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Engineering Visions 2018 – Smart Solutions

WOH – Water Optimising Home

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Foreword

This project was carried out as part of the summer school "Engineering Visions 2018 – Smart Solutions" in Enschede, The Netherlands. The program consists of a short two-week project, focused around developing visions for the future and promoting international cooperation.

We, the project group, were given an issue that requires thinking towards the future to solve the problems of tomorrow. The issue presented was the increasing need for water in a world where population is growing.

As part of the project, all members had to perform a DISC personality test, to see how different people would respond to various situations, and how you worked with them in an efficient way (See Appendix A).

We acknowledge that the ideas presented in this report may not be economically viable as of current measures, but having faith in the future of technology, we believe that systems similar to the ones explained here will be available for use by all humans in the future. Water shortage is something that will affect us all and cannot be ignored. We hope that the ideas developed in this project will be a small part towards helping create a sustainable world in the future.

The WOH project group

Enschede (Netherlands), September 2018

Abstract

Global water shortage is an increasing problem, and with population increasing whilst fresh water levels stay constant, the future may be grim. This report presents a concept for helping mitigate this problem within the household sector.

The problem of global water shortage currently and in the future is introduced. A summed-up description of the problem is given, and goals are set for how to solve it. The vision is defined as having "A household with a low water footprint".

Defining the problem was followed by planning, research, concept generation, assembly and a final check phase.

A WOH (Water Optimising Home) concept is presented, focusing on saving and reusing water within the household. The concept consists of several systems that reduce or eliminate the usage of water, including a washing machine, a dishwasher, a toilet, a system for supplying sewage to local farms, an efficient plumbing system, a mist shower, a local water recycling system within the house, a switch for taps and a rainwater collector. A short animation was also created to help raise awareness for the issue.

Finally, the concepts are discussed together and individually, highlighting strengths and weaknesses. The report finishes by giving some suggestions for how to change human behaviour regarding water waste.

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Glossary

Term	**Explanation**
Blackwater	Water that comes from sewage and contains faeces and urine
Fresh water	Water that is deemed clean enough to drink or cook with.
Greywater	Wastewater generated in households from streams without faecal contamination, i.e. all streams except for the wastewater from toilets. Sources of greywater include sinks, showers, baths, washing machines or dish washers etc.
Wastewater	Water that is no longer clean due to human use
Water footprint	How much fresh water is consumed by a person or used for production of a product/service.

1 Introduction

1.1 Background

This engineering vision is about the future, specifically focusing on the future state of our environment and water resource systems. When considering the future, it seems there are two choices: to passively let the future happen and react to it, or to proactively shape the future by taking steps that will beneficially impact the state of the world and the resources available to those living in the future. Humans benefit and suffer today from the decisions made by their preceding ancestors.

Water is the driving force of all nature. Unfortunately for our planet, supplies are running dry at an alarming rate. The world's population continues to grow while the amount of fresh water stays constant.

97.5% of seawater can't be used for human consumption. The global demand on water is predicted to rise by 55% between 2000 and 2050 (Smedley, 2017). The shortage of water is largest in the agricultural sector, approximately 70% of water withdrawals (UN-Water, 2018). With food production needing to grow by 69% by 2035 to feed the growing population (Smedley, 2017), water shortage will become an increasing problem. Water withdrawal is also an increasing problem for the energy industry; water usage for cooling in power stations is also projected to increase by over 20% in the near future (Smedley, 2017).

Even though household water only accounts for 10% of the global water shortage, it is the largest growing sector (UN-Water, 2018) and a very crucial part of our survival. Without water in households, society won't function. Being reliant on fresh water reserves is a problem, since these are rapidly decreasing (Smedley, 2017). Furthermore, if the quality of water is dependent on the quality of the fresh water reserves, this requires humans to heavily invest in keeping these resources unpolluted and uncontaminated. For this reason, it is desired to have a more decentralised handling of water, reusing and recycling water locally in houses and smaller communities.

1.2 Project basis

The purpose of the project is to create a vision about future states of technologies and human behaviour that can solve the current problems. The problem was formulated in one sentence: The water shortage in the future due to increased population, climate change and pollution.

As the project is carried out during an intensive course working with visions for the future, there are several points of interest relating to this:

- The group can go outside the bases of current technology
- The group must be realistic in their visions and are not to disobey basic natural laws

- Since the project mainly focuses on visions for the future, it is not necessary to go too far into detail on each instance of the system

1.3 Goals & Vision

Because of how wide the topic is and the limited time, the project focused on fulfilling the following goals:

I) Combine technologies to create a household-system that minimises the need for fresh water and maximises the use of recycled wastewater.

II) Educate people on the long-term benefits of preventative and recycling methods relating to water.

The vision for the future was determined as:

A household with a low water footprint.

