SEMiLLA Sanitainer

From shipping container to circular sanitation solution in Ghana

Koos Berg

August 2021

Delft University of Technology
Faculty of Industrial Design Engineering
Integrated Product Design

Koos Berg
4457269

Supervisory Team

Chair: Jan-Carel Diehl
Mentor: Marian Loth
Company mentor: Peter Scheer

Acknowledgements

I want to thank some important people for supporting me during this project. First of all, I want to thank Peter from Semilla Sanitation for giving me the opportunity to do this project. I want to thank my supervisory team from the university, Jan-Carel Diehl and Marian Loth for their time, support, input, and feedback on the project.

I want to thank Jeroen from Geberit for his time and input in the field of sanitation and sanitary products. I want to thank mister Leszek from Kan-Bud for thinking along about the design possibilities in containers. Mister Bas from Feenstra has helped me designing the water heating system. Mister Maarten from Greenlink Solar helped me with the design of the energy generation systems. Mister Collins from Ghana helped me getting insights into the context of Techiman in Ghana. All these experts gave me the knowledge and helped me understand their domains.

Summary

Poor sanitation is a challenge around the world, more than 2 billion people lack access to basic sanitary facilities like a toilet. In Ghana, it is estimated 25% of children under the age of five die because of diarrhea. A disease that often can be prevented by providing hygienic sanitation facilities.

Tackling the problem across the whole of Ghana is challenging because of the large scale. Therefore the scope of this project is smaller, looking into the city of Techiman. Public sanitation in Techiman is far from ideal, sanitation facilities are usually dirty, smelly, and lack proper handwashing facilities. The waste streams are stored in pit latrines. When these are emptied, the sludge is dumbed without treatment in the environment, contaminating the groundwater.

Semilla Sanitation Hubs has access to different proven technologies to recycle human waste streams. These technologies originate from the European Space Agency and are used in space, but Semilla is looking for concepts to bring these to earth.

In this project, I designed a concept for a sanitary facility together with Semilla, based inside a standard 20 feet shipping container. It features seven toilets, six urinals, two handwashing facilities, and two showers. For a small entrance price, all visitors of the Techiman market have access to hygienic sanitation facilities.

Three different waste streams are collected independently and recycled using the technologies of Semilla. Yellow water is processed into fertilizer and clean water, and black water is recycled into biogas, and drinking water. Grey water is collected on-site and used to flush the toilets. The facility functions stand-alone, meaning freshwater is won on-site, and all energy required to run the facility is generated using solar panels.

This report elaborates on the final design, the considerations, and design decisions that led to this concept. Five stakeholders: the users, the company, the cleaners, the mechanics, and the container builders, and their influence on the final design are discussed extensively.

Content

PART I: Introduction

1.1 Introduction	8
1.2 Personal goals	9
1.3 The problem	10 - 11
1.4 Goal of the assignment	12 - 13
1.5 The company	14 - 15

PART II: Background information

2.1 Overview of the facility	17 - 18
2.2 Stakeholder mapping	19 - 22

PART III: Detailing

3.1 Waterflow	26 - 31
3.2 Business case	32 - 33
3.3 Cleaning of the facility	34 - 37
3.4 Lay-out of the container	38 - 42
3.5 Impression	43 - 46
3.6 Inclusiveness	47 - 48
3.7 Technical space	49 - 50

PART IV: Toilet stalls

4.1 Stakeholder analysis	52 – 53
4.2 The design	54 – 55
4.3 Measurements toilet stalls	56 – 58
4.4 Sitting toilets	59 – 64
4.5 Supported toilets	65 – 67
4.6 Squatting toilets	68 - 70

PART V: Handwashing facilities

5.1 Stakeholder analysis 72 – 74
5.2 The design 75 – 76
5.3 Time simulation 77 – 79
5.4 Watersupply 80 – 82
5.5 Soap supply 83 – 84
5.6 Drying hands 85 – 88
5.7 Garbage bin 89
5.8 Ergonomics 90 – 91
5.9 Production methods 92 - 95

PART VI: Showers

6.1 Stakeholder analysis 97 – 98
6.2 The design 99
6.3 Temperature 100 – 103
6.4 Shower components 104 – 107

PART VII: Containerbuilding 108 – 112

PART VIII: Urinals

8.1 Stakeholder analysis 114 – 115
8.2 The design 116 – 117
8.3 Waterless urinal 118
8.4 Cleaning urinals 119 - 120

PART IX: Energy + shipping

9.1 Energy supply 122 - 124
9.2 Shipping 125

PART X: Conclusion

10.1 Conclusion 127 - 129
10.2 Recommendations 130 - 131

Sources 132 - 140

Appendix B: Cost watersupply 141 - 143

Appendix C: Cutting and bending drawings 144 - 147

Appendix D: Shower water heating principles 148 - 149

Appendix G: Company appendix 150 - 167

Appendix H: Shipping components 168

Appendix J: Project brief 169 - 175

* Missing appendices are uploaded seperately

PART I
Introduction

1.1 Introduction

This report elaborates on my graduation project of the master Integrated Product Design from the TU Delft. I did this project in collaboration with Peter Scheer from the company Semilla Sanitation Hubs and Marian Loth and Jan-Carel Diehl from the faculty of Industrial Design Engineering from the TU Delft. Together with this team, the assignment is formed.

This report is built around my final design for the sanitary facility SEMiLLA Sanitainer. It shows my progression, conclusions, and reasoning.

In the first part of this report, the introduction, the context, and the challenges are discussed. Besides, my personal goals for this project and the company I worked with, Semilla Sanitation Hubs, are elaborated upon.

The second part gives background information. Stakeholder analysis and an overview of the system show how the project took shape and how the whole system around the sanitation facility works. Within this report, five stakeholders play a dominant role.

The third part of the report starts with renders of the final design, to give the reader a complete overview of the design. After this, the design will be elaborated upon in detail by lifting out certain aspects of the solution. Piece by piece the overview provided earlier will be detailed out.

This report discusses four major subsystems of the whole facility, the toilets, the urinals, the handwashing facilities, and the showers. Besides these subsystems, relevant topics such as and energy generation, the water flow system and the lay-out of the facility will be discussed.

1.2 Personal goals

In the last year of my masters, I did a project about water filtration. Together with a team of 6 students, we designed a filter by making a lot of prototypes. This project was special for me since it made me realize that design can significantly improve people's lives. After this, I took a course called 'Design for Emerging Markets' in which I was taught more about designing for people who need it most. I found out that this is what I would like to do in the future, making an impact on people's lives. I do not want to design the next sleek coffee machine, I think we do way too many of these designs as a society. I think sustainability and resource shortages have become more and more relevant. Our generation of designers has the responsibility to look critically at the climate and the sustainable development goals before we even start a project.

Besides following my passion by choosing this project I have stated some personal learning goals at the start of this project, which are the following:

In my reflection I will get back to these learning goals.

Managing a complex project with different stakeholders on my own.

Draw my line from the advice of different experts.

Quick educated decision making, instead of procrastinating hard decisions.

Make a 1:1 model of the final design.

1.3 The problem

Poor sanitation is a problem around the world, over 2 billion people lack basic sanitation facilities like toilets [1]. Poor sanitation is linked to the transmission of cholera, diarrhea, dysentery, hepatitis A, typhoid, and polio [1]. An estimated 25% of the death of children younger than five years in Ghana is due to diarrhea [5]. It reduces well-being and improves anxiety and the risk of sexual assault [1]. Ghana has a sanitation coverage of only 15 %, making it the seventh-worst performing country worldwide when it comes to sanitation [2]. In 2017, Ghana's open defecation rate reported 18,06% [3]. Only 27% of urban Ghanaians have access to improved sanitation facilities [4]. Needless to say, poor sanitation is a serious challenge in this country.

Especially in urban areas, private toilets are rare. With an average household of 4,5 people and usually small housing, the lack of space is the most prominent reason not to place a private toilet [5, 6]. Placing a toilet can be expensive. On top of that, it brings annual costs for emptying the tanks for example [7].

If you do not have access to private toilets, a possible solution is to use public toilets. However, these public sanitation blocks are often dirty, unhygienic, and smelly. Only around 38% have handwashing facilities [5]. Figures 1, 2, 3 and 4 show currently used sanitation facilities in Techiman.

Figure 1: Outside sanitation facility Techiman

Figure 2: Inside sanitation facility Techiman

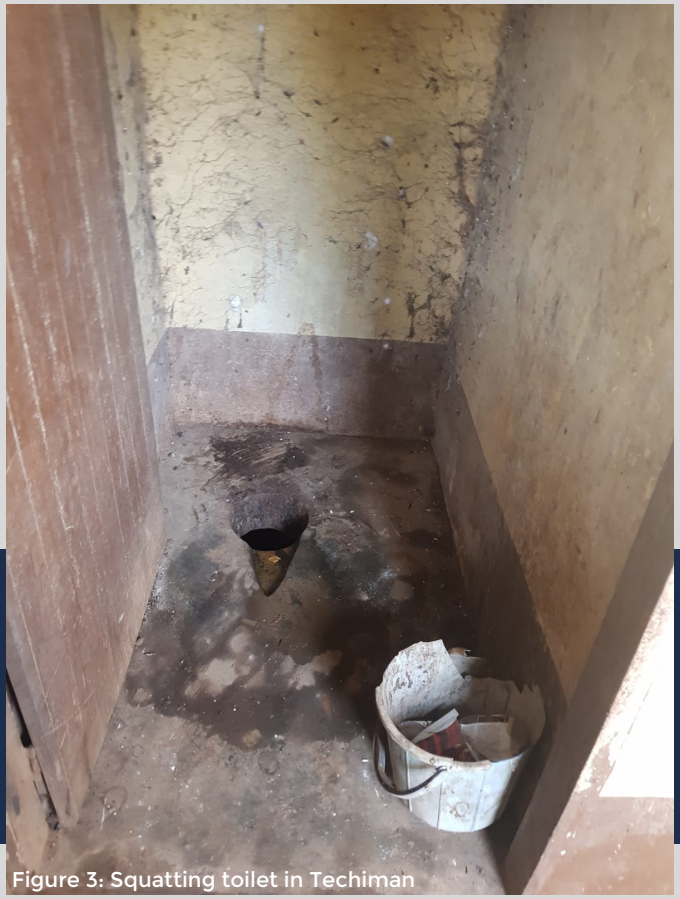


Figure 3: Squatting toilet in Techiman

Figure 4: Sitting toilet in Techiman

When public toilets are not available or too dirty, 40% of the people choose to openly defecate [5]. This can cause problems since human waste contains several germs, some of which can cause diarrhea [8]. Flies can spread these germs easily by sitting on the waste first and then sitting on the food someone is about to eat. When it rains heavily, waste can be washed into the river. Children are playing in the river and people drink from it.

Even if there is public sanitation around, proper waste collection and processing can be expensive. Resulting in illegally dumping the sludge somewhere, which connects the sludge to the surface water, shattering the gains made by increasing sanitation coverage [30].

In my project, I try to encourage people to use clean sanitary facilities to prevent them from defecating openly. I want to do this by providing clean sanitation opportunities. Besides that, I want to provide hygienic options for washing hands. I want to encourage people to wash their hands after using the toilet. Furthermore, I want to treat human waste correctly to prevent it from ending up in the environment.

1.4 Goal of the assignment

Trying to provide everyone in Ghana with clean sanitation, handwashing facilities and waste treatment at once is not possible. Together with Semilla, it was chosen to focus on a specific context in Ghana: a crowded market in Techiman.

In the city of Techiman live around 68.000 people. On crowded market days like Wednesday, Thursday, and Friday 15.000 people visit this market. On non-market days there are other activities, and around 8.000 people are present at the marketplace [20]. There are public sanitation facilities at the marketplace, but these cannot accommodate all visitors on the market. Moreover, these facilities are dirty because so many people need to use them, this is a prominent reason for people to avoid these. Like many other sanitation facilities in Ghana, these make use of pit latrines, Figures 5, 6.

A pit latrine is a big storage underneath the sanitation facilities where everything that is flushed through the toilet is stored. Emptying these can cause problems. A visitor of the local toilet facilitation told an employee of Semilla Sanitation the following: “Some time ago a hole was dug next to the pit latrine, then all the sludge was dumped in there and the hole was covered again.” This means all feces still end up in nature, which results in contaminated drinking water.

Figure 5: Pitlatrine outside in Techiman

Figure 6: Pitlatrine

Figure 7: Sanitation facility in Techiman

Together with Semilla Sanitation, I want to give the visitors of the market in Techiman the possibility to go to a clean toilet with a sewage system and proper handwashing facilities. This is what I define as clean sanitation. Especially in times of Covid-19, this is important. Moreover, I want the waste to be treated properly, to prevent it from contaminating the groundwater.

In collaboration with Semilla Sanitation, the scope of the project is shaped. I will design a sanitary facility. This means I will provide a solution containing toilets, urinals, showers, and handwashing facilities. The base for this design is a 20 ft. high cube shipping container. Within this sanitary unit, three different water streams are collected independently in stationary tanks outside the container: yellow water from the urinals, black water from the toilets, and grey water from the showers and the handwashing stations. These streams are treated using the technologies of Semilla Sanitation. In the next chapter, I will go into detail about these and the company itself.

The three main goals of this assignment are the following :

Give the visitors of the Techiman market a possibility to visit a clean and hygienic toilet, urinal and shower.

Provide possibility for hygienic handwashing.

Threat the waste water correctly to prevent the groundwater from getting contaminated.

1.5 The company

This project is done in collaboration with Semilla Sanitation, this chapter gives some background information about this company. Semilla Sanitation is a company founded by Peter Scheer. It is located in Doetinchem in the Netherlands. Semilla has a close collaboration with Nijhuis Industries, which is a big company focused on water filtration. The headquarters in the Netherlands of Semilla is in a container office inside one of the big assembly halls of Nijhuis Industries. Only Peter Scheer is active for Semilla in the Netherlands. I have been in touch with mister Collins, living in Ghana. Misses van Loon is active in Kenya, in total three people work for Semilla Sanitation Hubs.

The core of the company is its technology. This is a technology to recycle human waste streams. When collected separately yellow water, only consisting of urine, can be recycled into clean drinking water and fertilizer. Black water, collected from toilets, can be recycled into biogas. This technology is derived from the MELiSSA project of the European Space Agency. The ESA uses these technologies in space to convert sanitary wastewater into clean water and nutrients for food production. Semilla is looking to find concepts to use this innovative technology on earth instead of in space. The company has built different concepts around this technology.

Semilla is doing this in the Western market, as well as in the humanitarian market. For the West, for example, the GreenPee is found, Figure 8 and 9. The Greenpee is a public urinal for cities. Yellow water is collected in a big reservoir and recycled into biological fertilizer, which can be used to grow the plants in the city. Closing the loop is the core of the company.

Within the humanitarian market, this is also the case. In different countries in Africa projects are starting in which Semilla is working. In Uganda, for example, the company is working on a big biodigester to produce biogas. In Kenya, a project around waste treatment is rolling out. In Ghana, a project around sanitation, which I will work on is starting up. These projects are mainly paid by subsidies. Therefore Semilla needs to get these subsidies to generate the money needed to keep these going.

SEMiLLA
sanitation hubs

Figure 8: GreenPee in Amsterdam

Figure 9: GreenPee in Mechelen

PART II
Background info

2.1 Overview of the facility

This chapter gives an overview of the system around the design of the sanitation facility. It gives an impression of what the system looks like and how it functions. It won't go into detail about design choices or working principles. As said in the introduction, this will be elaborated upon in the third part.

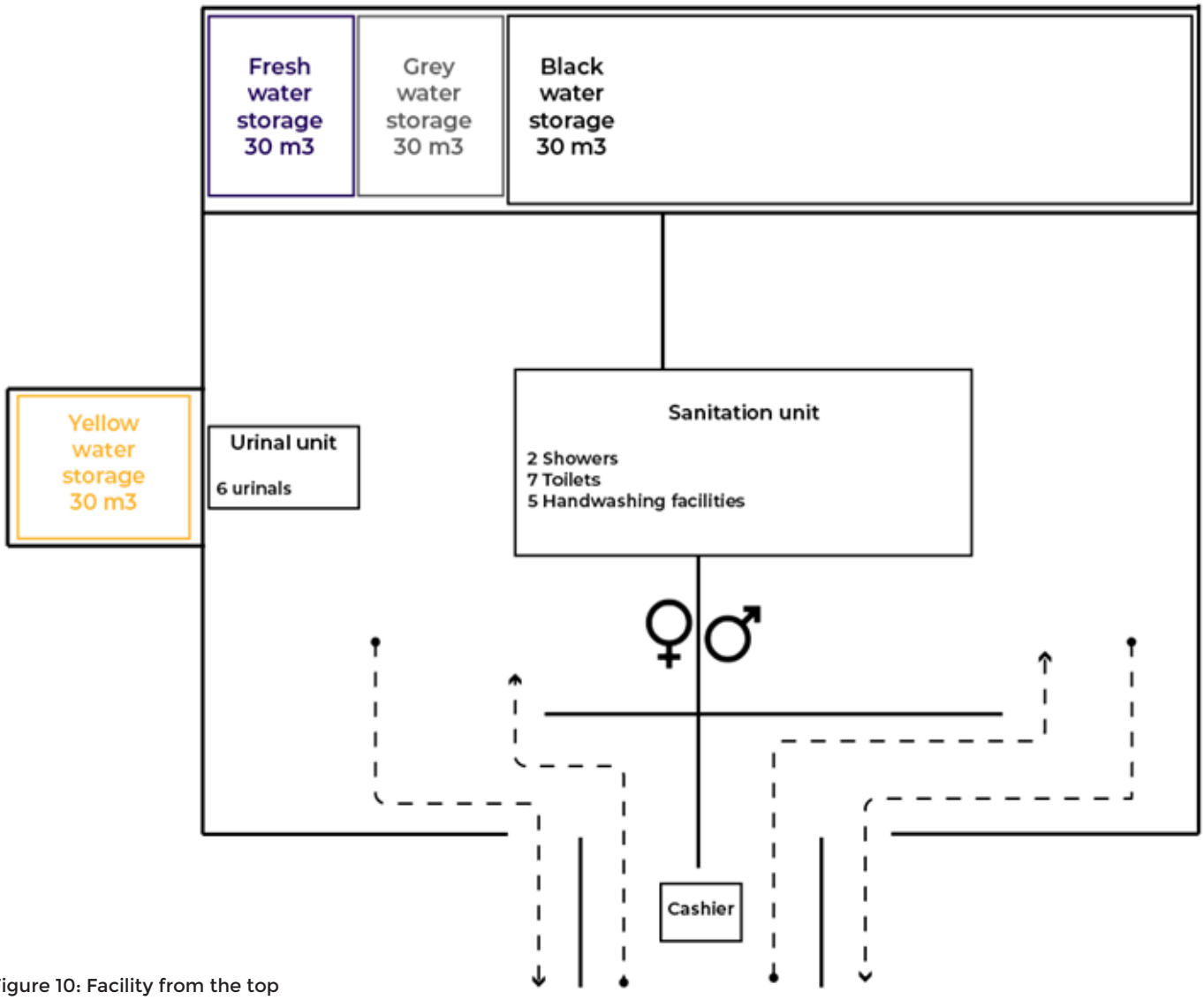


Figure 10: Facility from the top

The center of the facility is the sanitation unit, equipped with two showers, seven toilets, and five handwashing facilities, Figure 10. In the men's section of the facility, a separate urinal unit, carries six standing urinals. The whole facility is enclosed with fences to prevent people from entering. To enter the facility the users have to walk past the cashier's desk. The cashier charges the users before they can enter. The exit is located next to the entrance, the cashier has an overview to prevent people from sneaking in via the exit. A guard is present at all times to make sure users feel safe, prevent dangerous situations and stand by the cashier.

All waste water streams are collected in storage tanks dug into the ground. Every day a vacuumtruck empties the black water tank, and every week the yellow water tank is emptied. The grey water tank won't be emptied since grey water is recycled on-site. Grey water is collected from the showers and the handwashing facilities. It is used again to flush the toilets.

At the site of the facility, a well is attached to a filtration system. There is always clean drinking water available for the facility. I won't go into detail about this system, since this is out of scope. A 5 m3 storage tank of fresh water is placed in the overview, Figure 10.

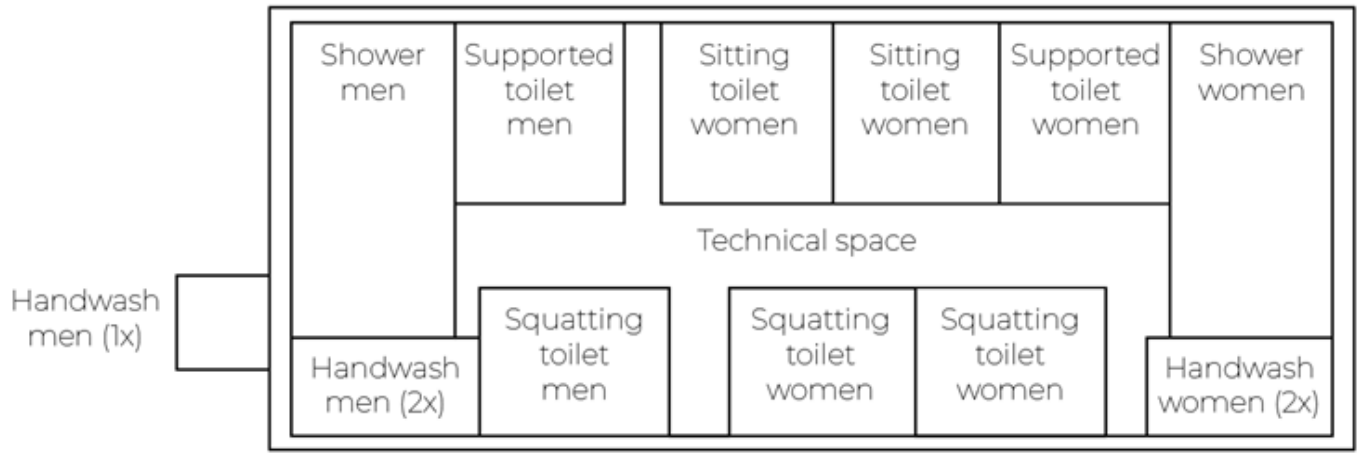


Figure 11: Lay-out of the container

The sanitation unit is built from a standard 20 ft. high cube shipping container. The outer measurements are 6.058 x 2.438 x 2.891 mm [24]. The men's section includes one supported toilet, one squatting toilet, one shower, and three handwashing facilities. The women's section includes one supported toilet, two sitting toilets, two squatting toilets, one shower, and two handwashing facilities. In the technical space between all the stalls tubing system, transporting all water stream to or the storage tanks lays. Figure 11 shows the layout of the container.

The whole facility will be opened from 05.00 to 23.00 every day. During each of these 18 opening hours per day, there is one guard, one cashier, and two cleaners available.

2.2 Stakeholder mapping

As one of my personal goals is to manage a complex problem, stakeholder mapping is important. This tool helps to recognize the different stakeholders in the project and identify their interests.

Users: Obviously, these people are important. They need to be willing to pay for a visit to the sanitation unit. One of their main interest is a clean facility [5]. Most important is that the users are satisfied and willing to pay the entrance fee for the services they receive.

Semilla Sanitation Hubs: Semilla is the company I work with, together we are coming up with the concept and are looking to make an impact. They translate waste recycling methods used by the ESA in space to applications on earth. They want to make money with the concept to place more of these units across Ghana and in a later stage in Kenya.

Cleaners: The cleaners are an important element of the workforce. Most interviews and research about sanitation in Ghana tell the importance of clean toilets and showers. A dirty facility is not inviting to visit.

Service mechanics: When something breaks down in the container mechanics are available to service it. They are hired by Good Sanitation Ghana to make sure the facility keeps on running.

Cashiers: The main job of the cashiers is to charge money from the users and let them into the facility. At the same time, they serve as supervision. It is important to provide them with a safe way of storing the received cash and minimizing the risk of being robbed.

Guards: The guards are present to make the users and employees feel safe. Going to the toilet brings the users in a vulnerable position, guards are present to protect them if necessary. They prevent fights in the facility and help if there are problems with payment.

Good Sanitation Ghana: This company will exploit the facility. They will hire all employees and will take care of the unit and its users.

Kan-Bud container builders: The container is produced by the company Kan-Bud from Poland. They prescribe certain rules to make the container producible.

Geberit: This is the company Semilla works together with and provides the toilets and other sanitary products. They can also help in the development process of the unit and advise on products and tubing.

Greenlink Solar: This is the company that provides the solar panel system.

Nijhuis Industries: Nijhuis is a water filtration company that closely works together with Semilla. Nijhuis provides tools and manpower to work on the unit and helps to realize the final product.

WHO: The World Health Organization's main interest is to provide as many people with clean sanitation opportunities as possible to prevent people from getting sick.

These stakeholders are mapped according to the method of Michael F. Ashby from the book Materials and Sustainable Development [31]. All stakeholders are mapped on the influence they have on the final design and the interest they have in the final design, see Figure 12.

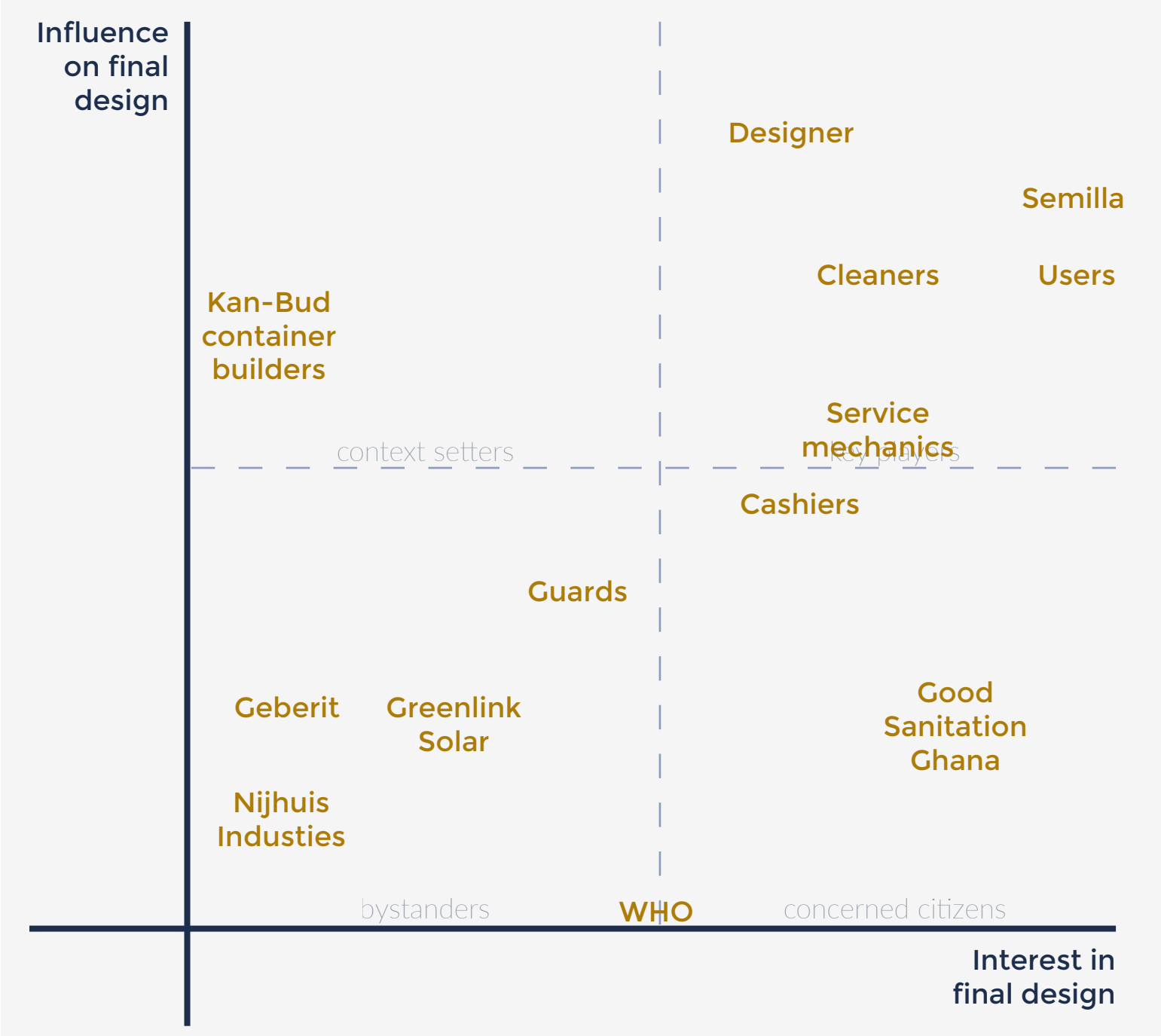


Figure 12: Stakeholder mapping

As a designer, this graph tells which parties I have to take into account most to end up with a design fitting the context of these stakeholders. It is important which parties have a large influence on how the design will end up looking. Therefore I focused on the stakeholders at the top of this graph: the users, cleaners, company, service mechanics, and the container builders. I will get back to these five stakeholders, to explain certain decisions and choices in this report. These five stakeholders and their main concerns are shown in Figure 13.

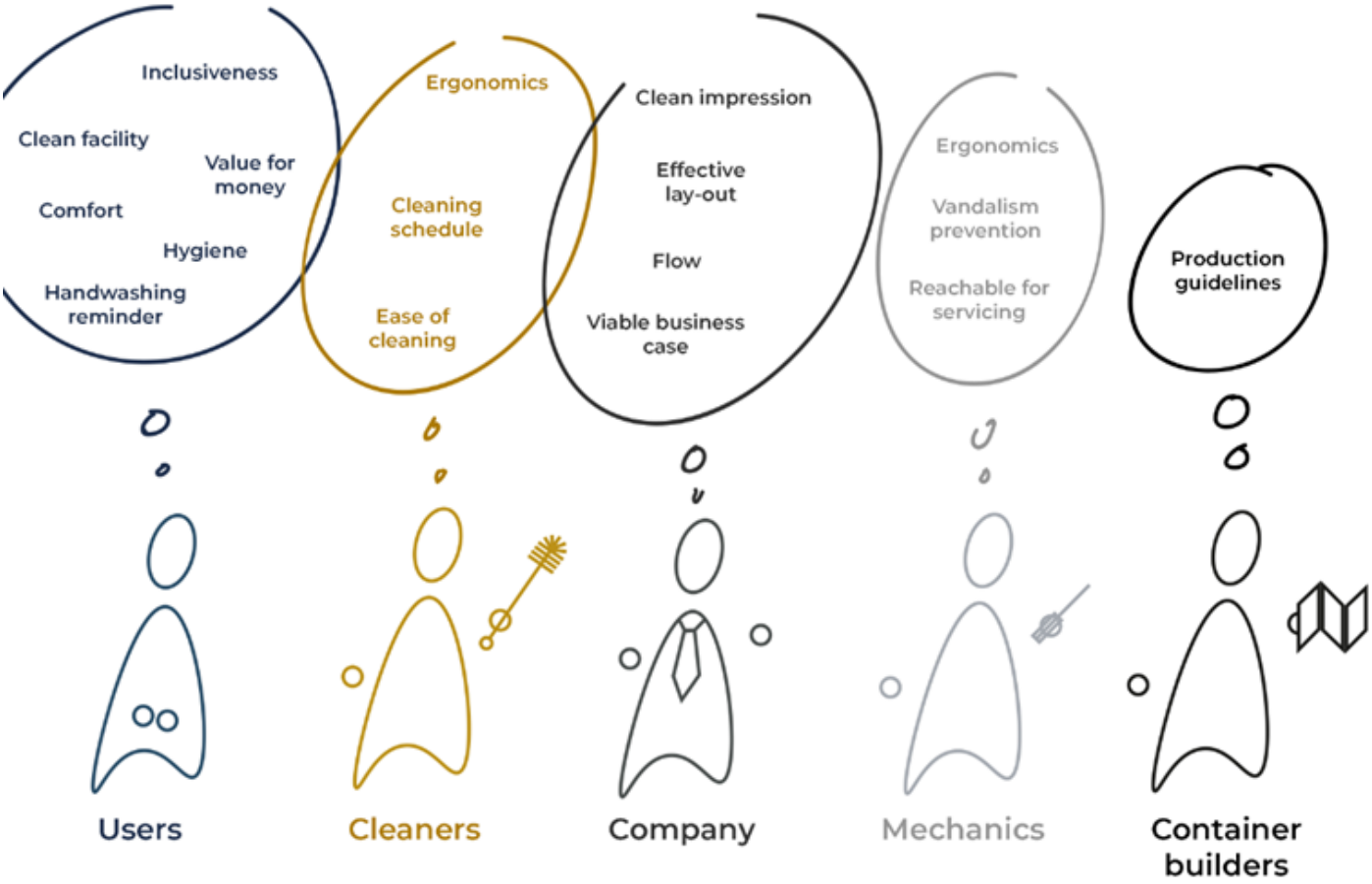


Figure 13: Stakeholders main concerns

Users

For the users, a clean facility is most important [5]. Overall comfort inside the whole facility is important to have a pleasant experience. To prevent them from getting sick, the facility should be hygienic, and proper handwashing facilities should be in place. The most prominent reason why people do not wash their hands is forgetfulness [44]. The users should be reminded to wash their hands. Furthermore, the inclusiveness of the design provides different people with different needs a safe and clean sanitation place, not only a small group. Last but not least, users have a great interest in the entrance fee of the unit since they need to be willing to pay for the service they receive, it should be worth it for them.

Cleaners

Cleaners are hired by Good Sanitation Ghana to provide users with a clean facility. The unit should be designed in such a way it is easy to clean. Cleaning should be executable in the time the cleaners have, specified in the cleaning schedule. Moreover, ergonomics is important to prevent the cleaners from getting injured while cleaning the whole day.

Company

The main interest of the companies Semilla and Good Sanitation Ghana is to make money while making an impact. Therefore the sanitation unit must be part of a viable business case that generates money in the short run and the long run. The available space in the containers should be used to its full extent by implementing as many cubicles as possible. Users should leave the cubicles fast, so other people can use them again, securing a flow within the facility. A clean first impression of the whole facility enlarges the mental distance related to feces [13].

Service mechanics

The service mechanics show up when something breaks down or needs planned servicing. They should be able to access all vulnerable parts of the facility, preferably in a central place. Choosing an anti-vandalism design will save them a lot of work and just like the cleaners, they value ergonomics while working.

Container builders

Kan-Bud does not have a large interest in the design of the unit, but they do have a big influence. They have a set of guidelines the designer has to follow to make the design producible. Not following their rules would lead to a malfunctioning or more expensive design.

In this report, small icons will refer to the stakeholders involved, Figure 14.

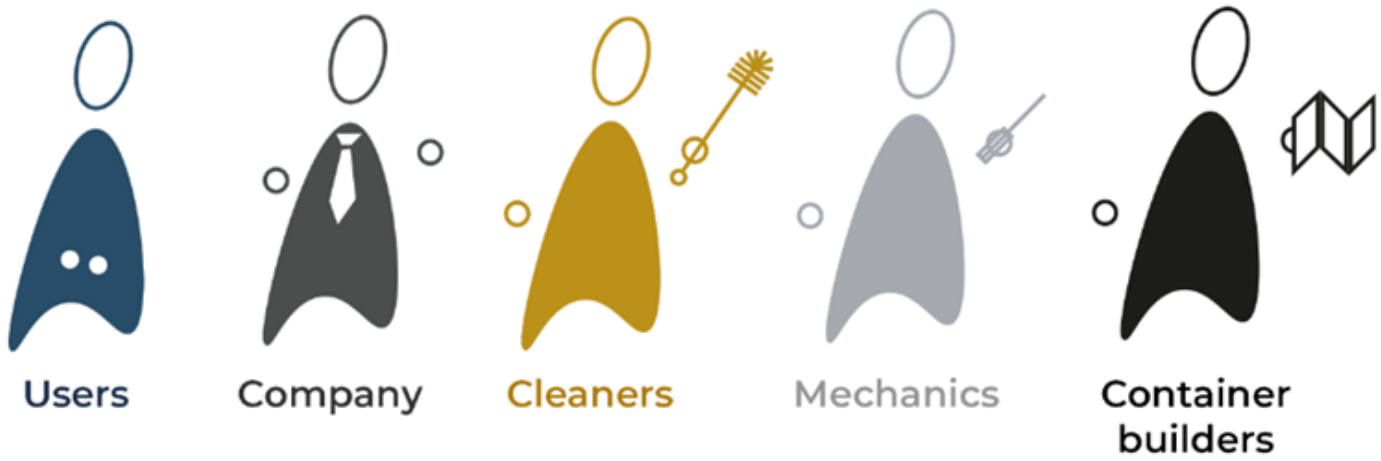
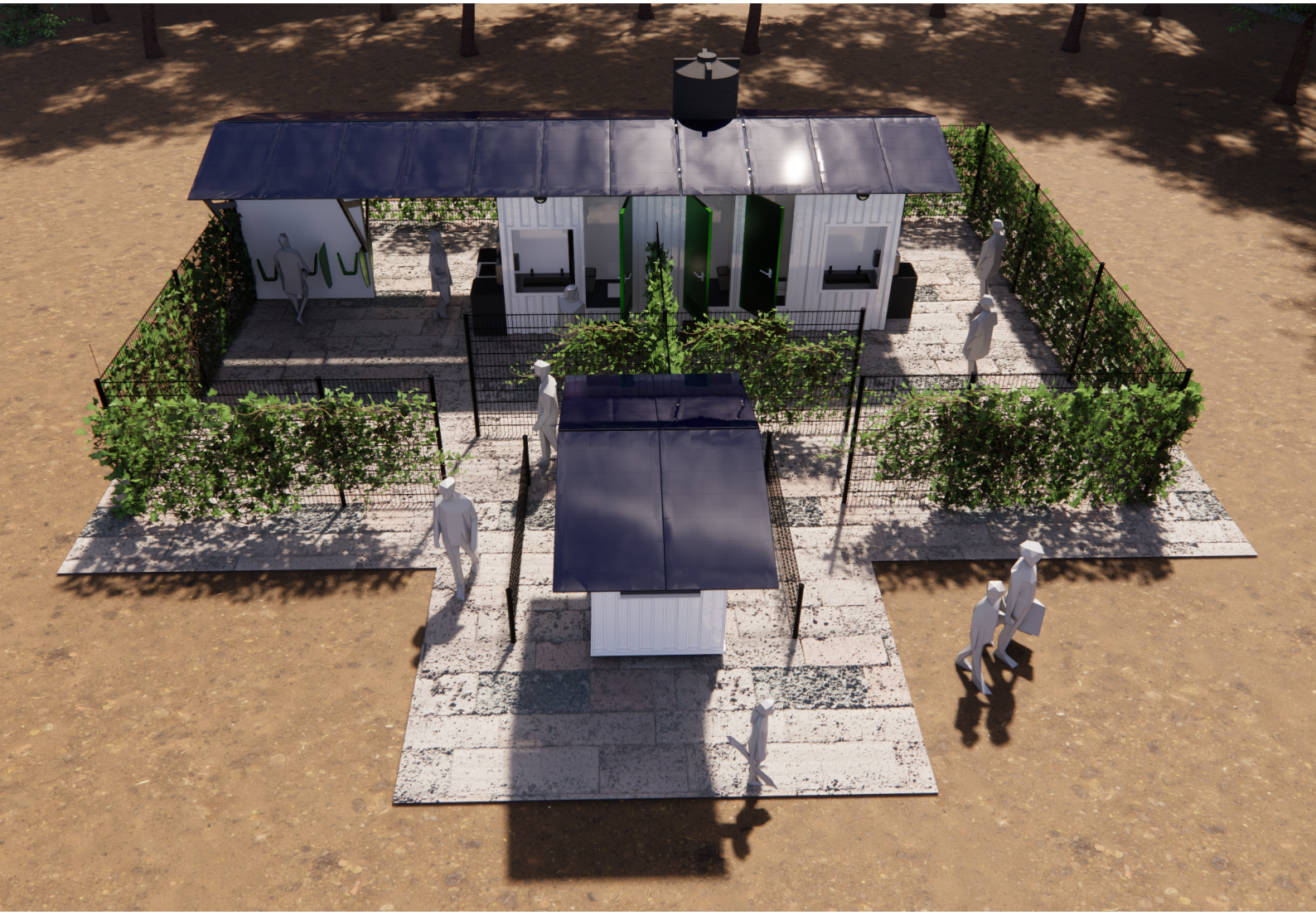
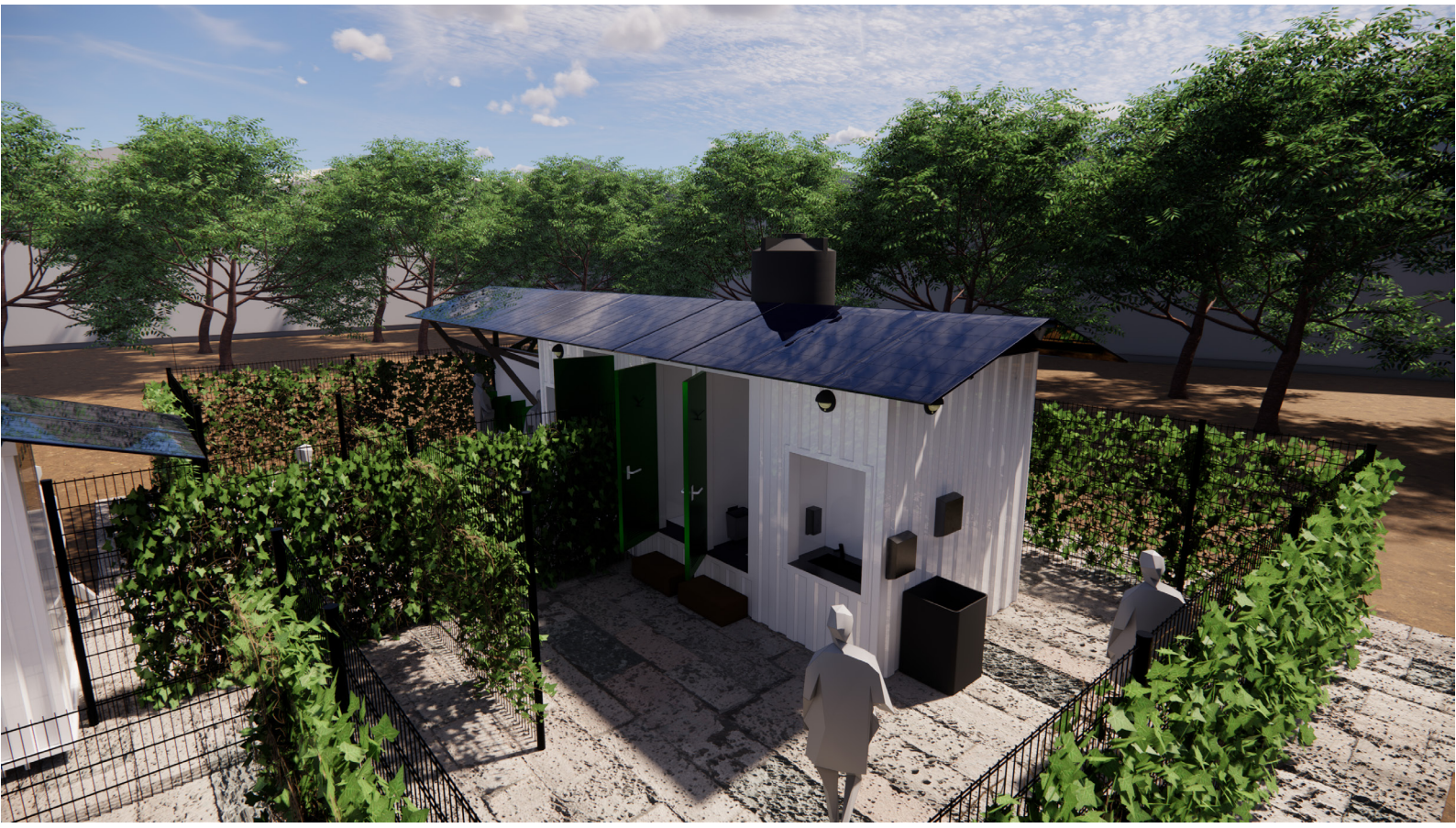


Figure 14: Icons in the report

PART III
Detailing





3.1 Water flow

The water system within the facility involves four different water streams. Instead of a freshwater stream and a wastewater stream in a regular household, fresh, grey, black, and yellow water are separated. Figure 15 explains how the different streams are connected.

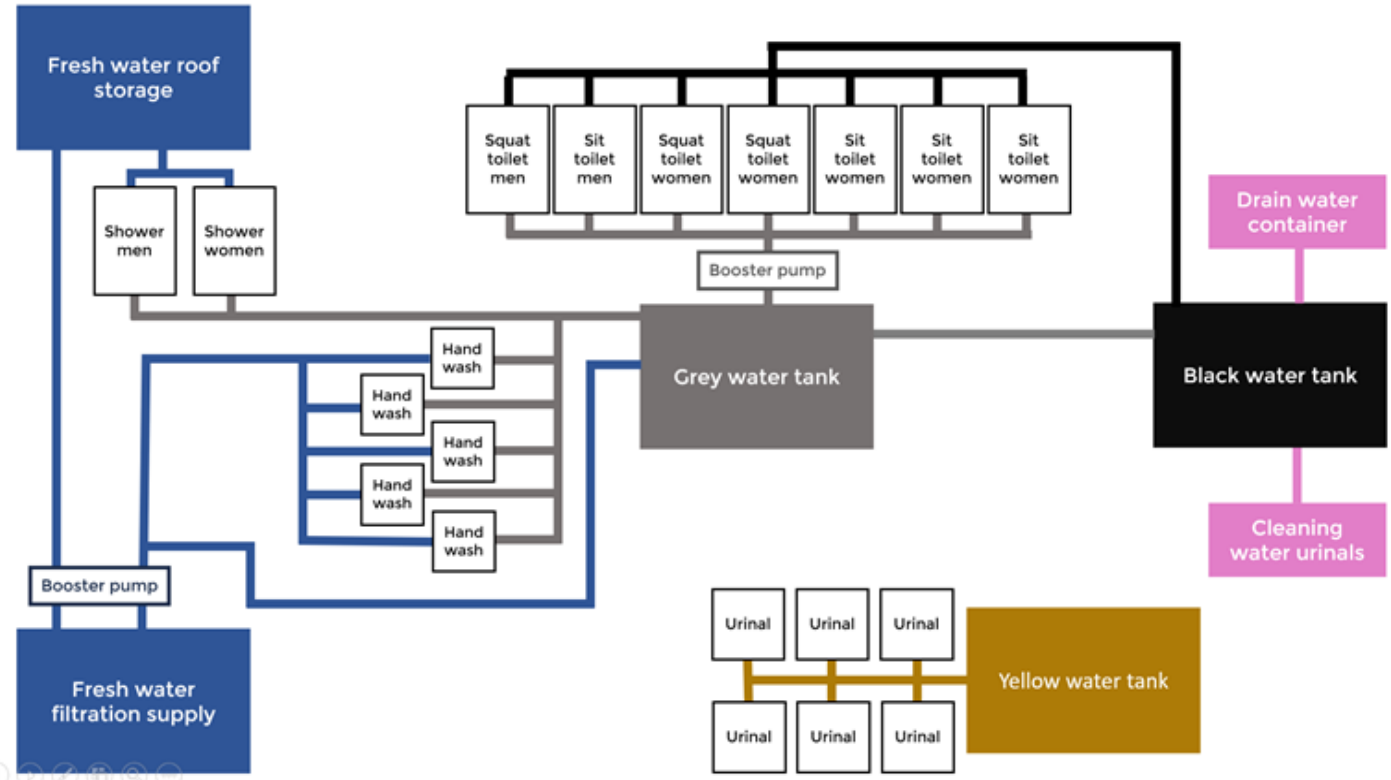


Figure 15: Waterflow system

Freshwater

Freshwater from the filtered water supply gets pumped to a tank on the roof of the container with a booster pump. This tank has a capacity of 1000 L. The water is used for the showering. The weight of the fresh water on the roof supplies the pressure needed for the showers to run. Depending on the outside temperature and the sun exposure the temperature of the water differs day by day. A float switch makes sure this tank never runs empty. I will get back to this system in section 6.3.

The same booster pump pumps water to five different handwashing stations. All tubing connected to the booster pump is pressurized up to 4.3 bars [58].

The same boosterpump pumps water to the 5 different handwashing stations as well. By using a boosterpump all tubing connected to it is pressurized up to 4.3 bars [58].

Grey water
By gravity grey water from the showers and the handwashing stations flows into the grey water tank. This tank is equipped with a float switch sensor as well. When the tank is about to run out of water, freshwater is pumped into the grey water tank. There is always water available to flush the toilets. An overflow connection between the grey water tank and the black water tanks prevents the grey water tank from flooding. In the unlikely event that too much grey water is produced, the surplus will flow to the black water tank by gravity.
Grey water is pumped to the toilets using a booster pump. The water is treated before it gets pumped to the toilets. I won't go into detail about this process since it is out of the scope of the project.

Black water
The black water tank is filled with the water stream from the toilets in the facility. Like the grey and yellow water tanks, it has been dug into the ground. The black water flows into the tank through gravity. Cleaning water from the central drainage of the container and the urinals also collects inside the black water tank.

Yellow water
The yellow water system works with gravity, no external freshwater flows into the system except for when it is cleaned. The system does not interfere with the water system of the sanitation container.

Figure 16: Vacuumtruck

3.1.1 Storage tanks
The water streams are stored in different tanks. A total of 2400 urinal visits each day produce 600 L of yellow water. This leads to 4.3 m^3 of yellow water each week, Appendix A - Income. For all water streams, estimations are being made beforehand by the company based on the number of visitors they expect. The yellow water tank is emptied once a week. I chose a storage tank of 5 m^3 for this stream.
The tanks are emptied using a vacuumtruck. The hose of the vacuumtruck needs to reach up until the bottom of the tank. Therefore all tanks are equipped with a screw cap on top of the tank. This opening should be bigger than the diameter of the hose of the vacuumtruck to prevent forming a vacuum inside the tank, Figure 16.

Yellow water tank

The yellow water tank has two outlets, one big outlet on the top for the vacuumtruck, and an inlet for the collective pipeline of the urinals, Figure 17. The tank is dug into the ground so the yellow water from the urinals runs into the tank by gravity.

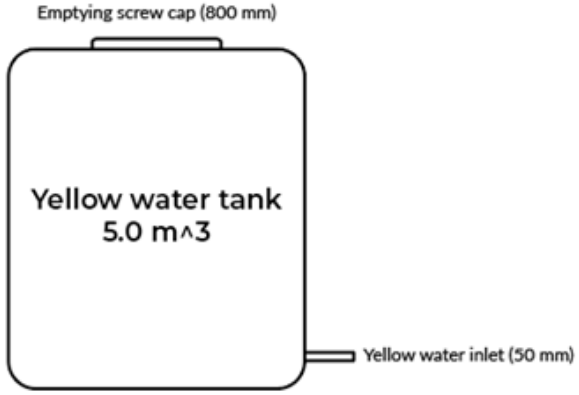


Figure 17: Yellow water tank

Black water tank

Black water is collected every day. 12.3 m^3 of black water is collected every day, Appendix A - Income. This is collected in a tank of 30 m^3. Something may go wrong with the vacuumtruck, which makes it impossible to collect waste that very day. Therefore the tank has a capacity of a little more than two times the daily dose.

The black water tank is equipped with five openings, one big one op top for the hose of the vacuumtruck, one opening for the black water from the toilets to flow into. The third opening is for an overflow connection to the grey water tank. A surplus of grey water flows into the black water tank. The last two openings collect cleaning water from the container and the urinals unit, Figure 18.

