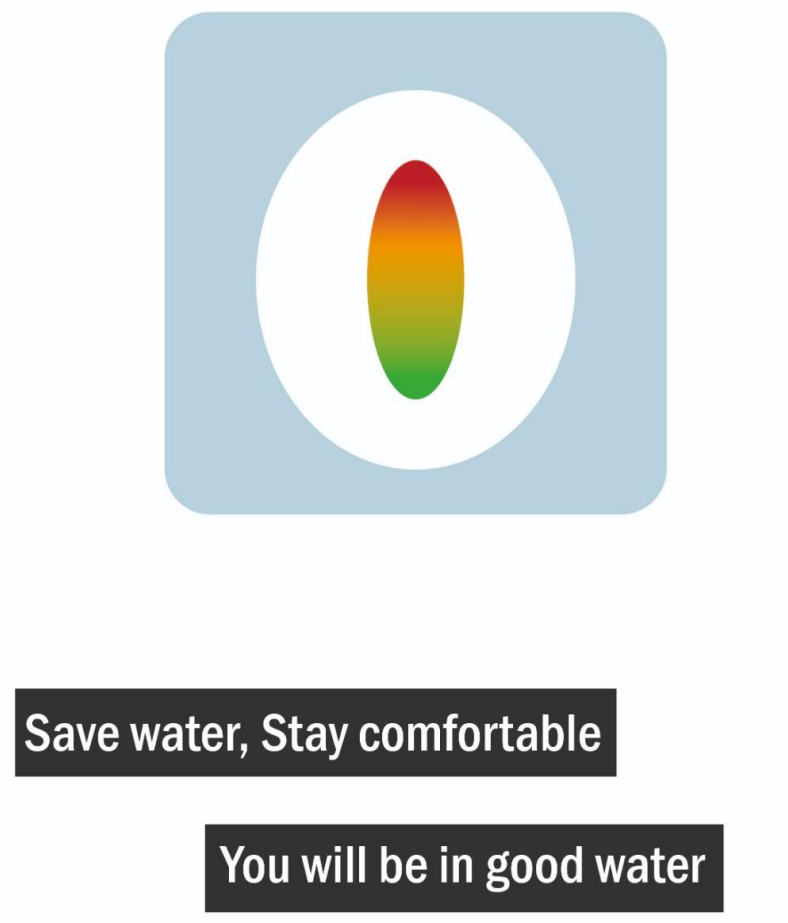
UNIVERSITEIT TWENTE.

SMART ENVIRONMENTS PROJECT



DOCUMENTATION REPORT

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Chapter 0: Introduction

This project will cover several important aspects regarding climate change and aims to offer creative and innovative solutions to tackle this issue. In order to successfully achieve this, research has been conducted and information has been found regarding problems related to the environment, for example biodiversity, gas fracking or the acidification of oceans. After discussion the conclusion was made to tackle the water wastage issue.

The focus of this project is on water in living spaces and ways of using it more efficiently. For example, the usage of a dishwasher instead of washing the dishes by hand, collecting the rainwater, or drip irrigation. The desired goal is to make people acknowledge the use of water in the shower more efficiently. This goal should be fulfilled by analysing and letting them know how much water they use while showering.

Besides this, the intention is to reduce the water usage, particularly in the shower. This topic was chosen because it was found to be the most wasteful in a household. Furthermore, the paper will look into the development of the final product specifically from the ideation phase to the designing phase to the analysis of the product and finally a conclusion and evaluation.

Chapter 1: Literature Review

In order to have concise and clear idea, the first step to do is research and find literature related to the topic of climate change that will allow us to find a topic that interests us and that has a high significance in the realm of Climate change. In order to do that, there has to be a number of sources found and briefly summarised to decide based on them.

1. In this National Geographic article, the effects of global warming are discussed. Since 1906, the average temperature has increased more than 1.6 degrees (globally) and the effects of this can already be seen today with melting glaciers, animal migrations, and change in precipitation patterns and levels. What must be noted is that global warming and climate change are ethe same, climate change not only encompasses rising temperatures, but it also encompasses extreme weather, rising sea levels and all other impacts unlike global warming which just considers temperature levels. Ice melting has led to global sea rise (3.2mm a year), populations collapsing (i.e., Adélie penguin in Antarctica), increased rainfall but also more droughts, wildfires, and water shortages. With this situation, species such as jellyfish, mosquitoes or crop pests are thriving and are further threatening our environment. [1]
2. Paola Arias, a leading climate activist, along with over 233 other professionals does not believe that the COP26 (Conference Of the Parties – where they discuss global climates) will have any threat of the current climate crisis. In a recent survey 60% of people said that they expected the global temperature to increase by at least 3 degrees by the end of the century, which is way more than what was said in the Paris agreement. In a survey, 88% of voters said that there was a climate crisis going on and just under half of the voters suggested that it was affecting their life decisions. In the same survey, 60 % of voters answered that they felt sad/anxious due to the impacts of climate change. In the latest report signed by 195 countries, it was concluded that fossil fuel emissions are leading to huge planetary changes and that action must be taken immediately before it is “beyond reach”. Overall, the survey is what one would expect but it is true that 60% of IPCC authors (who contributed to the paper) views are not expressed in the survey. But there is some hope, since over 20% of participants believe that nations will actually try to limit rising temperature and two thirds of voters voted that they are advocates for the climate. The survey asked if the IPCC authors would be more involved and in what respect since their representation has gone increasing on a global scale since 1990. [2]
3. In this article we see where the greenhouse gases come from. They are found in the production of 29 different food products including meats and vegetables. Each product is divided into each phase of production including land use exchange, farm, animal feed, processing, transport, retail, and packaging. The data was gathered from 38.000 commercial farms from over 119 countries. The diagram shows in a visual representation the drastic differences between meats and other foods. This shows that animal eaters have a much higher carbon footprint than non-animal eaters as they emit over 20kg of CO_2 per kg. Overall, the biggest impact is seen during the change of land use and the farming feed. The retail and packaging sectors have a low and pretty much insignificant effect on the environment. [3]
4. This article is about the influence of global warming on sea levels. The article explains what influence rising sea levels have on the weather. It shows that the rising levels of the ocean directly impact life on earth in a negative way. The article also explains what is causing the oceans to rise, which is largely human influence. Due to the average temperature on earth rising, the ice caps are melting. This makes the volume of the

water in the ocean bigger. The article then makes a detailed prediction of what will happen if humans do not change their behaviour. [4]