1.4 Scope

The project covers the following topics:

I) Water saving technologies for households

- I.I Washing machine
- I.II Dishwashers
- I.III Toilets
- I.IV Showers
- I.V Local recycling of wastewater
- I.VI Taps

II) Human behaviour and awareness

- II.I How human behaviour impacts water usage
- II.II Whiteboard animation (video)

2 Method

This represents the procedure used for approaching and accomplishing the predefined task. It is divided into the following phases.

2.1 Defining the problem

This phase involved identifying the problem and its components. A proper definition helped create the scope for the project and contributed to understanding the problem. This gave the project a smoother transition into the middle phases, when coming up with solutions. The project scope and goals were decided, and these were the basis for the group's worded vision. Finally, different areas were identified in which the goals could be achieved.

2.2 Planning phase

A strategy for how to achieve the goals was planned out. The project was broken down into smaller tasks/assignments, and a tentative schedule was made for meeting the deadlines.

2.3 Research and concept phase

The affected areas of the problem were researched separately, using the strategy decided in phase 2. Concepts for each area were brought forward based on research and the group's ideas. The results were discussed, and further work and research was carried out to perfect the decided concepts and their plausibility.

2.4 Assembly phase

The information was brought together and assembled into a full concept of a house that reduces the need for fresh water. The concepts were discussed together and altered according to feedback from the group and mentors.

2.5 Final check and presentation

The final phase involved checking through the results to make sure they fulfilled the goals. Preparations for the presentation were made, and a short movie was created to improve people's attitude towards saving water and reusing recycled water.

3 Results

The created concept was named WOH – Water Optimising Home. Its purpose was to be a house with a low water footprint, that minimises the need for fresh water and maximises the use of recycled wastewater.

3.1 Washing machine

Instead of using water to wash the laundry, liquid carbon dioxide (CO_2) is used in the future. CO_2 is passed under high pressure into a specially designed washing machine (See Figure 1). At a pressure of 50 bar and a temperature of -73° C, CO_2 behaves like a liquid, removing dirt and grease effectively and quickly. The low temperature also kills any bacteria and makes the laundry fresh and soft, and at the end of the wash cycle, the laundry is dry and can be reused directly. After the CO_2 has cleaned the laundry, it will be returned to the tank by a pump and can be reused. This system eliminates the need for both water and cleaning chemicals. This type of system is used in industries today and might therefore be available for households in the future. (Von Ullrich, 2009)

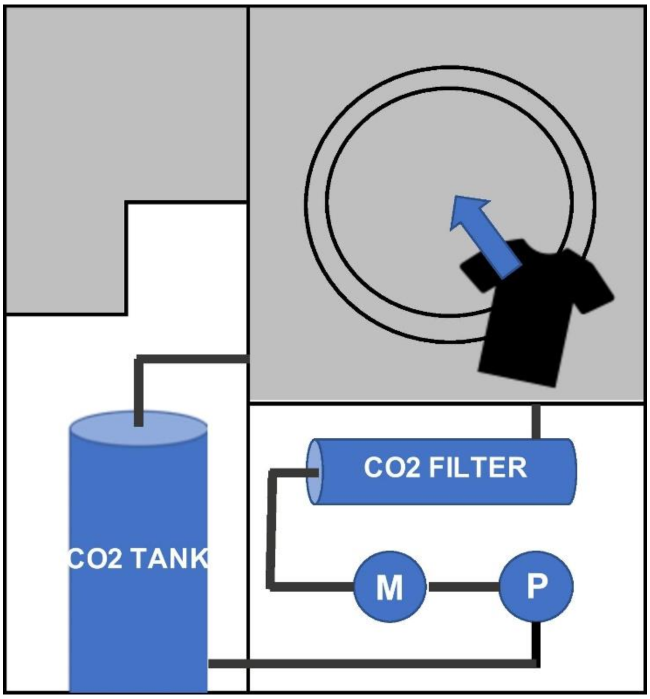

Figure 1 A schematic of the CO_2 washing machine.

3.2 Dishwasher

The water-eliminating dishwasher of the future will use a technique called Carbon Dioxide Snow Cleaning (Sherman, 2007).

The liquid CO_2 is stored in a tank (See Figure 2). When the dishwasher is turned on, the CO_2 is propelled at the dirty dishes at moderate velocities. Upon impact, the liquid CO_2

transforms into the gas phase, drastically increasing in volume and forcing the remaining food off the plate (Sherman, 2007). After the cycle is finished the CO_2 vapor will be collected and reused by using the method suggested by (Keith, et al., 2018). This system yields food remains that will have to be collected at the bottom of the dishwasher. It also eliminates the need for water and cleaning chemicals.

