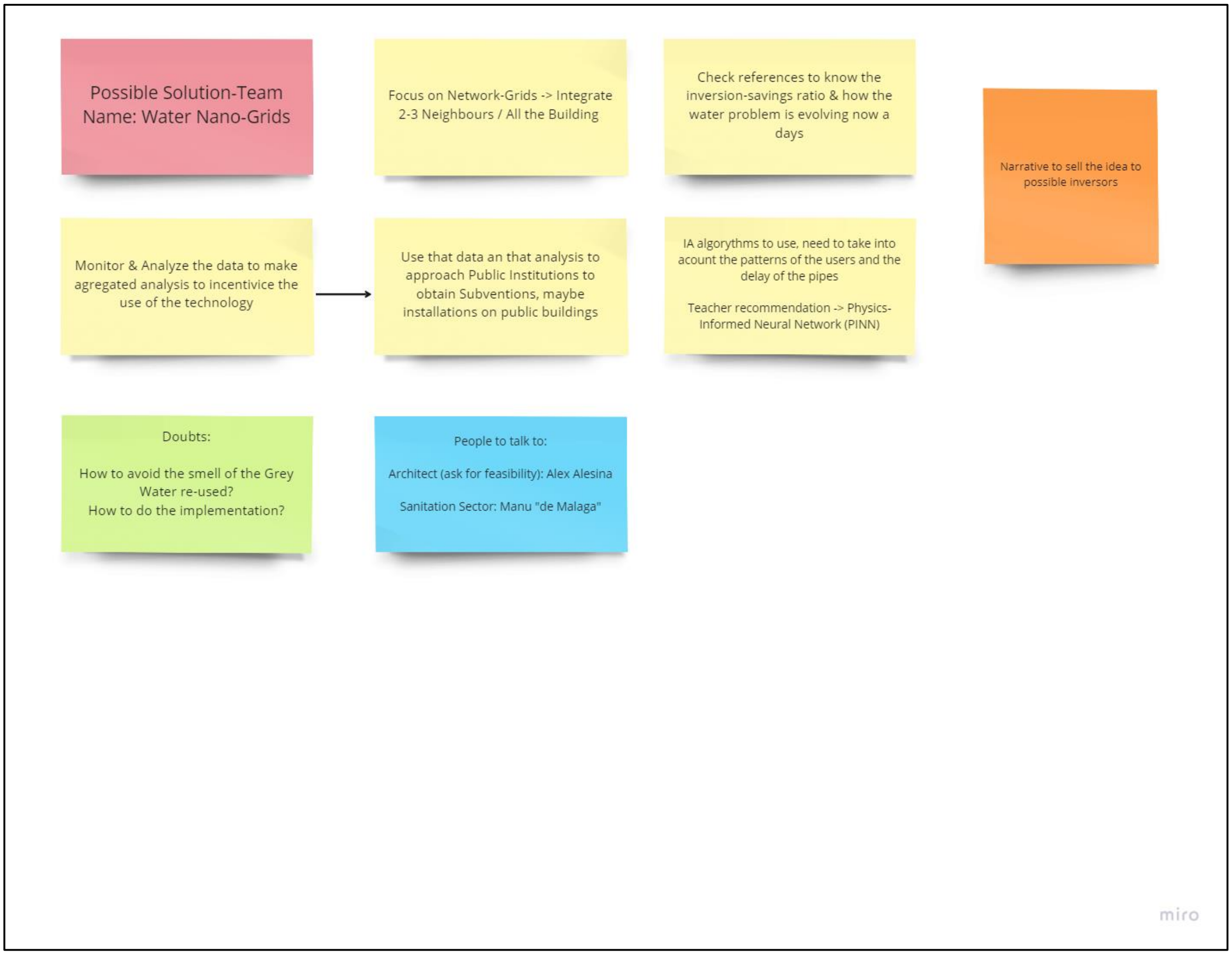
- Goals
    - Create and implement a system that allows users in apartment building to save the greatest amount of clean water
    - Inform users of the importance of these practices and make them aware of the future problems this may cause
    - Sense of community and care

2.2 Possible Solutions

After the Vision Board we started defining how to accomplish our goals with different solutions:



And after the insights from a session with the coaches:



We manage to frame our initial solution:

A water re-circulation system for existing residential buildings

2.3 Initial Solution

The idea of our initial solution is to improve the efficiency of water used on the buildings. To do that first we need to understand how water is used nowadays on the buildings.

2.3.1 Introduction

Nowadays, in residential buildings the water from the municipality is used and directly goes to the sewer, without considering if it is clean, grey or black water.