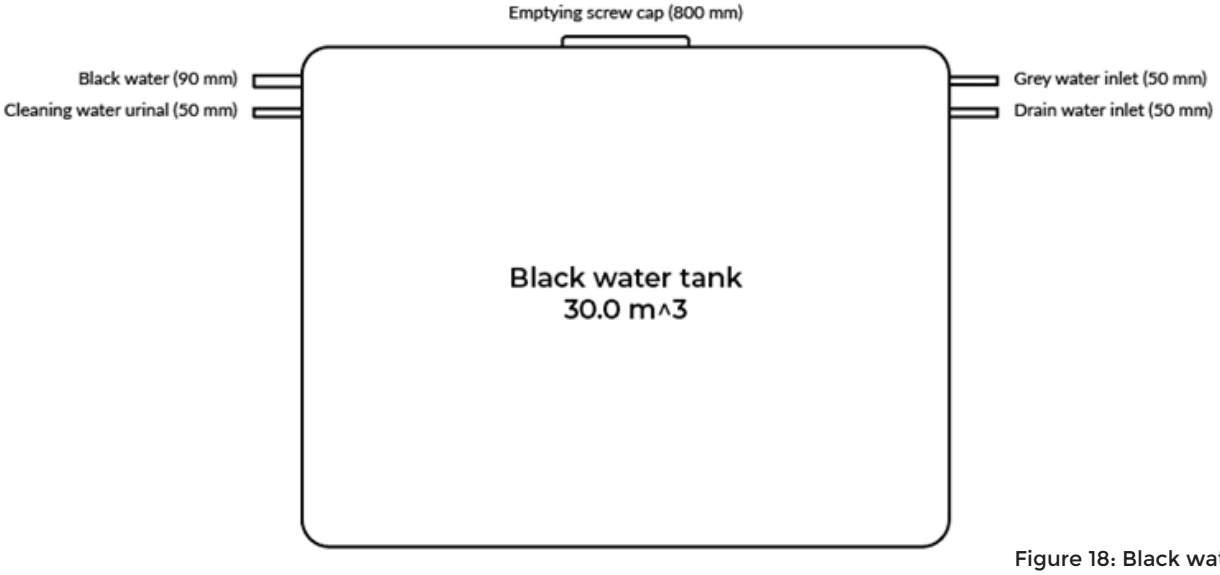


Figure 18: Black water tank

Grey water tank

12.275L of grey water is produced each day. Every day 12.250 L is needed to flush the toilets, meaning there is an estimated surplus of 25 L of grey water each day.

Since showering and flushing happen at the same time, it is not needed to have a tank that can store the total amount of 12.28 m^3 grey water. I chose to make use of a tank of 5 m^3. To get a surplus of 5.000 L of grey water, 143 more showers than toilet visits have to be made. For a shower of 10 minutes, this will take 23.8 hours. This means the tank of 5.000 L will only be too small if for 1.3 days no one will use the toilet and the showers are occupied constantly. This is very unlikely. This tank should have a big opening on top in case it needs to be emptied by a vacuumtruck. Besides that, a fresh and grey water inlet and an overflow outlet connected to the black water tank are featured. Naturally, one outlet is connected to the toilets for flushing water, Figure 19.

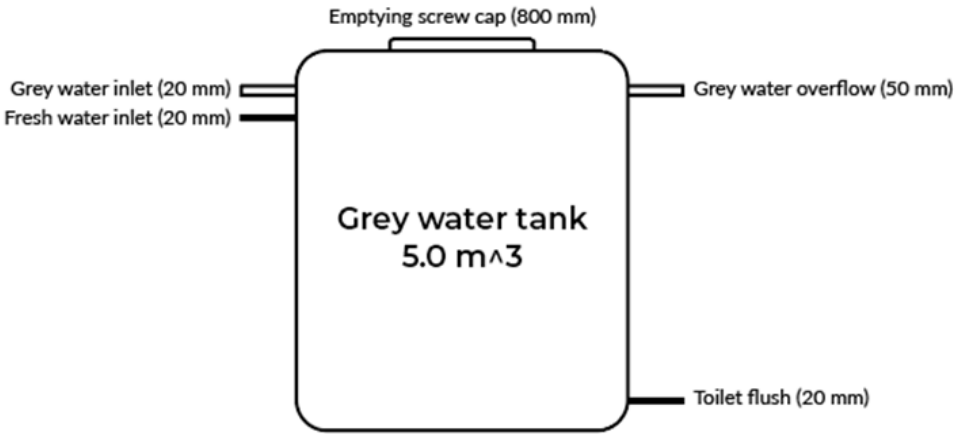


Figure 19: Grey water tank

3.1.2 Sewega systems within container

Within the container, in the space between the cubicles, the whole system of pipelines lays. All drains from the cubicles collect in one central pipe running to the storage tanks, Figure 20.

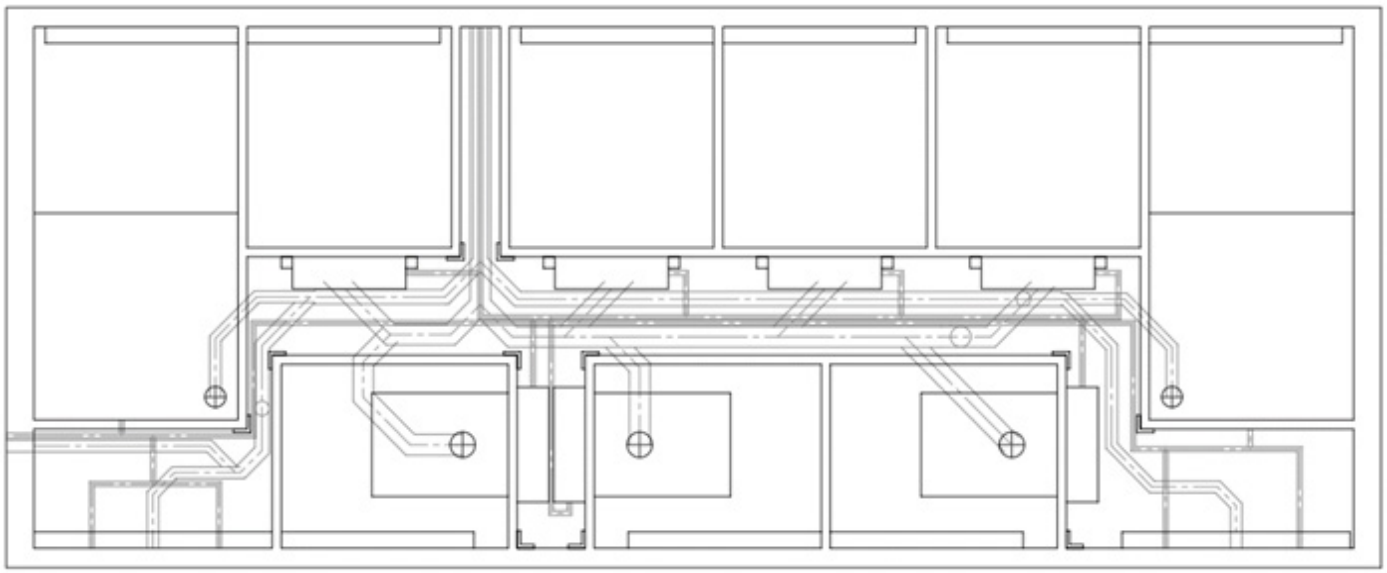


Figure 20: Sewega system inside container

Together with mister Bosman, a sanitation expert in drainage technology from the Dutch company Geberit, a set of rules were determined for the tubing system:

- Instead of bending in 90 degrees, take two bends of 45 degrees each, accounting for a better flow.
- To drain without pumps, the tubing should be placed under an ideal slope of 1%.
- Do not connect two pipes at a 90-degree angle, but in 45 degrees instead, to accommodate for better flow.
- Directly after the toilet, the drain should run straight down for at least 10 cm.
- The grey and black drains should be vented to prevent air from entering the system by flushing getting trapped in the pipelines.

Grey water system

Grey water is won at the showers and the handwashing facilities and collected in PE pipes with a diameter of 50 mm [42]. Where two 50 mm pipes meet, they continue in a 63 mm pipe. This pipe lays on the bottom of the container and the water flows using gravity. At the points where two 50 mm tubes meet, an air vent is placed through the roof of the facility. These vents are indicated with black circles Figure 21.

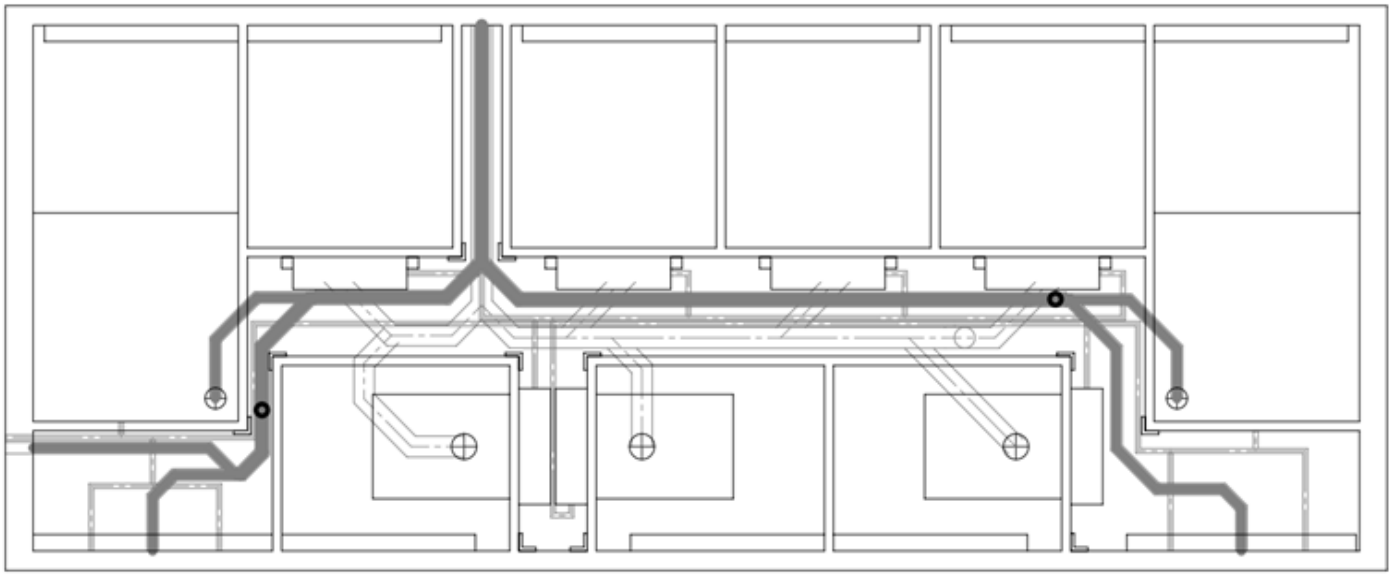


Figure 21: Grey water drainage

Grey water is pumped from the tank to the toilets inside the facility using a booster pump. For this, a standard flexible tube of 20 mm will be used [43]. Flexible hoses like these do not have to meet the rules stated before. The tubing plan of the grey water input is shown in Figure 22.

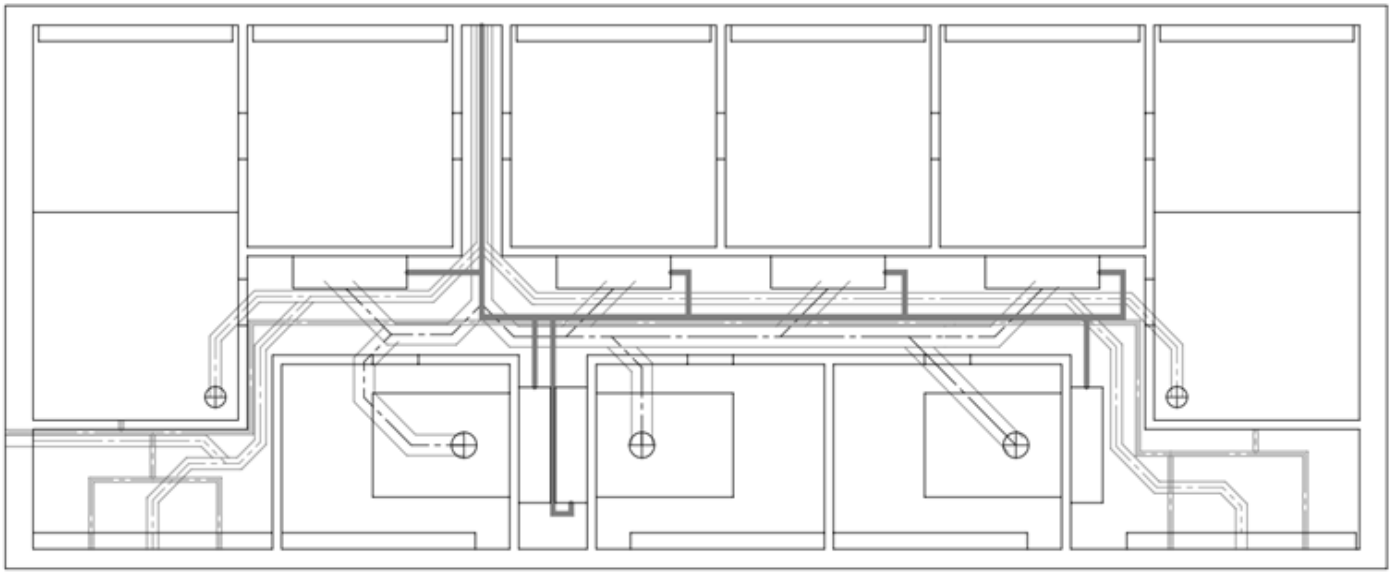


Figure 22: Grey water supply

Black water system

The minimal width of a sewage pipe connected to a toilet should be 90 mm unless the toilet is flushed with more than 7 liters of water, then it should measure 110 mm [38]. The toilets in the facility are flushed with 5 L of water, so a 90 mm pipe suffices. This pipe lays on top of the grey water pipe and has to follow all rules previously discussed. The grey circle in Figure 23 indicates the air vent.

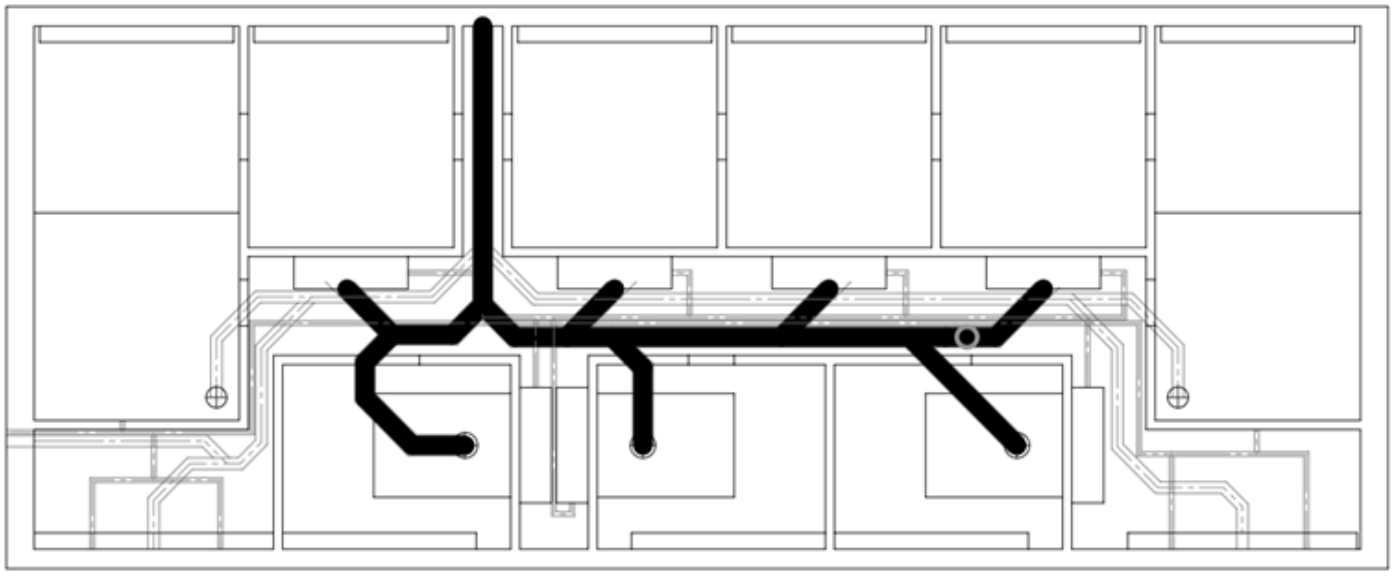


Figure 23: Black water drainage

Fresh water system

Freshwater is pumped to the handwashing stations and the shower water storage tank. Just like the pressurized grey water, a flexible hose of 20 mm is used, Figure 24.

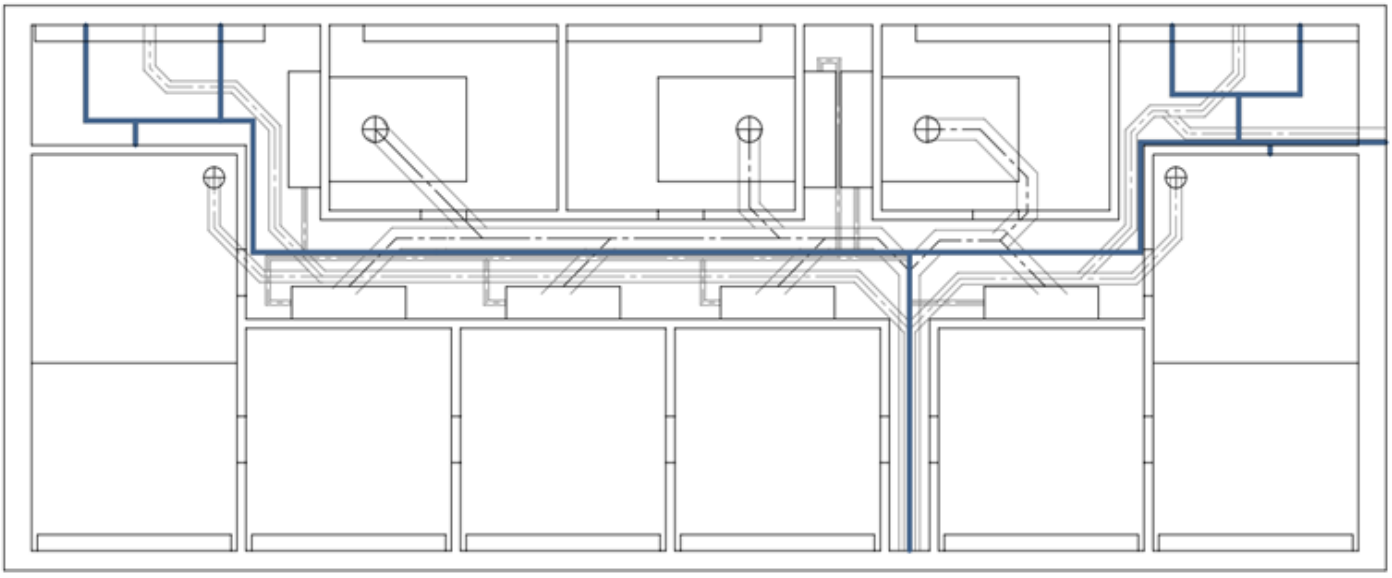


Figure 24: Fresh water supply

3.2 Business case

The business model of the sanitation unit consists of two revenue streams. In the first place, the visitors of the facility pay for their visit. The amount they have to pay differs per facility they will be using. The entrance fee for a urinal visit is 0,2 Cedi, which is around €0,03. The toilet costs 0,5 Cedi or €0,08, and for a shower, the users pay 1 Cedi which is around €0,15. According to Stip, C.M., the average cost of a public toilet lies between 40 and 50 pesewas, Peprah, D. argues this is around 45 to 80. This means the prices handled are in the lower end of the spectrum [5, 7].

All water streams are collected and recycled into drinking water, fertilizer, and biogas, which will be sold again. Only this is not covering all costs for running the facility, therefore it was chosen to charge for entrance.

At the market in Techiman, a well will be made. After filtration, this provides fresh water needed for the handwashing facilities and the showers. The freshwater source will be used to sell filtered, safe, and cold bottled water. This serves as a third revenue stream at the market of Techiman. A bottle with half a liter of water costs 0,7 Cedi or €0,11.

The calculation of the revenue can be found in Appendix A - Income. As can be seen, the toilets generate by far the most income out of the entrance fees. The men's and women's sections together generate 37% of the total income. Only the sales of cold bottled water generate more, 42%, Figure 25. I won't go into detail about this since this lies out of the scope of the project

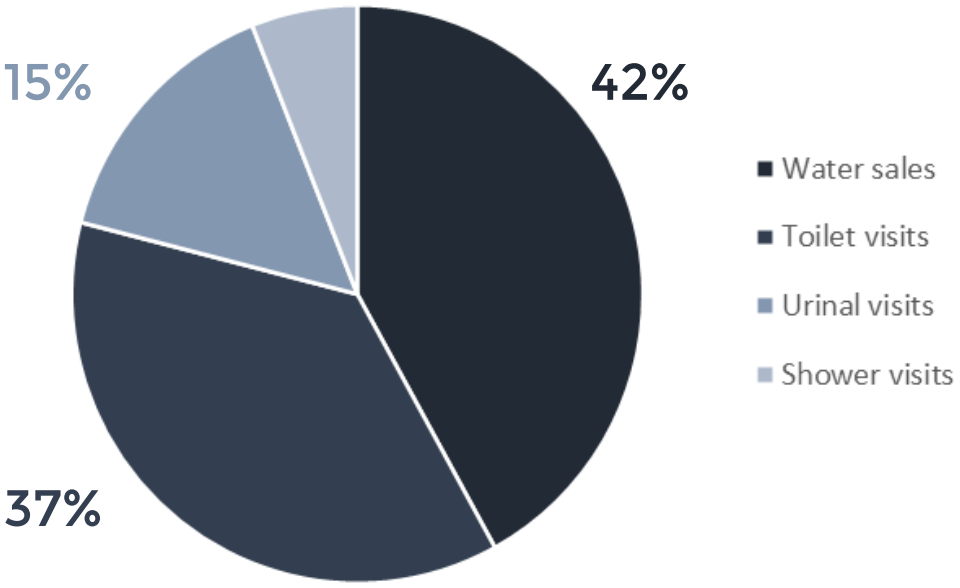


Figure 25: Income distribution

The toilets are most important for the company since they bring in the most money. It is important the toilets are to the liking of the customers, so they will keep on using them in the long run. A clean toilet facility is most important for the users [5]. At any moment in the facility, there are at least two cleaners present, the company aims to clean the toilets quickly every three visits. The next chapter elaborates on the cleaning schedule. Cleaning has to be done quickly since a toilet being cleaned cannot be used by visitors, meaning the company loses money. Therefore the toilets must be designed in such a way that they are easy to clean.

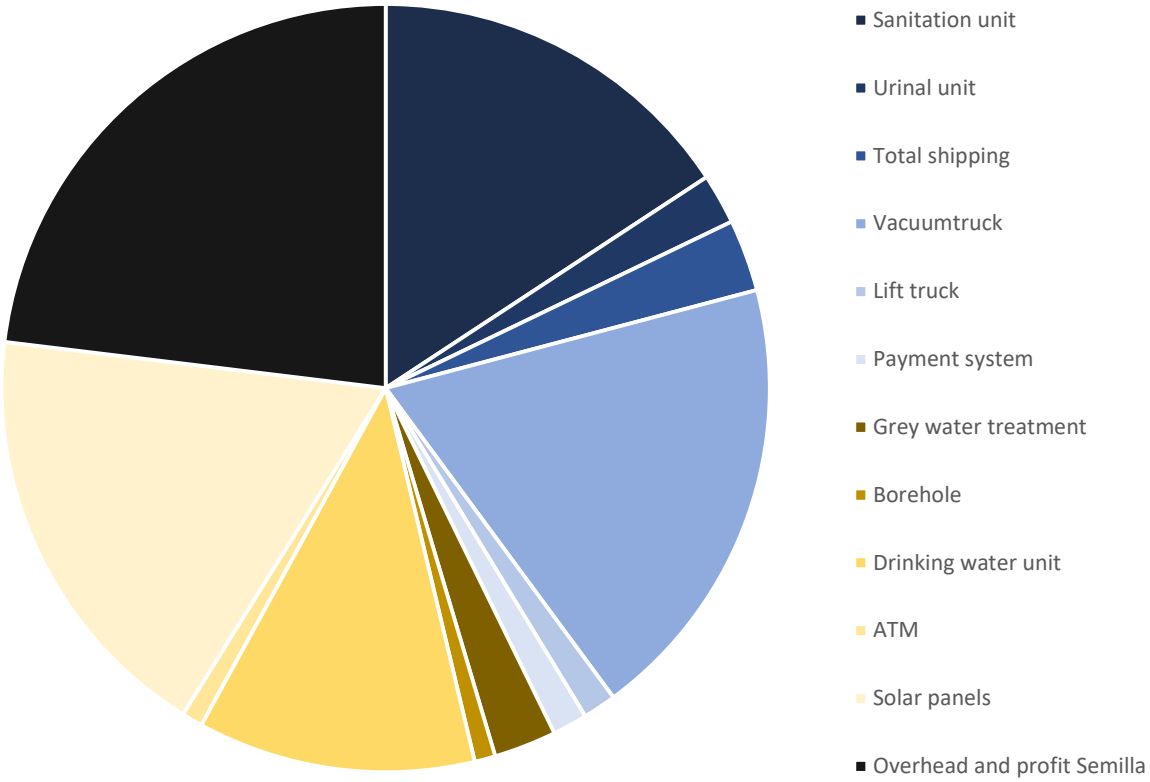


Figure 26: Structure CAPEX costs

Cost calculation

The costs of the sanitation container are relatively low compared to the total cost, Appendix A - Costs. The costs of the vacuumtruck are estimated at 65.000 euros, whereas the container will cost around 54.000 euros. Other important CAPEX costs include shipping, drinking water installation, and the grey water treatment. With total CAPEX costs of around 342.000 euros, the container and the urinal unit together cost 18%. Figure 26 shows the structure of the CAPEX costs.

As explained in the stakeholder analysis, Semilla will sell the project to Good Sanitation Ghana, this company will then exploit the facility. This means they hire the employees and cover the reoccurring costs. Semilla needs to make money as well, therefore a margin of 30% of all CAPEX costs is calculated. These are the overhead and profit costs for Semilla in Figure 26.

The profit remains the same over ten years because the amount of visitors stays the same, Appendix A - Calculation. Moreover, each year reserves 3% of the total investment for spare parts. In the first year, investments have to be made, therefore there is a loss in the first year. When grants and other subsidies can be applied, these investment costs can be (partially) covered. To make profit in the first year already, extra subsidies have to be privided or costs have to lower. At the moment Semilla is working on a collaboration with Klimaatfonds, this can solve this problem.

3.3 Cleaning of the facility

Clean toilets are the most important for the users, here lies the quality of this concept [5]. I want to guarantee a clean toilet for every visitor, by providing a cleaning schedule. This schedule is repeated every 90 minutes. One cleaner is responsible for the men's section, cleaning two toilets, six urinals, one shower, and three handwashing stations. The other cleaner is responsible for the women's section, cleaning five toilets, two handwashing stations, and one shower, Figure 27.

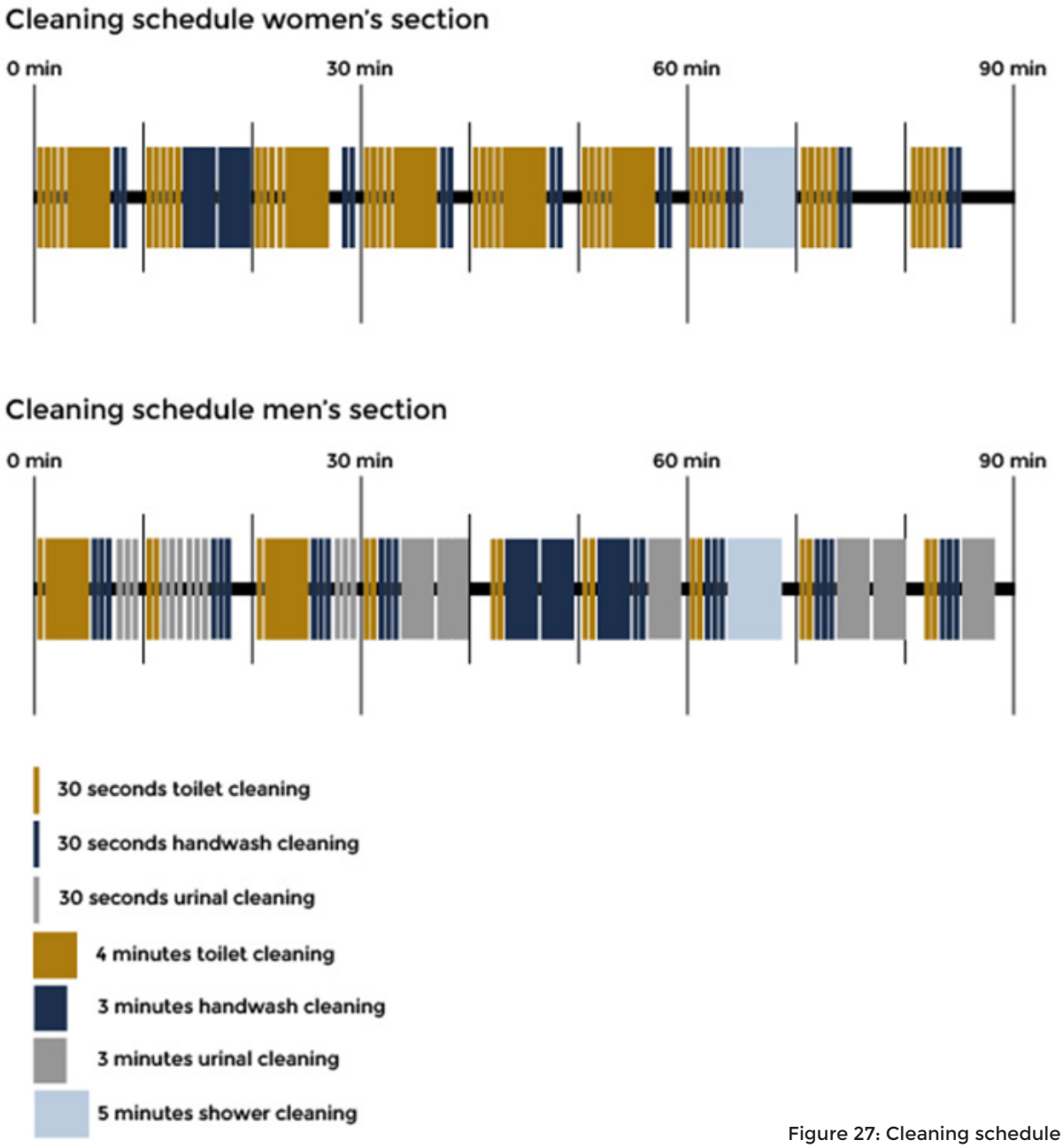


Figure 27: Cleaning schedule

This is by no means a strict schedule, the cleaners at the site can flip it around how they like, as long as the facilities are cleaned like described below. The main goal for providing this schedule is to check whether the facilities can be cleaned according to plan with two cleaners available.

Toilets

Each toilet is cleaned every three visits, more or less every 10 minutes. Cleaning done frequently does not take long. It involves disinfecting all places that make contact with the skin. In a toilet, the door handle, the toilet seat, the flush button, and the door lock will be cleaned. The toilet itself will be inspected, if necessary rest of the feces will be removed. If unpalatable things are inside, the inside of the garbage will be covered with a paper towel. This cleaning will not take more than 30 seconds.

Every 30 visits or every 90 minutes, a big cleaning session of 4 minutes will be conducted in all toilets. Every day this is done around 12 times. This includes everything that is done during the quick cleaning session and spraying and cleaning the whole outside of the toilet with soap and cleaning the bowl with bleach. The floor is mopped, and the outside of the garbage bin is cleaned. If filled, the garbage bin is emptied.

Handwashing facilities

Just like the toilets, the handwashing facilities are cleaned in two different ways. A quick clean is focused on disinfecting the components the visitors touch with their hands: the taps and the towel dispensers. Spilled soap or towels are removed. This quick session takes around 30 seconds.

Just like the toilets, the handwashing facilities will be cleaned thoroughly every 90 minutes. This means cleaning out the sinks, cleaning all components like the tap, soap dispenser, and towel dispenser. Finally, the soap and towels are checked for refilling and the trash bag is replaced if necessary. Also, the floor around the handwashing facilities is cleaned. It is estimated to take around 3 minutes.

Showers

The showers are cleaned every six visits, in this case, every hour. Cleaning of the showers will take around 5 minutes. In these 5 minutes, everything making contact with the skin will be disinfected: the coin machine, the door handles, the lock, the shower tray, and the benches. All hairs are removed and the floor, walls, hooks, and shower drain will be cleaned.

Urinals

Urinals won't be cleaned as much as the toilets. Every 30 minutes a quick cleaning of the urinals will be executed. Just like the other quick cleans, this will only take around 30 seconds. The whole urinal is cleaned with soap and flushed with water.

A thorough clean will be done every 60 minutes, during this cleaning session the floors, side panels, and the wall will be cleaned. This will take approximately 3 minutes. On average, the urinals will be cleaned every 20 minutes, so every 8 visits.

3.3.1 Time per visit

In Appendix A - Income a calculation is made on how long a visit to a facility should take on average to make sure all users can use the facility. This calculation is made based on 18 opening hours a day with an even distribution of visitors at every moment. This is a hypothetical time since it does not take into account cleaning in-between visits.

To calculate the cleaning time per visit, the total time spent cleaning each day is divided by the number of visits per day. The maximum average time is calculated by subtracting this cleaning time from the hypothetical time. This is the time the users have in the cubicle, Table 1.

Facility	Visitors per day	Hypothetical time (sec)	Cleaning time per visit (sec)	Maximum average time (sec)	Estimated average time (sec)
Urinals	2400	162	7	155	47
Toilet men	700	185	16	169	162
Handwash men	3100	63	5	58	38
Shower men	100	648	54	594	-
Toilet women	1750	185	16	169	166
Handwash women	1750	74	6	68	38
Showers women	100	648	54	594	-

Table 1: Time per visit

With 2400 visits to the urinal each day, every man has 155 seconds per visit. This should be more than enough since literature tells us men spend on average 39 – 47 seconds at the urinals [39, 40].

For the toilets, both men and women have 2 minutes and 49 seconds for their visit. Recent research tells the dwelling time, the complete duration from entering a facility to leaving it (including washing hands), for men is 136 seconds on average and for women 166 seconds [41]. This is in line with observations in the train toilet from Marian Loth, arguing men take 162 seconds and women take 131 seconds to urinate in a seated position [13]. The actual duration for men will probably be longer since most men will use the toilet to defecate only since urinals are available for urinating.

The estimated time for a visit to the toilet compared to the maximum time does not differ much, Table 1. If it appears that the visitors take a bit longer on average than the maximum time, there is no more place for 350 visitors a day per facility. The first tests in Ghana have to point out how much time people need and how many people a day would want to visit the facility.

The time spent inside the shower cubicle is harder to predict since less research is done on this topic. For each shower, 25 L is used. With a flow rate of 5 liters per minute, this comes down to a showering time of five minutes. There are five more minutes left to dry and change. The practice has to point out whether one shower can serve 100 people a day.

The number of users per day per facility has been estimated by Semilla during a visit to the market. This is an estimation based on the number of visitors and the current sanitation situation. Some of the numbers provided by the company have been adjusted because of logistical reasons. To give an example: Initially, it was estimated that 200 people per day would use the shower. However, this is not possible since this only leaves 5 minutes per shower without taking into account time for cleaning. These are rough estimates, the first tests in Techiman have to point out if they were correct. Based on the data collected, the water streams and income should be recalculated.

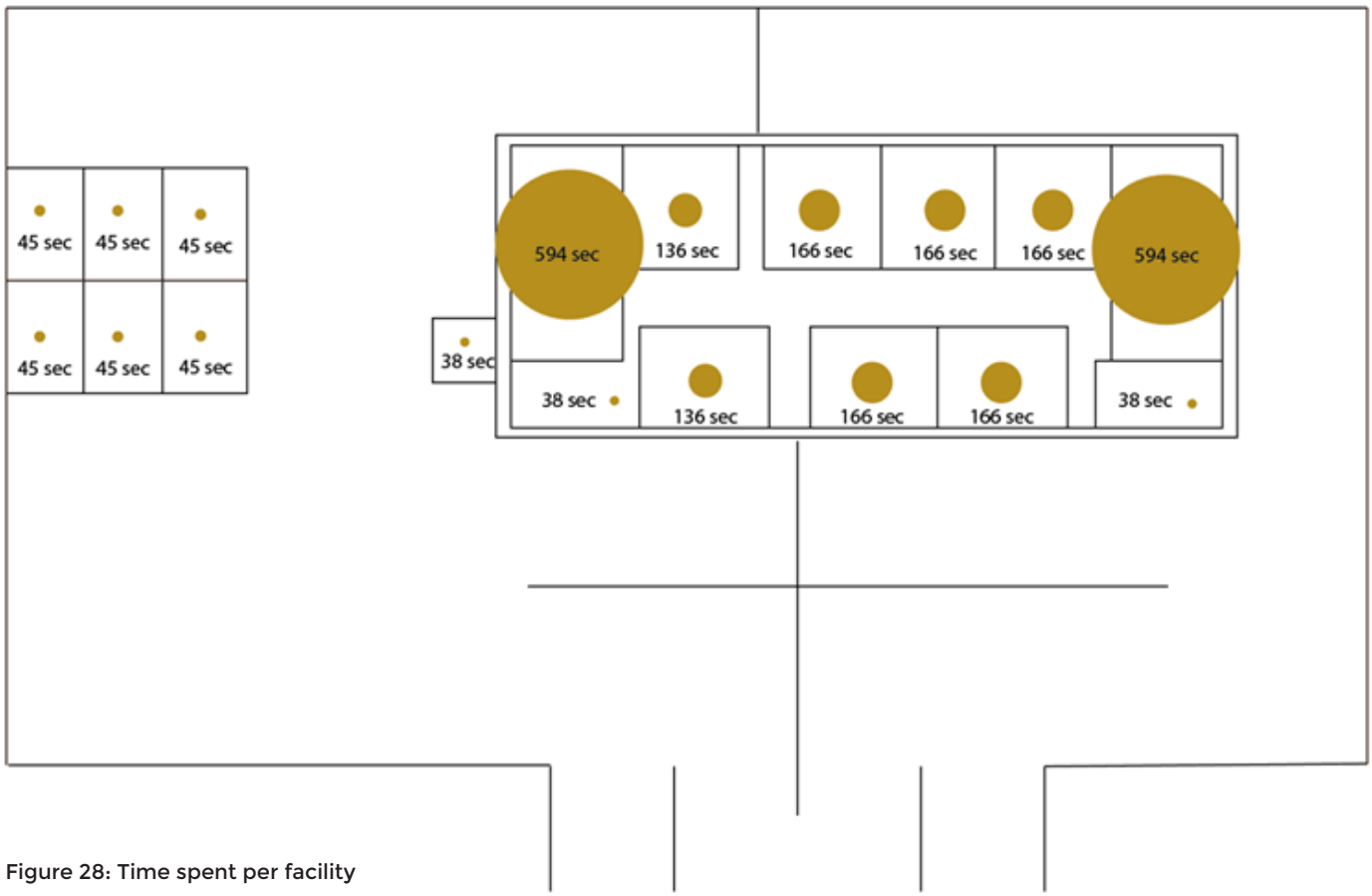


Figure 28: Time spent per facility

The time people spent in each cubicle differs a lot, Figure 28. In the showers, people take as long as 10 minutes whereas washing hands only requires 38 seconds.

3.4 Lay-out of the container

3.4.1 Measurements and shipping

A standard 20 feet high cube shipping container will be used. To be shipped as a container, the sanitation unit has to meet the CSC shipping container requirements [23]. The most important requirement from this agreement is that the shipping container can't be larger than its standard sizing: 6058 x 2438 x 2891 mm [24]. This means it is not possible to mount things onto the outside of the container during transport. Otherwise, the sanitation unit has to be shipped in a bigger container, increasing transportation costs drastically. The first version of the sanitation container will be shipped on a 40 ft. flat container, Figure 29. According to mister Wouters from Boschmans Steinacher Shipping, this is the most cost-effective way of transportation. It is possible to request a CSC plate. The sanitation container will be checked and only then it can be shipped as a container itself. This is an expensive process, it only becomes beneficial when shipping large amounts. For one container, however, this will be more expensive than shipping it on a flat container.

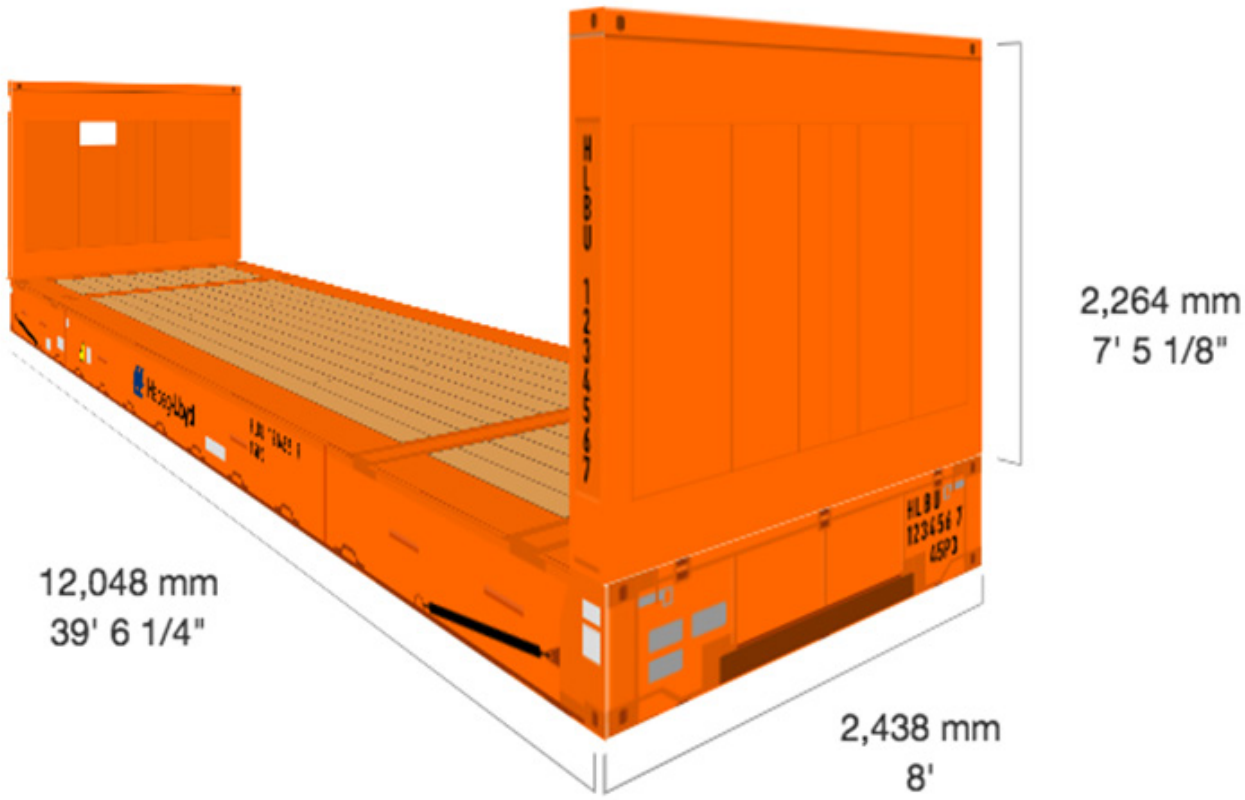


Figure 29: 40 feet flat container

My final design will be according to the CSC regulations, so in the future, a CSC plate can be requested if larger quantities of the container will be produced.

Together with the client and Kan-Bud, the container builder company, it was chosen to use an isolated container. These have a professional-looking finish on the inside and do not need further finishing. With isolation in place, the inside of the container measures 5740 x 2286 x 2573 mm. This is the limited space to work with, this cannot be increased.

3.4.2 Design

The final design of the layout of the sanitation unit is as can be seen in Figure 30.

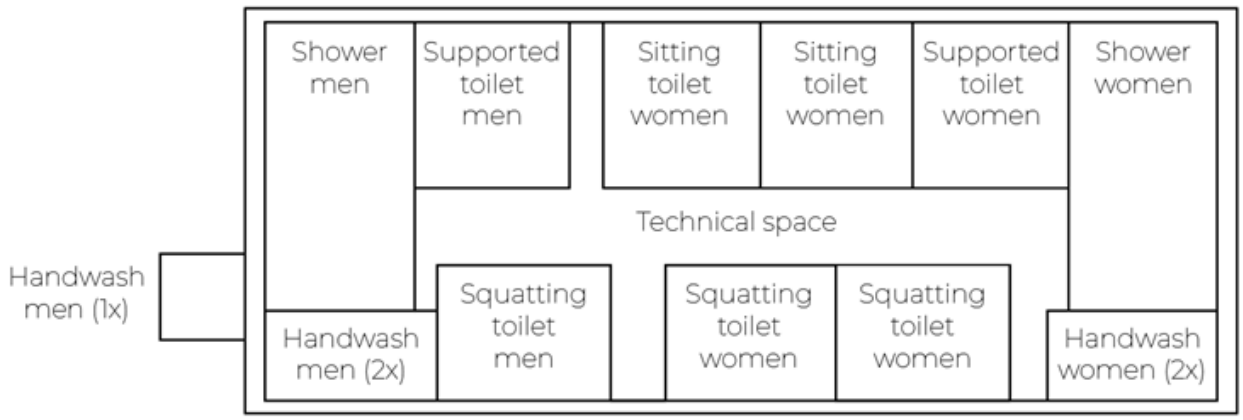


Figure 30: Lay-out sanitation container

The men's section includes one supported toilet, one squatting toilet, one shower, and three handwashing facilities. The women's section includes one supported toilet, two sitting toilets, two squatting toilets, one shower, and two handwashing facilities. In the technical space between all the stalls, the tubing to the storage tanks lays.
The toilet reservoirs are not located within the toilet stall but in the technical space, Figure 31. In the men's section, a third handwashing station is placed on the outside of the container. This station will be shipped inside one of the cubicles and installed in Techiman.

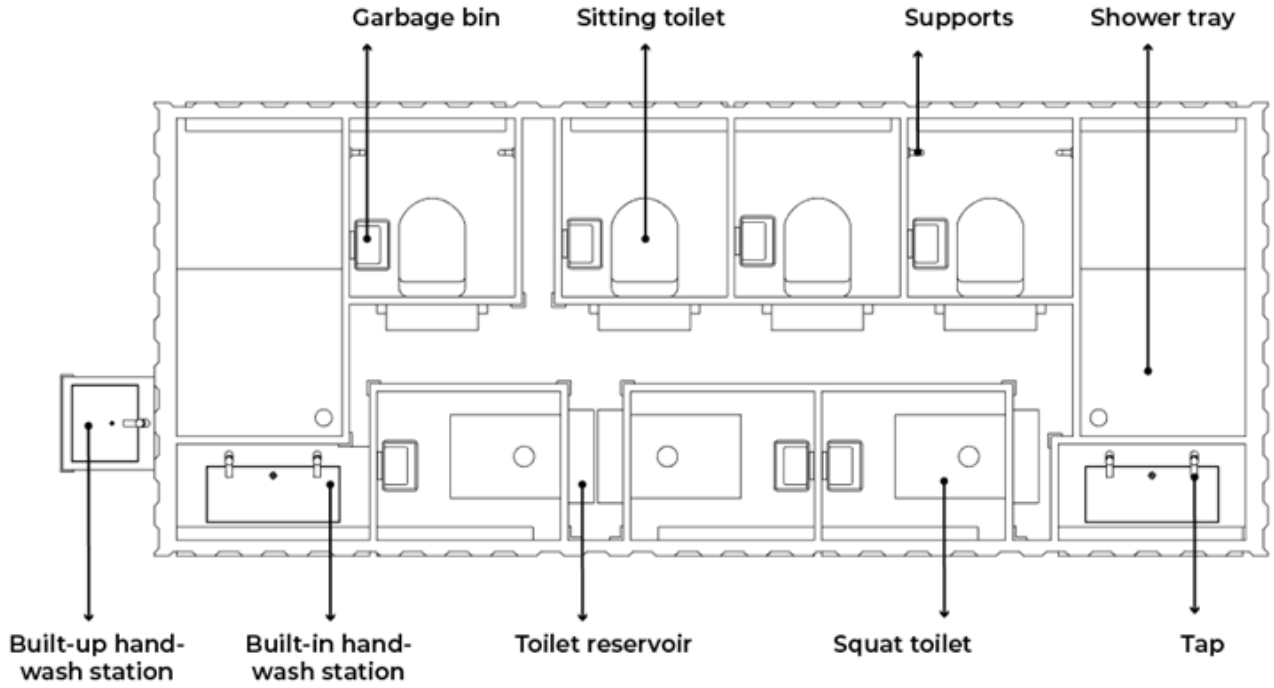


Figure 31: Detailled lay-out container

3.4.3 Stakeholders

To explain the design choices made that led to the current layout of the sanitation unit, the interests of the following five stakeholders will be discussed, see Figure 32.

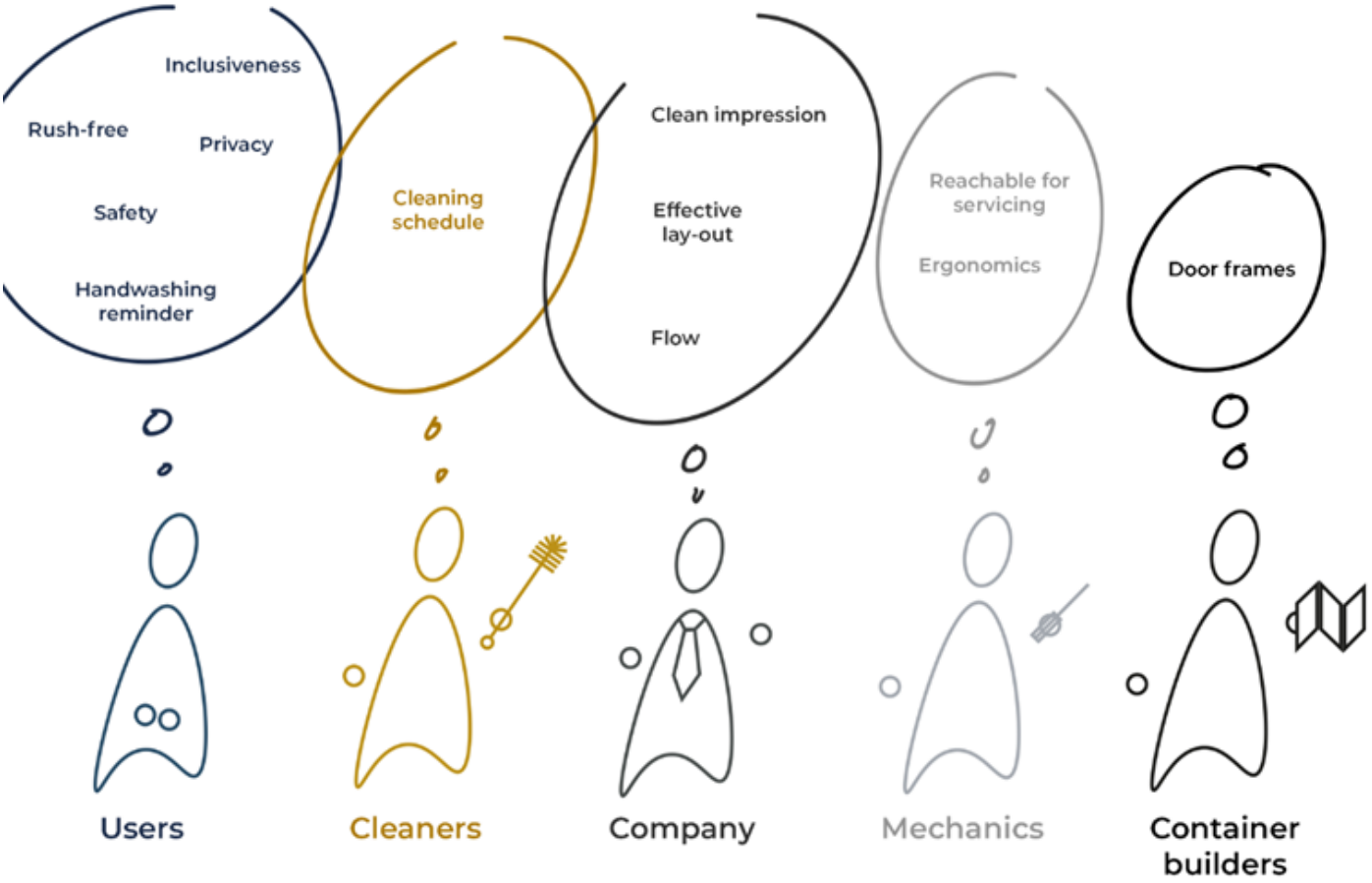


Figure 32: Stakeholders lay-out

Users

Inclusiveness

Research shows elderly, children, and less mobile people are underrepresented in public sanitation facilities within Ghana [5]. The main reason for this is that the facilities are not designed to fit their needs. Therefore I chose to incorporate squatting, sitting, and supported toilets in my design. In chapter 3.6 I will elaborate on this.