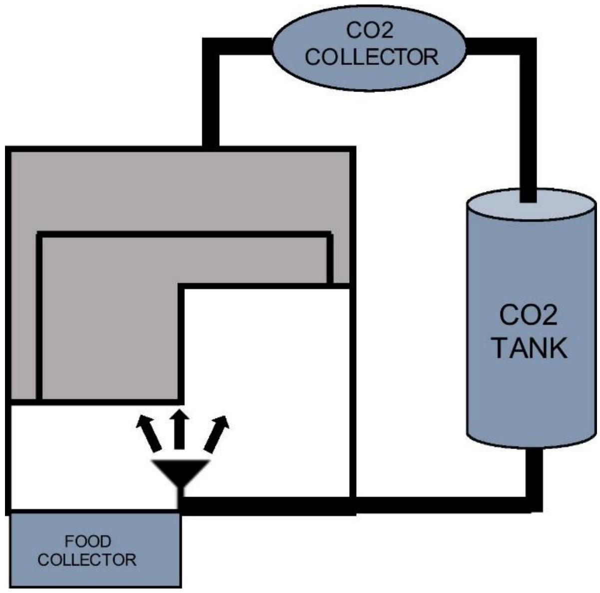

Figure 2 A schematic of the CO_2 snow cleaning dishwasher.

3.3 Toilet

Instead of using large amounts of water to flush like traditional systems, the toilets of the future will minimise the amount of water needed (See Figure 3). When the toilet is flushed a valve opens, and a vacuum pump sucks the waste into a tank, using the idea behind vacuum toilets found on airplanes (How Stuff Works, 2018). This tank contains what is called blackwater, which will be conveyed to local agricultural areas or urban greenhouse farms, that double up as waste treatment centres (See section 3.4).

A vacuum toilet won't use much water, less than 1 litre (Jets, 2018). Compared to a traditional toilet that uses 6 litres (Converse H2O, 2009), this concept saves 83% of the water.

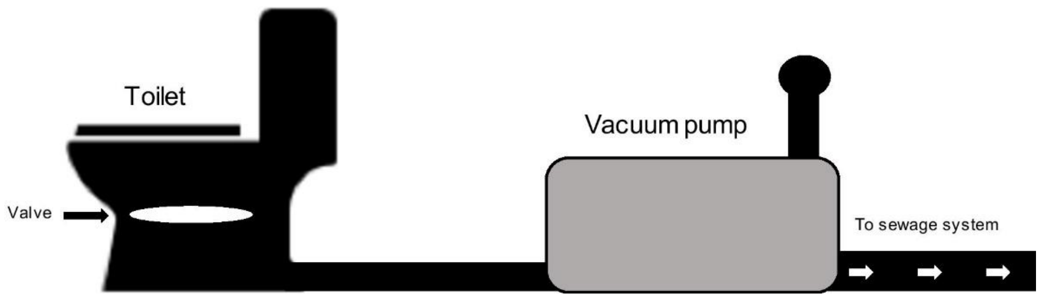

Figure 3 A schematic of how the toilet system works.

3.4 Community sewage handling

Here, the blackwater is put through a biogas reactor that produces energy that will be used to power the farms or warm up the greenhouses. The process also produces fertiliser as a bi-product, which will be used on the farms (SimGas, 2012). The food that is produced will be sold locally and consumed by the households supplying the farms with blackwater (See Figure 4). This creates a decentralised handling of sewage and production of food, which helps keep the cycle of water within smaller communities.

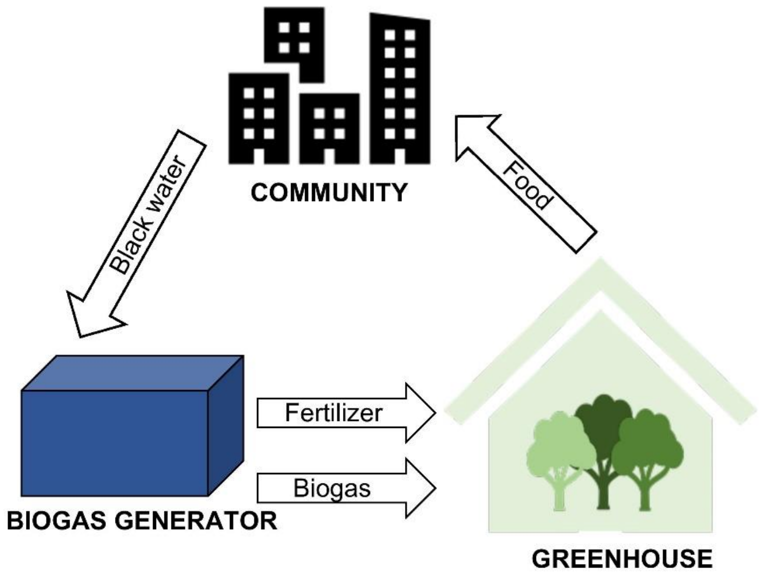

Figure 4 How the household and aggriculture affects each other.