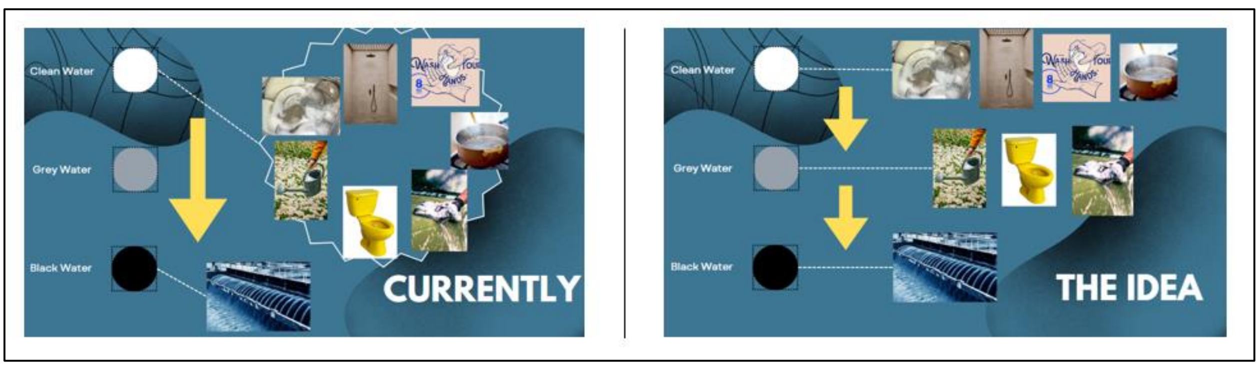
- Clean Water: water that is safe for ingestion, either when drunk directly in liquid form or consumed indirectly through food preparation.

- Grey Water: domestic wastewater generated in household buildings from streams without fecal contamination

- Black Water: in a sanitation context denotes wastewater from toilets which likely contains pathogens.

As can be observed, Clean Water and Grey Water can be re-used, to optimize the water efficiency of the households.

Based on that our initial solution aims to improve the water efficiency of residential buildings, using first the Clean Water, after that the Grey Water and finally the Black Water will go to the sewer.



2.3.2 Pipe System

Our initial proposal involves enabling old buildings in Barcelona to recirculate clean water and grey water among different apartments, reducing the need for municipal water. The primary objective of this system is to capture clean water used while heating the shower through a non-intrusive pipe system and repurpose it for activities requiring clean water, such as teeth brushing or dishwashing. Similarly, greywater will be captured in a parallel pipe system for use in activities that do not require potable water, such as flushing toilets or washing cars. Both potable water and grey water will be recirculated throughout the entire building. The proposal consists of three main components:

Installation of Sensors

Different sensors will be installed on all household appliances that use water. These sensors will measure the amount of water in the pipe system (further details will be provided later) and monitor water usage for different activities.

Shower Head Sensors:

- **Temperature Sensor**: Detects when water reaches the desired temperature. During the heating process, water that has not yet reached the required temperature is captured in a pipe buffer for storage and later use. Once the desired temperature is reached, the system allows water to flow through the shower head.

- **Proximity Sensor**: Controls water flow based on user proximity. Water flows only when the user is standing at a designated spot. If the user moves away, for example, while shampooing or lathering, the water flow stops.

Faucet Sensors:

- **Proximity Sensor**: Activates water flow only when an object is directly placed beneath the sensor.

Appliance Sensors:

- Sensors will inform the system when water can be used from the installed pipes and when it needs to be used by the municipal supply.

Installation of Pipes

The piping system will be installed on the bathroom floor, like underfloor heating systems, to ensure minimal disruption during installation. The plan is to connect all the systems in all the apartments through two external main pipes that carry water throughout the different floors.

Clean Water Management: The first pipe collects clean water from the shower that has not yet reached the desired temperature and stores it for use in other activities or appliances that require potable water. If there is insufficient water in the microgrid, sensors will allow water from the municipal supply to enter the system.

Greywater Management: The second pipe collects and stores greywater for use in toilet flushing or other activities that do not require potable water. Sensors monitor the greywater levels, ensuring the system does not collect excess greywater and supplements from the municipal supply if needed.

Additional Components

- **Pump**: A small pump will be installed under each sink to enable water flow within the system.

- **Filter System**: A filtration system will be installed on the greywater pipe to remove significant impurities.

This proposal aims to create a sustainable and efficient water management system in households, promoting water conservation through the intelligent use of clean and greywater.

2.3.3 IoT Network

To be able to automate, when to use the water stored on the pipes and when to use the municipality water and IoT network is implemented. This IoT network has three main parts the monitoring system, the server and the actuator system.

Monitoring System

The monitor system will measure the water flow rate that comes from the different inputs (shower, sink, dishwasher, washing machine) and will send it to a server via Wireless communication, the main parts of the system will be the following ones:

- **Ultra-Low-Power μC (microcontroller):** Central processing unit of the system.

- **ULTRARAM:** UltraRAM is a key component in the system for data storage and backup mechanism.

- **Ultrasonic Flow Meter:** Ultrasonic flow meters use sound waves to measure the flow rate of water.

- **LoRaWAN communication system:** Communication protocol for long-range communication with very low power consumption.

Server

Will receive the data from the monitoring system and using a **PINN AI will provide the guides for the actuator system.**

The **PINN AI (Physics-Informed Neural Network)** combines a deep knowledge of physical laws and the powerful learning capabilities of neural networks, which is ideal for our project that needs to consider the behavioral pattern of the users and the time delay of the water flow associated to the pipes.