5. In the USA there are 10.000 closed landfills and 3.000 open landfills. These landfills are necessary to reduce waste, prevent disease, and help keep communities clean. However, these landfills have terrible environmental and social impacts. When the mass in these landfills finally decomposes (after lots of years), methane gas is released which is 48 times more effective at absorbing the heat of the sun than CO_2 making it the most powerful GHG and one of the largest climate change contributors. Landfills on average take up 600 acres of land and required to have a plastic coating/jacket for protection, these usually leak which leads to contamination in a nearby water source. The ammonia that is released is nitrified through nitrification and causes eutrophication leading to lack of oxygen in many areas. Furthermore, this process also creates and leaves hazardous materials such as mercury. These landfills have terrible social impacts. New Yorkers who live near a landfill have a 12% higher chance to be born with congenital malformations and they also generate smoke, bugs, water contamination amongst other treats. Landfills should be avoided, and this can be done through avoiding single-use plastics, recycling, and composting. [5]
6. This article is about the importance of the oceans in climate change. Climate change is an atmospheric phenomenon which is greatly entwined with the ocean this has been made evident by the latest negotiations on climate in which “anchoring oceans” as recognised into the climate change regime. But there is still much to be recognised relating to the oceans and climate change. Most countries have land-based emission controls but only a select few have controls that are linked with the oceans. The issue with this is that the ocean has absorbed one third of CO_2 and 93% of human generated heat since industrialisation. Ocean climate mitigation could also lead to a reduction of 20% of reductions in emissions which would be a great leap forward to achieve the 1.5-degree goal. The main factor that must be changed is the marine industry since it is a very large contributor to emissions. Stopping this could be done through sustainable management practices and blue carbon-capture which has many benefits for conserving marine biodiversity. Despite the major threat, the international talks have been slow but the recent COP26 agreement made some progress by ensuring the importance of integrity of the ocean’s ecosystem. Overall, despite the COP26 agreement, a lot must still be done to make everyone realise how the ocean poses a huge threat to climate change and there are many existing mechanisms and laws (i.e., law of the sea convention) that have negative impacts on the ocean and therefore have large impacts on climate change. [6]
7. This article is about a new way to measure the effects of climate change on the planet’s water. NASA wants to develop a special satellite for this that can measure how much water flows into and out of lakes, rivers, and reservoirs as well as regional shifts on sea level. This satellite will be able to take a global snapshot of all surface water that we have now as well. Besides that, it will also be able to measure the ocean’s energy and heat storage, as well as how carbon moves through the ocean. It is important to measure the effect of climate change on the planet’s water, because water is one of the biggest resources required to sustain life. If the climate change continues it will lead to major landscape and geographical changes in the coming decades. Therefore, it becomes important to understand how much water sloshes around in Earth’s lakes, rivers, and oceans. This is a very important development, because with this new technique we can get a better image on the rising water levels. So, it does not only create an image of the sea levels, but also on the water levels in rivers, reservoirs, and lakes etc. [7]

8. This article talks about the environmental debate over meatless meat. It explains that meat plays a huge role in climate change, because the production of meat causes 15% of global emissions. These emissions are among others coming from cows that belch out methane, transportation, and the growth of crops to feed animals. Another downside of meat is that it requires large quantities of fresh water. For instance, one kilogram of pork requires 442 litres of water. But the article offers a solution for these problems and that is plant-based meat. Plant-based meat only requires 84 litres of water. Plant-based meat is also better for the environment because humans directly eat the crops instead of eating an animal that ate the crops. This is way more energy efficient and causes less emissions. That makes it very good to meet the climate targets and fight climate change. [8]
9. This article is about the influence of climate change on The Great Barrier Reef. It explains that climate change is the biggest threat to the future of The Great Barrier Reef. Due to the rise of the sea temperature parts of the Great Barrier Reef have bleached. Besides that, the increasing CO_2 level in oceans makes it harder for corals to grow. Coral reefs can recover from bleaching over time, but only if temperatures drop and conditions return to normal. The article also mentions some possible solutions to climate change like reducing emissions and helping coral reefs adapt. [9]
10. The impact of plastics does not only impact the oceans, but it also impacts the climate on the whole. Plastics are essential in today's commercial world as they are "durable, lightweight and cheap". But these plastics emit numerous GHGs. Currently, 4-8% of annual global oil consumption is associated with plastics and by 3050 it will take up 20%. Conservation is the best path, but it will take a large global effort to achieve this. The issue with plastics begins all the way in the start of the process. The initial phase starts with oil and gas development which is obtained through fracking which is very environmentally costly. The production and transportation cost emits from 12.5 to 13.5 million metric tons of CO_2. Since most plastic is made for single use, there are 3 ways to process the packaging: landfill, incineration, or recycling. Out of those three incarnations is the worst. Research suggests that only 2% of plastics are recycled. The lack of recyclable plastics is having large environmental impacts. This is seen through China as their contamination levels have increased a drastic level since countries sent their wats to China for a long time. Furthermore, plastic can break down into smaller pieces and fall into the water streams which is very bad not only for one's health but also for biodiversity and ecosystems. There are many solutions to this issue, but some include advocating for bio-goods, using only zero carbon energy sources but when generating these ideas, it is crucial to think about what materials will replace plastic in the future. [10]
11. Climate change is an evident event, but this is further proven by science. The proof comes by understanding the physics behind GHGs impact on the atmosphere as they trap some of the planet's heat before it can escape to space. In most of the world, in 2020 it was considerably hotter than in the 20th century this is due to the large emissions of industries (factories). In the science community, 90% of scientists agree with climate change being a reality but there are still notable figures such as Willie Soon who are against it by suggesting otherwise but that is done through a set of assumptions which do not make much sense. The research suggests that temperature has been getting measured and predicted from the 1800s and that the planet has not been this hot in the past 1.000 years. Scientists have tried to detect the causes of climate change and have agreed that humans are the main cause for this effect and that developed economies emit considerable emissions but that other countries such as China and India are the largest emission producers. The evidence behind GHGs causing temperature rising is done through predictions and models. Overall, the temperature increase is having

significant impacts on the environment. Some might suggest that climate change is a natural process which in part it is but has been speed up by human actions. Overall climate change not also leads to changes in precipitation levels and in the near future could have a range of consequences we could not imagine. [11]

12. Climate change can be defined as a variation in average weather conditions. The impacts of climate change have had the worst impact on the countries who have contributed the least to climate change. To measure climate change, earth-orbiting satellites are used. The causes of climate change are varied, the include natural causes such as volcanic eruptions and GHG concentration levels. Other causes are due to humans; this is done through GHG emissions. The levels of emissions are higher than the past 800.000 years and have risen 46% since preindustrial times. Burning of fossil fuels and transportation are also major sources of these emissions. Approximately 8.1 billion metric tons of CO_2 are released through fires and burning which is roughly 20% of all global CO_2 emissions. Despite oceans being able to absorb these gases the levels are so high that they are unable to absorb it all. The impacts of climate change include more extreme weather conditions, dirty/polluted air, higher health risks, rising sea levels, warmer and more acidic oceans, loss of biodiversity and ecosystems. There have been many international agreements to tackle these issues the most famous being the Paris agreement, but the action must start from the individual by acting themselves. [12]
13. Despite common belief, climate change and global warming are not the same thing. Global warming is in fact a contributor to climate change and refers specifically to the surface of the earth temperature. The term global warming was first coined in 1975 by geochemist Wallace Broecker but this phenomenon has been studied from the early 1800s. In the early 1900s was when the effects of climate change began to be researched and when small actions began to be taken. The causes for climate change are diverse. There is of course the greenhouse effect but in nature as volcanoes erupt and natural disasters occur, climate change still takes place. The greenhouse effect is in part caused by vegetation, but it has been increased even more by human activities. The GHGs humans have created and HFCs, PFCs and SF6 which are used in electrical transmission and aluminium production, have an effect on earth thousands of times larger than natural causes. There have been many studies and predictions regarding climate change, and it was concluded amongst other things that 97% of scientists agree that human activities have affected global temperature increases. Despite this, there are many sceptics who (in the USA its mainly Republicans) who note that this is a natural cycle and that that the use of HFCs and PFCs are a sort of solution to the alleged issue as before, CFCs were used which were much worse for the environment. The effects of global warming are vast. Around the world we have seen numerous fires (i.e., in California), severe flooding (i.e., in the Pacific Ocean islands), sandy storms (in East Coast USA) and many more. These impacts also affect biodiversity as habitats and species are lost including farmland which could and already has led to famine in some cases. There have been numerous international responses with treaties such as the Kyoto Protocol. The creation of UNFCCC, Paris Agreement (2015) … [13]
14. The article discusses the impacts of acid rain on ecosystems. Acid rain affects all ecosystems, but the clearest effect is seen in marine ecosystems such as lies and streams. The acid rain not only comes from the sky but additionally from soil which runs into the water stream whereby more aluminium is releases (which is terrible for the ecosystem). It is true that some species can tolerate high levels of acidity but on the whole most species can't tolerate high pH levels. Acid rain leaches aluminium from the soil which is harmful for plants and removes nutrients and minerals from the soils that trees need to grow. With larger trees, acidic fog can absorb nutrients which lead to the plants dying and going brown by making them weak and vulnerable. It must be noted that many forests and lakes have a "Buffering Capacity" which is a kind of protection

system against acid rain, so they aren't affected by it. Since acid rain is formed by nitrogen, this leads to a decline in fish population in coastal areas and also damages many materials which has lots of costs to maintain and repair. Furthermore, there are also other effects including the visible pollution, the negative impact on human health. [14]

15. This article gives a general introduction to soil erosion, specifically how it threatens agriculture. Soil erosion is essentially a process by which the impact from water or wind detach/remove particles of soil leading to soil deterioration. This has become a very common problem in the current time and it so threatening that lands worldwide might not be cultivable anymore. Erosion leads to very high inefficiencies in the agricultural sector. The eroded soil can flow into streams and waterways which is not good. Water can cause soil erosion when there is excessive rainfall as the soil cannot absorb it fast enough and leads to soil particle detachment and later on transport of detached particles into water. The main types of erosion are sheet, wind, rill, gully, and ephemeral erosion. The most effective and necessary measure to prevent this is to cover the soil with pasture or meadow as suggested by numerous studies. Another method is also managing the plant residue by reducing runoff and preventing the soil surface from flooding [15]
16. The video talks about how 83% of farmland is used for livestock. This is 26% of earth's total land area. It also mentions how the water needed for the meat and dairy industry is 27% of global freshwater consumption. This could be seen as a waste since only 4% of the proteins and 3% of the calories go into the beef that humans consume. The video explains further how much resources go into meat and how little it benefits humans. It also touches upon the topic of greenhouse gases [16]
17. This video shares a light on how much of a waste production of "stuff" is. A lot of items get thrown away because people do not need it and it ends up in oceans. Having factories operating so much is very bad for carbon dioxide in the atmosphere as well. It talks about how companies trick people into buying their products. It is stated that a zero-carbon world will most likely not happen with capitalism. Since capitalism is unsustainable. The video concludes that it is better to return to a lifestyle where we live for human needs focused on wellbeing instead of wants focused on pleasing our mental health. [17]
18. This article touches upon the coral bleaching issue. It starts out by explaining what it exactly is. According to the article, coral bleaching is when corals lose their original colours and change into white. This could happen due to the coral getting stressed out and kicking out the algae that live within it. They get stressed out because of the temperature in the ocean rising. When the temperature remains high resulting in the death of the coral. Other reasons mentioned by the article are low tides, pollution or too much sun. It is mentioned 75% of the world's tropical coral reefs experienced stress. 30% of this experienced stress so severely that the coral died. Further down in the article it talks about how wildlife and humans are impacted by this problem. For wildlife, it impacts biodiverse ecosystems. For humans, it impacts their livelihood, food security and safety. [18]
19. This article talks about the global average sea levels that have risen about 21 to 24 centimetres since 1880. The majority of this has happened in the last two and a half decades. The article blames the melting glaciers and ice and the thermal expansion of the water as the temperature goes up. is a problem for humans because a lot of large cities are located near a coast. Noticeably 8 of the world's 10 largest cities are near a coast. It can also affect existing infrastructure when there is a flood. It explains the methods used to measure sea levels as well. This is done by satellite altimeters and tide gauges. It is stated that the rise of the sea level relies on the rate of future carbon dioxide emissions and future global farming. The speed relies on the rate of glaciers and ice

sheet melting. The article ends with comparing observations from different seas with each other. [19]

20. This article discusses the Paris agreement's relevance to the COP26 summit. The Paris agreement was a single agreement made on December 12th, 2015, in Paris France in which 200 countries agreed on cutting greenhouse gases which are causing global warming and climate change. In the agreement, it was agreed to limit global temperatures to rise to 1,5 degrees and below 2 degrees. It was also agreed to limit GHG emissions from human activity between 2050-2100. These targets were set to be reviewed every five years and rich countries would help poorer countries with climate finance. This agreement is relevant to COP26 as many of the key points from that agreement will be discussed namely the limiting of 1,5 degrees. As for climate finance, in 209 only 79.6 billion USD was raised which is not the agreed upon goal to reach to 100 billion by 2020. The Paris agreement aimed to create a "climate neutral" world by 2050 by reducing GHG emissions as much as possible. In the past 5 years, temperatures have already increased 1,1 degrees, but scientists insist that there is still just enough time to prevent the growth for reaching to a point to which it is unreversible. [20]

Chapter 2: Identification of General Problems and Challenges

Now that there has been successfully identified sources and issues related to climate change, it is time to get more specific and find/identify a number of problems & challenges that are related to the publications that were found and summarised in chapter 1.

List of problems & challenges identified:

1. Eating less meat
   Research shows that eating meat causes a lot of emissions globally. Meat-eaters have a higher carbon-footprint than non. Meat takes a lot of effort and production to get where it is, desired for the food market. It needs transportation, a lot of water and crops to feed the animals to name a few. Cows themselves let out methane as well. All these processes are taxing on the environment. So, eating less meat results into the reduction of wasting resources since the demand decreases which allows the supply of farm animals needing to be catered to, decrease as well.

2. Replacing damaging sources of energy by green energy
   Emissions from factories, cars and other industries are causing the temperature to rise and affecting climates on the planet to alter, in some cases for the worst. A number of these emissions is caused by the usage of fossil fuels and other fuels that cause a lot of CO_2 output. These emissions must be reduced, and green energy must be replacing these damaging sources of energy.

3. Rising sea levels
   Due to temperatures rising more ice is melting into the sea. This increases the volume of sea water. The rising of this water impacts infrastructure made by humans and also the creatures living inside of the sea.

4. Bleaching corals
   Corals start to bleach when they are stressed. This stress is caused by the rising temperature in the sea. It eventually dies when the temperature does not lower. This is a problem because the corals are disappearing. Certain sea creatures and humans depend on them. So, the biodiversity is threatened and the livelihood of humans that live near them.

5. More extreme weather conditions
   Due to global warming, you can see clear signs of climate change. Not only do you see this problem occur during warmer seasons, but it also happens in the colder seasons. The occurrence of a wildfire, tsunami or other type of natural disasters are increasing rapidly. This is a big threat for humans, infrastructure, and nature itself.

6. Consuming less energy
   Energy is wasted in a lot of sectors. Even in homes it gets wasted a lot by for example leaving a light on even though it is not necessary anymore. Majority of this energy is not green energy, so it is costly to produce. Getting materials originated from nature to use

for energy, is draining the earth. To reduce or nullify this occurrence people must be more aware of how they should use their energy.

7. Rising temperatures
   The results of rising temperatures are showing clearly. The summer seasons are becoming more extreme to bear, ice including permafrost, is melting. This becomes a problem for wildlife and humans. It is easier for wildfires to start in this environment.

8. Misuse of clean drinking water
   In the Netherlands drinking water is used for everything in a household. It even gets used as toilet water. Water taps are left turned on without this being necessary leading to unnecessary water usage. This is worrying since there are countries that do not have the same access to clean drinking water as Dutch people do. Knowing that the water gets wasted in ways like these is alarming.

9. Toxic gasses that remove the ozone layer
   Many facilities, cars, ships, and different machines, nowadays emanate lots of CO_2 gas that dangers the Ozon layer. People started developing electronic cars that no longer use fuel and use rechargeable battery, but there are still a lot of cars that basically need to be changed and the industry of this type of cars will continue for at least 5 – 10 years. The main problem lies with the factories and facilities because they are emanating too much CO_2, and even with filters they still pollute drastically. Nowadays the Ozon layer became very weak, and many fires are generated because of that. We should focus on preserving and helping the Ozon layer to regenerate, by reducing the factories or at least change how they usually work.

10. Soil erosion
    Because of many winds and storms in the agricultural area the soil becomes less and less usable. The soil does not have time to absorb the amount of water from strong rainfalls or from strong winds that damage the soil cultures. A good solution to help those soils recover is to add more and more often layers residual substance.

Chapter 3: Identification of Relevant Problems

In the previous chapter 10 problems and challenges related to climate change were identified, but there is still a necessity to narrow down even more and try to identify not just issues and problems related to climate change but also problems that are relevant and that have a direct impact on our daily living. In order to do this a smaller pool of relevant problems must be identified and understand why they are relevant.

This can be seen in the list below:

1. **Water consumption in living spaces**
   Water consumption in living spaces is very high compared to what is required in living spaces. This leads to large amounts of water being wasted which is not a good thing as the clean water cannot be used for other useful activities and issues such as dealing with water scarcity.

2. **Biodiversity**
   The decline in biodiversity is a very big problem. The estimation is that in a few decennia 1 million of the total 8 million species will be extinct. Climate change plays a huge role in this. This is because climate change disrupts the balance in many ecosystems on Earth. Not all the species are able to adapt to these changes and will have a big chance to disappear. Also due to the rising sea levels, some habitats of animals will simply disappear. This is another reason why climate change needs to be tackled.

3. **Pesticides**
   Pesticides are used to fight pests and diseases so that plants can prosper. However, it is found that majority of pesticides are bad for nature. It can cause damage to the soil, water, insects, and the plants themselves. An example of a bad pesticide is DDT. This was majorly used in the world, but it is found that it is enormously toxic. It has been banned for a lot of years now, but traces can still be found in nature. [21]

4. **Gas fracking**
   The practice of oil fracking refers to drilling for gas and then filling the ground with water and chemicals. The problem with fracking is that the practice pollutes the air and the water. This water and air pollution is in its place bad for biodiversity. Another problem with fracking is that is directly impacts the quality of drinking water. The most famous effect on drinking water is that the chemicals in drinking water in areas where oil is being fracked is that water becomes flammable.

5. **Oceans becoming more acidic**
   Ocean acidification is the process were the pH-levels of the ocean are rising. The pH-level of the ocean directly effects the life in the ocean in a negative way, mainly because the coral in the ocean is highly pH sensitive. The means that coral has trouble reproducing which negatively effects the whole ocean ecosystem.

Chapter 4: Problem Selection and Motivation

Now that there is a clear and concise list of relevant problems, it is now time to finally select the main problem to focus on. For this project, the main problem that was selected as the main issue is **Water consumption in living spaces** (the first option mentioned in chapter 3). As a group, this was decided for a range of reasons that will be explained below:

For starters, the Dutch average water consumption is 62,7 litres a day per shower per person. That is almost half of your water consumption every day. This is believed to be an urgent problem that must be tackled quickly. The energy consumption that water filter companies generate to clean the water and for the boilers at households to warm up the water is costly to the environment. According to a study, showering for 4 minutes less already saves you up to 70 euros on water and gas (see figure 1). [22] This is equivalent to one and a half years of cooking for an average family.

The large amount of water consumption in living spaces are also affected by laundry cycles, toilet usage, cooking and washing dishes are also factors that greatly influence the amount of water consumption in living places.

Measurements found that 2016 was the hottest year in history. This comes to show that increasing temperatures are proven to be bigger common threats than what they used to be. These temperature increases are leading to more drought. These drought threats have been evident in the Netherlands for the past few years. These droughts have been so alarming that people were even advised to not wash their cars. This shows how precious water can be. Water is often wasted due to unnecessary long showers or other consumptions. For this project, the focus lies on water consumption in households while showering.

For these reasons the decision was made to research how to implement certain ideas surrounding showers into a smart environment.

Chapter 5: Potential Solutions

With a clear problem established, it is time to look at potential solutions that could be used in order to solve the problem we have identified. In order to find optimal solutions, we must analyse them and see to what extent this solution would solve the problem, the risks this would bring, the requirements for those solutions, their impact and of course, how this can be tested and demonstrated.

The main solutions with their respective analysis are:

- **Shorter showers**
  Taking shorter showers would of course not be the complete solution to the issue but would be a major step in the right direction. The risks involved with this is that you might not be as clean, and one might be at risk of skin infections. In order to do this one simply needs to have the will to stop the water after you have finished showering and not leave it on unnecessarily. Doing this would essentially reduce the water consumption in a household which would therefore mean more resilience is created for water scarcity and less water would be wasted.

  In order to assess this, it would have to be tested in a large environment with a large pool of people and the impact could be seen/demonstrated by seeing how the amount of water usage before and after the reduction of showers affected water bills and scarcity levels in the area.

- **Take a shower instead of taking a bath**
  Baths take up considerably more water (and energy) consumption than taking a shower. A bath must be (re)filled each time to a specific water level depending on the size of the tub for people to wash and enjoy themselves. Meanwhile with a shower the amount of water used differs greatly. Some people have a short shower time usually beneath 15 minutes while there are some people who take at least 30 minutes. This is a big difference water consumption wise. You can shower for about 19 minutes in place of one bath. Regular showers use around 4 litres of water per minute so that could sum up to 76 litres of water used [23] So, someone who usually has a short shower duration could save a lot of water by switching to a shower instead of taking a bath.

  The risks of taking a bath are wasting water and damaging your skin. The requirements for this are a shower and a place for said shower. Another requirement would be the willingness of humans to change from a bath to a shower. This solution would have potential in helping with decreasing the water consumption in a household. This solution could be tested by having people try this out for at least 3 months so the amount of water used per month could be compared and analysed to see the difference in water consumption. This could be presentable by making graphs of the results and compare them to before switching to showers and afterwards.

- **Collecting rainwater**
  Collecting rainwater partly solves the problem of water consumption in living spaces, because this solves the amount of water that we use. On the other hand, it does not solve the big power consumption related to water usage. If you still want to get warm water, you still need to warm up the rainwater and that costs a lot of energy.

But the risk of collecting rainwater is that rainwater might not be clean enough. So, there might be some harmful bacteria or hazardous substances in the water that can be bad for your health. On the other hand, collecting rainwater allows you to collect green water that is not harmful to the climate. This is because you consume less energy, because you do not need to waste a lot of energy to clean the rainwater. Besides that, collecting rainwater lets people use less expensive and climate-damaging clean water. So, you save money with it and also save the climate.

The requirements for collecting rainwater will be a big water tank and pipelines to transport the water to and from the tank. But you might also need some sensors and software to measure how much water is in the tank, so that it will not overflow.

You can validate the effect of collecting rainwater by comparing the difference between your previous and current water and energy bill. If you pay less money, the idea of collecting rainwater has worked, because you have used less clean water and energy. This will help in tackling climate change.

The results of this idea are presentable by showing the mechanism of a collecting rainwater system. So, for example show some sketches about how this can work. Besides that, the effect of collecting rainwater can be shown by showing the water and energy bill before and after collecting rainwater. This will make clear for the public how it works and what the effect is.

- **Drip irrigation**
  Irrigation systems require in general much more water than you expect, and if the logic of the irrigations would work with drips of water at specified and programmed times, it would save more water. For example, you have an irrigation system that fills the fields with water 3 times per day but uses a lot of water. What if you changed the irrigation system to put drips of the water 3 times a day, covering the field as the normal water fills do? You would use less water, and this will help in ecosystem.

- **Using grey water to flush the toilet**
  Grey water is essentially the water that can be used for anything aside from drinking. Using this type of water when flushing the toilet would partially solve the issue of water usage in households. Using this method, you might be at risk that some of the grey water accidentally diverge into the water type which could cause health hazards. Doing this would require changing the tubing system inside the household and ensuring that the tubing that reaches the sink does not filter/clean the water before arriving to the toilet. As for the impact, doing this could significantly reduce overall costs of water as producing clean water is costly and clean water is more climate-damaging. The impact of this could be tested by testing the amount of water body runoff and measuring whether the value increases or decreases.

- **Washing dishes by dishwasher instead of washing it by hand** (Inez)
  Contrary to popular belief, washing the dishes by hand uses more water than using a dishwasher. It must be noted that this only works when you optimise the usage by filling your dishwasher to maximum capacity.

  A possible risk of using a dishwasher is that a dishwasher reuses its water, so for individuals with dietary restrictions a dishwasher could have a downside as the water may contain traces of food. Another possible risk with using a dishwasher is that the

soap required is not always eco-friendly. A way to circumvent this by using eco-friendly soap.

This solution does require the user to have a dishwasher, which can be expensive, hard to maintain and prone to breaking. The potential with dishwashers is that because it is technology, it can always be improved. For instance, dishwashers can be improved so that it uses less water. A possible way this can be tested is by letting multiple households use a dishwasher to do the dishes for a period and then letting the same household do the dishes by hand for the same period. Afterwards the water usage in both instances should be compared.

Chapter 6: Solution Selection

With a range of solutions now selected, it is time to finally select the solution that is going to be worked on and executed. For this project the solution that has been selected is that of **showering shorter and/or using less water**. As a group this was decided as everyone believed that it was the clearest solution of tackling the issue head on and is a solution that if executed correctly would have a large impact on the water consumption in living spaces.

Since the solution will consist of **showering shorter and/or using less water**, the objective is to use a water flow sensor to measure the amount of water that gets used by the shower. But if for some reason we are not able to get to that point during the project we can still make a shower timer by using LEDs and an Arduino.

Firstly, the focus is put on the water usage in showers since that is where most water gets used in a normal day. However, there is more collectable data besides this. For example, by using the same type of sensors on normal sinks and have an indication on how much water gets used.

In the perfect world there could be sensors installed on every water using appliance, this way a network can be created. This can be used for hook-up information station or an app. The goal is not to get people to stop using water but rather make them more conscious about how much water they actually use and what that means to the user.

The focus lies on the water usage in shower since this almost contains 50% of all water usage in the Netherlands per person. With the system that the group has in mind the total water usage can be monitored but also how much water is used per minute, this way it is possible to showcase how much water is used during the shower. People can choose to either shower shorter or shower with less power.

The desired goal for the sensors is to perhaps use them for more industrial applications as well. For example, restaurants and clubs use a ton of water while cleaning and making ice cubes. If there was a way you could monitor that it becomes a shocking amount.

A range of topics have been conducted regarding this issue. One of the studies suggested that *"While there are studies that suggest restaurant water usage of as much as 25,000 gallons daily, the more common estimate is that a typical sit-down restaurant uses 3,000 to 7,000 gallons per day, with an average of about 5,800. Another number that pops up in studies is 24 gallons per seat per day."* [24]

For the 24 gallons a day result that comes down to 90 litres per table, if there was a way to monitor this using the same sensors, then you would have the possibility to accurately display how much water gets used in a normal day.