3.5 Plumbing system

Another issue was that water is often wasted when waiting for it to reach the right temperature. Therefore, the plumbing systems in the house must be very efficient, not having long distances between the water boiler and the taps. The pipes leading warm water must also be insulated well so the waiting time is reduced or even removed. For mixing warm water and cold water, an electrical system will replace the traditional mechanical one, to increase the precision of the temperature regulator.

3.6 Shower

Existing shower designs are ineffective, using 7.9 litres/min on average (Home Water Works, 2018). To reduce the amount of water, a new concept for future showers is needed. This shower will use a mixture of current and future technologies.

A lot of water is wasted while waiting for the water to reach the desired temperature. The plumbing system described in 3.5 will be used, as well as an electrical temperature regulator with better accuracy and a faster response time (See Figure 5). This regulator will accurately show the temperature of the water before the tap is turned on, giving users the ability to reduce water waste.

A future technology, currently being developed (Nebia, 2016) (CINTEP, 2013), is the idea of splitting the water into millions of tiny droplets, creating a sort of mist that replaces the stream of water used for cleaning the body (See Figure 5). Using this technology, a larger area of the body can be showered at once, whilst reducing the amount of water used by up to 70% (Nebia, 2016) (CINTEP, 2013).

A reminder will be added that notifies the user when they have showered for 5 minutes, to make humans reflect on how long they are showering.

Figure 5 The shower of the future, using mist instead of water, and recycling it.

Finally, a recycling system for reusing the shower water will be implemented (See Figure 5). The collected water is filtered and quickly treated, being reused in the same session to reduce the need for a constant supply of new water. After showering, the water is sent to the local water recycling system (explained in 3.7).

3.7 Local water recycling system

A system for locally filtering and reusing water was developed (See Figure 6). The greywater gets collected from showers and sinks, is filtered and reused. Greywater can be filtered into fresh water (Cernansky, 2013) and although this is currently quite costly, the project group believes this technology will develop and become more available in the future. Rainwater is also collected using the system described in 3.9, which adds a small amount to the water cycle.

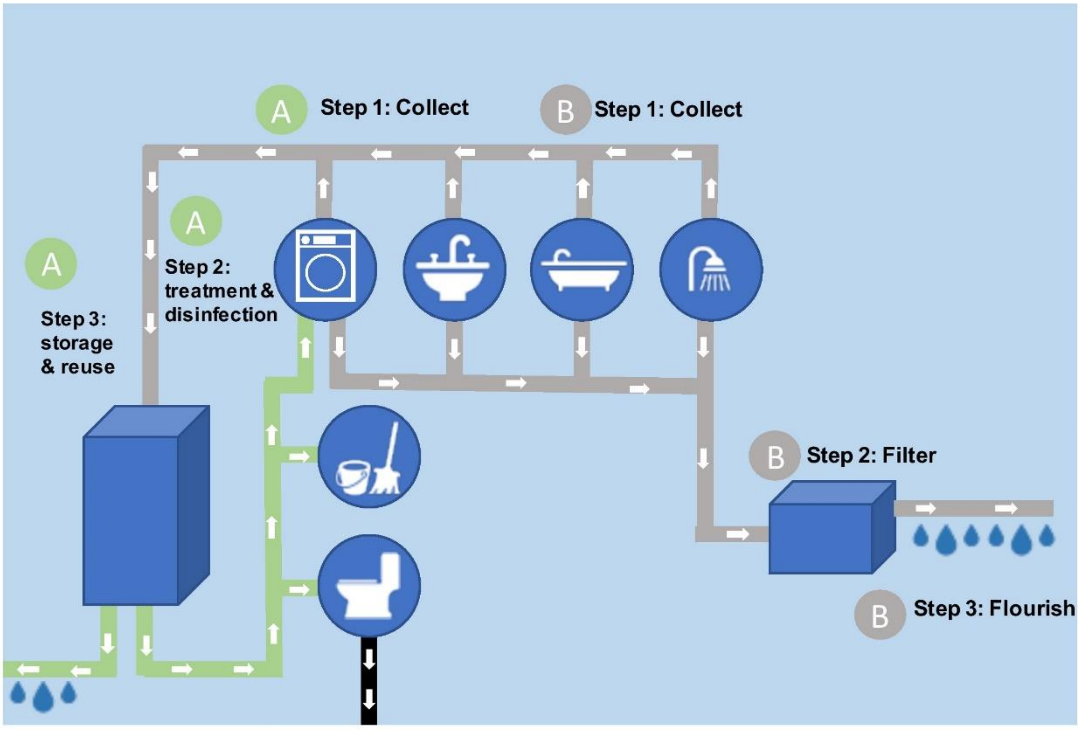

Figure 6 A schematic for the household water recycling system.