Actuator System

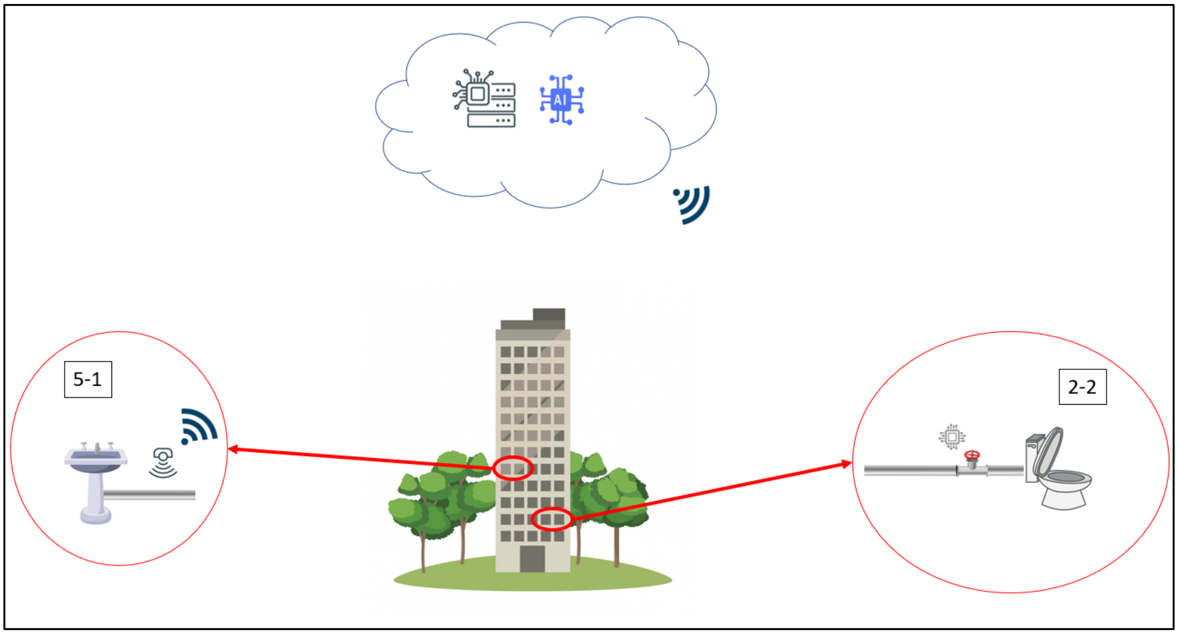
Based on the input received from the server the IoT device decides if the system's stored water should be used besides the municipal water for the different outputs (sink, dishwasher, washing machine, toilet), the main parts of the system will be the following ones:

- **Ultra-Low-Power µC (microcontroller):** This component serves as the central processing unit of the system.

- **LoRaWAN communication system:** Communication protocol for long-range communication with very low power consumption.

- **Relay module:** switch the higher current required by the solenoid valve.

- **Solenoid Valves:** this component uses an electromechanical solenoid to actuate a plunger, controlling the flow of water providing an on/off control.



2.3.4 App System

An essential component of our project involves the development of a user-centric application. This application serves as a dynamic facilitator, providing users with an array of tools and insights aimed at refining and optimizing their water consumption habits. Its significance lies in its ability to seamlessly integrate with the household sensors, enabling the collection of real-time data for accurate analysis. This integration enhances the relevance and precision of the information provided.

Moreover, the application adopts a multifaceted approach to empower users in managing their water usage effectively. Through its intuitive interface, users can delve into their water usage patterns, set personalized conservation goals, and access comprehensive insights based on their consumption data. These features not only enrich the user experience with practical guidance for sustainable living but also foster a deeper sense of responsibility and awareness among its users.

From real-time monitoring to personalized recommendations, the application offers a comprehensive suite of tools tailored to meet the diverse needs of its users. Some of these features include:

- **Configuration**
  The application facilitates the input of essential demographic and family data, including the number of household members, children, and pets. Furthermore, users can set personalized targets for water savings, aligning the system with their conservation goals and household requirements. By optimizing resources and identifying areas for improvement, the application enables users to make informed decisions about their water

usage habits, fostering a proactive approach to water conservation within residential settings.

- **System Efficiency Monitoring**
  A pivotal feature of the application lies in its capacity to provide real-time feedback on the efficiency of the water recirculation system. Users are afforded the capability to easily monitor the volume of water being recirculated, alongside insights into the resulting monetary savings. By facilitating informed decision-making regarding consumption behaviors, the application not only highlights the measurable benefits of our solution in optimizing water usage but also reinforces the significance of embracing sustainable practices. Through its promotion of awareness and accountability, the application assumes a critical role in nurturing a culture of conservation and environmental stewardship among users.

