SMART HOME

Oslo Metropolitan University

European Project Semester

Group 1

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PROJECT LETTER

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Abstract

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European Project Semester, OsloMet University
Abstract of report, Submitted 21 November 2022:
Creating a smart home device for reducing water usage

The major objective for this study is creating a smart home device. The study was mainly focused on creating a smart home device for reducing water usage, which can also be used for reusing water.

In the first part, the results of field research, desk research, and user interviews are presented. The field research helped us to know that tiny houses are getting more modern, which means that a smart solution will fit their way of living. Moreover, the interview showed that economic interest is a contributing factor for people to use less water.

Thus far, this study has determined that a smart solution to make people aware of their water usage is feasible, providing a proof of concept of it. The hand-in of this report gives the necessary tools to carry out the smart solution that is proposed, which are the calculations to determine the consumption of water as well as the development of the web and mobile application.

Introduction

At the beginning of the 21st century, due to human activity, there is an ongoing climate change and disruption. People have started to become aware of this climate change and want to act now. Some of these people have decided to live in a tiny home, which has a lower impact. Our goal with our project is to make a tiny home even more environmentally friendly than it is now by using smart solutions.

A tiny home is a small house that is designed to be energy-efficient and can be off-the-grid. The interior space is optimized, only what is necessary is kept. This allows for a small interior space and therefore the use of heating is more than limited. Because of the small size, these tiny homes are cheaper to build and maintain.

These tiny houses are perfect to limit the problem which is more and more recurrent in Oslo: the lack of water. Indeed, despite the quantity of water in Norway, Oslo is prone to a lack of drinking water during the summer. These tiny houses, which are built to consume the least number of resources such as water, can help limit the shortages.

To limit water shortages, we will try to reduce the water consumption of tiny houses. Indeed, only a few dozen liters saved per household becomes an immense amount of water saved on a national scale. We will propose a water system, which will allow us to reuse water from the shower, toilet and sinks for gardening. We will also propose a website/application to allow the user to track their water consumption live, and to offer advice on how to reduce their water consumption. The application will be able to incentivize users by giving them rewards/achievements for successfully achieving their water consumption.

1. Understand the context and needs

1.1. The brief

An ongoing research project from Oslo Metropolitan University, of the transdisciplinary research institute Consumption Research Norway (SIFO), is based on studying different scenarios for several living situations. Moreover, this research project is focused on how these scenarios could become “smart homes”, considering that the studied living situations are not traditional.

As the EPS group that will work for four months in collaboration with SIFO, we were shown all the scenarios that they are currently working on. We had to choose the one that we would work on during this semester. However, we already had a vague idea of what we wanted to focus on, so we chose the scenario that fit the most with our first intention, which is the following:

*“The **Tiny House Dweller** lives on the peninsula of Nesodden in the municipality of Akershus in Viken county, Norway. Her tiny house has a kitchenette, shower room, storage space, separate sleeping area and living room - all within a surface area of less than 20 sqm. She has lived there for five years. As an environmental activist, she has considerable knowledge of rules, regulations, and impact around waste, and she is in the process of transitioning into living more zero-waste. Her husband comes to the island in the weekends, and during the week works in Oslo.”*

Our first suggestion for the project was to create a smart water system, which allows reusing water in a household. The scenario cited above fits with this idea, and we decided to focus our project on this living situation: an environmental activist who lives in a tiny house, within less than 20 sqm in Nesodden.

This scenario has allowed us to scope down the problem we have had to work on. Creating a smart water system is a broad concept although, if it must fit in a tiny house of less than 20 sqm and has to be built for an environmental activist, with all the sustainability that this entails, the first idea is becoming more and more accurate.

The issue of water management as a sustainable challenge has been an important topic in recent years. It has become a global concern for several factors, especially climate change and population growth, that have reduced water availability because of the increased water demand (Boyle et al., 2013). Making the population concerned about the need to save water and trying to decrease the leak of sensitivity that humans have about their water consumption is the aim of this project, which fits in its entirety into the context of the brief.

Furthermore, the research question that we have proposed for this project is: “What type of smart solution could help reduce the water consumption and create more awareness among the population?”.

1.2. Interpretation of the brief

One of today's problems in the world is the shortage of clean drinking water. Research shows that households are using more water every year (Statistics Netherlands, 2022). Our vision is that in these present days the population can be more efficient with the use of water. Nowadays, we use all sorts of devices which make life easier and time more efficient. Therefore, creating more awareness of the use of clean drinking water will lead to a more efficient way of consuming water.

To achieve our goal, to create more awareness of the use of water, we had to scope and choose an audience. The audience needs to include a lot of types of personalities and characters. In combination with the scenarios that were present to us, we ended up with people that live in tiny houses in Nesodden.

Research shows that 50% of tiny house owners live in tiny houses because of the less environmental damage that is made by building them. The 50% that live in a tiny house because of the motivation to do better for the environment are potential customers of our end product (Boeckermann, L.M.2019). On the other hand, there is still a 50% group that cares less about the environmental impact. By offering a great product, which can motivate people to use less water, and telling them they are doing a good job of living in a tiny house, they can still improve their use of water more efficiently. We hope to create some interest and hopefully some awareness in this person's profile, but it would also be interesting if our solution could have an impact on everyone.

2. Methods

This section consists of four parts. First, we talk about which management methods we used and why we used them. We will also describe which role each team member has in this project.

In the second part, we will describe the different kinds of research methods we used and why they are relevant in the process of our project.

In the third place, design methods to come up with the proof of concept are described. And, lastly, prototyping methods used for the website and mobile application mockups are defined.

2.1 Management methods

Communication inside the team is a very important thing for us. We all agreed that we need to have good communication inside the team. The fact that we all came from different universities, each with their own standards, makes it quite hard sometimes.

Generally, we used WhatsApp as our main communication platform for planning team meetings and communication over things that are not directly relatable to the project. We agreed that for those reasons we want to use another platform to keep technical issues of share of thoughts separate from general communication. So, for that we used Discord, and we can share our thoughts on the project.

Inside the team, we all had our own function. In this paragraph, we describe which functions they were in the project and who was responsible for that.

Besides communication inside the team, we also had to communicate with our supervisor and our professors about the project. For this task, we decided that we want to communicate through one channel, instead of overtime with another person. Lara managed this for the time and kept the rest of the team members really good informed, by sending all the information directly towards the rest of the team by using our WhatsApp group chat.

During the project we came to several points where we had to make a decision. Making these decisions carries responsibility. Every member of the groups has their own expertise and knowledge about topics. Jelle and Naut well understood most decision points and could really good explain why we had to choose that direction.

Nicolas made clear that there was structure inside the team. He regularly sums up want needs to be done on which date. He was also responsible for the online structure. The team was confident that the documents needed to be shared on an online platform. So that everyone can work on it whenever he or she wants to do it. Because we knew from each other that we were not always available physically on campus. Nicolas made the Google Doc documents working for everyone, similarly he did for the other platforms we used for the project, for example Zoom. Andy was there for backup, if there were any problems with this Andy could help. Apart from this, he was there to check everything on grammar faults.

Gantt Diagram

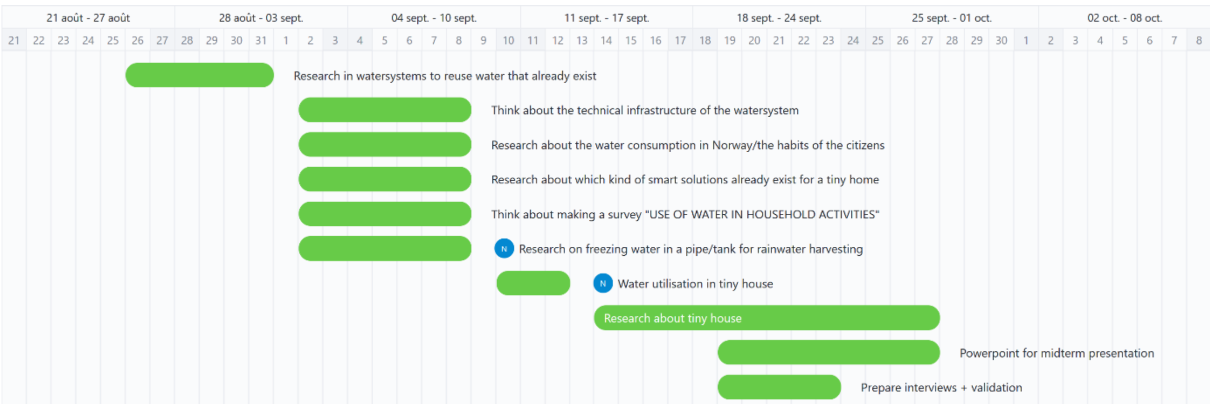


Figure 1 : Gantt diagram - part 1

We started by doing research in the first few weeks and then we started to think about the direction of our project. We wanted to have feedback from potential future users to take into account their feedback and then make the best solution. So prepared questions for the interview.