3.8 Tap

The group investigated concepts to locally heat water closer to the taps, to reduce the time one must wait for the water to reach the desired temperature. However, these concepts require a very high amount of energy to heat water quickly, even when operating at very high efficiencies. Therefore, it was determined that the kitchen tap shall not be focused upon, and that the plumbing system described in 3.5 was sufficient to reduce this type of water waste. Instead, a concept for choosing whether to use fresh water or recycled water was introduced.

Recycled greywater is not drinkable and shouldn't be used for cooking (Energie Tipp, 2013) but using it for other purposes can reduce the need for fresh water in the household.

A simple mechanical switch that changes between Recycled Water and Fresh Water is a solution to this problem (See Figure 7). The switch controls two different valves. The first valve controls the fresh water and the other valve controls the recycled water. A logical antivalence ensures that only one valve is open at a time.

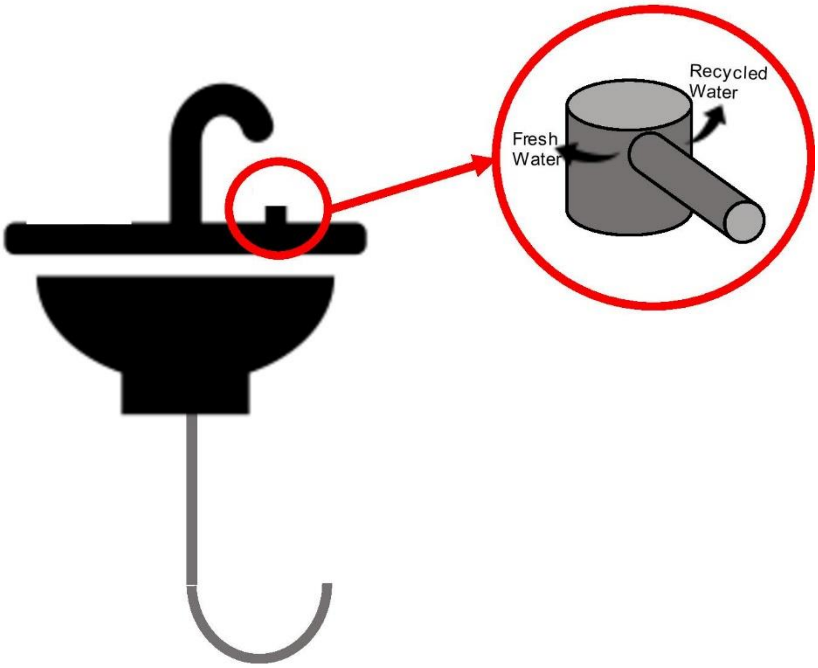

Figure 7 A schematic of the recycled /fresh water switch.

3.9 Rainwater collector

In areas that have a somewhat constant supply of rain, rainwater collectors will be used on the roof. Some of the rainwater will be put into the household water recycling system (3.7). The rest can be used for watering the garden (if the house has one). If there is not a garden, or if the garden is already sufficiently watered, the water can be transported through pipes to the local agricultural facilities to help complete the community's local cycle of water (explained in section 3.4).

3.10 Whiteboard animation (movie)

A short animation was created titled "Walter Water". It describes the story of a fictional character called Walter Water, how he ran out of water one day and had to learn about new technologies and methods for saving water. The film was created using a technique called whiteboard animation. Its purpose was to raise awareness for the issue and to make people change their behaviour about water usage and their ideas regarding new water saving technologies.

4 Summary of results & Conclusions

An overview of the house, highlighting all the system is seen in Figure 8.

1) A low water toilet that saves 83% of the water and then sends blackwater to local agricultural facilities to be converted into biogas and fertiliser.
2) A mist shower that saves 70% of the water, reuses it for the showering session and then sends it to the households recycling system.
3) A dishwasher that uses CO_2 snow blasting to clean the utensils, eliminating the use of water.
4) A washing machine that uses liquid CO_2 at high pressure to clean the clothes, eliminating the use of water.
5) A local water recycling system that filters and reuses all water in the house, except water used for toilets and drinking.
6) A switch that converts the tap between recycled water and fresh water, reducing the need to excessively filter fresh water.
7) A rainwater collector to meet the household's water intake needs.
8) An efficient plumbing system that reduces the time needed while waiting for water to reach a desired temperature.