With the other solutions mentioned in chapter 5 it became clear that a change in normal day to day behaviour is necessary. The question that came forth from this realisation was: why not start with the biggest usages?

With the solution clear, it is time to divide all of the necessary roles to the different members of the group. To do this successfully, it is essential to ensure that everyone is comfortable in their role and will be able to strive in that role. The divisions per person can be seen in figure 2 of the appendix.

In order for the solution to be successful, it is crucial that everyone executes their assigned roles on time and efficiently. Aside from considering everyone strengths and weaknesses, a specific effort has been made to ensure that everyone has a chance to work together. The shared objective is that when all tasks have been completed there is a functioning and presentable product.

Chapter 7: Methodology

With the solution selected and the roles divided, it is now time to prepare the methodology for the execution of the project. In order to do that efficiently, first data collection should be considered. With that established, a set of questions must be answered to find an optimal methodology.

Data collection
Firstly, data will be collected by letting several users test the smart shower and measure their water usage for 5 days. This will be measured with the waterflow sensor. The waterflow sensor gives the amount of water that goes through the pipeline per minute. Then the time that someone takes a shower is measured and multiplied by the water flow this gives the total amount of water that someone used.

Secondly, data is collected by a survey. The survey will be short and concise and will ask users questions regarding their hair length, shower duration, type of water cap, paying the water bill, estimation of water consumption, how often they shower, and pressure used in the shower. The reason for this selection is due to the fact that, all these factors influence the amount of water someone needs to wash themselves. With these data a profile can be created that displays what type of person is using it. Using these profiles, it is possible to give an estimate of how long a shower should be for this person.

It is also important to look at the expectancies of the users, so besides timing their showers the group thought it would be interesting as well to look at how long did they estimate they showered. If there is a large discrepancy, it might benefit the research.

The chosen focus for the product is to only raise awareness of water usage and not to shut off the water supply after a while. This is, because this will not make the product attractive to the consumer and then no one will buy it.

In order to ensure for optimal results, it is essential to recognise that the Waterflow sensors that will be used will not need calibration since they are calibrated from the factory. It is also crucial to recognise that the environment that will be used will need to be controlled since there will be water in its surroundings. To protect it, there must be a water-resistant casing build/used.

Throughout this process, data must also be collected and there are going to be two types of data that are going to be collected. Firstly, the time spent in the shower and the amount of water will be measured. Secondly, a survey will be sent out to see if people's expectations about their habits match the outcome of the data.
The time in which the data will be collected for the first type of data is when the person is in the shower, the survey should be taken shortly after. With the added survey a profile can, be formed of what type of user they are.
After the data is obtained, the data will be analysed by comparing results from the questionnaire with each other. This will happen in graph and chart form. Comparing it through a visual aid like graphs and charts gives a clear overview of actual change. With the information obtained, a relevant time period will be determined, and accurate

conclusions will be made with the help of the questionnaire analysis that will have been conducted.

Once the data is collected and analysed data from the form and the people that tested the product, insight will be gained into shower times and how it changes due to the use of the delivered product. From there on out changes will be made to the product.

In order to deem the final product as a valid product that does serve its purpose it should be validated. To validate the product there must be data that can be reviewed and evaluated. This data can be collected by sending out a questionnaire about the length of the shower time to people that are going to try the product. The questionnaire should be answered before the try-out, one or two weeks into the try-out and at the end of the try-out. This is to be sure that the product is giving the desired results of having shorter showers. People could start ignoring the product after a certain period so checking multiple times how their showering habits are changing through a questionnaire gives a better understanding of the use and effectiveness. The objective is to ask at least 10 people to test the product. From the findings of the questionnaire conclusions will be made to determine what the best showering time is. The final questionnaire will make clear how valid the presented solution is.

List of equipment:

- Waterflow sensor
- Arduino Uno
- Green, yellow, orange, and red LEDs (to indicate how much water is used)
- Breadboard
- Wires
- Resistors
- 3D printer
- Plastic cover

Design of product

The design of the product was essentially divided into two parts, a bottom base (see figure 3) and a top (see figure 4). When combining them together a final product design is visualised (see figure 5). The final design is simple enough not to be intrusive to the user while showering whilst also being designed in such a way that the pieces inside the product (i.e., Arduino board) are well protected such that water will not be able to access that section of the product. The LEDs in use are placed under the top piece of the product and is covered in such a way that it is not damaged by water but is still well seen.

The waterflow sensor is placed on the outside of the product to avoid any problems and with a small and compact size, the sensor is not intrusive.

When designing the product a few alternatives were studied one of which can be seen in figure 6 of the appendix.

Code of product

The code for the product can be found upon request.

Chapter 8: Validation

With the methodology in place, the next step is to validate the results that were found. In order to do this, the questionnaire will be analysed in detail and the prototype of the product will be tested.
As mentioned in the prior sections, a questionnaire was sent out to a pool of around 60 people. Participants were asked five multiple choice questions concerning their shower habits. Note that the outcome of this questionnaire is based on peoples own perceptions and this may not represent reality accurately.

The first question concerns the time people spent in the shower. This question is asked to determine how long people think they shower. The result of this question can be seen in figure 7. The existing literature suggests that the average person's shower duration is of about 8 minutes [25]. As seen from the poll conducted, over half of the participants say their showers are in fact shorter than the average shower length.

The second question concerns the amount of water people use in the shower. This question is asked to determine the amount of water used. The result of this question can be seen in figure 8. If we compare this to the existing literature on this subject, it is shown that the average person uses 62,7 litres per shower. [22] With this question, it is clearly shown that over 50 percent of participants believe that they use less water than the average consumer.

The third question concerns how many times a week people shower on average. This question is asked to determine the amount of water used weekly. The result of this question can be seen in figure 9. Based on figure 9, the majority of people shower 3 to 6 times per week. In theory your number of showers will evidently depend on the financial situation and lifestyle of the person. Someone with a more active lifestyle (i.e., more physical activities), would shower more often than someone who has a passive lifestyle or limited financial income. This question does not directly concern the product offered but knowing the shower habits of consumers is crucial when developing this sort of product. It is crucial to understand that the goal is to not reduce the shower times but to reduce the time showers take.

The fourth question asks whether the person pays their own water bill. This question is asked because it would be reasonable to assume that if a person has to pay more money for water, they will be more aware of their water usage. The result of this question can be seen in figure 10, here it is shown that over half of people either do not or do not know whether they pay their own water bill. This clearly demonstrates that many people are not aware of their own water usage and hence unaware of the environmental impact their water consumption has.

The fifth question asks whether the person would consider buying a product that limits their water usage. The result of this question can be seen in figure 11. It is shown that less than nine percent of people would not consider buying a product that would limit their water usage. Analysing this question in detail, it is evident that the product being

designed would clearly be marketable in today's market and would most likely have a large consumer support.

A second questionnaire was made for those who used the prototype. The questionnaire that was filled in after using the prototype had five questions. The first one was about how long the participant showered while using our product (figure 12). Here the received answer was 6 to 8 minutes. This is less than what the majority voted on the previous questionnaire.

The second question was related to how much water the participant thinks they used while showering (figure 13). The most answered answer was the same as the previous questionnaire, it being 30 to 50 litres.

The third question was related to the water pressure used (figure 14). This was to see a pattern in behaviour and water usage. The fourth question was asking whether the participant would consider implementing the product into their daily life. The participant answered that they would. This matches what was found in the previous questionnaire.

The final question was related to improvements that could be added to the final product. Here the participant said that they would like to see more colour options. This is important feedback that could be used in finalising design choices.

Chapter 9: Results and Conclusion

With everything now in place, the results for this product can finally be seen. At the end, the product that was made was a simple box with LEDs on the cover which change colour depending on the amount of water used. This is done by the waterflow sensor that is found on the exterior of the box and which can easily be attached to the shower cap.

With the results of the survey mentioned in chapter 8 the following conclusions can be made. People are aware of their shower times, but it is uncertain whether they are as equally sure about their water consumption during their showers. Majority believes they use less water than the average person. Over half of the participants does not pay their own water bill so they do not know the actual usage. Only a small percentage of the participants is not interested in a product that limits their water usage.

From the experiment conducted with the final version of the product, it was evident that the average shower times of users was still in place with the prototype users but surprisingly, the amount of water used was slightly less that average. In general, it was found that despite nearly forgetting to switch it on a few times, the experience was overall pleasant, and it was not too intrusive. Because there was not a lot of time to test it, clear results were not really seen in amount of water used but overall, the product is simple enough not to be intrusive to the user. In the long run it would also be a good tool to reduce water usage in the shower.

The difference in results is most likely due to the first survey having a larger group of participants than the prototype testing did. This was mostly due to time constraints. The solution to this is quite clear, a larger pool of people needs to test the prototype.

Another influence of the results is that the prototype testers did not have the time to test it out for a long duration. This was in largely due the time constraints but can easily be solved by giving more time for users as that way the results will reflect more accurately if patterns and tendencies of someone in the shower actually change over time or not.

The final product has room for improvement, there are additions that could be studied in the future. These could exist out of alternative design options as the one shown in figure 6 or include more personalised levels for the LEDs since different hair lengths and tendencies would change the amount of water needed. This could be done by using an NFC sensor that recognises the person when they are in the shower or alternatively, build an application in which you indicate who is entering the shower.

Additionally, this could also be added around different water sources in houses and connect all the nodes to really make the house itself a smart environment.

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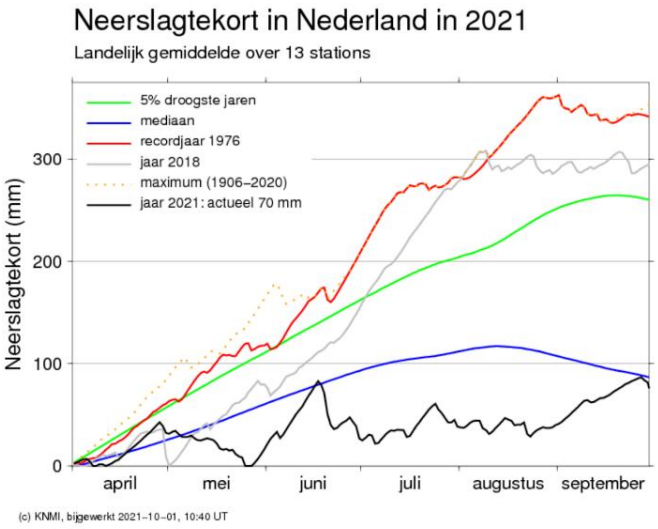
Appendix

Figure 1: A graph and table showing water consumption in an average Dutch household in 2021



Water for...	Litres per day
Shower	62.7
Toilet	35.3
Washing machine	12.3
Washing clothes (by hand)	2
Bathroom	5.8
Washing up (by hand)	4.6
Dishwasher	1.4
Cooking	1.3
Bathing	1*
Coffee and tea	1
Drinking	0.7
Other things	5.7
Total	**133.4 litres**

Figure 2: Table showing the division of roles in the group

Name	**Roles**
Soham	Team Leader, management & coordination
Tom	Design and building required hardware
Daan	Programming the code behind the solution
Alex	Analyse data received from questionnaire, and programming assistant
Rita	Analyse data received from questionnaire, documentation, and testing/validating the process
Inez	Prepare & send out the questionnaire, research, and documentation