Privacy

To increase the feeling of privacy, I have pushed the entrance of the showers to the back of the unit, Figure 33. By placing these facilities to the back, it will be less crowded in front of the showers. Especially in the shower stalls, where men and women are completely naked, I want to increase the feeling of privacy, knowing people waiting in line can't see you the moment you walk out of the cubicle.

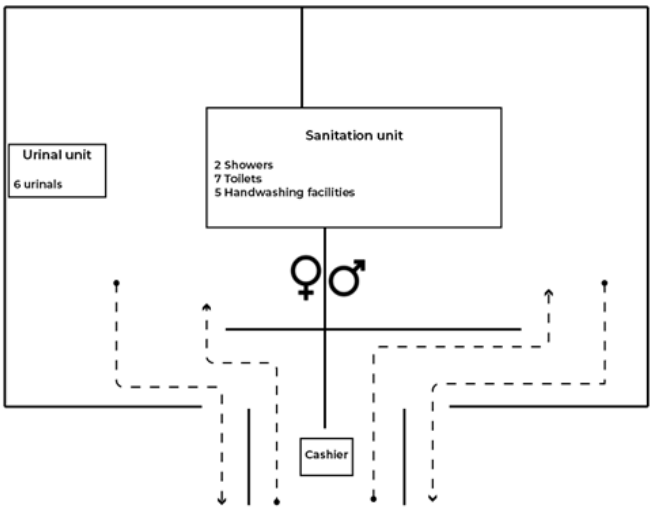


Figure 33: Men and women meet at the entrance

Feeling of safety

With using public sanitation facilities With using public sanitation facilities there is always the risk to get harassed. To reduce this risk I choose to work with large opening hours from 05.00 – 23.00, giving women the chance to visit any time of the day, not forcing them in a small-time schedule.

It is really important for women to feel safe in a vulnerable situation like using sanitation facilities [12]. Therefore I chose not to use gender-neutral toilets. Only offering gender-neutral toilets can make women feel unsafe, and maybe discourage them to use the facility, only making the problem bigger. Therefore I choose a clear separation between men and women as the Reinvent the Toilet project suggests [11].

The only place women and men meet in this design is in line in front of the cashier, Figure 10. The cashier is accompanied by a guard, to prevent robberies and to make women feel safe standing in line. Besides the guard, also other men and women stand in line, forming social control.

Not feeling rushed

The supported toilets designed for the elderly and less mobile people are placed in the back of the container. I did this to provide rest for them. A user of one of the toilets in the front might hear people standing in line talking, which can make them feel like they need to rush. I want to prevent this feeling for the elderly and less mobile people. Since these groups are already underrepresented, I do not want to scare them away from the facility [5].

Remind to wash hands

The most prominent reason why people do not wash their hands is forgetfulness [44]. The users should be reminded to wash their hands. Therefore I placed the handwashing facilities in the corners of the container. Moreover, the fences in the facility guide all users past the handwashing facilities on their way out. By seeing the facilities, the users will be reminded of them and hopefully, the handwashing rate will increase.

Cleaners

As explained in the cleaning schedule, there is one cleaner responsible for the men's section and one cleaner for the women's section. This was decided upon to prevent a situation in which the cleaners constantly have to walk from men's to women's section and vice versa. This would cost them valuable cleaning time. Besides that this makes it possible to employ men to clean the men's section and women to clean the women's section, which can contribute to the feeling of safety and comfort for both the cleaners and the users.

Company

Effective lay-out

the effectiveness. As many facilities as possible need to be fitted inside the space available. The more facilities in the container, the more people can have a shower or go to the toilet, the more money will be made in a set time.

Flow within the facility

The flow within the unit is important. Generally taking a shower takes longer than a visit to the toilet, moreover, the toilets will be used much more than the showers. Therefore the showers are placed in the back of the unit. This way the walking distance to the toilets is shorter, which adds to the efficiency. For the same reason, most sitting toilets are placed in the back. Elderly and less mobile people will mostly use these, making the squatting toilets faster to reach, improving the flow in these toilets.

Clean impression

A clean first impression of the whole facility enlarges the mental distance related to feces [13]. The first glance of a sanitation facility when someone walks in can set their attitude towards the cleanliness of the whole facility. To get a positive hygienic perception, it is best to see objects not associated with dirt. Therefore the handwashing stations are placed in the corners of the container, so these are spotted once the user passes the fences. The fences opposite the entrance are placed to improve the clean impression. Without these, people standing in line would directly face the squatting toilets, associated with dirt.

Mechanics

A technical space is located between toilet stalls, Figure 29. In this space, all reservoirs of the toilets are accessible by the mechanics for servicing or repairs. As can be read in the chapter 3.3.1 Waterflow, a system of drains is located in this space as well. For the mechanics it is most important they can ergonomically reach all components when needed.

Container builders

The container builders from Kan-Bud have a set of rules to be able to produce the container. One of those influencing the layout of the container concerns the doors. The doors measure 730 mm, around the doors 60 mm wide frames are welded, providing stiffness to the container walls. This means that the space between two doors can't be smaller than 120 mm. This influenced the position of the six doors in the back of the container, Figure 34. The same frame will be installed for big openings inside the container.

Figure 34: Frames around the doors in the container

3.5 Impression

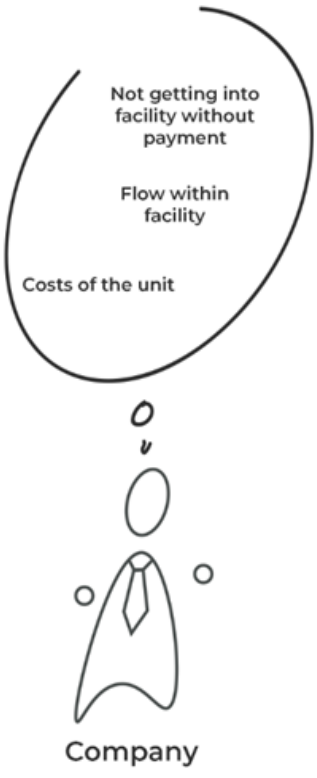
Public sanitation in Ghana can be dirty and smelly as argued in the introduction. With the Sanitainer I am looking to set a certain atmosphere around the facility, giving the facility the following impression:

- Hygienic: A clean impression of the facility gives the users a positive hygienic perception not associated with dirt [13]. This is elaborated upon in the chapter 3.4.3.
- Safe: The facility should be a safe place. The users should have trust in the facility being a safe place for them. Especially for women, it is important to feel safe and at ease to improve women's empowerment [11].
- Inviting: In the context of the market in Techiman, Semilla is not active yet, therefore the name Semilla is not known by the local people. The appearance of the container and the urinal unit, as well as the complete facility, should be inviting. The threshold to walk in should be low.
- Restful: Showering or going to the toilet can be a moment for yourself. The facility should have a restful, quiet, and easy impression.

Separations

One central entrance to the facility ensures everyone visiting the facility passes the cashier and has the opportunity to pay for their visit. To create a central entrance, separations have to be made. The company wanted to create these by setting building fences around the facility, see Figure 35.

Figure 35: Building fences



Fences are contrasting the desired values. They do not feel restful, let alone inviting. Besides, they are not a permanent solution, they are aimed at temporary use. Their lifespan is only three years [96]. However, it is necessary to provide a form of separation. Therefore I chose to add black fences shown in Figure 36. These are permanent solutions since the poles are dug into the ground 80 cm deep.

Figure 36: Black fences

Figure 37: Fences with plants

These fences can be modified by adding banners or growing plants to make the facility more inviting. In Figure 37 the fences around the facility can be seen. The green lines represent fences where plants are grown onto, Figure 38. The blue ones represent fences equipped with banners. In Figure 39 all fences are covered with vegetation.

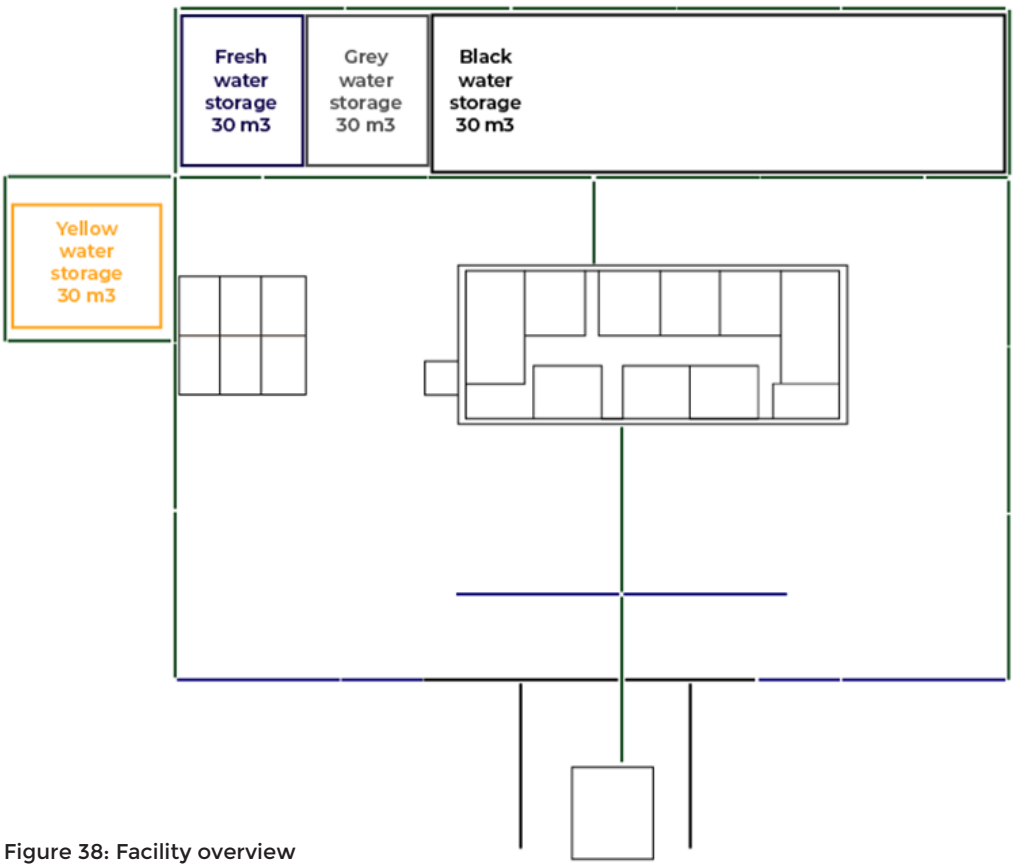


Figure 38: Facility overview

Figure 39: Fences vegetation

Besides creating a more restful and inviting atmosphere, growing plants on the fences also convey the company's story. It physically shows that from feces and urine, plants can grow.

Banners on the fences prevent people from looking inside the facility, improving the feeling of privacy. Moreover, these banners can be used to convey messages on how to use the toilets or how important clean sanitation is, and the dangers of open defecation, Figure 40. Instead of teaching the users about sanitation, it can be argued that taking a shower or going to the toilet should be an easy and calm moment for yourself. Instead of advertisements or banners telling how to act, banners can also be used to make the facility fit more in with the context, by displaying drawings of local people for example.

Figure 40: Banners

Sanitation container

The container is painted white to attract as little heat as possible, to prevent the cubicles from heating up to high temperatures. The doors are green to match the urinals. Within the small stalls in the container light colors are being used. Light colors make spaces appear larger than it is.

3.6 Inclusiveness

When designing for inclusiveness wheelchair users should not be forgotten. There is no toilet for wheelchair users in the facility, Figure 29. This has several reasons. According to local employee mister Collins, there is no access for wheelchairs to the market. The market is not paved, making maneuvering around the market in a wheelchair uncomfortable and hard, Figure 41, 42, 43.

Figure 41: Techiman market

Figure 42: Techiman market

Figure 43: Urinals at the Techiman market

Besides, there is a limited place inside the 20 feet container. According to the Dutch Bouwbesluit, a toilet for wheelchairs should measure at least 1650 x 2200 mm, or the length and the width combined should be 3850 mm [99]. This would mean this toilet will take up a large space compared to the current layout.

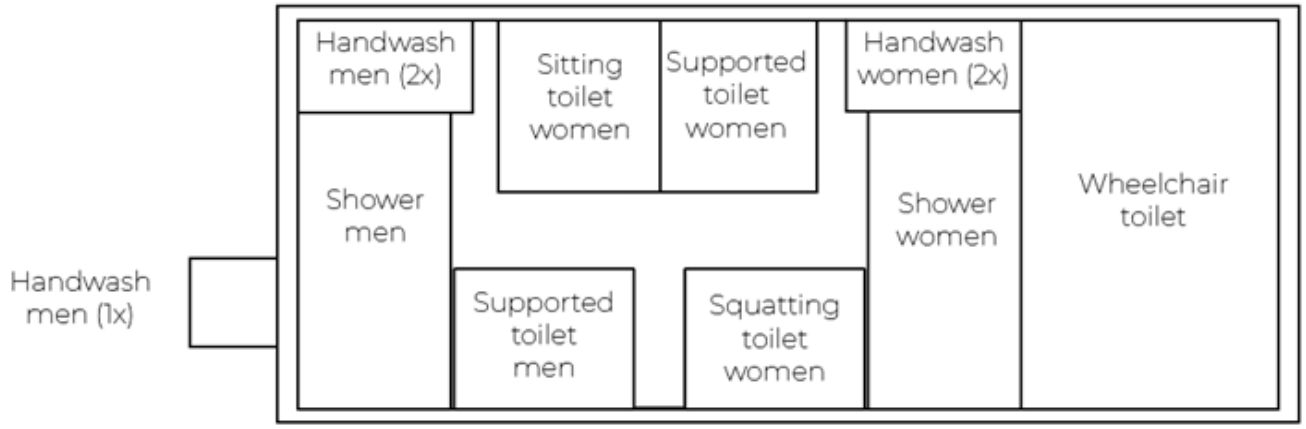


Figure 44: Lay-out with one wheelchair toilet

Adding one unisex wheelchair toilet in the facility reduces the number of toilets from 7 to 5, Figure 45. This leaves 4 non-wheelchair toilets. Adding a wheelchair toilet for men and a wheelchair toilet for women would reduce the number of toilets to 3 instead of 7, Figure 44.

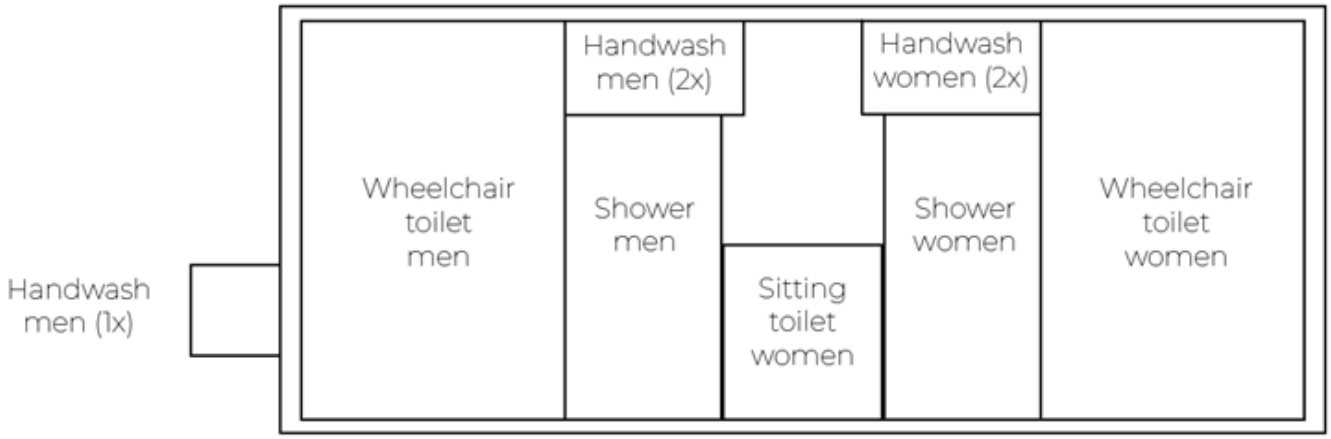


Figure 45: Lay-out with two wheelchair toilets

In other contexts, where wheelchair users are present, it might be necessary to add one or two wheelchair toilets in the container. Instead of a 20 feet container, it can be beneficial to add these in a 40 feet container, this way it takes up relatively less space, Figure 46.

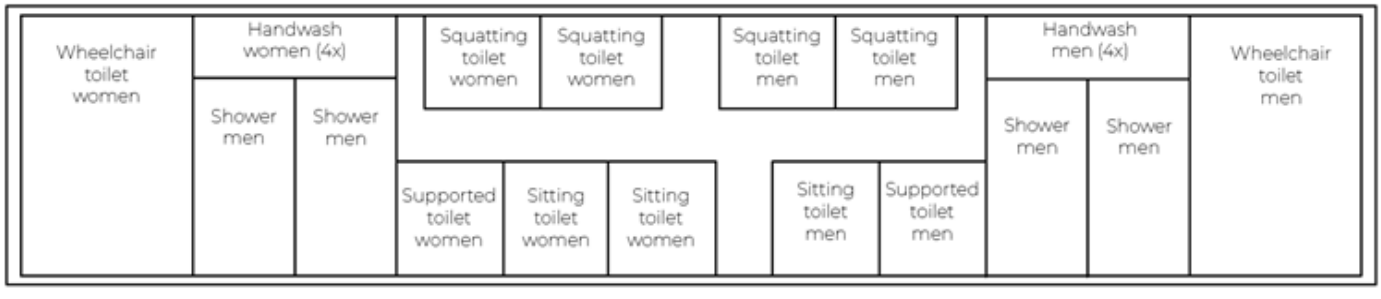


Figure 46: Lay-out in a 40 feet container

3.7 Technical space

In interviews with mister Bosman from Geberit, it became clear that it is important to have an accessible technical space inside the sanitation unit. Things may break down during long usage. The highest risk within the toilets is the flushing mechanisms and the float valves inside the reservoirs. Therefore it is important that the reservoirs can be accessed by a mechanic. Blockages can appear inside the system of tubing that runs inside the container. Mostly these blockages can be fixed from within the toilet stalls by disassembling the toilet bowls. However, all tubing needs to be accessible at all times by the mechanics.

By placing the reservoirs behind the toilet stalls, a small technical space is created which can be entered to do repairs. This space measures only 428 mm in width, Figure 47. This is very tight especially taking into account the reservoirs take up 140 mm. Increasing this width would mean that the toilet stall would decrease in size. Since each toilet will be visited 350 times each day, and the technical space will only be visited in case of breakages I prioritized the comfort of the users over the comfort of the mechanic.

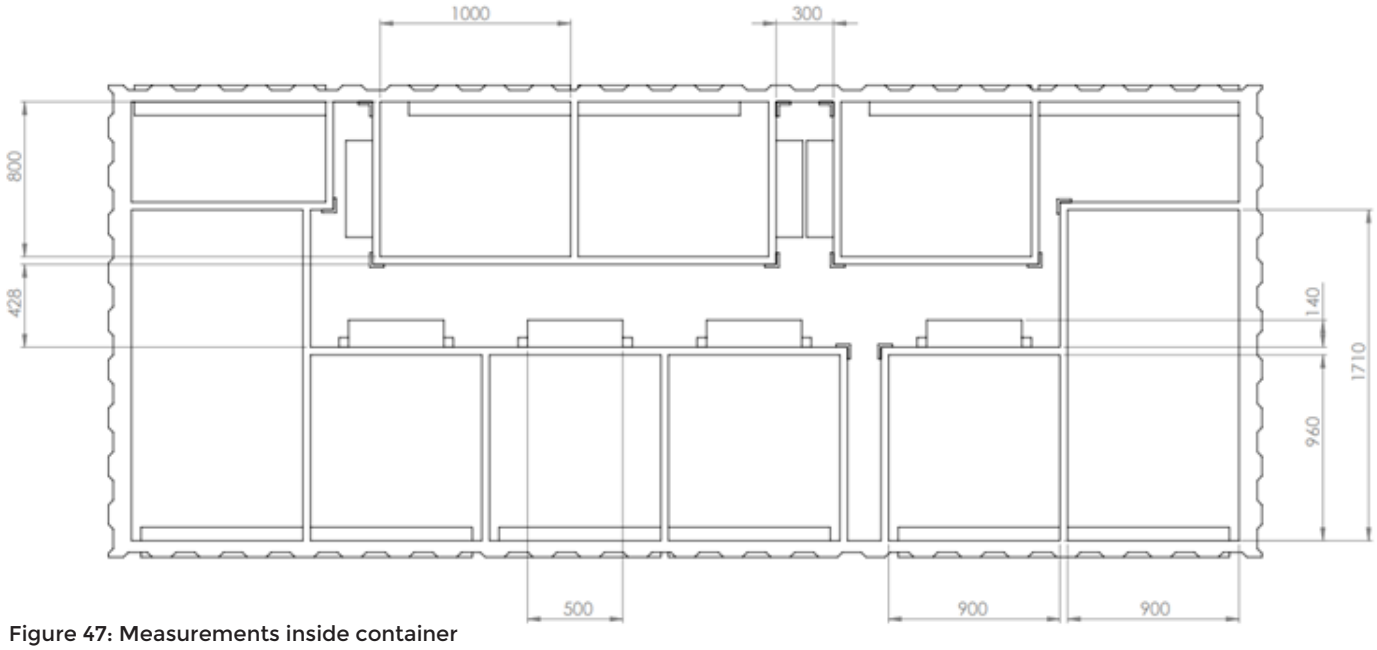


Figure 47: Measurements inside container

Together with Kan-Bud, it was decided to make hatches inside the cubicles of the squatting toilets to enter the technical space. These hatches can be opened when repairs are needed. These serve as the entrances to the technical space. In all of the three squat toilets hatches like these are applied, Figure 48. These hatches do not only serve as entrances but can be removed completely, to enlarge the space for repairs. When these are removed the mechanics have more space, making repairing ergonomically more comfortable. Some repairs can't be done from the squatting toilets, for example when something in the reservoirs of the squatting toilets needs servicing. Therefore the technical space needs to be passable to reach the corners.

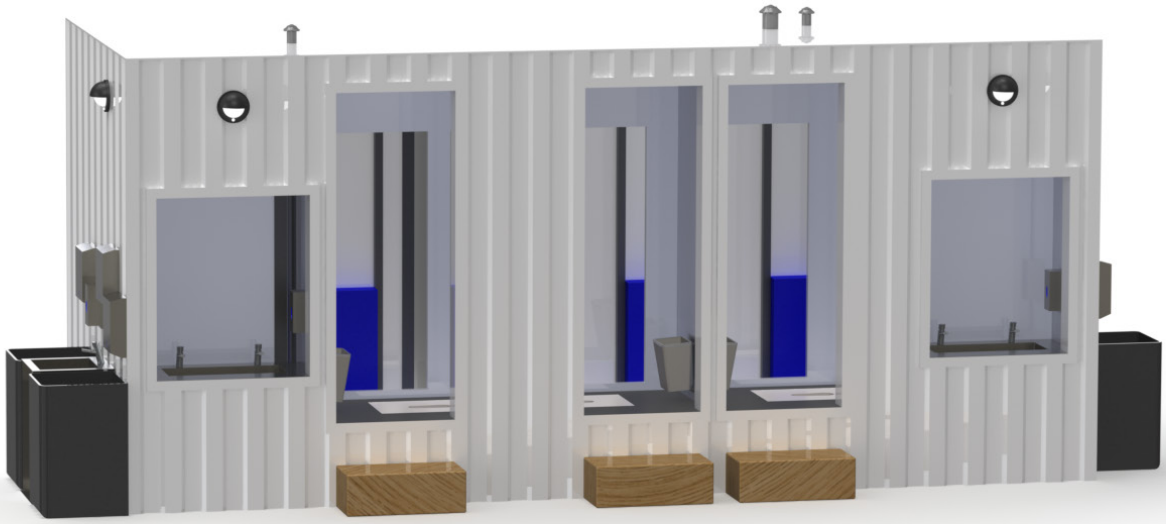


Figure 48: Hatches to the technical space, the blue boxes that can be seen in the technical space are the toilet reservoirs

PART IV
Toilet stalls

4.1 Stakeholder analysis

The toilets form the core of the sanitation container. As described in the problem definition, toilets in the facility aim to lower the open defecation rate among the visitors of the market in Techiman. According to the WHO open defecation perpetuates a vicious cycle of disease and poverty [88]. Counties with high open defecation rates have the highest levels of malnutrition and poverty and children dying under the age of five [89]. Clean sanitation represents the United Nation's Sustainable Development Goal number 6.2: "By 2030, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations" [90]. Figure 49 shows the interests of the five main stakeholders.

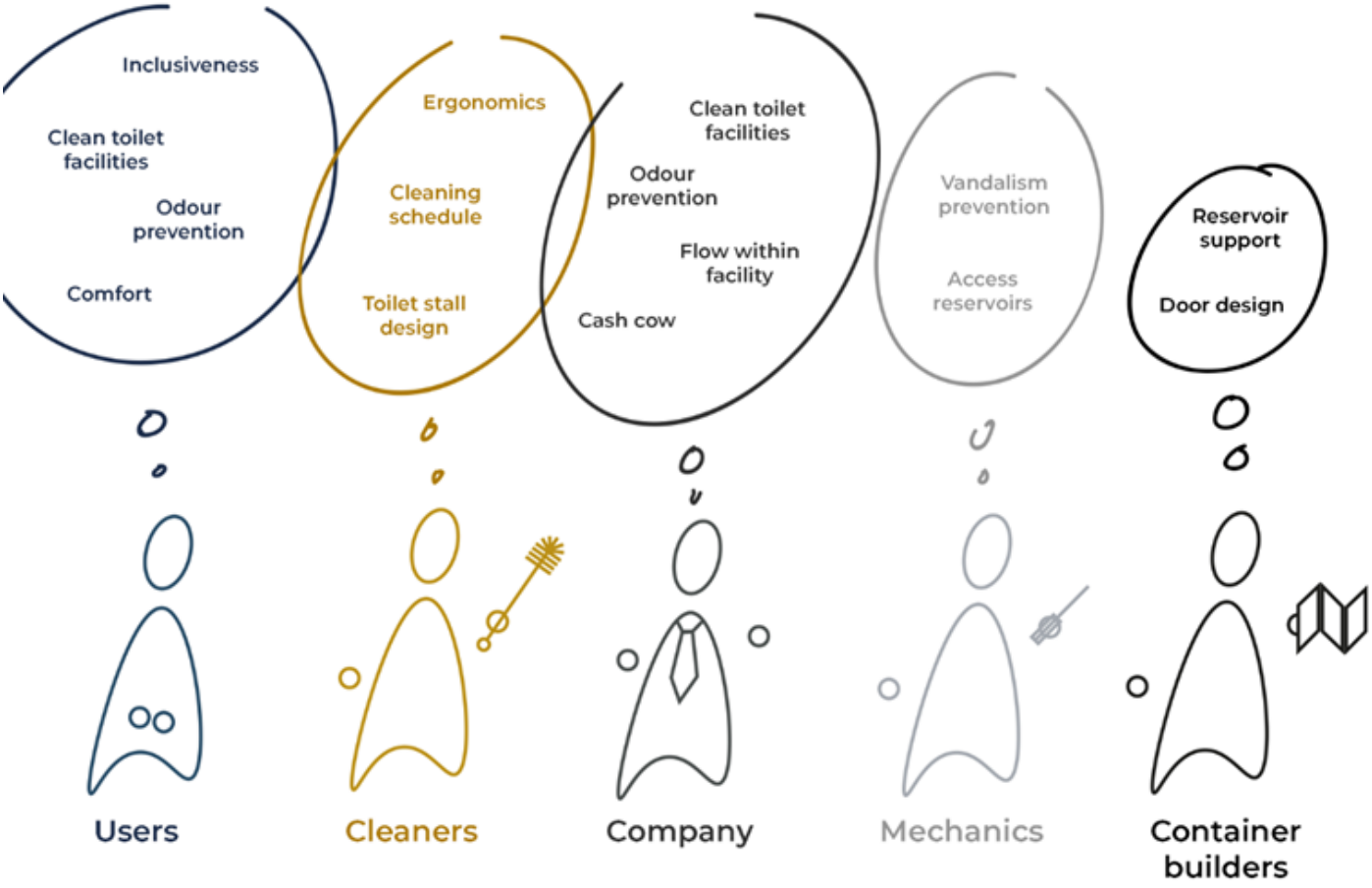


Figure 49: Stakeholder analysis toilets

Users
Research shows that the most important factor for users is the cleanliness of the toilet [5]. When provided with a clean, not-smelling toilet, users are more likely to choose this concept compared to the other sanitary facilities at the market, since these can be dirty, as shown in the introduction.
Besides cleanliness, overall comfort in the toilet stalls is important. For the elderly and less mobile, it is important that enough support is provided, to prevent accidents.

Cleaners
For the cleaners, the same principles apply to the toilet as for the whole sanitation unit. They want a toilet stall design that is easy to clean and does not take a lot of effort and time in their routine.

Company
As argued before, the toilet facilities are the cash cow in the container. The company earns the most money with its toilet facilities. Therefore it is important the toilet facilities meet the wishes of the users. It is important for Semilla that the toilet facilities are clean and not smelling. Just like in the rest of the facility the company values flow within the facility.

Mechanics
From all products the toilet stalls are equipped with, the reservoirs need the most servicing. Therefore it is important for the mechanics they can reach these when needed. Besides that, they benefit from an anti-vandalism design. Vandalism should be prevented by choosing the right products and by design, minimizing necessary repairs and services.

Container builders
In household applications, the reservoirs of toilets are mounted to the ground and the wall. In the container application, however, there is no robust wall to mount the reservoirs onto. The walls of the stalls are sandwich panels, and not made to support a toilet reservoir. For container builders, it is important to find a solution to install the reservoirs. Besides that, the rules regarding door design can have an influence on the perceived comfort.

Three different toilets
There are three different kinds of toilets within the facility: squatting toilets, sitting toilets, and supported toilets. Both squatting toilets and sitting toilets are common in Ghana according to mister Collins from Good Sanitation Ghana. Squatting toilets facilitate a more healthy way of defecating than sitting toilets and can prevent haemorrhoids [21]. When squatting, the rectum isn't blocked like when sitting, making it a more natural and healthy way to defecate [22].
A disadvantage of squatting toilets is that they do not provide a lot of stability, since the user needs to balance on his or her feet in a squatting position, especially for elderly and children this can be a problem. Moreover, Baker, P.D. argues that the lack of stability using squat toilets is the second most prominent reason, besides the dirtiness, for elderly and children to avoid public sanitation [5]. Therefore I chose to incorporate sitting toilets in the facility as well. Sitting toilets provide more support and require less balancing of the user.
I equip two sitting toilet stalls with supports on the walls. These toilet stalls are meant for less-mobile people to provide extra support when moving around in the cubicle. Supports allow the muscles in the arms to assist the leg muscles to enable a more stable movement sequence [56]. I will go into detail about these supports in chapter 4.5.

4.2 The design

Figure 50: Sitting toilets

Figure 52: Zoom in toilets: Elderly toilet - Squatting toilet - Sitting toilet

Figure 50 shows the sitting toilets, and Figure 51 shows the squatting toilets. Figure 52 shows the individual cubicles highlighting the different components in the elderly, squatting, and sitting toilet.

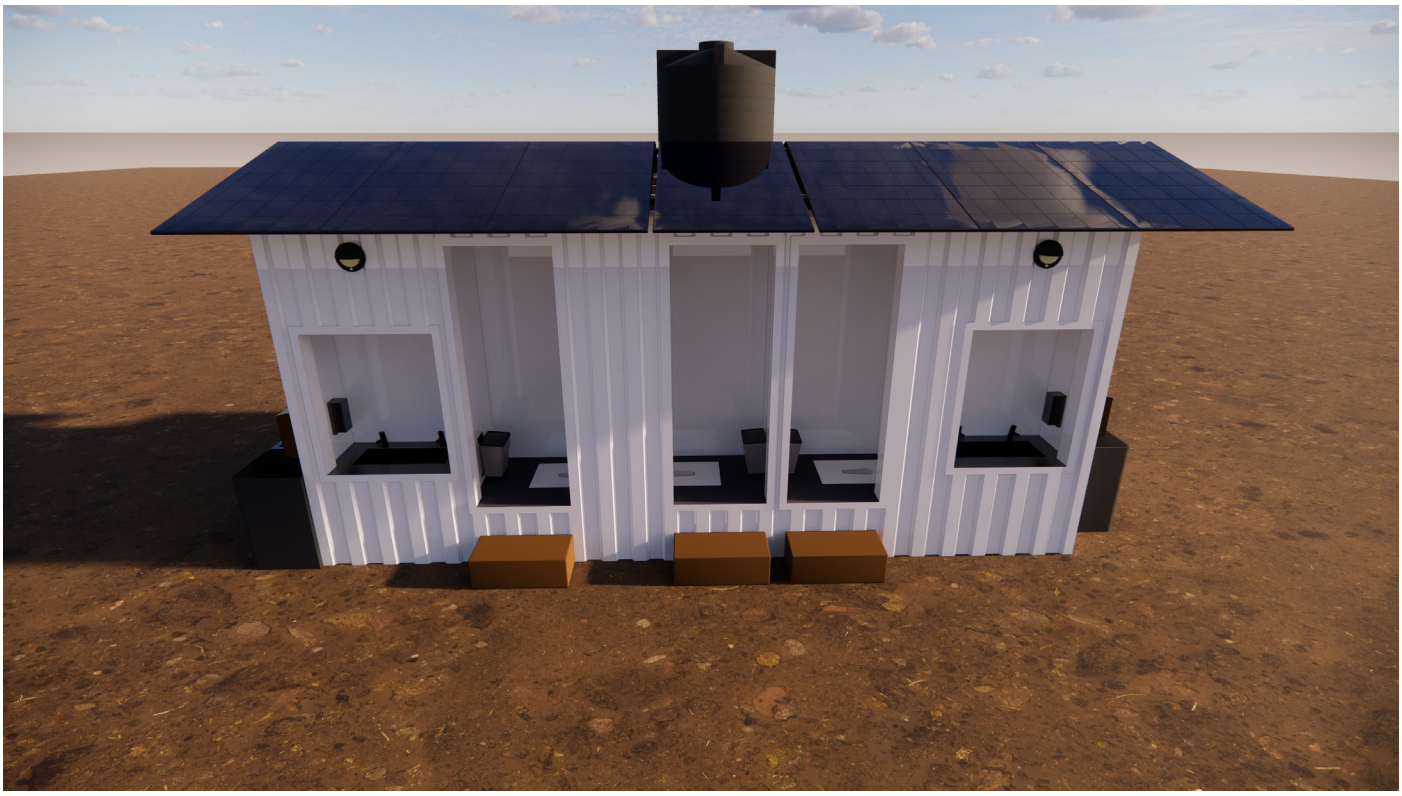
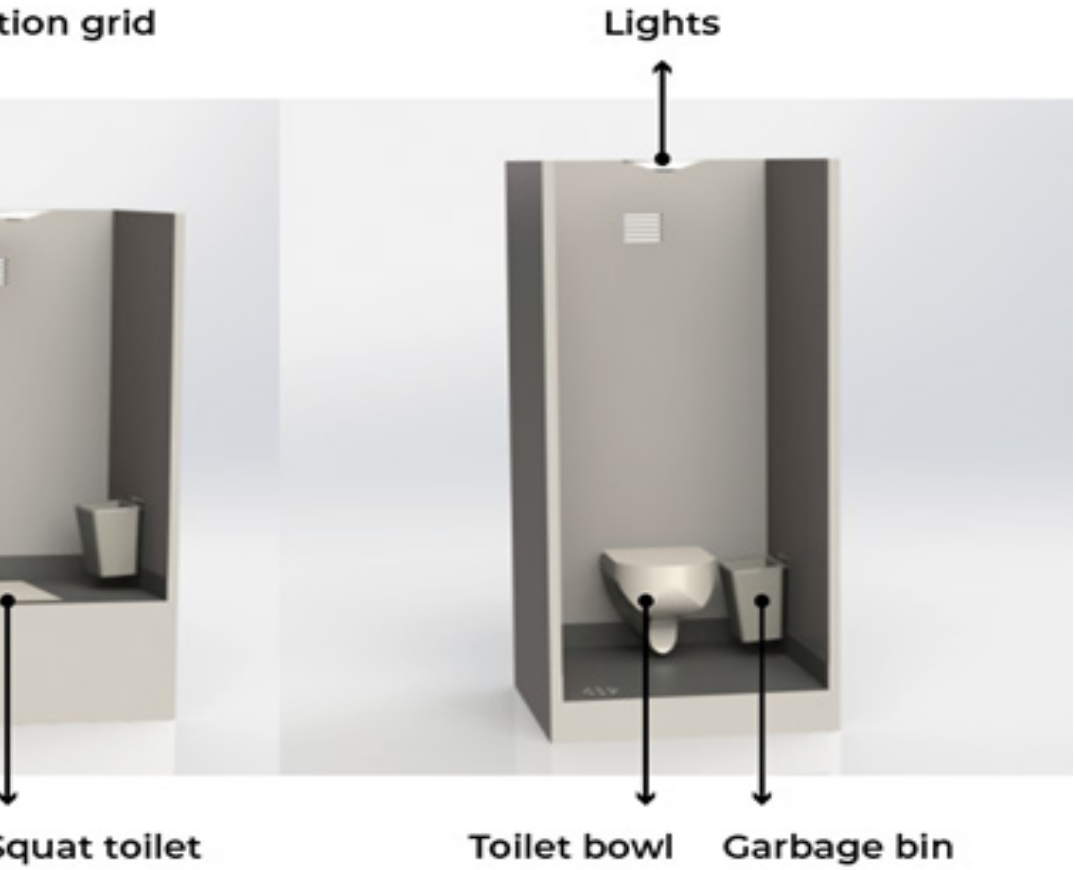


Figure 51: Squatting toilets



4.3 Measurements toilet stalls

The sitting toilets and the supported toilets measure 900 x 960 mm, Figure 53. The squatting toilets are oriented sideways and measure 1000 x 800 mm, Figure 54.

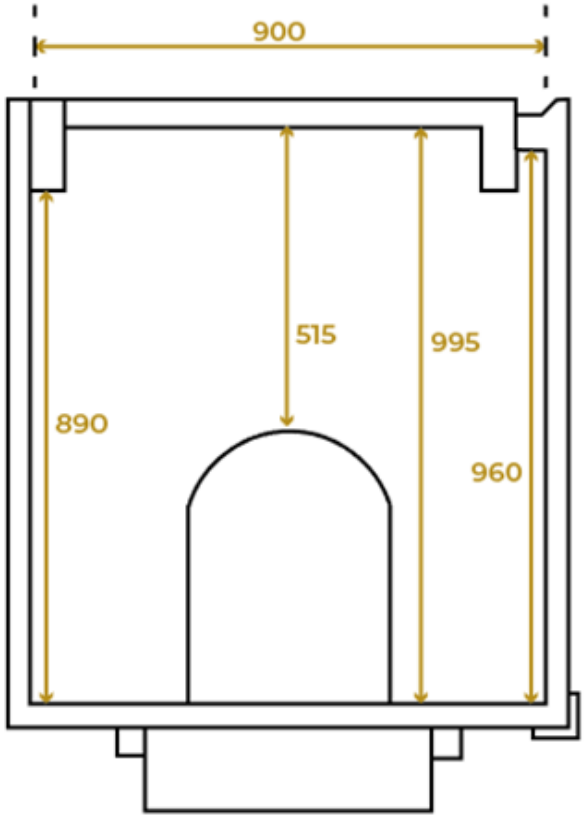


Figure 53: Overview sitting toilet

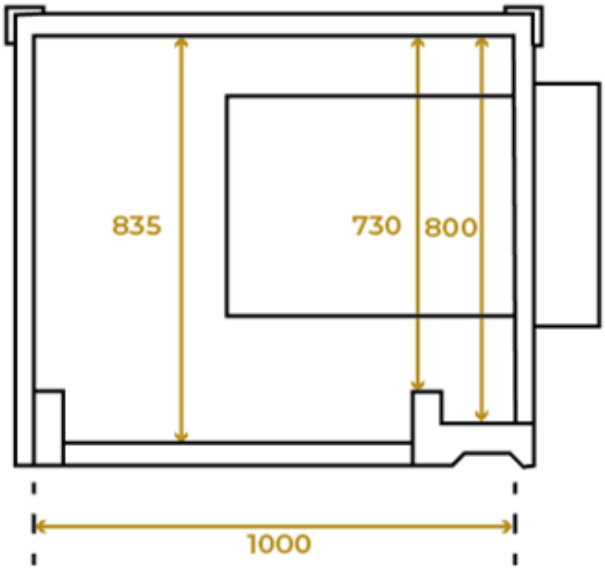


Figure 54: Overview squatting toilet

In collaboration with Kan-Bud, it was chosen to incorporate thin doors and place these all the way to the outside of the container. Looking at the sitting toilets this gives more legroom. Instead of 960 mm, the distance between the back of the stall and the door measures 995 mm, Figure 52. This gives a little extra legroom for the users.

According to the Dutch Bouwbesluit, in newly built houses toilets should measure at least 0.9 x 1.2 m [37]. I deviated from this by placing the reservoirs into the technical space. Because of this, the toilet cubicles became around 20 cm smaller. For the sitting toilets, the thickness of the wall is subtracted from this space as well, leaving a depth of 960 mm. When installing a shortened toilet with a depth of 480 mm, and taking into account the extra room of the door placement, this leaves 515 mm of legroom in front of the toilet.
Having enough legroom available in the toilet stalls adds to the feeling of comfort, which is in the interest of the users.

To determine the amount of legroom needed in the sitting toilet the DINED tables were used. Unfortunately, not all measurements required for this analysis were available for West Africa. Instead, I used the measurements for Dutch men and women 60+ measured in 2004.

To get an idea of how much room is needed in front of the toilet the abdominal depth, number 30, was subtracted from the buttock knee depth, number 33, Figure 55, Table 2. The answer gives an idea of how much of the upper leg sticks out in front of the toilet bowl. In Table 3 this is called legroom.

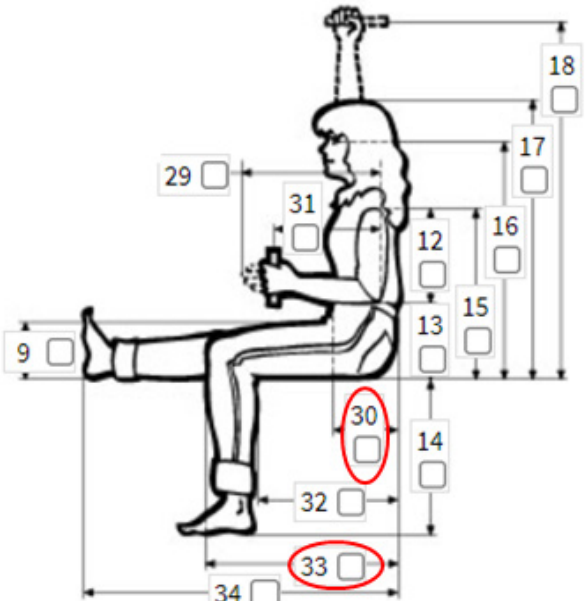


Figure 55: DINED measurements

	Buttock-knee depth (mm)	Abdominal depth (mm)
Dutch men 60+ P99	719	382
Dutch men 60+ P50	645	277
Dutch men 60+ P01	571	172
Dutch women 60+ P99	679	375
Dutch women 60+ P50	609	263
Dutch women 60+ P01	593	151

Table 2: DINED 30 and 33

Buttock-knee depth (mm)		Abdominal depth (mm)		Legroom (mm)
Dutch men 60+ P99	-	Dutch men 60+ P01	=	547
Dutch men 60+ P99	-	Dutch men 60+ P50	=	442
Dutch men 60+ P50	-	Dutch men 60+ P50	=	368
Dutch women 60+ P99	-	Dutch women 60+ P01	=	528
Dutch women 60+ P99	-	Dutch women 60+ P50	=	416
Dutch women 60+ P50	-	Dutch women 60+ P50	=	346

Table 3: Legroom calculations

This shows us that for men and women with P99 buttock-knee depth and a P01 abdominal depth the legroom of 515 mm probably is too small, meaning they have to sit with their knees against the door. However, a more realistic P99 buttock knee depth and P50 abdominal depth would fit without a problem.

	Foot length (mm)
P99 West Africa men	286
P99 West Africa women	244

Table 4: Foot length

FIgure 56: DINED foot length

Feet need to fit in the space between the toilet bowl and door as well. P99 feet of West African men and women both fit without a problem in the 515 legroom, Table 4. For this measurement DINED number 41 has been used, Figure 56.

Mister Bosman advised having a legroom of at least 450 mm to make sitting at the toilet and moving around in the stall comfortable for the user. These requirements are met with 515 mm of legroom. There are no regulations about the amount of room needed in front of a toilet, however different do it yourself websites advise at least 50 cm [62, 63].

Mister Bosman advised leaving a width of at least 800 mm for the toilet cubicles. A rule of thumb is that a sitting toilet measures roughly 40 cm in width, and on both sides at least 20 centimeters should be available, leaving a minimum width of 800 mm for the cubicle. Looking at the DINED tables, P99 in shoulder width for West African men is 462 mm, P50 measures 420 mm [55]. This means that 800 mm is enough to fit P99 shoulders in the stall.

4.4 Sitting toilets

The sitting toilets feature three main components: the toilet reservoir, the toilet itself, and the bin, Figure 57.

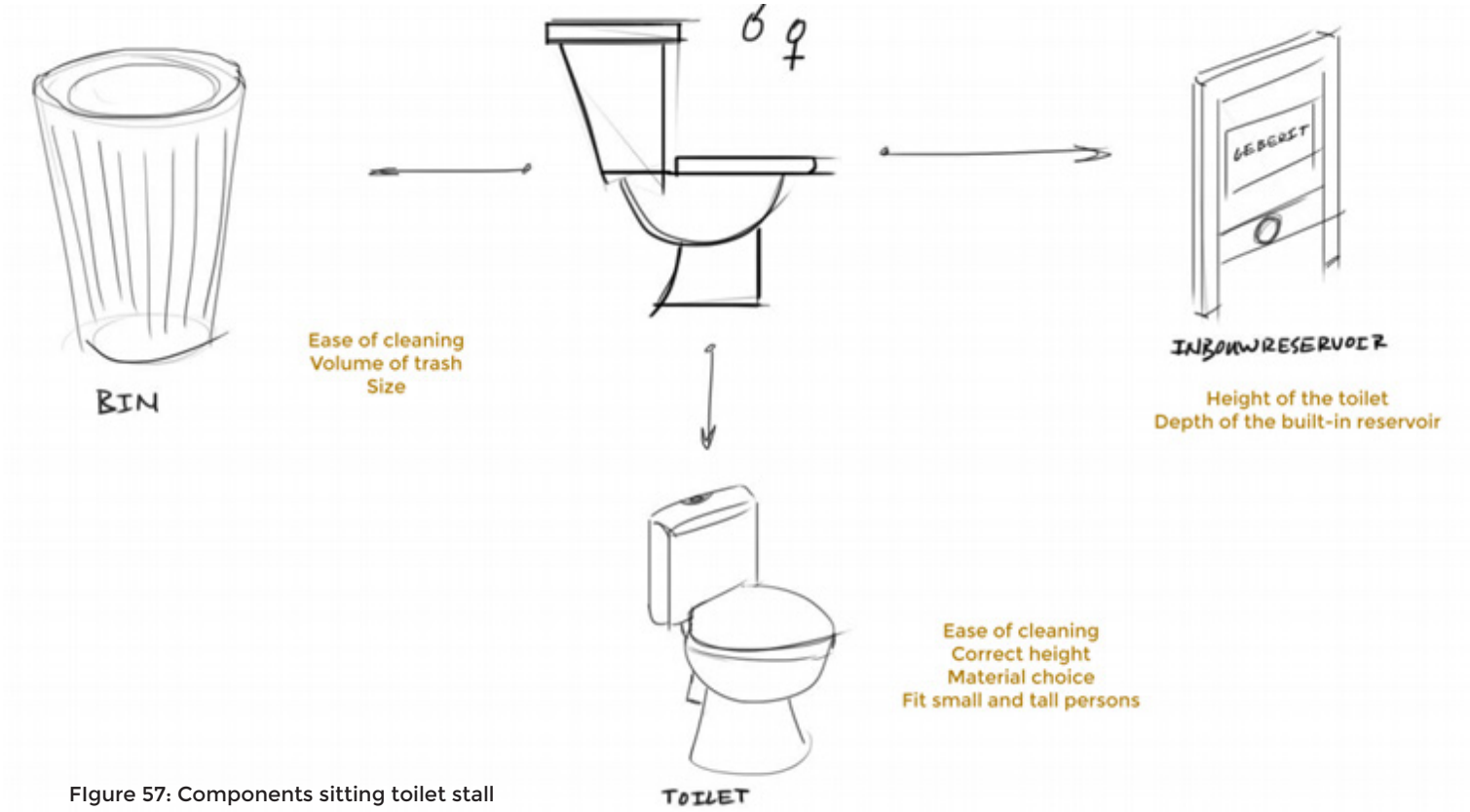


FIgure 57: Components sitting toilet stall

Toilet and seat

I chose to use a hanging toilet, mainly because of a practical reason, hanging toilets allow placing the reservoirs behind the back wall of the cubicles. This way all reservoirs can be accessed via the technical space. Another reason for this is the ease of cleaning. Hanging toilets are lifted from the ground, making mopping the floor easier than having the swoop around a standing toilet, making cleaning faster. Moreover, this contributes to the comfort of the cleaning staff. Instead of kneeling to clean the floor around the toilet and the harder-to-reach areas of the standing toilet, the cleaner can simply swipe a mop under the toilet and direct the access water to the drain, see Figure 58 and 59.

It was decided to implement a toilet with a seat but without a closing lid. The most prominent reason for this is that the lid is more vulnerable to vandalism. Moreover, it does not serve an important function in public toilets.

The choice was made to use a shortened toilet because of the small space available inside the toilet stall. With a shortened toilet, more legroom becomes available. With a regular toilet measuring around 530 mm in depth, a shortened toilet of 480 mm leaves 50 mm more legroom, contributing to the comfort of the users.

All Geberit toilets guarantee to carry 400 kgs when installed correctly. They are even tested with a load of 800 kgs. Breaking a hanging toilet is as likely as breaking a standing variant according to mister Bosman.

FIgure 58: Standing toilet

FIgure 59: Hanging toilet

Reservoir

The technical space in which all reservoirs are placed is small. Therefore it is important to take into account the installation of the reservoirs already. During installation 'normal' reservoirs have to be approached from the front or the back. In this design, however, the front of the reservoir is facing a wall. The back of the reservoir is hard to reach since there is limited space. Therefore a so-called planchet reservoir will be used, Figure 61. These reservoirs are approached from the top, making installation easier for the mechanics.

The float valve and the grey water connection are most critical and most likely to fail in the long run according to sanitation expert Jeroen Bosman. By using a planchet reservoir these can be accessed from the top, which makes the service way more easy and comfortable.