- **Usage Efficiency Analysis**
  Through intuitive interface design, the application empowers users to monitor and optimize water usage efficiency with precision. By filtering data according to specific faucets such as sinks, bidets, and showers, users gain actionable insights into their consumption patterns allowing for targeted adjustments to be made where necessary. Real-time line plots vividly depict clean water usage over time, while bar plots offer a comprehensive view of accumulated usage across varying timeframes. Through these features, the application equips users with the tools and knowledge needed to proactively manage their water consumption, ultimately contributing to greater efficiency and sustainability within residential settings.

- **Comprehensive Reporting**
  The application offers comprehensive reports that facilitate informed decision-making. Daily, weekly, and monthly analyses juxtapose actual usage data against user-set targets and reference benchmarks. Leveraging this data-driven approach, the application generates custom recommendations tailored to each user's unique circumstances. These recommendations enable users to make impactful contributions to water conservation efforts through simple adjustments in their daily routines, such as optimizing shower duration or reducing faucet usage. By empowering users with actionable insights and personalized recommendations, the application fosters a culture of proactive conservation and encourages individuals to play an active role in addressing the critical global water crisis.

In conclusion, the application represents a pivotal tool in our mission to revolutionize household water usage. Its user-centric design and robust feature set empower individuals to take tangible steps towards water conservation and sustainability. As we continue to confront the challenges posed by the global water crisis, the application stands as a beacon of innovation, inspiring users to cultivate mindful water consumption habits and secure a better, more sustainable future for generations to come.

2.4 Feedback

To know the viability of the project and the feasibility of it different feedback was received.

2.4.1 Surveys & Interviews

Civil Engineers Interview

To know the feasibility of the installation two interviews were carried out with two civil engineers:

- Manel Borrell Vilaseca:
  - "Ingeniera de Caminos Canales y Puertos"
  - Design Manager at "FCC Servicios Ciudadanos"
  - +32 years of experience

- Giovanni Stoffel
  - Civil Engineering
  - SM-Ingegneria Sagl, Director
  - +40 years of experience

Go to the annexed folder for the complete insights of the two interviews

The main conclusions of the interviews where the following ones:

- The installation of the system will imply a reduction of 30% around the water used on the building.

- With the nowadays technology, the implementation of the system will have a high monetary impact on the end-users.

- The system deeply impacts the structure of the building which implies a huge restructuring of it.

Anonymous Community Neighborhood Survey

Additionally, to know the will of the people to invest in the solution and to know their awareness about the topic we carried out an anonymous survey on a community of 120 households.

Go to the annexed folder for the complete insights of the survey

The main conclusions of the anonymous survey where the following ones:

- Community Description: Young adult community, on the process to start a family

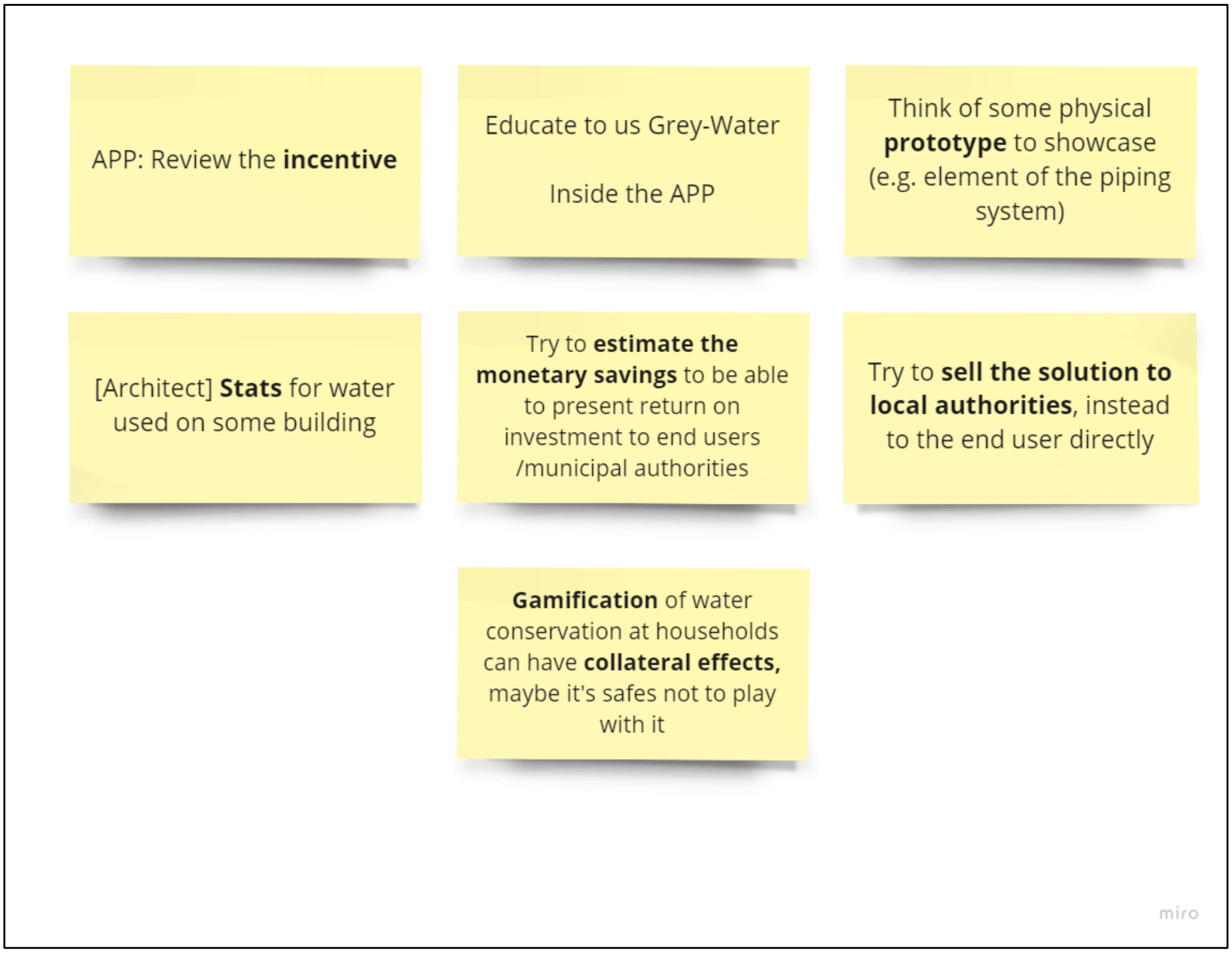
- Aware of the water scarcity, due to the recent crisis of drought in Catalonia