Figure 3: Diagram showing the bottom piece of the product

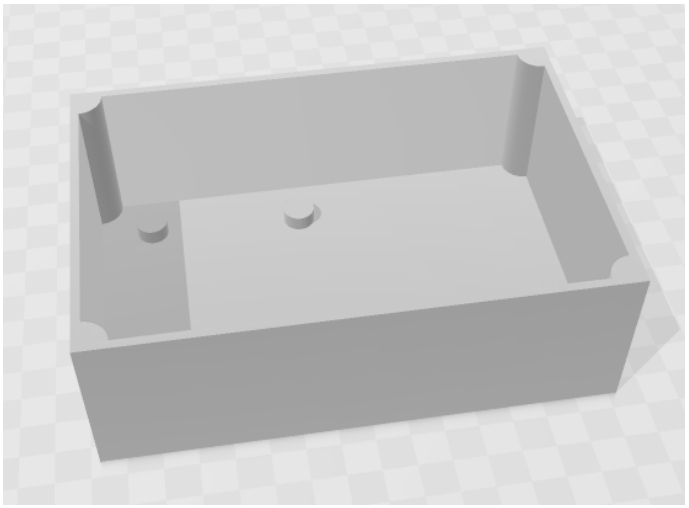


Figure 4: Diagram showing top piece of the product

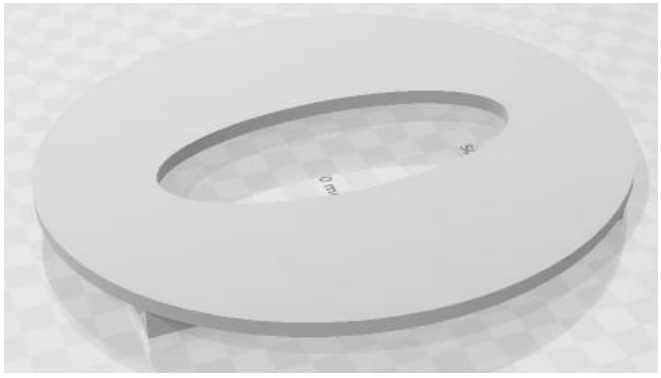


Figure 5: Diagram showing final design of product

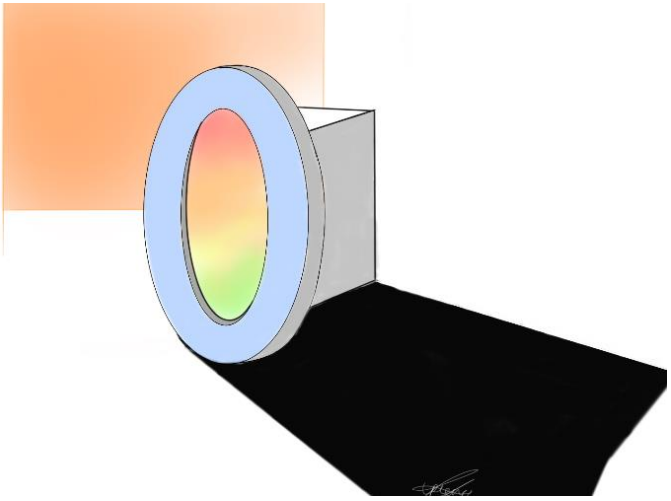


Figure 6: Alternative design of product

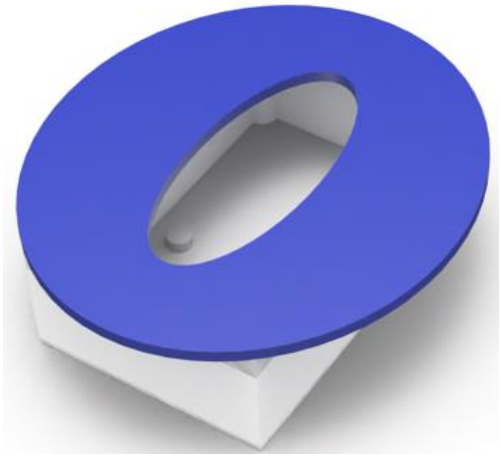


Figure 7: Pie chart of questionnaire asking how long people think they shower

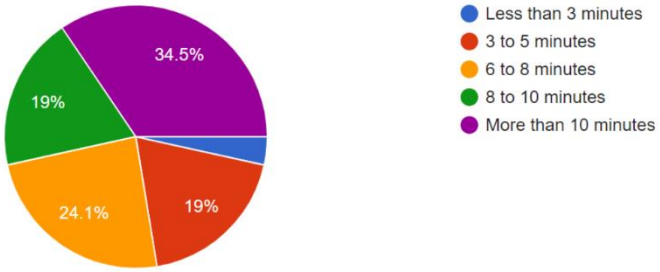


Figure 8: Pie chart of questionnaire asking how much water participants think they use during a shower

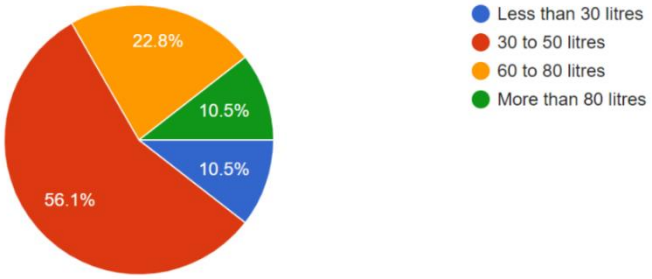


Figure 9: Pie chart of questionnaire asking how many times a week participants shower

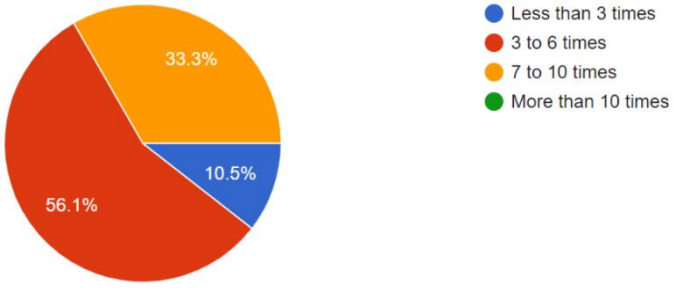


Figure 10: Pie chart of questionnaire asking if participants pay their own water bill

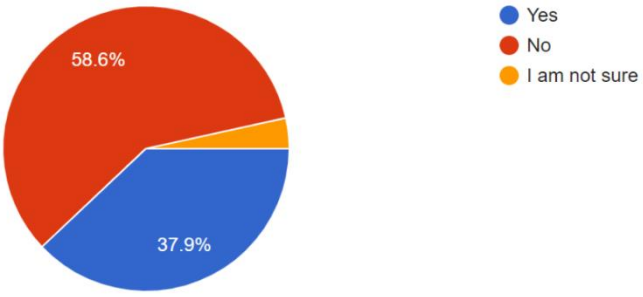


Figure 11: Pie chart of questionnaire asking if participants would use a product that limited water usage

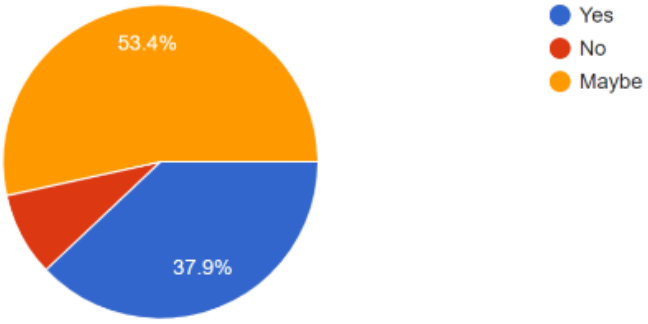


Figure 12: Pie chart of prototype questionnaire asking how long the participant showered while using our product

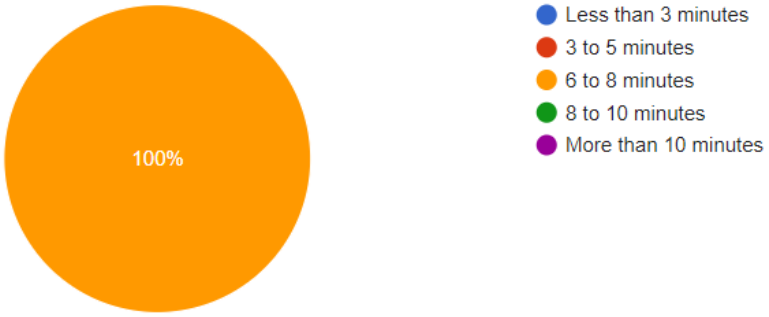


Figure 13: Pie chart of questionnaire survey asking how much water the participant thinks they used while showering

Figure 14: Pie chart of prototype questionnaire asking what water pressure the participant used

Figure 15: Pie chart of prototype questionnaire asking whether the participant would consider implementing this product in their daily life