The reservoir will be mounted on the floor of the container. The floor has a solid layer of cement board and plywood in which the legs of the reservoir can be mounted.
Since the toilet hangs onto this reservoir the reservoir must be mounted very stably. Only mounting it to the floor of the container won't be enough. In a household, reservoirs are mounted to the ground and the wall of the house. Here lies a problem for the container. The walls of the stalls consist of sandwich panels of 40 mm. These panels have two thin outer layers of steel. In between these layers, a foam core is located, Figure 60. A panel like this is not stiff enough to mount a construction like a reservoir onto.

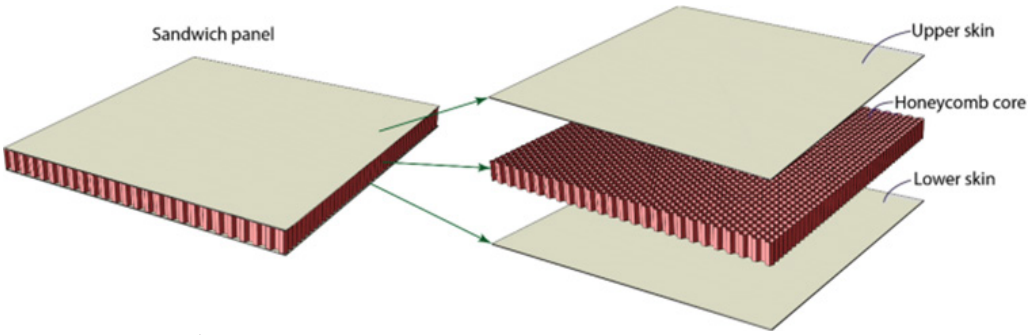


FIgure 60: Sandwich panel

To overcome this, a steel construction is added in the container. At both sides of the reservoirs of the sitting toilets steel beams of 50 x 50 mm are placed, Figure 62. These steel beams are welded to the ceiling and the floor of the container. The blue frame of the reservoir is secured with bolds to these steel beams. This way the toilet can hang on the reservoir without any problems.

FIgure 61: Planchet reservoir

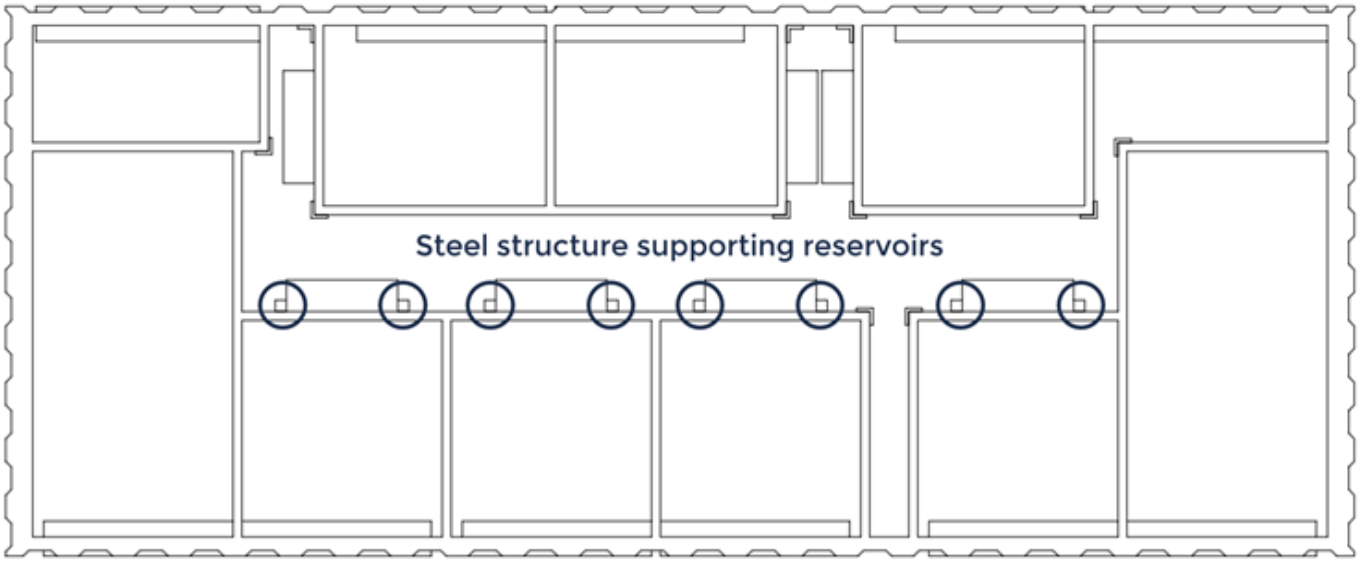


FIgure 62: Steel structure

Flush button

For the reservoir to flush the toilets, the users have to push a button inside the stalls. There are a lot of options for these bottoms. Dual flush systems allow the user to choose between a big flush or a smaller flush.

The toilets in the men's section are used primarily to defecate since there are separate urinals available. These urinals cost less than half of the entrance price of the toilets. In these toilets, I chose to incorporate a single button flush [64], Figure 63. This anti-vandalism flush button only allows for a big flush. Only a small metal bottom can be seen in the stall.

FIgure 63: Single button flush

The toilets in the women's section will be used for urinating and defecating. A dual flush system can save a lot of water. When women who only urinated press the small bottom, the toilet is flushed with 2 L of water instead of 5. When the big one or both are pressed the big flush of 5 L is activated. For this bottom, I also choose a metal option, which is less likely to break when exposed to vandalism, Figure 64.

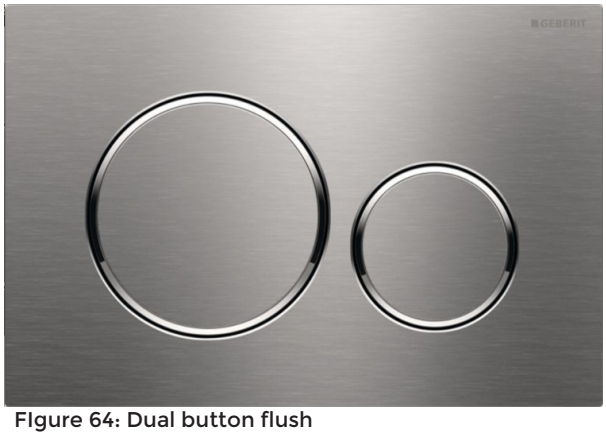


FIgure 64: Dual button flush

Hook

In all seven toilet cubicles, a hook is mounted to the inside of the door, Figure 65. Since the unit is placed on a market, people are likely carrying bags with bought products. The hook at the door provides a possibility to hang their bags from the floor while using the toilet. Leaving the bags on the floor can result in them picking up bacteria [67, 68]. Based on the findings of M. Loth, I decided to locate the hook at a height of 1250 mm [13].


FIgure 65: Hook

Garbage bin

Ester van Loon from Good Sanitation Kenia told me she identified a problem in the public toilets around Kenya [14]. Women tend to flush their menstruation products, causing weekly blockages. Therefore I chose to add a garbage bin in every toilet. Next to this, it is important to inform people that menstruation products should be thrown in the garbage bin instead of the toilet. Therefore a poster is placed in every cubicle with information on how to use the toilet. In the men's toilets, a bin is placed to prevent people from flushing waste.

A bin of 10 L will be used. Since cleaning staff comes around every toilet every 10 minutes, there is no need for a bigger bin. Moreover, there is not a lot of room in the toilet stalls, so adding a big bin will only take up the limited space available.

The main considerations for the bin are the following:

Wall mounted: To prevent the bin from getting stolen it should be mounted inside the toilet stalls.

Vandalism: It should be a simple and robust bin without many components that can be vandalized or break.

Non-touch: For hygienic reasons, the bin should not be touched to throw away something.

The open bin was considered the best option for the container. The main reason for this is its robustness. An open bin is a simple product, without components that can break easily, like a foot pedal operated bin for example. An open bin does not require the user to open a lid or touch the bin by any means, the user can simply throw their trash in it.

A disadvantage of an open bin like this is that everything inside is visible to the users. This can be very unpleasant to watch. However, cleaners visit each cubicle every 10 minutes. Cleaners check the bins at every visit. When something unpleasant to watch lays inside the bin, cleaners put a paper towel to cover it, so the next user is not scared away. When the bin is filled, the cleaners put a new bag inside.

I It was decided to modify a standard open bin slightly to mount it to the wall. At first hand, it was considered to cut, bend and weld an open bin out of a stainless steel plate. Using a standard bin instead appeared to be more cost-effective. Eventually, the following bin has been found.

This is a bin made out of PP with a capacity measuring 270 x 190 x 290 mm, it only costs 11 euro [57], Figures 66 and 67.

FIgure 66: 10 L garbage bin

FIgure 67: 10 L garbage bin

The mounting piece will be cut out of a stainless steel plate 14 times, 2 for each toilet stall, Figure 68. This piece is made to mount the garbage bin to the walls in the facility. Doing this reduces the chance of it getting stolen significantly. Moreover, it prevents it from falling over when someone kicks it accidentally, leaving the floor of the toilet stall covered in trash.

FIgure 68: Mounting piece

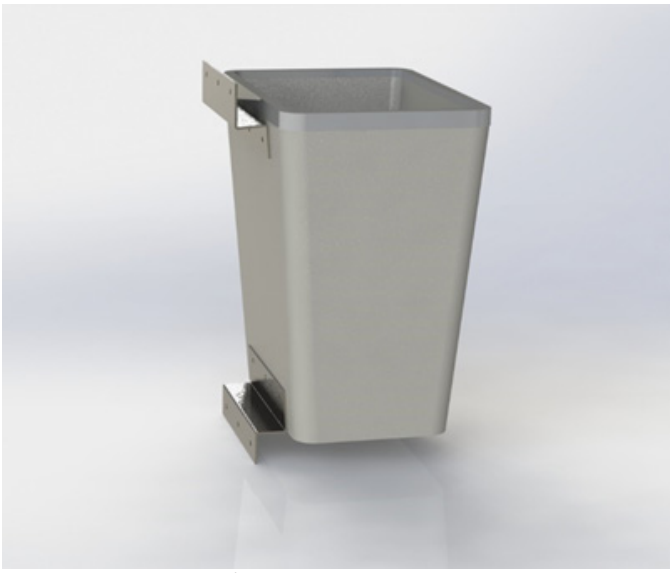


FIgure 69: Garbage bin assembly

This mounting piece is cut out of a 2 mm stainless steel sheet and then bent. The complete cutting and bending template can be found in Appendix C. Three small holes are drilled in the garbage bin to bolt the bin to the steel. The other three holes are used to screw the bin against the walls of the stalls. The total assembly can be seen in Figure 69.

The grey upper lid can be taken off to clamp a garbage bag. The garbage bin is located next to the toilet bowl in the sitting toilets, Figure 70 and 71. In the squatting toilets, the bin is located at the opposite wall of the toilet. The main reason for this is that the squatting toilets are narrower than the sitting toilets stalls and the bin might be obstructing to get a comfortable squatting position.

FIgure 70: Position garbage bin

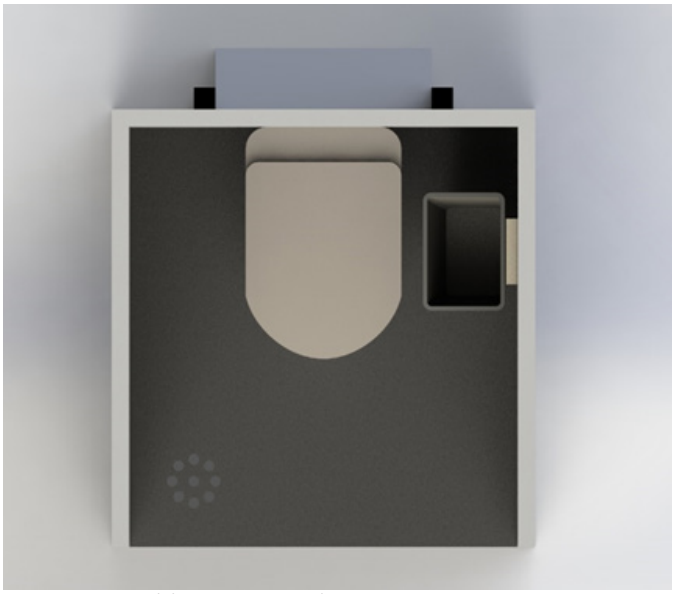


FIgure 71: Position garbage bin

4.5 Supported toilets

In the men's and the women's sections one toilet is designated for elderly and less mobile people. These are sitting toilets, just like the ones previously discussed. Like in the sitting toilets the reservoir is located behind the stall. The same Geberit products are used, and the garbage bins are the same. The only differences with the regular sitting toilet stalls are the toilet seats and that in these toilets support bars are installed. Providing the facility with support allows users to assist their leg muscles with the muscles in their arms to ensure a more stable position [56].

Research with elderly people shows vertical supports are preferred over horizontal supports for sitting down and standing up [56]. To sit down the users hang backward holding the supports, to stand they pull themselves forward. For wiping the buttocks, vertical supports were liked as well. Generally, the supports are held at shoulder height while sitting and at elbow height while standing. This accounts both for men and women.

The vertical support bars are preferred at standing elbow height and sitting shoulder height, Figure 72 and 73 [56]. These measurements were looked up using the DINED tables again, Table 5. Unfortunately, these measurements were not available for West African people, so the Dutch 2004 measurements were used again.

	Standing elbow height (mm)	Sitting shoulder height (mm)	Sitting shoulder height + toilet height (mm)
Dutch men P99	1188	668	1068
Dutch men P01	946	524	924
Dutch women P99	1094	614	1014
Dutch women P01	876	474	874

Table 5: DINED measurements 5 and 15

In the stalls, a vertical support bar at each sidewall of 600 mm is installed. These will be positioned 700 mm from the ground. The highest point will be 1300 mm from the ground. With this coverage P01, women and P99 men can grab the bar at standing elbow height and sitting shoulder height, Table 4. Important to state is that the measurements of West African people probably differ something from the values in the table. However, it gives an idea on which the position can be based.

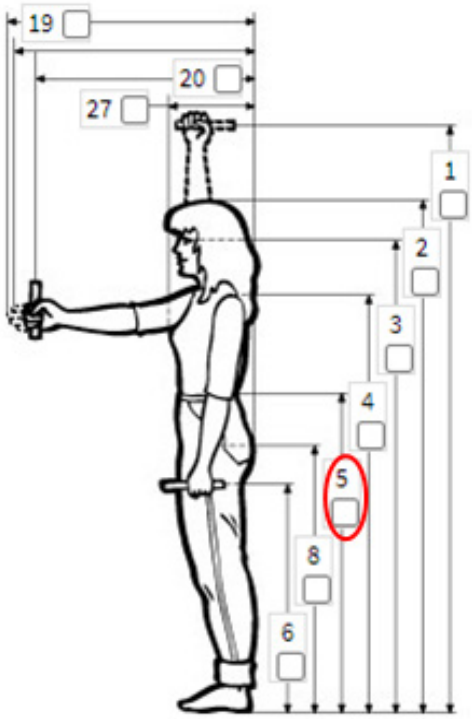


FIgure 72: Standing elbow height

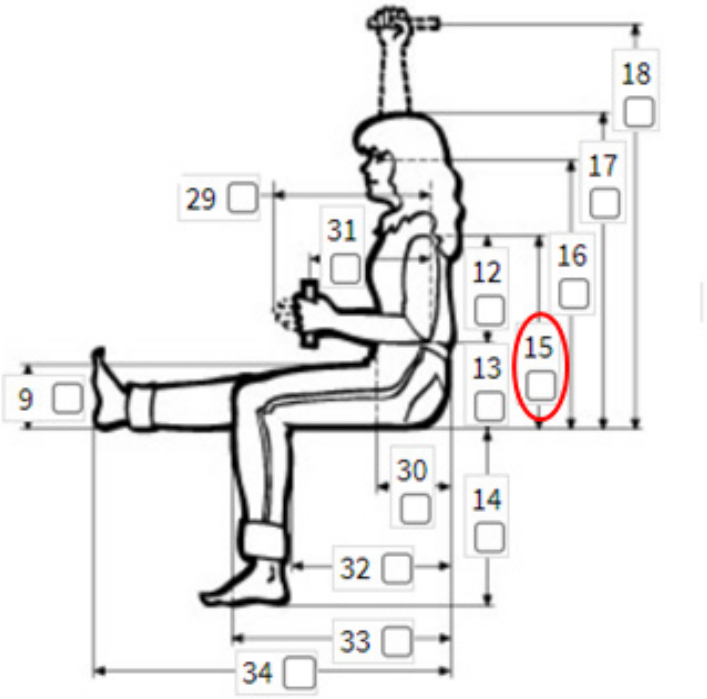


FIgure 73: Sitting shoulder height

According to the DINED values, generally speaking, looking at the available measurements most West African measurements are smaller than the same Dutch ones. Therefore it is likely the actual sitting shoulder height and standing elbow height are lower. This should not be a problem.

This uncertainty is the biggest reason to implement large support of 600 mm. With a big coverage like this, there is a chance most visitors can find a comfortable height to support themselves.

Toilet seat

As explained earlier, a seat without a lid was applied in the regular sitting toilets, because it had no clear function and only added something that can break into the toilet stall. M. Loth, however, advised me to add a seat with a lid in the supported toilets. Based on her research some people close the lid and take a seat on the toilet and use it as a chair, for example, to prepare a catheter [13].

Underneath an overview of the supported toilet can be found, Figure 74 and 75. Based on the research from Molenbroek, J.F.M. and Bruin de, R from 2007, the supports are located 350 mm in front of the toilet bowl.

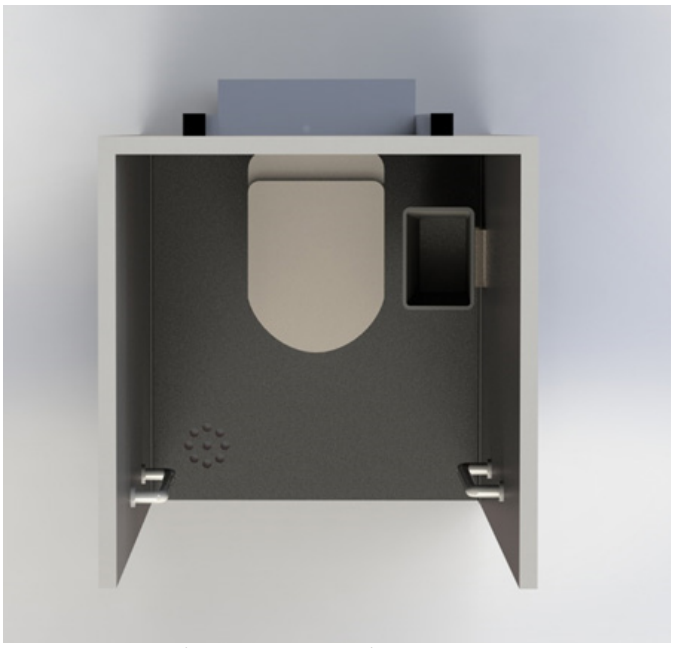


FIgure 74: Overview supported toilet

FIgure 75: Overview supported toilet

4.6 Squatting toilets

For the squatting toilet, the same considerations have to be taken into account as for the sitting toilets. The interests of the five main stakeholders remain the same.

Reservoir

For the squatting toilets, the same planchet reservoirs previously discussed will be installed. Unlike in the sitting toilets, no toilet will be hung onto the reservoir. The reservoir is connected to the squatting toilet bowl through a pipe, to flush the squatting toilet. These reservoirs are mounted to the ground and the sandwich panel of the squatting toilet cubicle. Because these reservoirs do not have to support a toilet but only themselves, there is no need to support them with an extra steel structure. Mounting these to the floor of the container will be sufficient to prevent them from falling over.

Flush button

For the same reasons explained earlier, in the men's squatting toilet a single flush button is installed. In the women's section, the dual flush variant is used. Since the same reservoir is used, the same buttons can be used.

Squatting toilet bowl

Just like most sanitary products applied, the squatting toilet bowl is produced by Geberit [65]. Geberit is a partner of Semilla and has helped with projects in the past, Semilla needs to keep this relationship intact. Therefore Geberit is preferred over other suppliers.

The sitting toilet cubicles are equipped with drains to drain cleaning water. I chose to use an elevated floor in the squatting toilets, this way the bowl lays flush with the ground, Figure 76. The cleaners can clean the floor and wipe the access water in the toilet drain, therefore there is no need for an extra drain in the squatting toilet cubicles. Furthermore, it is no problem cleaning agent ends up in the black water storage. Black water can still be recycled containing these substances.

FIgure 76: Elevated toilet floor

Height of the elevated floor

The container builders will install the squatting toilets, they need to know at what height the floor needs to be set. Different factors influence the height of the floor. These are discussed below.

Design of the toilet bowl: The design of the squatting toilet is shown in Figure 77. The lowest point of the bowl is 18 cm lower than the top.

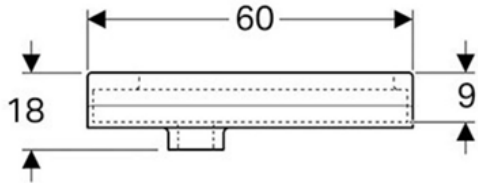


Figure 77: Design of the toilet bowl

Bend of the drain: To add a bend to the drain, the thickness of the tube is added: 9 cm.

Drain system: As explained earlier, the grey water drainage system lays underneath the black water system. There is not enough room inside the container to lay these two next to each other. Therefore the diameter of the grey water tubes should be added: 5 cm.

Slope: For every meter of length, the tube should drop 1 cm. Measured from the exit, the black water drain measures around 4 meters, adding an extra 4 cm in height.

Container: All stalls have a step of 15.9 cm, due to the isolation and the floor in the container

The total height of the step users have to take to get on top of the elevated floor is 52 cm. The height of the floor relative to the existing floor of the container measures 36 cm, Figure 78.

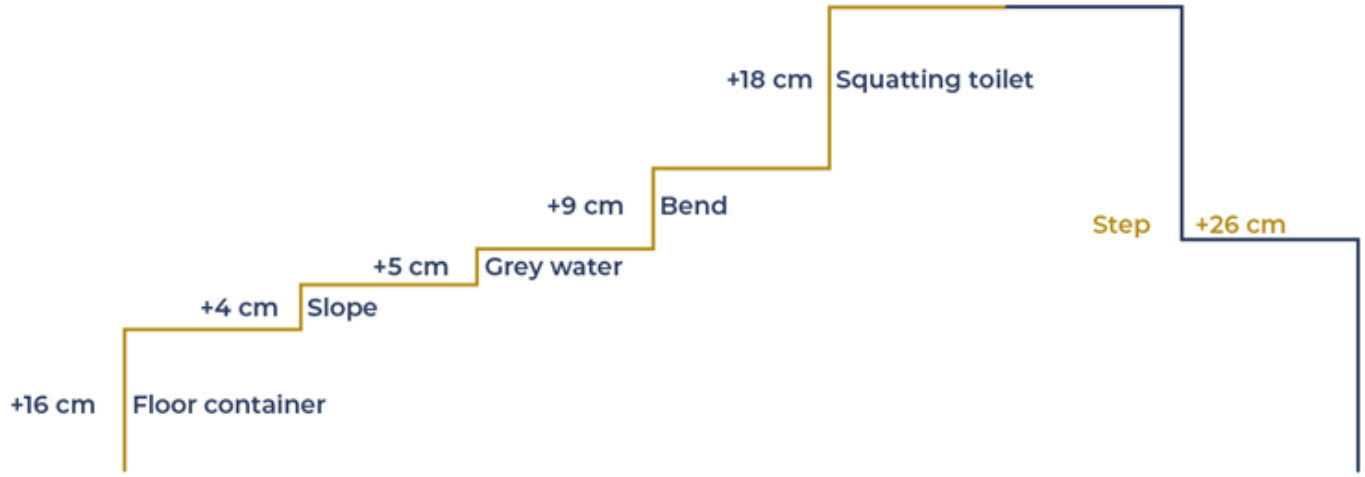


Figure 78: Step height

Taking a step of 52 cm to enter the toilet might be too much. Even for vital people, this might be uncomfortable. Therefore I chose to add a step in front of the container. This wooden step is mounted onto the container to prevent it from slipping away. It covers half of the step, measuring 26 cm in height.

To make the floor elevated a wooden or metal structure will be made supporting the toilet bowl. On top of that, a panel will be mounted as a floor.

Drain squat toilets

The back walls of the squatting toilets are mounted on top of the elevated floor. The rest of the walls will be mounted onto the floor of the container, Figure 79. Placing the back walls like this leaves an open space for the drain to be directed towards the central drain.

Across the whole width of the stall, the drains can be placed towards the central drain. This gives a lot of freedom to place the black water drains. Because of this design decision, the drains of the squat toilets can be placed like they are in Figure 80.

FIgure 79: Backview elevated floor

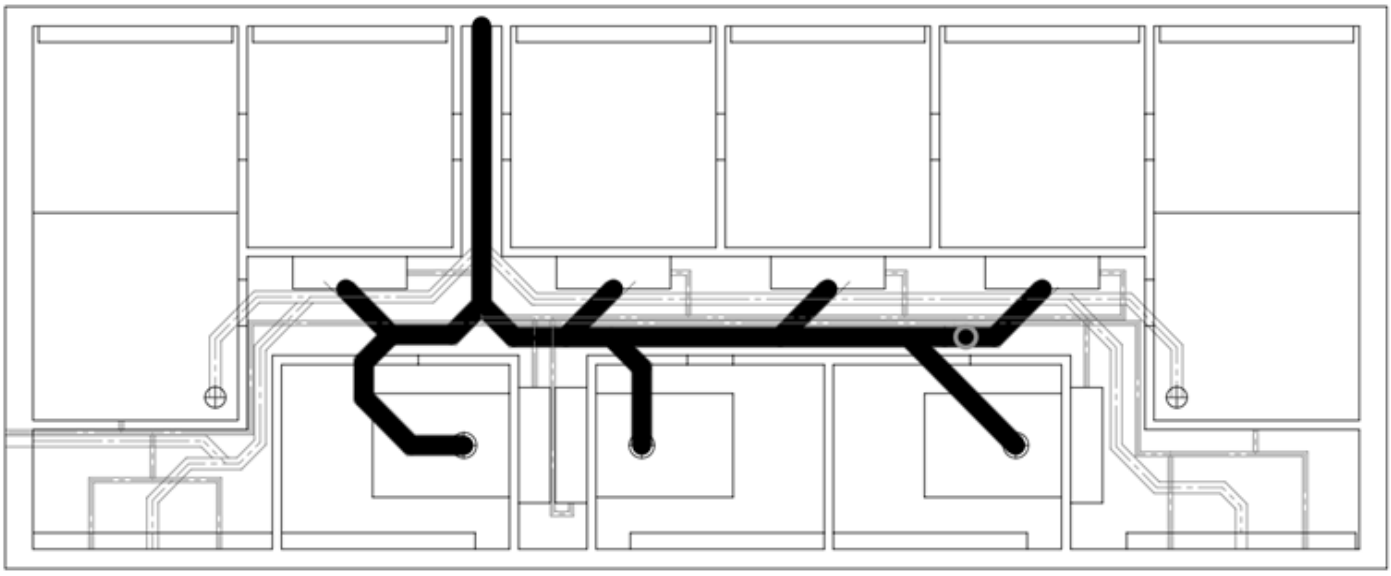


FIgure 80: Black water drainage

PART V
Handwashing facilities

5.1 Stakeholder analysis

Introduction

As argued in the problem definition, poor sanitation has been linked to 25% of the death of children younger than five years in Ghana [5]. Diarrhea is caused by bacteria, viruses, and parasites, most of which are spread by feces-contaminated water [74]. Rotavirus and E-Coli are the most common agents in low-income countries [74]. It is also commonly spread from person to person, especially with poor personal hygiene [74]. Providing clean toilet facilities alone is not enough to prevent the users from getting sick. To minimize risks users should wash their hands with soap after visiting the toilet. It can significantly reduce the incidence of childhood infectious disease [59, 84].

Only providing handwashing facilities is not enough for everyone to start washing their hands. Improving the handwashing rate is a more complex problem. Studies in Atlanta, Chicago, New York, and San Francisco show handwashing rates of 85% in 2010, 77% in 2007, and 83% in 2005 [85]. In all of these facilities, handwashing facilities were available.

Other conditions also influence the handwashing rate. Clean sinks and signs encouraging hand washing improves the number of people washing their hands [85]. A gender bias is present, women tend to wash their hands longer and more often than men. Handwashing rates are influenced significantly by the handwashing behavior of others [86]. A study among female college students shows fewer students leave without handwashing when someone else is in the sink area [88]. The location of sinks influences the handwashing rate [87]. To conclude, improving handwashing rates is complex, and influenced by a lot of factors.

Stakeholders

When providing sanitation possibilities I consider handwashing facilities essential. As described before, in the current situation handwashing facilities are missing in most sanitation facilities in Ghana [5]. Washing hands hygienically after visiting the toilet reduces the expectancy to get sick significantly [59]. A clear goal I set for myself at the start of this project is to provide the users with hygienic handwashing facilities. Again, the interests of the five central stakeholders provided the base on which design decisions were made, Figure 81.

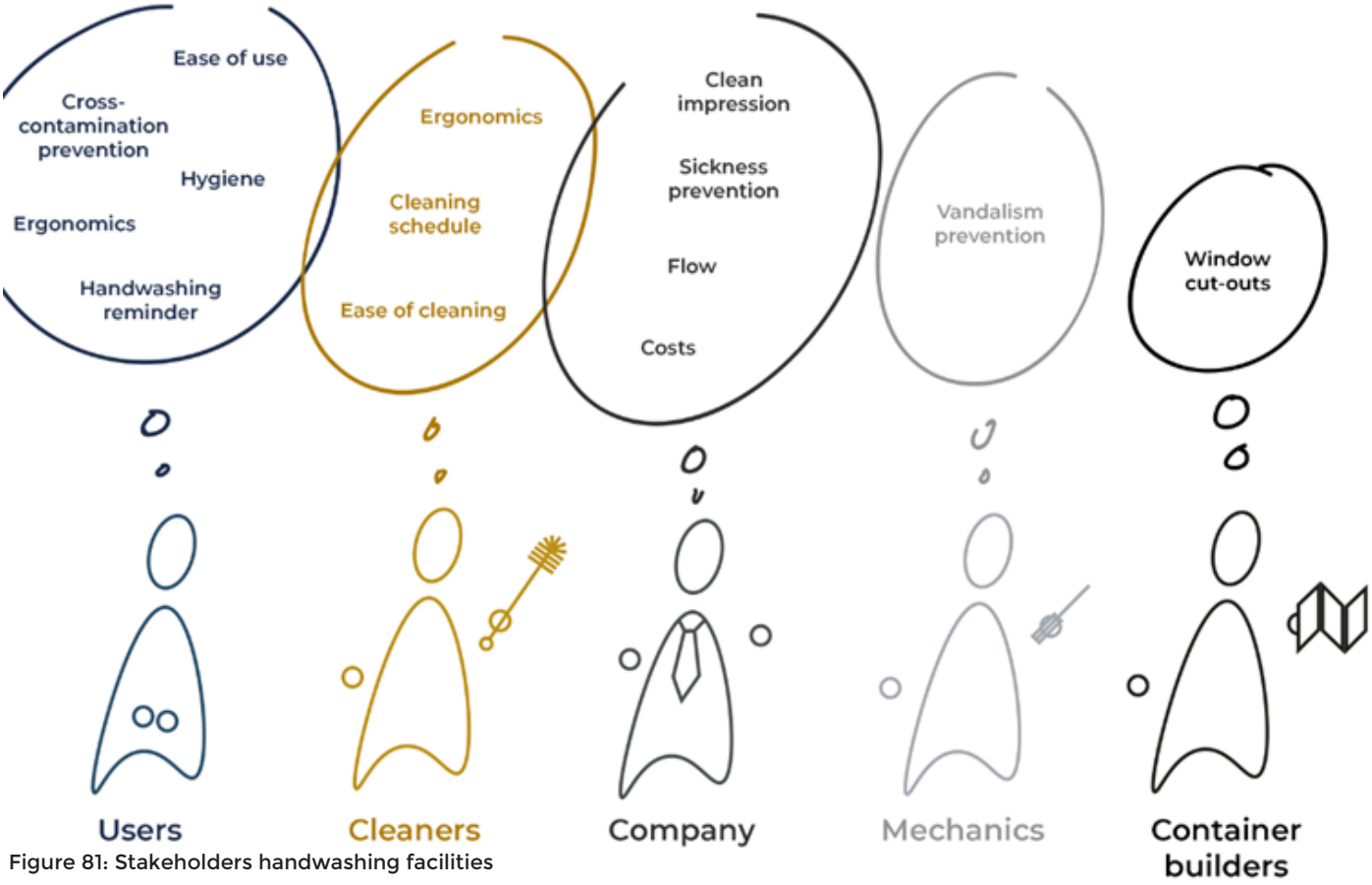


Figure 81: Stakeholders handwashing facilities

Users

Reminding the users to wash and and making this easy

From the user's point of view, the facility has to make washing hands easy and turn it into something logical to do so it eventually becomes a habit. Only reminding the users of the dangers of not washing hands is not enough for this [45]. It is important awareness is created. Together with local NGO's options for awareness campaigns will be explored. One of the reasons why people do not wash their hands is forgetfulness [44]. As explained earlier, the placement of the sinks contributes to this. When the visibility of the handwashing stations is improved, the handwashing rate improves as well [87]. When there are long queues in front of the handwashing stations it is more likely people will skip handwashing and leave the facility. Therefore there should be enough handwashing stations in the facility.

Hygienic handwashing facilities and preventing cross-contamination

It is important for the users that the handwashing facilities are hygienic, which means the chance of cross-contamination should be limited. Cross-contamination happens when bacteria from one person's hand are left on the tap, and the next person touches the tap again. Preventing cross-contamination can be in the design, but also the cleaning schedule.

Comfort

Overall comfort for the handwashing facility has a lot to do with ergonomics. When at the correct height and in reach, the users won't notice anything. When the ergonomics are neglected the user will experience discomfort and notice the facilities are not designed to fit their proportions.

Company

Costs extra service

From a company's point of view, washing hands is an extra, necessary, service. Semilla makes money on providing toilets, urinals, and showers. The visitors pay to use these facilities, for the handwashing facilities, however, nobody is paying. This means that providing this only costs money. Therefore it is important that this extra service does not cost a disproportionate amount of money.

Prevent the user from getting sick

On the other hand, a clean and hygienic facility is important for the company. It is hard to compete with open defecation since this can be done everywhere, does not costs anything and you do not have to wait in line. One of the most important benefits the sanitation unit has over this is hygiene. When using the facilities you are less likely to get sick. To accomplish this claim it is important people wash their hands. If they do not do this they are more likely to get sick from diarrhea [59]. Consequently, the trust in the facility will shrink.

Flow different station

The flow in the handwashing stations is important for Semilla. People should be able to wash their hands at all times and queue formation should be prevented.

Company

Mechanics

For the cleaners, the same principles apply to the handwashing stations as for the whole sanitation unit. They benefit from easy to clean facilities, to match their cleaning schedules and have enough time to get their targets.

Mechanics

Container builders

Since the handwashing facilities will be built inside the container, windows are cut out the side. Just like the doors, a 60 mm frame is welded around this cut-out.

Container builders

Cleaners

For the cleaners, the same principles apply to the handwashing stations as for the whole sanitation unit. They benefit from easy to clean facilities, to match their cleaning schedules and have enough time to get their targets.

Cleaners

5.2 The design

The final design of the handwashing facilities looks like this. At the women's and the men's section there is a handwashing station with two taps and two soap dispensers located inside the sanitation unit. At the men's side, there is a third handwashing station on the outside of the container. The three paper towel dispensers, the third soap dispenser, and two garbage bins are located here as well. This station has only one tap. For the women's section, the two paper towel dispensers and the garbage bin are located at the side of the container. The next chapters will elaborate on all the design decisions, product choices, and production methods.

Figure 82: Men's handwashing stations

Figure 83: Built-up handwashing station

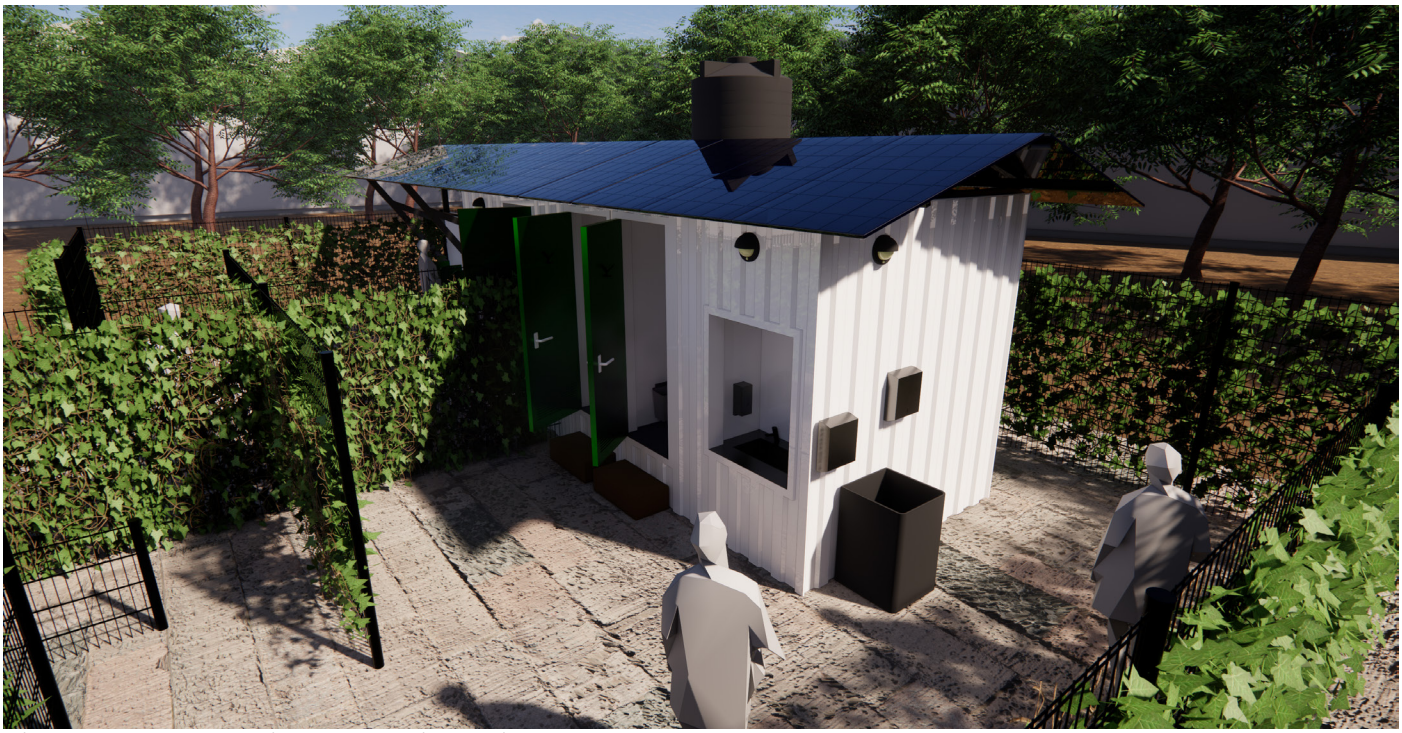


Figure 84: Women's section handwashing station

Figure 85: Women's section handwashing station

5.3 Time simulation

In the chapter Business case, Appendix A is explained. In chapter 3.3.1, the different available times for each facility visit have been explained, including the handwashing times. The available time per handwash is 58 seconds for men and 68 seconds for women, Table 1. As explained earlier it is important people wash their hands hygienically. It is advised to scrub hands with soap for at least 20 seconds [46]. Based on different videos from the WHO and Johns Hopkins Medicine Department of hospital Epidemiology and Infection Control I made the following advice on washing hands.

1.	Rinse hands with water	3 seconds
2.	Get soap from the machine	2 seconds
3.	Scrubbing hands with soap	20 seconds
4.	Rinse hands with water	5 seconds
5.	Drying hands	8 seconds
Total time of washing hands:		**38 seconds**

Probably not everyone will wash their hands after visiting the toilet. People who do wash their hands might not take as long as 38 seconds to do so. However, I have left room for every visitor to wash for at least 38 seconds in my design. I want to prevent the formation of queues during peak hours. To do this I want everyone using the handwashing basins to have around a minute. With two handwashing stations in the men's section, every visitor would only have 37 seconds. Therefore I decided to add another handwashing station, increasing the available time to 58 seconds. In the women's section this is not necessary, since two handwashing stations provide every visitor with 68 seconds of handwashing time already.

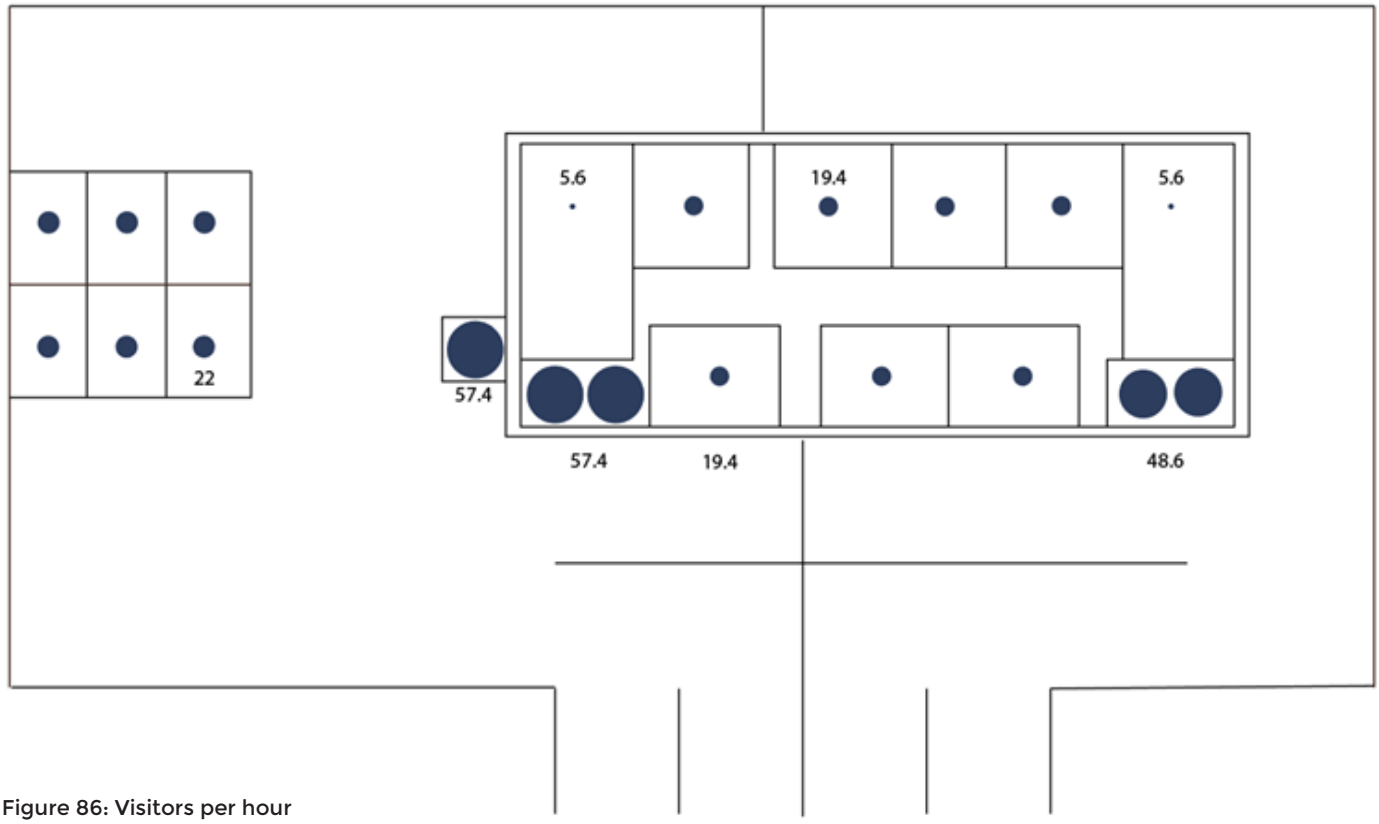


Figure 86: Visitors per hour

This overview in Figure 86 shows the number of visitors per hour per unit. The handwashing stations will be used the most by far. Every hour each handwashing station will be used by 57 men and in the women's section 49 women will wash their hands. Per day this means the men's handwashing stations will be used 1033 times and the women's 875 times.

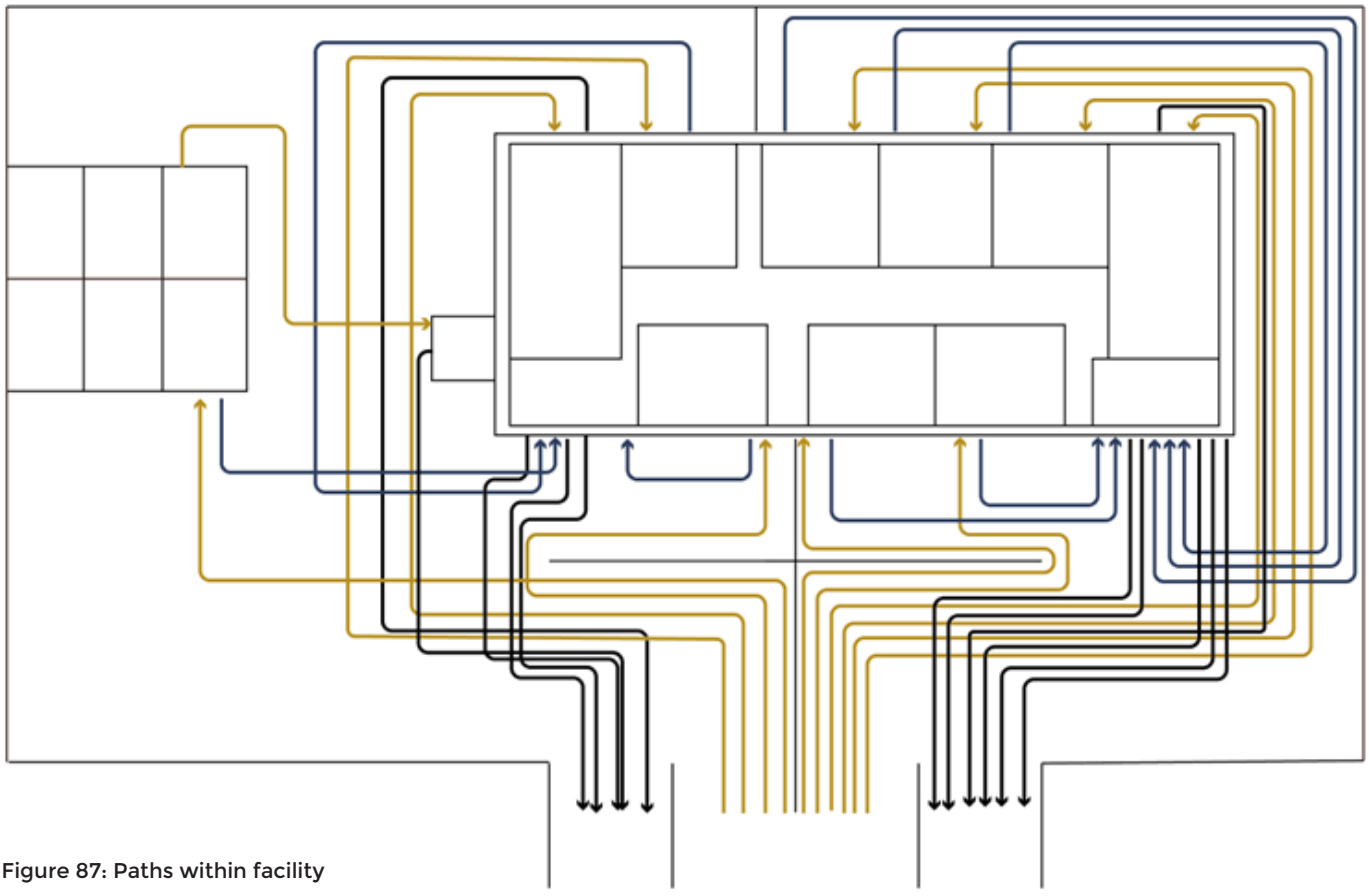


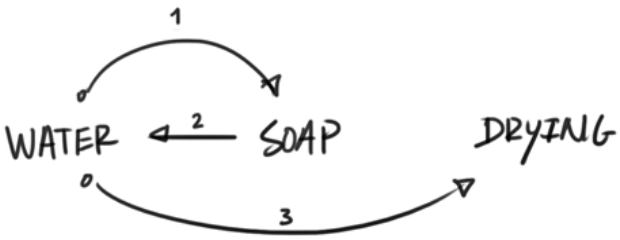
Figure 87: Paths within facility

The visual from Figure 87 shows the different paths people take in the unit. The blue lines direct the users to the handwash facilities. The handwashing facilities, the entrance, and the exit are very crowded. Therefore there must be no obstructions placed here. I explicitly chose not to place an extra handwashing stand at these places in the men's section. Instead, I placed this at the side of the container.

Moreover, placing the third handwashing station at the side of the unit makes it easier to connect it directly to the existing blue and grey water systems that run inside the container. If it would be loose and not connected to the container more complex systems have to be in place to collect the grey water and supply it with fresh water.

Flow

It is important the handwashing components are correctly aligned, to improve the flow of handwashing. Therefore the soap is located next to the tap. This way it is easy to get hands wet, grab the soap, and rinse the hands again. Unfortunately, it was not possible to locate the paper towels on the way out of the facility. Instead, it is mounted at the other side of the container.



5.4 Watersupply

There are different ways to supply the user with water to wash their hands. The most suitable for the application are visualized below, Figure 88.

The main considerations when choosing a water supply are the following:

Hygiene: The change of recontamination should be as low as possible when taking water from the supply.

Ease of cleaning: With an easy-to-clean water supply, the time needed to clean will lower. This is beneficial for the users since fewer queues will form, and for the cleaners.

Costs: People are not paying for handwashing, so this is an extra service in the facility.

Hufterproof: The system should be as little vulnerable to vandalism as possible.

Ease of use: Taking water should be intuitive and easy for the user.

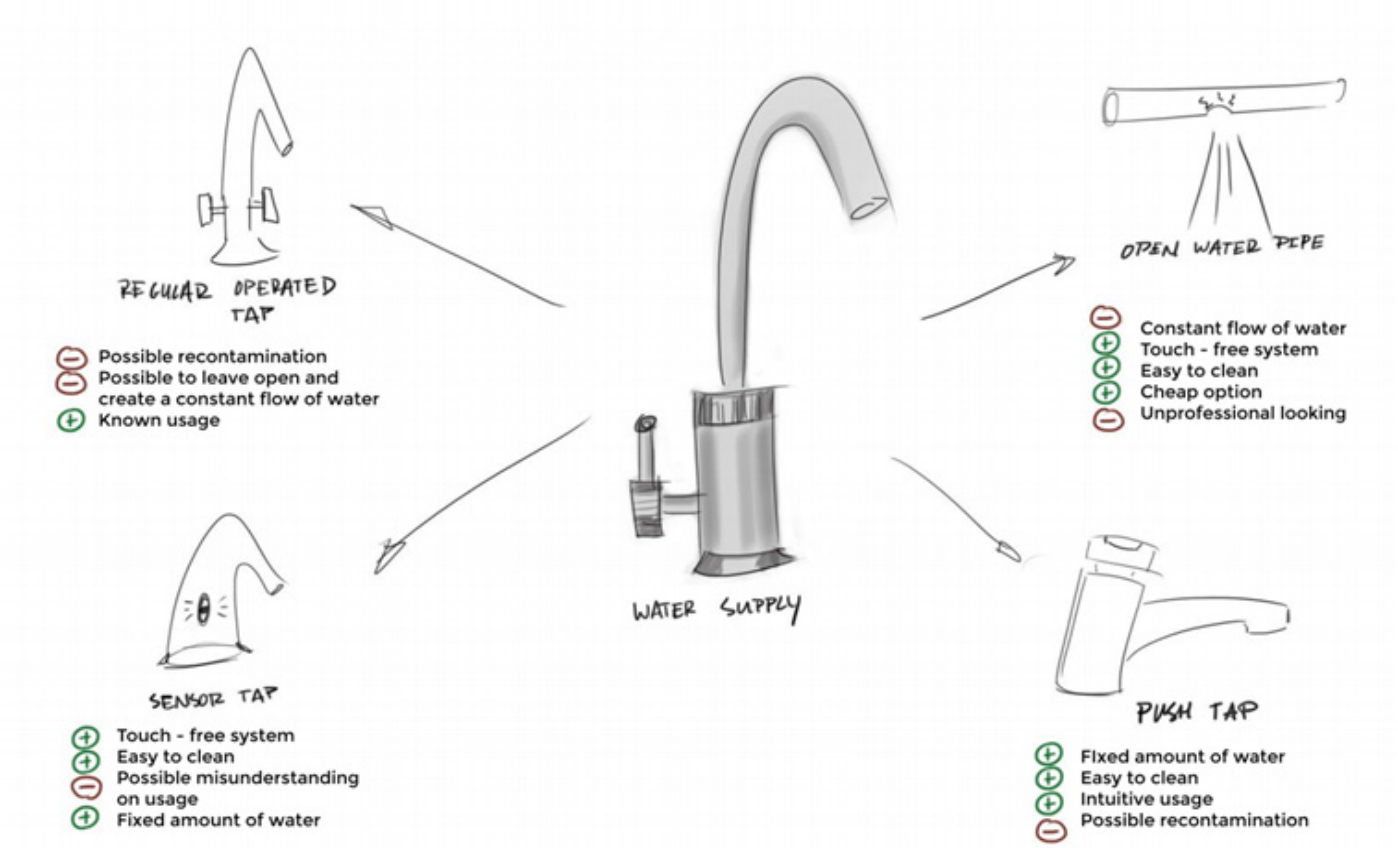


Figure 88: Four options for water supply

To get an overview of how the four different water supplies in Figures 88 compare to each other, Harris profiles were made, Figure 89, 90, 91, 92. It is important to state that this is just to get an overview of the options available and decisions cannot be made based on a Harris profile. These are filled out based on intuition.