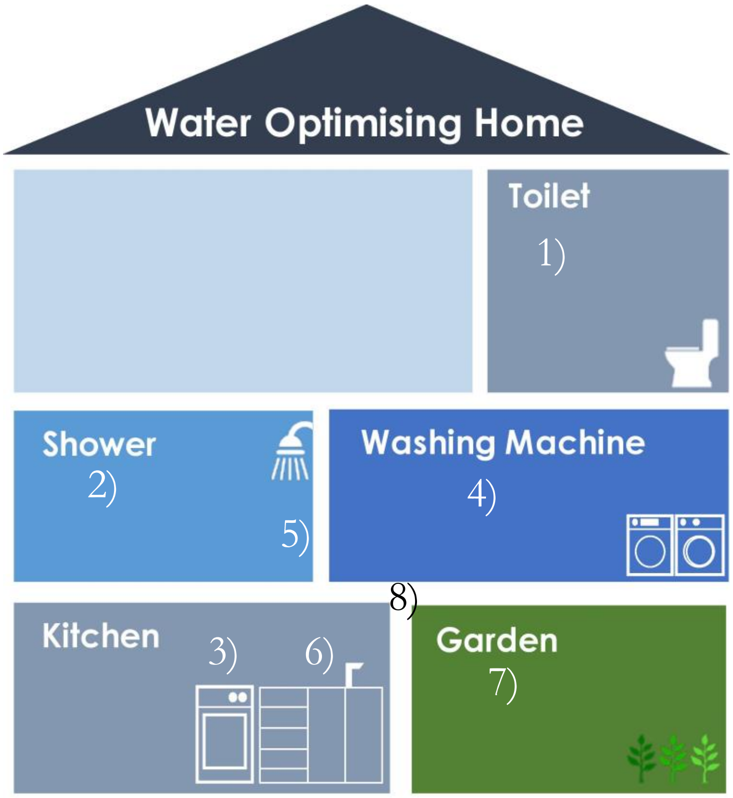

Figure 8 An overview of the WOH house.

A short whiteboard animation movie was created: "Walter Water", to help raise awareness for the issue and to change consumers behaviour and attitude towards new technologies.

5 Discussion

5.1 About WOH

In general, the Water Optimising Home saves a fair amount of water, and will be an important part of the future of water management. However, there are some problems with the concept.

Given that households only stand for 10% of the water shortage worldwide, this may not have the biggest impact on reducing global water withdrawals. Focusing on agricultural saving may have given a larger decrease in the total water shortage. However, as mentioned in the introduction (section 1.1), water within households is an incredibly crucial part of our society's survival. Being very dependant on fresh water reservoirs will create even bigger problems in the future, since these are already being depleted. Therefore, focusing on the household sector is a very crucial part of reaching a sustainable handling of water.

Also, the implementation of these systems may be costly and take, since building infrastructure is a slow process and people might not want to spend money on changing their systems quickly (instead they would possibly prefer to wait until things are being renovated).

5.1.1 CO_2 Washing machine & Dishwasher

The advantages of the CO_2 washing machine and dishwasher is that they eliminate the need of water. They also operate without cleaning chemicals, which reduces the impact of toxic substances on the environment. However, one must keep in mind that the production and cooling of liquid CO_2 requires energy, most likely a lot more than using a current machine. Although the energy consumed by these new concepts might be high, one has to remember that water usage is removed, which in turn is an environmental benefit. Imagining that these systems might not be implemented for quite a while, it gives humanity some time to hopefully move more towards renewable energy sources, being able to handle this increase in energy. In addition, a very stable washing machine is needed to withstand the high pressure of 50 bar.

5.1.2 Low water toilet, Sewage system and Biogas generator

This system's advantages are the reduced use of freshwater and the reuse of blackwater. Along with human consumption, this is the only part of the household that "loses" water. However, it is lost to a local agricultural facility where it is used to produce food that will be sold back to the providers of blackwater, therefore helping close the water cycle within a smaller community. This helps households and communities be more independent and not reliant on a freshwater reserve. By reusing water locally, we are able to continue developing our society and will not face as grave challenges with water shortage as we are predicted to.

However, chemicals that are used for cleaning the toilet could be a problem as they will enter the greenhouse cycle. So, we need to change the behaviour of consumers to convince them to use biodegradable detergents, or even more ideally, remove non-biodegradable detergents from the market. However, this will of course be straining on other aspects of society, so it isn't that easy.

Also, the transport of the black water in remote areas may be difficult. Therefore, this might mean that there will be a need to install smaller biogas reactors, greenhouses etc. within houses, and the fertiliser can be used locally within the household.

5.1.3 Shower

The shower reduces the need for fresh water massively, by both having a more efficient method of propelling water, but also through recycling water. Also, having a shower that allows for more efficient showering, as well as a 5-minute reminder, will hopefully make the user shower more quickly and will lead to a change in the human behaviour. Having a more efficient plumbing system with an accurate temperature regulator will reduce the amount of water wasted while waiting for the desired temperature. However, these systems require filters and therefore maintenance, which could be an added cost that most people can't afford until further into the future. Also, implementing the water recycling systems in existing houses might be tricky, meaning the introduction of these systems might take long.