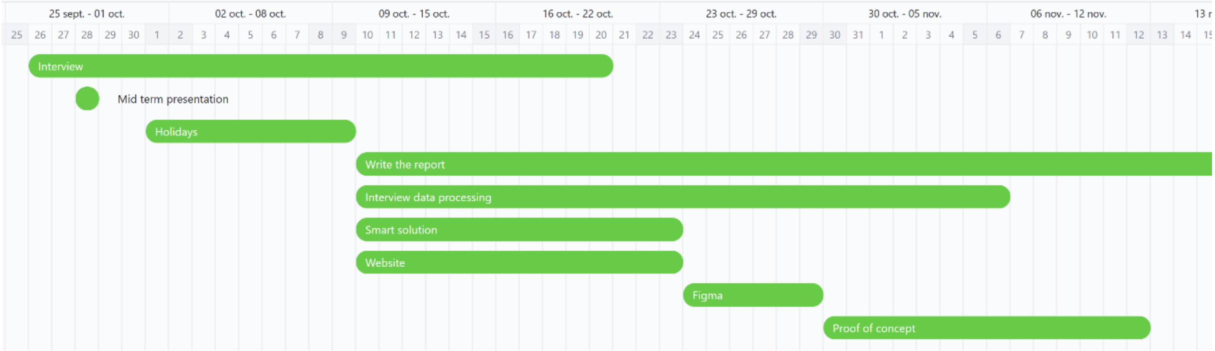


Figure 2 : Gantt diagram - part 2

It took a long time to find people to answer our interview, hence the longest time to finish this task. Once we had answers to our interview, and conclusions had been drawn; we had a clearer vision for our project. We knew that the project was really viable and that people were willing to use our solution. We started writing the report and developing the website, as well as doing the calculations for the water system itself. With all our work, we could make the proof of concept.

2.2 Research Methods

2.2.1 Desk Research

Desk research is an important type of research, it can serve as a basis for creating guidelines and knowledge development. Executing desk research effectively could lead to new ideas and directions for a specific field. To conduct efficient desk research, we followed some simple guidelines for our literature to ensure quality (Snyder, H. 2019). Firstly, we use peer-reviewed resources. Secondly, we use sources from known journals. Finally, the source is read carefully so that no mistakes are made. Another big reason for using desk research is that it has a time advantage in comparison with primary research (Editorial Aela. 2022).

In the first weeks of the project, we spent a lot of time doing research. Working on a project with tiny houses is new for every member of the group. As a group, we did not have a lot of knowledge about tiny houses, not even about water systems for tiny houses. The best way to get more knowledge about the topic was by reading theses, papers, and journal articles about tiny houses and the way they use water. Most of these reports were found on Google Scholar.

Doing desk research helps us to get more knowledge about tiny houses and information which sort of similar smart home devices already exists. And reading sources about this topic can also be crucial in the future for our project.

Besides the information we can possibly directly use in our project, we also read a lot of information which gave us a lot of background information. For example, things that already had been tried in the past and didn't go as planned. So those papers gave us a good overview of where to begin on this topic.

2.2.2 Field Research

In the scenario we got for our project there was named a specific location, Nesodden. We visited the municipality by taking the ferry from Oslo center. We took a walk in that area and searched for tiny houses. We studied the area and the tiny houses.

The goal of visiting Nesodden was to get an overview and impression of the municipality. We also wanted to know how modern the tiny houses are. And if possible, we wanted to discuss our ideas for the project with some tiny house owners. To gain information about why they live in a tiny house, how their living experience is, and to know about their habits and water usage.

2.2.3 Interview with users in a focus group

Focus groups provide insight into habits and principles. These habits and principles are enriched through perception and opinions in a group setting because of a deeper thought process than in individual interviews (Carey M. 1994).

Doing interviews with the potential users of our product is a good method for us to gain more information about the user and their needs. This could give us a better view of what we need to include in our product, and which things are not priorities.

First, we thought that the best way to gain that information was by doing a survey online. This survey includes open questions about the motivation to live in a tiny house, if they are using any smart home device and how much they care about sustainability. We shared this in several Facebook groups, especially for tiny house owners in Norway, and in one general Facebook group. Because of the minimum responses, the source was invalid and not usable for our research.

To make the best product for the user we were convinced that we needed the user information. To have a view on how the potential users use water, we did an interview with students that are currently living in Oslo.

We chose to interview students between the ages of 19 and 22. This is the group where we could make the biggest impact (Greenbiz. z.d.). There was an equal mix between genders that came from different parts of Europe. Despite this not being the group that is specifically living in a tiny house at Nesodden, we think that this mix of people gives us a good indication and gives a good representation of the people on Nesodden.

The most important answers were for us to know what their motivation should be to use less water. In addition, we asked them how aware they are at the moment of their use of water, and if they would improve their water use if we created an app that made them aware of their water usage.

2.3 Design Methods

2.3.1. Sketching proof of concept

Sketching is a method of design especially effective for illustrating ideas, sharing thoughts and solving problems (Craft B. 2009).

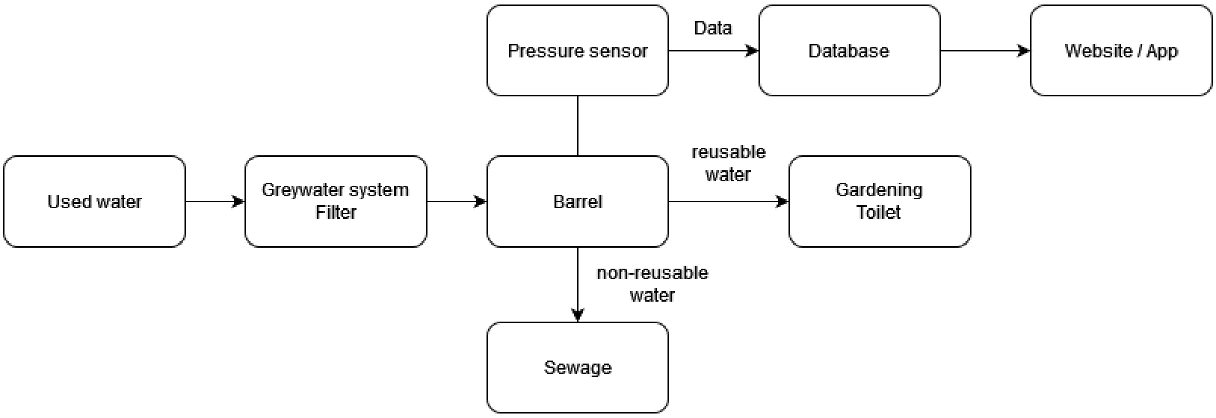


Figure 3 : Proof of concept

The used water goes through the greywater system which is constituted of filter. The water that comes out of the filter is clear. The greywater system only removes particles, the water is still not drinkable by humans because of the presence of bacteria. The greywater can be reused in gardening or for the toilet. The filter keeps the waste and discharges it to the sewer.

For the smart part, a pressure sensor is located in the barrel. It will calculate how much greywater the user reuses. This sensor will write data on a database. This database will connect to the website and app to display this information to the user. The user will be able to track its greywater usage.

In the future, a phone application will be developed, to display the same information on a phone, because there is less friction to use an application than a website. We saw that nowadays fewer people are connected to the website now to retrieve information.

2.4 Prototyping Methods

2.4.1 Website

Backend

There are three tabs on our website: The home page which includes a login page that redirects the user to another page with their data. The last page is a page for the user to log out.

For the homepage, there is a short presentation of the company and the solution. There is also a login form for the user.