- Are interested in installing a water reuse system but not willing to invest a lot of money (500€ - 2000€) on the inversion mainly due to the cost.

- There is not clear a main reason to install the system, it's a combination of saving, government subsidies and the environmental benefits

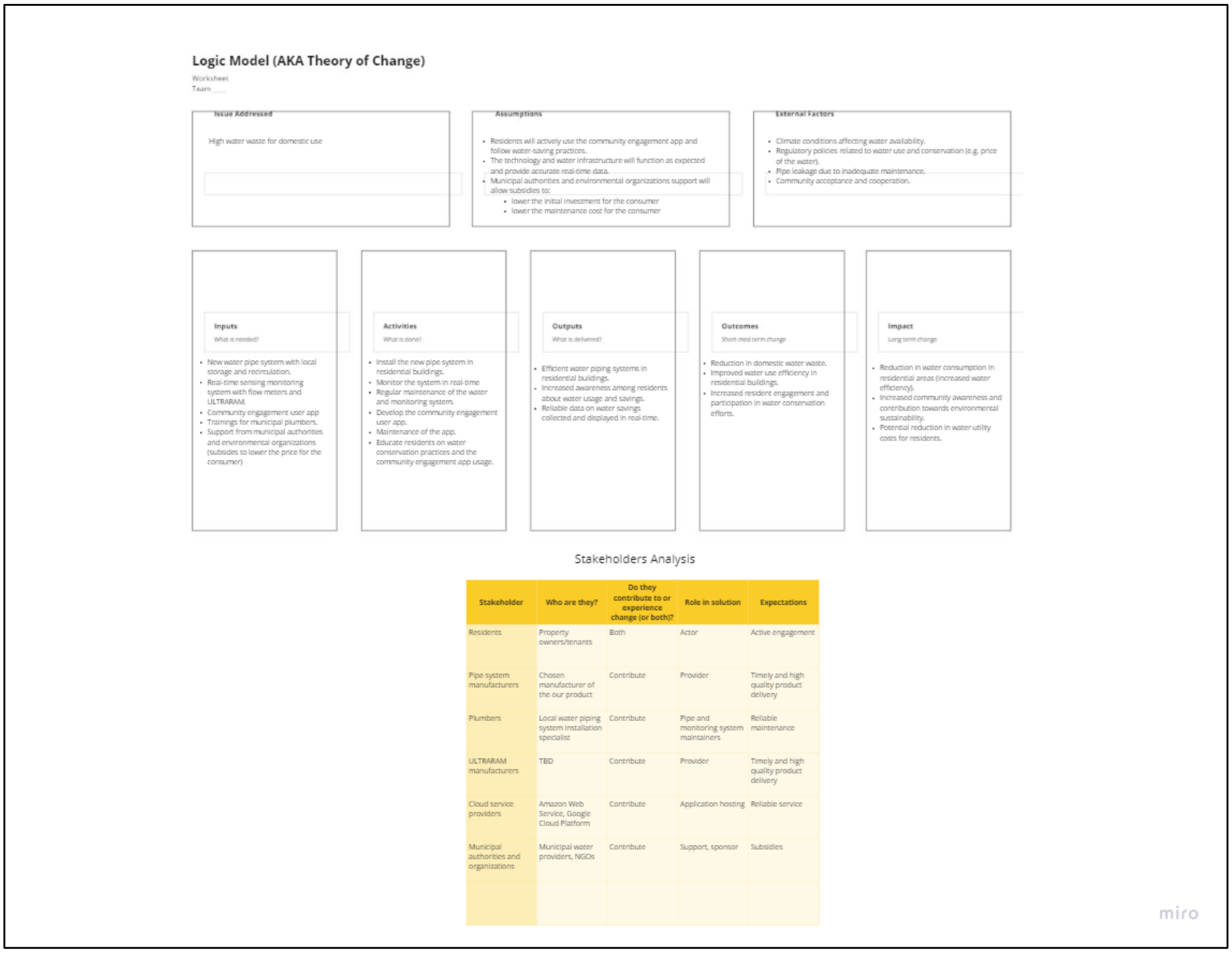
2.4.2 Mid-Term Presentation

From the Mid-Term Presentation, we got the following feedback.



2.4.3 Social Impact Session

For the social impact session, we prepared the Logic Model (AKA Theory of Change) and the Stakeholder Analysis.


Logic Model (AKA Theory of Change)

Worksheet
Team ___

Issue Addressed

High water waste for domestic use

Assumptions

- Residents will actively use the community engagement app and follow water-saving practices.
- The technology and water infrastructure will function as expected and provide accurate real-time data.
- Municipal authorities and environmental organizations support will allow subsidies to:
  - lower the initial investment for the consumer
  - lower the maintenance cost for the consumer

External Factors

- Climate conditions affecting water availability.
- Regulatory policies related to water use and conservation (e.g. price of the water).
- Pipe leakage due to inadequate maintenance.
- Community acceptance and cooperation.

Inputs
What is needed?

- New water pipe system with local storage and recirculation.
- Real-time sensing monitoring system with flow meters and ULTRARAM.
- Community engagement user app
- Trainings for municipal plumbers.
- Support from municipal authorities and environmental organizations (subsides to lower the price for the consumer)

Activities
What is done?

- Install the new pipe system in residential buildings.
- Monitor the system in real-time
- Regular maintenance of the water and monitoring system.
- Develop the community engagement user app.
- Maintenance of the app.
- Educate residents on water conservation practices and the community engagement app usage.

Outputs
What is delivered?

- Efficient water piping systems in residential buildings.
- Increased awareness among residents about water usage and savings.
- Reliable data on water savings collected and displayed in real-time.

Outcomes
Short-med term change

- Reduction in domestic water waste.
- Improved water use efficiency in residential buildings.
- Increased resident engagement and participation in water conservation efforts.

Impact
Long term change

- Reduction in water consumption in residential areas (increased water efficiency).
- Increased community awareness and contribution towards environmental sustainability.
- Potential reduction in water utility costs for residents.

Stakeholders Analysis

Stakeholder	Who are they?	Do they contribute to or experience change (or both)?	Role in solution	Expectations
Residents	Property owners/tenants	Both	Actor	Active engagement
Pipe system manufacturers	Chosen manufacturer of the our product	Contribute	Provider	Timely and high quality product delivery
Plumbers	Local water piping system installation specialist	Contribute	Pipe and monitoring system maintainers	Reliable maintenance
ULTRARAM manufacturers	TBD	Contribute	Provider	Timely and high quality product delivery
Cloud service providers	Amazon Web Service, Google Cloud Platform	Contribute	Application hosting	Reliable service
Municipal authorities and organizations	Municipal water providers, NGOs	Contribute	Support, sponsor	Subsidies

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The main feedback received from the session was related to the app data and the idea of the leaderboard.

Since you are doing a leaderboard, the other neighbors can know your water consumption, which is not a good implementation that respects the privacy of the user. That's why, to respect the privacy of the end user's, the leaderboard is going to be removed and the app will just focus on your personal data, without being possible to know the data of the other users.

2.5 Conclusion

The initial solution was to equip entire buildings with water recirculation systems, but high costs and structural complexities led us to refine our approach. By focusing on a smaller solution attached to flats, especially bathrooms, we simplified the implementation and reduced the costs. On that basis, our solution can be framed as follows:

Water re-circulation system for existing residential flats

3. Our Solution: Proposal for Efficient Water Use in Household Bathrooms

The current household water usage is often inefficient, primarily due to a lack of awareness and actionable information regarding water conservation. Although the issue of water availability is well-known, the information necessary for individuals to implement effective conservation measures is insufficient. Our proposal aims to address this by focusing on optimizing water usage in bathrooms. This includes using clean water solely for activities that require it and recirculating grey water for toilet flushing.

3.1 System

Installation of Sensors on Shower Heads and Faucets:

- **Shower Head Sensors:**
  - **Temperature Sensor:** Detects when water reaches the desired temperature. During the heating process, water that has not yet reached the required temperature is captured in a pipe buffer for storage and later use. Once the desired temperature is reached, the system allows water to flow through the shower head.
  - **Proximity Sensor:** Controls water flow based on user proximity. Water flows only when the user is standing at a designated spot. If the user moves away, for example while shampooing or lathering, the water flow stops.
- **Faucet Sensors:**
  - **Proximity Sensor:** Activates water flow only when an object is directly placed beneath the sensor.

Both sensors will be equipped with wireless communication devices to transfer usage data to an application discussed in a later section.

Non-Intrusive Piping System:

- **Installation:** The piping system will be installed on the bathroom floor, like underfloor heating systems, to ensure minimal disruption during installation.
- **Clean Water Management:** The first pipe collects clean water from the shower that has not reached the desired temperature and stores it for use in the sink. If there is insufficient water in the microgrid, sensors will allow water from the municipal supply to enter the system.

- **Greywater Management:** The second pipe collects and stores greywater for use in toilet flushing. Sensors monitor the greywater levels, ensuring the system does not collect excess greywater and supplements from the municipal supply if needed.

Additional Components:

- **Pump:** A small pump will be installed under the sink to enable water flow within the system.

- **Filter System:** A filtration system will be installed on the greywater pipe to remove significant impurities before the greywater enters the toilet tank.

This proposal aims to create a sustainable and efficient water management system in household bathrooms, promoting water conservation through the intelligent use of clean and grey water.

3.2 IoT Network

The IoT Network in comparison with the initial solution is simplified, due to the huge reduction in the number of inputs and outputs, but nevertheless the three fundamental parts are the same: the monitoring system, the server and the actuator system.

Monitoring System

The monitor system will measure the water flow rate that comes from the different inputs (showers and sinks) and will send it to a server via Wireless communication, the main components will be the following ones:

- **Ultra-Low-Power µC (microcontroller):** This component serves as the central processing unit of the system. The ultra-low-power characteristic ensures efficient energy consumption.

- **ULTRARAM:** UltraRAM is a key component in the system for data storage and backup mechanism. It provides a combination of fast switching speed, low switching energy, and non-volatile memory characteristics.

- **Ultrasonic Flow Meter:** Ultrasonic flow meters use sound waves to measure the flow rate of water. They are non-intrusive and can be mounted on the outside of the pipe, making them easy to install and maintain.

- **LoRaWAN communication system:** Communication protocol for long-range communication with very low power consumption and offers good scalability for large-scale deployments.

Additionally, the faucets will have **movement sensors** to detect when to turn on and off. For the shower faucet, a **temperature sensor** will be also placed to know when the temperature has reached the user desired heat, to let the shower provide the water at the defined temperature, the water not hot enough will be stored on the pipe system to be available on other faucets.

Server

Will receive the data from the monitoring system, will store it and analyze it using an **AI language model system;** to provide personalize information to the user via the mobile app. Additionally, the server will communicate with the actuators to know when to use the water inside the systems or the municipal water.

Actuator System

Based on the input received from the server, the IoT device decides if the system's stored water should be used besides the municipal water for the different outputs (showers, sinks and toilets), the main parts of the system will be the following ones:

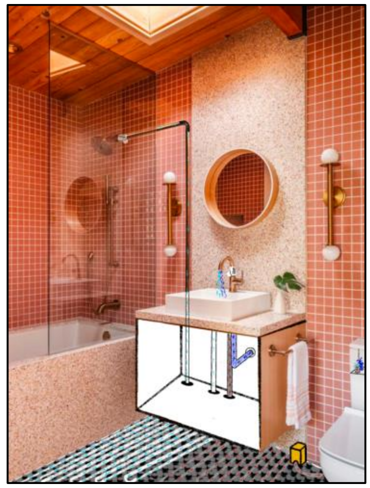
- **Ultra-Low-Power µC (microcontroller):** This component serves as the central processing unit of the system. The ultra-low-power characteristic ensures efficient energy consumption, aligning with the overall goal of reducing power requirements

- **LoRaWAN communication system:** Communication protocol for long-range communication with very low power consumption and offers good scalability for large-scale deployments

- **Relay module:** switch the higher current required by the solenoid valve

- **Solenoid Valves:** this component uses an electromechanical solenoid to actuate as a plunger, controlling the flow of water providing an on/off control. Also, they have a simple design and are easy to install and operate

Additionally, the grey water pipe storage system will contain a **filter** to clean up the water to reduce possible stink.



3.3 App System

The application is designed to allow users to visualize their water usage while providing tips on how to be more efficient. It is divided into three main information systems:

- **Input**: Users will input data such as the number of people living in the household, shower duration, and the presence of pets. Additionally, users will set desired targets, enabling the system to measure water usage based on their objectives. Sensors on the shower and faucet will provide real-time data on water usage, including the amount of water drawn from the municipal system and the amount used.

- **Output**: The application will provide users with real-time metrics on their water usage, which can be visualized in different formats. Users can view data in real-time (past 24 hours) or aggregated over a week or month. This will allow users to track their progress towards their water usage objectives and understand their consumption patterns. Additionally, users can see how much water and money is being saved.

- **AI Integration**: The application will utilize an AI language model to analyze the data received and generate personalized water usage tips. These insights will help users understand how to improve their water efficiency and minimize consumption.

3.4 Financial Viability

The NanoGrid system is designed to recycle water in bathrooms, aiming to significantly reduce water consumption. This chapter presents the NPV analysis of the system, which evaluates the financial viability by considering both the direct costs and benefits, as well as the environmental benefits associated with water savings.