The filters may also struggle so separate smaller particles found in washing products. Similarly to the toilet detergents discussed in section 5.1.2, there must incur a change our human behaviour, and possibly even the producers behaviour, in order to remove these harmful particles from the cycle.

5.1.4 Local water recycling system & Rainwater

Collecting rainwater for the house's cycle will account for the water that is lost via human consumption. In the cases where rain is not too available, a small input of water will be needed to keep the cycle going. However, if this input can be minimised the goals for this project will be fulfilled. One must also remember that collecting rain water may have an impact on the ground water levels. This possible connection should not be ignored, and the amount of water removed from the ground water ecosystem must not be too severe.

The technologies that recycle greywater and filter it to make freshwater exist but are rarely used. Implementing these will be an important part of the household water recycling system, since they help close the cycle.

The potential ecological benefits of greywater recycling include:

- Reduced freshwater extraction from rivers and aquifers
- Reduced energy use and chemical pollution from treatment
- Groundwater recharge
- Reclamation of nutrients
- Greater quality of surface and groundwater when preserved by the natural purification in the top layers of soil than generated water treatment processes.

The potential economic benefits of greywater recycling include:

- Reduced demand for fresh water, leading to a reduced use of fresh water, which will mean that the cost of domestic water consumption is significantly reduced, while alleviating the pressure of global water resources.
- Can reduce the amount of wastewater entering the sewer or on-site treatment systems, therefore not requiring as expensive systems.

Demand on conventional water supplies and pressure on sewage treatment systems is reduced by using greywater. Re-using greywater also reduces the volume of sewage effluent entering watercourses which can be ecologically beneficial. In times of drought, especially in urban areas, greywater use in gardens or toilet systems help achieve some of the UN's goals for ecological sustainability.

5.2 Human behaviours and awareness

People can help minimise the pollution of grey water by being cautious about what goes into their drains, this can be done by avoiding products that contain i.e. plastic microbeads.

People's behaviour towards water consumption and wasting water has a direct influence on the crisis the world is facing, and will continue to face in the future unless it isn't addressed. Therefore, raising awareness and educating people on the role of water in their lives and the importance of its availability will have a great impact on reducing the amount of wastewater generated per person.

Awareness can be raised through adverts and open talks given to individuals wherein they will be educated on the role and importance of water, as well as tips on saving more and using less. In the same manner, people must also be convinced to accept and adopt new systems that come into place to help them reach the common goal we humans have of providing water for all.

Individuals can be informed about changes they can make in their day-to-day usage of water in different areas, that will influence them and the people around them. There are the direct influences: showering, cleaning etc. and the indirect influences: eating food that doesn't require a large amount of water to produce, choosing products that are made/grown locally to reduce the water footprint that comes from transport etc. However, this also includes convincing people to use newer technologies and methods, like those described in this report.

However, since humans often are conditioned depending on what they have seen/done previously in their life and what they perceive as good or bad, it is important to continuously teach individuals and emphasise the need to reduce wasted water and recycle it. We want people to see this as a habit, not an inconvenience.

Therefore, social behaviour can be polished via the following points:

- Sharing information and forecasts on water resources.

- Providing regular updates on water related and environmental issues.
- Inform the public about the status of stewardship of public infrastructure.
- Persuading people to choose politicians that want to focus on solving water issues.
- Universities and companies should offer smaller optional courses related to water and environmental issues (this is something that affects us all, not just the people majoring in it).
- Implement teaching methods related to not wasting water as early as kindergarten to create awareness in children, therefore making this a normal part of their life.
- Implement government policies on the usage of water to be followed by every individual.
- Making people accept the new technologies that will be arising. Without acceptance, there will be no usage.

5.2.1 Whiteboard animation

The whiteboard animation "Walter Water" serves its purpose well. It was made by request to raise awareness for saving water and raise acceptance of new technologies. The film may be more appropriate for children, given the layout of telling a story about a man who runs out of water and must work to try and change it. However, we believe adults may also learn from the film since most people aren't implementing the mindset and technologies that Walter is using. This isn't a certainty though, since people tend not to focus on the problems which they are aware of, and having a film that seems very catered towards children might not help this fact.

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Appendix A. DISC-analysis

In order to get to know each other better and to see what kind of personalities we are dealing with, we performed a DISC test and discussed this in retrospect. Even if it was unpleasant to discuss the profile, it turned out in the end that we can assess much better what kind of people we are dealing with and how to work with them. Thus, it was also easier to allocate the work accordingly to the people.

It turned out that most of us have a focus on dominance. However, during the project it turned out that this didn't necessarily mean these people never listened or reasoned. We were always able to work well together and lead dissuasions where everyone could contribute their own opinion. However, the discussions were usually quite intense, as there were often disagreements on different topics. A little bit of dominance was definitely present amongst most members.