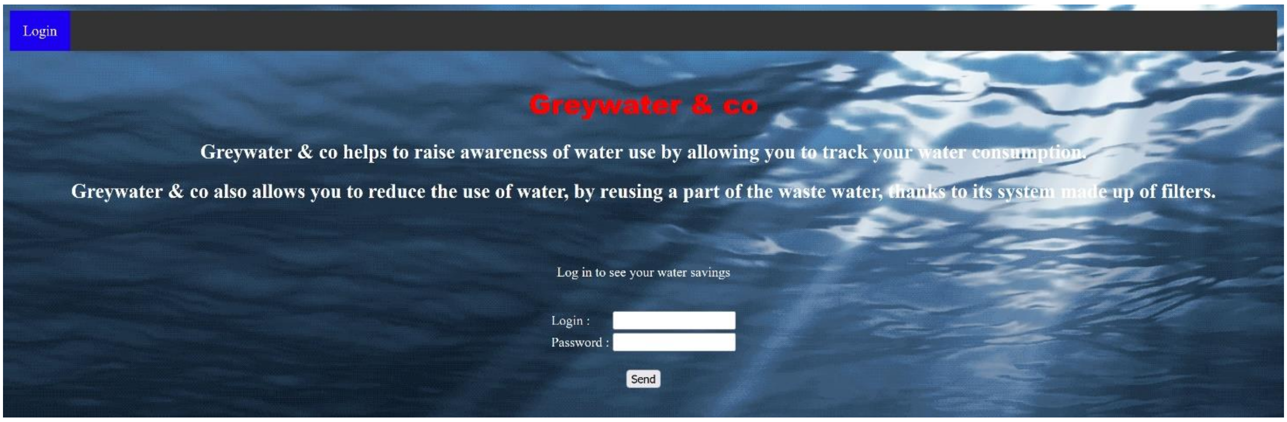
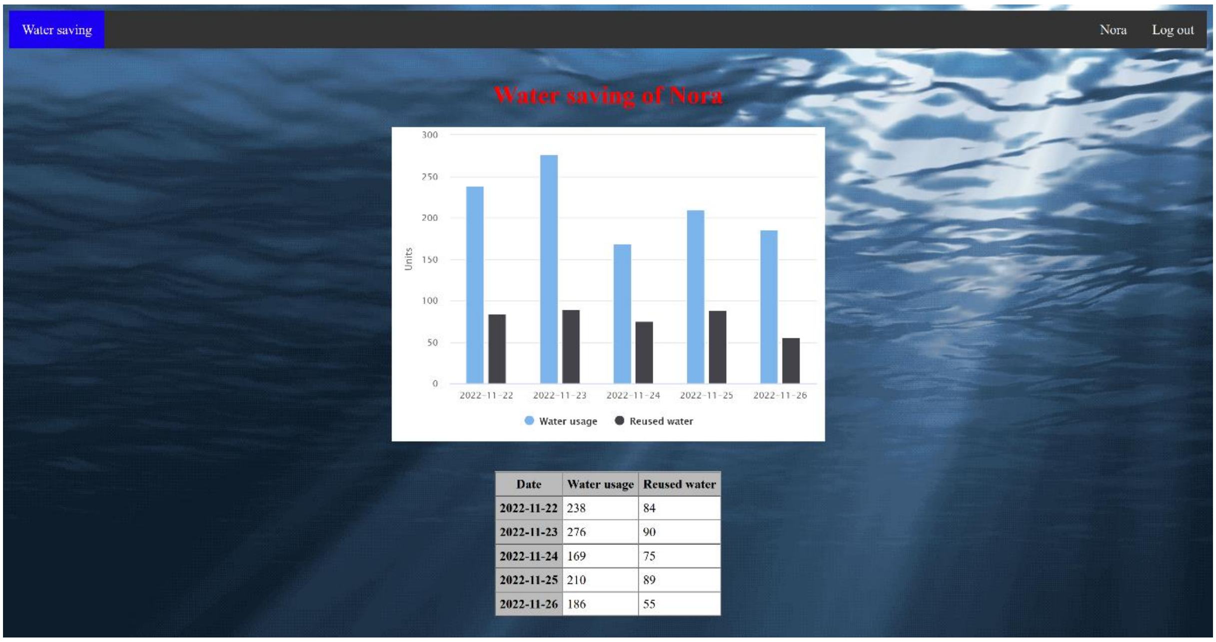


Figure 4 : Website login form

This page has been coded in PHP, because PHP, unlike pure HTML, allows us to create dynamic websites. For the user login, the website queries the database, if the credentials of the person trying to log in are correct. If they are correct, then the website redirects the user to its page, with its data. The website deposits a cookie on the user's device, with one piece of information: the user's name.



Date	Water usage	Reused water
2022-11-22	238	84
2022-11-23	276	90
2022-11-24	169	75
2022-11-25	210	89
2022-11-26	186	55

Figure 5 : User data displayed by website

Once the user is logged in, the website redirects them to their page, with their information. Thanks to the cookie, the website knows which user is currently logged in, and therefore the right information to search and display.

There is a graph and a table. For the table, it is quite simple: you just have to connect each cell to the database. The first column is connected to the date, the second to the total water use and the last column to the greywater use.

For the graph, it is like the table. Except that a *javascript* package will compile the data and make a graph.

```
<script src = "https://ajax.googleapis.com/ajax/libs/jquery/2.1.3/jquery.min.js">
</script>
<script src = "https://code.highcharts.com/highcharts.js"></script>
<script src = "https://code.highcharts.com/modules/data.js"></script>
```

Figure 6 : Javascript script

Limitation

During the interview, it was understood that users wanted to see graphs of water consumption, as well as ways to understand where in the house the most water is consumed and receive advice.

With basic HTML you can't make a summary that shows which part of the house pollutes the most. That's why we created high-fidelity UI/UX mockups, to have a projection of what a future potential production mobile app could look like.

To generate these high-fidelity mockups from scratch, we utilized a collaborative interface design web application, called Figma. Design inspiration was taken from several existing mobile applications that we ourselves utilize, such as Strava, and other social media platforms for gamification and social sharing features.

Website technology searching

A website is the first step so that users can see their water consumption, as well as the amount of greywater reused. We realized that in Norway, people cannot know how much water they use, and this is a problem because you must be aware of how much water you use to be sensitive to water usage. On the website that we are creating for this project, there will be a homepage presenting our company and our product with a login form. Once the users are connected, they can track the utilization of water, and how much water they have saved.

In the long term, there will be an application, so that the user must make even less effort to track his water consumption. The application will take the main lines of the site.

For the website to work, we need certain prerequisites. On the material side, we need a server to host a website and a database that contains user information. The server is a raspberry PI 4, with raspbian for the OS. The server has 4 cores. Which is powerful enough for our use.

Each request to the website has a duration of 70ms. The test was done in Strasbourg, France, as the server is hosted in France.

Location	Date	Time	Duration	Status
Strasbourg	10/13/2022	12:20:45 PM	70 ms	OK

Figure 7 : Ability of the server to handle requests

$$\frac{4}{0.07} = 57$$

The server can handle 57 requests each second.

On the software side, Apache2 is the service that hosts the website. Then, we need a database to store users' information, like their login credentials, or their data. The database used will be MariaDB, which is a fork of MySQL. MariaDB is faster than MySQL. Finally, PHP will allow you to make the website dynamic. We will use the PHP module MySQLi to connect the website to the database. The website will update with the database.

Data

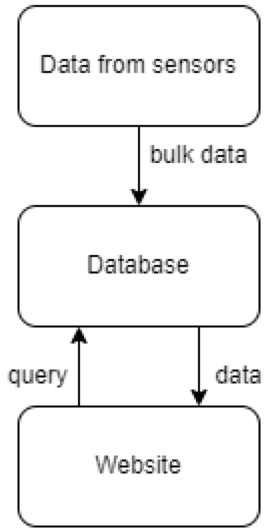


Figure 8 : Data interaction between script & Website

The database is filled by a data source which is the pressure sensor. In our prototype, we will write data by hand into the database, the date, the amount of clean water and grey water reused. The website will display the data from the database.

Database

user	date	water_usage	reused_water
Nora	2022-11-20 00:00:00	232L	48L

login	password
Jakob	Jakob123
Nora	Nora123

Figure 9 : SQL tables

There are two tables in the database. The Credentials table allows users to log in to the website. It is a user/password combo. The password is not encrypted to simplify comprehension.

The second table is used to store data on users' water consumption. For each entry, we have:

- the user's name
- the date
- total water used
- total gray water used

With this 4 information, we can easily track water consumption information for each user.

2.4.2. Mobile Application High-Fidelity UI/UX Mockups

The design mockup process, in chronological order, consists of the ideation stage, wireframing stage, and mockup stage.

The ideation stage involves brainstorming as many relevant features and ideas as possible for the final prototype. These ideas can range from the worst possible idea to ideas that inspire new and future visions. This stage finally involves filtering and narrowing down the best ideas, whether that be qualified by innovation or practicality.

The wireframing stage involves creating rough layouts of pages that will solve the problems generated in the ideation stage. These wireframes tend to be barebone and minimalist- they are usually black and white and have no visual detail outside of simply communicating the flow of information and functionality through the layouts created.

Finally, the mockup stage aims to build upon the designs generated in the wireframing stage. The goal is to generate robust products that represent what the final delivered product will look like. The mockups provide a layer of substance and visuals atop the functionality that was previously established. To observe the mockups generated for this project, please refer to Section 4.4.

3. Research Results

3.1 Desk Research Results

The previous step to determining which type of technology should be installed in tiny homes is researching which systems already exist. That is, studying which water systems are more suitable for the context of our project and the needs of tiny homes users in Nesodden.

For the technology determination, understanding which water systems already exist and how they work is essential. There are two types of water systems depending on if the house is connected to the grid or not. Therefore, the first step to determine which water system we want to carry out is researching the different options.

Secondly, we have to determine which kind of filtration and purification system we want to incorporate. The third step is to research about water disposal, to know where to deposit the water that we want to be reused.

And finally, to finish with the technology determination, it is important to know which water-consumption smart devices already exist, and how could we use them, in order to improve the water system that we will determine.

3.1.1 Types of water systems

As mentioned previously, there exist plenty of tiny house plumbing options. The most important thing to consider, in order to decide which type of plumbing to install in a tiny house, is if the house is grid-connected or if it is off-grid. We have based our research on this difference, so when determining the proof of concept, we will be able to choose between a tiny house connected to the grid or not.

<u>Grid-connected water systems</u>

Water of households that are grid-connected comes from the municipal sources. Therefore, the wastewater is disposed through a sewer system and ends up in the municipal purifier.

The innards of a public water system are the following: water source, water treatment and water distribution. The water source is where potable water comes from, which can be obtained from groundwater or surface water. The second step is the water treatment, and it requires filtration and disinfection. Lastly, water distribution, which consists of a network of pipes in order to transport water from the treatment facility to the users.

<u>Off-grid water systems</u>

An off-grid water system is a water supply that is not connected to a municipal water system, even though its components are the same: water source, water treatment and water distribution.

There exist many different off-grid water systems, as there are plenty of options for sourcing, treating, transporting and storing water. The following is a list of different options for these parts:

- Water sources
  - Natural Spring
  - Well
  - Rainwater Collection
- Water storage
  - Rain Barrels
  - Cisterns
- Water filtration and purification
  - Sedimentation
  - Filtration
  - Chlorination
- Powering the water system
  - Electric pump
  - Solar panel water pump
  - Gravity-fed water system
- Water disposal
  - Greywater systems
  - Blackwater systems

Having this overview of how water systems work, our project is going to be a mix between the knowledge that we have acquired researching on grid-connected water systems and off-grid water systems.

The first part of the water source is going to be the same as grid-connected households; the water will reach the tiny house via the public water grid system. Thereafter the water is used, it will follow the water filtration and purification phase, which will end towards the water disposal. This last step will be the one that will allow water to be reused. However, the water that will not be possible to reuse will fall off the sewage. Moreover, this project is not focusing on powering the water system, as the tiny house is connected to the grid, therefore it receives both water and electricity.

3.1.2 Water filtration and purification

For reusing water, we need to filter it before. we have several techniques:

- Sand filter
- GWDD / GWTS[1] filter

[1] GWDD : Grey-Water Diversion Devices

- Thermopervaporation

Each technique has advantages and drawbacks.

The sand filter consists in sending the water through in the sand, and particle stay stuck in the sand, and water rises naturally.
The sand filter can remove the largest particles, and a part of microbiological and organic solutes from dirty water. The water can be reused for gardening but not for human consumption. Maintenance is complicated because you have to clean the sand: you must do it often, and it's not that fast or convenient

GWDD/GWTS filters are larger filters, allowing for better filtration of water compared to the sand filter. It also allows you to filter a larger quantity of water. They can therefore treat water from a shower, or from the kitchen.

Thermopervaporation is the most advanced filter, using state-of-the-art technology to make the water reusable repeatedly. We use very fine filters which are very fragile and extremely expensive (used by NASA). Maintenance is almost impossible without exploding costs (several million). Even if on paper this technology is the best, it is not usable in real life because of the cost and the size of the filter.

The most interesting filter for our case is the GWDD/GWTS filter, because it is not excessively expensive, and allows to filter a good water flow, while remaining easy to maintain.

3.1.3 Water disposal

Having water disposal is essential, as water must go somewhere after it is used. It has already been presented that the water which will not be reused will go into the sewer that leads to municipal wastewater treatment facilities.

There are two options for where to dump the water that is going to be reused: greywater or blackwater systems. This project will work with a greywater system because it does not need as much careful treatment as blackwater systems need.

Greywater is the water that comes from showers, tubs, sinks, and washing machines. This wastewater does not need as much treatment as the water that comes from the toilet for example. Therefore, the process that greywater has to go through, as long as it wants to be reused, is more elementary than the treatment for reusing other types of wastewaters that derive from other parts of the house.

The procedure of treating the water is done with the help of a greywater system, which, as the name implies, is a system that accumulates wastewater to process it, so that the water can be reused. The method used in this system is determined by the filtration phase, which can be very wild. Although there are many options to create different types of filtrations, they all have the same purpose.

Moreover, if we go deeper into the types of filtrations, we can realize that the diverse variety of filters follows the same patterns. Consequently, each greywater system can be adapted to different circumstances, such as the user's budget or the purpose for which the water will be reused and for how long.

Reusing greywater has a wide range of benefits apart from lowering the water bill. Focusing on sustainability, the advantages are clear: there is almost zero waste of water. In addition, if this water is used for tendering the garden, the soil and plants can benefit from the organic matter that the greywater contains (Maimon A, 2018). As a matter of fact, greywater can be reused, which contributes to our sustainable and economic welfare.

3.1.4 Example of a smart water consumption device

This section will focus on an already existing smart device to track water consumption in a house, or even in a more general way, which could allow tracking the leaks in the water network.

Fuentes & Mauricio, 2020, propose a water consumption measurement system that also includes the detection of water leakage. This system integrates user location together with historical data and is based on an Internet of Things (IoT) architecture. These three features are necessary for several reasons. The first one, knowing the location of the user allows us to identify a possible leak if the user is not home. The second aspect, the historical data of the user's consumption of water leads to a pattern of water consumption, which can be used for different purposes, such as general statistics, or for the users themselves. Lastly, connecting a system to an IoT architecture permits capturing the data obtained through the sensors that compose the system.

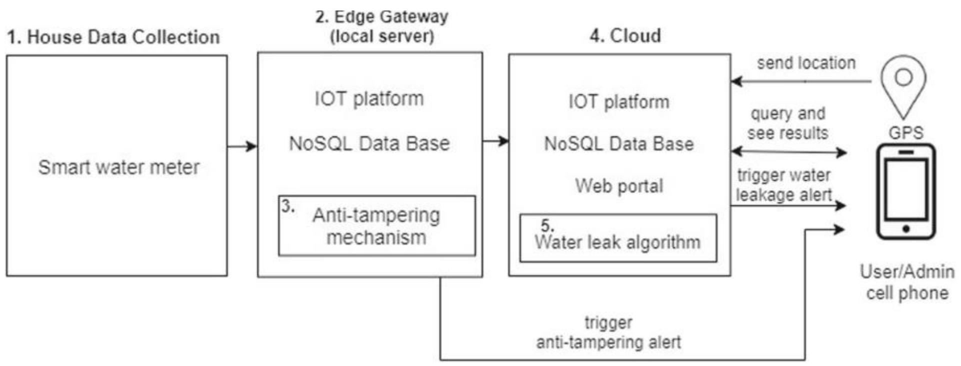


Figure 10 : Diagram of the water consumption measurement system. (Fuentes & Mauricio, 2020)

By way of illustration, Fuentes & Mauricio (2020) show how the data collected through the smart water meter flows in the Data Base and the IoT platform, which transfer it through the web, and consequently, the user's phone.

Even though a generally accepted definition of Internet of Things is lacking, a definition is given by Singhania (n.d.) who describes that the term Internet of Things has technical, social, and economic significance. It refers to scenarios where it exists a network that connects several devices in order to generate, exchange and consume data with minimal human intervention.

It is now understood that IoT plays an important role in monitoring different data and linking it in order to create a network with several devices. This has been seen in Fuentes & Mauricio study, who have shown that creating an IoT architecture is the appropriate option to interconnect different devices, in their case, sensors.

3.2 User Research Results

During the interview, it became clear to us that the biggest motivation to use less water is money. If it would save a significant quantity of money to use less water, they would use less water. At the time, while living in Oslo, the water price was included in their rent, so they didn't feel the financial advantages of using less water.

The most open question we asked them was which sections should not be missing in the app to make them use it. The answer opened our minds and was really interesting for us. One of the answers was that the app needs to show which parts of the house have the most elevated use of water, if possible, in a visual way with an overview of the house. Someone else added to that answer that she possibly wants to use less water, but she doesn't know where to start. So, if we add tips in the app for the users to save water, they will know how to get started to decrease their water usage.

Note that in Appendix 7.1. Can be found in a table with the questions and answers that we obtained in the focus group.

4. Proof of concept

4.1 Overview of the smart water system

This chapter examines whether it is physically possible to combine the greywater system with the collecting barrel and sensor. This is realized by making some assumptions backed up by sources. Further details are described in the upcoming chapters.

It follows a diagram that shows how all the key points in the research are gathered together in the concept that we present:

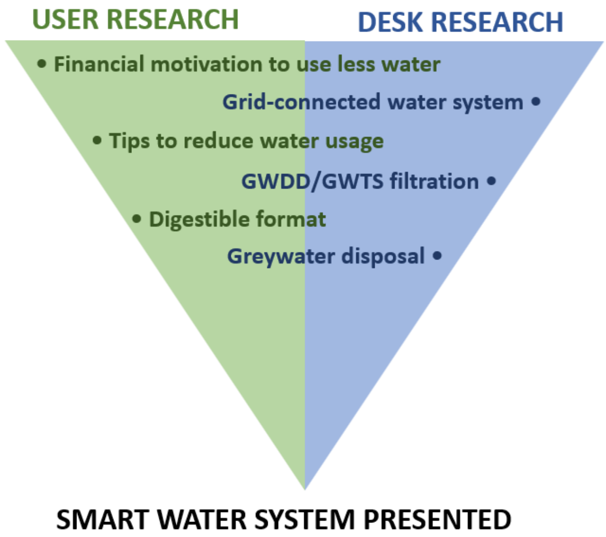


Figure 11 : Visual diagram of the key points in the research generating the final concept

Following the structure of the previous section, the first step is to determine if the tiny house that we are working on is connected to the grid or not. It was decided that the potential tiny house that could incorporate our water system would be connected to the grid, therefore it receives both water and electricity. Although many people would believe that tiny houses are not connected to the grid, it cannot be extrapolated to all, since after the different types of research that has been done, we can conclude that there are tiny houses connected to the grid. This decision has been made for reasons of complexity, which would increase if the tiny house were not connected to the grid.

The principal idea of the technology determination is to make a proof of concept of a barrel where the water that comes from the toilet, the shower and the sinks will end up. This tank incorporates a pressure sensor at the basis, which makes this water system smart. Moreover, before this barrel it takes place the filtration phase. As was pointed out in the water disposal research, the water system presented in this project treats greywater and the water is reused particularly for tendering the garden. After the research that has been done, we believe that is the most appropriate option to work with, as trying to treat blackwater is more convoluted. However, even if this system can just reuse water to tender the garden, we believe that the filtration part is worth it, as some of the greywater can be reused. Obviously, there will not be zero waste in this system, but with this reusing phase that we are proposing, it is a big step to take to make it tend to zero waste.

Following the filtration phase, the water runs through the barrel where the pressure sensor is installed. The pressure data collected from the sensor is sent to the network. After calculations needed to determine the water consumption are made, the new data is sent to the website. The website is connected to an app, to make things more convenient for the user, asshows that the usage of mobile phones has been increasing in the last twenty years (Paiano et al., 2013).

In the next sections, the calculations and the background of the website will be explained, as well as a mock-up of the app.

To conclude with the determination of the water system, it follows a descriptive image:

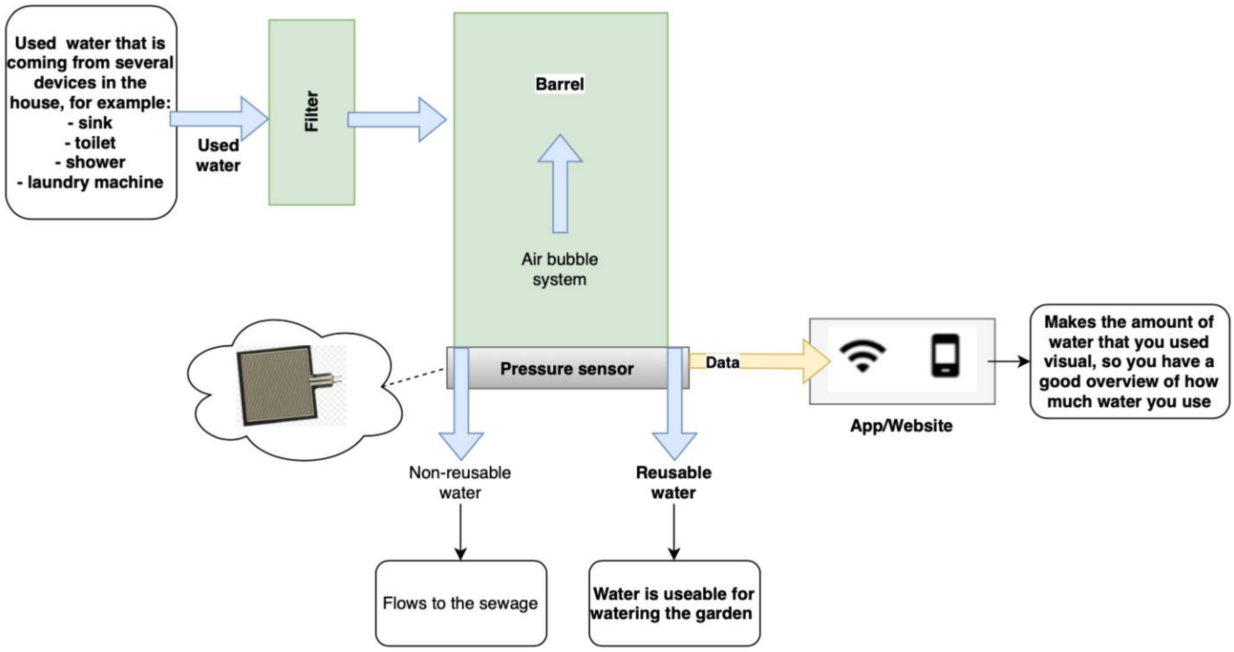


Figure 12 : Descriptive image of the technology determination

Figure 12 shows the different parts of the water system explained above. From left to right we can see the water that comes from the sinks and toilet, that ends up in the tank where the filtration phase takes place. Following the filtration part, there is a barrel, that has a pressure sensor at the bottom, which collects the pressure data and sends it to the network. At the end of the process, it is shown that some part of the water filtrated goes to tendering the garden. The rest of the leftover water goes to the sewage.

To conclude, we must consider that this smart solution may be connected to other smart devices. This is the reason why in the previous subsection there is an example of a smart device connected to an IoT architecture. The IoT, as already seen, allows connection between several smart devices. In this phase of the project, where we only have studied the proof of concept of this smart solution is not needed, but in future iterations, has to be taken into account that this smart device can be connected to others, by simply associating them in an IoT architecture.

4.2 Installation of the smart water system

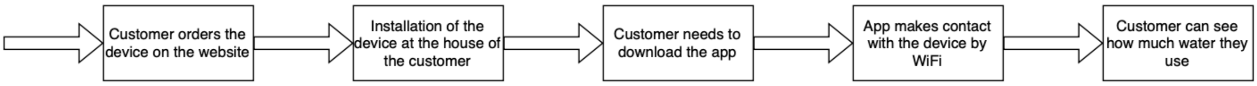


Figure 13 : Customer Journey diagram

The customer journey describes the way the customer goes through, from ordering the device till it gets fully operational. It shows an overview of the total Proces where the customer is involved.

The installation process will involve an external barrel pre-fitted with a pressure sensor and filtration system to be installed at the user's home, to their existing water system. Once installed, used water will be fed through the system as illustrated earlier, filtered, and weighed at recurring intervals over time. The device will be connected to the applications through the user's existing Wi-Fi network, or similar. The data from the sensor will then be fed into the application at recurring intervals and will require a quick registration of the user onto the systems to tie the data to. The user can then view the data at any time through the application and use it as they see fit.

4.3 Calculations of the water system

4.3.1 Pressure system in collecting barrel

For the proof of concept, a barrel is needed for the storage of used water. This is done in such a way that the amount of water used each day can be calculated with a pressure sensor. The data that is obtained with the pressure sensor is used in a formula to calculate the amount of water that is in the barrel. This is done with the formula (Cengel et al., 2016)

$$P = \rho * h * g \tag{1}$$

$$h = \frac{P}{(\rho * g)} \tag{1.1}$$

Density ρ= 1000 kg/m^3 for water
Gravity g= 9,81m/s^2constant
Hight h=variable in meters
Pressure P=variable in Pascal this is measurable with the pressure sensor

With this formula, the height of the water is calculated. The assumption is made that the contamination in the water is negligible for the density of the water. This is statistically provable with an example of using soap while showering. On average people use 4,5 milliliters of soap while showering. The water usage for a 5-minute shower is 40 liters per person. Using the density of the soap in the calculation changes the value of the height only by 0,0070% which is a neglectable amount.

Finally, the calculated height in the barrel is used to determine the volume in liters. This is achieved with the formula:

$$V = h \cdot l \cdot w \qquad (2)$$

Wide w= constant in meters

Length l= constant in meters

Height h= variable in meters

Volume V= variable in m^3

4.2.2 Water pipe system

The law of Bernoulli is a physics law that describes the flow behavior of liquids and gases and relates the pressure changes with speed and altitude. Commonly, this formula is used in aerodynamics and hydrodynamics (Ibáñez, M., Ramos, M.C.). A point often overlooked is that the Bernoulli equation comes is only applicable under certain circumstances. Firstly, the flow should be stationary. Secondly, the density is constant. At last, the energy cast by friction is negligible.

In this project, Bernoulli's law is used to establish if the water flow will make it. From the Greywater filter towards the collecting barrel. The points of calculation are shown in figure (14)

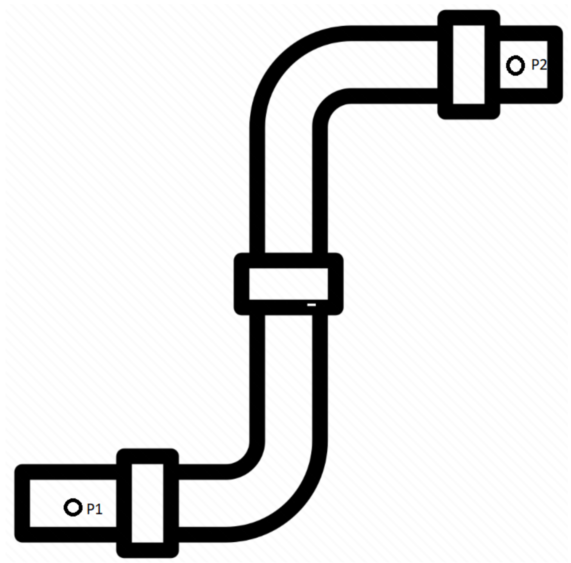


Figure 14 : Drawing of the pipeline with the 2 points for flow calculation. (Hub, 2022)

The Bernoulli formula:

$$P_1 + 0{,}5 \cdot \rho \cdot \left(\frac{Q_1}{A_1}\right)^2 + \rho * g * h_1 = P_2 + 0{,}5 * \rho * \left(\frac{Q_2}{A_2}\right)^2 + \rho * g * h_2 \qquad (3)$$

$$Q_2 = \sqrt{\frac{P_1 - P_2 + 0{,}5 \cdot \rho \cdot \left(\frac{Q_1}{A_1}\right)^2 - \rho \cdot g \cdot h_2}{0{,}5 \cdot \rho}} \cdot A_2 \qquad (3.1)$$

Variables Point 1	**Variables Point 2**

Pressure **P1** = 2,3 bar *Density* **ρ**= 1000 kg/m^3 for water *Gravity* **g**= 9,81 m/s^2 constant *Flow* **Q1** = 5 L/min *Square meter* **A1** = 4,7*10^-5m^2 *Height* **h1** = 0 m (Lowest point)	*Pressure* **P2** =2,15 bar *Density* **ρ**= 1000 kg/m^3 for water *Gravity* **g**= 9,81m/s^2constant *Flow* **Q2** = Unknown amount in L/min *Square meter* **A2** = 4,7*10^-5 m^2 *Height* **h2** = 1,5 m (Highest point)

Table 1 : Variables in Point 1 and Point 2

To calculate the flow in point 2, A few assumptions about the conditions need to be made. At first Gravity and the Density of water are constants. Secondly, area A in square meters is the surface area of the pipe. This surface area has a professional standard of 4,7*10^-5 m^2 in houses (Gundaraniya, 2022). Thirdly, the flow in point 1 is 5 L/min (Gray Water PumpSaniflo Depot, 2022) determined by the Greywater filter. Finally, the pressure in P1 is 2,4 bar and reduces by 0,1 bar each meter upwards which means the pressure in P2 is 2,25 bar ("Waterdruk, information - Aquacombi", 2022). Filling in the given parameters in formula (3.1) shows that the flow Q in point 2 is still 5 L/min.

4.3 Website

There is a version of the site, a beta site, which will only offer the main functionality, without worrying about the frontend. There will also be visuals of what the website might look like once the frontend is coded.

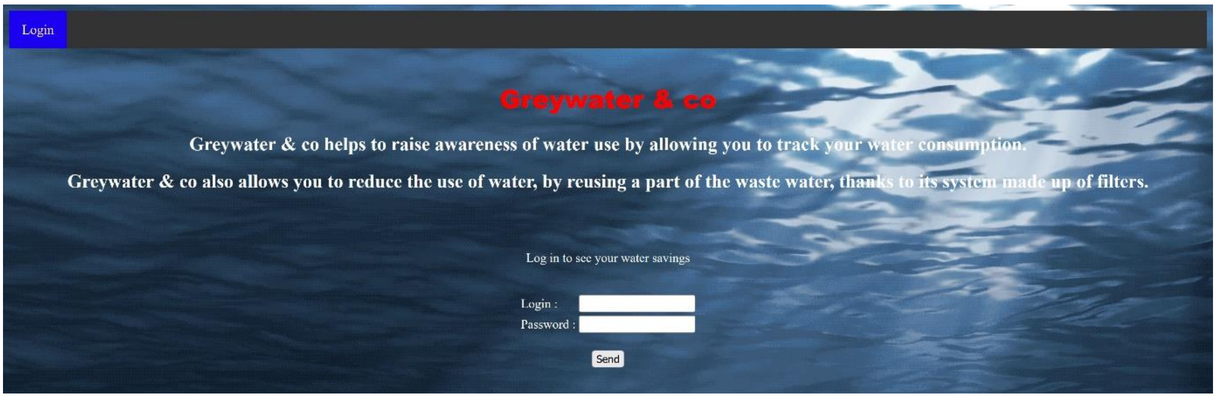


Figure 15 : Website's log in page

For the moment there is a connection system. Users can log in with a login/password combo.

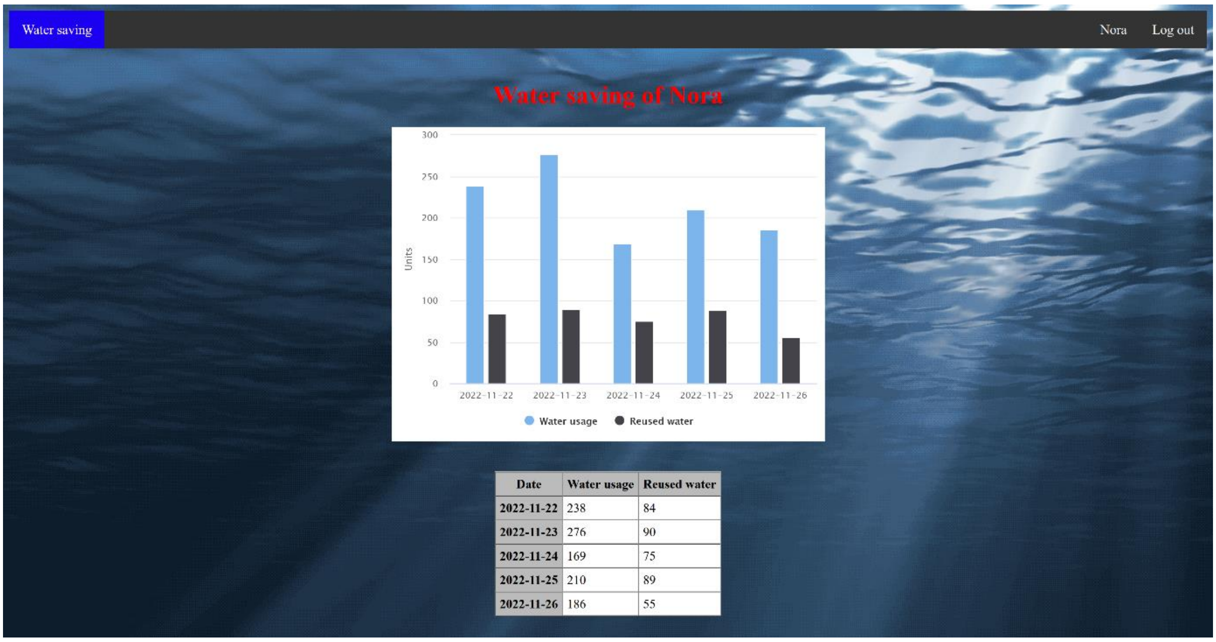


Figure 16 : First page of the website: user's water saving

Once the user is logged in, a tab is displayed showing the logged-in person's water usage. It shows the data, which is separated between the total water used and the grey water reused. The user can log out using the logout button at the top right.

On this front page of the website, the users can see their water use values, as well as how much grey water is reused. There is a graph that summarizes water usage, which is responsive. That means that if you put your mouse over the graph, it displays the actual value. It follows an enlarged image (Figure 17) of the graph that can be seen in the first page of the website:

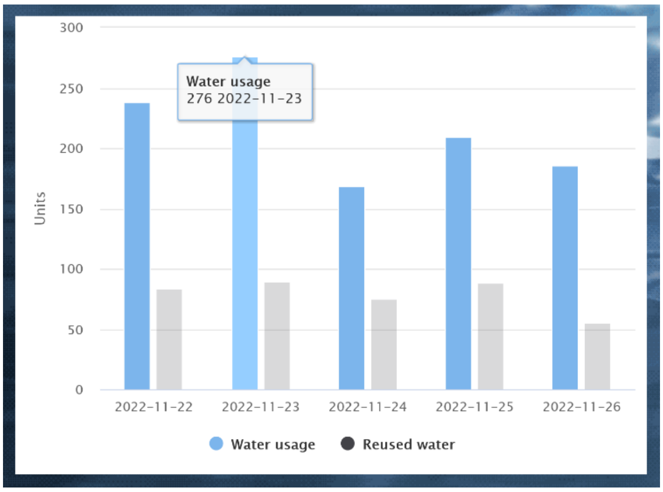


Figure 17 : Graph of water usage

4.4 High-Fidelity UI/UX Mockups

These high-fidelity UI/UX mockups conceptualize a potential future mobile application.

4.4.1 Home Page

As illustrated in Figures 16 and 17 the 'home page' or 'primary dashboard' presents the most important information in an easily digestible format with high contrast visuals and graphs. This includes the user's progress and how aligned it is with goals they have manually set for themselves, as well as a breakdown over most significant time periods, such as weekly, monthly, and annually.

The bucket visual illustrates a potential application of gamification that would motivate users to either invest more effort toward their goals or continue their current behavior if it is shown to trend positively. The former is achieved with the bucket visual being closer to empty than full- showing significant room for improvement on the user's end. The latter is achieved with the bucket reaching close to max capacity visually, encouraging the user as they are seemingly closer to achieving their set goal.

The visual also provides the user with data in a more digestible format than other formats, for example, static data in plain text and numbers, which the user may find difficult to quantify or contextualize.

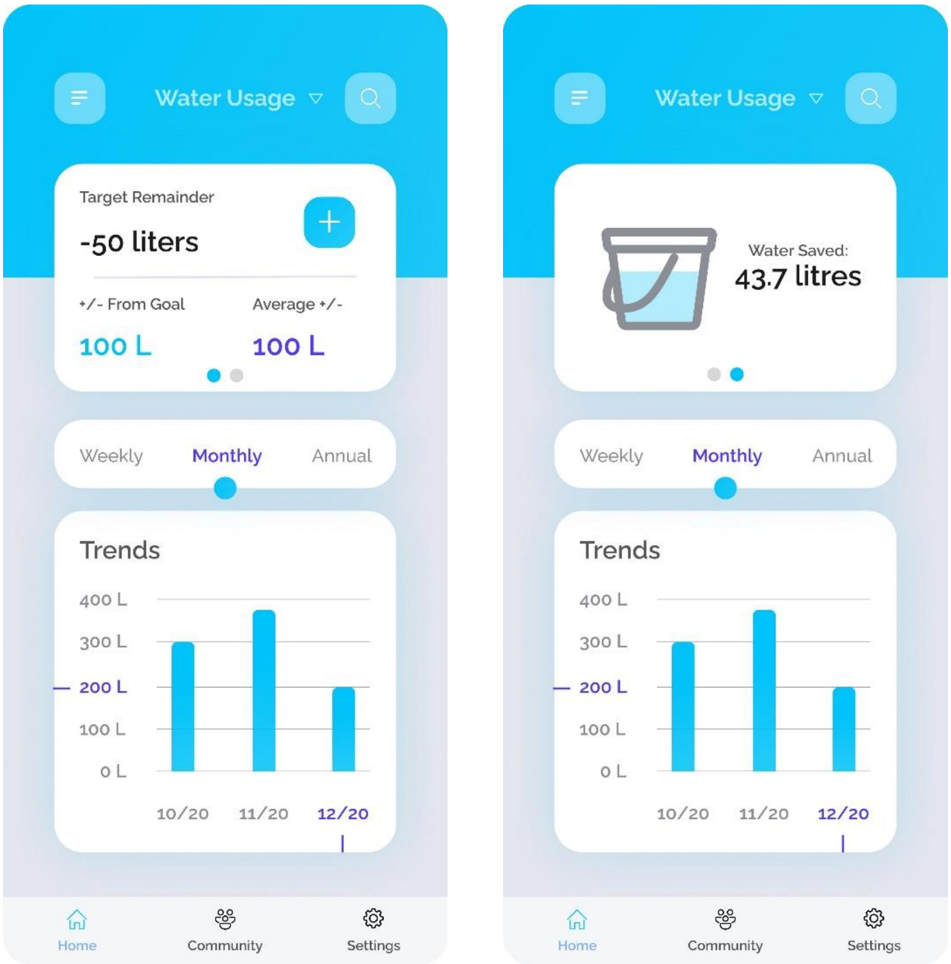


Figure 18 & 19 : Mobile application home page

4.4.2 - 4.4.3 Interior Breakdown Page

As illustrated in Figures 19 and 20, there are additional views that display more specific information in alternative formats. In Figure 18, a top-down view of the user's household can be observed, with the ability to drill down into any specific room and observe its usage relative to the cumulative usage, as well as other rooms and utilities. This more granular view can be observed in Figure 19, with tooltips to potentially learn ways to further reduce water consumption in those specific rooms.

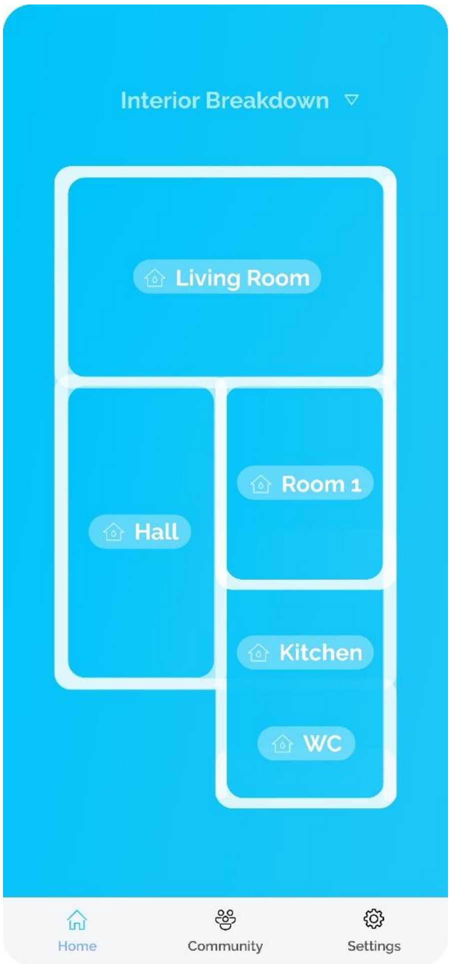


Figure 19 : Top-down view of the user's household

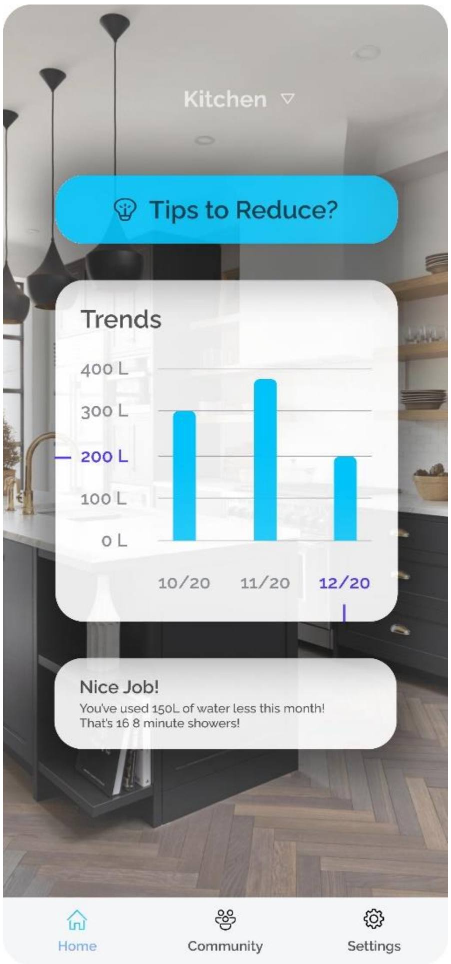


Figure 20 : Tooltips to reduce water

4.4.4 Achievement Badges Page

As illustrated in Figure 21, there is a view that displays the user's badge collection. This demonstrates a potential feature that utilizes gamification to encourage users' repeated positive behaviors. When the app determines a user has accomplished all requirements, that user will be awarded a badge for completing that respective set of requirements. This feature's power is amplified by social factors, such as social sharing and 'bragging rights' within their social circles or communities.

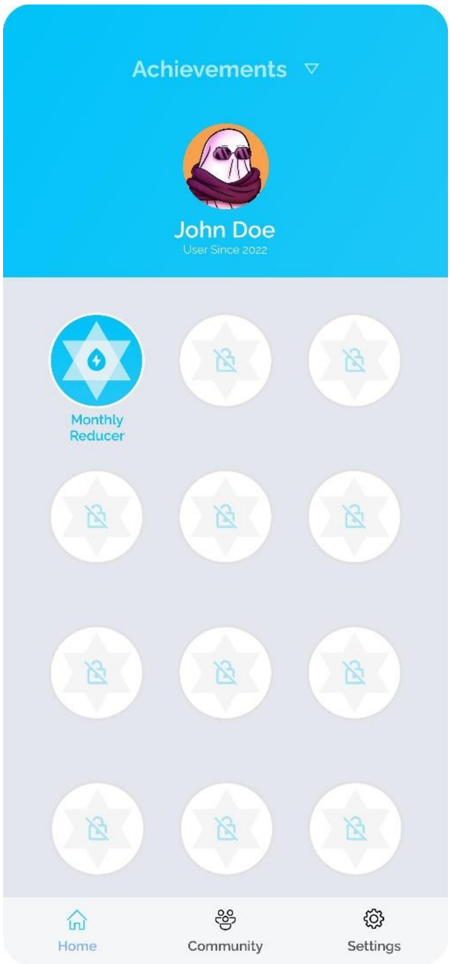


Figure 21 : Achievement badges page

4.4.5 Data Collection & Privacy

With the collection and utilization of user data for the purpose of calculations through both the website and mobile application mockups, concerns over data collection and privacy are expected. In response to these concerns, all data collection and privacy, as well as scope of usage should be clearly outlined in terms of service that are completely voluntary and optional to opt into. Additional features can further be limited based on user consent to data collection, such as the granular breakdown view of their household, which would require the user to at some time provide this layout data. All data collected will also only be used for the user's personal benefit and will not be required to be shared with third parties.

5. Discussion Chapter

As was pointed out in the introduction of this report, we had a brief and a research question on which to base our project. The brief took an important part in the beginning of the process, as we thought of a solution that would fit the context presented in the first chapter of this report. The research question mentioned in the presentation is: “What type of smart solution could help reduce water consumption and create more awareness among the population?”. In this chapter, there is a discussion of whether we have managed to answer the question or not.

5.1. Solution presented related to the brief

This project has accomplished finding out an answer to the research question that we pointed out at the beginning of the process, according to the brief presented. We have been able to design a smart solution that could help the environmentalist activist who is living in a tiny house in Nessoden to live in a more sustainable way. The smart solution helps to reduce water consumption as well as create more awareness of the user’s water usage. Our solution, as can be seen in the previous chapters, is formed into two parts.

The first part of the smart water system consists of the water system itself. The system is designed to reuse the greywater that comes from the sinks, shower, and toilet into the water for gardening (Maimon A, 2018). The solution that we offer is a good beginning for a system that will reduce the consumption of water in a household.

The water system is connected to a website and an app, where the users can track their consumption of water in their household. We are aware that nowadays people are more into using their mobile phones instead of their laptops (Paiano et al., 2013) but we think that by presenting both options we can reach more people. Moreover, with this smart solution, apart from people being able to know how much water they consume, it also allows for creating awareness among the population.

Returning to the brief, the smart water system that we have come up with matches the situation of the environmentalist activist who is living in a tiny house in Nesodden. She has knowledge of the impact that is generated around waste, and she is in the process of transitioning into living more zero-waste. Our solution can fit in the tiny house, as the barrel will be placed outside the tiny house, so the dimensions of the barrel are not a problem. Moreover, going deeper in the water system, it helps her live more zero-waste as some part of the water that she will consume, will be reused. To finish, the addition of the app that tracks her water consumption will make her even more aware of her water usage and will help her to think about more solutions to become more zero-waste.

5.2 Answer to the research question

We can extrapolate the solution we have designed for the environmental activist to a general solution, for any type of household and user. The smart water system proposed in this report can be part of all kinds of living situations, as everyone can have an interest in knowing how much water they are consuming, either for sustainability or economic reasons. Therefore, this project not only helps to improve the living situation presented in the brief, but also each household that has running water.

In conclusion, this project has achieved to answer the research question, as the smart water system that is presented in this report helps reduce water consumption in a tiny house, as well as in any household, and helps create more awareness among the population with the website and the mobile application.

5.3 Further research

In this section, we will describe further research that could be done related to this project.

We believe that the smart water system that could be built with our proof of concept, could be a smart device that could be interconnected to other smart devices in the house. Thus, Internet of Things (IoT) is a topic where to have research on if this project is continuing carried out.

Another subject that it could be interesting to do research on is the different types of filtrations that exist in the market, as well as perhaps creating a new type of filtration, which could be done by mixing the ones already existing.

Finally, another interesting point to study could be adding other features to the app, to make it easier for the customer to use it. Research could also be done on some tips for users to reduce their consumption of water.

6. Reflection Chapter

The project made it clear for us that future users are ready to reduce their water consumption. The next group could use our work to start building a real prototype and building a smart solution.

6.1 Difficulties faced during the process

During the project, we encountered several problems, which were either solved or avoided. We only had 4 months to complete this project, which was not enough time to make a full-scale, working prototype. That's why we decided to make a proof of concept, which proves that our system could be feasible.

To make the proof of concept, we needed data from users living in a tiny house, to know which would be the best solution for these future users. It was very difficult to get in touch with the inhabitants of tiny houses in the town of Nesodden. Indeed, we learned on the spot that the tiny houses of the city were improved into real houses. The inhabitants of the only tiny houses that we saw were not interested in the project and they refused to answer our questions. We then went through alternative channels: social networks. We focused on Facebook, because there were groups with only Norwegians living in tiny houses, unfortunately, the groups either blocked us or ignored us. In the end, we came across people who weren't living in tiny houses but who could help us to understand their relationships and uses of water, as everyone is related to this topic, not only tiny house users. We got good feedback and ideas on what we could add to the final application.

There was also a communication problem at the beginning. We made a Gantt diagram from the beginning to follow the progress of the tasks. As no one was responsible for the tasks, progress was not smooth. This was corrected by writing down systematically who was to do what. Which solved our communication problem. We then commented all the time on our progress in our chat group. This helped us a lot and allowed us to move forward much faster despite the fact that not everyone had the same work pace.

6.2 Instructions for next groups

As pointed out in the previous chapter, there is more research that could be done related to the project that we have carried out.

Next year, this Smart Home project can be divided into two groups. The first group can work on the mobile application, and the other can work on the full-scale prototype.

We advise the group that is making the mobile application to constantly get feedback on the app. We think that user experience is really important to make the app better every time.

The group that is working on the full-scale prototype advises keeping an eye on the market. Nowadays reusing water is a hot topic, full of innovations. Because of these constant innovations, there will constantly enter new technologies the market. These technologies are possibly useful for this project.

7. Appendix

7.1 Focus group Questions and Answers

Question	Person 1	Person 2	Person 3	Person 4
Which are your water usage habits?	Using the sink Washing Shower (10-minute).	Every 2 days (15-to-20-minute shower).	Shower every day (5-minute).	Shower every day (10-minute).
Do you think you have to change your habits?	Money is a big reason to change habits	Money not the problem. Guilt would play a role	Guild plays a role	Money would be a reason to change habits
Are you using a smart home device to track water consumption?	Is not using any app	Does not know	Using an app to check energy prices	Using an app to check energy prices
Are you interested in using a water consumption app?	Yes, if it saves money	Yes, interested in tracking water consumption	Yes, if it saves money	Yes, already checks electricity app daily.
How would you use the app?	Comparing with other people. Month by month use. Compare to average	Layout of the house to see where the water consumption is.	It would be nice if the app had tips to reduce water consumption	Compare data monthly, and to average consumption
Gamification	Consequences of saving water/achieveme nts	Stopped using Strava because of the competitive side.	Challenges to reduce water. Does not want to share data.	The app could have goals to achieve

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