Assumptions

The analysis is based on several key assumptions:

- The average one-bathroom apartment hosts 1.67 people.
- Annual water savings of 60,833 liters per year per system.
- Annual water bill savings: €18.25 for 1.67 people.
- Annual maintenance costs: €80.
- Environmental value flows: €25 annually.
- Initial investment: €1785.
- The discount rate is 5%.
- The analysis considers a 50-year time horizon.
- The calculations assume a 4 m² bathroom.

Initial Investment Costs

The initial investment costs are detailed as follows, focusing on the components provided by NanoGrid and other necessary costs:

- **Cost of ceramic flooring per m²**: €60 (€15/m² for 4 m²)
- **Cost of cement per m²**: €60 (€15/m² for 4 m²)
- **Cost of serpentine (20 m)**: €60
- **Cost of plumbing supplies not covered**: €200
- **Cost of labor per m²**: €240 (€60/m² for 4 m²)
- **Cost of labor: travel cost (plumber and carpenter)**: €200
- **Cost of pump**: €150
- **Cost of set of movement, temperature, flow sensors**: €200
- **NanoGrid gross margin (60%)**: €1025

Total Initial Investment: €1785

NPV Calculation

The NPV calculation involves estimating the total cash flows over the lifespan of the NanoGrid system and discounting them to present value. The following sections detail the costs, savings, and environmental benefits considered in the analysis.

1. Water Saving Benefits The system is expected to save water, translating into cost savings:

- Annual water saving: €18.25

2. Maintenance Costs Annual maintenance costs are projected at €80.

3. Total Annual Cash Flow for Standard NPV Combining the maintenance costs and water saving benefits gives the total annual cash flow:

- Total annual cash flow: €18.25 (savings) - €80 (maintenance) = -€61.75

4. Standard NPV Calculation Using a discount rate of 5%, the NPV is calculated by discounting the total cash flows over the system's expected life span (50 years):

$$NPV = \sum_{t=1}^{50} \frac{-61.75}{(1+0.05)^t} - \text{initial investment}$$

Calculating this:

$$NPV = -61.75 \times \left(\sum_{t=1}^{50} \frac{1}{(1+0.05)^t}\right) - 1785$$
$$NPV = -61.75 \times 18.2559 - 1785 \text{ (The sum of a 50-year discount factor at 5\%)}$$
$$NPV \approx -€1,127.14 - 1785$$
$$NPV \approx -€2,912.14$$

Integrated NPV Analysis
The integrated NPV analysis incorporates the environmental benefits from water savings:

- Enhanced environmental value: €25.

1. Adjusted Total Annual Cash Flow Revised total annual cash flow considering the environmental benefits:

- Integrated total annual cash flow: €18.25 (savings) + €25 (environmental value) - €80 (maintenance) = -€36.75

2. Integrated NPV Calculation Using the same discount rate, the NPV is recalculated with the adjusted cash flows:

$$NPV = \sum_{t=1}^{50} \frac{-36.75}{(1+0.05)^t} - \text{initial investment}$$
$$NPV = -36.75 \times 18.2559 - 1785$$
$$NPV \approx -€671.88 - 1785$$
$$NPV \approx -€2,456.88$$

Conclusion & Results

The NPV analysis of the NanoGrid system, along with the integrated NPV analysis, reveals that both the standard and integrated NPVs are negative. This indicates that, from a purely financial perspective, the system may not be viable under the current cost and savings assumptions. However, the substantial environmental benefits and potential for long-term water conservation should not be overlooked. These factors could play a critical role in decision-making, particularly for stakeholders prioritizing sustainability and environmental impact over immediate financial returns.

- **Standard NPV**: Approximately -€2,912.14

- **Integrated NPV**: Approximately -€2,456.88

These results highlight the importance of considering both financial and environmental aspects in the evaluation of sustainable technologies like the NanoGrid system.

4. Key Learnings

This section contains the different learnings that we have acquired from the CBI4AI course:

- **Increased Awareness on Water Scarcity Issue and Current Inefficient Water Use:** We developed a deeper understanding of the critical issue of water scarcity and recognized the widespread inefficiencies in current water usage practices.

- **Collaboration in a Multidisciplinary Team:**
  We experienced the significant benefits of collaborating with team members from various disciplines, which brought diverse perspectives and innovative ideas to the project.

- **Working Under Time Pressure, on Ambiguous Tasks, with Limited Information at Hand:**
  We learned how to stay focused and productive despite the pressure of tight deadlines and the challenge of working with limited information and ambiguous tasks.

- **Importance and Effectiveness of a Structured Solution Design Process:**
  We saw firsthand that a well-structured design process is crucial for developing effective and efficient solutions.

- **Relevance of Iterative Solutions:**
  We understood the value of an iterative approach, where continuous testing and refinement lead to a more robust and reliable system.

- **Need for Early Feedback and Validation:**
  We recognized that gathering early feedback from users and stakeholders is essential for validating the system's design and functionality, leading to better outcomes.

- **Effective Communication:**
  We realized that clear and consistent communication among team members is vital to keep everyone aligned and the project on track.

- **Project Management and Time Management:**
  We saw the necessity of a well-structured project plan with clear milestones and efficient resource allocation for project success.