It was also found that people with a high level of steadiness communicate more intensively than others with a lower value. Nevertheless, all integrated well into the group, and we had many interesting conversations, even though they often spun out of the problem's scope. Especially the people with a large amount of influence were always able to hold talks and keep the project going.

Also, it could be seen that people with a lot of steadiness were able to work efficiently and productively when given a set task, whereas those with a lower value partly had problems to stay on a certain problem. However, in the end we all felt like everyone contributed to the project.

Since we did not have much compliance in our team, it was partly unclear how to work with such a person. Although, the people with a higher proportion than others tried to bring some structure into the project. We still felt like towards the end of the project, all were able to work in a structured and goal-oriented way.

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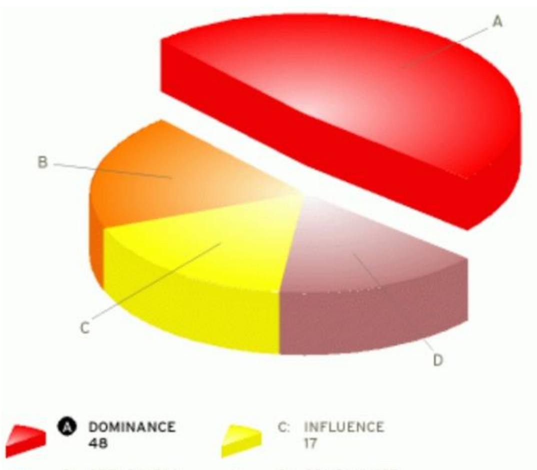

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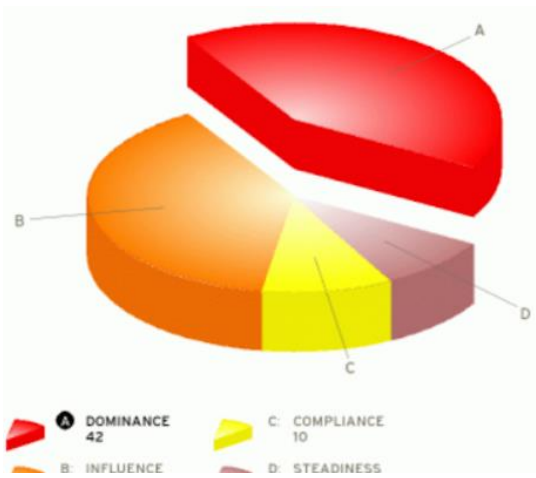

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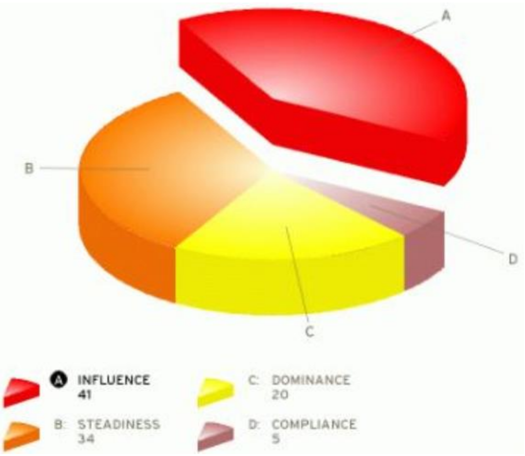
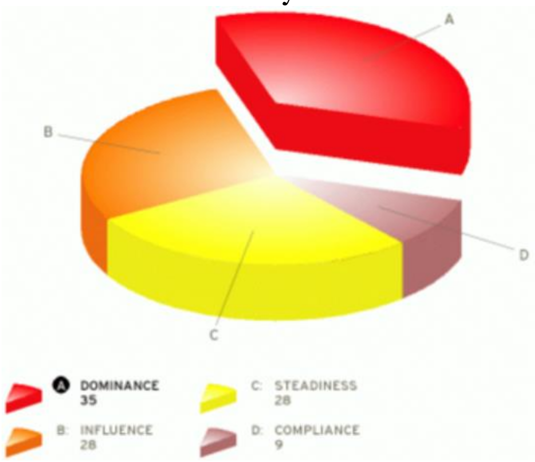


Amy:



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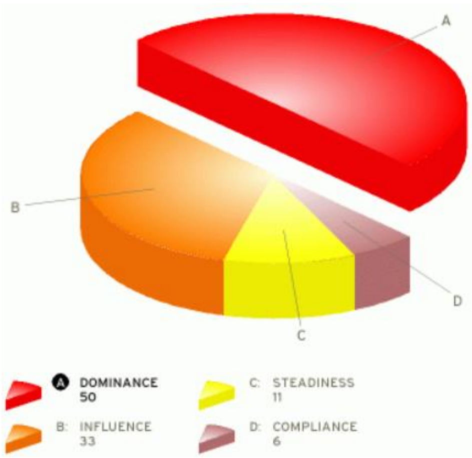

Karim: