BACHELOR THESIS

Creating water consumption awareness with a data physicalization

The HydroSumption project

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Abstract

One of the environmental issues in the world is the consumption and supply of water. At the University of Twente (UT) up to 2 million+ liters of water is used per month in her buildings. Many members of the UT community, consisting of students, staff and visitors, have no idea of the amount of water being used on campus. The Energy Data platform web app was developed by the Campus & Facility Management (CFM) to provide insight on the consumption. This web app allows users to see the water consumption of the University of Twente. However, the energy data platform has not been successful in creating awareness of water consumption in the UT community. During the project a physical data visualization is created to provide members of the UT community with insight into the water consumption on campus to create awareness for the consumption of water on the UT. The project concept will be developed based on requirements set by stakeholders, CFM and the UT using an explorative design approach. Research into characteristics of effective data visualizations and an analysis of the Transtheoretical Model of Behaviour change will be used for evaluating and ideation of the prototype concept. From evaluations and user testing, the HydroSumption prototype was, besides minor recommendations, deemed to be interesting, easy to use and easy to understand by the UT community and successfully created awareness of water consumption within the UT community.

Acknowledgements

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List of abbreviations

CFM	Campus & Facility Management
UT	University of Twente
LTA	Long-Term Agreements
CreaTe	Bachelor program Creative Technology
EV	Eco-Visualization
TTM	TransTheoretical Model of behavior change
EEA	European Environmental Agency

1. Introduction

At the University of Twente (UT) energy is being consumed in all buildings. The consumption is being monitored by Campus and Facility Management (CFM). During this project a solution will be developed to connect the data gathered by CFM to the UT community, consisting of students, staff and visitors. The first chapter will include a description of the current situation, the challenges presented by the project, the research question to be answered and an outline of the thesis.

1.1 Situation

The Dutch government has set goals to reduce the usage of fossil energy such as coal and oil in the near future. These goals are set in the climate agreement [4] and aim to reduce the CO2 emissions with 49% by 2030 and 95% by 2050 compared to 1990. In addition to these reduction goals, the generation of all electricity should be CO2 neutral by 2050 [1].

The UT is one of over 1000 companies and government institutions that have signed the Long-Term Agreements on energy efficiency in the Netherlands (LTA's). The goal of these agreements is to stimulate organizations to create and adopt energy efficiency plans and practice systematic energy management [5]. On the campus of the UT, there are several systems, ideas and installations in place that provide sustainable sources of energy such as heating, water and electricity [1,2]. An example of such an installation is the "koude cirkel", a deep pond in the middle of the university. The water in this pond is used to cool down university buildings and research equipment, which was previously done with drinking water [22]. Other Initiatives regarding water sustainability can be found on the sustainability page of the UT [22].

Members of the UT community have a significant impact on the energy consumption on campus. Currently, all energy usage on the UT campus is published in a web app on the CFM website, the Energy Data Platform [3], a screenshot of the web app is shown in Figure 1. On this web app, the user can select which buildings and energy types they would like to get more information about. This web app however, is not successful in creating enough awareness within the UT community about the subject of energy consumption. Many of the community members are not aware of the existence of this data platform. Or the data is not presented interestingly enough to create thought with the viewer about their own energy consumption.

Figure 1.1: Data web app from CFM on the UT energy usage.

All the water that is being used by the UT is supplied by Vitens, the biggest water supplier in the Netherlands [23]. Most of this water is being extracted near Hengelo, a city close to the UT [24]. This location pumps about 4.8 million m3 of groundwater annually. For that reason, Vitens has considered their impact on nature and how they can assure water availability in the future, their contributions and goals are shortly listed in Figure 1.2 [25]. Their main mission is to extract the groundwater without causing harm to the environment. To ensure the minimal impact of the water extraction it is also important that not only Vitens but also the consumers are aware of the consequences that might impact the environment due to their water consumption [23].

SDG	Vitens' contribution (including Vitens Evides International)	Link to materially important topics
6 CLEAN WATER AND SANITATION	Clean drinking water and good sanitation facilities This goal is our primary focus and our core task. In the Netherlands, we supply high-quality water at a low cost to society twenty-four hours a day and seven days a week. Internationally, we and our partners help local organisations provide clean drinking water in developing countries (VEI). We are actively involved in 46 projects in twenty countries, scattered across three different continents.	• Protection of groundwater resources. • Drinking water quality. • Drinking water delivery dependability. • Partnerships. • Nature management and conservation.
9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Innovative and sustainable infrastructure The infrastructure for water is an essential precondition for prosperity and well-being in our country. Each year, we invest approximately €130 million (gross) in replacing and developing our infrastructure. New technology is tested within the 'Infrastructure of the future' (Infrastructuur van de toekomst) programme. Such as our project in Friesland, where we are testing innovative technology for a data-driven infrastructure. In 2018, we also took action together with our suppliers of pipe material in order to adapt our network to the requirements of the circular economy. They have prepared raw material passports that identify the materials used in our infrastructure, in support of circular innovations.	• Drinking water delivery dependability. • Dialogue and lobbying. • Innovation. • Material flows. • Data-driven processes.
11 SUSTAINABLE CITIES AND COMMUNITIES	Sustainable cities and a sustainable living environment Water is a basic human need, and therefore an important factor in a sustainable community or city. In the Netherlands, we are actively pursuing infrastructure innovations in this field. In our international work, we are active in rapidly urbanising areas such as Nairobi and Bangladesh, where we focus on creating a balance between the living environment and water management.	• Drinking water delivery dependability. • Dialogue and lobbying. • Innovation. • Partnerships. • Nature management and conservation. • Data-driven processes.
12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Responsible consumption and production Vitens sustainably manages and ensures efficient use of natural resources. Our residual materials, by-products that are directly generated during the drinking water production process, are sold as a high-value raw material wherever possible. If the residual materials cannot be sold as a high-value raw material, they are put to good use. We try to reduce our production of waste as much as possible. If waste is unavoidable, we investigate how it can be recycled or utilised in some way.	• Material flows.
15 LIFE ON LAND	Repairing ecosystems and preserving biodiversity Natural processes and biodiversity provide a strong defence for our groundwater resources. Our sites are managed in accordance with the requirements of the Sustainable Land Management Certificate. We have been awarded Gold-level Sustainable Land Management certification. We actively invest in increasing our nature values and protection through nature area development to store water or create water catchment areas.	• Protection of groundwater resources. • Nature management and conservation.
17 PARTNERSHIPS FOR THE GOALS	Partnerships for our goals We collaborate with various parties in order to carry out our primary mandate. For example, we jointly participate in campaigns for a clean habitat. In support of this, we also work together with parties that share the same concerns or have the same ambition, even though they may be motivated by other interests. Such as our participation in the soil coalition with a.s.r. and Rabobank. Our shared concerns about the soil are the common factor and this activity also helps us achieve SDG 6 and SDG15. We also collaborate internationally with local water utilities in order to implement projects.	• Protection of groundwater resources. • Nature management and conservation. • Dialogue and lobbying. • Innovation. • Partnerships.

Figure 1.2. Viten's Contribution and sustainability goals [25].

1.2 Challenge

The challenge presented for this bachelor thesis is to create an energy data representation that will present data in such a way that it will raise the awareness of consumption within the UT community. For the scope of this thesis and visualization design, water consumption is chosen as the core data for the visualization to create a more defined representation and be able to focus more on connecting the data with the user. The representation should be able to engage with UT community members in such a way that they will be interested in the overall consumption of the UT and their own personal consumption. The data visualization created in this project will be made as a physical installation, also known as a data physicalization, determined by the author of this thesis.

1.3 Research Questions

The main research question to be answered in this thesis is:

How to design a UT community water consumption data physicalization that creates awareness on the water consumption on campus?

To be able to answer the main research question above, the following sub-questions have been derived and will also be answered in this thesis:

- *How to personalize data presented in this data physicalization?*
- *What elements in this data physicalization activates people to change their behavior towards water consumption?*

1.4 Thesis outline

The first chapter introduces the project by describing the situation and goal of this paper. The second chapter provides a background analysis, state-of-the-art review and a literature research on related work to this project to create a basic understanding of the subject. Chapter three includes an overview of the methods used for ideation and analysis of the prototype. In the fourth chapter there is a stakeholder identification and analysis, as well as project requirements and initial idea generation. In the specification chapter the chosen idea is further elaborated along with a list of final requirements and user scenarios to understand how the prototype is meant to function. After that the sixth chapter includes a list of used components and solutions for found problems during the realization of the prototype.
In the evaluation section stakeholders are asked to review the prototype and share their thoughts on the design. Lastly, the eighth chapter answers the research questions, as well as state future recommendations.

2. Background

This chapter outlines background information that is required for the completion of this thesis. The chapter will include a literature review to define information and gain information about the subject, as well as a state-of-the-art review of existing work and projects related to the project.

2.1 Literature review

The goal of the literature review is to gain new knowledge about data visualizations, energy representations and the projection of their information, as well as learning about methods to increase environmental awareness regarding water energy consumption. In this part the sub-research questions as listed in section 1.3 are addressed.

2.1.1 Introducing visualizations

Information visualizations are tools that can be used to project information in ways that are easier to relate and understand for users, "*Abstract— Information visualizations can amplify human cognition by transferring strenuous cognitive operations with abstract data into visual reasoning processes with external graphic representations*." [6]

People make decisions about how they behave based on their knowledge and understanding regarding a subject. In order to change the behavior of an individual they have to gain comprehensive information that will change their view [7]. In the case of this project the subject is about their awareness of water consumption on the UT.

2.1.2 Eco-Visualizations

A common term used for data visualizations that focus on representing energy data as a way to promote sustainable behavior is Eco-Visualizations or EV. According to Holmes [8] Eco-visualizations are a form of data visualizations that combine art and scientific information to provide new strategies for localizing energy conservation. Their goal is to promote responsible resource management and conservation. In another paper by Pierce, Odom & Blevis [9], eco-visualizations are defined as *"any kind of interactive device targeted at revealing energy use in order to promote sustainable behaviors or foster positive attitudes towards sustainable practices".* They state that these visualizations offer strong potential to provide people with more access to information and the tools to manipulate the information data in meaningful ways to achieve goals.

2.1.3 Eco-Visualizations strategies

As this research is about designing a data physicalization concerning water consumption, a form of EV, it is important to provide the characteristics that determine the effectiveness of such visualizations. According to Pierce, Odom & Blevis [9] the most important of these characteristics are aesthetics, feedback and competition.

Aesthetics

In the field of information visualizations there has been an increasing emphasis on the importance of art and aesthetics. As a visual representation of data, an EV must be able to attract people with aesthetics that "*present enough of an enigma to keep an audience interested without being easy to solve*" [9,10].

Within the field of information visualizations there are 2 distinct types of visualizations; the first is artistic visualization and the second is pragmatic visualization. An artistic visualization is best used as a way to express a point of view. Whereas the more traditional pragmatic way of presenting information is less subjective and provides a more neutral presentation of data. An example of pragmatic visualizations is the current CFM web app displayed in Figure 1.1. An effective EV is a combination of these both, providing the information in a comprehensible way while still insinuating a desirable behavior change.

Feedback

The second of these characteristics is feedback, being a product of the collection and visualization of data relating to energy resource consumption. This feedback can take several forms [9]. A common approach of feedback in EV's is by using cues or indicators to guide the user towards a desired action or behavior. Some ways to do this are by giving numerical feedback, giving back numbers that show your usage, or ambient feedback like colors associated with good or bad behavior. A study by D.C Mountain [11] has shown that devices using such real-time feedback can lead to 10% energy savings.

Another form of feedback is to give consumers a more in depth feedback. Giving users a pattern of their consumption. This way a consumer can explore their consumer behavior in more detail and therefore make a better informed decision about their future behavior. Uneo et al. [12] has tested several residential homes on the effectiveness of such a feedback method, and their study has shown a 9% reduction in power consumption. However, feedback is only a way to inform the viewer, who will then create their own motivation based on their knowledge [18].

Competition

Humans in a community tend to gain a competitive nature towards each other. They want to be the best or most successful person within a group of peers [32]. This nature can be used to promote discussion and sustainable energy consumption behavior. By setting up a competition to reduce your consumption of energy in which individuals can compete. The Oberlin College studied that use of a real-time data visualization that created a competition between students to have the least energy consumption in their dorms [15]. The results of the study have led to a reduction of energy usage of 32%, a total overview of the results is shown in Figure 2.1. Another similar study conducted by another researcher at the Indiana University Bloomington campus where the standings of individual water consumption were updated bi-weekly resulted in a reduction of 33.008 KWh in a month compared to the baseline of the previous 3 years[9], that equals the consumption of 36 average households.

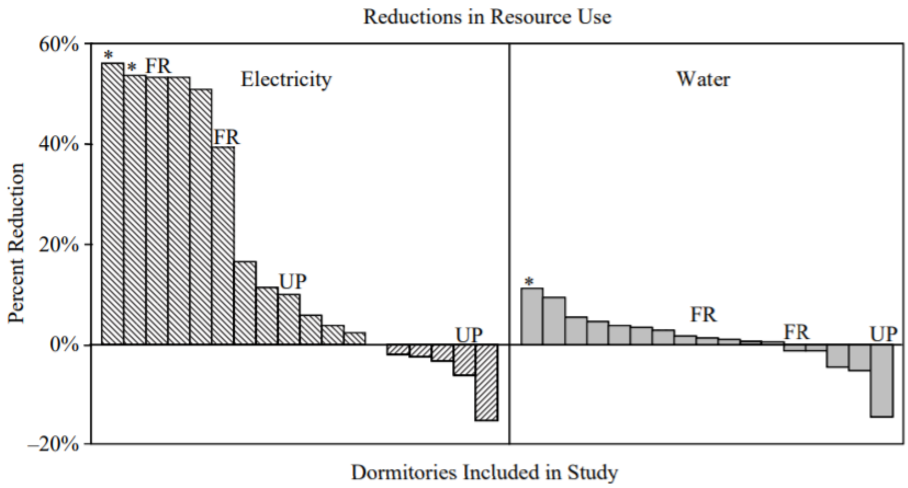


*Figure 2.1: Results of the Dorm competition by the Oberlin College. The notation FR and UP stand for Freshman (FR) only and Upper class (UP)only students dorms respectively. Each bar represents a different dorm. The * represents dorms receiving higher quality feedback. [15]*

2.1.4 Transtheoretical model

Understanding how to change the water consumption awareness of individuals and what steps will need to be taken to achieve the prospected goal is important for the design of the data physicalization. The TransTheoretical Model of behavior change (TTM) developed by Prochaska and Velicer [16] is therefore to be used for this project. This model is focussed on the changing of behavior from a health perspective. However, since the first steps of changing the behavior of other people is to make them aware of the issue, the decision making and process steps can still be applied to this project. According to the TTM changing behavior involves a process consisting of six stages; precontemplation, contemplation, preparation, action, maintenance and termination. As the goal of this project is to increase the awareness of water consumption, the last three stages of action, maintenance and termination are less important than the first three. Therefore, only the first three are further explored.

Precontemplation

During this stage people do not intend on taking actions regarding their behavior in the foreseeable future, which is defined as 6 months by Prochaska and Velicer. People are not informed enough about the consequences of their behavior or are not motivated to change.

Contemplation

The contemplation stage is where people are considering to take actions within the foreseeable future. They have gained more knowledge of the consequences of their behaviour, both positive and negative.

Preparation

The last stage that is discussed is preparation, the time when people intend to take actions within a month or less.

To determine which of the previously mentioned three phases is most appropriate to apply to the project it is necessary to analyze what stage the UT community is currently in. In order to conclude that stage, a survey about the current knowledge of the community members regarding the impact of their water consumption is required.

2.1.5 Application of the phases of the TransTheoretical Model

How to apply the TTM model to this project depends on several factors. Both the EV general design and the specific requirements by the UT community are important. There is no universally applicable method or "one size fits all" solution that will always render the best possible results; "*Most technologies are limited as they use a "one-size-fits-all" solution – that is, they provide the same feedback to differently motivated individuals, at different stages of readiness, willingness and ableness to change*", as He, Greenberg and Huang [17] described their proposal of recommendations to TTM.

Their proposal states that motivation is based on several constructs; attitudes, beliefs and values. From these, the attitudes are easiest to change where the values of a person are most likely to endure. Attitudes are defined as learned prejudices to a person or situations. How people respond to a situation based on what they heard or know about the subject at hand. Beliefs are what the person knows from experience or facts. It is the way people understand reality. Values are the moral ideals a person views desirable. These describe what a person views as right or wrong.

Based on this information, the recommendations for each stage are described below:

Precontemplation

In this phase the goal is to introduce a person to the problem at hand and allow them to acknowledge their current water consumption behaviour as problematic. Some people might be reluctant to consider changing [19], which is why "*information should be provided in moderation as more intensity will often produce fewer results*"[17]. The following three recommendations are made by He, Greenberg and Huang [17] regarding this phase:

1. Provide neutral, non-biased personal feedback that show both positive and negative consequences of a person's behaviour, as well as the benefits to the individual. This way people become more open towards new information and considerations.
2. To compare behaviour to social norms, this is best done by using descriptive and normative messages.
3. Provide personalized feedback to small actions instead of greater overall feedback, for instance the impact of not having a tv or computer plugged in all the time.

Contemplation

The goal of this phase is to tip the balance of a person's opinion. From knowing what the problem is to actually wanting to take action. In order to achieve this goal a visualization design could make use of [17]:

1. Personalised feedback focussed on the positive consequences of behaviour change. As well as provide the negative consequences of not changing behaviour. Emphasize the positive impact or improvements changing behaviour can have on the person's life and present the negatives as loss rather than gain or continuation.
2. Remind individuals of their positive views and attitudes towards sustainability, encouragement of change and the difference between their pro-sustainability attitudes and their current behaviour.
3. Encourage the person to take their changes in smaller steps. Provide encouragement to small steps that together form the larger end goal.
4. Community pressure, by providing access to an energy usage community website so people can see how other people have changed their behaviour and how it affected their life.

Preparation

During the preparation phase individuals want to take action to change their behaviour and are preparing or planning on how they want to do it. To support them, a visualization should help individuals develop their plan to be as effective and accessible as possible. Recommendations for this phase are [17]:

1. Help individuals set specific goals they want to achieve with altering their behaviour as compared to before they were aware of issues. This is best done by doing the easiest goals first and the most difficult last.
2. Help individuals with determining different methods of achieving the above mentioned goals. Encourage them to use their own knowledge and expertises to execute their plans.
3. Within sustainability communities, as mentioned in the contemplation section. Provide the option of getting a “sustainability mentor”, someone who is in a further phase of their behaviour change then the person seeking help that can help reflect back on what positive impact a behaviour change has had in their lives.

2.1.6 Processes of change in the TransTheoretical Model

Progressing from one phase to another requires work. A person needs to experience or apply certain processes of change. In the works of Prochaska [9] there are 10 of these explained. These processes are: Consciousness raising, Dramatic relief, Self-reevaluation, Environmental reevaluation, Self-liberation, Social liberation, Counterconditioning, Stimulus control, Contingency management and helping relationships. Each of these processes are briefly explained individually.

Consciousness raising is about raising awareness of issues, their cause and their consequences. The ultimate goal associated with this process is to find a solution for a particular problematic behaviour using tools such as feedback, education, confrontation and media. This process fits best in the Precontemplation phase.

Dramatic relief is focussing on the emotional link people have with the issue at hand. The emotion will then be used as a motivational tool towards the next behaviour change phase. Methods for this process include psychodrama, grieving and personal testimonies. The Contemplation phase is most applicable for this process.

Self-reevaluation combines cognitive and affective assessment of a person’s self-image with and without having reached the desired behaviour change. An example is to compare the users current life with his life when the benefits of altering behaviour have started. Some methods are to use role models and value clarification. The best phase to use this process in is the Contemplation phase.

Environmental reevaluation is similar to self-reevaluation in method and phase applicability but focuses on the effects on a person’s environment rather than self-image. How do their actions affect the people around them? For this process it is important to create empathy withing a person towards his environment. The contemplation phase is the most applicable for this process

Self-liberation is believing and being committed that a person is able to change their stance or behaviour. A well known example of this are New Year's resolutions. Motivation researches have shown that it is important to provide people with choices, as people with 2 choices are generally more motivated than people who only have one choice available. This process is best implemented in the Preparation phase.

Social liberation means other people provide support to a person and help him progress. They can provide them with counseling and empower their good intentions. This process is especially effective to people dealing with depriving or oppression. For this process the Preparation and Action phase are most interesting.

Counterconditioning is providing alternatives or replacements for unwanted behaviors. Suggesting minor alterations will eventually combine to major changes in behaviour. Again the Preparation and action phases are most useful here.

Stimulus control is best described as providing hints or even forcing a change upon a person. An example is taking a standard task in the day and making it harder for the person to use their conventional behaviour and “forcing” them to adapt their way. This method is best used in the contemplation and later three stages of change.

Contingency management provides consequences of the actions of a person. These consequences are used to steer them in the right direction. Most applicable in the later three stages of change.

Helping relationships is a combination of trust, caring and acceptance to support a person. An example of this is counseling or buddy systems. This method is used in the later three stages of change.

2.1.7 Conclusion

When combining the design for an effective water consumption eco-visualization with the transtheoretical model, it becomes clear that the design of a data physicalization to raise awareness of water consumption within the UT community is dependent on the following factors: 1) The phase in which a user is, precontemplation, contemplation and preparation; 2) Their mindset and current awareness regarding water consumption; 3) In order to better connect the data with the user, the data needs to be personalized, this can be done by providing feedback that the user is able to relate with and compare to their own personal consumption. This data feedback should be real-time and remind people about the pros and cons of sustainable water consumption; 4) Provide the UT community with means to compare their own behaviour to that of other people within the UT community. As for the aesthetics of the design, it should be clear to the user what the presented data is in a quick observation that is both informative and interesting enough to draw their attention.

2.2 State of the art

There are many possible ways to create an EV. Some of the possible methods have already been developed into working prototypes and market products. In this section some of these comparable projects are analyzed for their benefits and weaknesses. At the end of the section there is a summary of the analysis.

2.2.1 Comparable Projects

Power Aware Cord

The power aware cord [13] is a power cable that emits light if it is powered. The intensity of the light is dependent on the amount of power running through the cable. The goal of the project is to give users direct feedback on their energy consumption. This might trigger people into talking about energy and perceiving the light emitted by the power cord as electricity, even if that would realize on a logical level that it is just a representation. One of the benefits noted by the developers is how it enables a user to address the interface from afar and to be able to perceive the information from afar rather than to interact with the device physically. Below in Figure 2.2 there is a visualization of the power aware cord.

Figure 2.2: The power aware cord by STATIC [13]

7000 oaks and counting

7000 oaks and counting is an interactive EV artworks created by Tiffany Holmes [14]. It is composed of a sequence of animated clips constructed from tree images as can be seen in Figure 2.3. The images change depending on the carbon loads in the Illinois building of the American National Center of Supercomputing Applications. The aim is to stimulate individuals working in the building to make commitments towards reducing their CO2 footprint. People who have achieved this can then apply to be incorporated into the artwork as a form of reward for their behaviour. The eventual goal is to make the entire building CO2 neutral and show people that small changes in behaviour such as turning off the lights or biking to work can over time or in larger groups have a significant impact on CO2 emissions.

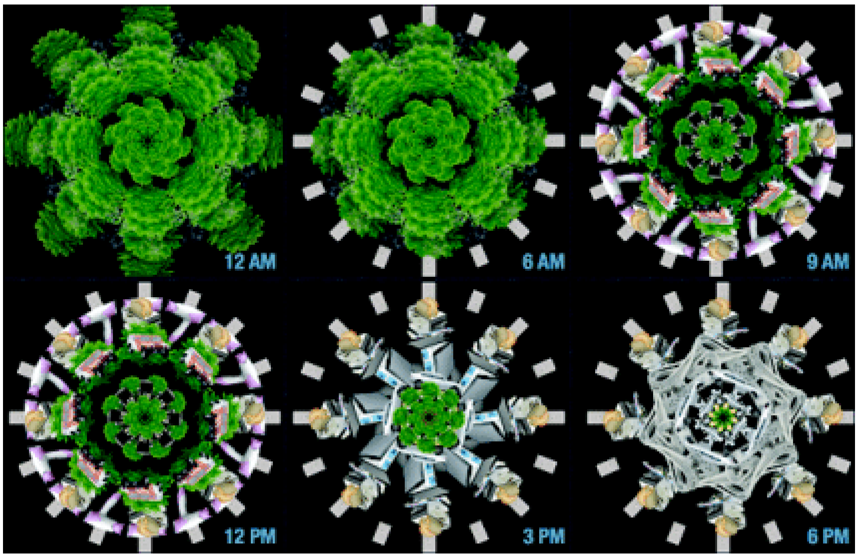


Figure 2.3: 7000 Oaks and counting by T. Holmes [14]

Nuage Vert

A public art installation in Helsinki presented in 2008, Nuage Vert [21], or green cloud, is an artwork by 2 artists, H. Evens & H. Hansen in collaboration with Helsinki energy. The artwork was a projection of green lights onto a vapor cloud coming from the city's power plant. By doing this it enabled residents of the city to see how their energy consumption behaviour could affect the output of the power plant as direct feedback during a campaign called “Unplug”. This means that all people within an area would unplug their electrical devices for a short time to see how this would affect the artwork. If less power was consumed, the green cloud would increase in size as an aesthetic metaphor for emissions. The goal of the project is to; “*confront the city dweller with an evocative and aesthetic spectacle”*[21]. The artwork is shown in Figure 2.4 below.

Figure 2.4: Nuage vert in Helsinki [21]

European Environment Agency

Most instances of showing data regarding water consumption is done in more traditional ways, in the case of the European Environment Agency [19] it is done using a form of pie chart, shown in Figure 2.5. Within this visualization there are elements that are meant to steer the viewer to an opinion. The behaviour regarding water usage such as showering or using the tap when brushing your teeth are separated into 2 categories. The first one category is marked with a happy smiley, indicating good or desirable behaviour while the second one is marked with a sad smiley, indicating bad and undesirable behaviour. At the end there is a simple visual comparison between water consumption with desirable behaviour, the happy smiley, versus the water consumption with bad behaviour, the sad smiley.

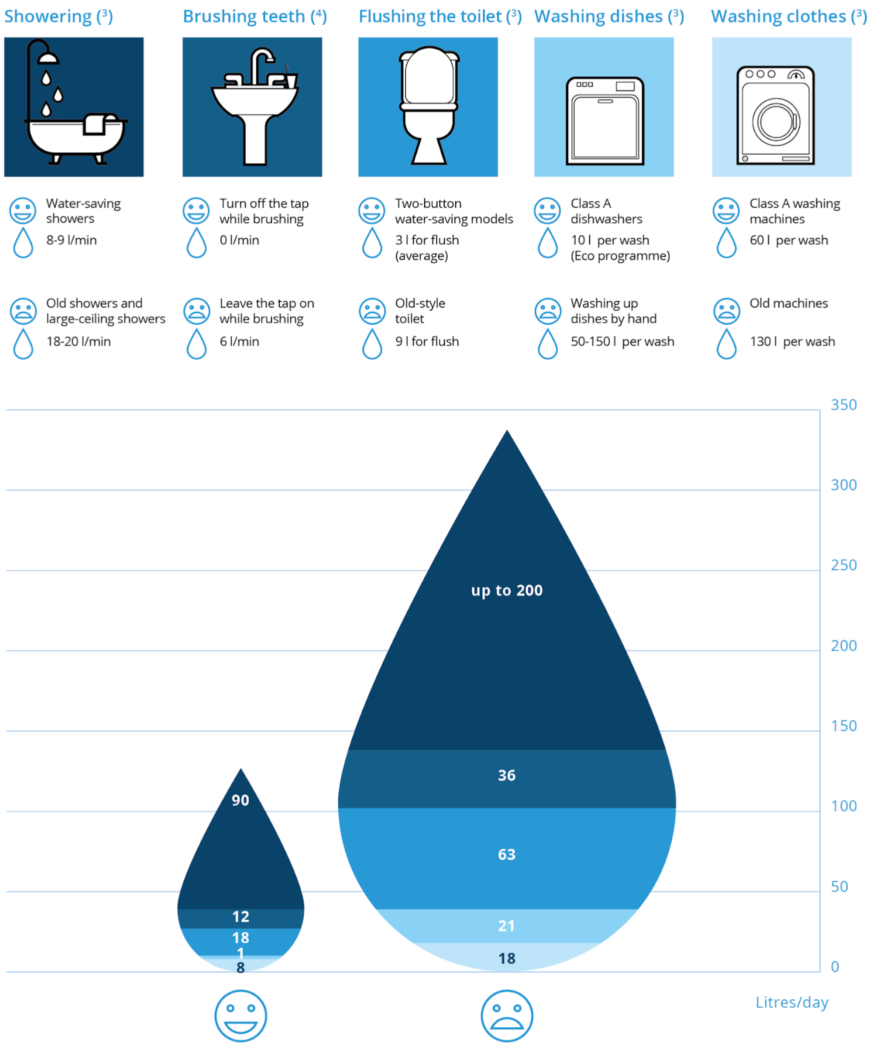


Figure 2.5. European Environmental Agency visualization of water consumption. [19]

Waterlicht

Waterlicht is a project by the Dutch artist D. Roosegaarde [20]. It is a display of the seawater level rising in the Netherlands, with blue LEDs and lenses filling a field with waves, as a virtual flood shown in Figure 2.6. The goal of this project is to raise thoughts and awareness about the issue of rising sea levels and the importance of water innovations. The best feature of this project is its aesthetic appeal. In a video linked in the article [20], many viewers state that they liked the installation specifically due to the design. Another strong convincing feature is the immediate relation to a viewer's personal consequences. They can see how their home could be affected by the rising water.

Figure 2.6. Waterlicht in Amsterdam. [20]

2.2.2 Analysis

The projects and installations described in the state of the art are all different ways to display information to a person. Both physical and digital visualizations are being used to create awareness for environmental consequences of energy usage. Most of them use direct feedback to tell the viewer what the impact is of their current behaviour. Although WaterLicht and the EEA take more time to process and do not offer any real-time feedback. It is worth noting that all examples are aesthetically pleasing, most notably the WaterLicht project. Another interesting observation is that most visualizations make use of lighting effects with colors that are representative of the energy type they try to achieve or in the case of Nuage Vert the green color represents nature.

Each of the examples stated can be seen as a visualization within the definition of one of the TTM phases. In table 2.1 below there is a short overview of the examples and their corresponding TTM Phase. The power Aware cord and WaterLicht are clear examples of Precontemplation visualizations. They state only the facts and do not compare them with alternatives, all the information is displayed in a neutral manner. Even though it can be argued that the WaterLicht project compares the future water levels with the current ones, the two are not being presented right next to each other. Nuage Vert is most representative for the Precontemplation phase as well, but in the case of this example it is combined with an action. The people of Helsinki were asked to reduce their energy consumption as much as possible by turning off all their electronic devices. Despite this being a fairly unrealistic change in energy consumption, it does also provide the people with a way to reduce their energy consumption, therefore the preparation phase is also appropriate for this example. It does not provide a feeling of right and wrong nor is it attempting to persuade the people towards a certain stance, therefore the contemplation phase is not applicable. The EEA example is a clear example of contemplation. The smiles provide a clear distinction between right and wrong behaviour and provides a very biased view on its information. It also provides some forms to reduce water consumption and therefore it also has preparation phase elements. 7000 Oaks is the most difficult one to pin down, as it aims to persuade people into taking measures towards sustainability, but does not provide predispositioned information. By allowing viewers to compare their own consumption behaviour with that of other users in the building they might still spark a sense of better or worse, which would put this example in both the precontemplation and contemplation phase.

Phase Example	**Precontemplation**	**Contemplation**	**Preparation**
Power Aware Cord			
7000 oaks			
Nuage Vert			
EEA			
WaterLicht			

Table 2. Overview of state of the art represented as TTM phases.

Furthermore, it is interesting to look at the processes described in section 2.1.6 and determine which ones are being used by the examples given. The first example, the Power Aware Cord, provides a way to monitor usage and raise consciousness in the user about power consumption, therefore it can best be described as a consciousness raising process. 7000 oaks and counting works by allowing the user to compare their behaviour to what other people have done to improve their own consumption sustainability. It is best described as a combination of environmental reevaluation and stimulus control. Nuage Vert is an example of both self and environmental reevaluation, the unplug event allows users to see the result of changing their actions and how they benefit both themselves as well as the people around them. The EEA Visualization makes use of dramatic relief and emotions by using smileys that simulate emotions with certain behaviour. The WaterLicht project is also a form of dramatic relief as it presents its data in a very dramatic way and inspires people to experience or feel what the effects of their actions will be. Yet it is also a form of Consciousness raising as it also provides its information in a neutral and unbiased way.

3. Methods & Techniques

In this chapter there is an analysis of methods to be used in the ideation and realization of the data physicalization and an analysis of all the stakeholders.

3.1 Creative Technology design process

For this graduation project the design process taught in the bachelor Creative Technology is used. In this process the generation of ideas and creation of prototypes is handled in phases, as shown in Figure 3.1. The process consists of main phases; ideation, specification, realization and evaluation. During the ideation phase the basic requirements for the project are determined through stakeholders, as well as the generation of preliminary ideas based upon the basic requirements. The specification phase will then use these preliminary ideas to create an understanding of how the final product or design will function and how users will interact with it. The realization phase is where the prototype is fully developed, here the specification of components and structure is explained. During the evaluation phase the prototype is tested by potential users.

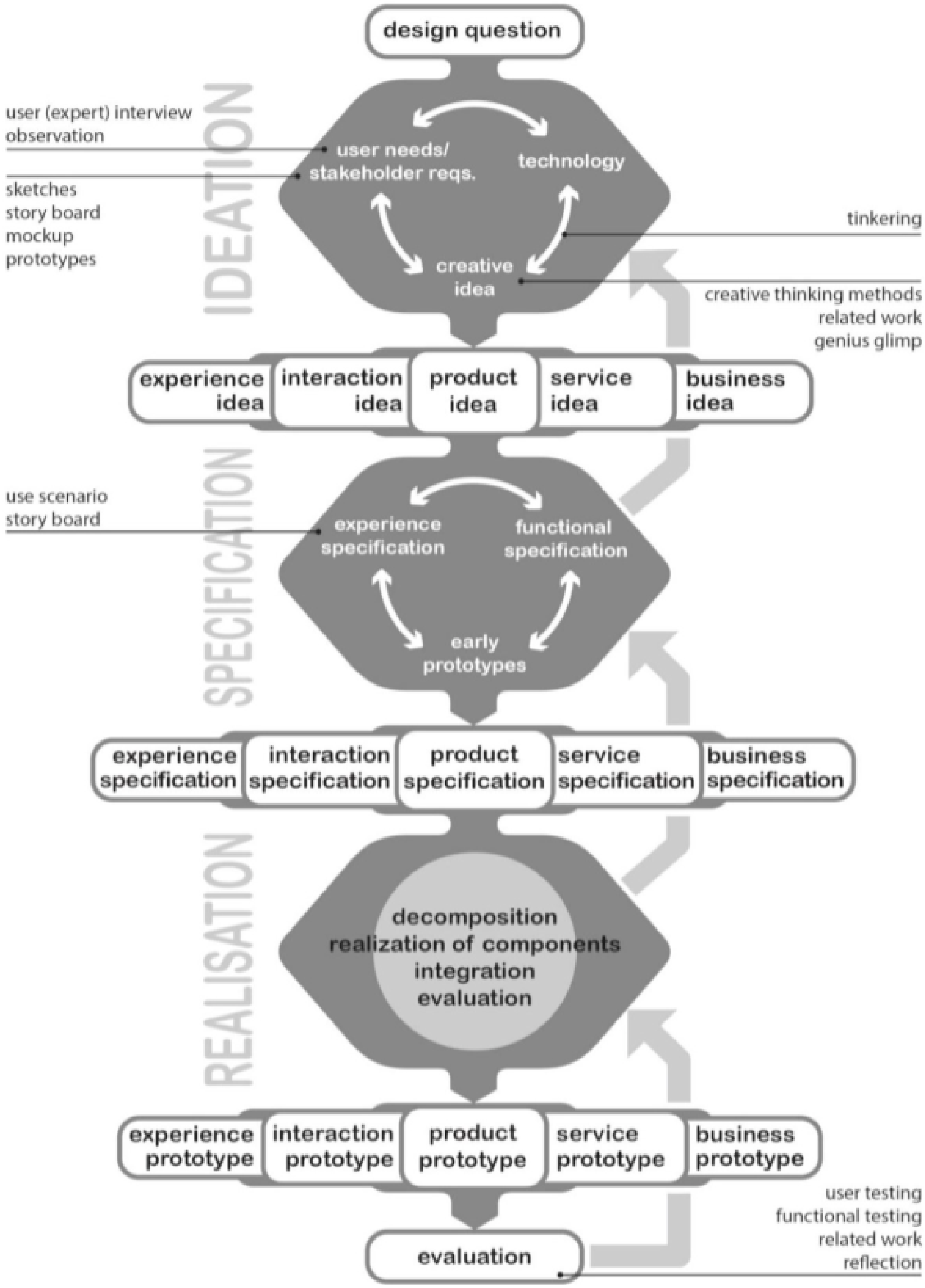


Figure 3.1. Creative technology design process steps.

3.2 Ideation phase

The ideation phase described the context of the project and initial prototyping ideas. In this section the methods used to analyse the background context and client wishes are described along with a method to determine the preliminary ideas.

3.2.1 Stakeholder identification

Determining what the limits and requirements of a project are is important to know before the design phase can begin. One of the best methods to learn about these is to conduct research on potential users and other parties or stakeholders that might interact with or are affected by the system [26]. For this analysis they are categorized by their role in the project, these roles are determined as: User, Developer, Decision-maker and Legislator.

- User: People who will interact with the product and control it directly.
- Developer: This category includes everyone who worked on the realisation of the project, programmers, analysts, trainers, project managers are examples of people falling into this category.
- Decision-maker: People within the development team part of the decision-making structure. This includes managers, financiers and user managers.
- Legislators: Governing instances and legal and safety executives that may produce guidelines for operation that will affect the development and/or operation of the system

3.2.2 Stakeholder analysis

Some stakeholders hold more power of influence or impact than others. They also possess different levels of interest towards the project. Determining how to handle stakeholders is based upon these variables. This can be done by creating a power-interest matrix [27]. In this matrix the stakeholders power and interest towards the project are easily compared to know how to handle them.

3.2.3 TTM phase analysis

As described in section 2.1.4, potential users can have different states of awareness. Identifying the phase in which the UT community currently is important. Building a data physicalization that is appropriate for all three phases is difficult and would take a lot of time, therefore only one of these phases is chosen to focus on. All of the different phases have different requirements in how to progress onto the next phase. By creating a survey where the current awareness level and knowledge of the UT community is being tested the preliminary ideas can be modified to fit the current phase. In this survey users are asked whether they consider themselves to be energy sustainable and what they currently are doing or know what they can do to improve their water consumption sustainability. Their answers will determine which TTM phase requirements will be used. The questionnaire can be found in appendix B.1, as well as the ethical consent from in appendix A.1 and A.2.

3.2.4 Client interview

The client for this project is involved in the decision-making of prototyping and identification of important features and requirements. There are interviews with the client where potential ideas are presented and discussed. As well as identifying the strong and weak points of the designs. The interviews are conducted in an online meeting due to social limitations from the coronavirus. They are semi-structured with lots of room for open discussion. This allows the interviewer to ask predetermined questions about specific design choices and requirements and progress further upon answers given by the client.

3.2.5 MoSCow requirements

The preliminary requirements found in the ideation phase are categorised into several groups. These groups are set by the MoSCow method [28]. This method categorises requirements into must have, should have, could have and won't have. The group given to each requirement will be based on the results of the stakeholder analysis, client interview and phase analysis. By doing this, the importance of specific requirements can be determined. Trying to satisfy one requirement might influence the solution for other requirements. Which priorities are important are based on who set the requirement and how big their prospected impact on the effectiveness on the final prototype is. In addition to this there are two additional types of requirements: functional and non-functional requirements. The functional requirements answer what the system does or doesn't do and the non-functional requirements answer how the system fulfills requirements, they do not influence the function of the system [30].

3.2.6 Idea generation

Using the preliminary requirements set in the ideation phase a list of preliminary ideas is generated in a brainstorming and feedback session between the developer and supervisors. First the developer creates a large amount of ideas, these ideas will then be reviewed on their feasibility and effectiveness by both the developers and supervisors. After this first evaluation the developer takes the strong points of the first ideas and creates a set of preliminary ideas that will then be further evaluated by the developer, supervisors and client to determine a final concept.

3.3 Specification phase

One of the preliminary ideas described in the ideation phase will be specified further for a final prototype design. In this section the methods used to gain perspective on prototype interaction and development are described.

3.3.1 System functional architecture

The prototype will be composed of several components and systems working together to provide the user with the desired functionality. These components are broken down into functional architecture blocks. These blocks show the flow of data through the system and how the individual components interact with each other. The system architecture will be described on different levels.

3.3.2 Data analysis and personalization

The data that is collected by CFM is categorised per building. However, some buildings facilitate more people than others. To see how well each building is doing per occupant the amount of consumed water will need to be analyzed. In addition, the data also needs to be presented in a way that users can easily comprehend the data. To do so a form of measurement unit will need to be added that users can relate to more easily than the cubic meters currently presented in the CFM web application.

3.3.3 User scenarios

The interaction between user and prototype can be different for each different individual. Because of this the requirements for the prototype might differ for different persons. A user scenario is a description or walkthrough of how specific users interact with the prototype. They consider a user's background, motivation and interest towards the subject. By investigating how users will respond to the prototype new requirements can be identified. Therefore, a multitude of user personas are used to walk through an interaction with the prototype.

3.3.4 Final requirements

Based on finding from the user scenarios and data physicalization requirements a list of functional and non-functional requirements is made. These requirements are a detailed version of the existing list of requirements given in section 4.2.1. These final requirements are used to evaluate the final prototype.

3.4 Realization phase

During the realization phase the prototype is built. In the documentation of this report the realization phase will include a detailed description of how individual parts are built and what complications were solved with what solutions.

3.4.1 Component selection

The components used in the prototype are selected based on criteria such as reliability and effectiveness, as well as how well they fit in the overall design of the prototype. During the realization phase several possible hardware components are tested and altered based on any problems that might arise. Once all the individual components work they are combined into a prototype of the installation.

3.4.2 Aesthetic design

The aesthetics of the prototype are roughly thought out during the ideation phase. During the realization these designs are altered to fit the components that are selected. Once the design obstructs the use of components, a new version of the design is created to accommodate for the desired components.

3.5 Evaluation phase

During the evaluation phase the functionality and satisfaction of the prototype is tested using the final requirements set in the specification phase. The evaluation is done using three different methods. A user survey, client evaluation and functional testing.

3.5.1 Functional testing

The last part of testing focuses on testing the functional requirement implementations, reliability and efficiency of the prototype. As well as its sturdiness. The efficiency is tested by measuring the time it takes for the prototype to complete certain tasks and processes. The reliability is tested by comparing the data presented by the prototype to the data given by the energy data platform. In addition, the amount of failures or errors will also be included in the accuracy of the system. The sturdiness is tested by how much force the system can take and how watertight it stays over extended testing.

3.5.2 Client evaluation

Once the prototype has been created and is functional the client is asked to review it. In this review the client will evaluate whether the prototype is satisfactory. Any findings or recommendations given by the client are used to determine further improvements and recommendations. In appendix B.4 there is a list of questions asked during the client evaluation of the prototype.

3.5.3 User survey

During the user survey, members of the UT community are asked to interact with the prototype and fill in two questionnaires. The first questionnaire, as presented in appendix B.2, is given to them before they see or interact with the prototype. This survey is used as a baseline of their current knowledge. This knowledge will then be compared to the results of the second questionnaire, listed in appendix B.3 which is taken after the participant has interacted with the prototype. The difference between the info obtained by the questionnaires is used to determine if the participant has gained additional knowledge or awareness about water consumption on the UT and her buildings. Lastly, these findings are used to determine whether the prototype has achieved the final requirements.

The participants of the evaluation are adult members of the UT community. All participants are people who work or study in the Zilverling building during the testing of the prototype. Since this is the chosen location for the installation to be placed in. All participants agreed to participate in the research and signed the consent form stated in appendix A.3.

4. Ideation

In this section the background context of the project is analysed. Stakeholders are analysed and based on these findings a set of preliminary requirements and ideas is created.

4.1 Stakeholder identification

There are multiple stakeholders involved in the development and implementation of this project. Identifying them is crucial for identification and categorization of requirements and limitations regarding the design and functionality of the installation. In section 3.1 there are several categories of stakeholders explained. In Table 4.1 below the stakeholders are categorized into the 4 previously mentioned categories.

Category	Stakeholder	Contact
User	UT teaching staff	Various
	UT students	Various
	UT supporting staff	Various
	UT visitors	-
Developer	D.W.A v.d Veen	-
Decision-maker	CFM	B. Marechal
Legislation	Supervisors	R.G.A Bults & Z. Zalewska
	SEE Utwente	S. Maathuis

Table 4.1 Stakeholder Category Index

4.2 Stakeholder analysis

The UT community consists of several subgroups such as students, teachers and supporting staff. Each of these subgroups have a different level of interest and influence over the project and should therefore be counted separately. In Figure 4.1 all the subgroups have been placed in a power-interest matrix [27]. This matrix is used to categorize the subgroups into 4 categories. The power is described as the influence the subgroup has over the project and the interest is the interest level of the subgroups into the project.

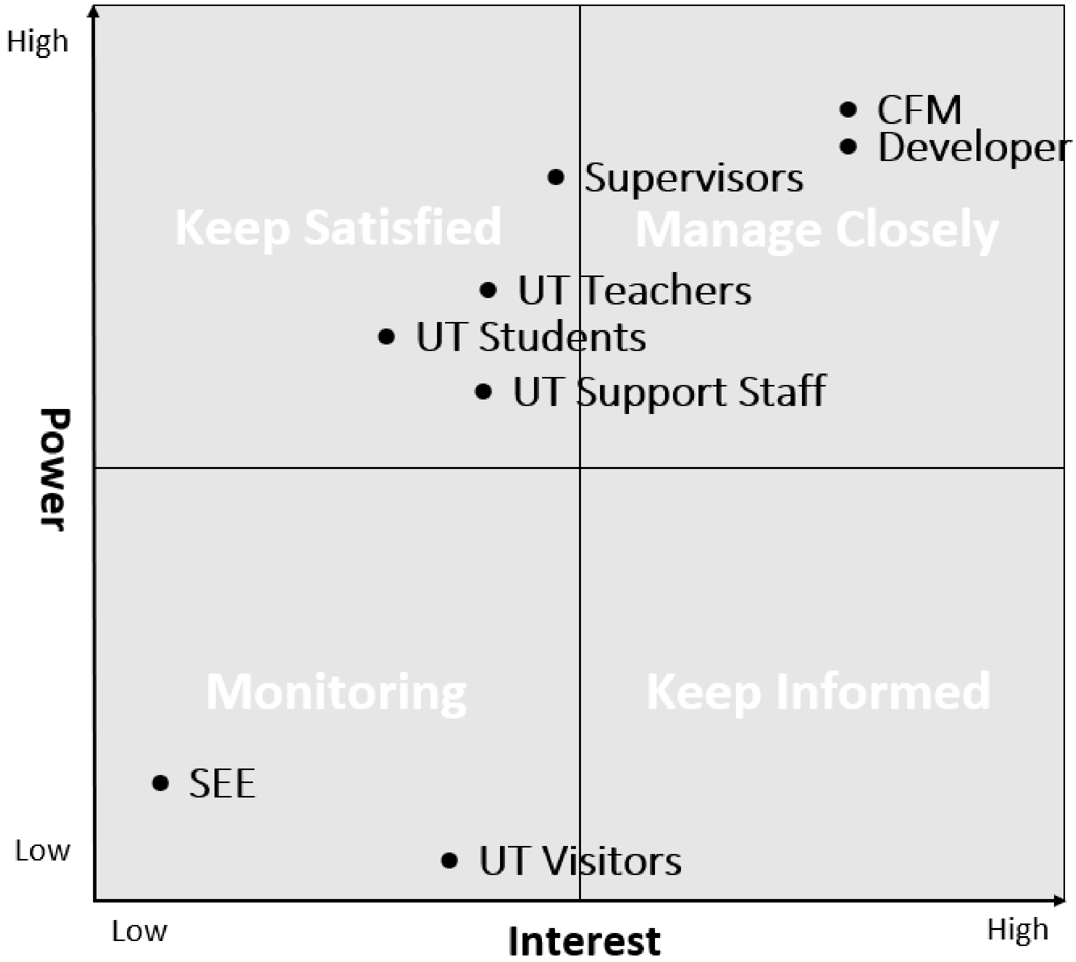


Figure 4.1 Power-interest matrix

4.2.1 UT community

The UT community consists of four subgroups, students, teachers, supporting staff and visitors. Each subgroup has different interests and influence over the project. Therefore they are counted as separate in the power interest matrix in Figure 4.1,

Students

Students are numerous at the University of Twente. They study different subjects and have different interests. They spend a lot of their time on campus and therefore have a big impact on how their behaviour influences water consumption within the buildings they work in. However, besides their own consumption and slight peer pressure upon their friends students do not have much power/influence as an individual. Their interest is average, students on average spend fewer years on the UT then staff does and are therefore less interested in the long term consumption of the UT. As such, they should be kept satisfied with the data physicalization.

Teachers

Teachers have a determined office and working space on campus and can relate their consumption more to an individual building then student can.This will likely make them more interested in their water consumption. The power of teachers is similar to students but slightly higher as teachers usually hold a higher degree of awareness of their surroundings on campus then students as they spend more time on the UT. This increased time will allow them to pick up more knowledge about the campus.

Supporting staff

Supporting staff is very similar to teachers, with the exception that they often do not have the same level of education as teachers. This means that their understanding of the implications of the prototype might not be as high as teachers, causing their power to be lower then then teachers. However they still have a defined working space and spend more time on campus then students similar to teachers.

Visitors

In general, visitors spend less time at the university of twente than the above mentioned groups and therefore hold less power. Their interest level is about the same as UT staff or students. Most visitors on the UT come to learn from the UT and are interested in projects done by the UT students and staff, but as they do not have a defined workspace on campus they are not concerned with the long term impact on the UT. The visualization might be interesting for them to see what projects are being done to improve water sustainability. Due to their lack of power and interest that fall in the monitoring range of the power-interest matrix.

4.2.2 CFM

The Campus and Facility Management holds great interest and power for the project as the client. CFM is represented by B. Marechal, Policy officer of environment and sustainability on the UT and H. Hobbelink, Contract manager of CFM. As the managing entity of various water installations and maintenance on campus their power and interest is significant. CFM should be managed closely.

4.2.3 Supervisors

The supervisors for this project are R.G.A Bults and K. Zalewska. They are closely involved in the decision-making structure of this project and hold great power and interest towards the project, however it is lower than the power and interest of CFM as they are not affected by the water consumption as much as them. They should be managed closely as well.

4.2.4 Sustainability, Energy & Environment (SEE) Utwente

The Sustainability, Energy & Environment program [31] is an organization within the University of Twente that is responsible for the management of sustainability, energy and environmental projects. Their interest in the project is neutral to low as their focus is on directly achieving a better sustainability and larger projects, while this project focuses only on awareness. Their power over the design of the project is not very high as they manage installations that directly influence water sustainability rather than tools to raise awareness. They fall into the monitoring category for this project.

4.2 Client Interview

In an interview with the client for this project, CFM, the preliminary requirements and initial ideas were discussed. From this interview it became apparent that there are no strict requirements from the client for this project. A few notes and recommendations were given regarding the effectiveness and feasibility of the project. The most important recommendations were to create something that would maintain its interest from viewers even in the future, as many people from the UT community will see the installation several times. And to keep a close eye on the scale of the physicalization, this includes both the scope of the data as putting it in a more relatable perspective for viewers. They also emphasized that the energy data platform was meant for people who are already more knowledgeable about the meaning of its data.

4.2.1 Preliminary requirements

Based on the recommendations given by the client, background research and several meetings with the project supervisors a list of requirements has been made in table 4.2. This list includes requirements into three categories; 'must have', 'could have' and 'should not have'. The must have requirements are necessary to be implemented into the design, while the ‘should not’ are to be avoided. The could have requirements are useful to put in but are not required for an effective design.

Category	Requirement	Explanation
Must have	Display water consumption data per UT building	The goal is to connect data from the Energy data platform to the UT community. Displaying the data per building will make members of the UT community identify more with the data
	Be interesting to view multiple times	Viewers should not lose interest in the project over time
	Be aesthetically pleasing	An aesthetically pleasing object will draw more attention
	Provide ways to compare the UT water consumption to more understandable scales as bathtubs filled, minutes showered, toilets flushed and washing machines used	Raw data presented in M^3 is hard to understand, additional measurement scales will make it easier for users to understand data
	Obtain interactive input from the user to control the prototype	An interactive installation will be more interesting for viewers.
	Be interesting to view multiple times	People working in the building where the installation is should not lose interest in the water consumption over time
	Raise awareness for water consumption on the UT campus	The Energy data platform, and the prospected installation, inform the UT community and therefore should increase their understanding of water consumption on campus.
	Be a physical visualization of data	The goal of the project is to create a physical installation which people can easily access
Could have	Show the water flow within the data physicalization	Using water will increase the interest of potential viewers
	Display the consequences to the environment of water consumption on the UT	Providing insight in consequences could have a stronger influence

	Display water data based on the consumption per individual person in a building	Individual consumption makes behavioral differences more clear to the users then complete buildings
	Display a method for viewers to gain more information about the subject by reaching the Energy Data Platform	Users interested in more information would like to have easy access to the Energy Data Platform
Will not have	Include data from buildings with more then double the consumption of other included buildings to prevent large differences	Displaying data from buildings with large differences makes it hard to see changes in the consumption of the smaller building
	Display information unrelated to water consumption on the UT	Providing too much information might confuse users
	Display water consumption data from more then 4 buildings	Having many buildings to display makes it harder to see differences between individual buildings

Table 4.2 Preliminary requirements

4.3 User Survey

The results from the current phase analysis survey, seen in appendix C.1, showed that most members of the UT community that responded to the survey were unaware of the amount of water being consumed by the UT and the amount of water measurements saved. Many people also stated that they did not consider themselves an environmentally responsible person and a large group of people does not make an effort into conserving water from their consumption. This would suggest that the awareness of the UT community mainly lies in the precontemplation phase. This would mean that the data physicalization requirements will be based on the recommendations stated by He, Greenberg and Huang [17] as described in section 2.1.5.

4.4 Preliminary Ideas

In the previous section a set of preliminary requirements is listed. These requirements are used in this section to serve as a basis for a set of preliminary ideas. These ideas are described in the sections below. From these ideas, a final concept will be chosen to be further developed in the specification and realization phase.

4.4.1 Groundwater based visualization

This idea involves a tank filled with pebbles/rocks to represent the ground with the groundwater that it holds, as shown in Figure 4.2. When a viewer requests to see how much water is consumed within a timespan via an input panel on the front of the installation. Water from this groundwater tank is pumped into several smaller tanks higher up that represent the water consumption of different things such as bathrooms, buildings or equipment. As the “groundwater” tank drains, a sensor detects how low the water level has gotten and uses this to calculate how much a flower “withers”. This flower is a representation of the effect that the consumed water has on the environment as the water is subtracted from the groundwater as mentioned in the introduction. To give users a way to quantify the information there are several options possible, one is to create a scale index on the small tanks that shows both the actual number of consumption as a more understandable scale such as amount of minutes showered or toilets flushed. The goal is to use the “Environmental reevaluation” method as well as “consciousness raising” as mentioned in section 2.1.6 to provide a new level of awareness to users. This installation is placed in a spot on the UT where it is visible and allows potential users to walk up and interact with it. The data displayed by the prototype will be based on which building the installation is placed in to spark interest in potential users.

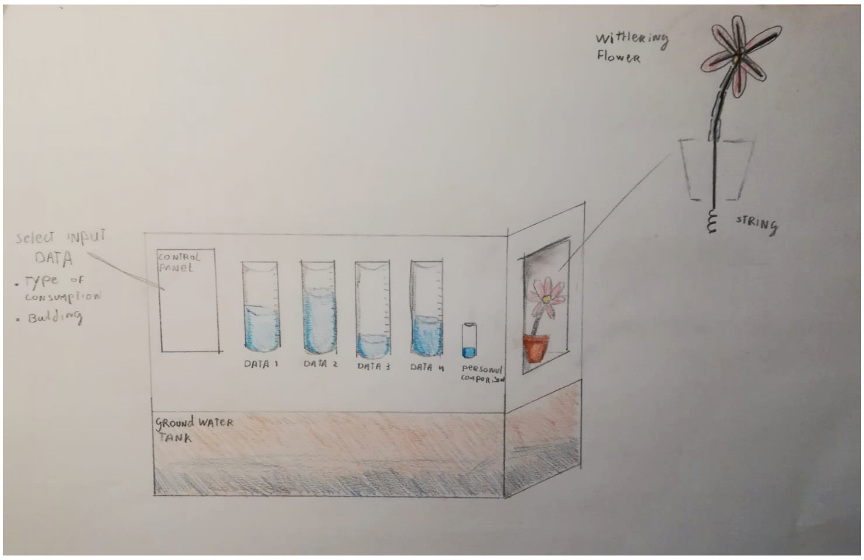


Figure 4.2 Groundwater based idea

4.4.2 Fake rain cycle

This concept is based on rain and groundwater. As these are the most common sources of water on the UT campus (Vitens uses groundwater as described in chapter 1), the user is given an amount of rain/groundwater and can divide them into different groups such as sanitary water, plant water, consumption water (drinks), cooling water etc. If the user does not provide enough water to any of the categories the category will show the negative effect it will have such as withering plants, dirty toilets or overheating machines. But not all water is suited for every application, for instance, water collected from rain can't be used for human consumption. This will add another layer of thought to the prototype as users have to think more intensively about how they divide the water. Once the water is divided, the effects are shown as well as how the university divides its water usage. In order to relate the data to more understandable measures the data is also present in more understandable measurement scales such as minutes spent showering or compared with how much a regular household consumes yearly/monthly. This idea is visualized in Figure 4.3. This concept informs users of the current situation but does not provide consequences of water consumption. The information that it provides is presented in an interactive way with a means of comparison to how others would do something. This comparison could then spark an interest in the user as to why other people handle water consumption differently and make users think more about the water consumption on campus, subsequently increasing their awareness.

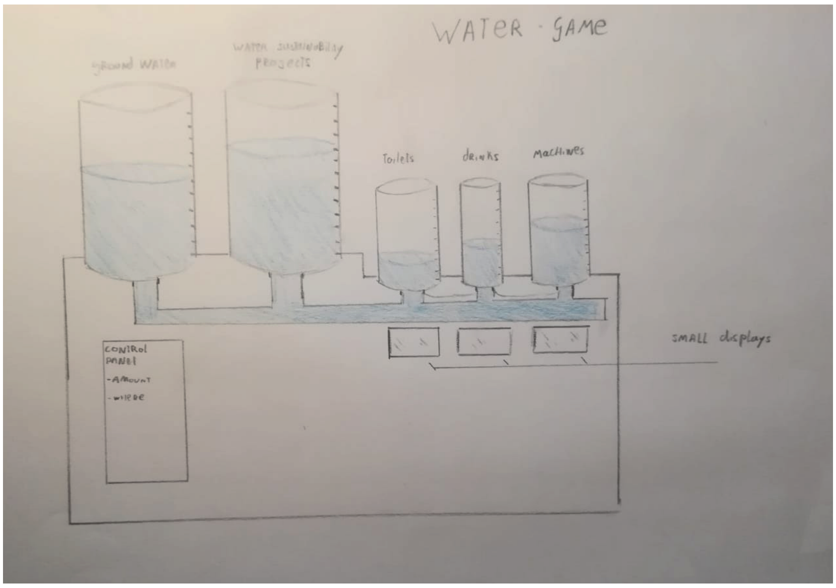


Figure 4.3 Fake rain idea

4.4.3 Campus map

This concept includes a map of the campus where each water sustainability project such as storage tanks, waterless urinals etc. is presented as a miniature on top of small tanks, a sketch of the idea is shown in Figure 4.4. The miniature will then show where on campus certain water management projects are located and how well they are doing in saving water. In these tanks there could be water where the amount does not present the water usage but the amount of water being saved by using this sustainability innovation. In addition to the water saved the installation could also show the source of the water being saved, for example rainwater or common tap water. This feature can be shown by creating several "source" tanks next to the campus map and LED strips leading from these tanks to the miniature tanks. Users can interact with the prototype by pressing a button that will highlight selected miniatures, these miniatures will then light up and a short description of the water management project will be displayed on a screen to provide information to the user. To give the user a sense of what the data actually means this concept needs to offer a comparison to the users own consumption. This is given by presenting additional data on the aforementioned screen such as the average consumption per household or the equivalent in water by pools or barrels of water.

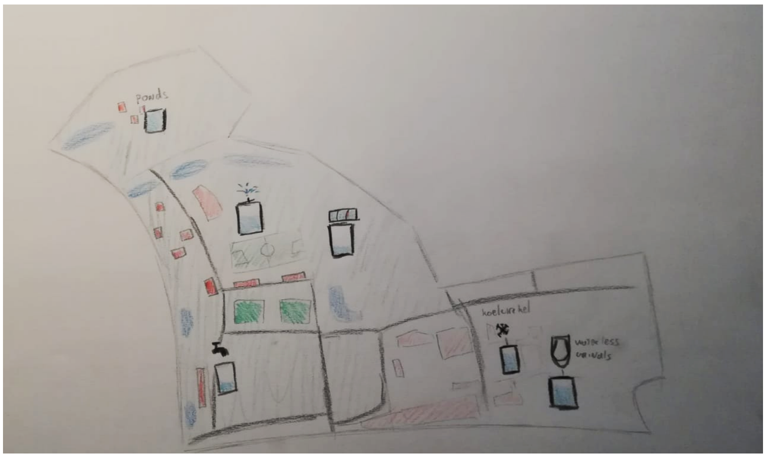


Figure 4.4 Campus map idea

4.4.4 Water Devices Room

This concept is based on a room or installation with several types of devices that use water such as toilets, showers or simple coffee machines, a design sketch is shown in Figure 4.5. Each of these devices will have a button that users can click to “use” the individual devices, and they are then shown how much water they just consumed by using that device. The amount of used water will be displayed in small tanks next to the device. In addition to showing the usage of a single usage of the device it will also tell the user how much that is compared to the overall consumption of for example the entire Zilverling in a day. The goal is to give users a better understanding of the amount of water being consumed by the buildings each day. The small consumption of the device will be easier to understand for viewers then the larger consumption by an entire building, the comparison will make the data more understandable for users. Besides the goal mentioned in the previous ideas, this concept also connects current measurements being taken on campus to reduce water to the UT community.

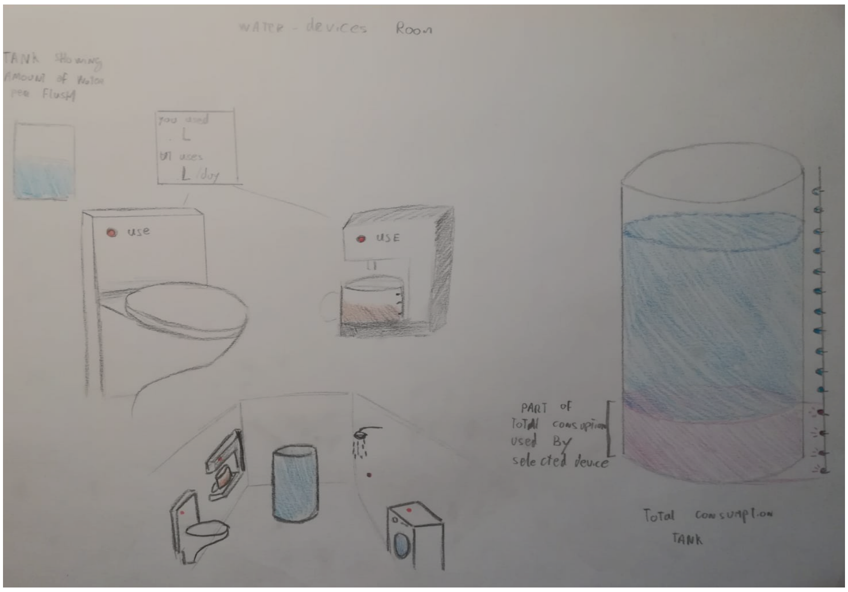


Figure 4.5 Water devices room idea

4.5 Ideation Final concept

From the ideas described in section 4.3 a final concept needs to be selected. All the ideas were discussed with the project supervisors and client. The feedback from these discussions favored the first and fourth ideas, with a slight preference for the first one. The campus map was least liked due to several reasons, most notable the feasibility. Many of the water sustainability installations to be included in the map do not have a way to measure their effectiveness, making the project hard to realize. The main appealing feature for the selection of the first idea was the immediate feedback presented by the lowering groundwater and withering plan. As well as how easy it was for the user to comprehend the data compared to other installation ideas.

5. Specification

In this chapter the final chosen design of chapter 4 is further explained and specified. This includes scenarios of potential users interacting with the envisioned data physicalization.

5.1 Functional design

In this section the functional architecture of the installation is explained and discussed. Here a description on how the system will operate and how all the different components are interacting with each other is given.

5.1.1 Global system overview

The system will include several components; water data handling, physical systems and interaction input. A central computer will combine all of these components into a working prototype. The “HydroSumption” prototype will display the water consumption of 4 UT buildings next to each other for individual months. These months can be selected by the user. Below in Figure 5.1 there is a flowchart of the functioning of the system. The system gains user input in the form of a selection panel. This panel consists of 12 buttons each representing a month of a year. The computer takes the user input to select which data to be gathered from its database and sends a command for the appropriate actions to the actuators of the system. Sensors will then provide direct feedback to the computer about the current water level of the water tanks and the computer can then calculate how much more the actuators need to do to achieve the desired representation of the selected data. The calculated difference between the current and desired water level is then pumped out or into the water tanks to display the desired water level for the selected month.

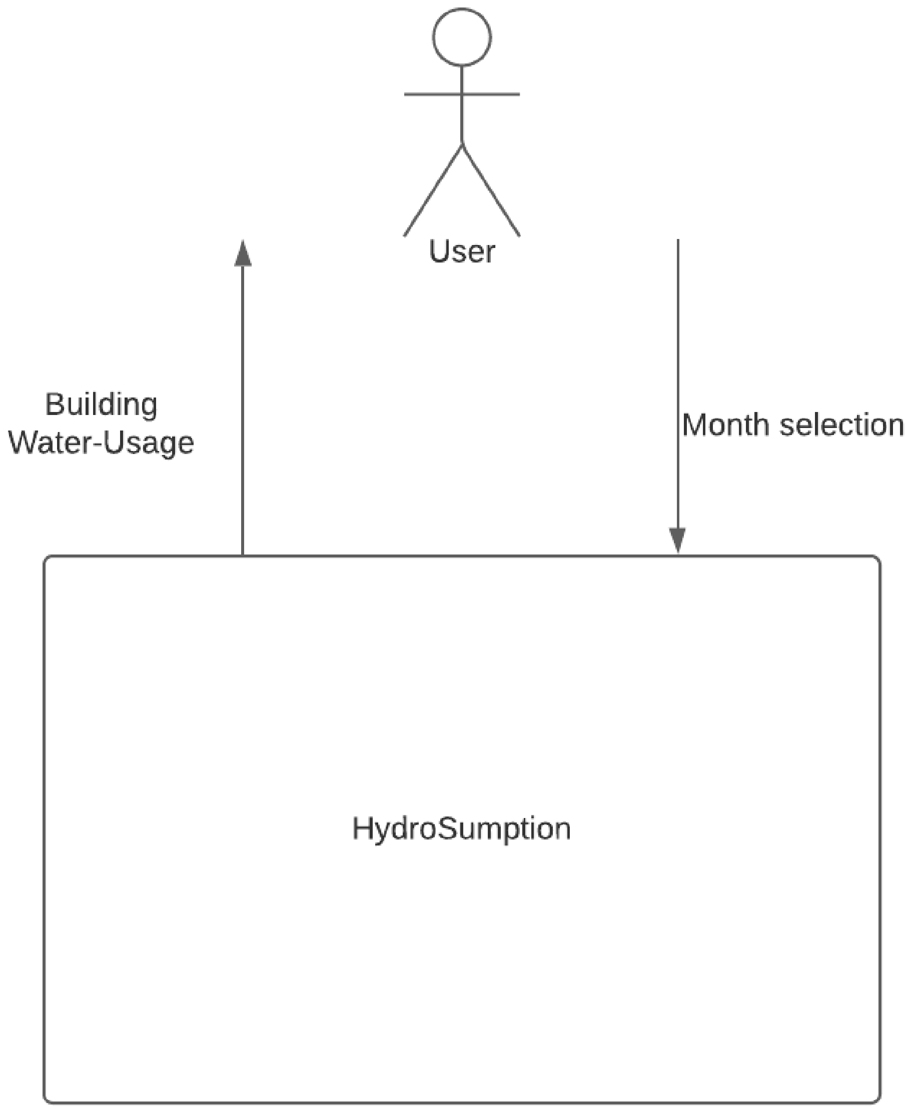


Figure 5.1 System Level 0 overview

In Figure 5.2, a more detailed overview of the system is shown. It shows the flow of data and the interaction between different components within the system. The system input is shown on the top left, the last pressed button is remembered by the system's input panel controller. This controller then lights the LED next to the last pressed button to display which month is selected, as well as forward the selection to the data handler. The data handler then requests the water consumption per building from the water storage database. Once this data is received it is forwarded to the water level calculator. This calculator maps the consumed data to the water tank and requests the current water level of the tanks, if they are different then the desired water level is then sent to the building-water animator. This animator will then control the flow of water in or out of the water tank with pumps, depending on whether the desired water level is above or below the current level. The animator activates the pumps needed to set the water level to the desired level. This causes the water level to obtain the desired level and display the water consumption of the buildings in the selected month.

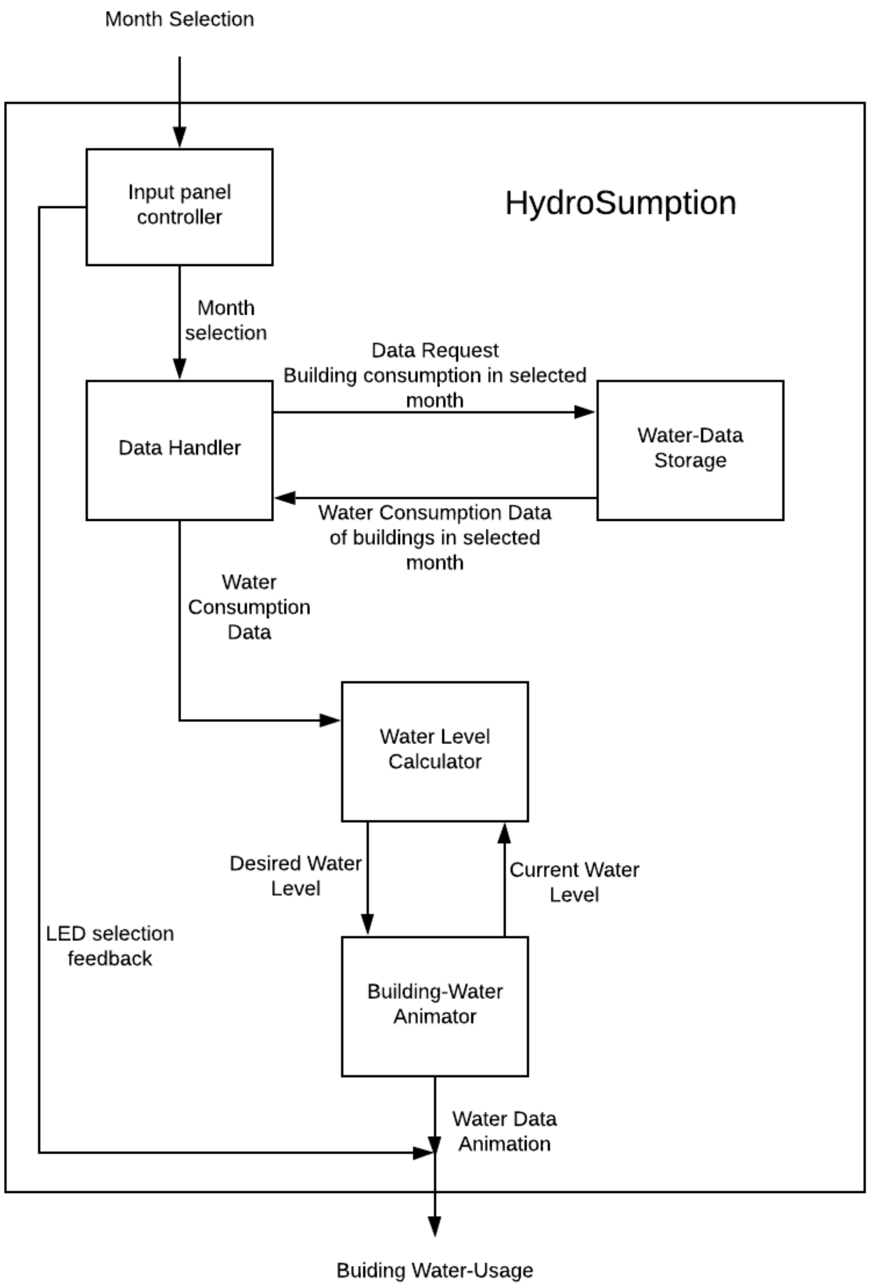


Figure 5.2 System Level 1 overview

5.1.2 Input & Feedback

The user interacts with the physicalization by choosing which month's data to be displayed by the water tanks. This interaction is done with a control panel on the installation itself. On this panel users can select a month of the year 2020. The panel consists of 12 LED's and 12 buttons. The user pressed a button which sets the LED next to it to on and activates the prototype to display the data from that month.

The feedback of the installation will come in 2 forms. The water data displayed in the water tanks and the LED's next to the selection buttons. The LED shows the selected month and the water level representing the consumption of water within one of 4 buildings. The buildings chosen are the Zilverling, Citadel, Cubicus and Spiegel buildings on the UT campus.

5.2 Personalizing data

In section 2.1.4 and in the TTM by Prochaska and Velicer [16], users must be able to identify themselves with the provided data to build a successful data visualization. In this section the methods used to provide the data on a more personal and understandable level to the users is described.

5.2.1 Building Separation

All data that is used in the installation is drawn from the Energy Data Platform database [3]. This database will hold data on several buildings and periods of water consumption on the UT. The data is not available in real time. This means that the data being used for the data physicalization must first be selected and analyzed. The data used for this installation is drawn from the Energy Data Platform [3]. The data here only displays the total water consumption and the consumption for each building of the UT. As the UT has a high number of buildings each listed separately, a selection of these buildings is made. This selection is based on the average consumption of the buildings. If buildings with large differences in average monthly consumption are chosen it becomes harder for users to perceive differences in the consumption level of the smaller building. The building selection is also based on the location where the system is located, for which the Zilverling building has been chosen. Therefore Zilverling and three buildings with comparable consumption are chosen. These are the Citadel, Ravelijn and Cubicus buildings.

5.2.2 Quantifying data

The water consumption data that is displayed is based on the entire consumption of a building, making it hard to identify with the use of a single person. Providing data that is personalized is more understandable for the user to relate to. In the thesis by S.T.H. Metten[29] there are calculations provided for the water and energy consumption per person in the Zilverling building. According to the calculations each person in the Zilverling building uses ~14.1 L of water each day.

5.2.3 Measurement visualization

The data that is given in the Energy Data Platform is measured in cubic meters, whilst people can easily understand how much a meter is, it is hard for them to visualize the amount of water that fits in a cubic meter. To make it easier for users to comprehend the numbers that are given by the prototype a secondary scale needs to be added with something that people can recognize, such as the amount of water that fits in a bathtub, is used per minute of showering, by flushing the toilet or using the washing machine. For the scope of the prototype all the aforementioned scales will be tested along with cubic meters. Which of these is the most effective measurement scale will be determined with user evaluations.

5.2.4 UT Covid-19 situation

During the Covid-19 pandemic the buildings of the UT were partially closed and all students and staff were advised to stay away from campus. This resulted in some interesting changes in water consumption. For example, the amount of water used in October 2020 at the Zilverling building was about 1 to 3 m3 of water per day, whilst during that same time period a year earlier the amount of water used was doubled with weekdays ranging from 8 to 10 M^3 of water used per day.

5.3 User scenarios

In the user scenarios several possible interactions between the user group and the data physicalization are explored. These scenarios are used to identify how the user might experience the interaction with the installation. First the personas used in the scenarios are briefly described.

5.3.1 Persona description

One person that is interacting with the data physicalization can have a different background or interest list then another person from the user group. Therefore it is important to describe the characters of the personas used in the user scenarios. From several of the sub-user groups, students, staff and visitors, a persona has been created to run a scenario of interaction.

Student

Mike is a 23-year-old student of Computer Science at the UT. He lives on campus and likes to play video games or have some drinks with his friends. During the weekdays he spends most of his time in the Zilverling building working on his projects or chatting in the study association room. Mike is not concerned with his water consumption and does not think about the sustainability of water resources.

Staff member

Bob is 47 years old and is a staff member at the UT, he teaches design courses to students and is often found in lecture rooms or his office in the Zilverling building. He is moderately interested in sustainability and tries to limit his use of energy and water and tries to avoid wasting it. He often talks to his colleagues about the importance of sustainability in the design of a project. He also has taken some measures at his home by taking solar panels and LED lamps. In his spare time Bob likes to play sports or spend time with his wife and children.

Visitor

Lisa is a student-to-be who is visiting the university to orientate her study choice. She is 18 years old and lives with her parents in Utrecht. She spends her time playing volleyball and socializing with her friends. She has an interest in the environment and sustainability but does not yet know how much consumption there is around her.

5.3.2 Interaction scenario

Student

Mike is walking through the Zilverling building and walks by the data physicalization. He gets interested by the aesthetics and comes closer to investigate and becomes interested in its function. Mike notices the control panel where he can see the options to select different months. Curiously he clicks on the January button because that is his birthday month to see what happens. The installation starts pumping water into the smaller tanks. Mike is surprised by the amount of water being pumped into the tank labeled Zilverling. He reads the description on the prototype and learns that the installation displays the water consumption in UT buildings per month. This makes him think about what things in the Zilverling consume such a large amount of water. He clicks the March button to see what changes. The water level in the tanks starts to be changed by the pumps. After having viewed the installation Mike continues walking and goes to the bathroom and thinks about the installation, and instead of using the large flush button he now uses the small one as he now knows the amount of water being consumed by the Zilverling.

Staff member

Bob is walking to the coffee machine and sees the data physicalization. Interested by what a student has made he walks up to it and examines its design. He quickly deduces that the pipes are filled with water and that they represent water relations in the UT buildings. He presses the button for the month of June and hears the prototype’s pumps starting and the LED switching to the month June. The water within the pipes begins to rise. Bob examines the pipes more closely to see how they function. A little more reading around the prototype teaches him that the tubes represent consumption data of different UT buildings, Zilverling, Cubicus, Citadel and Ravelijn. He is intrigued by the high number of water consumed in a single month by these UT buildings. He spots the QR code on the top left of the prototype and curiously he scans the QR code to learn more about water consumption on the UT. He ends up at the energy data platform of CFM and sees all the buildings' consumption. With his newfound knowledge he goes on to get his coffee. At the machine he starts chatting with some colleagues and tells them about the prototype and what he has learned about water consumption on the UT, passing awareness on to them as well.

Visitor

Whilst on her way to her car to return home from the open days, Lisa stumbles across the data physicalization. Curious to what students from the UT are able to do she decides to investigate the installation. She presses the October button and sees the water tanks filling up with water. She sees the lines and sees that the Zilverling consumes around $180M^3$ of water per month. At first this number is insignificant to her as she does not know how much water that actually is. When she turns to the other side of the scale she sees the amount in a number of bathtubs filled. She is surprised that the Zilverling is using 1500 bathtubs of water per month. Lisa then looks at the other buildings and sees that the Ravelijn also uses 180 M^3 of water per month and that it is equivalent to 3000 minutes of showering. Lisa decides to press another button to see what the installation does. She presses the April button and notices the blue LED next to the button lighting up. She hears the pumps starting and sees the water level falling down to 1200 bathtubs per month for Zilverling and sees Ravelijn rising to 1600 bathtubs filled per month. She starts to wonder why one building consumes more water then the other buildings and asks a student walking by if they know the answer. They start a conversation about water consumption and press the November button. They discuss the changes of water level again. Leading to an increase of their awareness about water consumption on the UT.

5.4 Final Requirements

During the ideation phase a first set of preliminary requirements was created. This list functioned to narrow down the ideation process. In addition to the requirements listed in section 4.2.1 there are more requirements added after the initial ideation. These requirements are listed in table 5.1 below. These additional requirements are based on user satisfaction when interacting with the prototype and efficiency of the prototype. These final requirements will then be used to evaluate the final prototype.

Category	Requirement	Functional or Non Functional
Must have	Display water consumption data per UT building	F
	Be interesting to view multiple times	NF

	Be aesthetically pleasing	NF
	Obtain interactive input from the user to control the prototype	F
	Provide ways to compare the UT water consumption to more understandable scales as bathtubs filled, minutes showered, toilets flushed and washing machines used	NF
	Raise awareness for water consumption on the UT campus	NF
	Be a physical visualization of data	NF
	The water level must reach its desired position within 10 seconds	F
	The prototype must inform the user about its function and meaning of the data	NF
	The prototype must be build sturdy enough to be able to move it to a different location	NF
	Display the source of the water consumption data, which is the Energy Data Platform	F
Could have	Show the water flow within the data physicalization	F
	Display the consequences to the environment of water consumption on the UT	F
	Display water data based on the consumption per individual person in a building	F
	Display a method for viewers to gain more information about the subject by reaching the Energy Data Platform	F
Should not	Include data from buildings with more then double the consumption of other included buildings to prevent large differences	F
	Display information unrelated to water consumption on the UT	F
	Display water consumption data from more then 4 buildings	F

Table 5.1 List of Final requirements

6. Realization

In this chapter the specified idea of the specification phase is realized. The phase will consist of three sections, the first section will focus on the hardware choices and implementations, the second will focus on design aspects and the third section will explain the software components.

6.1 Hardware

The prototype is built with several individual components that work together to create a functioning system. These components and their communication can be seen in Figure 5.2. In the section below each electrical component's function and implementation is explained, along with any design changes made during the prototyping phase. A full overview of the hardware circuit can be found in appendix D

6.1.1 Input panel

The user needs to be able to interact with the prototype and have influence on what water consumption data is being displayed. To do this an input panel is created consisting of several buttons. These buttons will represent the individual months of a year that can be selected to be viewed. All of these buttons are connected to a central processor which will then take the selected month and use that information to display the required month data. The pins of the Arduino mega used for the input panel are described in table 6.1. In addition to these buttons there needs to be a form of feedback for the user to see which month has been selected. For this reason an LED strip has been added next to the buttons.

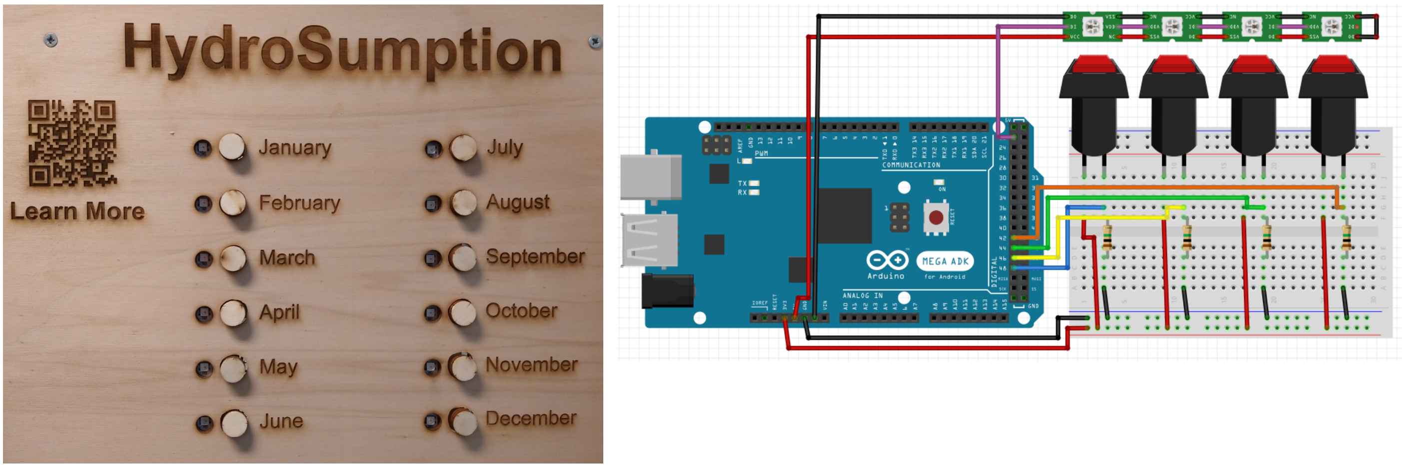


Figure 6.1, The prototype input panel and the used circuit (4/12 switches)

The LEDs on this strip are used as an indicator which button or month has been activated as seen in Figure 6.1. To constrict the program from gaining additional input while the water display is being visualized the input panel is frozen in the software to prevent further input. In addition to the input panel there is also a QR code on the side that will direct the user to the energy data platform of CFM so interested viewers can learn more about consumption on the UT.

6.1.2 Sensors

Water inside each of the four tanks is constantly changing, therefore it is important to have an accurate sensor that is capable of measuring the height of the water in the individual tanks. For this reason the HC-SR04 supersonic sensors, as seen in Figure 6.2, have been chosen. These sensors rely on sound waves that bounce back from a surface. By measuring the time it takes for the pulse to return a distance between the water surface and the sensor can be calculated. These sensors are placed at the top of each water tank pointing downwards. The connection of the sensors to the Arduino mega is described in table 6.1

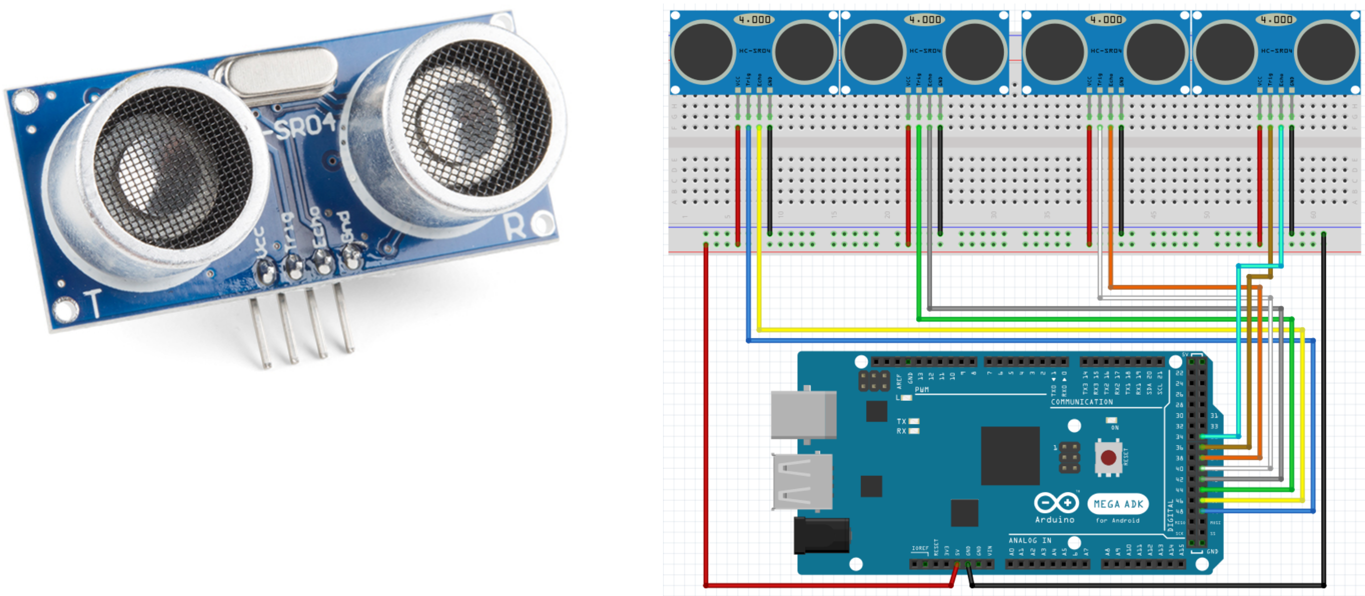


Figure 6.2, HC-SR04 supersonic sensor and the implemented circuit

6.1.3 Water displacement

In order to get the water level to the desired level an input and an output actuators are needed. For the input actuator a Comet Elegant 12VDC pump has been chosen. This pump is controlled by using irf520n Mosfet switches on the low side of the pumps as depicted in Figure 6.3. These mosfets will only allow current to pass through once a current is applied to the gate port. Four of the comet elegant pumps are positioned in the main water reserve tank and are used to input water into the smaller building tanks. The other four pumps are positioned in the small tanks and are used to pump water out of the display tanks into the main reserve tank. To supply power to the pumps an ATX power supply unit is used. The connection pins on the Arduino are described in table 6.1.

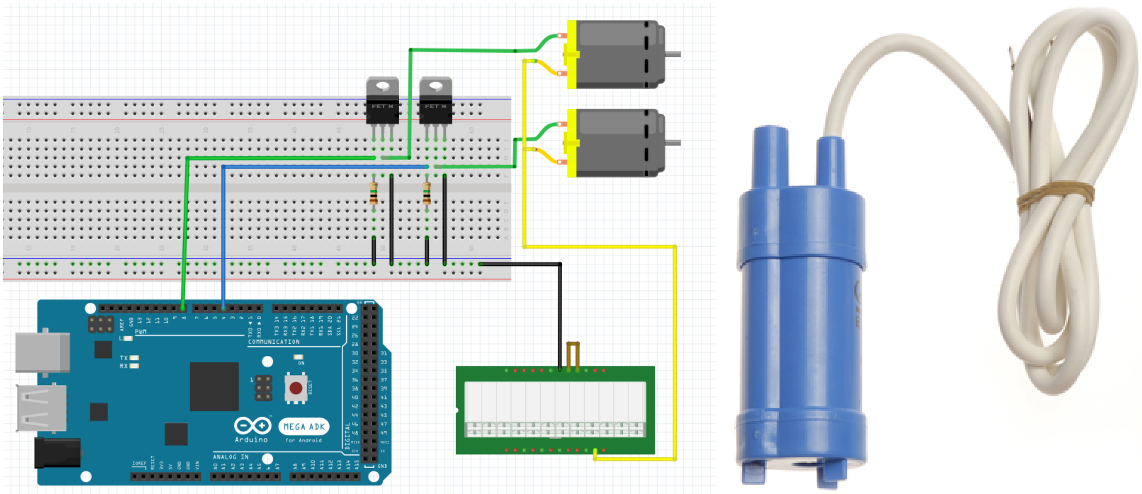


Figure 6.3 Mosfet switch circuit with DC motors as pumps. On the Right the Comet elegant pump is shown.

6.2 Design

To support the prototype's structure and create a visual image some components required support. The design of these supports is described in the section below.

6.2.1 Water tank design

The small water tanks displaying the building water consumption data are made using PVC tubing. The water tanks are made in a U-shape, where one side is made of see-through PVC and the other side houses the output pump and input hose. The water level in both sides is equal as described by stevin’s law of communicating vessels [33]. The connections of the water tanks were sealed with PVC glue and silicon kit. The sensors are placed on the see-through side of the water tanks on the top, as shown in Figure 6.4. As there are no pumps on this side of the U-shape, the water level does not suffer from distributions such as bubbles or waves. On the backside of the prototype there is a large water tank acting as a reservoir for water. This water tank can be seen in Figure 6.5.

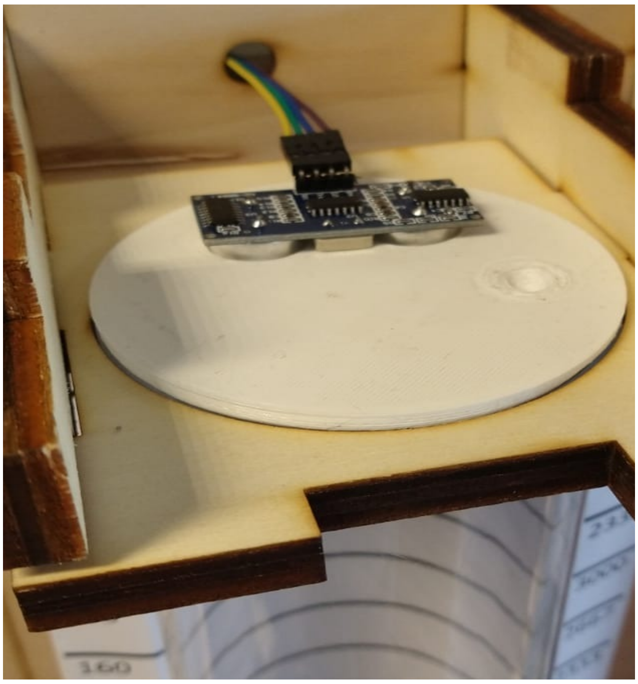


Figure 6.4 Sensor placed on top of the water tank

Figure 6.5 Large water tank behind the backside of the installation

6.2.2 Structural Support

The first concept of water tanks was supposed to stand on wooden stands that would support the weight by distributing it to a support beam behind a front cover panel. The second iteration of water tanked requires different support. These water tanks rest on a wooden beam, as can be seen in Figure 6.6 left, and are prevented from tipping and sliding by wooden clamps, shown in Figure 6.6 right. One side of the tanks is positioned in front of the cover panel whilst the other side is behind it with the pumps.

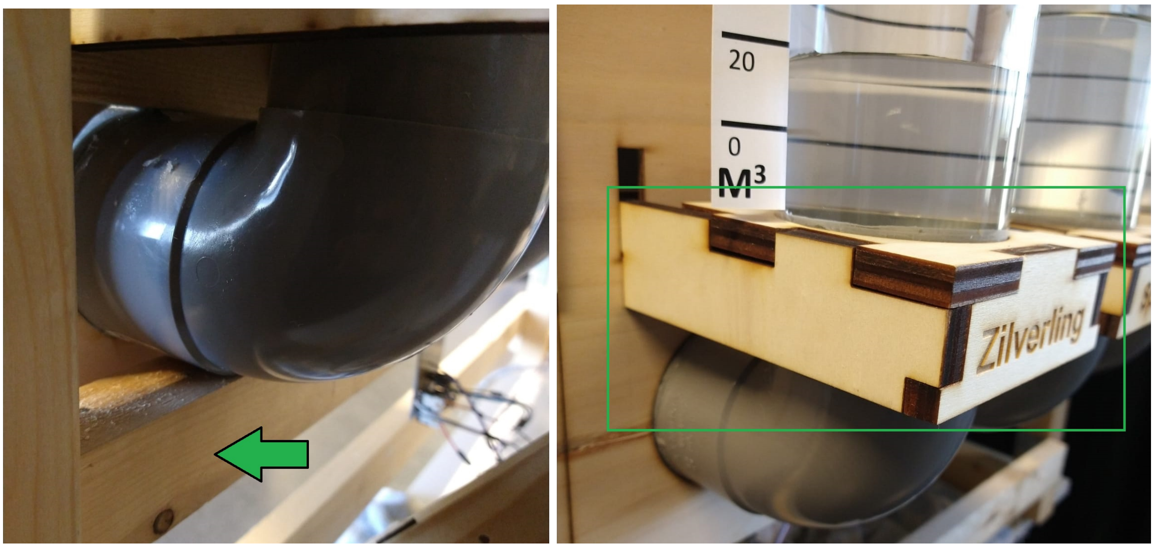


Figure 6.6 Left: wood beam supporting the weight of the tank. Right: wooden brace preventing the tank from tipping over, both indicated with green.

6.2.3 Data scale

The data presented in the energy data platform is expressed in cubic meters. This measurement is easy to understand for experts and provides a standard measure. However, not every member of the UT community can easily relate to something if it is based in metric numbers. For this reason additional scales have been added next to the standard metric scale, these extra scales can be found in Figure 6.7. These scales consist of more everyday recognizable tools such as; amount of bathtubs filled, minutes showered, toilets flushed and laundries done. During the evaluation phase all four of these scales are compared next to each other to determine which of the scales is easiest for people to understand.

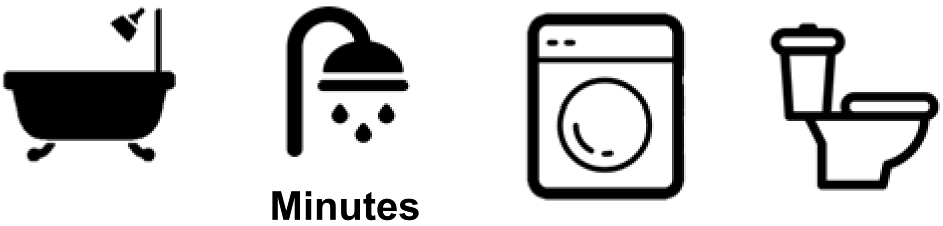


Figure 6.7 Additional scales added for data comprehension. From left to right; bathtubs filled, minutes showered, times using a washing machine and toilet flushings.

6.3 Software

In this section the software application is described. The complete code used in the prototype can be found in appendix E.

6.3.1 Control software

The controller used for running the software and steering the individual components is an Arduino mega ADK shown in figure 6.8. This controller has been chosen for its increased amount of available digital pins and is capable of PWM control over 8 individual pins, in table 6.1 below an overview of the pin usage can be found. These PWM pins are used to control the water flow coming from the pumps.

Arduino pin	Function
4-7 PWM	Control output pumps
8-11 PWM	Control input pumps
22	Control of LED strip for input feedback
30-52 (even numbers)	Input button readout
39, 43, 47, 51	Echopin for supersonic sensor
41, 45, 49, 53	Triggerpin for supersonic sensor

Table 6.1 Arduino pinout overview.

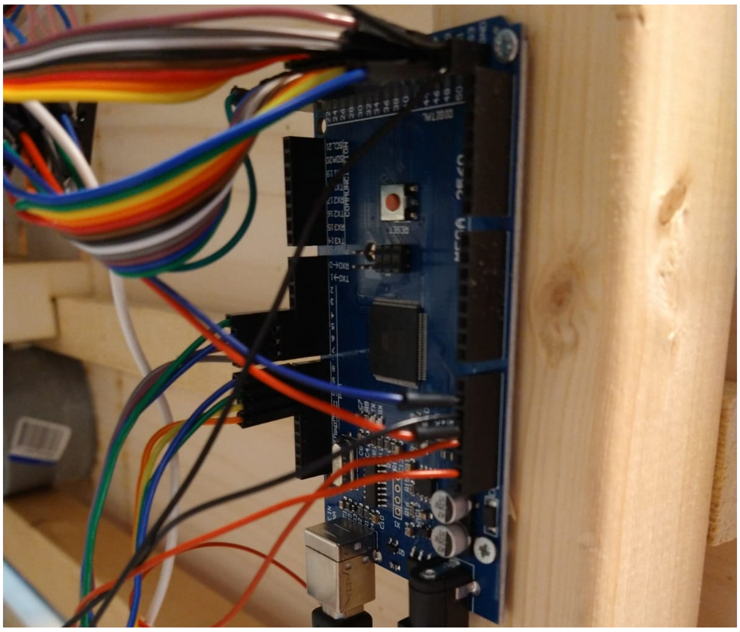


Figure 6.8 Arduino used for the prototype

6.3.2 Data implementation

The data used for the prototype is gathered from the energy data platform. The used data is the water consumption of the Zilverling, Ravelijn, Citadel and Spiegel buildings. The Zilverling building is the prospected building where the prototype is displayed. The other buildings were the most comparable buildings in consumption, choosing different buildings would result in large differences between the buildings making it impossible to create an accurate scale for the lower consumption buildings.

In the software the data is stored in four arrays of float values. Where each number in the arrays stands for a specific month. Each float value is hardcoded into the arduino and downloaded beforehand from the Energy Data Platform. These values are set as the desired water levels each time the input panel gains a different input.

6.4 Completed prototype

The completed prototype is shown in Figure 6.9. All of the above-mentioned components are incorporated into the design, with the electrical wiring, pumps and water tanks being hidden behind the main front panel. On the left side of the prototype shown in figure 6.8 is the input panel, marked with blue, with the name of the project and a QR code, marked with yellow, to the Energy Data Platform. Below the buttons there is a short description,marked with green, of the project and prototype which reads: "*The University of Twente has a multitude of buildings in use. These buildings all require water to function for toilets, water taps and other water related facilities. The data presented in this visualization is the consumption data from January to December 2020.*". On the right the buildings consumption tanks are shown, marked with purple. These are the tanks that display the water consumption data and are labeled with the name of the building of which they display the water consumption data. On the paper behind the tanks there are data scales, marked with red, on the left all four tanks have M^3 and on the right side they have, from left to right, amount of washes in a washing machine, amount of bathtubs filled, minutes showered and toilets flushed. The icons used to display these scales are shown in Figure 6.7.

Figure 6.9 Front view of the finished prototype

7. Evaluation

In this chapter the designed prototype as described in the realization phase is tested and evaluated. During the test the effect of the prototype on the awareness and knowledge of participants are tested. In addition, the function of the prototype is tested and compared to the function requirements.

7.1 User evaluation

During the evaluation of the prototype, members of the UT community working in the Zilverling have been asked to participate in the evaluation. For the evaluation, participants were asked to fill in a survey, which can be found in appendix B.2 and B.3 before and after interacting with the prototype. The first survey, appendix B.2, tested their knowledge and expectations, the second survey, found in appendix B.3 tested whether their expectations were correct and if they learned information from the prototype. The results of the surveys can be found in appendix C.2 and C.3

7.1.1 Survey results

Water consumption

The results of the TTM phase analysis survey, as seen in appendix C.1, showed that many of the participants expected the buildings on the UT to be using much less water than they actually do. When the participants were asked to estimate which buildings used the most water they were largely correct in stating Horst and Carre, however, when they were asked to estimate how much these buildings consumed they often stated that they expected a consumption of 1000 to 100000 Liters or 1 to 100 M3. In reality the Horst building consumed around 1600 M3 of water per month. Comparable results were shown when the participants were asked which buildings they thought consumed the least amount of water. With the majority of estimated consumption of the buildings being between 100 to 10000 liters per month.

For the second survey participants indicated that the amount of water consumed was higher than they expected. Participants also said that before they interacted with the prototype they had no good idea or reference on how much one liter or cubic meter of water actually is. The participants also thought that the amount of water consumed was excessive.

But many of them also stated again that they did not know what was normal or what was minimally required to keep the buildings functioning.

Design and function

In addition to an evaluation on the knowledge and awareness of water consumption the participants were also asked to share their thoughts on the design and function of the prototype, as well as which of the additional measurement scales was easiest for them to understand. Around 66% of the participants expressed they understood the data scale and could comprehend what the displayed data meant and how much it was. The participants were divided into what was easiest for them to understand, the cubic meters scale or the additional scales. Of the additional data scales the majority of the participants indicated that the amount of bathtubs was the easiest option for them to understand, with none of the participants choosing the wash machine option. In post-testing talks they stated that they could not imagine how much water a washing machine uses since it is hard to see inside the machine.

All participants stated that the function of the prototype was easy to understand and to interact with. They also liked the immediate feedback offered by the LED buttons. The rising and falling of the water levels was considered smooth and satisfying to look at by the participants, with some of them stating that it was a little mesmerizing to look at.

7.1.2 Suggestions

Part of the second evaluation survey was to elaborate on the answers provided by the participants. In these elaborations several participants suggested small changes that could improve the prototype. These suggestions are listed below with a short motivation;

- Add colored dye in the water to increase the contrast between water and air, this will make it easier for viewers to read the water consumption levels.
- Add a short explanation or legend to what the additional measurement scales mean. Most people were able to successfully perceive the meaning of the scales but could not completely comprehend some of the scales. It was also suggested to make the Figures larger.
- Painting the prototype to make it more appealing for potential users.
- Remove the shower head from the bathtub, this could cause confusion in the meaning of that measurement scale. Other participants stated the opposite, were the inclusion of the shower head made it clearer that the icon represented a bathtub.

7.1.3 Important observations

During the evaluation of the prototype there were several statements from the participants that are interesting for future improvements and the effectiveness of the prototype. These observations are discussed further in this section

Several of the participants were more interested in the prototype due to the inclusion of the months of 2020 where Covid-19 measures hindered students and staff from working in the UT buildings. They were interested in which of the UT buildings reduced their consumption most during the lockdown period. They were most surprised by the amount of consumption the Ravelijn building had in the October and November period of 2020. They perceived that the Ravelijn building residents were less strict in following the corona guidelines. This sparked a sense of pride that the residents of buildings they worked in themselves, with whom they identified themselves, were doing better.

During one of the testing by participants the prototype malfunctioned twice, with only one of these failures being noticed by the participants. The first error was likely a faulty sensor readout which resulted in one of the water pumps turning off before the desired water level was reached. This malfunction occurred despite software measures that require the sensor to be read a second time before turning off the pumps. The participants did not notice this error as they did not know what the true consumption levels are. The second malfunction was caused by one of the electrical connections losing contact which caused the system to stall. This issue was resolved by reconnecting the wires and taping them tight.

The QR code added on the prototype was not used by any of the participants. One of the participants did ask what the QR code did but did not scan it to learn more information. The participant did say that they like the inclusion of the source of the data and additional information in this way.

7.2 Client evaluation

Alongside a user evaluation, the prototype will also be evaluated in an interview with Brechje Marechal from CFM. During the interview the prototype was evaluated based on the aesthetics, functionality and whether the client’s expectations are met.

Brechje Marechal was pleased with the aesthetics of the prototype and it exceeded her expectations. She described it as professional looking and clear how it worked and what it represented. The functionality of the prototype was clear and easy to understand. She saw potential for the prototype to be used as a display during the sustainability weeks on the UT.

Additionally, she believes that the prototype can successfully raise awareness of water consumption within the UT community.

During the interview Brechje had some suggestions for future work or improvements that could be made to the prototype. The additional scales were clear to her, however, they could be made clearer by adding a quantity sign, #, by some of them to make it clearer that they represented an amount of uses. In addition, she mentioned the possibility of having the prototype display data based on consumption per member of a faculty rather than building consumption. This could improve interest in the prototype among the UT community. Lastly she offered an idea to put an LCD screen that would display questions for the user to make the user think more about water sustainability.

7.3 Requirement evaluation

Determining how successful the prototype is based on the requirements set in the specification phase. In table 7.1 below the requirements are listed along with whether the requirements have been met. Some requirements have partially been fulfilled or the results of the evaluation have been indecisive, these requirements are further evaluated in section 7.3.1 below.

Category	Requirement	Succes s	explanation
Must have	Display water consumption data per UT building	Yes	All data was drawn from the energy data platform and used per building
	Be interesting to view multiple times	No	The data does not provide additional or different information over time
	Be aesthetically pleasing	Yes/No	Elaborated in section 7.3.1
	Obtain interactive input from the user to control the prototype	Yes	Users could interact with the system using buttons to provide the system input
	Provide ways to compare the UT water consumption to more understandable scales as bathtubs filled, minutes showered, toilets flushed and	Yes/no	The additional scales provided comparative means, but some of the icons caused confusion amongst testing participants

	washing machines used		
	Raise awareness for water consumption on the UT campus	Yes	The evaluation showed that UT members learned obtained a greater understanding of UT water consumption
	Be a physical visualization of data	Yes	The prototype has been constructed
	The water level must reach its desired position within 10 seconds	No	The water level did not reach the desired level in 10 seconds of the difference between months was large
	The prototype must inform the user about its function and meaning of the data	Yes	The addition of a small plaque with a short description told users about the function and meaning
	The prototype must be build sturdy enough to be able to move it to a different location	No	During the testing phase some of the wires had come loose. In addition the water tubes are hard to connect to the tanks correctly.
	Display the source of the water consumption data, which is the Energy Data Platform	Yes	The “learn more” QR code refers to the source of the Data
Could have	Show the water flow within the data physicalization	Yes	The data is shown as water levels in tanks with the water level rising and falling
	Display the consequences to the environment of water consumption on the UT	No	The prototype does not include a display of consequences
	Display water data based on the consumption per individual person in a building	No	All data shown was based on consumption per building
	Display a method for viewers to gain more information about the subject by reaching the Energy Data Platform	Yes	The added QR code provides additional information to interested viewers
Should not	Include data from buildings with more then double the consumption of other included buildings to prevent large differences	Yes	The selected buildings all have comparable consumption making it easy for users to compare

	Display information unrelated to water consumption on the UT	Yes	No unrelated information was incorporated in the design
	Display water consumption data from more then 4 buildings	Yes	The installation included data from 4 buildings

Table 7.1 Requirement completion overview

7.3.1 Indecisive requirements

As shown in table 7.1, three requirements are neither achieved nor failed. These requirements are: aesthetics, measurement comprehension and prototype speed. These requirements are not met satisfactorily.

Aesthetics

In the user evaluation, participants expressed that they did find several aspects of the prototype very pleasing, such as the rising and falling of the water level. But they also stated that some components, such as the paper scale and lack of color, were out of place or left out. The paper scale aesthetics can be mostly disregarded as these were added for testing purposes. The lack of color can be changed in later improvements, once those have been made the aesthetics requirement is met.

Measurement comprehension

The evaluation participants were divided whether they understood the given measurement scales. Whilst some participants said they could comprehend the scale perfectly fine, others stated to find it difficult to imagine how much a washing machine or bathtub meant in volume of water.

Prototype speed

The prototype could fill all the tubes at the same time at the maximum pump speed. However, when the water level had to rise or fall from maximum to minimum or vice versa, the total time for the water to reach the desired level was 25 seconds. Whilst this is the fastest the pumps could handle it could cause a loss of interest with the viewer. However, most of the water changes were shorter and were achieved in under 10 seconds. Furthermore, the evaluation participants liked to see the rising and falling of the water, which made the increased time to reach the desired level look less long.

8. Conclusion

In the conclusion the research question is answered based on the findings of the evaluation of the developed prototype. The main research question of this thesis was:

How to design a UT community water consumption data physicalization that creates awareness on the water consumption on campus?

This research question is answered with the aid of the following sub questions:

- *How to personalize data presented in this data physicalization?*
- *What elements in this data physicalization activates people to change their behaviour towards water consumption?*

8.1 Research findings

8.1.1 Main research findings

The goal of this thesis and the development of the HydroSumption prototype has been to create awareness for the amount of water consumed within the UT buildings. This goal has been achieved according to the evaluation of the prototype.

By creating a platform where members of the UT community can see the information gathered by CFM and provided in the energy data platform in an interesting and interactive way. Potential users can use the HydroSumption prototype to compare the consumption of different UT buildings between each other and to scales commonly found in a user's everyday life.

8.1.2 Sub questions

How to personalize data presented in this data physicalization

Presenting raw water consumption data to members in the UT community is not enough to make them understand the meaning and significance of water usage on the UT. From the literature review we learned that people respond more interested and understand Figures better if they can personally relate to them. These relations can be made by creating a comparison between the dataset and a measurement scale that is present in a viewer's everyday life.

During the evaluation phase participants showed to find it easier to understand a data scale they could visually imagine. Out of the four suggested measurement scales (bathtubs, shower minutes, washing machine and toilet flushes), most participants said to understand the data best when comparing the water consumption data to the equivalent in bathtubs filled.

Additionally, users showed increased interest in how their main office building did compared to other buildings, sparking a sense of competition. As confirmed by the literature in section 2, this is one of the main methods of sparking interest among potential users.

What elements in this data physicalization activates people to change their behaviour towards water consumption?

The results of the initial user survey in the ideation phase, most people within the UT community were unaware of water consumption and its significance. They also had no knowledge of actions taken to reduce the water consumption of the UT. In addition, they had no plans of taking actions themselves or taking actions to reduce water consumption. According to the TTM model described in the literature section this would place them in the precontemplation phase.

Using the recommendations stated in section 2.1.5, the prototype provides the UT community with neutral, unbiased information in the form of a factual data display. Along with this data the prototype provided viewers with means to compare the data to more relatable "norms". The results of the evaluation form showed that the prototype successfully transferred members of the UT community to the second phase of the TTM model, the contemplation phase.

In addition to transferring UT community members to the second phase, some participants of the evaluation showed to start progressing into the third phase. The comparison between buildings sparked a competitive feeling in participants that promoted them to reduce their consumption so that the water consumption of their main building would decrease more than the consumption of "rivaling" buildings.

8.2 Future recommendations

The HydroSumption project has aspects that can be improved in the future. These aspects have partially been identified during the realization phase of this project. In this section these aspects are noted and explained.

Evaluation suggestions

During the evaluation phase participants were asked to state any recommendations they might have for future versions of the prototype. These recommendations have been stated in section 7.1.2 and below with the exception of icon alteration. This suggestion is disregarding because other participants stated that the aspect to be improved was positive to them:

Add colored dye

Adding color to the water makes it easier for viewers to note the height of the water levels due to a contrast increase. It is recommended to use a clear dye and preferably a color that is associated with water such as blue or cyan.

Scale legend.

The current prototype incorporates several additional scales expressed with icons. While many participants perceived these icons correctly, a multitude of participants expressed that they did not know much about the maximum content of a bathtub or the usage of a shower, toilet or washing machine. By adding a legend that explains the content of a single unit of these scales the ease of understanding might be increased.

Paint

By adding paint to the prototype the view is more appealing for potential users. In addition, extra visual aspects such as water droplets that could project the goal of the prototype more clearly to viewers.

Data incorporation

The current data displayed in the prototype is from four UT buildings during 2020. But this data could be expanded with additional years or buildings. An extra year could be added by buttons that represent specific years.

By adding LCD panels to the water tanks instead of having engraved building names the building represented by the water tanks could be changed by the user as well. This will however pose problems as the difference of consumption between some buildings is large enough to cause the smaller consumption building to take up a maximum of 10% of the total height of the tube.

Another possible data improvement is to add a Wi-Fi component that could directly access the energy data platform. Such an implementation would make it possible to select data from a large span of years without having to upload the additional data to the Arduino database array.

Consequence feedback

During the ideation phase, the initial idea incorporated a withering flower and a “groundwater” tank to represent the impact of water consumption on nature. These components have not been created for the final prototype but could improve the understanding of consequences of water consumption among the UT community.

Appendix A: Information brochure and consent forms

A.1 Information Brochure

Dear reader,

Thank you for your interest in participating in this research, in this information brochure I would like to give some more information about the research.

Purpose

This research is part of my graduation project for the BSc Creative Technology. The project is creating a data physicalization to raise water consumption awareness in the UT community. The goal of this research is to gain insight on user experiences on interacting with the data physicalization.

Procedure

In this research you will be asked to asses a prototype data physicalisation. This prototype is an interactive representation of water consumption on the UT campus designed to be placed in university buildings. The purpose of the prototype is to create awareness of water consumption within the UT community (student, staff or visitor). With this prototype you can choose specific data to be displayed and gain insight in the amount consumed. In addition to this it will show you how your own actions might influence the water consumption on campus.

Important

Some important notes before you can start:

- You must be a member of the UT community (student, staff or visitor) and 18 years or older to participate in this research.
- This questionnaire is completely anonymous and no sensitive or personal information will be collected.
- Participation is voluntary and you have the right to withdraw at any moment without a reason
- Participation in this questionnaire should take no more than 15 minutes.

Thank you for your participation in this research.

If there are any question about the project or the survey, you can contact:

Researcher:

D.W.A van der Veen, Creative Technology student at the University of Twente.

d.w.a.vanderveen@student.utwente.nl

Supervisors:

Dr Ing R.G.A. Bults, Coordinator graduation projects Creative Technology & SmartXP supervisor at the University of Twente

r.g.a.bults@utwente.nl

Dr. K. Zalewska

Programme coordinator/lecturer at Creative Technology at the University of Twente

k.zalewska-kurek@utwente.nl

If you have any complaints about this research, please direct them to the secretary of

the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at the University of Twente, P.O. Box 217, 7500 AE Enschede (NL), email:

ethics-comm-eemcs@utwente.nl)

A.2 Online survey consent form

Dear participant,

Thank you for participating in this questionnaire about knowledge of water sustainability on the University of Twente. The project aims to develop a prototype of a data physicalizing that raises awareness regarding water consumption and sustainability on campus. During this survey, your knowledge will be tested, please answer the question without consulting additional information or people. Filling in this questionnaire should take no more than 15 minutes.

Before starting the questionnaire, I ask you to agree to the following statements below: I hereby declare that:

- I give consent to collection of my answers in the questionnaire, to be used by the research for analysis.

- I know I have the right to withdraw this consent without giving any reason and am aware that I can leave this study at any time.

- I know that all data gathered will be made anonymous and if used in scientific publication will not be linked to myself.

- I am aware that my data will not be shared to third parties without my express permission

- I know that I can contact the researcher by the contact information below if I want more information about the research, both now and in the future.

- I know that if I have complains about this research I can address it to the secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at University of Twente, P.O. Box 217, 7500 AE Enschede (NL), e-mail: ethics-comm-ewi@utwente.nl).

- I voluntarily agree to participate in this study.

If I have any questions about the project or the survey I can contact:

Researcher:

D.W.A van der Veen, Creative Technology student at the University of Twente.

d.w.a.vanderveen@student.utwente.nl

Supervisors:

Dr Ing R.G.A. Bults, Coordinator graduation projects Creative Technology & SmartXP supervisor at the University of Twente

r.g.a.bults@utwente.nl

Dr. K. Zalewska

Programme coordinator/lecturer at Creative Technology at the University of Twente

k.zalewska-kurek@utwente.nl

A.3 Prototype evaluation consent form

Dear reader,

Thank you for your interest in this prototype and helping with the evaluation of the prototype.

Before continuing please agree to the following terms:

- I have been informed in a clear manner about the nature and method of the research as described in the information brochure

- I give consent to collection of my answers in the questionnaire, to be used by the research for analysis.

- I know I have the right to withdraw this consent without giving any reason and am aware that I can leave this study at any time.

- I know that all data gather will be anonymous and if used in scientific publication will not be linked to myself.

- I am aware that my data will not be shared to third parties without my express permission

- I know that I can contact the researcher by the contact information below if I want more information about the research, both now and in the future.

- I know that if I have complains about this research I can address it to the secretary of the Ethics Committee of the Faculty of Electrical Engineering, Mathematics and Computer Science at University of Twente, P.O. Box 217, 7500 AE Enschede (NL), e-mail: ethics-comm-eemcs@utwente.nl).

- I voluntarily agree to participate in this study.

If there are any question about the project or the survey, you can contact:

Researcher:

D.W.A van der Veen, Creative Technology student at the University of Twente.

d.w.a.vanderveen@student.utwente.nl

Supervisors:

Dr Ing R.G.A. Bults, Coordinator graduation projects Creative Technology & SmartXP supervisor at the University of Twente

r.g.a.bults@utwente.nl

Dr. K. Zalewska

Programme coordinator/lecturer at Creative Technology at the University of Twente

k.zalewska-kurek@utwente.nl

Signed in duplicate:

……………………………   ……………………………

Name subject   Signature

I have provided explanatory notes about the research. I declare myself willing to answer to the best of my ability any questions which may still arise about the research.

……………………………   ……………………………

Name researcher   Signature

Appendix B: Survey questions

B.1 online survey questions

What is your role within the UT community? *

- ◯ Student
- ◯ Teacher
- ◯ Non-Teacher Staff
- ◯ Visitor
- ◯ Other: ______________________

Do you think it is important to save energy and water to preserve the environment? *

- ◯ Yes
- ◯ No

Do you consider yourself a environmentally responsible person? not waste energy and water *

- ◯ Yes
- ◯ No

Do you take measure to reduce your water consumption? eg short showers *

- ◯ Yes
- ◯ No

Water consumption measures

Can you name some measures you take to reduce your water consumption? *

Your answer

Questionaire on water sustainability

Do you leave water running while brushing your teeth? *

- ◯ Yes
- ◯ No

Do you know how many liters of water are being used per minute of showering? Please state an estimate *

Your answer

Do you know the difference in liters of water usage between using the big button and the small button when flushing the bathroom? *

	0	1	2	3	4	5	6	7	8	9	10	
Difference in Liters	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	◯	Difference in Liters

Which water projects on campus do you know off? *

- [ ] Spraying lawn from the ponds
- [ ] Technohal using rainwater to flush toilets
- [ ] Collecting and filtering rainwater from the hogekamp to water sport fields
- [ ] Cold circulation cycle in front of the horstbuilding
- [ ] Waterless urinals
- [ ] Sensor water taps
- [ ] I dont know any water projects on campus
- [ ] Other: ______

Do you know how many liters of water a person uses on average per day in the netherlands? *

- ○ 20 -40 L
- ○ 41 - 60 L
- ○ 61 - 80 L
- ○ 81 - 100 L
- ○ 101 - 120 L
- ○ 121 - 140 L
- ○ 161 - 180 L

Do you know how much water the Universtity of Twente uses in 1 day on average? (without corona lockdown) *

- 50.000 - 100.000 L
- 100.000 -150.000 L
- 150.000 - 200.000 L
- 200.000 - 250.000 L
- 250.000 - 300.000 L
- 300.000 - 350.000 L
- 350.000+ L

B.2 Evaluation questionnaire part 1 questions

What is your name? (if you are not comfortable with giving your name you can also give another word or nickname, but please remember it) *

Your answer

What is your role within the UT community? *

- Student
- Teacher
- Staff member
- Visitor

How old are you? *

Your answer

Which UT buildings do you work in most? (please state 1-3 buildings) *

- [ ] Ravelijn
- [ ] Cubicus
- [ ] Zilverling
- [ ] Carré
- [ ] Horst
- [ ] Waaier
- [ ] Citadel
- [ ] Nanolab
- [ ] Technohal
- [ ] The Gallery
- [ ] Spiegel

Which UT buildings do you think use the most water per month on average? *

- ◯ Ravelijn
- ◯ Cubicus
- ◯ Zilverling
- ◯ Carré
- ◯ Horst
- ◯ Waaier
- ◯ Citadel
- ◯ Nanolab
- ◯ Technohal
- ◯ The Gallery
- ◯ Spiegel

How much water do you think that building consumes per month in Liters? *

Your answer

Which UT building do you think use the least water per month on average? *

- ◯ Ravelijn
- ◯ Cubicus
- ◯ Zilverling
- ◯ Carre
- ◯ Horst
- ◯ Waaier
- ◯ Citadel
- ◯ Nanolab
- ◯ Technohal
- ◯ The Gallery
- ◯ Spiegel

How much water do you think that building consumes per month in Liters? *

Your answer

Questionaire part 1

In the prototype 4 UT buildings have been chosen for data projection, these are Zilverling, Spiegel, Ravelijn and Cubicus. These buildings have been chosen due to their comparability in function and size.

How much water do you think these buildings use per month on average? *

Your answer

B.3 Evaluation questionnaire part 2 questions

What is your name? (or other calling from the previous questionaire) *

Your answer

Was the data scale easy to comprehend? *

- Yes
- No

Would you like to elaborate on your answer?

Your answer

Which of the different measurement scales was easiest for you to relate to? please rate the option from easiest to hardest *

Choose

- Minutes showered
- Times using a washer
- Times flushing a toilet
- number of filled bathtubs

Were the prototype functions easy to understand? *

- ◯ Yes
- ◯ No

Would you like to elaborate on your answer?

Your answer

Was the amount of water consumed in a month about what you expected? *

- ◯ Yes
- ◯ No, it was more
- ◯ No , it was less

Would you like to elaborate on your answer?

Your answer

Do you think the amount of water consumption is more then neccesary? *

Your answer

Can you name any measures you know of of water sustainability here in the UT buildings? *

Your answer

Do you have any remarks on the functionality of the prototype? *

Your answer

Do you have any remarks on the aesthetics/visual aspects of the prototype? *

Your answer

B.4 Semi-structured client interview

Wat is uw eerste indruk van het prototype?
What is your first impression of the prototype?

Vind u het prototype makkelijk in omgang?
Do you think the prototype is easy to use?

Voldoet het prototype aan wat u voor ogen had?
Does the prototype meet your expectations?

Denkt u dat het prototype de UT gemeenschap bewust kan maken van het verbruik van water op de UT campus?
Do you think the prototype will create awareness withing the UT community about the usage of water on the UT campus?

Ziet u punten waar ruimte is voor verbetering?
Do you have suggestions for improvements?

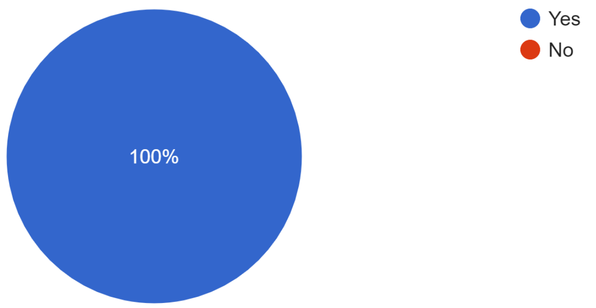
Ziet u toekomstmogelijkheden voor het project?
Do you have a future vision for the project?

Appendix C: User survey results

C.1 Online survey results

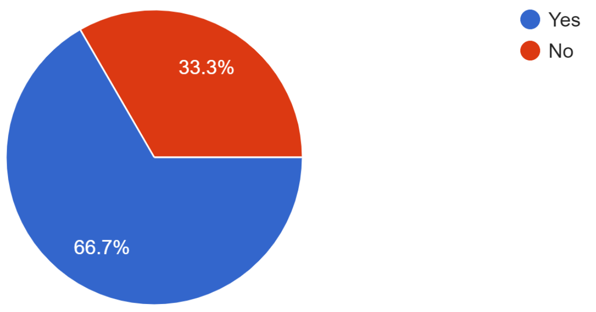
What is your role within the UT community?
3 responses

Do you think it is important to save energy and water to preserve the environment?
3 responses



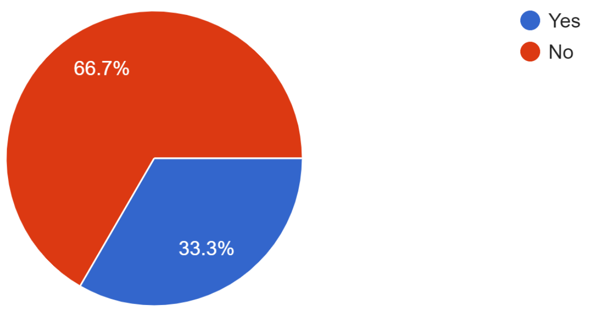
Do you consider yourself a environmentally responsible person? not waste energy and water

3 responses



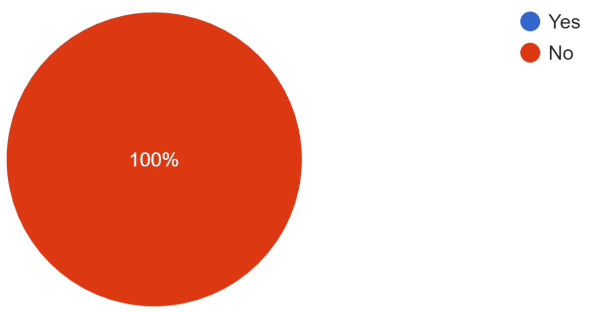
Do you take measure to reduce your water consumption? eg short showers

3 responses



Do you leave water running while brushing your teeth?

3 responses



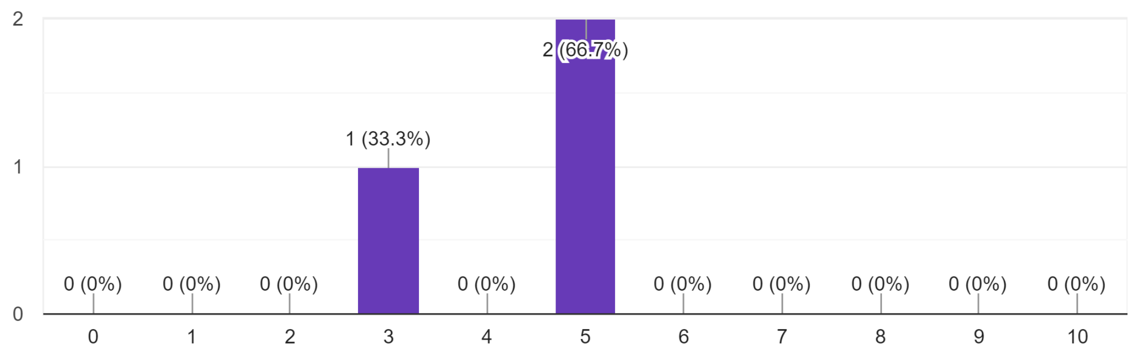
Do you know how many liters of water are being used per minute of showering? Please state an estimate

3 responses

5
5 liters of water
7

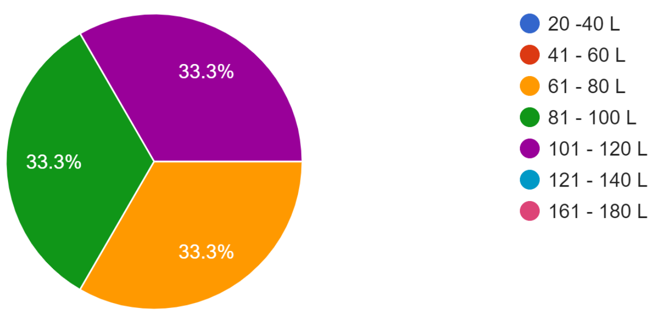
Do you know the difference in liters of water usage between using the big button and the small button when flushing the bathroom?

3 responses



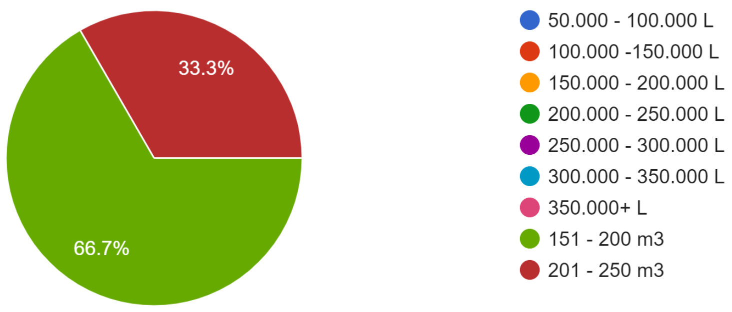
Do you know how many liters of water a person uses on average per day in the netherlands?

3 responses



Do you know how much water the Universtity of Twente uses in 1 day on average? (without corona lockdown)

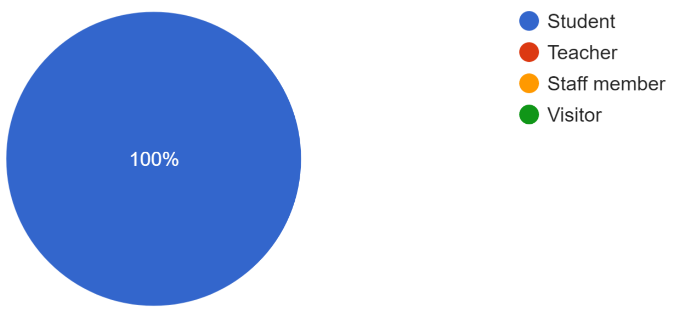
3 responses



C.2 evaluation questionnaire part 1

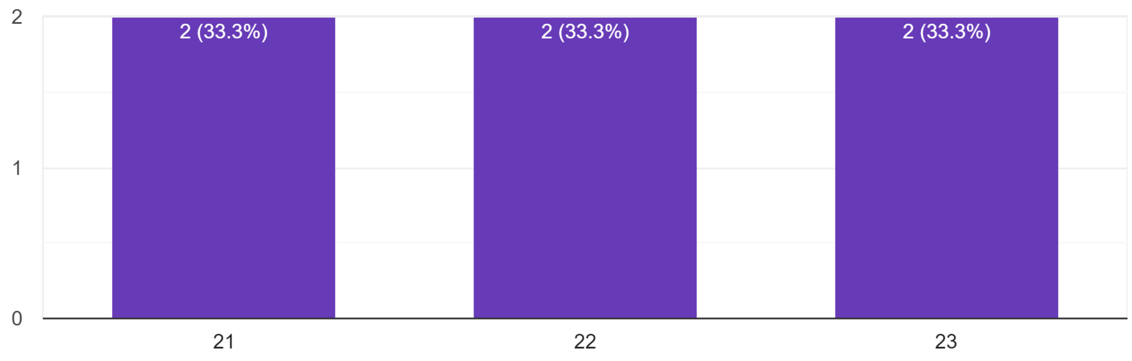
What is your role within the UT community?

6 responses



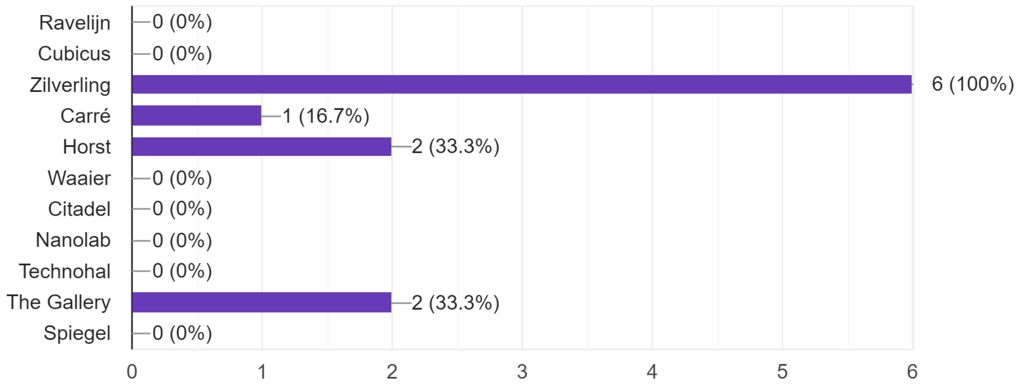
How old are you?

6 responses



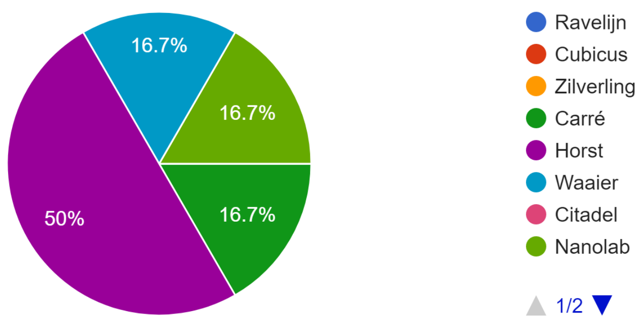
Which UT buildings do you work in most? (please state 1-3 buildings)

6 responses



Which UT buildings do you think use the most water per month on average?

6 responses



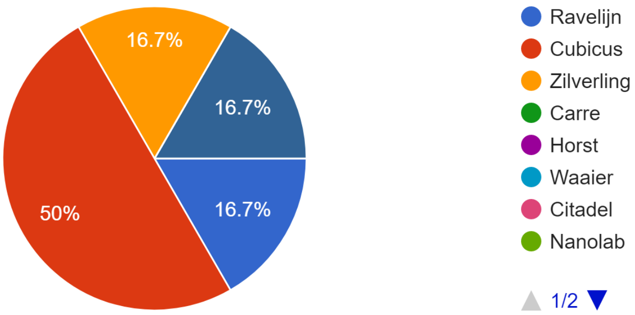
How much water do you think that building consumes per month in Liters?

6 responses

35000
150
55.000
2000
50000
1.000.000

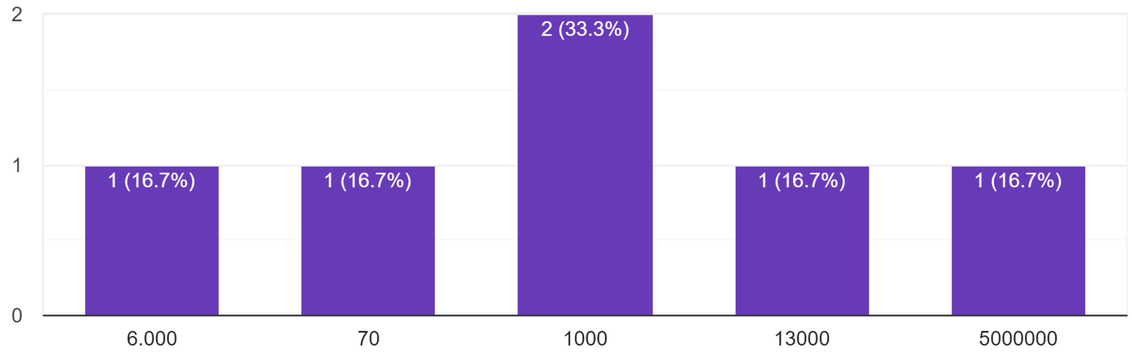
Which UT building do you think use the least water per month on average?

6 responses



How much water do you think that building consumes per month in Liters?

6 responses



The next question is regarding the Zilverling, Ravelijn, Spiegel and Cubicus buildings being displayed in the HydroSumption prototype

How much water do you think these buildings use per month on average?

6 responses

24000

120

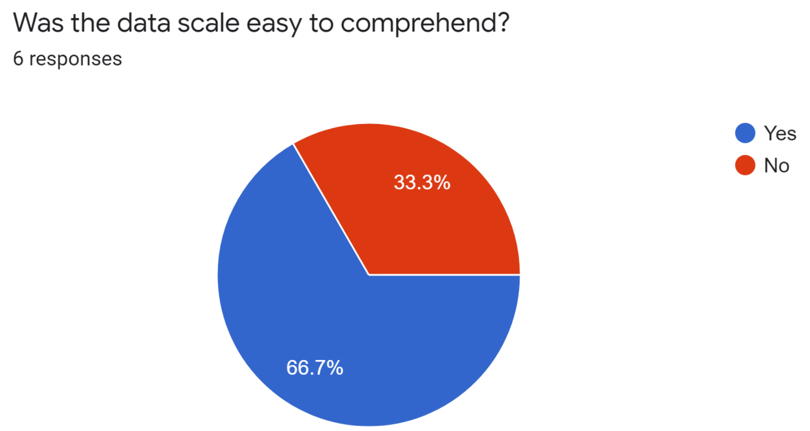
8.000

1000

25000

7500000

C.3 evaluation questionnaire part 2



Would you like to elaborate on your answer?

5 responses

De figuren waren niet heel duidelijk, en M3 ipv L gebruiken vond ik vaag. Verder was het wel makkelijk om te vergelijken

It is clear! The only thing I had to think about is what the shower and other icons meant, but I guessed the meaning right so clear. Maybe a question like how many showers for example would make it more clear. Now that I read the next question: I thought it was amount of showers but it turns out to be minutes. Not that clear.

After a brief moment of investigation the purpose became clear

I know 250 bath tubs is a lot, but I can't make a picture in my head on how much

The cubic meters are clear to understand, though it couldbe improved by adding coloured water to improve the clarity

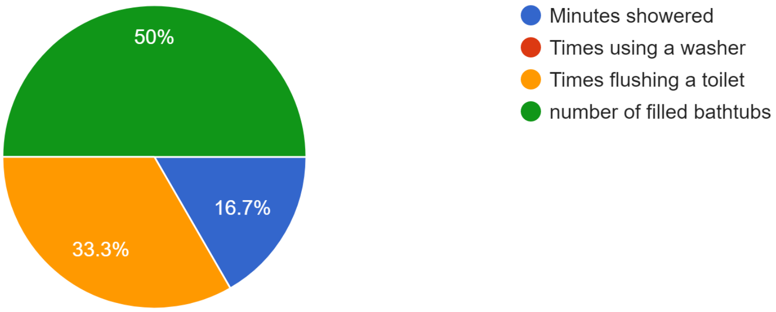
And i like the gimmick of the washmachine and the bathtubs but they should be extra not a focus

Translation from Dutch to English:

“The icon Figures were not very clear, and using cubic metres instead of liters was confusing. Otherwise it was easy to compare”

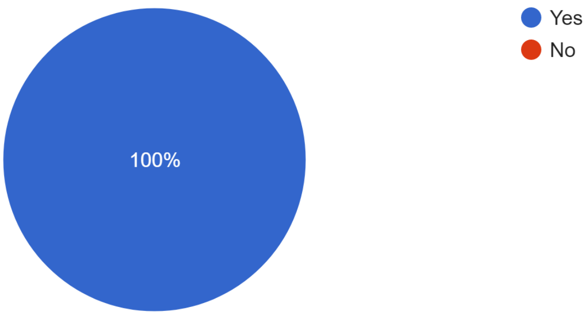
Which of the different measurement scales was easiest for you to relate to? please rate the option from easiest to hardest

6 responses



Were the prototype functions easy to understand?

6 responses



Would you like to elaborate on your answer?

5 responses

Just press the month to see how much water the building uses, pretty easy

Clear, also nice feedback added with the lights to remember what you are looking at. Seeing the differences form is nice, seeing it get less or more makes it even easier to see the differences.

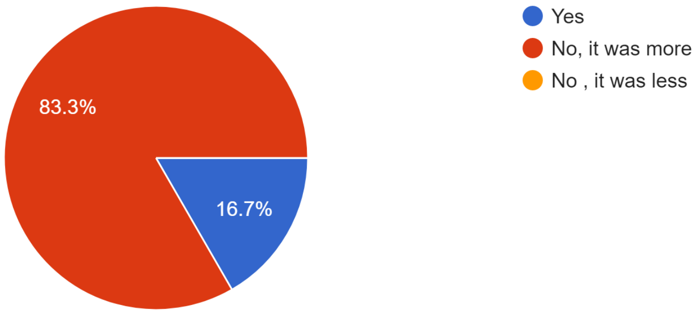
Button makes machine go brrrrr

Buttons are not hard to use

The buttons are clear, there arent that many functions

Was the amount of water consumed in a month about what you expected?

6 responses



Would you like to elaborate on your answer?

5 responses

I looked at how water in a bath fits, and than just did a random guess

I don't pay per liters or anything for my campus house so I did not have any reference material I suppose.

Wow thats a lot of water, what do we use all that water for?

I guessed a really low number, but now that I know how much liter a tub uses, I would've guessed a higher number

I had no clue and no point of reference as it isnt anything that i worry about in day to day life

Do you think the amount of water consumption is more then neccesary?

6 responses

I have no clue

Yes. I am assuming it has to do with cafetaria and machines etc. But I expect a lot to be unneccesary, as we all use way too mucb water anyway.

Definitely

Yes, I think there are a lot of ways to save water, but I'm not sure what the university does at the moment.

I have no clue

I am not qualified to answer this question since I have no knowledge regarding this topic

Can you name any measures you know of of water sustainability here in the UT buildings?

6 responses

I think the warm/cold bath at Horst, and I think they have a underground basin to safe water in

Like I said I assume cafetaria, drinks, coffee etc, machines (apparatuur)

Smart toilet, ensceton

Not really. As far as I know, there are only the sinks with the tab that stops running after a while.

To be fare, all i know is a brick in the toilet reservoir

Waterbarrel at the Zilverling

Do you have any remarks on the functionality of the prototype?

6 responses

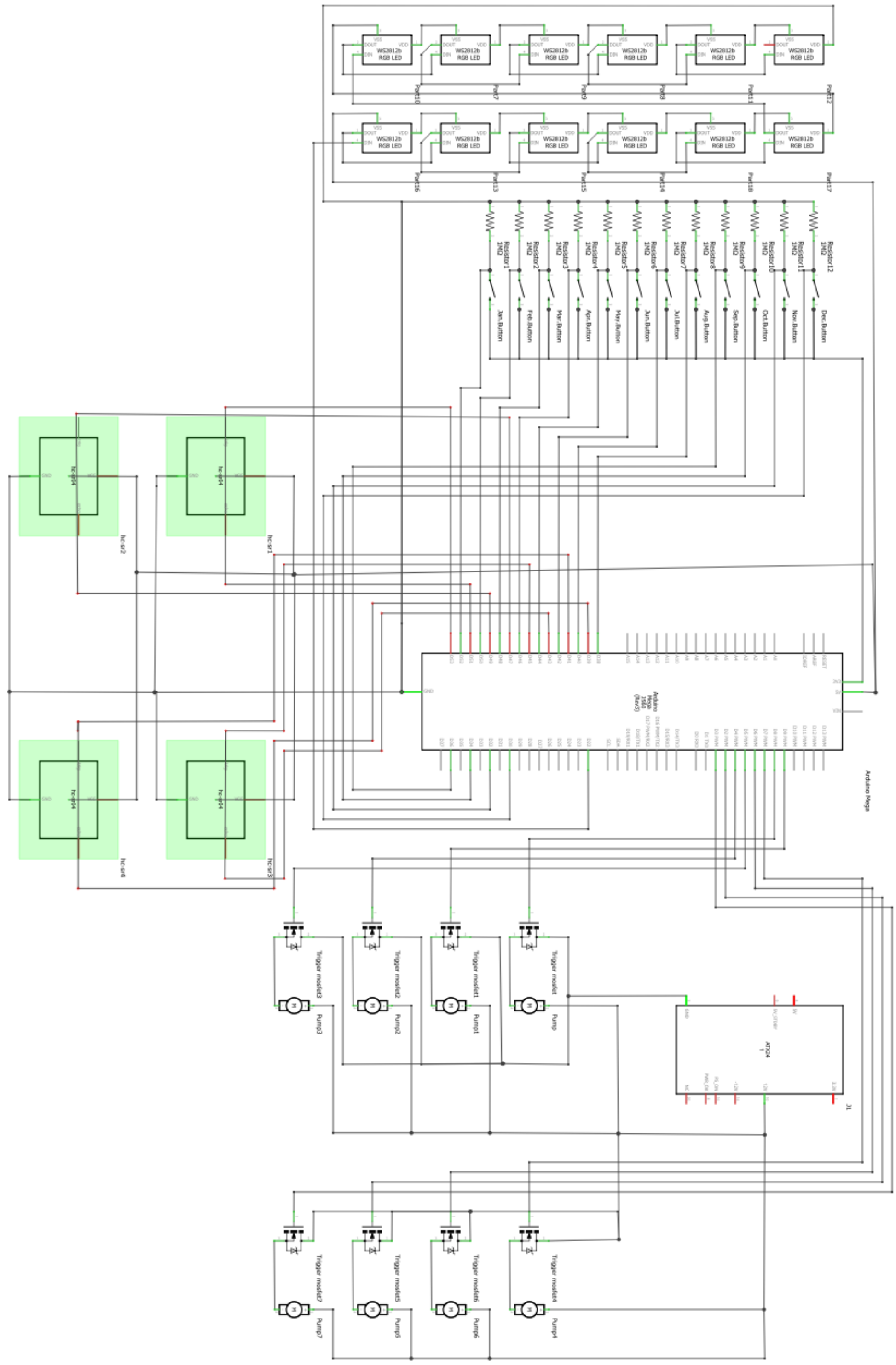
- Before fixed, januari button was stuck.
- No, functionality is nice.
- Worked great, machine go brrrrr
- It works really well! I have no remarks. Since this is a prototype, there are some design things that could be improved, but that is not necessary for now.
- It just works ~Todd Howard
- It wasn't turned on when I tried to use it

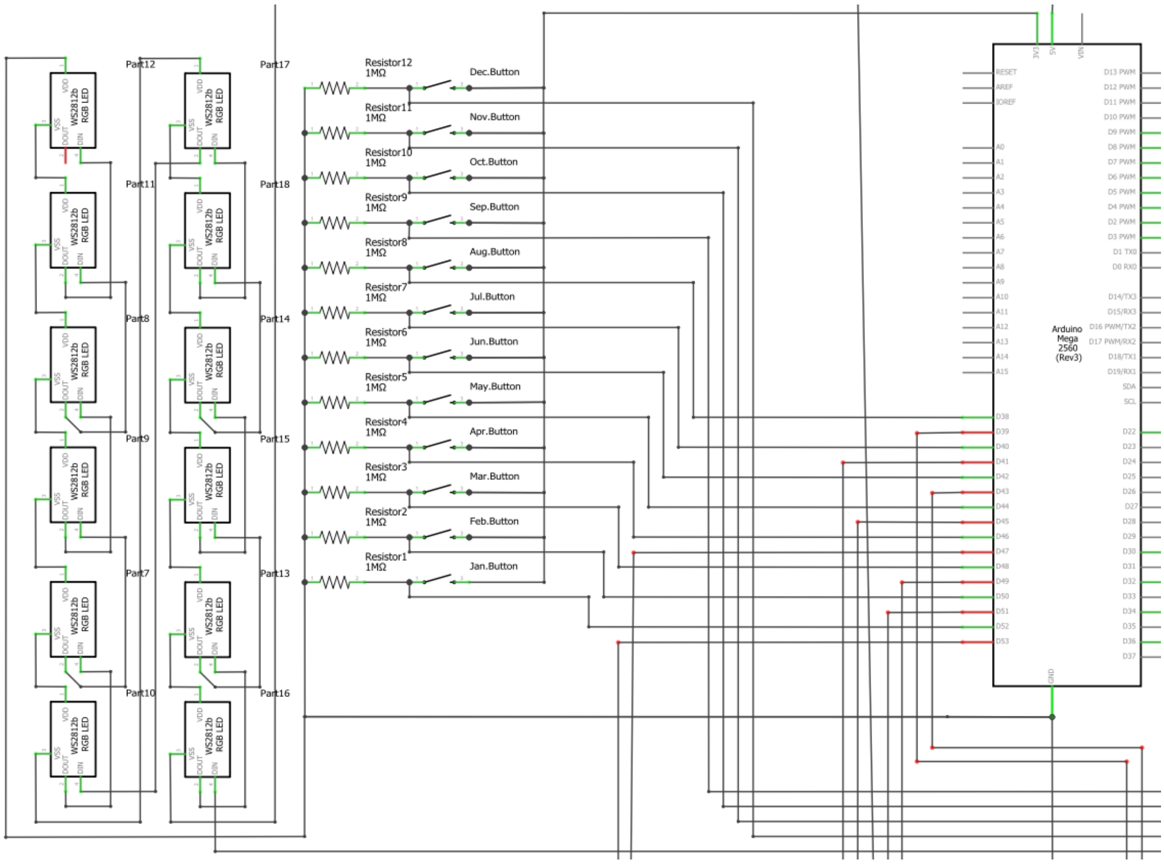
Do you have any remarks on the aesthetics/visual aspects of the prototype?

6 responses

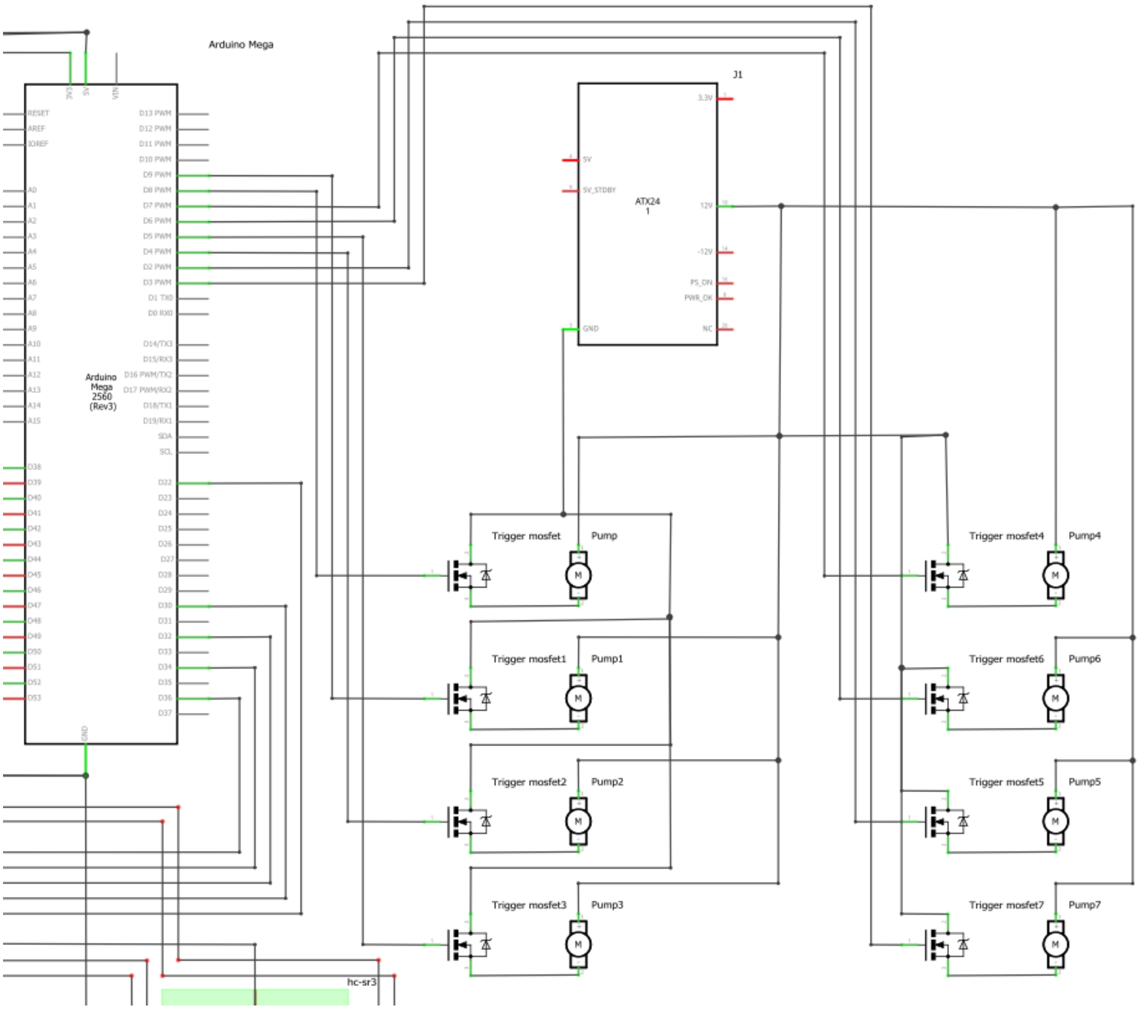
- The front seems good, but you see all the wires stick out every else. Seems a bit not finished
- I think it looks nice! The learn more is a very nice touch for those interested, while this prototype educates us in a playful way. I do think that the bath should not have a douche to make it more clear.
- Needs more LEDs
- Like mentioned before, it looks good for a prototype. For now you can see wires and it is mostly made of wood, but since this is a prototype, this is fine.
- Maybe a bit of paint?
- Aesthetics were okay, but if the containers for the water were more directly integrated into the design than the metrics could've been lasered into the structure so that there would be no need for the paper.

Appendix D: Hardware circuit diagram

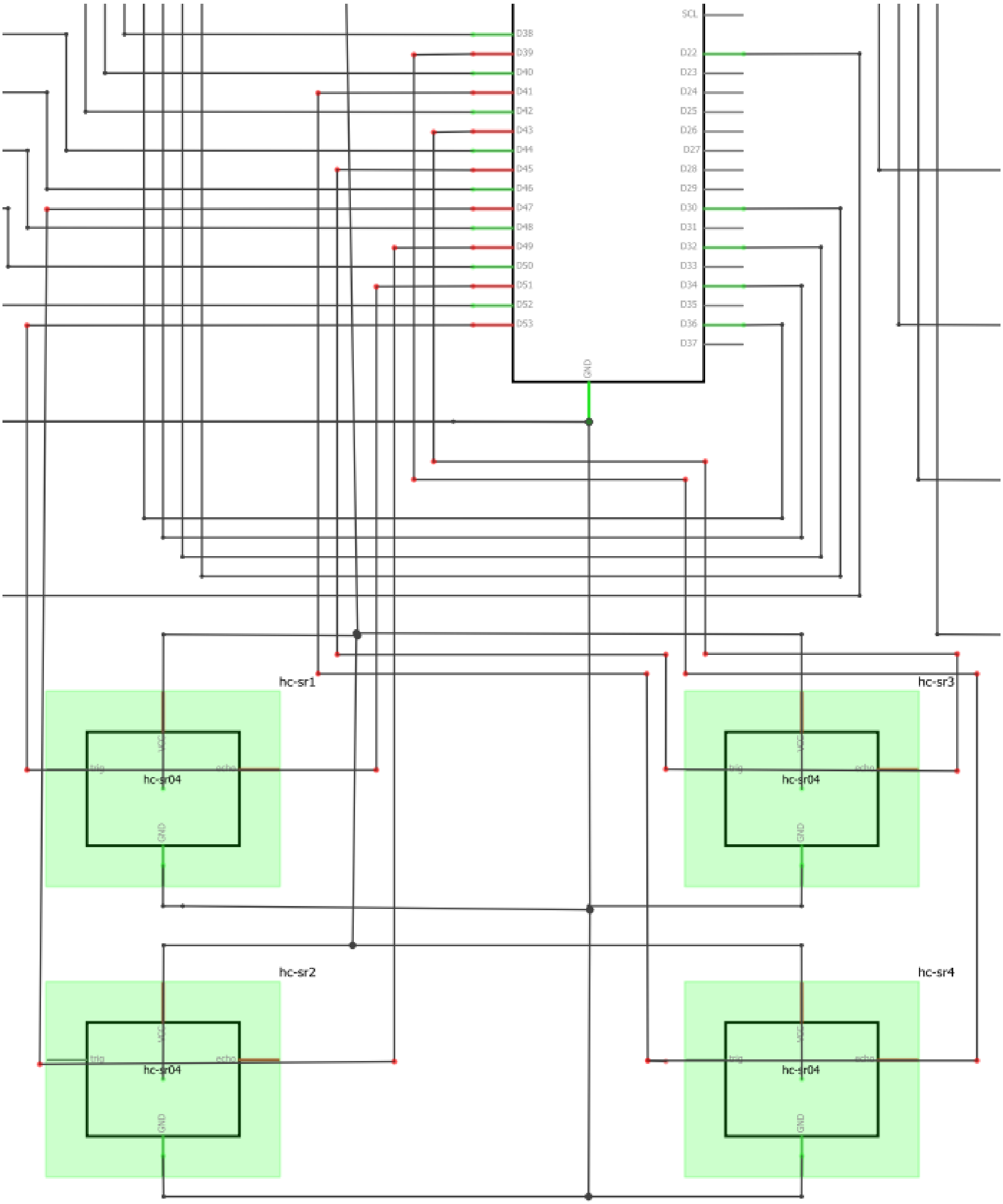




Input panel circuit



Pump circuit



Sensor circuit

Appendix E: Software overview

The code used on the Arduino to run the prototype:

```
//Variables for LED indication
#include <FastLED.h>
#define DATA_PIN 22
#define NUM_LEDS 12
CRGB leds[NUM_LEDS];

//test values
int testnum = 4;

//Variables for scaling the data to the water tank
float scaling = 8.95;
float threshold = 0.5;
float tanksize = 28.7;

//Data
float Zilverling[] = {205.98, 187.99, 107, 7, 5, 14, 14, 21, 78.96, 48, 40.92, 26.94};
float Spiegel[] = {151, 152.8, 104, 37, 40, 50, 54, 55, 95.7, 78, 139.11, 66.04};
float Ravelijn[] = {195.01, 201.18, 130, 14, 19, 23, 35, 31, 100.59, 123, 183.90, 58.04};
float Cubicus[] = {102, 97.2, 83, 8, 8, 10, 6, 7, 48.35, 45, 28.97, 18.05};

//Determines speed of pumps, needs to be between 0 and 155
int spe = 50;

//Tank variables
float desired[4];
float current[sizeof(desired)];
bool correct[sizeof(desired)];
float current2[sizeof(desired)];

//Button variable and input pins
int button[] = {52, 50, 48, 46, 44, 42, 40, 38, 36, 34, 32, 30};
```

```
int selection = 11;
int now, prev;

//Sensor pins and variables
int trigPin[] = {53, 49, 45, 41};
int echoPin[] = {51, 47, 43, 39};
float distance[4];
long duration[4];

//Pump and valve pins
int pump[] = {8, 9, 10, 11};
int valve[] = {4, 5, 6, 7};

void setup() {
  Serial.begin(9600);
  prev = selection;
  Serial.println("starting");
  delay(2000);
  //Define LEDs on input panel
  FastLED.addLeds<WS2812B, DATA_PIN>(leds, NUM_LEDS);
  for (int i = 0; i < sizeof(button) - 1; i++) {
    pinMode(button[i], INPUT);
  }
  //Set pinmodes
  for (int i = 0; i <= 3; i++) {
    pinMode(trigPin[i], OUTPUT);
    pinMode(echoPin[i], INPUT);
    pinMode(pump[i], OUTPUT);
    pinMode(valve[i], OUTPUT);
    correct[i] = true;
  }
  Serial.println("Setup Complete");
  delay(100);
}
```

```
void loop() {
  //run inputpanel
  now = inputpanel();
  Serial.println(now);
  if (now != prev) {
    for (int j = 0; j <= 3; j++) {
      correct[j] = false;
    }
    prev = now;
  }
  //only run the tankcontrollers if the input has changed
  while (correct[0] == false || correct[1] == false || correct[2] == false || correct[3] == false) {
    for (int i = 0; i <= testnum - 1; i++) {
      if (!correct[i]) {
        Serial.println(i);
        Serial.print("desired: ");
        Serial.println(desired[i]);
        current[i] = sensor(i);
        Serial.print("current: ");
        Serial.println(current[i]);
        if (current[i] > desired[i] + threshold) {
          Serial.println("pump");
          analogWrite(pump[i], 200);
          digitalWrite(valve[i], LOW);
          delay(5);
        }
        if (current[i] < desired[i] - threshold) {
          Serial.println("valve");
          digitalWrite(valve[i], HIGH);
          digitalWrite(pump[i], LOW);
          delay(5);
        }
        if (current[i] < desired[i] + threshold && current[i] > desired[i] - threshold) {
```

```
        digitalWrite(pump[i], LOW);
        digitalWrite(valve[i], LOW);
        //second measurement to prevent false measurements from stopping the pumps early
        current2[i] = sensor(i);
        if (current2[i] < desired[i] + threshold && current2[i] > desired[i] - threshold) {
          Serial.println("stop");
          correct[i] = true;
          delay(5);
        }
      }
    }
  }
 }
}

float sensor(int i) {
 digitalWrite(trigPin[i], LOW);
 delayMicroseconds(2);
 //send audiopulse
 digitalWrite(trigPin[i], HIGH);
 delayMicroseconds(10);
 digitalWrite(trigPin[i], LOW);
 //determine time for audiopulse to return and calculate distance
 duration[i] = pulseIn(echoPin[i], HIGH);
 distance[i] = duration[i] * 0.017;
 return distance[i];
 Serial.println("error on: ");
 Serial.print(i);
}

int inputpanel() {
 //read the state of all buttons
 for (int i = 0; i <= 11; i++) {
  //if triggered set desired tank levels and selection
```

```
    if (digitalRead(button[i]) == HIGH) {
      selection = i;
      delay(10);
      desired[0] = tanksize - Zilverling[i] / scaling;
      desired[1] = tanksize - Spiegel[i] / scaling;
      desired[2] = tanksize - Ravelijn[i] / scaling;
      desired[3] = tanksize - Cubicus[i] / scaling;
    }
  }
  //LED feedback on month selection
  for (int j = 0; j <= 11; j++) {
    if (j != selection) {
      leds[j] = CRGB::Black;
    }
  }
  leds[selection] = CRGB::Blue;
  FastLED.show();
  delay(100);
  return selection;
}
```

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