Costs in this Harris profile are based on the costs in Appendix B.

	-2	-1	+1	+2
Hygiene	■	■		
Ease of cleaning		■		
Costs			■	■
Ease of use			■	■
Hufter-proof		■		

Figure 89: Harris profile regular operated tap

	-2	-1	+1	+2
Hygiene			■	■
Ease of cleaning			■	■
Costs			■	■
Ease of use			■	
Hufter-proof		■		

Figure 90: Harris profile open water pipe

	-2	-1	+1	+2
Hygiene				
Ease of cleaning				
Costs				
Ease of use				
Hufter-proof				

Figure 91: Harris profile push tap

	-2	-1	+1	+2
Hygiene				
Ease of cleaning				
Costs				
Ease of use				
Hufter-proof				

Figure 92: Harris profile sensor tap

Push taps are incorporated in the facility. It is not the most hygienic option of the four, however, the benefit of a push tap is that it is operated by pushing the bottom, which can be done with the elbow or the back of the hand. Regular taps require more intensive touching by turning the knobs of the tap, which can't be done easily with an elbow. Moreover, the water stops running automatically, so there is no need to touch the tap after the hands are washed, reducing the chance of recontaminating clean hands significantly. Furthermore, it makes leaving the tap running impossible since it closes automatically. An open water pipe is spilling a lot of water. Letting the water run for 18 hours per day would lead to huge water losses. The ease of use is an advantage of the push tap compared to the sensor-operated tap. Usage of a push tap is intuitive, and understood easily, in contrast to sensor taps which are more likely to be misunderstood. With an average price of around 28 euros (Appendix B), the push tap is relatively cheap, especially compared to sensor taps, costing 100 euros. A regular tap would be slightly cheaper at around 25 euro.

The biggest disadvantage of push taps is that it can supply more water than needed. In this specific application, this is not a big problem, since all grey water will be recycled on-site. According to the calculations, there is a minor surplus of 25L grey water per day. I calculated 1.5 L of water for every handwash. If the tap would run for 10 seconds with each push, with an average flow rate of 3 L/minute, the user can push three times for this. Only two are needed, one to rinse hands before getting soap, one to rinse the soap from the hands. An extra push was taken into account.

Spilling water is not an issue in this concept because virtually all grey water will be used to flush toilets. When there is no grey water available freshwater will be used. Therefore not turning freshwater into grey water can be seen as spillage in this case.

5.5 Soap supply

Besides water, soap is necessary to wash hands hygienically. There are different ways to provide this soap to users. The four most promising ones for my application are shown in Figure 93.

The main considerations when choosing a soap supply are the following:

Hygiene: The change of recontamination should be as low as possible when grabbing soap.

Anti-theft: The solution should be mounted to the wall and should not have loose components, since these are vulnerable to theft.

Costs: Filling or replacement of the whole system.

The cheapest options to provide soap are solid soap bars or bottles of liquid soap. The biggest disadvantages of these options is the likeliness to get stolen and the possibility of cross-contamination. Bacteria are more likely to transfer on wet surfaces than on dry ones [25]. Specifically, soap is usually taken with wet hands, meaning that non-touch systems are preferred. Moreover, per day around 4850 people visit the toilets, which means the prevention of cross-contamination is important. Therefore sensor-operated soap dispensers are preferred over push soap dispensers despite being cheaper.

The company CWS is a big player in the western hygienics world. In a call with one of their employees, the context of the sanitation facility in Ghana was explained. It was discussed that around 4850 users share five public handwashing facilities. She advised using heavy-duty material for the soap dispensers and towel dispensers. These are metal dispensers that are made to last

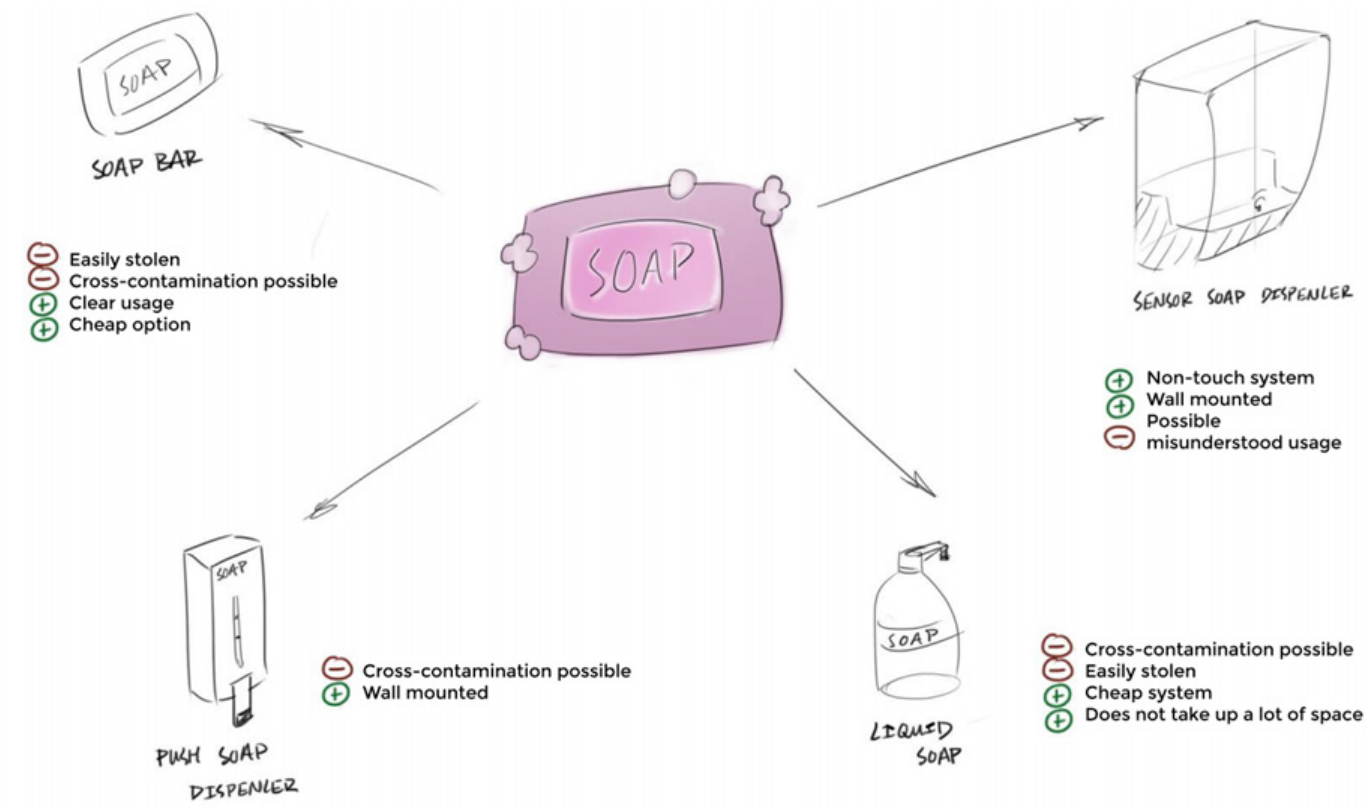


Figure 93: Four options for soap supply

and are used in places with a high number of visitors like factory facilities. Therefore I looked into metal dispensers instead of the cheaper plastic variants. Besides being sturdy I looked into soap dispensers that can be filled with different kinds of soaps. The company can find the best deal for soap and use this to reduce costs.

This soap dispenser, Figure 94, has a volume of 1L. With around 1,5 ml of soap per person per washing cycle, one tank has around 667 servings [29]. Every day the soap dispensers have to be refilled.

Figure 94: Sensor soap dispenser

Figure 95: Elbow soap dispenser

The sensor soap dispenser costs 75 euros and is made out of 304 stainless steel. The website advertises it as a vandal-proof, super-strong dispenser for high-risk vandalism places [29].

Compared to an elbow soap dispenser, Figure 95, this dispenser is more rigid and less vulnerable to vandalism. However, the elbow dispensers are cheaper, costing 52 euros [47]. The implementation of automatic dispensers costs the company around 115 euros more. This accounts for 0.2% of the costs of the container. Looking at the durability and the hygienic benefits, I consider this worth it.

To prevent people from misunderstanding, it is important to provide them with the correct information and explain how to use the dispensers.

Placement

The soap dispensers are placed above the sinks. When soap is spoiled it falls in the sinks instead of on the floor. Cleaners can easily wipe away the access soap.

5.6 Drying hands

After washing your hands it is important to dry them because transmission of bacteria is more likely to occur from wet skin than from dry skin [25]. For drying hands there are multiple solutions, each having its specific advantages and disadvantages, see Figure 96.

The main considerations when choosing a hand drying system are the following:

Hygiene: The change of recontamination should be as low as possible when drying the hands.

Anti-theft: The solution should be mounted to the container, to reduce the chance to get it getting stolen.

Costs: The purchase as well as the running costs should be as low as possible.

Flow: Drying of the hands should be fast because fast drying means that people will leave the handwashing station faster, resulting in higher efficiency.

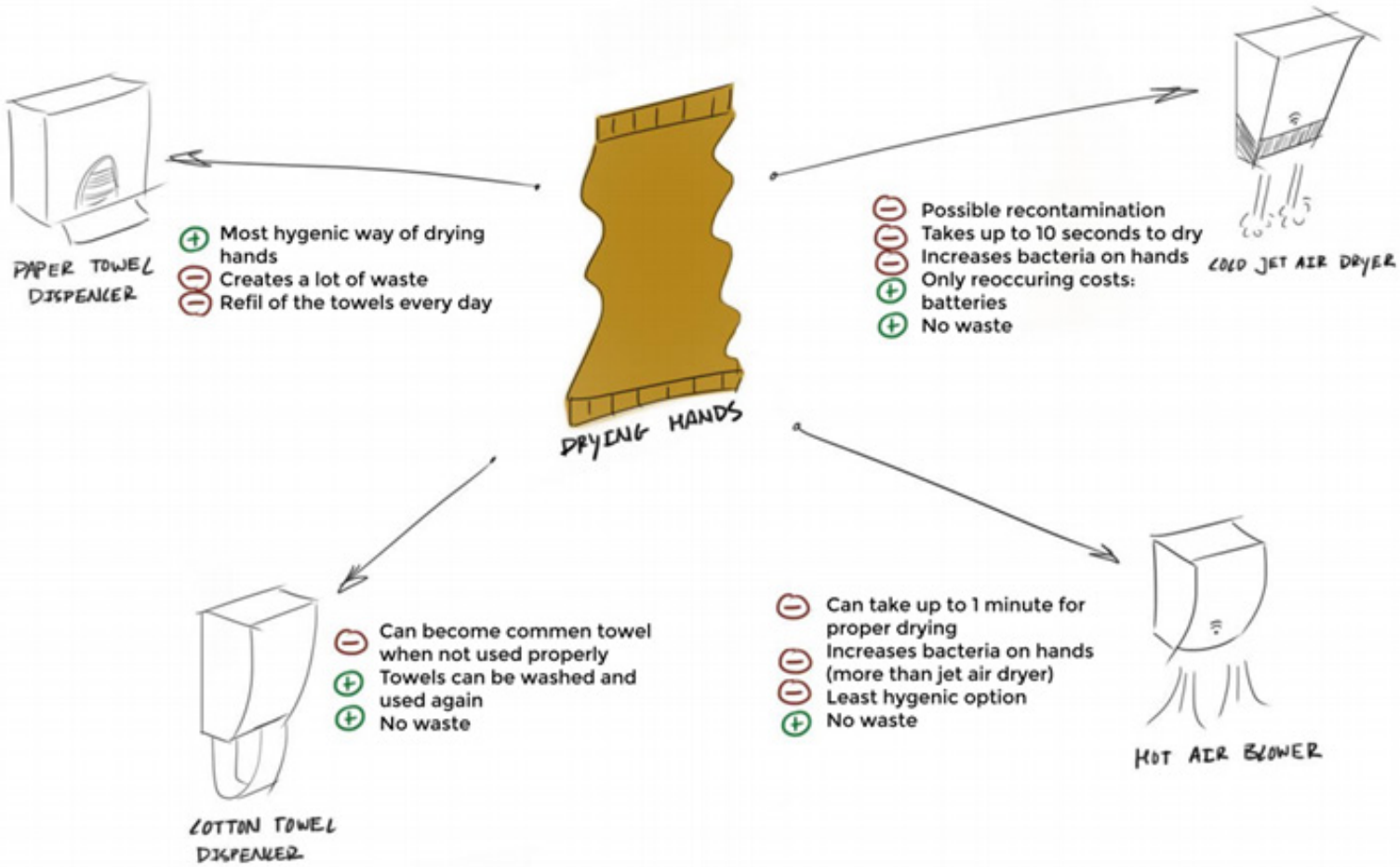


Figure 96: Four options for drying hands

Paper towels are the most hygienic option for drying hands. Because of the physical contact between the towel and the hands bacteria are transferred onto the paper towels. This is missing in blowdryers [25]. This makes these two options the least hygienic. Moreover, the blowing can cause cross-contamination, because bacteria from elsewhere in the facility are 'blown' onto the user's hands [25]. The biggest disadvantage of paper towels in the context of the sanitation unit is the amount of waste. Appendix A - Income shows the expected amount of visitors. If every visitor washes their hands, per day 4850 paper towels are needed. Besides being bad for the environment, around the facility big bins are needed to discard these towels.

I would want to use a cloth towel dispenser instead of the paper towel, despite it being a less hygienic option [25]. A cloth towel dispenser is a more sustainable option since the cloth rolls can be washed and reused again, whereas the paper towels are thrown away after usage, Figure 97. This eliminates the need for big garbage bins and the accessory activities like emptying and cleaning. Sustainability and circularity are the core of the whole system of treating the water streams.

Figure 97: Cloth towel dispenser

In the call I had with CWS I explained I wanted to use cloth towel dispensers in Ghana. However, this is not as easy as it seems. The towel rolls are hygienically cleaned using specially designed machinery. CWS and all other suppliers work with a subscription model, the used rolls are picked up from the facility, and clean rolls are supplied. The dirty rolls are transported to special laundry facilities in which they are cleaned, pressed, and rolled. The employee of CWS told me these facilities are not present in Ghana and bringing it to a regular laundry service is not an option since they do not have the special equipment to do the job. She recommended using paper towels instead since blow dryers will take long to dry hands and are not a hygienic option.

Together with mister Collins from Good Sanitation Ghana we came to the conclusion that there are no hand towel services in Ghana. Setting up a system like this just for this sanitation unit will be far too expensive. The most common method for drying hands is using paper towels.

Costs

The paper towel dispenser itself is not that expensive. Just like the soap dispenser, this is a 304 stainless steel dispenser with and vandalism-proof design, Figure 98. Five dispensers cost 180 euros [48]. A disadvantage of paper towel dispensers is the reoccurring costs of buying paper towels. The price for 5000 pieces of Z folded towels is €13,47 [49]. The yearly price can be found below in Table 6.

Besides the paper towels, also other investments like garbage bins and garbage bags have to be made.

Figure 98: Paper towel dispenser

	Amount (per day)	Total costs
Investment costs paper towel dispensers	5	€180,-
Year supply paper towels	4850	€4726,-
Garbage bags	6	€358,-

Table 6: Costs paper towels

I looked into the costs cold jet dryers come with. I found the following jet dryer, Figure 50. This jet dryer costs €569,- a piece [50]. These run on 230 V, so extra solar panels are needed to generate enough power. The calculations for the total investment price can be seen in Table 7.

This specific blow dryer uses 1900 W, and only 2W while on standby. To blow-dry the hands of a user, 12 seconds are needed [51]. The total wattage needed in a year is calculated in Table 7.

One solar panel generates 1.3 kWh per day, Appendix F. This means that 24 extra solar panels are needed to power the blow dryers alone. The total solar panel system with 25 panels costs 61.800 euros, Appendix A - Costs. It is estimated the solar panels themselves account for a third of this price. The other costs are made for the system of batteries etc. around the panels. Adding 24 solar panels would add almost 30.000 euros to the total investment costs.

Figure 99: Jet dryer

	Amount (per day)	Total costs
Investment costs jet dryers	5	€2843,-
kWh per day blowing	4850	30,70 kWh
kWh per day standy	6	0,15 kWh
Solar penals	24	€19.776,-
Total costs		**€22.619,-**

Table 7: Investment costs jet dryer

Currently, the facility is working with 25 solar panels, implementing 24 more would mean a separate field has to be in place. Another disadvantage of this system is its vulnerability. When these blowers are used this often, it is likely something can go wrong. When one of these breaks down and a new one has to be installed this will cost almost 600 euros. In comparison with a new towel dispenser, this is a lot of money.

5.7 Garbage bin

Since paper towels are used, it is necessary to provide bins around the facility to discard used towels. Instead of small bins, it was chosen to add one big garbage bin in the women's and two bins in the men's section. The main reason for this is that small garbage bins can easily flood and the users can miss them when they want to discard their towels, which can leave the facility messy. Moreover, this means the cleaners have to empty the bins more often.

These big containers have a volume of 100 L, Figure 100. Standard garbage bags can be used in these containers. It measures 510 x 530 x 852 mm [58].

These containers are positioned underneath the towel dispensers, so towels can be thrown away easily, Figure 101.

Figure 100: 100 L garbage container

Figure 101: Placement garbage bin

5.8 Ergonomics

Within sanitation, ergonomics is important, as explained before it can have a big influence on the perceived comfort by the user. Especially in handwashing, it is crucial. When the components of the handwashing station are out of reach for people, handwashing becomes impossible, something that has to be avoided as much as possible. Therefore I tried to base all measurements inside the handwashing facilities on research or measurements from DINED.

The sinks will be mounted at 800 mm from the ground, based on research done by M. Loth [32]. This is so children and smaller adults can still reach the taps. The research shows that taller individuals lean forward to reach the tap and generally find this acceptable.

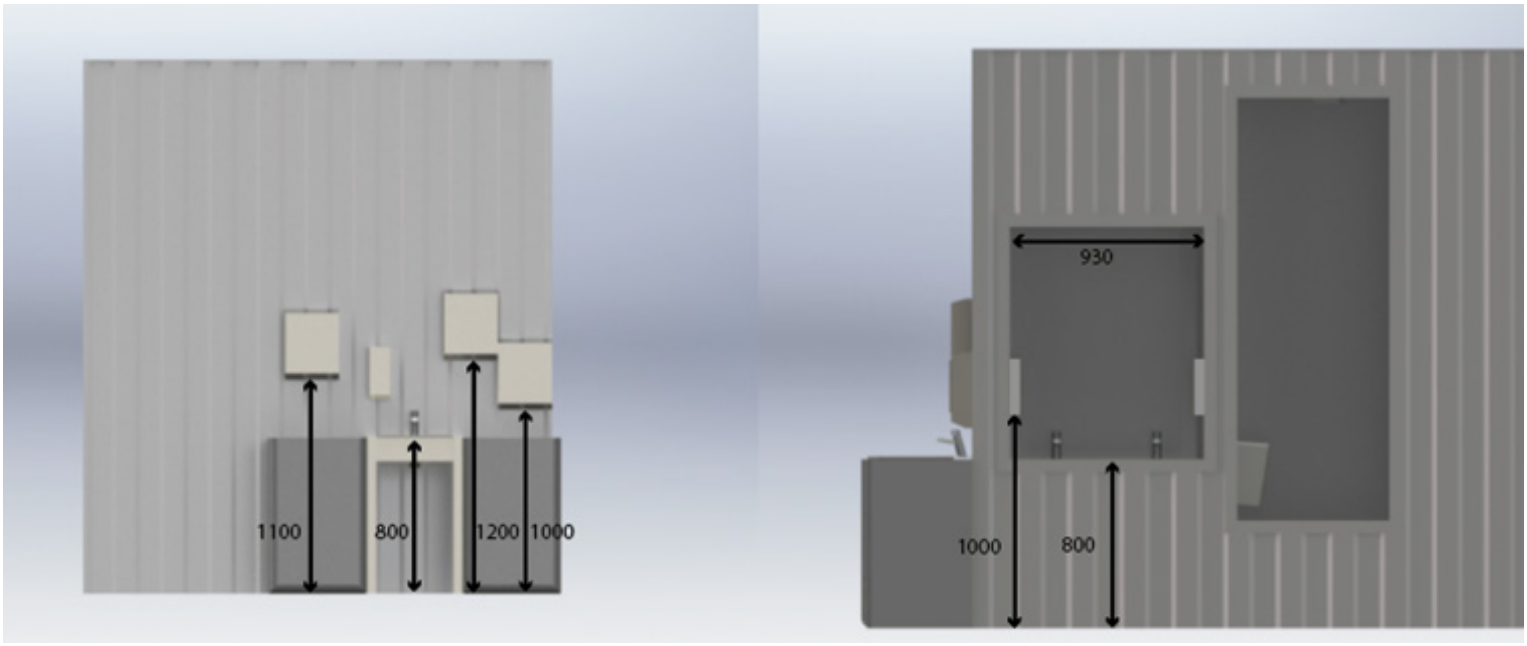


Figure 102: Measurements handwashing facilities

For the built-in handwashing facilities, it is important that taller people are able to lean forward inside the opening without bumping their heads against the container. DINED tells the P99.95 posture height for West African men is 1900 mm. Therefore the height of both windows is set at this number, this means that virtually all West African men can fit under the opening and won't bump their heads when washing hands.

The bottom of the soap dispensers is located 1 meter from the ground up, Figure 102. This is a recommended height by Sutter Health [53]. The same counts for the paper towel dispensers. I chose to hang the three towel dispensers at three slightly different heights so people can choose which one they feel is best. The maximum height for these paper towel dispensers is 1200 mm according to PSD America [54].

The width of the window cut out is 930 mm in the men's section. The two taps are 480 mm apart. This is done because the P99.96 shoulder width for West African men is 480 mm according to DINED. For the women's section, the cutout measures 885 mm and the taps are 460 mm apart because this is P99.96 shoulder width for West African women. Placing the taps like this means that virtually all West African men and women men can stand straight in front of the taps without touching each other's shoulders.

5.9 Production methods

This chapter will elaborate on how the handwashing stations are produced and how they look in detail. The two built-in handwashing stations consist of plateaus between the inner walls of the container, Figure 105. Onto these plateaus, a sink and two taps are mounted. The third handwashing station at the men's section can be seen as a table with two legs, mounted onto the container. Onto this table, a sink and a tap are mounted. Both the built-in handwashing stations, as well as the built-up handwashing station and the sinks will be produced in-house. Semilla works closely together with Nijhuis Industries. Nijhuis can supply Semilla with the tools and produce, and install the handwashing stations.

Built-in handwashing stations

The biggest advantage of locating handwashing stations in the container is that little adjustments have to be made for shipping. In a call with Boschman and Steinacher Logistics, it became clear these open windows only have to be covered temporarily for shipment.

The built-in handwashing stations consist of a big stainless steel plate that has been cut to size, the design for this is shown in Figure 103 and 104. Underneath this plate, two legs will be welded.

Figure 103: Handwashing table without sink

Figure 104: Handwashing table with sink

The legs are mounted on the floor of the container. At the back of the table, a strip of 4 cm has been bend in 90 degrees, Figure 104. Holes within this section allow the table to be mounted against the back wall of the men's shower cubicle. Together with the shower wall, the sidewall of the men's squatting toilet, and the wall of the container the men's handwashing table is encapsulated. As the rules of Kan-Bud say, around the window cut-out accessing the handwashing station, a steel frame is welded to the container. The front of the table lays on top of this frame and is fixed to it. All edges of the table meeting the walls are finished with a layer of silicone kit, to prevent water from leaking around the edges of the table.

Figure 105: Men's section handwashing stations

In the middle of the table, a gap is left open in which the sink will be welded. In the top, the two round holes are meant to install the taps. The washing table at the men's and women's sections differs slightly in shape, but the principle is the same: the table is shaped in a way the surrounding walls of the toilet and shower are used to enclose the washing table.

Nijhuis Industries has access to a laser cutter for stainless steel sheets and they can bend and weld this material as well. Therefore it is possible to produce the handwashing tables ourselves. These have to but cut out of a big sheet and the mounting strip has to be bent. Producing the sinks ourselves saves money, and it is possible to produce the sinks custom to the space available in the container.

Just like the table itself, the sinks will be formed out of a 2 mm thick stainless steel plate. They consist of an open box, with small openings for a drain. At the bottom, an outlet ring of 50 mm is welded on which the tubing can be mounted. A slight bend is applied to the bottom of the sink to guide water towards the outlet, Figures 106, and 107.

After forming the sinks, they can be welded onto the table making a watertight connection between the two parts.

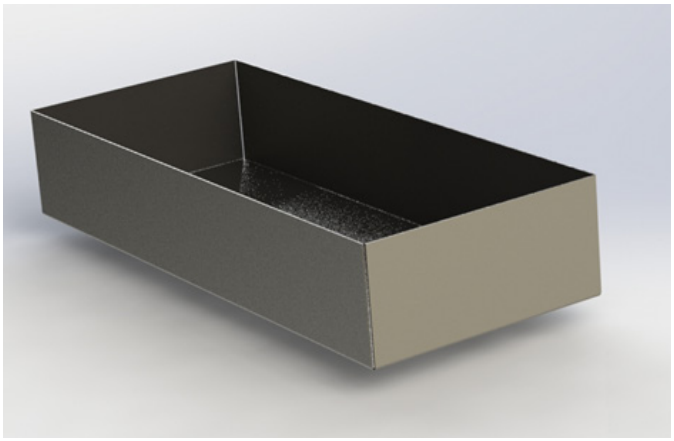


Figure 106: Sink

Figure 107: Bottom of the sink

Built-up handwashing stations

I In the men's section, there is an extra handwashing facility mounted to the side of the container, at this facility only one tap is installed. This table looks very similar to the built-ins, only being smaller, Figure 108 and 109. Underneath the legs of this table, a flat piece of stainless steel will be welded. The flat piece can be mounted to the floor.

Figure 108: Built-up handwashing table without sink

Figure 109: Built-up handwashing table with sink

Lasercutting

The tables are cut out of a 2 mm thick stainless steel plate. This is a plate of 3000 x 1500 mm [61]. From the same plate, the three sinks and the outside handwashing stand can be cut, Figure 110. The plate that is welded underneath the legs of the outside handwashing facility is cut out as well. Next to the parts discussed 14 mounting pieces for the garbage bins in the toilets are shown in the bottom right.

After cutting the sinks and tables are bent into shape, Figure 111. The red lines represent a 90-degree bend, the green lines in the sinks represent a minor bend which makes sure the water is guided in the outlet. The cutting drawing and the bending drawing can be found in Appendix C as well.

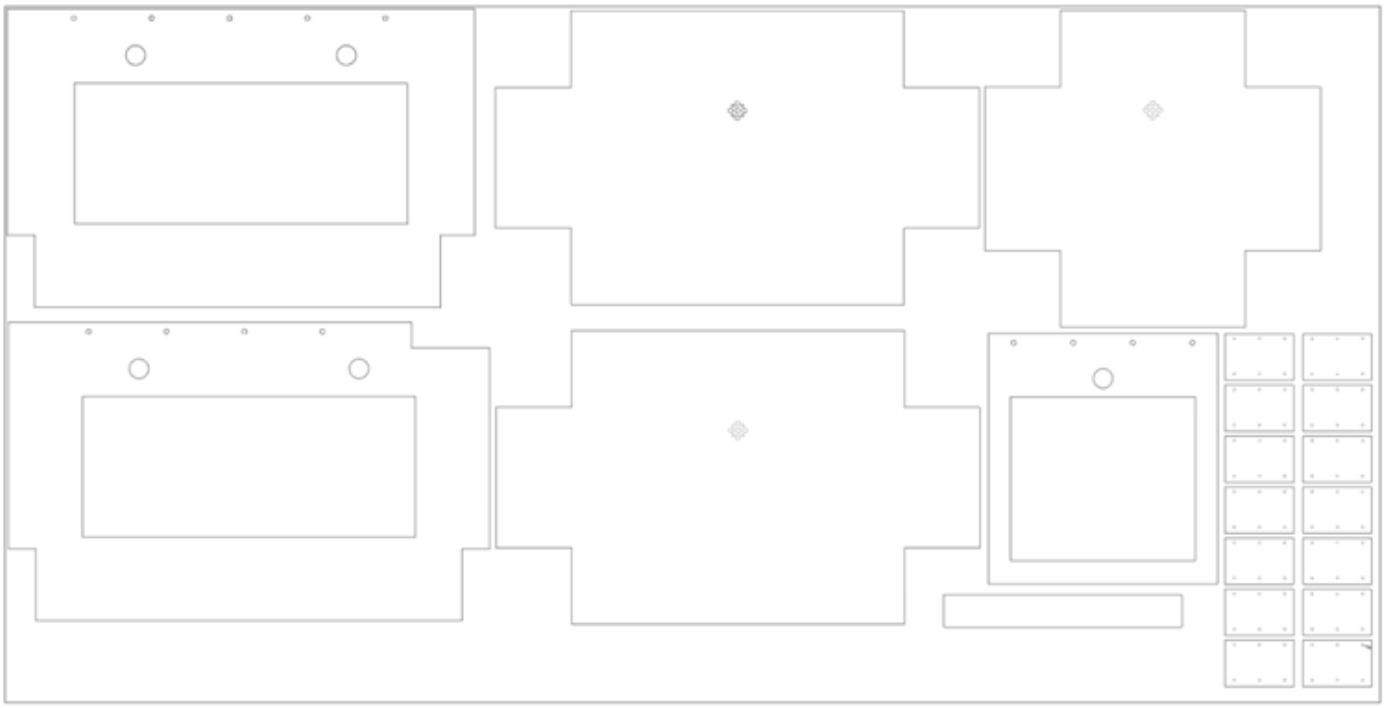


Figure 110: Cutting drawing

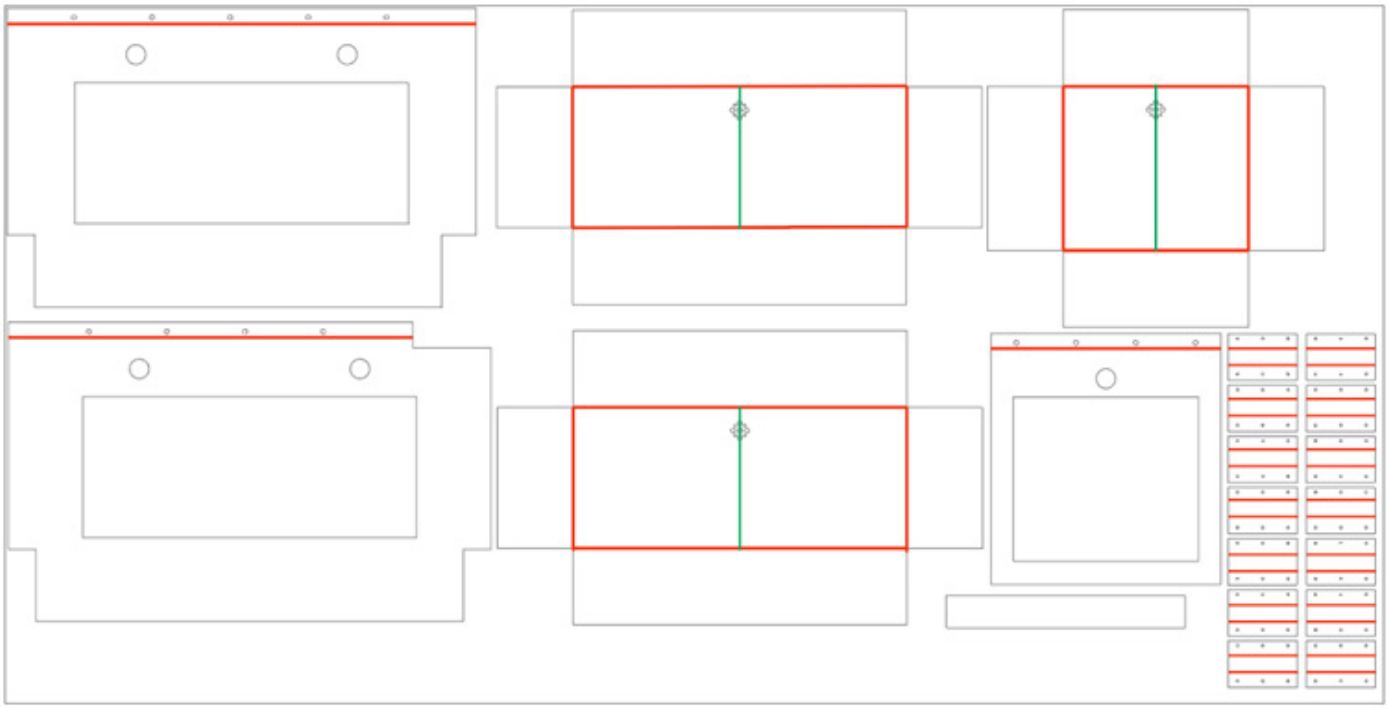


Figure 111: Bending drawing

PART VI
Shower stalls

6.1 Stakeholder analysis

Every day it is estimated 200 people will use the two showers in the facility, Appendix A - Income. With 25 L each, these 200 visits cost 5.000L of water. On the other hand, these showers supply every day around 1.000 toilets with flushing water. When the showers remain unused, less grey water is collected. When there is too little grey water, fresh water is used to flush the toilet, Figure 15. Therefore the shower can be seen as an extra service provided, not costing extra water.

Personal hygiene such as washing one's selves is related to preventing infections and unpleasant odors. Besides that, it can help our mental health [77]. The need for showers might be less than for toilets or handwashing facilities concerning sickness prevention however, it is an extra service for the users. Owning a shower is often not an option for the working class in Ghana [76]. They have to look at other options such as public showers to wash.

Just like the previous subsystems of the design, also the design of the showers is looked upon by the 5 main stakeholders, Figure 112. Their most important factors are shortly discussed below.

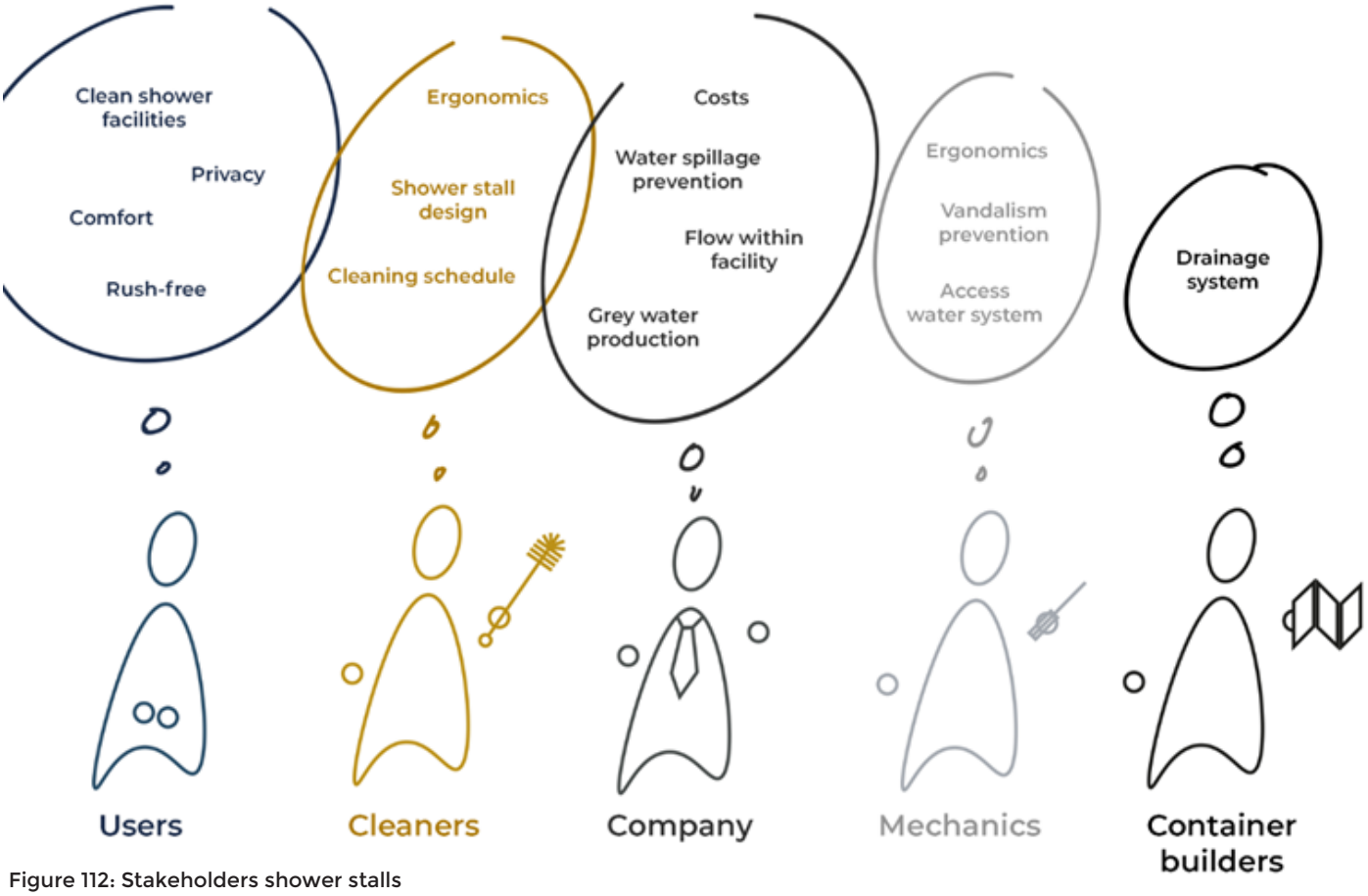


Figure 112: Stakeholders shower stalls

Users
The interests of the users can be summarized as having a comfortable showering experience. The temperature of the water, privacy, overall comfort, and a clean facility are important factors in this. Besides that, they do not want to feel rushed.

Cleaners
Just like before, the most important interest of cleaners is that the facility is easy to clean, so they can clean the facility quickly and work comfortably according to the cleaning schedule. Like in the sitting toilet stalls, in the changing area in the showers, a drain is installed to make cleaning easier.

Company
For the company, it's important to maintain a flow of people in the showers and meet the set amount of visitors per day. Therefore the users mustn't shower too long, moreover, the company wants to avoid spilling water by letting the showers running. As can be read in the business case, the showers earn the company the least amount of money, so costs should be kept low.

Mechanics
The mechanics have the biggest interest in a shower which can be serviced relatively easily, meaning all important connections can be accessed via the ICE technical space or from the shower cubicle itself.

Container builders
Just like the subsystems discussed before, the container builders look at the design from a practical point of view and want to know how the water drainage and water supply runs to, and from the showers.

6.2 The design

The final design of the showers looks like the pictures show in Figure 113, 114 and 115 In the men's and women's sections there is one shower located at the short side of the container. The shower is divided into two sections: a shower section with a shower tray, a showerhead, and a splash screen, the changing section is equipped with a small bench, three hokes to hang clothing, a ventilator and a coin-operated timer to get the shower running.

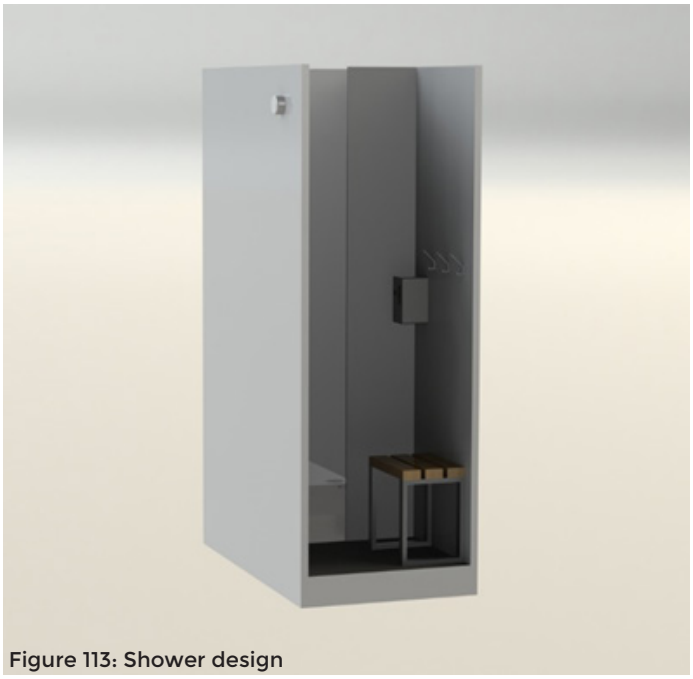


Figure 113: Shower design

Figure 114: Shower design

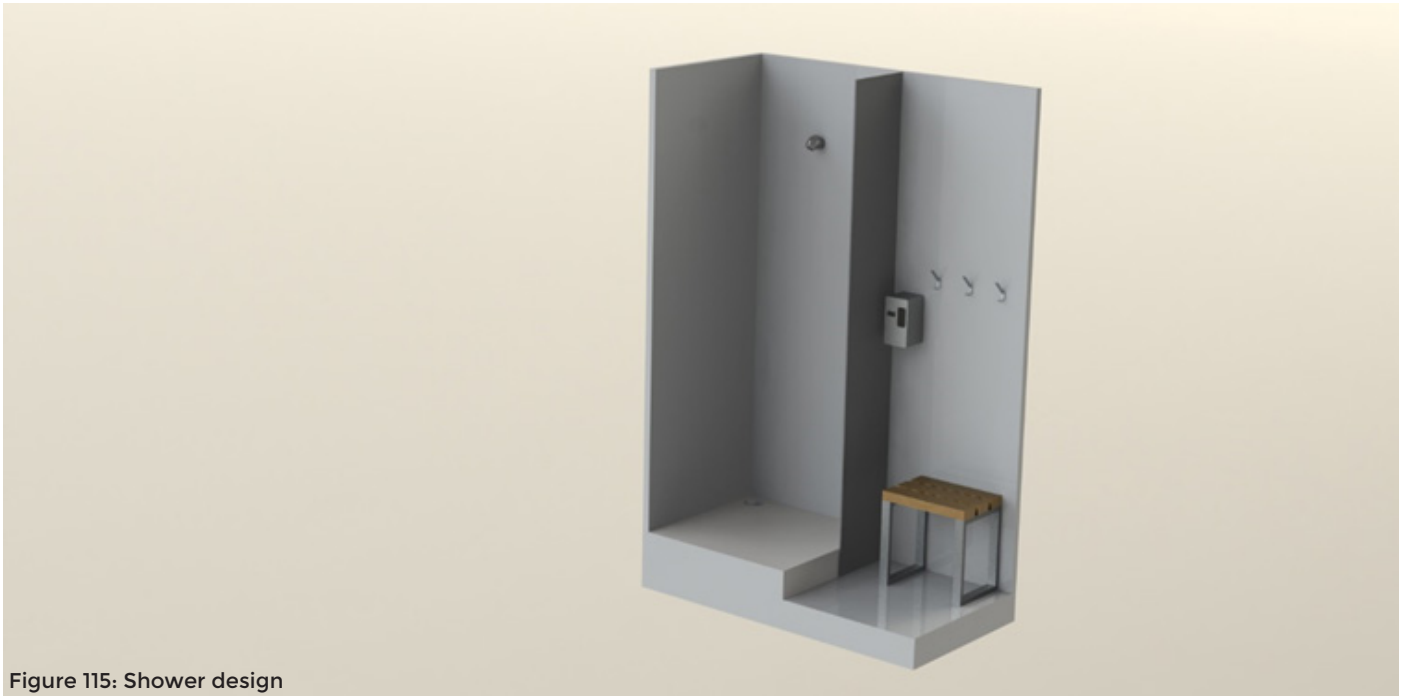


Figure 115: Shower design

6.3 Temperature

A freshwater source is located at the market in Techiman. Water is pumped from the ground and directly filtered. There is a constantly fresh and filtered water supply to be used for the sanitation unit. Research in groundwater in the north of Ghana shows the temperatures at different sources fluctuate between 28.8 and 32.8 ℃. [70]. Research in the neighboring country Ivory Coast shows groundwater at the coast in Abidjan lies between 25.5 and 28.6 ℃ at different sources [71]. In the other neighboring country in Togo in the Kara region, the average groundwater temperature is 28.7 ℃ [72]. Groundwater temperatures are consistent with air temperature. The further inland, the higher these temperatures [71]. Therefore I estimate the groundwater temperature in Techiman to be around 28 ℃.

Mister Collins from Good sanitation Ghana told me most of the showers in public sanitation blocks in Ghana are not heated, so people are used to a lukewarm shower. I found different sources claiming most shower facilities only provide cold showers in Ghana [9, 10].

Cold water, used for the handwashing stations, is around 28 ⍰. For the users, it is most comfortable if they can choose themselves at what temperature they want to shower, just like in most homes in the Netherlands. In most homes in the Netherlands, 95 percent, water is heated by burning gas [79]. There is no gas connection and no connection to the electricity network at the site in Techiman. The only reasonable way to heat the water is by using the sun. There are multiple ways to go about this. The two most promising options, solar heating panels and a shower tank on the roof, are discussed in Appendix D Shower water heating principles. Appendix E shows calculations on the showerwater temperature of both methods.

In a discussion with Feenstra and Semilla, it was decided that a solar heating system probably was not worth it for this application. With the estimated costs of 15.000 euros (Feenstra), it would increase the costs of the container by 25% while the shower temperature would only increase to 32 degrees Celcius, Appendix E. Besides that, it would take up the space needed for solar panels to keep the facility running. Placing a shower tank on the roof increases the water temperature by 0.9 degrees on average, meaning the shower temperature is around 29 degrees Celcius, Appendix E.

Figure 116: Shower tank

6.3.1 Shower water heating

A 1000 L tank is placed on top of the roof of the container, Figure 116. The working principle of the shower water system is shown in Figure 117. Freshwater is pumped up from the soil and filtered, and stored in a freshwater storage tank. Using a booster pump water is pumped up to the shower water storage tank on the roof. This tank is placed in the sun, so the water can be heated. Placing the water tank higher than the showers also provides the pressure for the showers to run, so no extra pumps are needed. The solenoid valves are opened when a coin is inserted in the coin-operated timer, resulting in a water flow from the showers. When 5 minutes have passed the valves are closed again, closing off the water stream.

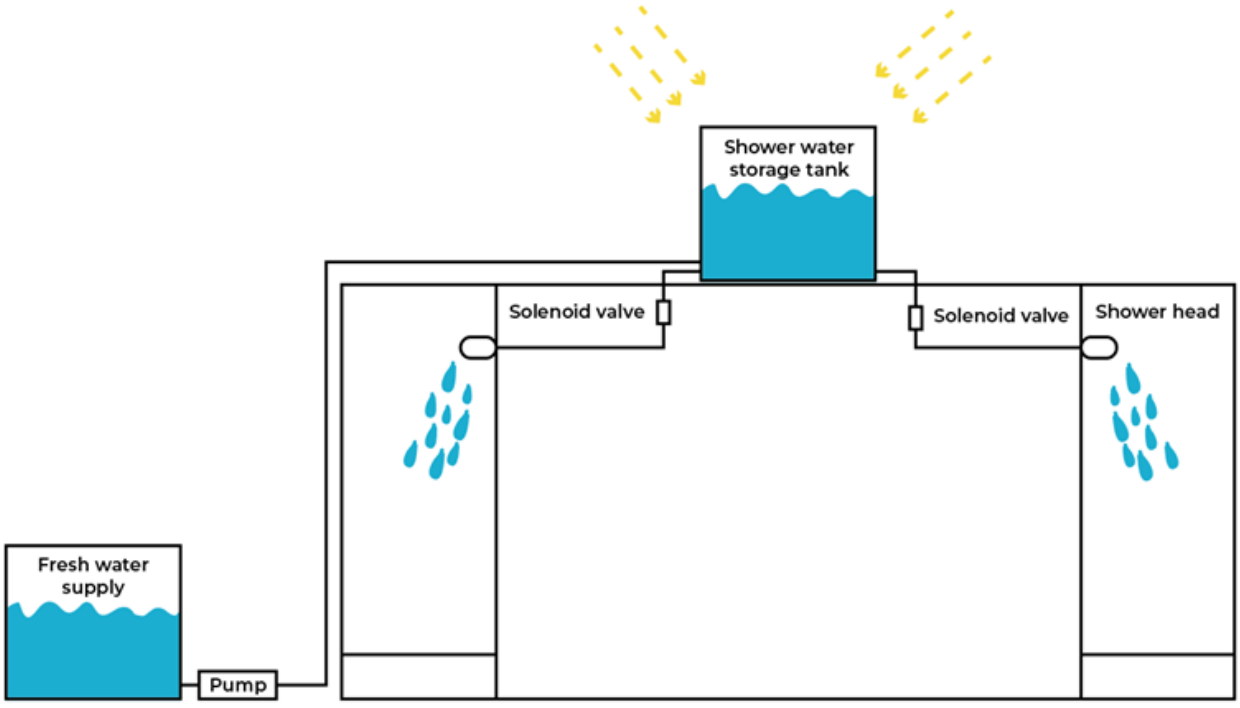


Figure 117: Working principle showers

Inside the water tank, a switch valve is located, Figure 118. The working principle is shown in Figure 119. The blue floater floats and the yellow cylinder sinks. When the water level is high, the blue floater floats, and the switch inside is turned off, situation A. When the water level drops, the blue floater is floating on top of the water, meaning it is upside down compared to situation A, and the switch is turned on. The switch has been connected to the fresh water pump. When the switch turns on, the pump starts working, filling the shower water tank. With this system, the minimum volume of the tank can be adjusted by adjusting the length of the cord. The longer the cord, the less the minimal volume. When the volume in the tank drops, the pressure of the shower water drops with it.

Figure 118: Switch valve

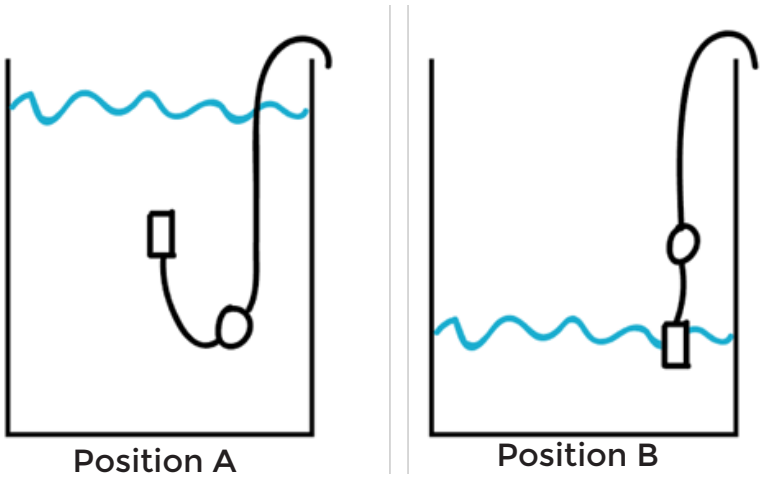


Figure 119: Switch valve working principle

It was decided to place the shower water storage tank in the middle of the container to make sure the tubing for both showers is the same length, so pressure loss is the same (around 2.5 kPa). This way the pressure and flow rate of both showers are the same.

The shower tank will be painted black to prevent light from entering. This prevents algae from growing inside the tank. Besides that, a painted black tank will heat up faster than a transparent one.

Kan-Bud will install a steel construction like Figure 120 on the roof of the container to support the water tank. The tank is bought locally, so won't be shipped from the Netherlands.

Figure 120: Container construction by Kan Bud

6.3.2 Legionella prevention

Legionella is a bacteria that is present in small numbers in groundwater [93]. It only causes problems for humans when it multiplies. This happens when the water is heated between 30 and 45 ℃. the optimal temperature is 37 ℃ [93]. The best circumstances for legionella are still standing water. For this to happen water has to stay still for days [93]. In tubing above ground, this can be a problem since it can heat up easily.

Reducing risk for legionella has been taken by choosing for a water tank of 1000L, the tank gets emptied five times a day since 5000L shower water is needed. Besides, the solenoid valves are placed as close to the water tank as possible, minimizing the volume of water standing still inside the tubing. A small volume of water standing still inside tubing heats up faster than a large volume of water standing still in the tank.

According to the Dutch Rijksoverheid, the water system has to be analyzed by a certified company specialized in legionella prevention. This analysis shows where legionella bacteria can grow [94]. Based on this analysis a legionella plan will be written [94].

The water system should be cleaned regularly, it can be flushed with chlorine, just like what is done in swimming pools [95]. Therefore there must be a big opening on top of the shower water storage tank to clean the inside properly.

6.4 Shower components

6.4.1 Shower tray

Standard shower trays measure 900 x 900 mm [36]. The width of the shower cubicles has been adjusted to this and measures 900 mm as well. According to the Dutch Bouwbesluit, a shower room should measure at least 1.6 m^2 [35]. Based on this the dimensions of the changing section are determined. As in the toilets, a frame around the doors influences the space available in the changing area, Figure 121.

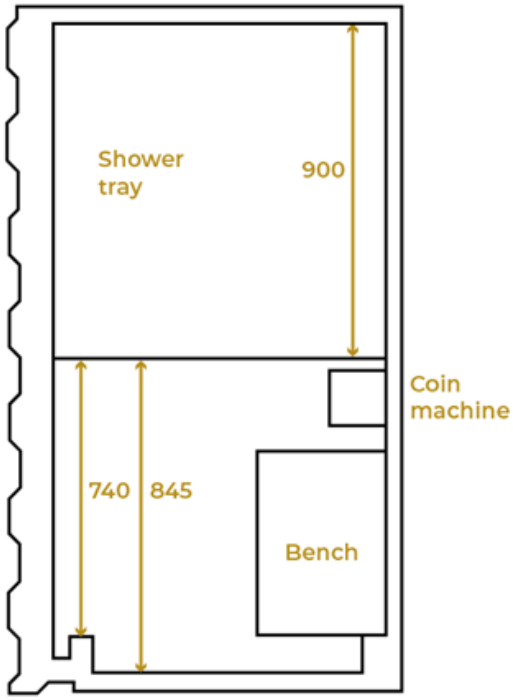


Figure 121: Dimensions shower cubicle

High shower trays were incorporated into the facility. The shower trays are 13.5 cm in height, with a height of 10 cm underneath, Figure 122 This allows the grey water drains to be placed under the necessary slope to drain with gravity. As argued before, the grey water drains lay on the floor of the container. It covers roughly 4,5 meters inside the container. Taking into account the rules described with the squatting toilets, the shower drain needs at least 4.5 cm of vertical space. The siphon takes up an additional 5 cm [78]. At least 9.5 cm of vertical space is needed, the shower tray allows for 10.

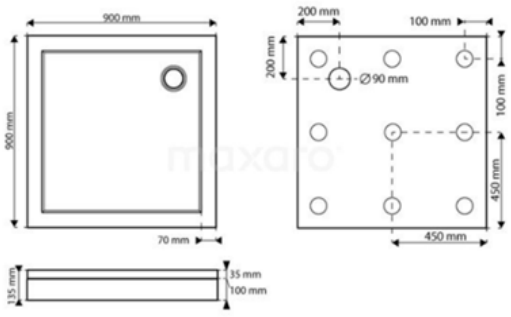


Figure 122: Shower tray

6.4.2 Shower head

The most important criterion of the showerhead is its resistance to vandalism. I choose to incorporate showerheads commonly used in public showers, like in dressing rooms at sports clubs, Figure 123. In a discussion with a technical counselor, it became clear this shower can run with pressure provided by a column of meter water. The tank on the roof supplies this pressure. The flow rate will be around five liters per minute.

The technical specifications of the showerhead provide the spray pattern of the shower, Figure 124 [73]. Based on this pattern it was decided to equip the shower stall with a screen preventing the changing area to get wet.

6.4.3 Splash screen

The showerhead is placed at 2000 mm measured from the surface of the shower tray. To keep the changing area as dry as possible, the showerhead is placed at 400 mm measured from the back wall, Figure 125. The more the showerhead is placed towards the changing area, the more likely this will get wet.

The average stature height of a West African man is 1670 mm according to DINED [55]. The spray pattern does not exceed 400 mm at 33 cm underneath the showerhead, Figure 124. Therefore it was decided to have a splash screen of 400 mm in width. This leaves 500 mm to enter into the shower area, Figure 126.

The splash screen is made of an HPL board. HPL board has a very low moisture absorption level, making it hygienic and easy to clean [80]. The Splash screen will be mounted to the floor and the ceiling.

Figure 123: Shower head

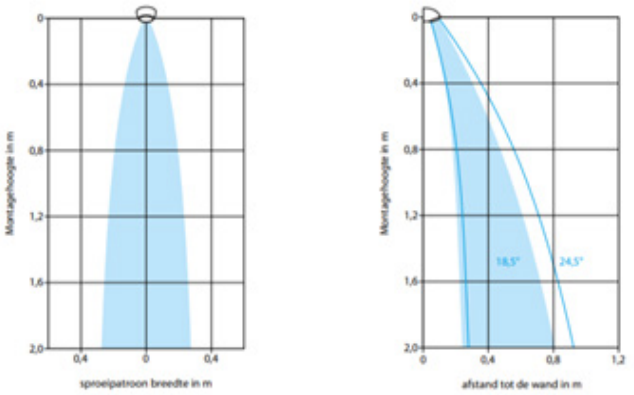


Figure 124: Spray pattern

Figure 125: Measurements shower stall

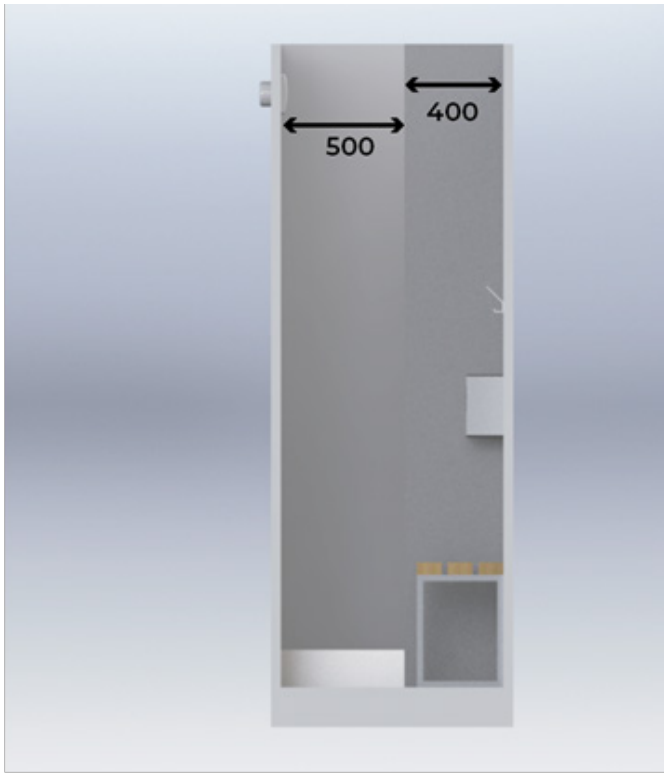


Figure 126: Measurements shower stall

6.4.4 Coin operated timer

As Figure 112 shows, Semilla's main objective is not to waste water and generate flow in the facility. To accomplish this it was chosen to incorporate a coin-operated timer in the shower facilities, Figure 127. At the cashier, the visitors can buy a coin for the showers. The showers run for 5 minutes after the coin has been inserted. This prevents the users from leaving the shower running and wasting water. It defines a flow within the facility as people can't shower longer than five minutes unless they buy two coins.

Figure 127: Coin operated timer

The coin-operated timer is installed in the changing area, Figure 125. As can be seen, it features a timer. It is not possible to mount it in the showering area because of safety issues. The moment the users insert a coin, they can see the timer starts counting down.

When a coin is inserted, a solenoid valve connected to the water supply opens. When the time runs out this valve is closed, making the water stop running.

An employee of Leisure Controls International Ltd advised to use grooved tokens in places vulnerable to vandalism, Figure 128. Using flat tokens it is more likely people will try to insert other common coins, possibly damaging the system.


Figure 128: Grooved coins

The price for a shower is twice the price of a visit to the toilet and five times the price to visit the urinals, Appendix A - Income. This system with coins prevents people from showering while they paid to visit the toilet.

Just like the soap dispensers, the coin-operated timer is hung at 1000 mm measured from the ground up, Figure 125.

6.4.5 Ventilation

Inside the shower cubicles, ventilation is required to supply the space with oxygen and to remove CO2, water vapor, odors, and dust particles [75]. For bathrooms with showers, natural ventilation is not enough, by UK standards shower rooms should be ventilated by at least 54 m3 per hour [69]. Therefore in both of the showers, a fan is installed, Figure 129. These fans work with moisture sensors, meaning they turn on when the air in the shower exceeded a certain threshold of humidity. Especially in times of Covid-19 this has become even more important.

Figure 129: Shower fan

The fans are placed in a hole in the container. These smaller holes do not require a supporting frame welded around like the big openings for doors and windows. Instead, a small frame suffices, Figure 130.


Figure 130A: Small holes in the container


Figure 130B: Backside


Figure 130C: Finished holes

The ventilation shafts, the holes in the roof for venting the drainage system, and the holes for the water supply of the outside handwashing unit are made using these same cuts. In Appendix G the technical drawings of the container can be found, indicating these small openings.

6.4.6 Bench

A small bench is added to the design of the showers in the changing area. The bench is mounted to the floor so it won't be able to move around. The users can have a seat while changing.

6.4.7 Hokes

To hang clothing while in the shower, hokes have been mounted to the wall. The splash screen is located at the side of the hokes to prevent the clothing from getting wet while the user is showering.

PART VII Container building

7.1 Constructing the container

Kan-Bud, the company delivering the container, does most of the construction. They deliver the shipping container and isolate it. They also make sure the steel construction, supporting the toilet reservoirs, is in place. They place the inner walls building the cubicles. Kan-Bud will place the doors and take care of the cutouts for the handwashing facilities and the exit for the tubing. On request, these men can also install the toilets, showers, electrical system, and tubing system already. This means that almost the whole container is assembled already when it will be shipped to the Netherlands. In Doetinchem the handwashing tables will be made and installed. Then the container is finished and ready to be shipped to Ghana.

The finish of the floor, roof, exterior, and interior walls can be seen in Figure 131.

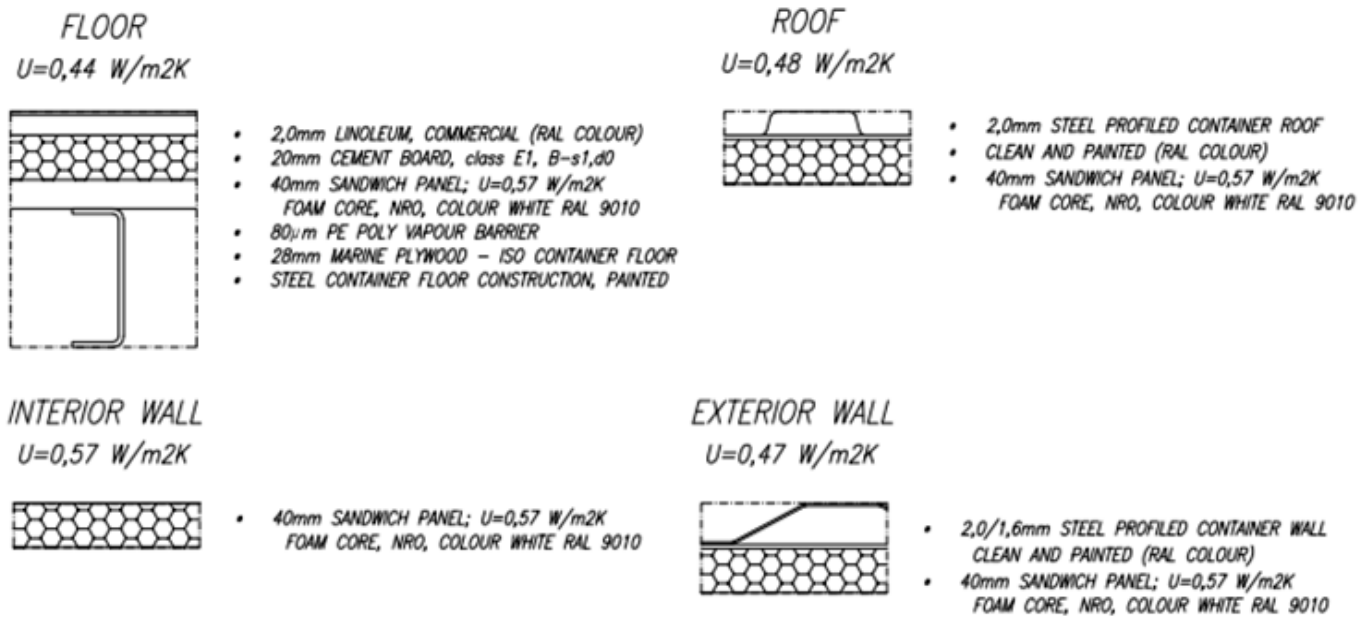


Figure 131: Container finish

7.1.1 Inner walls

As argued before, the inner walls consist of 40 mm sandwich panels. A mounting profile is screwed into the floor and the ceiling. The sandwich panels can slide into these profiles. The steel structure to support the reservoirs is welded to the floor and the roof of the container. After that, the layers of plywood, isolation, and cement board are added. At the corners of the sandwich panels, another steel structure is added, Figure 132. These consist of corner profiles. Kan-Bud advised to add these at the vulnerable corners of the structure, to provide the inner walls with extra support. Like the reservoir supports, these steel profiles are welded to the floor and roof of the container.

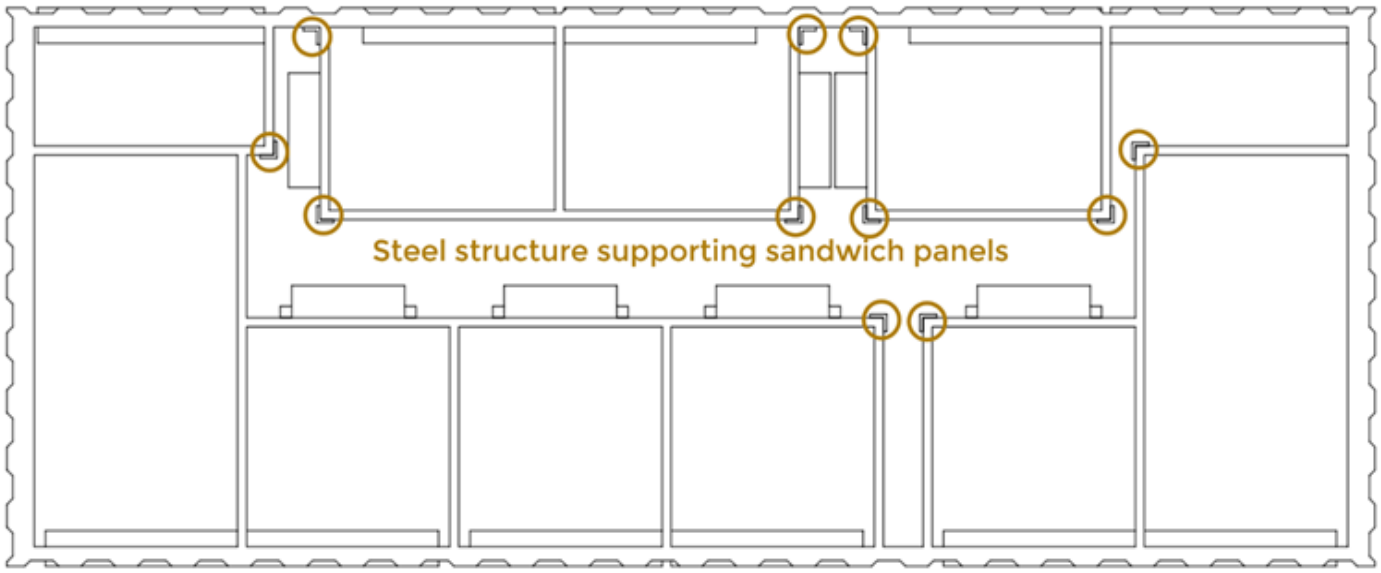


Figure 132: Steel supporting structure

7.1.2 Floor

The top layer of the floors in the facility is made of linoleum, Figure 133. Kan-Bud recommended linoleum flooring since they have done multiple sanitation projects with these floors. They told me it is excellent for sanitation purposes since it is easy to clean, especially in combination with drains. Besides that, it is a durable material, suitable for intensive usage.

Another advantage of linoleum flooring is that it can be welded against the walls, creating plinths. These can be as high as 100 mm, Figure 133. With plinths like these, the cleaners can throw half a bucket with water and a cleaning agent inside and start mopping the floor. The plinths make a watertight connection with the walls. Moreover, they give a clean, and professional-looking finish to the cubicles.

Figure 133: Linoleum floor with plinth

7.1.3 Drains

As explained earlier, all sitting toilets are equipped with drains, the main reason for this is that it can make cleaning easier. For the same reason, the changing section of the showers is equipped with drains. A big drain is added in the technical space, Figure 134. In the unlikely event of leakage in one of the tubing systems, this drain prevents the water from leaking into the cubicles.

Within the cubicles, small drains with a diameter of 100 mm are installed. The drain in the technical space is bigger.

All the drains collect in one 50 mm pipe underneath the container, Figures 135 and 136. Underneath the exit of all drains in the container, the drain will exit the container. The drain is connected to the black water storage tank. As argued before, the cleaning agent inside the black water stream does not influence the recyclability of the stream.

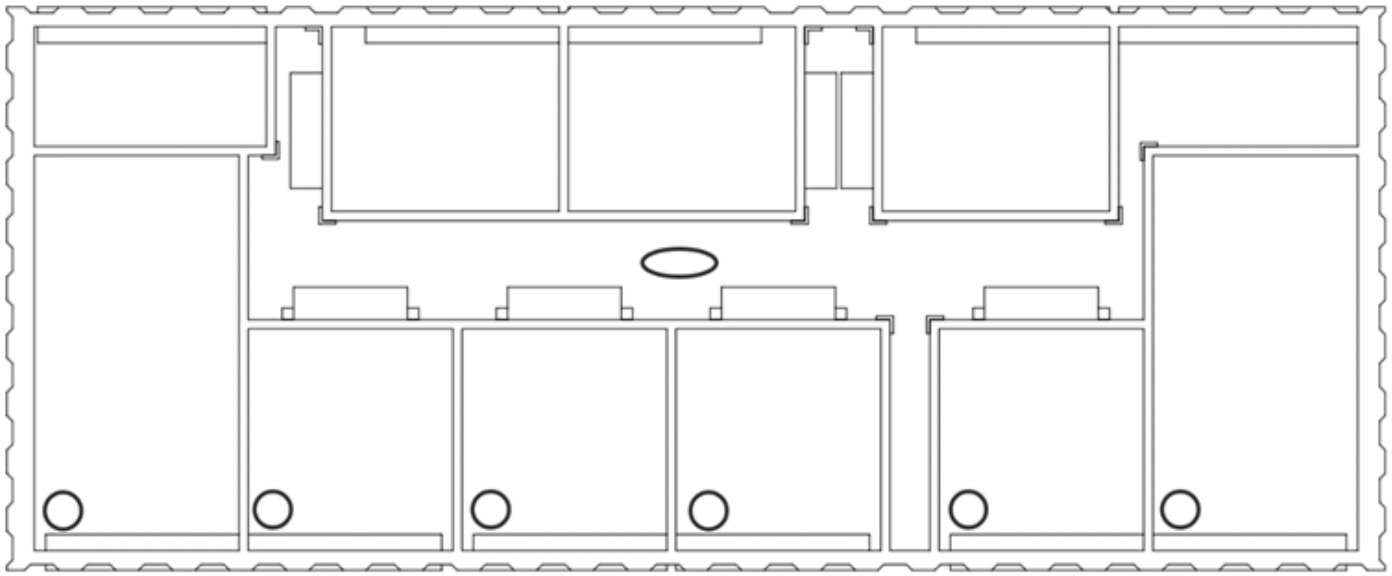


Figure 134: Drains within facility

Figure 135: Drains underneath container

Figure 136: Central outlet drains

7.1.4 Ventilation

Within the toilet cubicles in the unit, only natural ventilation is used, no powered fans, air conditioning, or blowers are implemented. Every door in the facility features a grid, Figure 137. Without a grid or opening inside the doors, it becomes hard to close the doors. The reason for this is that you try to push air in an already filled closed-off cubicle. When the door is closed, it is hard to open the door again. Via the grids air can travel through the doors when opening and closing, solving this problem.

In the back wall of every toilet cubicle, there is a small grid that can let air from the cubicle to the technical space. Air can travel freely through the whole container. Opening and closing doors in the facility add to the ventilation since air is pushed through the different ventilation grids. A window or connection to the outside air suffices as a ventilation method for toilets, according to UK ventilation regulations [69].

In the shower stalls, active ventilation is provided by a fan, chapter 6.4.5.

Figure 137: Ventilation grids in the doors

7.1.5 Lighting

Outdoor lighting can improve the feeling of safety for the users in the facility [11]. On the outside of the facility, different lights are placed to lit up the facility in the darkness. Eleven standard lights are placed around the facility: seven around the container, two in the urinal unit, and two at the cashier's desk, Figure 138.

Figure 138: Outside lights

Inside the cubicles, it is important to have lighting, since almost no natural light enters the cubicles when the door is closed. Movement sensor-operated lights are applied in all cubicles. This eliminates the need for cleaning light knobs and reduces the chance of recontamination.

PART VIII
Urinals

8.1 Stakeholder analysis

In the men's section is access to urinals. Yellow water is collected in a separate tank and consists of pure urine. To process the urine to fertilizer it must be as clean as possible, therefore the urinals won't be flushed with water.

By adding standing urinals in the facility, the flow will be improved. As argued before, a visit to the urinals takes significantly shorter than a visit to the toilet, chapter 3.3.1. Adding six urinals to the facility improves the number of people that can be helped, thus the impact, greatly.

Semilla is currently working on designs for female urinals as well. A separate female urinal unit can be added to the facility, improving capacity for women. This gives women also an extra and cheaper option for a urinal instead of a toilet. Tests in the Reinvent the toilet project suggest that women would also like to have a urinal option. However, it was not clear whether this was because they wanted a separate place to urinate and defecate or whether they wanted a cheaper option for a toilet visit [11].

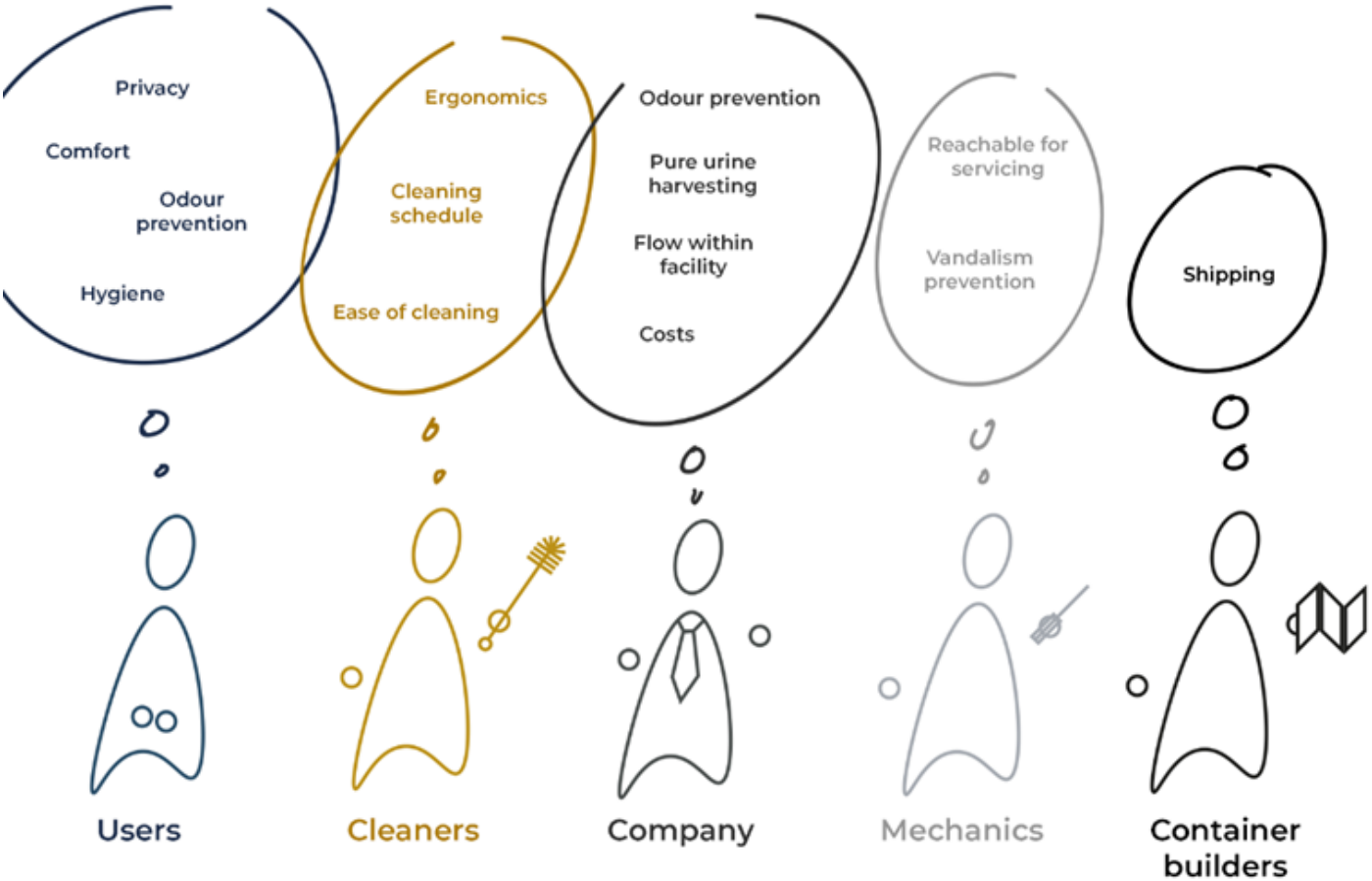


Figure 139: Stakeholders urinals

Users

For the users, it is important that the facility is clean and hygienic and no bad odors come from the facility. In contrast to the toilet facilities, the urinals are not located in a private cubicle, however, privacy is important while urinating, since this can feel like a vulnerable position. It is comfortable for the users to be protected by the weather while using the urinals.

Cleaners

The same accounts for cleaning the urinals as for cleaning the container. Cleaning should be easy and quick.

Company

Just as for the users, for the company, it is important to prevent bad odors. These can spread around the whole facility, which may lead to a less clean impression of the facility in general. Besides that, the company wants to have a flow in the facility and keep the costs low. To process the urine, it should be collected as clean as possible.

Mechanics

It is important for the mechanics they can reach all parts in the urinal unit that need maintenance. This should be taken into account when designing the unit.

Container builders

The container builders will not build this unit, since the urinals are not placed inside the container. The unit needs to be transported in a separate 40 feet shipping container. With the design, this has to be taken into account.

8.2 The design

The GreenPee discussed before is a waterless urinal to be placed in Western cities, Figure 8. The green urinals from the GreenPee will be used in the urinal unit as well, Figure 8. The molds to produce these are in the possession of the company, these can be produced for only 29 euros each.

The design of the urinal unit is similar to the GreenPee. The green urinals are mounted onto a stainless steel plate, Figure 141. Small holes are cut in this plate, the urine flows into the piping system of the urinal via these holes. These stainless steel plates are mounted onto a metal frame, Figure 140.

Sewage system

Just like the sewage system of the container, this piping system is made of PE and has been prefabricated. Instead of a 1% slope, a 4% slope is better [100].

Privacy sheets

Between the individual urinals, partition walls have been placed to improve privacy while using the urinals. One of the remarks in the Reinvent the Toilet project was that men missed these [11]. Instead of placing stalls around the urinals, these privacy sheets provide some privacy while a large flow of visitors can be achieved compared to cubicles. Moreover, it is common for urinals to be aligned like this, without a cubicle.

Placement

Underneath the unit, two blocks of concrete are visualized. These are dug into the ground to fix the unit and stabilize it, making it less vulnerable to the wind.

Figure 140: Sewega system inside urinal unit

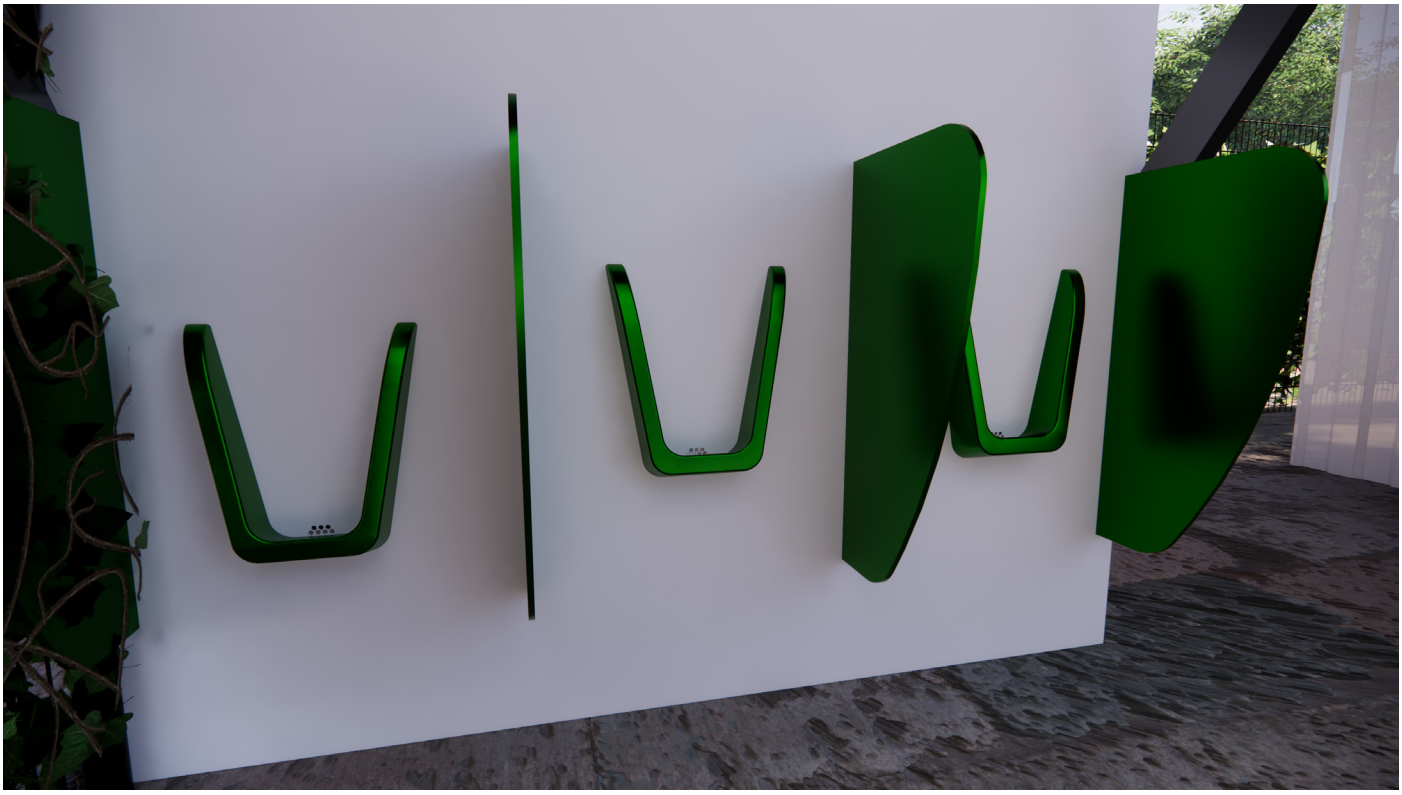


Figure 141: Zoom-in urinal unit

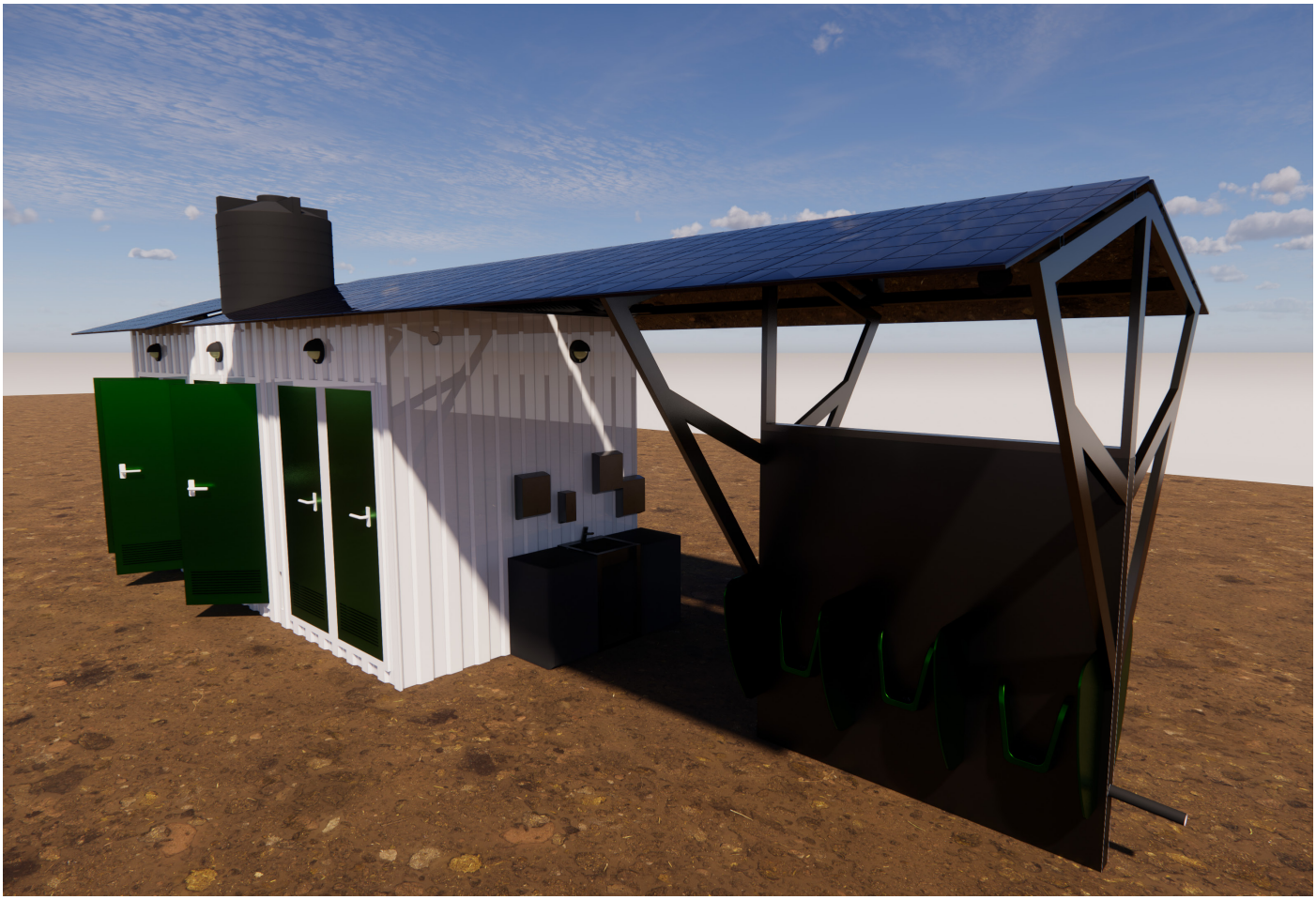


Figure 142: Urinal unit

8.3 Waterless urinal

To collect urine as clean as possible it was decided to include waterless urinals instead of water flushed urinals. When flushing urinals, urine gets diluted, making the process of fertilizer production not commercially viable. A regular urinal is flushed with 3 liters of water, so waterless urinals safe 7.200 L of water per day and 2.628.000 L of water per year. Even though water is recycled on-site, virtually all grey water is used to flush toilets, Appendix A - Income.

When choosing waterless urinals instead of flushed urinals odor control is crucial for user acceptance [81]. Waterless urinals can produce overwhelming odors when no measures are taken [82]. Water is associated with hygiene and has a symbolic hygienic value of age-old experiences of cleaning the body with water [13].

The design of the urinal unit is discussed with sanitation expert mister Bosman. According to him, most odors are produced by urine rests in the toilet and on the floors. The tubing system is very short compared to tubing systems within big offices for example. Therefore, urine odor vapors will be minimal, most odors will come from urine rests instead. To reduce odors, he advises cleaning more often instead of implementing a stench trap. Besides that, urine should be fed into the tank at the bottom, so urine vapor above the urine can't get to the tubing. The urine in the tank acts as a stench trap. An advantage of the facility is that the urinals are situated in the open air instead of inside the container, odors will not fill a room, instead, odors can be taken with the wind easily.

Discussing with sanitation experts Jeroen Bosman and Marian Loth, it became clear both of them do not favor waterless urinals. The most prominent reasons for this are the odors and the urinals becoming messy easily. Since these urinals are not flushed every visit, little hairs and other dirt can make them look unhygienic and dirty even after one visit. This makes regular cleaning by the cleaning staff even more important.

Besides odor control, the formation of scale in the tubes can form a problem as well. Depending on the flushing water, scale formation can be reduced or aggravated. The higher the pH and total dissolved solids (TSD) in the flushing water, the more scale will form [83]. Scale can be removed using different methods with or without chemicals. PE pipes have a lifespan of over 100 years and are chemical resistant. Compared to PVC piping the PE joining is stronger than the PE pipe itself because of fusion joining, whereas joints in PVC pipes are usually weak points [97].

8.4 Cleaning urinals

As mister Bosman advised, it is important to clean the urinals regularly. Just like the toilet cubicles, the urinal unit has been designed with this in mind.

Smoothness

All components that come into contact with urine, should have a smooth, non-porous surface, minimizing urine rests to stick onto the surfaces. Urine rests sticking onto surfaces causes odors and bacterial biofilm growth, both need to be prevented as much as possible [100].

The urinals are produced by injection molding. I advise producing these out of LDPE since it achieves a non-sticky and smooth surface finishing [100].

Since urine is corrosive, it is best to use stainless steel for the back wall [100]. Stainless steel is available in different surface finishes. Even though it is one of the smoothest finishes, I do not recommend a mirror No. 8 finish. Instead, it is better to use a less reflective finish like a 2B finish [102].

Urinal blocks

Urinal blocks will be placed inside the urinals to mask odors. Upon interaction with urine, the blocks release their odors, masking the urine odors [98]. Every day two of these blocks will be used for every urinal to mask smells. The gutters lead the water to a small reservoir under The.

Gutter

Spillage of urine on the ground or the walls of the urinal can cause odors. Therefore a gutter has been placed at both sides of the urinal, Figure 143. This way the water used for cleaning can be swooped in these gutters easily.

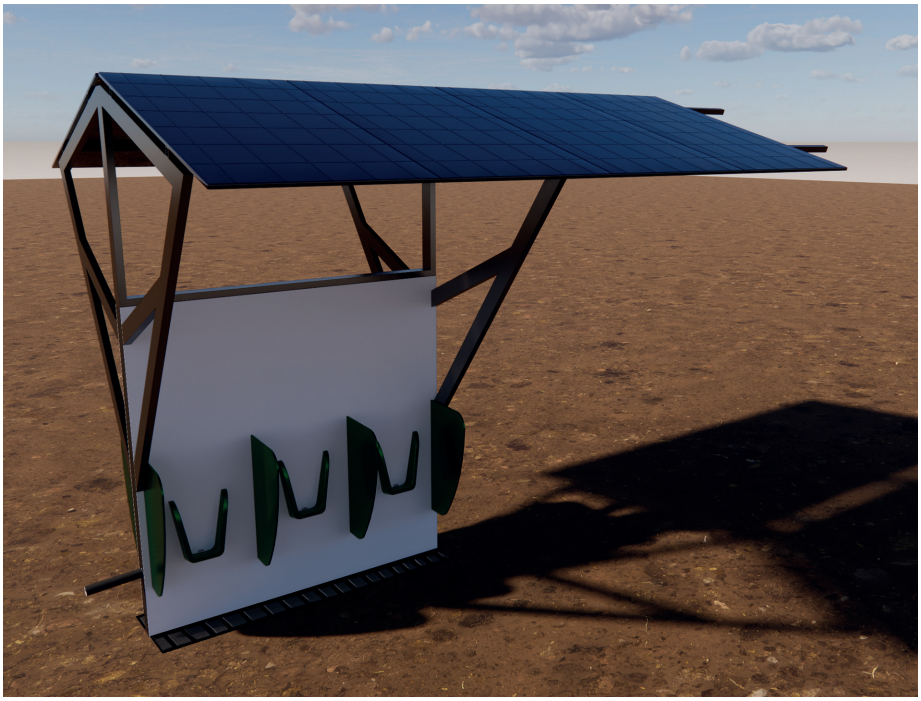


Figure 143: Gutter at the base of the urinal

The gutters lead the water to a small reservoir under the ground. Withing this reservoir submersible pump pumps the cleaning water into the black water storage tank, Figure 144.

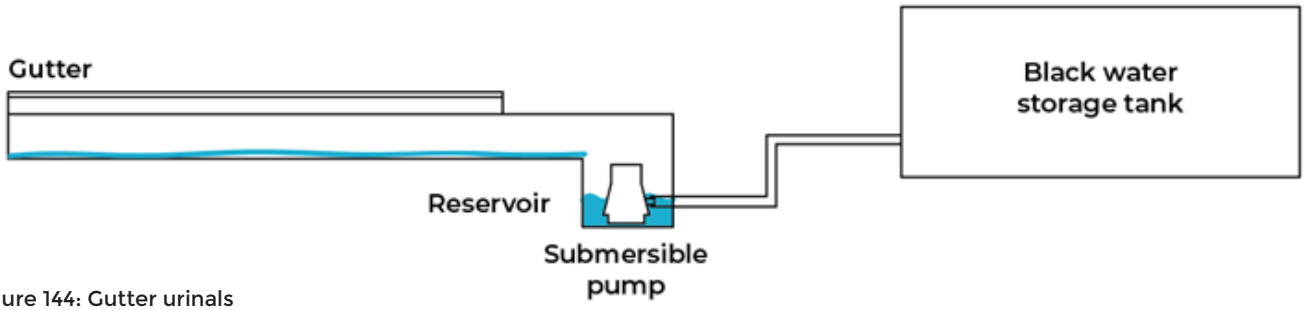


Figure 144: Gutter urinals

When the water in the reservoir exceeds a certain level, and the pump is (partially) submerged in water, it starts pumping until the water level has dropped.

Figure 145: Submersible pump

Around the urinal unit, hygienic tiles could be paved. These tiles are cleaned easily since dirt, and urine rests hardly stick to them. These types of tiles are often used in swimming pools.

8.4.1 Ergonomics

The urinals are mounted at 610 mm, Figure 146 [13]. It was chosen to mount one urinal at each side at a lower level, 510 mm, to make urinating for smaller men and children more comfortable. The same method is applied as with the towel dispensers. The total width of the wall of 2000 mm is divided into three sections of 630 mm.

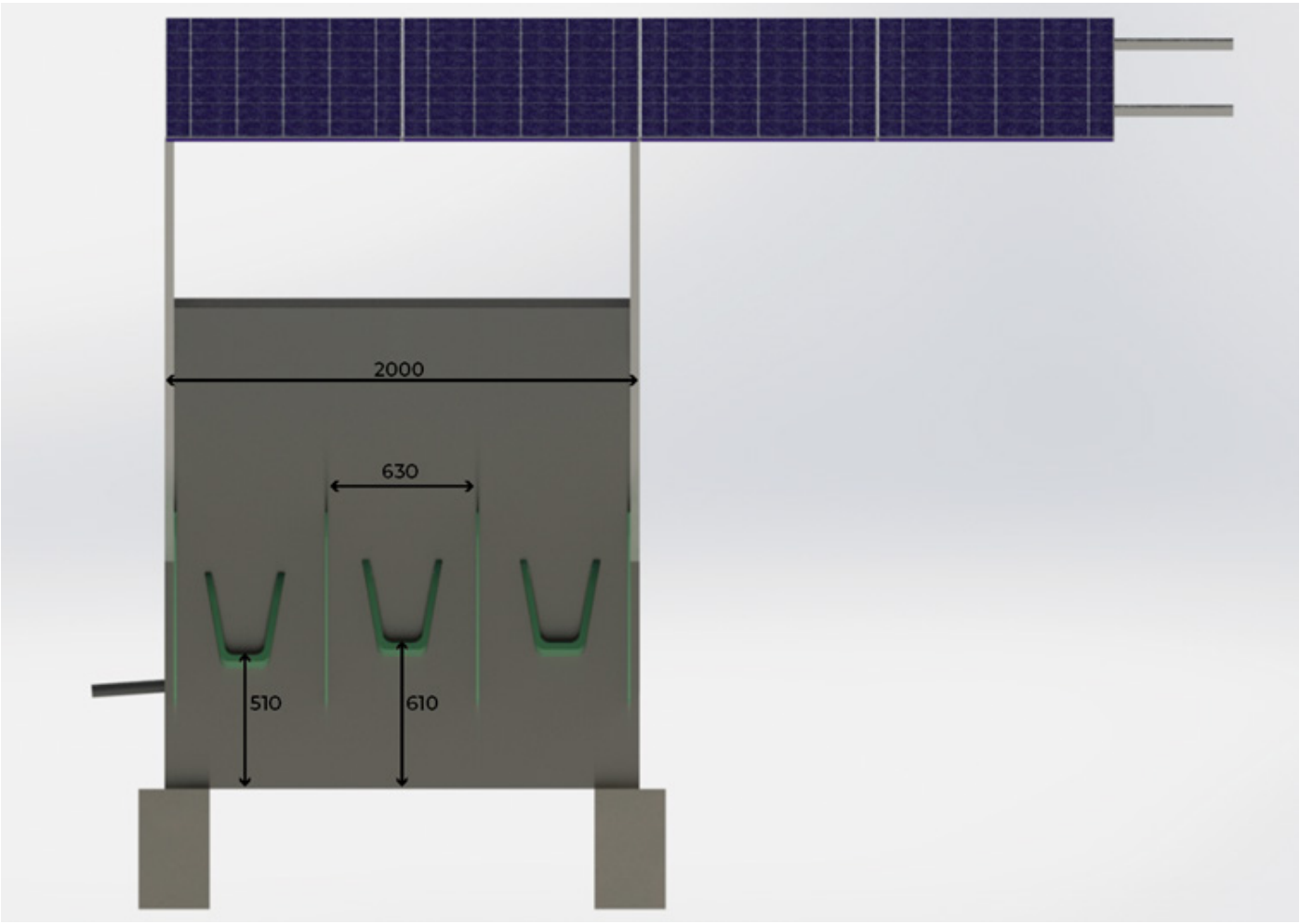


Figure 146: Ergonomics urinals

PART IX
Energy
+
Shipping

9.1 Energy supply

9.1.1 Introduction

It is not possible to connect to a local power supply at the market in Techiman. The complete sanitation facility has to operate off the grid. All power required to keep the facility running has to be generated by a system of solar panels. As can be read in Appendix F, the solar radiation power around Techiman is high, making the climate ideal for solar panels. As explained in the introduction, Greenlink Solar will provide the solar system. In a discussion with them, it was decided to place the facility in an East-West orientation maximizing performance of the solar panels oriented like shown, Figure 147.

Figure 147: Solar panels in the facility

9.1.2 Power consumption

Not all powered components have been discussed. The ATM, grey water filtration system, and the drinking water pump were not elaborated upon in this report since this is out of scope. However, they are included in Appendix F in the calculation of the number of solar panels. All components consuming power in the facility have been incorporated in this calculation.

The booster pumps are responsible for the largest power consumption. These account for 1500 W each, Appendix F. Powering coolers increases the total energy demand greatly. Instead of 25 panels, a system of 36 panels needs to be in place, Appendix F. A larger construction on top of the container or a small field next to the facility is necessary to place these extra 11 panels. I advise selling the bottles of drinking water uncooled since this eliminates the need for a solar panel field next to the facility.

In total 25 solar panels measuring 1,7 square meters each, are needed to generate enough power to keep the facility running. These are placed on top of the container, the urinal unit, and the cashier's desk.

9.1.3 Construction

To place the solar panels on top of the container steel constructions will be welded. The construction guarantees the solar panels lay at an angle of 17 degrees, the optimal angle in Ghana [105]. The tubing required for this is cut in the Netherlands. Parts of the construction will be welded before shipping, other parts will be assembled at the Techiman site. The main reason for this is that shipping will be easier. Solar panels are mounted to the construction in Ghana.

Figure 148: Solar panels construction container

Figure 148 shows the solar panel construction placed on top of the container. Part A is welded in the Netherlands. This triangle consists of tubes measuring 100 x 40 mm of 3 mm thick. In Techiman the four tubes of 40 x 40 mm are welded onto these supports, Part B. These tubes are solar panel rails. The solar panels are clamped onto these special rails. This construction in screwed into the roof of the container. The container does not have to be modified to do this.

The same accounts for the construction on top of the urinal unit. The big supports, Parts A, are constructed in the Netherlands. The four rails are welded onto these in Ghana. The urinals need to be leveled with the container since these rails are welded onto the construction, in Figure 149, on top of the container as well. This creates a roof between the urinals and the container. Part A is welded onto the urinal wall in Techiman, after shipment.

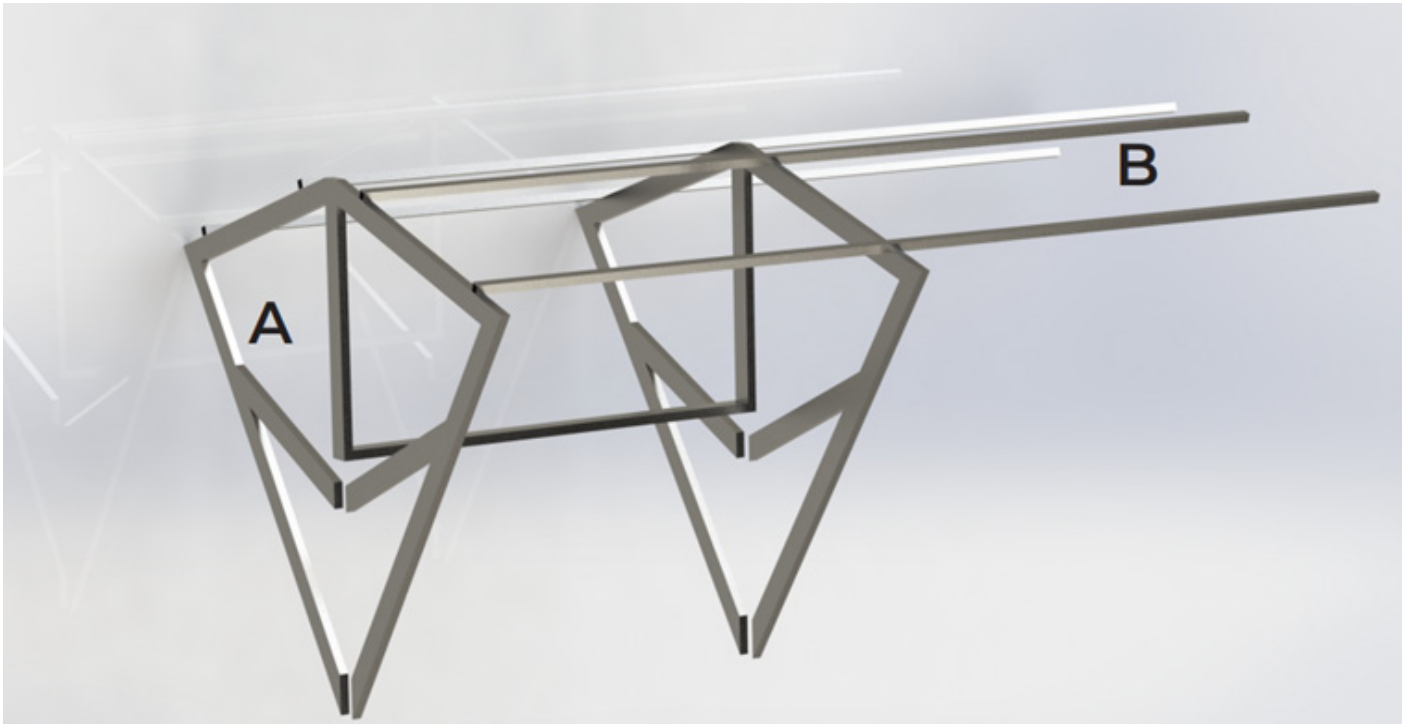


Figure 149: Solar panels construction urinal unit

9.1.4 Recommendations

A detailed calculation needs to be done to find the exact number of solar panels required to run the system. I discussed my calculations with Greenlink Solar. My calculations do not involve losses by batteries and conversion. In consultation with the client, it was decided I won't go into detail about energy storage and conversion because of time restrictions. More detailed calculations can show the need for more solar panels. In the current design, it is not possible to place more panels on the roof of the facility. The company has to decide whether they want to place a solar field next to the facility or find a different solution. There is no more room on the roofs of the facility, but constructions can be made to place solar panels on top of the storage tanks for example.

Another option is to add an aggregate as a backup. When the battery pack runs out of energy, the aggregate can make sure there is enough power to keep the facility running. I do not advise this, since it does not fit the image of the facility. As the subtitle of this report suggests, the facility is aiming at circularity, powering the facility by burning fossil fuels does not fit in with this.

In collaboration with Greenlink, the battery pack and the power transformers have to be designed. Solar panels generate 24 V power, whereas most components require 230 V. The container builders from Kan-Bud can provide the electric circuit inside the container. They offered to place the lights, fans, coin-operated timers, and solenoid valves already. A detailed energy drawing of the whole system has to be made.

As shown in Appendix A – Costs, the costs of the total solar energy system are estimated at 61.800 euros. This estimate has been made by Semilla and Greenlink Solar. In the future when the total system is designed, this price should be recalculated as well.

9.2 Shipping

As argued before, the sanitation unit is transported using a 40 ft. flat container. All of the costs of shipping the sanitation unit are specified in Appendix A - Costs. This includes shipping from Doetinchem to Antwerp, douane and terminal handling costs, shipping from Antwerp to Tema, and making a Bill of Lading.

Besides shipping the sanitation container, other parts like the urinal unit, fences, and cashier's desk also have to be shipped. These part and their measurements can be found in Appendix H. Together with mister Wouters from Boschmans and Steinacher Shipping, it was decided that shipping is done best in a 40 ft. container. These are more common than 20 ft. containers and cost less to transport while twice as much space is available. The total costs of the transport of the 40 feet container are significantly lower than the shipping costs of the flat container carrying the sanitation unit, Appendix A - Costs.

The total costs of shipment of the 40 ft. container are €2.875,- whereas shipment of the 40 ft. flat container costs €6.120,-.

The inside measurements of a 40 ft. container are 11.621 x 2.286 x 2.539 mm. In this space, all components in Appendix H can be transported.

The storage tanks are bought locally, these are too big to fit inside the container. The websites where these can be found are based in Ghana, Appendix A - Costs. The same accounts for all reoccurring items such as the toilet paper or the urinal blocks.

The urinal unit is split into three parts: The urinal wall, and the two parts of the solar panel constructions (A and B), Figure 149 and 150. At the facility site in Techiman, Part A of the construction is welded onto the urinal wall. After that the rails supporting the solar panels are welded onto the structure. The complete unit will be dug into the ground, and leveled with the container. Concrete will fill the holes around the legs of the urinal wall, securing it in place. Lastly the rails of the solar panels is connected to the solar panel construction on top of the container.

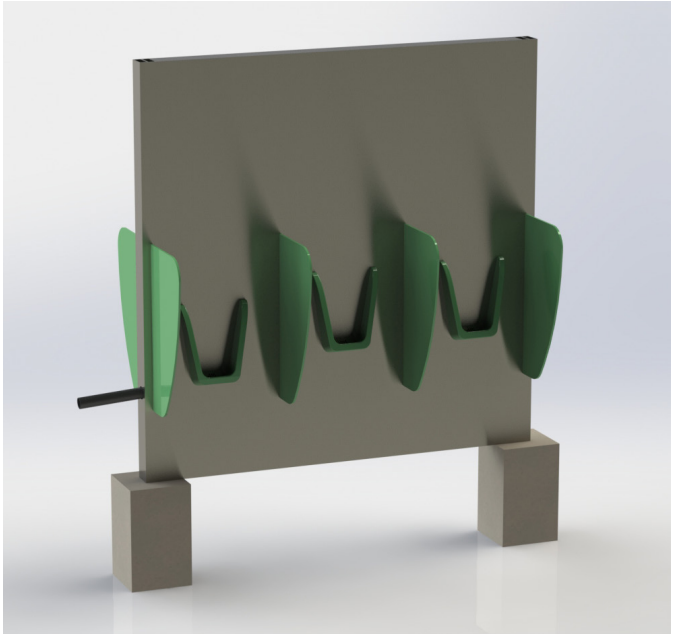


Figure 150: Urinal wall

PART X
Conclusion

10.1 Conclusion

At the start of this report, the importance of clean sanitation is discussed. Transmission of different diseases such as cholera, diarrhea, and typhoid are linked to unhygienic sanitation facilities [1]. In Ghana specifically, it is estimated that 25% of children dying under the age of five die because of the consequences of diarrhea [5]. Public toilets currently used in Techiman are often dirty and smelly. However, only providing clean toilet facilities is not enough. Washing hands before touching food and after visiting the toilet is crucial in sickness prevention. This can significantly reduce the incidence of childhood infectious diseases [59,84]. Besides clean sanitation and handwashing, the third goal of this project is treating wastewater correctly to prevent it from contaminating ground- or surface water. This chapter discusses the impact the Semilla Sanitainer facility can make concerning these three major goals.

Clean sanitation

It is estimated that the toilets in the facility are visited 894.250 times every year. The urinals will be visited 876.000 times and the showers 73.000 times.

Toilets

A total of 2.450 people can make use of a clean toilet every day. On the most crowded days, 15.000 people visit the market in Techiman. This means that during their visit, 16.3% of the visitors can visit a clean toilet.

Urinals

2400 men can use a urinal during their visit to the market every day. Assuming half of the visitors are male this means 32% of men visiting the market can visit the urinals during their visit.

Showers

A total of 1.400 people can shower once per week because of the implementation of the Semilla Sanitainer.

Handwashing facilities

Measuring the benefits of the handwashing facilities is hard since it is not sure everyone washes their hands. Preventing diseases is done best when people wash their hands consistently, meaning they wash every time after defecation, after cleaning babies' bottoms, before food preparation, before eating, and before feeding children [101].
Nevertheless, this facility provides every visitor with the possibility to wash their hand using clean and hygienic handwashing facilities. Public toilets in Techiman now totally lack handwashing facilities. In Ghana, only 38% of public sanitation facilities feature handwashing facilities [5]. Semilla sanitation facility is responsible for a possible increase of 4.850 people washing their hands every day.

Waste treatment

Based on the estimations of usage of the facility, the amount of waste treated is calculated. The most prominent benefit of the system is that these waste streams do not end up getting dumped in rivers or somewhere else in the environment.

Yellow water

The urinals are visited 2400 times, leading to 600 L of urine per day, Appendix A - Income. Within the facility, 219.000 L of urine is processed yearly. After treatment, this is processed into 197.100 L of clean water and 21.900 liters of fertilizer.

Black water

A total of 268.275 kg of feces is being collected every year. Together with the flushed water, this adds up to a total of 4.739.525 L of sludge. From this 72.996 m^3 biogas can be produced.

The Semilla sanitation facility prevents 268.275 kg of feces and 219.000 L of urine from being dumped in nature. These waste streams will not penetrate and contaminate water that is being used for drinking, washing, and playing in.

Company

To make a large impact in Ghana, the facility should have a viable business case. When the Angel investor, DHI, and Semilla grant are applied, the break-even point is in the second year, Appendix A - Calculation. To make money earlier in the lifetime of the facility, the investment costs should be lowered, or partially subsidized. As explained in section 3.2 it is best for Semilla to work with Klimaatfonds, to cover a part of the investment costs. Every year Good Sanitation Ghana, the exploiter of the facility, is making 93.000 euros. Semilla is charging a total of 30% of the CAPEX costs, making around 79.000 euros for each facility sold. It is interesting to place more facilities across Ghana, increasing the total impact made. Moreover, the costs of production and recycling of the waste streams will drop with more facilities. It would be ideal to have five sanitation facilities and one central recycling facility. This way costs for the vacuumtruck, for example, can be divided by five facilities instead of one, lowering investment costs per facility.

Current situation

New situation

10.2 Recommendations

This project ends with a final concept. For the Semilla Sanitainer to become a success in Ghana, and in a later stage across sub-Saharan Africa, further steps have to be taken.

Further testing

I consider further testing the most important in this stage. I could not visit Techiman to see the context. I had to base myself on research and the help from a local employee. It is important to make a concept like this fit the context it is placed in. A first version has to be made and tested in Techiman to check assumptions made during the project.

The most important assumptions are made to estimate the earnings of the facility. How many people do use the facility per day? How much time do they spend at the facility? Is it possible to serve the number of people per day estimated?

It is important everyone feels safe using the facility. When women or other groups of people are underrepresented in the facility, the causes for this should be found. Would it help if men can't see them standing in line for the facility? Or are there other causes?

Finally, interviews with the local community can give insights into what they find important in public sanitation. Or what they would change in the facility. Based on these new insights gathered changes in the design can be made.

Different context

Placing more facilities in Ghana or other countries changes the context, having consequences on the design of the facility. The Semilla Sanitainer is designed to fit the market in Techiman, placing it in another context might not fit.

Semilla is also active in Kenya. It is planned to place similar sanitation facilities in Kenya as well. Instead of a stationary sanitation facility at one marketplace, the facility has to travel to seven different markets every week. According to Semilla, having a stationary facility in these seven towns is not profitable, there are too few potential users on non-market days.

Having a traveling facility requires a different design. Preferably all facilities are located inside the container. Transport should be as easy as possible. The water system should be connected to local storage tanks and water supply quickly.

This design uses waterless urinals and offers toilet paper to clean after defecation. In Muslim societies, this can cause problems. Cultural ideas require them to use water for body and facility cleansing practices. Water is associated with hygiene [104]. Instead, anal cleansing and flushed urinals should be used.

As argued before, the market is not accessible for people in wheelchairs. In a different context where people in wheelchairs visit the facility, a specially designed toilet, and shower might be necessary.

The design might need to change when situated in a context with other users. At a school, for example, the height of the facilities needs to be lowered. Besides, an awareness creation focus can be applied, focussing on teaching children young to wash their hands.

Concluding, the new context should be researched and the design should be adjusted to it, before placement.

Realization

Before the container can go into production, Semilla has to make agreements with Kan-Bud, the container builder. The collaboration has to be taken to the next step and meetings have to be planned to detail out the final design. An inquiry has to be made including the installation of all Geberit products.

Far future

When larger quantities of containers will be shipped, it becomes beneficial to get them CSC certified. The container will be checked and its carrying capacity is determined. With a CSC plate, the Sanitainer can be shipped as a container, it does not have to be shipped on top of a 40 ft. flat container anymore. This saves a lot of costs, Appendix A - Costs. Instead of more than 6.000 euros, shipping will cost less than 3.000 euros.

A complete recycling facility is dedicated to the first facility. In the future, however, five facilities are opened for one recycling facility, lowering the total costs.

Sources

(1) World Health Organization (2017). Sanitation Key facts, retrieved from: https://www.who.int/news-room/fact-sheets/detail/sanitation#:~:text=Poor%20sanitation%20is%20linked%20to,assault%2C%20and%20lost%20educational%20opportunities.

(2) Smith-Asante, E. (2015). Ghana world's 7th dirtiest country, retrieved from: https://www.graphic.com.gh/features/features/ghana-world-s-7th-dirtiest-country.html

(3) Dowden, R. (2020). 8 facts about sanitation in Ghana, retrieved from: https://borgenproject.org/facts-about-sanitation-in-ghana/

(4) Thrift, C. (2007) Sanitation Policy in Ghana: Key Factors and the Potential for Ecological Sanitation Solutions, retrieved from: https://www.ircwash.org/sites/default/files/Thrift-2007-Sanitation.pdf

(5) Peprah, D. Baker, K.K. Moe, C. Robb, K. Wellington, N. Yakuba, H. Null, C. (2015). Public toilets and their customers in low-income Accra, Ghana, retrieved from: Public toilets and their customers in low-income Accra.pdf

(6) Africa geportal (2019). Average household size in Ghana, retrieved from: https://www.africageoportal.com/datasets/204b7e62782b4a4795f7d56823dcfb68

(7) Stip, C.M. Thomas, S. Gambrill, M. (2019). Container-based sanitation: one way to reach the last mile for sanitation services, retrieved from: https://blogs.worldbank.org/water/container-based-sanitation-one-way-reach-last-mile-sanitation-services

(8) Geeta, J. Sampath Kumar, S. (2014). Open Defecation: Awareness & Practices of Rural Districs of Tamil Nadu, India, retrieved from: https://www.researchgate.net/profile/Sampath-Kumar-Srinivasan/publication/269305923_Open_Defecation_Awareness_Practices_of_Rural_Districts_of_Tamil_Nadu_India/links/5486b3000cf2ef34478c063f/Open-Defecation-Awareness-Practices-of-Rural-Districts-of-Tamil-Nadu-India.pdf

(9) Amanda. (2014) Hot vs. Cold Showers, retrieved from: https://amandacoxdesign.wordpress.com/2014/10/14/hot-vs-cold-showers/

(10) Agape Volunteers. (2011). Volunteer in Ghana, retrieved from: https://cdn.locomotive.works/sites/5ab130be74c4833febe6b45a/content_entry5aba37ba74c4837dc15d1b7f/5aba38c9a2f4220ad945dddc/files/Agape_Volunteers_Ghana_-_Information_Booklet.pdf?1582199242

(11) A. Jansen, Jansen, G. Melgarejo, M. (2013). Reinvent the toilet, user tests in Behrampura slum – India, retrieved from: RTTC TUDelft IDE - Field Research Report (2013) FINAL EDIT.pdf

(12) Diehl, J.C. Jansen, A. (2013). Women empowerment, Improving Women's Well-Being Through Sanitation Solutions. Retrieved from: 2_Women_Empowerment_-_Flyer.pdf

(13) Loth, M. (2021). Design for Sanitation: How does design influence train toilet hygiene? Retrieved from: https://doi.org/10.4233/uuid:1d5f7ea6-8464-48dd-b593-f2cba9c1f493

(14) Van Loon, E. Good Saniation Kenya (personal communication, February 22, 2021)

(15) Molenbroek, J.F.M. De Bruin, R. (2011), Overview of the FRR Project; Designing the Toilet of the Future, retrieved from: Friendly rest room developing toilets of the future for disabled and elderly people.pdf

(16) Dekker, D. Buzink, S. Molenbroek, J.F.M. (2011), User Preferences Regarding Body Support and Personal Hygiene in the Toilet Environment, retrieved from: Friendly rest room developing toilets of the future for disabled and elderly people.pdf

(17) Jansen, A. Jansen, G. Melgarejo, M. (2013), User tests in Behrampura slum – India, retrieved from: RTTC TUDelft IDE - Field Research Report (2013) FINAL EDIT.pdf

(18) Curtis, V. Cairncross, S. (2003), Effect of washing hands with soap on diarrhoea risk in the community: a systematic review, retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S1473309903006066

(19) Egan, M. Tagliaferri, G. Chowdhury, V.R. Mottershaw, A. Xu, Y. (2020). Testing the efficacy of coronavirus messaging, experiment: How to wash your hands, retrieved from: https://www.bi.team/wp-content/uploads/2020/03/BIT-Experiment-results-How-to-wash-your-hands-international-comparison.pdf

(20) Scheer, P. Semilla Sanitation Hubs, personal conversation

(21) Dimmer, C. Martin, B. Reeves, N. Sullivan, F. (1996) Squatting for the Prevention of Haemorrhoids? retrieved from: https://documents.uow.edu.au/~bmartin/pubs/96tldp.html

(22) Kos, A. Langeweg, S. (2017) Everything You Always Wanted to Know About Toilets, But Were Afraid to Ask Schrijen-Lippertz

(23) Overheid, wettenbank (2014) Internationale overeenkomst voor veilige containers (CSC), Geneve, 02-12-1972. Retrieved from: https://wetten.overheid.nl/BWBV0003233/2014-07-01

(24) CTL-ICS bv (2020) 20FT High Cube Geisoleerde Container, retrieved from: https://www.containersales.nl/project-details/20ft-high-cube-geisoleerde-container/#1563964792512-cb9d4f67-7a779afe-2483

(25) Huang, C. Ma, W. Stack, S. (2012) The Hygienic Efficacy of Different Hand-Drying Methods: A Review of the Evidence. Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3538484/

(26) Handdoekentoiletpapier.nl (2021) Euro Products, Z-vouwhanddoekjes, 2-laags, recycled tissue, 3800 stuks. Retrieved from: https://www.handdoekentoiletpapier.nl/z-vouwhanddoekjes-2-laags-recycled-tissue

(27) Paterson, M. Dodge, M. (2012). Touching Space, Placing Touch. Retrieved from: https://books.google.nl/books?hl=nl&lr=&id=WUGgCwAAQBAJ&oi=fnd&pg=PP1&dg=touching+space,+pla

(28) Uniqcare facility services. (2020). Productinformatie Handdoekautomaat Retractable wit Uniq. Retrieved from: https://www.uniqcare.nl/upload/pdf/7846Uniqcare_handdoekautomaat_retractable_10.2.pdf

(29) Horeca grootkeukenshop. (2021). Mediclinics Zeepdispenser automatisch RVS wit 1000 ml 14040. Retrieved from: https://www.horecagrootkeukenshop.nl/mediclinics-zeepdispenser-automatisch-rvs-wit-1000-ml-14040/?gclid=Cj0KCQjw9YWDBhDyARIsADt6sGbQ7wUwr3bOYwLFIsrvk9n7EZPuxdXGGkNa26a7o0nUnFqyPFHUE-gaAk7aEALw_wcB

(30) Opel, A. (2012). Absence of faecal sludge management shatters the gains of impoved sanitation coverage in Bangladesh. Retrieved from: http://www.ecosan.at/ssp/issue-12-faecal-sludge-management/SSP-13_Oct2012_4-10.pdf

(31) Ashby, M.F. (2015). Materials and Sustainable development. Butterworth-Heinemann

(32) Loth, M. van Eijk, D. Molenbroek, J. (2014). Mock-up test of two train toilet modules. Retrieved from: Mock-up test of two train toilet modules.pdf

(33) Fixr. (2021). Comfort Height vs Standard Toilet. Retrieved from: https://www.fixr.com/comparisons/comfort-height-vs-standard-toilet#cQ

(34) Tegels & Sanitair depot. (2021). Inbouwreservoir Geberit UP100 Basic Inbouw Frontbediening. Retrieved from: https://www.tegeldepot.nl/inbouwreservoir-geberit-up100-basic-inbouw-frontbediening-in-hoogte-diepte-verstelbaar

(35) Bouwbesluit Artikel 4.19.1 (2012). Afmetingen badruimte, retrieved from: https://www.bouwbesluitonline.nl/docs/wet/bb2012/hfd4/afd4-3

(36) Badkamerwinkel. (2021). Afmetingen inloopdouche, retrieved from: https://www.badkamerwinkel.nl/blog/hoe-groot-moet-een-inloopdouche-zijn/#:~:text=Een%20standaard%20douchecabine%20is%2090,breed%20en%20120%20centimeter%20lang.

(37) Bouwbesluit Artikel 4.11.1 (2012). Afmetingen toiletruimte, retrieved from: https://www.bouwbesluitonline.nl/docs/wet/bb2012/hfd4/afd4-2#:~:text=Artikel%20 4.16.&text=Een%20toiletruimte%20als%20bedoeld%20in%20artikel%204.14%20heeft%20 een%20vloeroppervlakte,van%20ten%20minste%202%20m

(38) Mavin. (2021). Vermijdt vernauwing. Retrieved from: https://www.wavin.com/nl-nl/ kenniscentrum/nieuws/vraag-t-wavin-toilet-aansluiten-op-standleiding#:~:text=Bij%20 een%20toilet%20waarbij%20het,mag%20geen%20vernauwing%20aangebracht%20worden

(39) Davidson, P.J. Courtney, R.G. (1976) Revised scales for sanitary accommodation in offices, Build. Environ. 11 51-56, Retrieved from: Revised scales for sanitary accommodation in offices - ScienceDirect

(40) McCall, R.J. Gleye, P.H. Singer, L. (1971) The Men's Room

(41) Gwynne, S.M.V. Hunt, A.L.E. Thomas, J.R. Thompson, A.J.L. Seguin, L. (2019) The toilet paper: Bathroom dwell time observations at an airport. Retrieved from: https://www.sciencedirect.com/science/article/pii/S2352710218301098?casa_ token=M90HK7h2l8UAAAAA:Mr8Sm5lLqp2iGWG_p4DtqbEkKsGgrEaHTq5iPbMR5tItg_ yWh_n5gLfOEAQnqW5njcznKcf23A

(42) Geberit (2021) Geberit leidingsystemen. Retrieved from: https://www.geberit.nl/ producten/leidingsystemen-voor-afvoer/geberit-pe/

(43) Sels, J. (2019) Zo pak je de aanleg van badkamer en toilet aan in een renovatieproject. Retrieved from: https://www.ikgabouwen.be/zo-pak-je-de-aanleg-van-badkamer-en-toilet-aan-in-een-renovatieproject/

(44) Gawai, P.P. Taware, S.A. Chatterjee, A.S. Thakur, H.P. (2016) A cross sectional descriptive study of hand washing knowledge and practices among primary school children in Mumbai, Maharashtra, India. Retrieved from: https://www.researchgate.net/profile/ Harshad-Thakur/publication/310689180_A_cross_sectional_descriptive_study_of_ hand_washing_knowledge_and_practices_among_primary_school_children_in_Mumbai_ Maharashtra_India/links/58355d4c08ae102f073b74d4/A-cross-sectional-descriptive-study-of-hand-washing-knowledge-and-practices-among-primary-school-children-in-Mumbai-Maharashtra-India.pdf

(45) Seimetz, S. Kumar, S. Mosler, H.J. (2016) Effects of an awareness raising campaign on intention and behavioural determinants for handwashing. Retrieved from: https://academic. oup.com/her/article/31/2/109/2363188?login=true

(46) Centers for Disease Control and Prevention (2020) Show me the science – How to wash your hands. Retrieved from: https://www.cdc.gov/handwashing/show-me-the-science-handwashing.html

(47) Hygienepapier. (2021) Ingo-man I1217021 Zeepdispenser Alu 0,5 L. Retrieved from: https://www.hygienepapier.nl/zeepdispenser/ingo-man-zeepdispenser-alu-0-5l-k-plus-i1417021/

(48) Hsdonline. (2021) Brushed Stailess Steel Multifold Paper Towel Dispenser. Retrieved from: https://www.hygienesuppliesdirect.com/products/prod251711-pro-range-brushed-stainless-steel

(49) DiscountOffice. (2012) Handdoekvulling Budget Z-vouw 1 laags. Retrieved from: https://discountoffice.nl/p/handdoekvulling-budget-z-vouw-1l-voor-h3-23x22cm-5000st/

(50) Sanitino. (2021) Jet Dryer Handdroger. Retrieved from: https://www.sanitino.nl/jet-dryer-handdrogers-handdroger-jet-dryer-compact-silver-8596220010308?utm_source=GooglePlatformy&utm_medium=Search&utm_campaign=GoogleMerchant#productinformatie

(51) Xxlhoreaca. (2021) Dyson airblade handdroger. Retrieved from: https://www.xxlhoreca.com/nl/dyson-airblade-handdroger-hu02-grijs.html?utm_source=googleshopping&utm_medium=cpc&utm_campaign=Hygiene%2FHanddrogers&utm_term=Dyson%20Airblade%20Handdroger%20V%20-%20HU02%20Nieuw%20-%2035%25%20Stiller%20-%20Grijs%2FNikkel&utm_content=Dyson&gclid=CjwKCAjwmv-DBhAMEiwA7xYrd3mmlYMA3IF3Wlj8RO5tmKdfG2yZPOlNkXc82bYlGcnxzVtTUnKq0xoCmx4QAvD_BwE

(52) Attua-Afari, A. (2019) The development of a solar photovoltaic market in Ghana. Retrieved from: https://www.lexafrica.com/2019/08/the-development-of-a-solar-photovoltaic-market-in-ghana/

(53) Sutter Health. (2013) Paper Towel & Soap Dispensers at Toilet Rooms. Retrieved from: https://www.sutterhealth.org/pdf/physicial-access-compliance/H2-108-paper-towel-and-soap-dispensers-at-toilet-rooms.pdf

(54) PSD America. Compliant ADA Dispenser heights and Locations. Retrieved from: https://www.tbr.edu/sites/tbr.edu/files/media/2015/04/ADA%20Dispenser%20pamphlet.pdf

(55) DINED. 1D Database West Africa Shoulder breadth. Retrieved from: https://dined.io.tudelft.nl/en/database/tool

(56) Molenbroek, J.F.M. Bruin de, R. (2007) Hand support to assist toilet use among the elderly. Retrieved from: Hand_supports_to_assist_toilet_use_among_the_elder.pdf

(57) Dennisdeal. (2021) Waste bin. Retrieved from: https://www.dennisdeal.com/products/2l-6l-10l-waste-bins-creative-simple-nordic-desktop-trash-can-with-without-cover-for-office-home-living-room-bathroom_1616558?variant=31946461610074?utm_source=google&utm_medium=cpc&utm_campaign=gss

(58) Wildkamp. (2021) Ebara Hydrofoorpomp. Retrieved from: https://www.wildkamp.nl/product/ebara-hydrofoor-type-gp-aga-a-2-00-m-60h-gws-1-5kw-4-3-5-4-bar/15353892

(59) Ladegaard, M.B. (1999) Hand hygiene and sickness among small children attending day care centers. Retrieved from: https://europepmc.org/article/med/10487104

(60) Viveen, P. (2021) Zonnepanelen prijs, wat kosten zonnepanelen per kWh? Retrieved from: https://www.verbouwkosten.com/zonnepanelen/prijs/#:~:text=com%2014%3A26-,Per%20m%C2%B2,totaal%201%2C63%20m%C2%B2%20groot.

(61) Uittenbogert. (2021) RVS geborstelde plaat 3000 x 1500 Retrieved from: https://www.uittenbogert.nl/producten/rvs/platen/-696-rvs-geborstelde-plaat-/

(62) (2020) Minimale beenruimte in toilet. Retrieved from:https://eatsleepdress.com/afmeting-toilet/

(63) Sanitairwinkel. (2021) Welke afmeting moet je toilet hebben? Retrieved from: https://www.sanitairwinkel.nl/page/3833/advies/tips/afmetingen-toilet/

(64) Installatievakwinkel. (2021) Geberit HyTouch inbouw handdrukker met pneumatische spoelactivering Retrieved from: https://www.installatievakwinkel.nl/geberit-hytouch-inbouw-handdrukker-met-pneumatische-spoelactivering-chroom-115-943-21-1

(65) Saniweb. (2021) Geberit Publica Hurk Closet Retrieved from: https://www.saniweb.nl/geberit-publica-hurk-closet-45x60x18-cm-wit-208580000.html

(66) Badkamerwinkel.(2021) Rada douchekop vandaalbestendig inbouw Retrieved from: https://www.badkamerwinkel.nl/rada-douchekop-vandaalbestendig-inbouw-6-l-min-chroom-21715016-vr106?gclid=CjwKCAjwtpGGBhBJEiwAyRZX2s5N3wJsfAyhhyv_otsE2SnlB_5BZBi9MQt4G5_g2La4gjrTFF7ymxoCmQIQAvD_BwE

(67) Greed, C. (2003) Inclusive Urban Design. Public Toilets. Oxford: Architectural Press

(68) Rawls, S. K. 1988. Restroom Usage in Selected Public Buildings and Facilities: A Comparison of Females and Males. Retrieved from: https://vtechworks.lib.vt.edu/bitstream/handle/10919/53598/ LD5655.V856_1988.R384.pdf?sequence=1.

(69) HM Govnerment. (2015) The Building Regulations 2010, Ventilation. Retrieved from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/468871/ADF_LOCKED.pdf

(70) Saana, S.B.B.M. Fosu, S.A. Sebiawu, G.E. Jackson, N. Karikari, T. (2016) Assessment of the quality of groundwater for drinking purposes in the Upper West and Northern regions of Ghana. Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5120165/

(71) Adiaffi, B. Marlin, C. Oga, Y.M. Massault, M. Noret, A. Biemi, J. (2009) Paleoclimatic and deforestation effect on the coastal fresh groundwater resources of SE Ivory Coas from isotopic and chemical evidence. Retrieved from: https://www.sciencedirect.com/science/article/abs/pii/S0022169409001176

(72) Zoulgami, S. Gnazou, M.D.T. Kodom, T. Djaneye-Boundjou, G. Bawa, L.M. (2015) Physico-chemical study of groundwater in Northeast of Kara region (Togo). Retrieved from: https://www.ajol.info/index.php/ijbcs/article/view/121836

(73) Radacontrols (2021) Rada vaste douchekop VR106. Retrieved from: https://www.radacontrols.com/media/61288/rada-vr106-datasheet-102020.pdf

(74) WHO (2017) Diarrhoeal disease. Retrieved from: https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease

(75) Ministerie van Binnenlandse Zaken en Koninkrijkrelaties (2012) Bouwbesluit 3.29 Luchtverversing verblijfsgebied, verblijfsruimte, toiletruimte en badruimte. Retrieved from: https://rijksoverheid.bouwbesluit.com/Inhoud/docs/wet/bb2012_nvt/artikelsgewijs/hfd3/afd3-6

(76) Chalfin, B. (2014) Public things, excremental politics and the infrastructure of bare life in Ghana's city of Tema. Retrieved from: https://anthrosource.onlinelibrary.wiley.com/doi/full/10.1111/amet.12062?casa_token=KlwKjBa9UwgAAAAA%3A9-fCZ4b8KXj4yK5KG5BGTMo2GCZFdvoWjlbB7qJr-ul7oNJvUerbFNVLjtbNREp9IXDisTn-BgnLrtU

(77) R. Shyam (2017) Personal hygiene Retrieved from: http://eprints.cmfri.org.in/12226/1/Training%20Manual%20on%20Theeranaipunya%20III%20Scaling%20up%20Fisher%20Youth%20Domains%20in%20Cognitive%20Development_2017.pdf#page=70

(78) Bol.com (2021) Sifon Daisy Retrieved from: https://www.bol.com/nl/nl/p/sifon-daisy/9300000002913136/?Referrer=ADVNLPPcef3cf002b3e199b005a636c64000040746&utm_source=40746&utm_medium=Affiliates&utm_campaign=CPS&utm_content=txl

(79) Beekhuis, G. (2021) Dit zijn de 3 grootste gasslurpers bij jou thuis. Retrieved from: https://www.hier.nu/themas/stroom-en-gas/dit-zijn-3-grootste-gasslurpers-bij-jou-thuis

(80) Accessfloorstore (2020) HPL Features & Advantages of HPL. Retrieved from: https://www.accessfloorstore.com/news/143--what-is-high-pressure-laminate-hpl-features--advantages-of-hpl-floor-tiles

(81) Munch, E. v. Dahm, P. (2009) Waterless urinals: a proposal to save water and recover urine nutrients in Africa. Retrieved from: https://sswm.info/sites/default/files/reference_attachments/MUENCH%202009%20Waterless%20urinals%20%20proposal%20to%20save%20water%20and%20recover%20nutrients%20in%20Africa.pdf

(82) Chipako, T.L. Randall, D.G. (2019) Urinals for water saving and nutrient recovery: a feasibility study. Retrieved from: file:///C:/Users/koosb/Downloads/186157-Article%20Text-473336-1-10-20190506.pdf

(83) Hashemi, S. Han, M. Kim, T. (2015) Identification of urine scale problems in urinals and the solution using rainwater. Retrieved from: https://iwaponline.com/washdev/article/5/2/322/30116/Identification-of-urine-scale-problems-in-urinals

(84) Aunger, R. Schmidt, W. Ranpura, A. Coombes, Y. Maina, P.M. Matiko, C.N. Curtis, V. (2010) Three kinds of psychological determinants for hand-washing behaviour in Kenya. Retrieved from: https://www.sciencedirect.com/science/article/pii/S027795360900728X

(85) Borchgrevink, C.P. Cha, J. Kim, S. (2013) Hand Washing Practices in a College Town Environment. Retrieved from: https://www.jstor.org/stable/26329601?seq=1#metadata_info_tab_contents

(86) Lankford, M.G. Zembower, T.R. Trick, W.E. Hacek, D.M. Noskin, G.A. Peterson, L.R. (2003) Influence of Role Models and Hospital Design on the Hand Hygiene of Health-Care Workers. Retrieved from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2901948/

(87) Cloutman-Green, E. Kalaycioglu, O. Wojani, H. Hartley, J.C. Guillas, S. Malone, D. Grant, V. Grey, C. Klein, N. (2014) The important role of sink location in handwashing compliance and microbial sink contamination. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0196655313014958?casa_token=aFzKw09jRaAAAAAA:pVmQe4WZUXlIXYlhdJZWnqlAhgXp1_QfnnBQrn8RETgiV7WOY7Dv_2GpAPvkkkhVyWsod13lDg

(88) Drankiewicz, D. Dundes, L. (2003) Handwashing among female college students. Retrieved from: https://www.sciencedirect.com/science/article/pii/S0196655302482065?casa_token=VVDYeS_IYCcAAAAA:bZSER4X4CwQIJCU9spPTDpht6_JFw-Lw6o5zbfpggbpZpgnplJgPIlZzXt0_Voma8OkJw69hag

(89) WHO (2019) Sanitation. Retrieved from: https://www.who.int/news-room/fact-sheets/detail/sanitation

(90) United Nations (2021) Goal 6: Ensure availability and sustainable management of water and sanitation for all. Retrieved from: https://sdgs.un.org/goals/goal6

(91) C. Schillings, R. Meyer, Trieb, F. (2004) Solar and Wind Energy Resource Assessment (SWERA) Retrieved from: https://openei.org/datasets/files/710/pub/ghana_10km_solar_country_report.pdf

(92) HRSolar (2021) HPC-2,5 collector, technische specificaties, Retrieved from: https://www.hrsolar.nl/wp-content/uploads/2018/03/Handleiding-HRsolar-V5.1-Specificaties-HPC-25.pdf

(93) Ministerie van Volksgezondheid, Welzijn en Sport. (2001) Legionella, Antwoorden op de 35 meest gestelde vragen. Retrieved from: file:///C:/Users/koosb/Downloads/legionella-25-vragen.pdf

(94) Rijksoverheid (2012) Legionella, uw zorg?! Retrieved from: https://www.rijksoverheid.nl/onderwerpen/legionella/vraag-en-antwoord/wat-moet-ik-als-eigenaar-van-een-instelling-doen-om-legionella-te-voorkomen

(95) Strooming (2021) Legionella voorkomen. Retrieved from: https://www.strooming.nl/legionella/voorkomen/

(96) Bouwhekken Nederland (2021) Levensduur bouwhekken. Retrieved from: https://www.bouwhekkennederland.nl/veelgestelde-vragen

(97) Acu-tech piping systems (2021) Plumbing materials: PVC and PE pipes. Retrieved from: https://www.acu-tech.com.au/2019-archive/plumbing-materials-pvc-and-pe-pipes/

(98) Chariar, V.M. Sakthivel, S.R. Waterless Urinals, a resource book. Retrieved from: https://web.iitd.ac.in/~chariarv/WLUResourceBookFinal.pdf \

(99) Bano Benelux (2021) Mindervalide toilet Retrieved from: https://banobenelux.com/mindervalide-toilet/

(100) von Munch, E. Winker, M. (2011) Technology review of urine diversion components. Retrieved from: https://www.susana.org/_resources/documents/default/2-875-giz2011-en-technology-review-urine-diversion.pdf

(101) Billig, P. Bendahmane, D. Swindale, A. (1999) Water and Sanitation Indicators Measurement Guide. Retrieved from: https://ec.europa.eu/echo/files/evaluation/watsan2005/annex_files/USAID/USAID1%20-%20Water%20and%20sanitation%20indicators%20measurement.pdf

(102) Velling, A. (2019) Stainless Steel Finishes Explained – DIN & ASTM. Retrieved from: https://fractory.com/stainless-steel-finishes-din-astm/

(103) Blom, B. Feenstra (personal communication, July 1, 2021)

(104) Hashemi, S. Han, M. Kim, T. (2015) Identification of urine scale problems in urinals and the solution using rainwater. Retrieved from: https://iwaponline.com/washdev/article/5/2/322/30116/Identification-of-urine-scale-problems-in-urinals

(105) Felix, A. Sarsah, U. A. Sarsah, E. A. (2013) Optimization of tilt angle for solar collectors in WA, Ghana. Retrieved from: https://www.imedpub.com/articles/optimization-of-tilt-angle-for-solar-collectors-in-wa-ghana.pdf

Appendix B: Costs watersupply

Sensor operated taps

	https://www.toolstation.nl/schutte-vital-sensor-wastafelkraan/p15021?channable=002a91696400313530323 1d9	**99 euro**
	https://www.sensorkranenwinkel.nl/webshop/sensorkranen/chroom/detail/138/bust-koud-water-sensorkraan.html	**129 euro**
	https://www.sanitairwinkel.nl/p/77161664/nemo-go-o-matic-infraroodkraan-inclusief-flexibels-en-fixatieset?gclid=Cj0KCQjw9_mDBhCGARIsAN3PaFPgmEhC2_0ghxF5UxikbyvmLXf-uIUUWjx7WD5764Fy6sWiKsNRYIkaAmwGEALw_wcB	**87 euro**
	https://www.bol.com/nl/p/excellent-wellness-design-badkamermeubel-sensor-kraan-wastafelkraan-type-f-808/9200000087198713/?Referrer=NLGOOFS&utm_source=google&utm_medium=free_shopping	**90 euro**
	https://www.gamma.nl/assortiment/grohe-wastafelkraan-bau-cosmopolitan-met-infrarood-sensor-chroom-13cm/p/B128636	**130 euro**

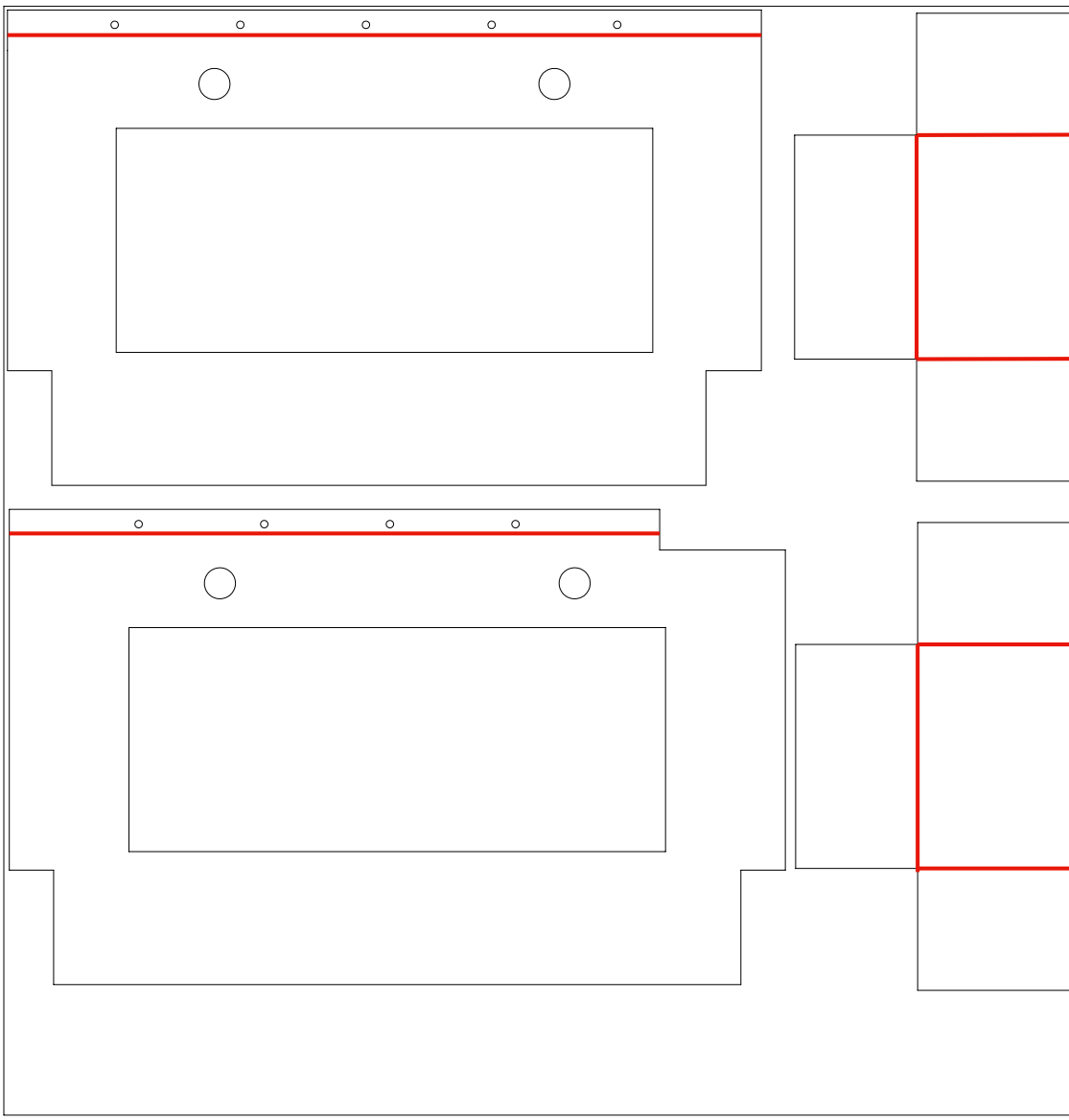
Push taps

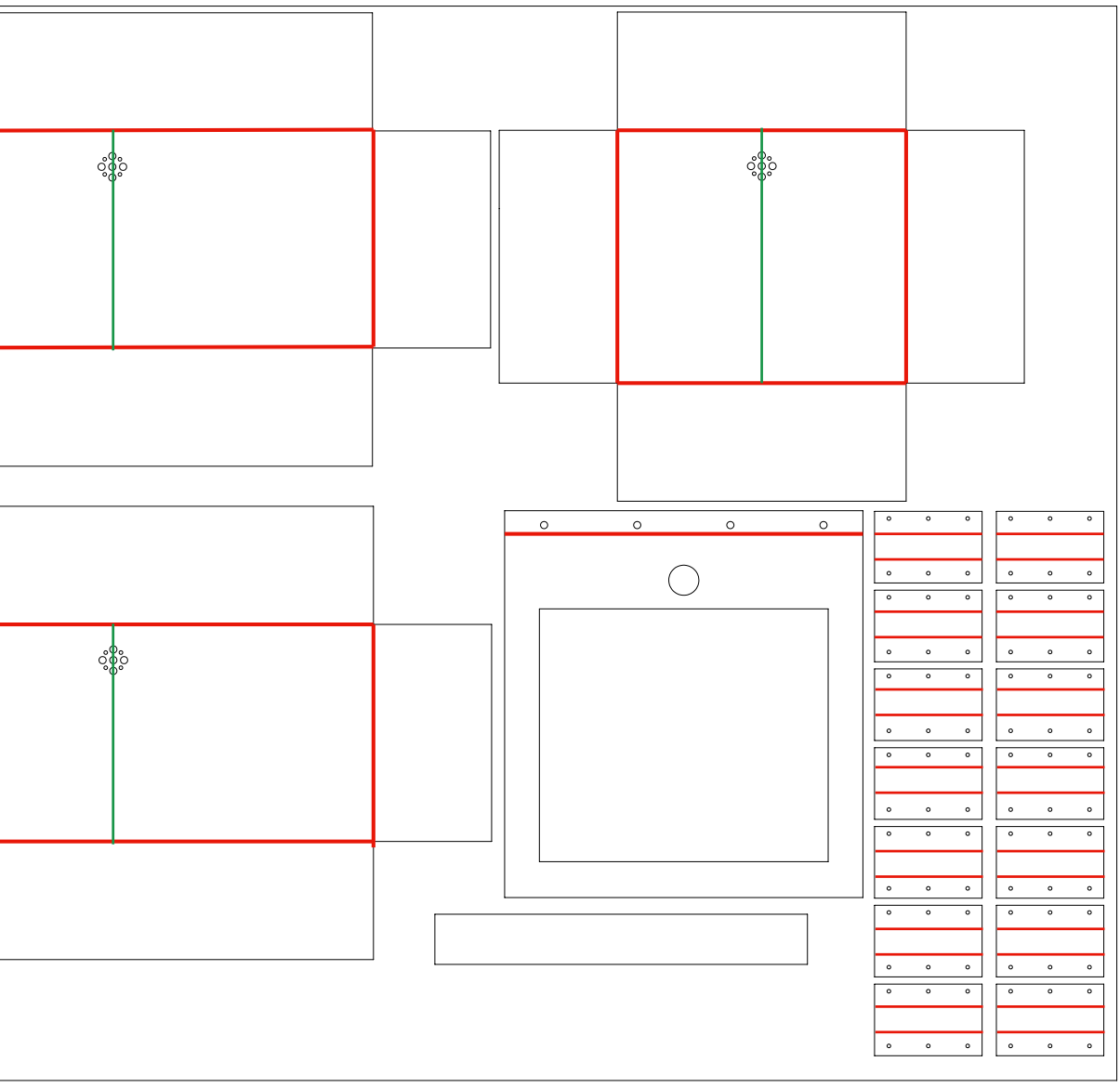
	https://www.gamma.nl/assortiment/handson-fonteinkraan-jerome-met-drukknop-chroom/p/B527014	**37 euro**
	https://www.x2o.nl/blaufoss-ritaro-zelfsluitende-kraan-chroom-32722?channable=01e1377765625f736b7500333237323236&gclid=Cj0KCQjw9_mDBhCGARIsAN3PaFMuSrEYyqwl0h47ZVBgR6I4qpFbPhFjC92g6HnGnCtB2OlXfaS6cCAaAhBuEALw_wcB	**55 euro**
	https://www.badkamerenco.nl/best-design-toiletkraan-delay-staand.html?gclid=Cj0KCQjw9_mDBhCGARIsAN3PaFOX1NqIfW9W9F36bSDMGd3MSFMIfMUTurc1DzSJsQpuP7f8dygkDroaAjUREALw_wcB	**45 euro**
	https://www.badkamerwinkel.nl/plieger-autostop-toiletkraan-zelfsluitend-1-2-autostop-chroom-72002-29-3501?gclid=Cj0KCQjw9_mDBhCGARIsAN3PaFOi70ydtUj9yCQfi7Xyj06HHjfmRjAij_ez5yjgbbcGbABsTaZvvRoaAtajEALw_wcB	**36 euro**
	https://www.x2o.nl/linie-zelfsluitende-koudwaterkraan-press-chroom-1743?channable=01e1377765625f736b75003137343389&gclid=CjwKCAjwmv-DBhAMEiwA7xYrdztqSBdm03vSJ5LbN8utYM1mzLuLc2Y4QInv0K7cKrru3oKw4Sg9-xoCu3MQAvD_BwE	**35 euro**

Regular taps

	https://www.badkamerwinkel.nl/venlo-nimbus-ii-project-eco-fonteinkraan-chroom-f3151aa	**30 euro**
	https://www.badkamerwinkel.nl/grohe-bauflow-fonteinkraan-chroom-20575000	**34 euro**
	https://www.bol.com/nl/p/schutte-athos-wastafelkraan-mengkraan-met-waste-chroom/9200000035850866/?Referrer=NLGOOFS&utm_source=google&utm_medium=free_shopping	**30 euro**
	https://www.praxis.nl/badkamer-keuken-wonen/kranen/wastafelkranen/baseline-wastafelmengkraan-hoog-chroom/10040946?utm_campaign=shopping&utm_content=&utm_source=google&utm_medium=organic&utm_term=	**30 euro**
	https://www.x2o.nl/sarah-wastafelkraan-39001?channable=01e1377765625f736b7500333930303193	**30 euro**
	https://www.gamma.nl/assortiment/ok-wastafelkraan-met-hendel-chroom/p/B509173	**19 euro**
	https://www.gamma.nl/assortiment/ok-wastafelkraan-met-hendel-en-waste-chroom/p/B509172	**26 euro**
	https://www.gamma.nl/assortiment/ok-wastafelkraan-2-knops-ketting-chroom/p/B509179	**26 euro**

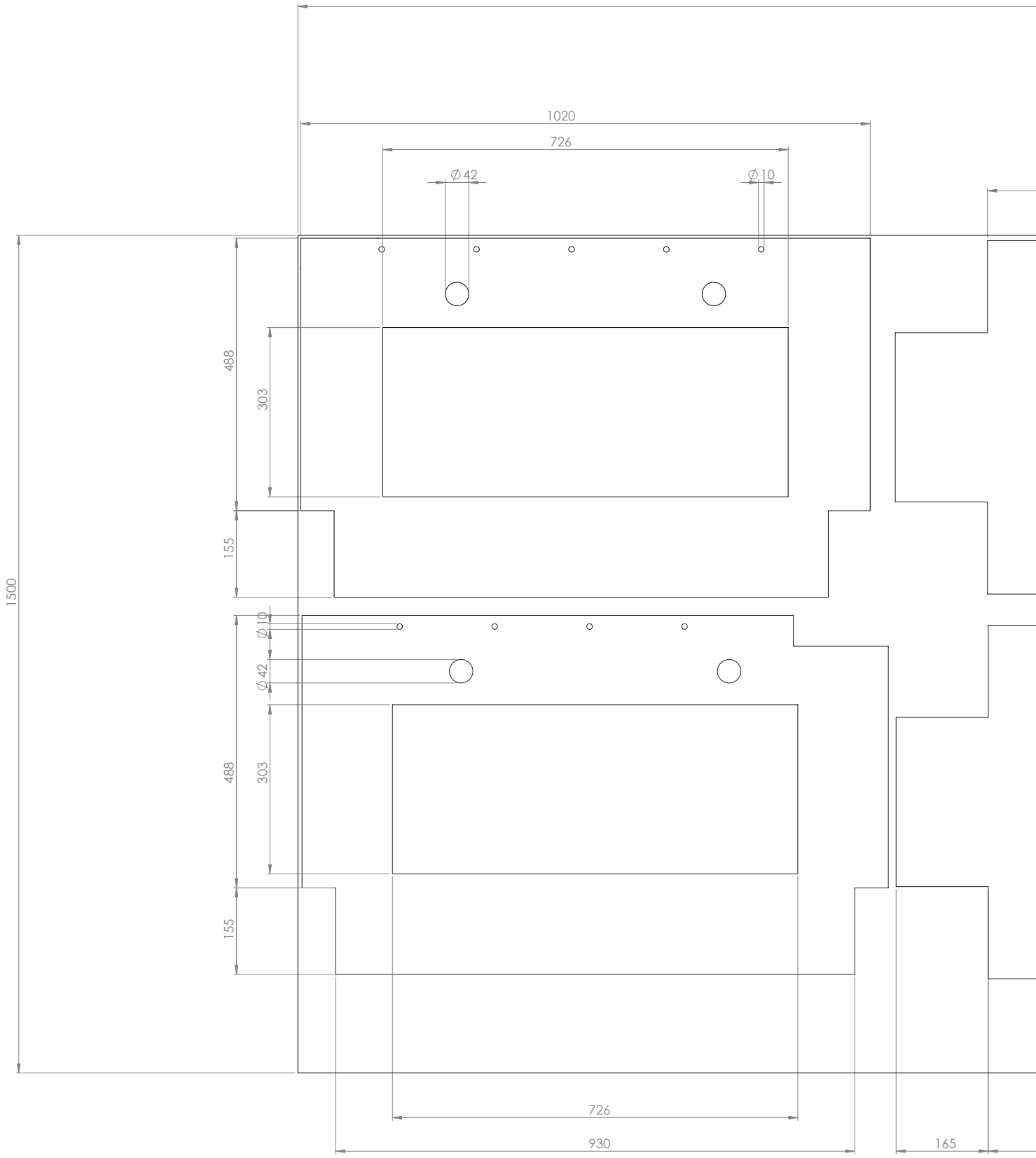
Appendix C: Bending drawing

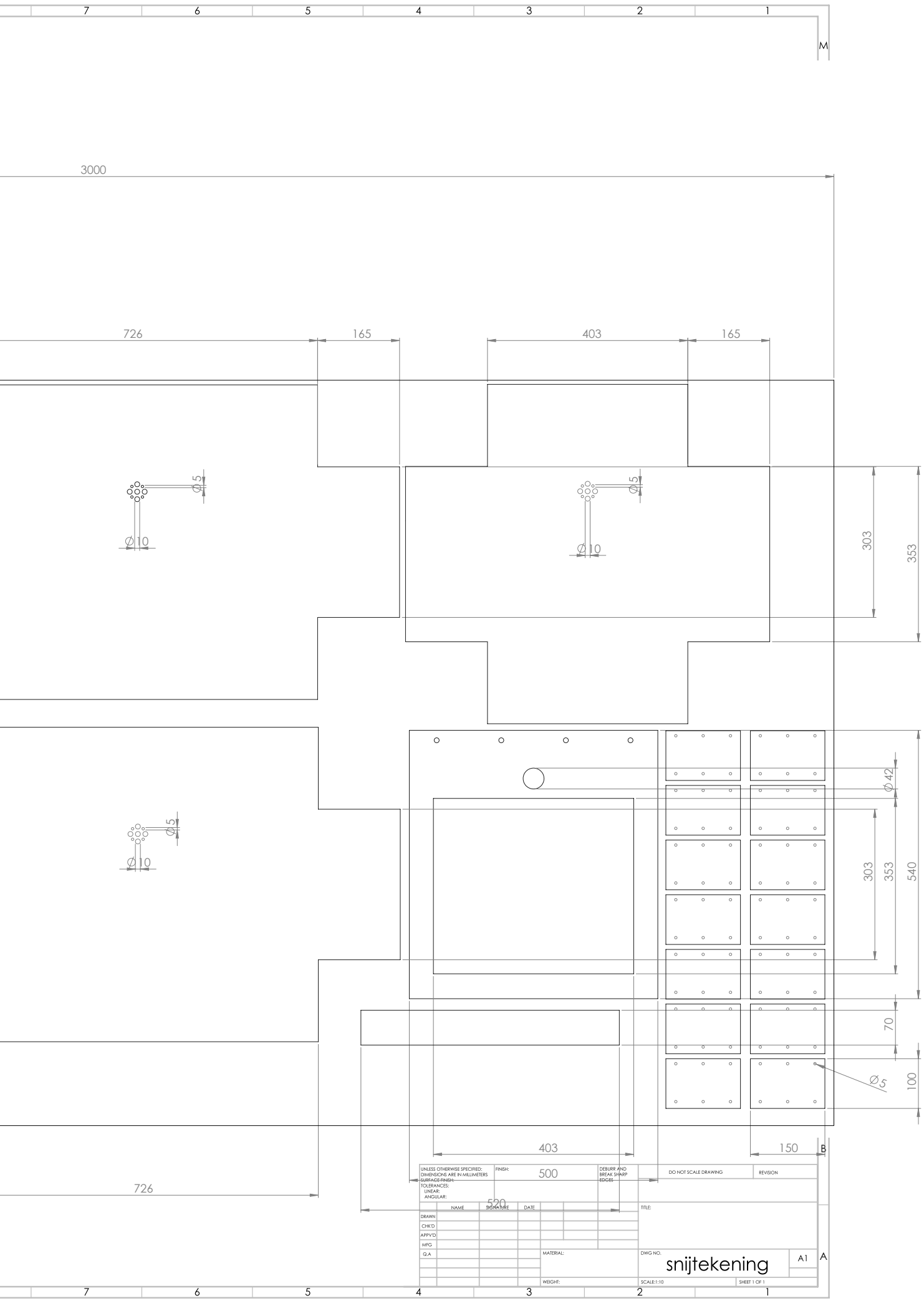




UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBURR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO. buigtekening	A1
				WEIGHT:		SCALE:1:10	SHEET 1 OF 1

Appendix C: Cutting drawing




7 6 5 4 3 2 1
M
3000
726
165
403
165
Ø5
Ø10
303
353
Ø42
540
70
100
150
B
A
500
520
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
CHK'D
APP'VD
MFG
Q.A
MATERIAL:
WEIGHT:
TITLE:
DWG NO.
snijtekening
A1
SCALE:1:10
SHEET 1 OF 1

Appendix D: Solar water heating principles

Solar heating panels

Solar heating panels look like solar panels but work differently. Instead of generating electricity, these panels heat water in a boiler tank, Figure 1. The water in this tank is heated to 65 ℃ [104]. A liquid inside these panels is heated by the sun. This liquid is pumped to the boiler tank to transfers its heat to the water inside. Sensors inside the tank make sure the water does not exceed 65 ℃, by turning off the pumps no more hot liquid is pumped into the boiler tank.

Hot water from the tank is mixed with cold water, to get the shower water at the desired temperature. As argued before, the cold water temperature in Ghana is around 28 ℃. Each shower consists of 25 L of water. To heat the shower water to 32 ℃, a total of 3L of hot water is mixed with 22 L of cold water, Appendix E.

Figure 1: Solar heating panels

The possibilities for solar heating were discussed together with an expert in solar heating from the company Feenstra. In the region of Wenchi, close to Techiman in Ghana, the solar power radiation is 5.020 kWh/m2 per day [91]. In August, however, this is 4.1 kWh/m2 per day [91]. The solar heating panels have an efficiency of 67% [92]. To generate enough hot water year-round, calculations are made based on the average solar power radiation in August, the month with the lowest value. Appendix E Water temperature, show calculations of the water heating system. To make sure all visitors can shower at 32 ℃, a total of 14 m^2 of solar heating panels, and a boiler tank of 800 L is needed. Theoretically, 105 L of water can be heated per hour. Only 36 L hot water is needed per hour, the rest is stored inside the 800 L boiler tank. When the sun is not shining anymore and no more extra water can be heated, hot water from the boiler tank is still available for showers.

In a house application in the Netherlands, the system is connected to a boiler as well. This boiler system guarantees hot water is heated to 65 ℃, see Figure 2. When the sun was not powerful enough or the water is cooled down, the boiler acts as a backup. No backup boiler is available in Techiman in Ghana, since there is no connection to gas. Since there is no backup, the coverage of solar panels has been multiplied by 1,5, as advised by Feenstra [103]. When the sun is not shining heavily for some time still hot water can be produced.

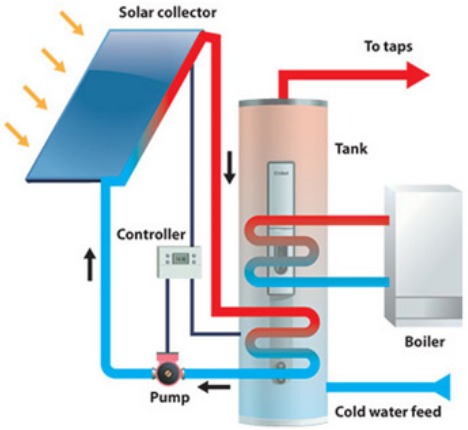


Figure 2: Backup boiler system

Tank on the roof

Placing a tank on the roof of the container, let the sun heat this water. A big disadvantage compared to a solar heating system is that this system can't be controlled. Calculations are made on how much the water will heat in the tank, however, the temperature of the shower water depends on the weather conditions. When it gets dark, the water won't be heated, so showers will be colder than when the sun is shining. The temperature of the shower water using a solar heating system can be set. It only drops if there is not enough sunlight for a longer time.

Based on the average solar power radiation of 5.020 kWh/m2 per hour, it is estimated that the temperature of a full tank of 1000 L of water will rise 4.41 ℃ when it sits in the sun for a full day, Appendix E Water temperature. In this application, however, water will not stay still for a full day. Instead, a total of 5000 L is used every day. The total volume of the tank gets flushed five times a day. On average the water stays in the tank for 4.8 hours, so the temperature rises 0.9 ℃ on average, meaning E Water temperature. The water mustn't reach an uncomfortable high temperature, this is very unlikely. For the water to hit 40 ℃ it needs to sit in the sun for three days straight without anyone taking a shower.

Considerations

From a user's perspective, the solar heating system is preferred. The water is to 32 ℃ instead of 29 ℃. Moreover, the temperature is more consistent, it is less dependent on the current weather conditions since it can buffer hot water when the sun is shining for times the sun is not shining. With the tank this is not an option, when the sun is shining heavily the shower water will be warmer than at night for example.

From the company's perspective, however, it is the other way around. The entrance price for the shower will be kept the same with both methods. The system of solar heating costs around 15.000 euros, according to the estimates of Feenstra. Besides that, it involves extra pumps and sensors which are more vulnerable than a tank on the roof.

The most prominent reason not to implement a solar heating panel system is the required space. The total roof surface of the 20 feet container is around 14,8 m^2 [24]. This would mean the total roof surface of the container has to be covered with solar heating panels. This space, however, is also needed to place solar panels to generate power. To generate enough power for the system to run 40 square meters solar panels are needed, Appendix F. To incorporate these and heating panels, a field of panels is needed next to the facility. This field has to be protected from vandalism or people who might want to steal these.

Appendix G:
Company appendix

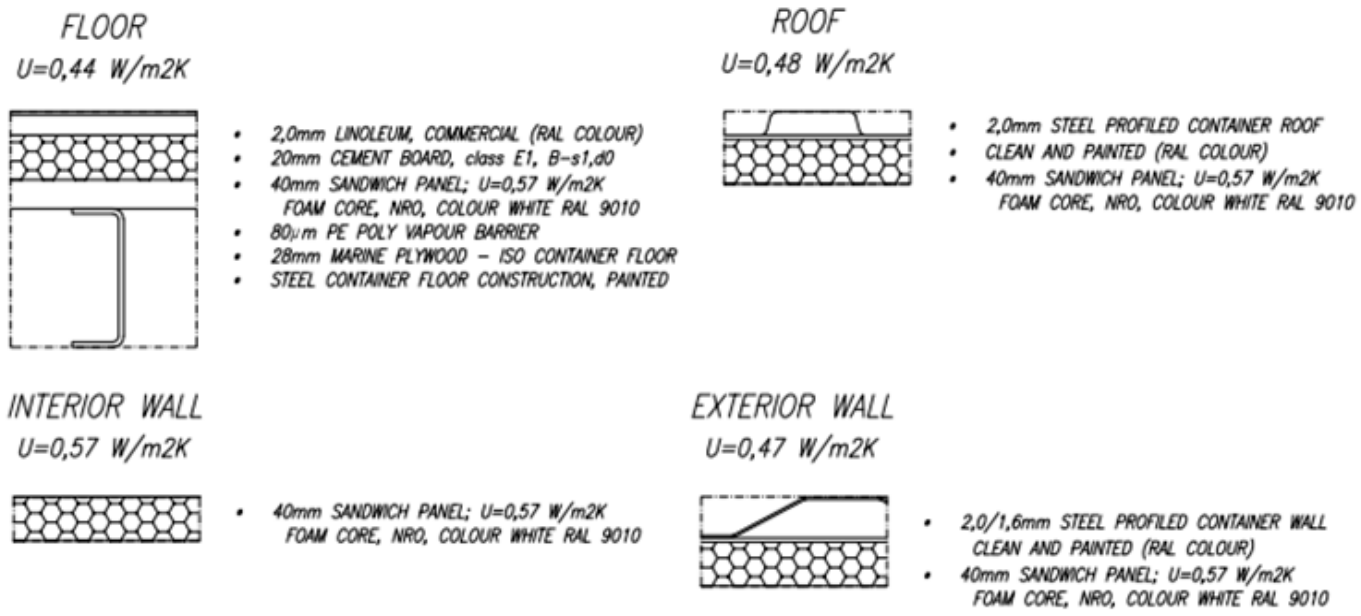
This appendix consists of important material for the company to proceed with the project. In a separate folder the 3D model will be sent.

List of contacts

Company	Contact person	Contact details
Kan Bud	Leszek Majchrzak	lmajchrzak@kan-bud.com
	Anna Szyrmer	aszyrmer@kan-bud.com
Geberit	Jeroen Bosman	Jeroen.bosman@geberit.com
		+31651594545
Greenlink Solar	Maarten Strengers	maarten@greenlink.solar
		+31626339349
Feenstra	Bas Blom	duurzaam@feenstra.com
		+31646747579
Apreco	Corine Brandhorst	info@apreco.nl
Zelfbouwcontainer	Bas van der Veen	info@zelfbouwcontainer.nl

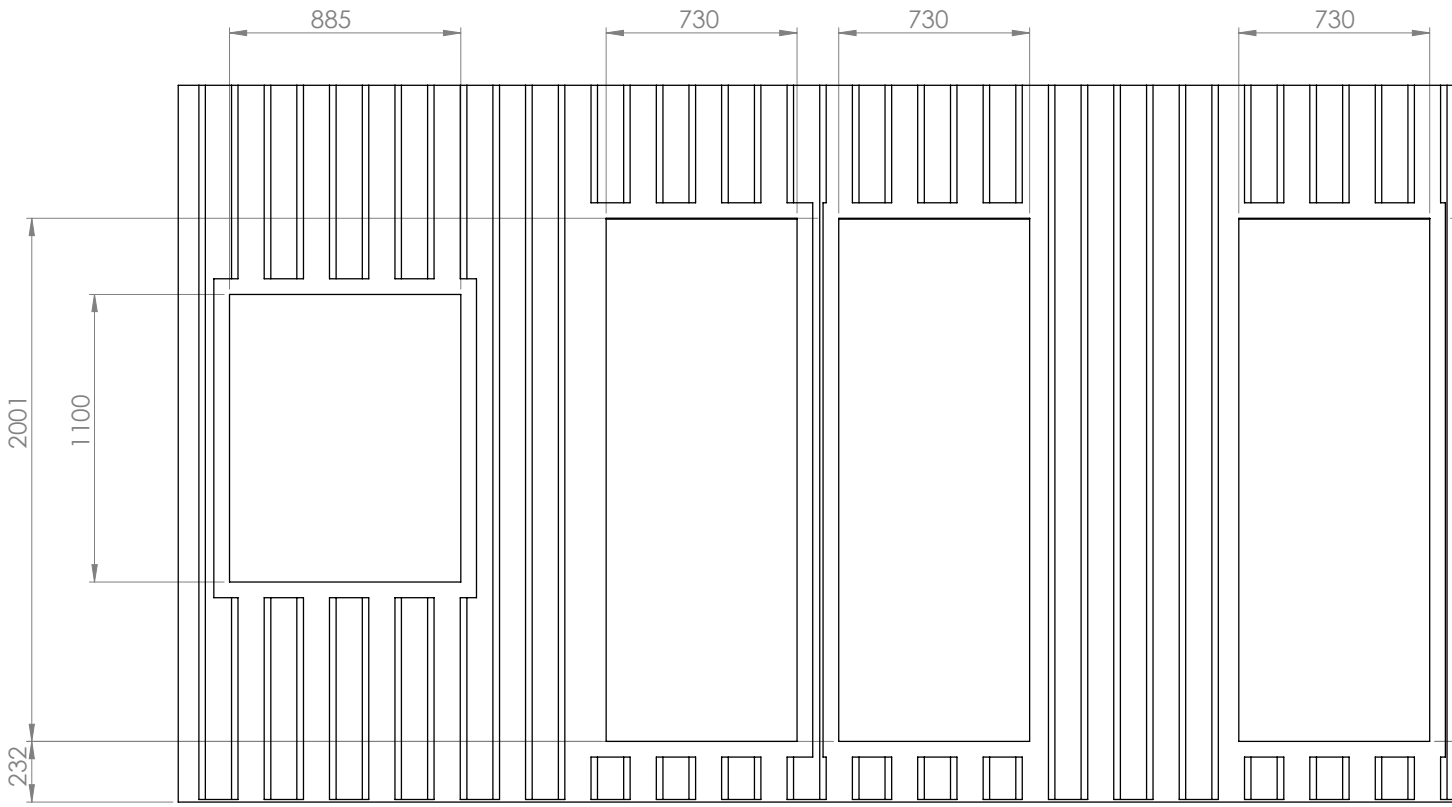
Agreements external parties

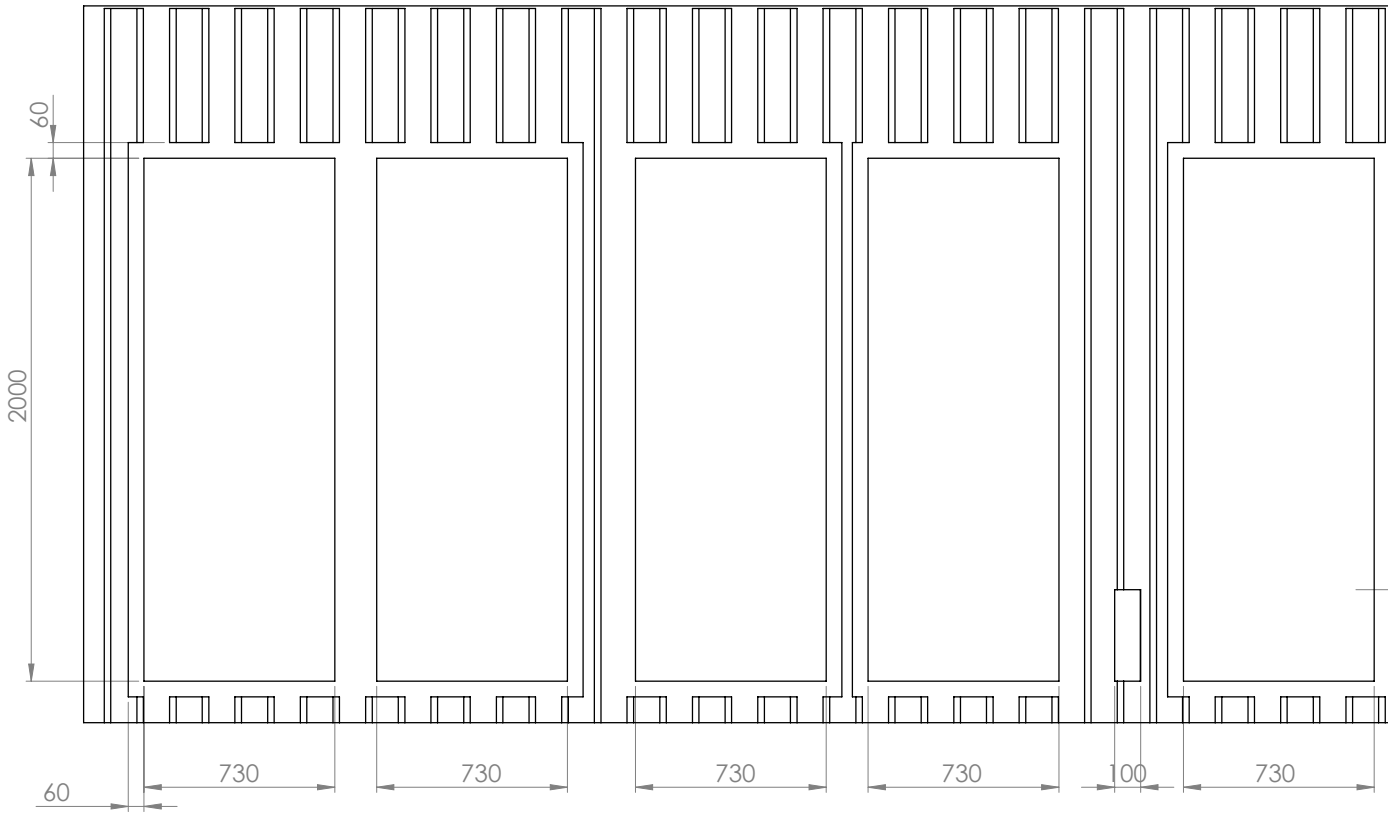
The following materials are used in the container:



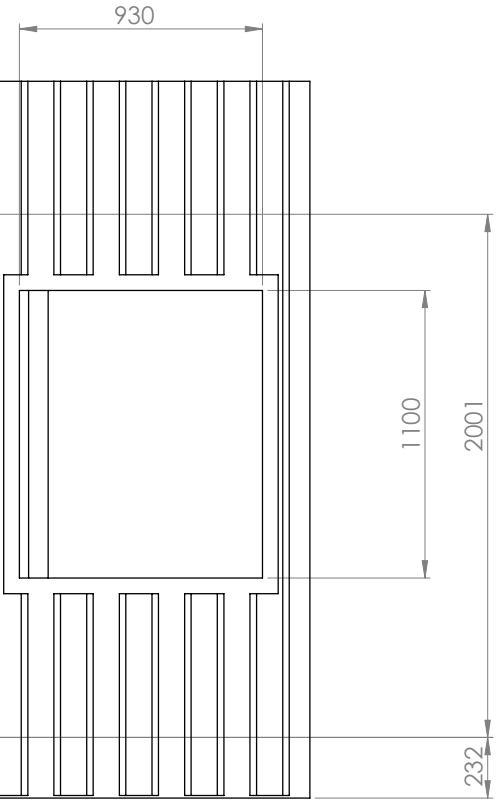
With external parties the following agreements have been made:

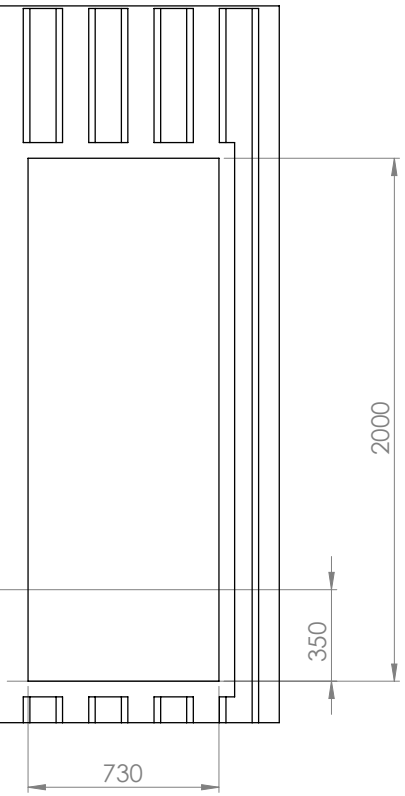
- Steel supporting structure is welded inside the container to support reservoirs.
- Another steel supporting structure is in place to support the interior walls, at the corners.
- Big opening (doors and handwashing openings) have a 60 mm wide frame welded around.
- Small openings (fans, ventilation sewage system, and outlet sewage system) do not have a frame around.
- Rough estimation for the costs is currently: 25.000 for the adjusted container and 10.000 for installation of all components. Together with mister Majchrzak, a detailed inquiry should be made. Also, clear agreements on what is installed in Poland and what in the Netherlands should be made.
- Apreco is the company that made an inquiry for the prefabricated black, grey, and yellow drain tubing system.
- Kan Bud will contact Semilla about the costs of a construction on top of the container to support the 1000 L shower water tank.


885
730
730
730
2001
1100
232

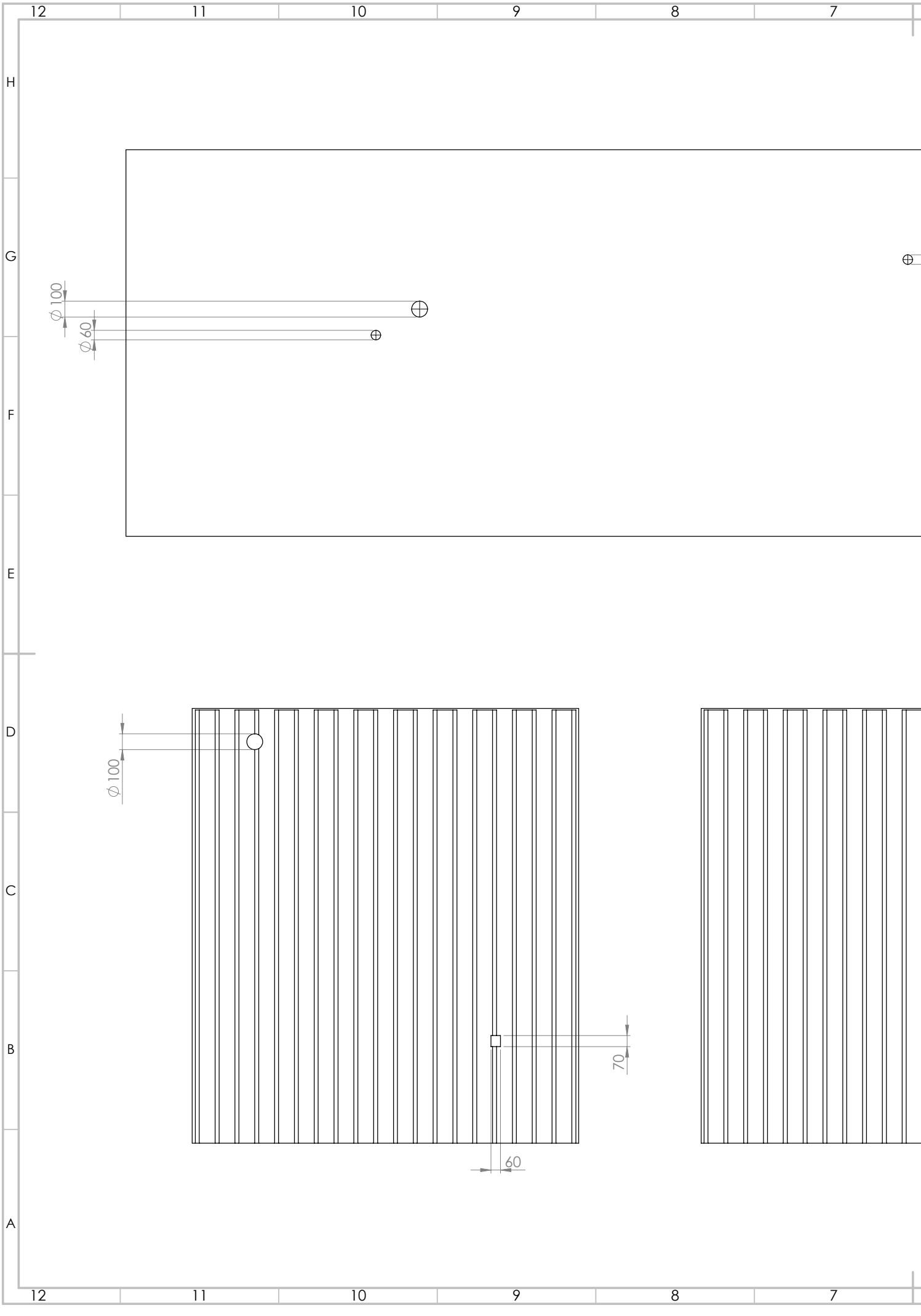

60
2000
60
730
730
730
730
100
730

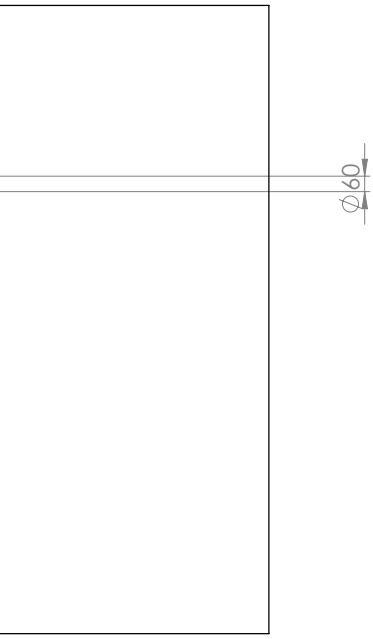
Technical drawings

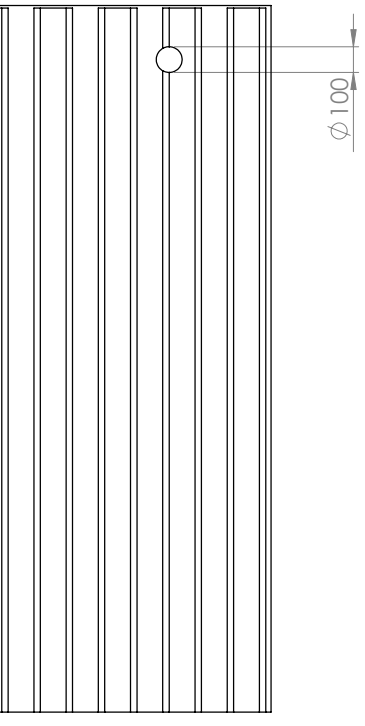




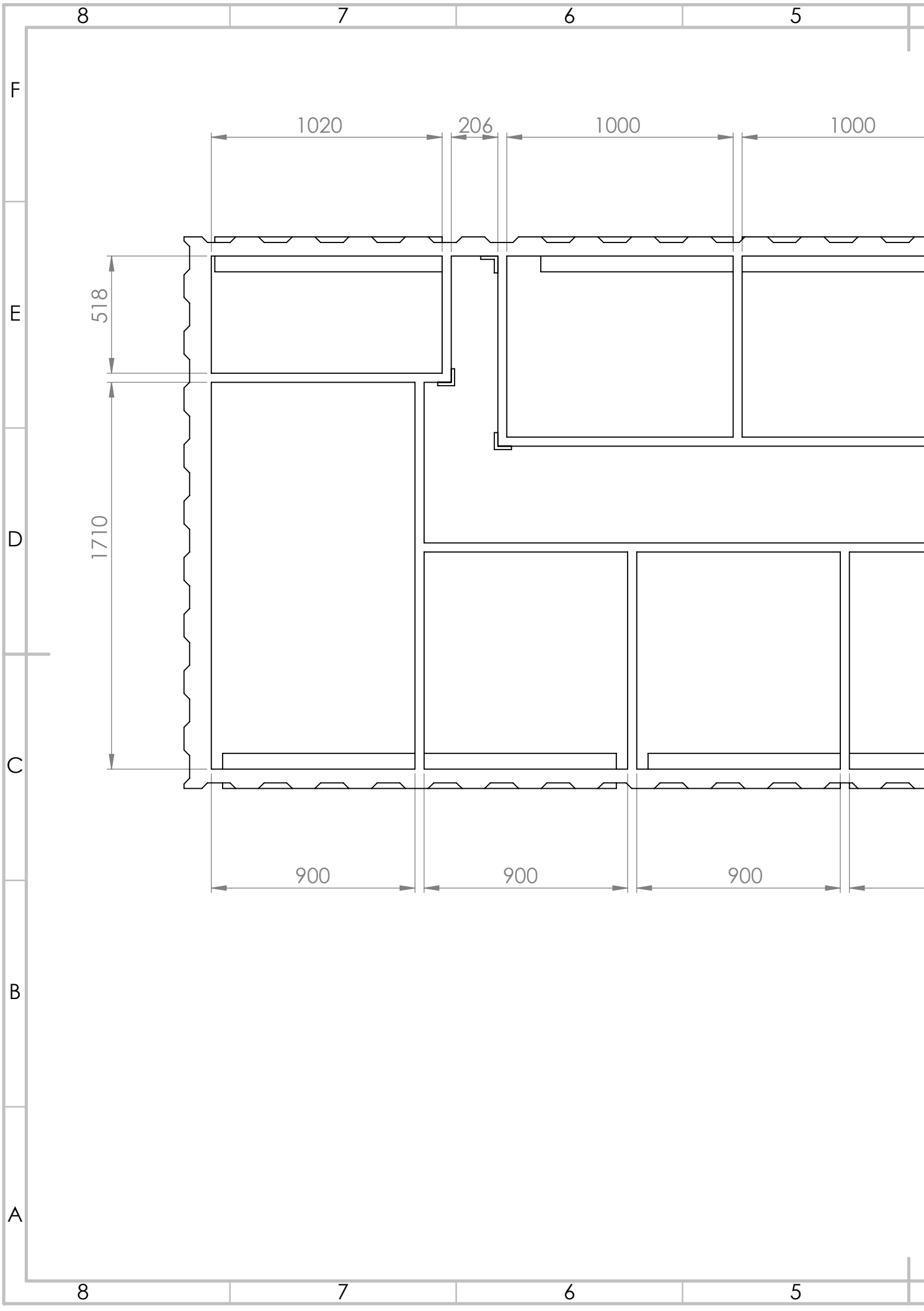
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBURR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A3
						casco tekeningen Kan Bud	
				WEIGHT:		SCALE:1:50	SHEET 1 OF 1

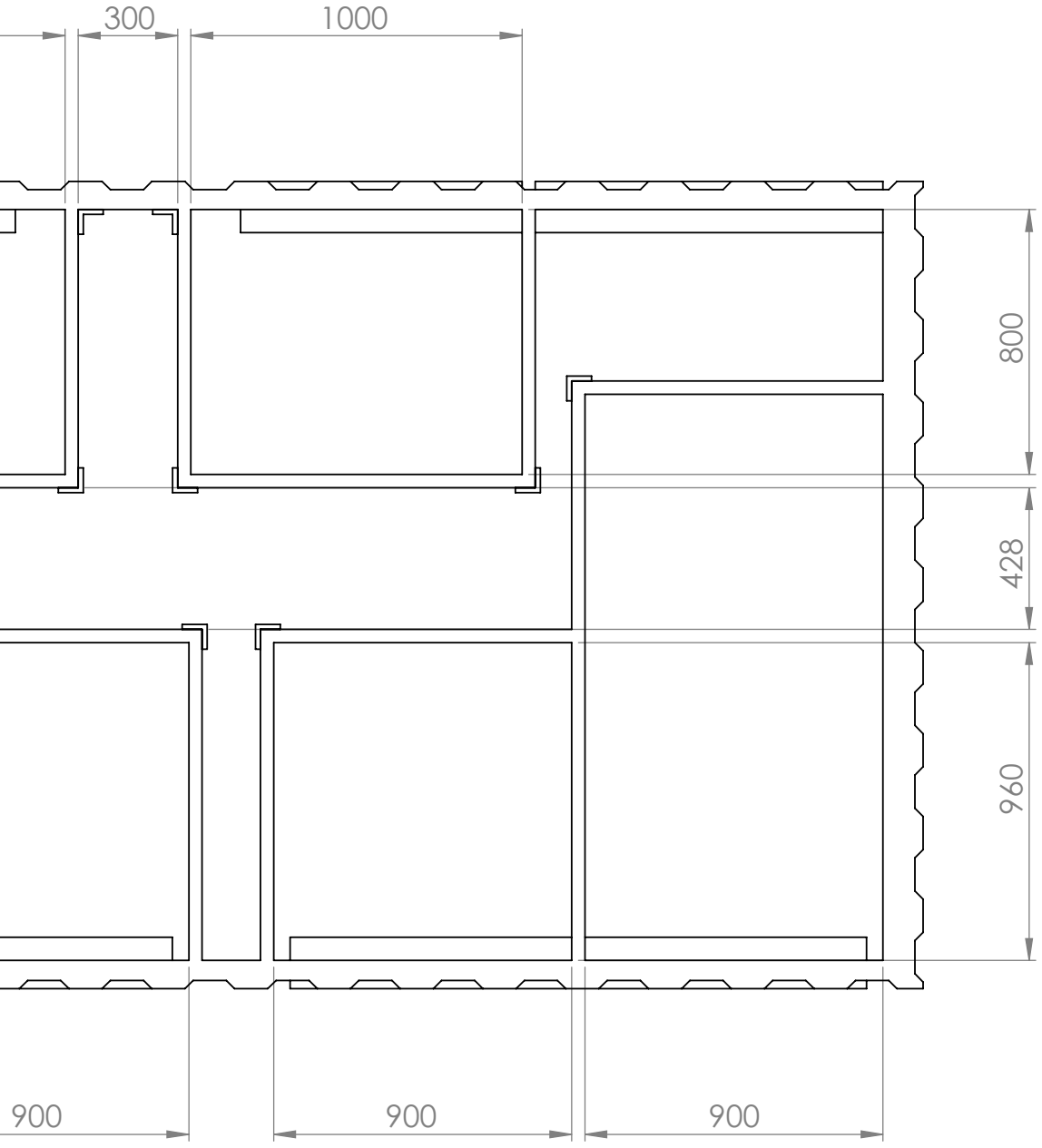

12
11
10
9
8
7
H
G
F
E
D
C
B
A
∅100
∅60
∅100
70
60





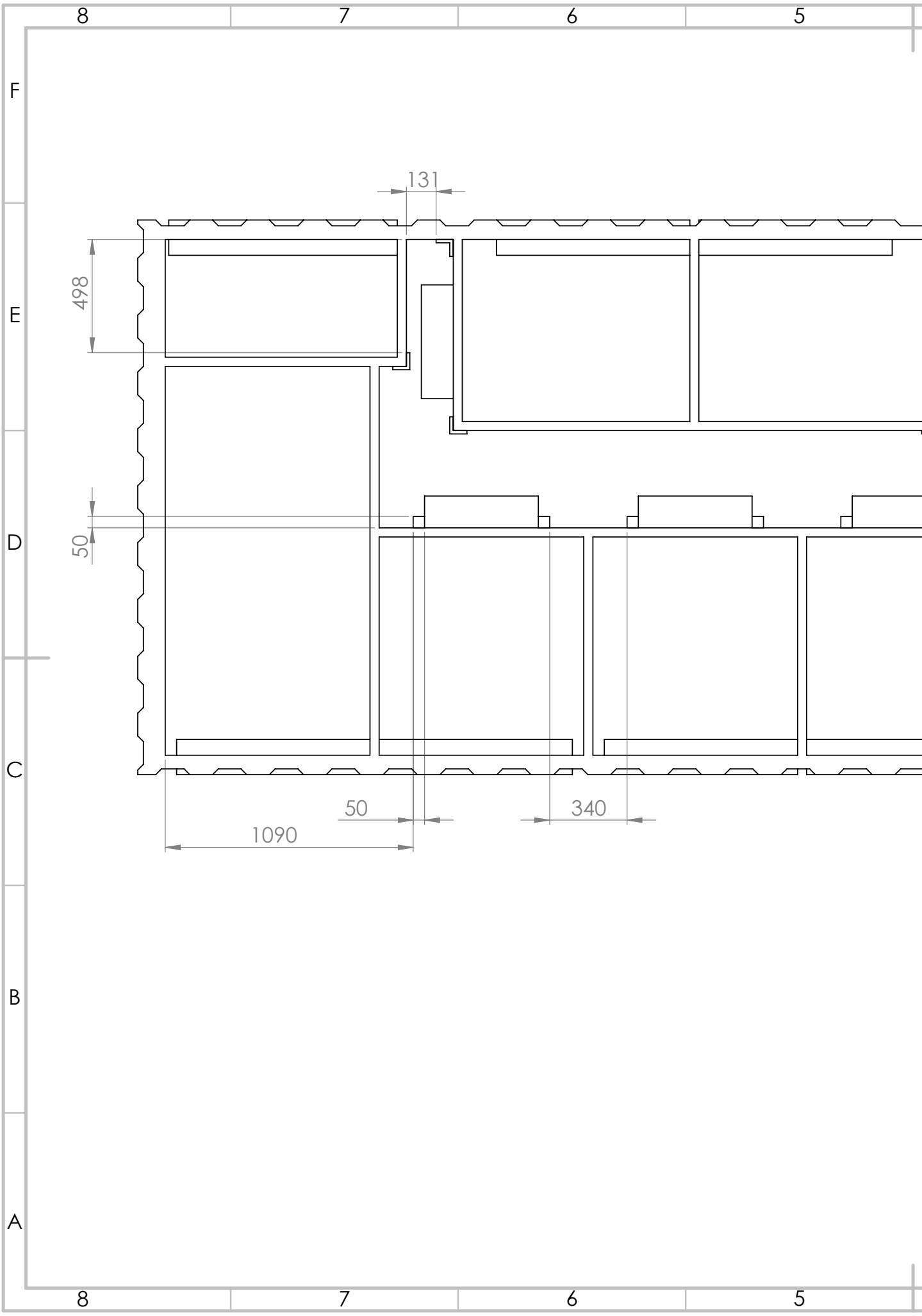
UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A3
						casco tekeningen Kan Bud	
				WEIGHT:		SCALE:1:50	SHEET 1 OF 1

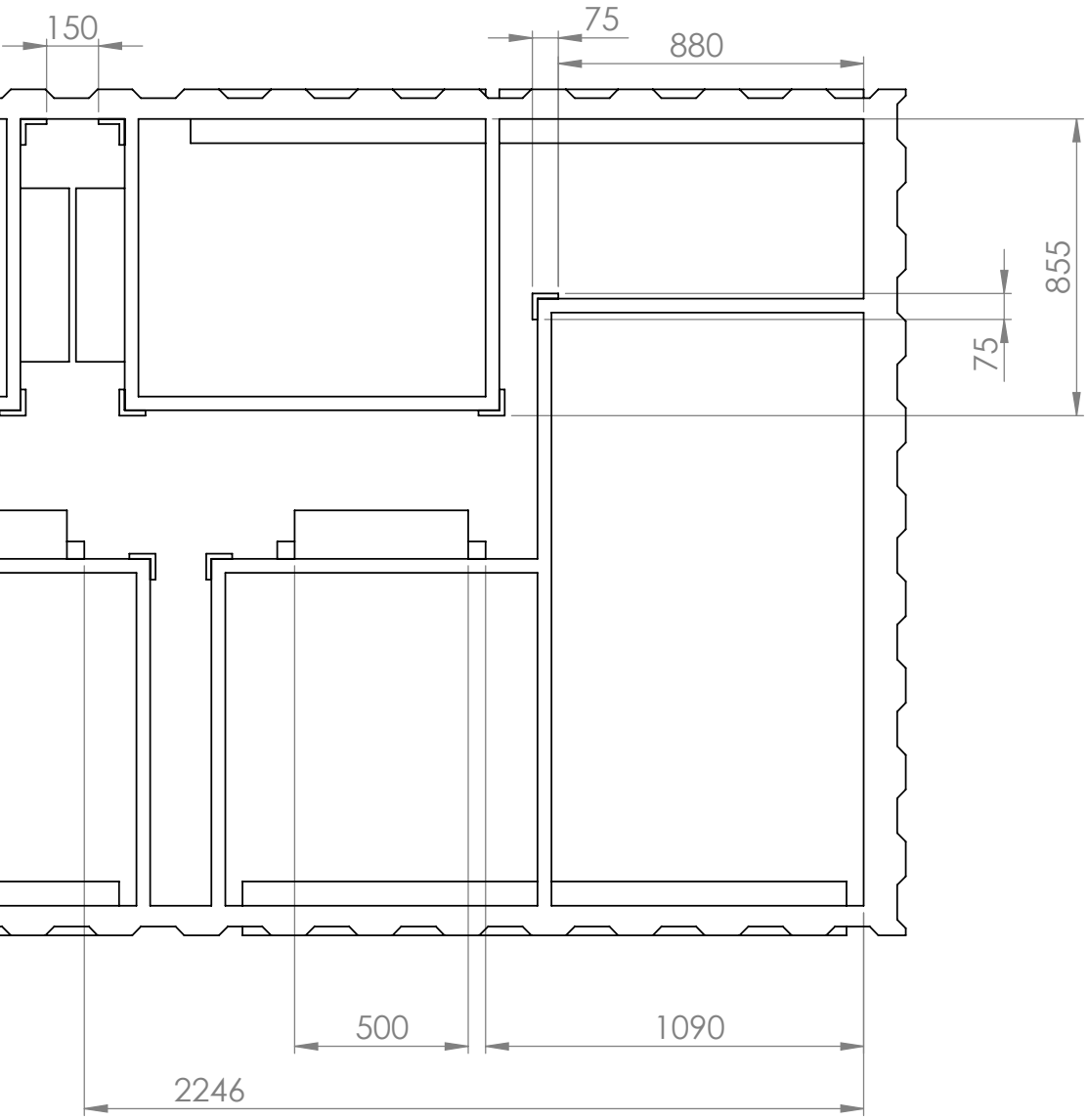

8
7
6
5
F
E
D
C
B
A
1020
206
1000
1000
518
1710
900
900
900



UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE				TITLE:
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A3
				WEIGHT:		SCALE:1:50	SHEET 1 OF 1

casco tekeningen Kan Bud

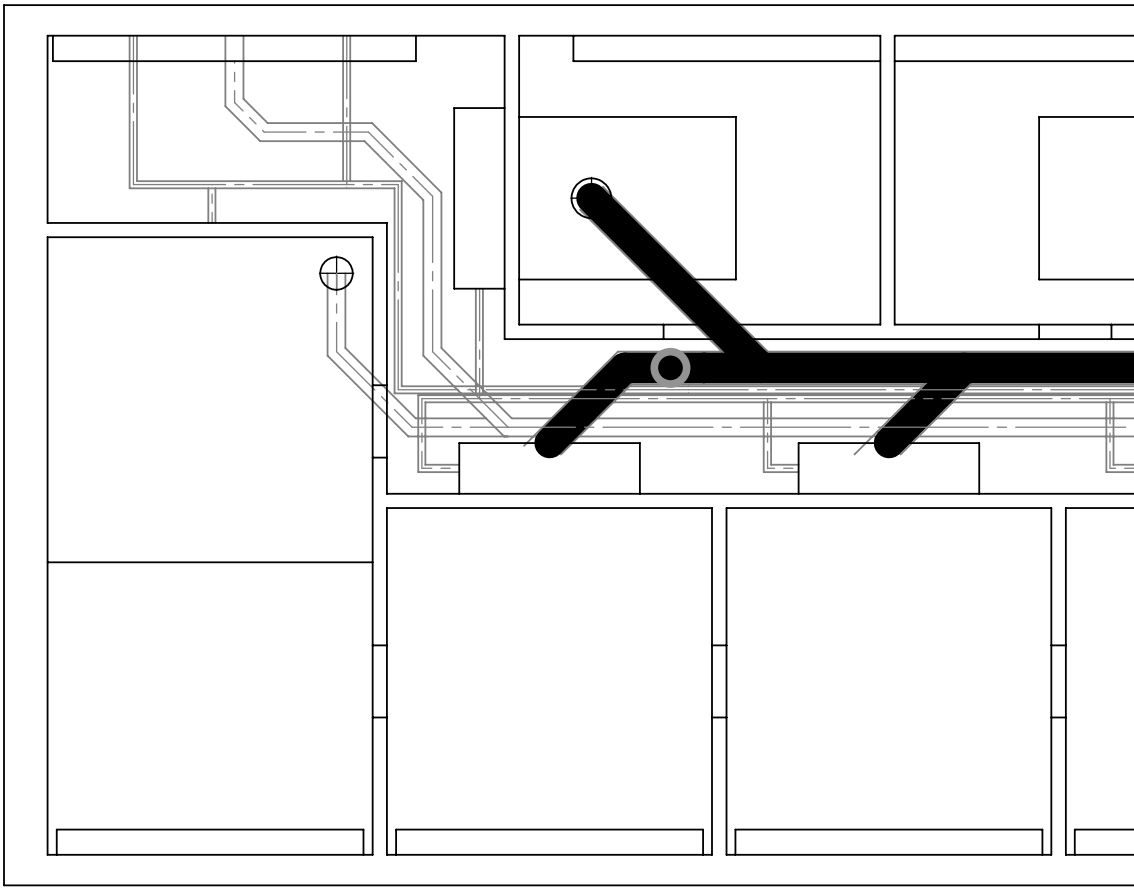

8
7
6
5
F
E
D
C
B
A
131
498
50
50
340
1090

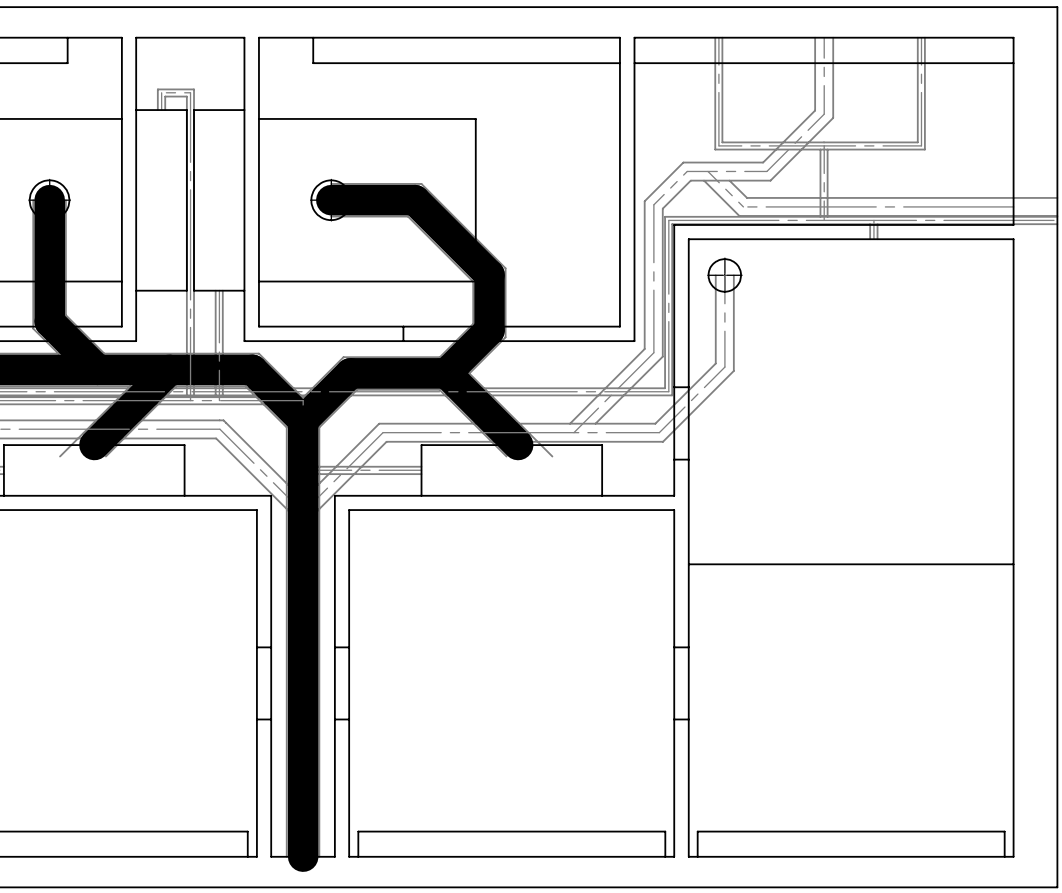


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBURR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A3
				WEIGHT:		SCALE:1:50	SHEET 1 OF 1

casco tekeningen Kan Bud

Black water drain

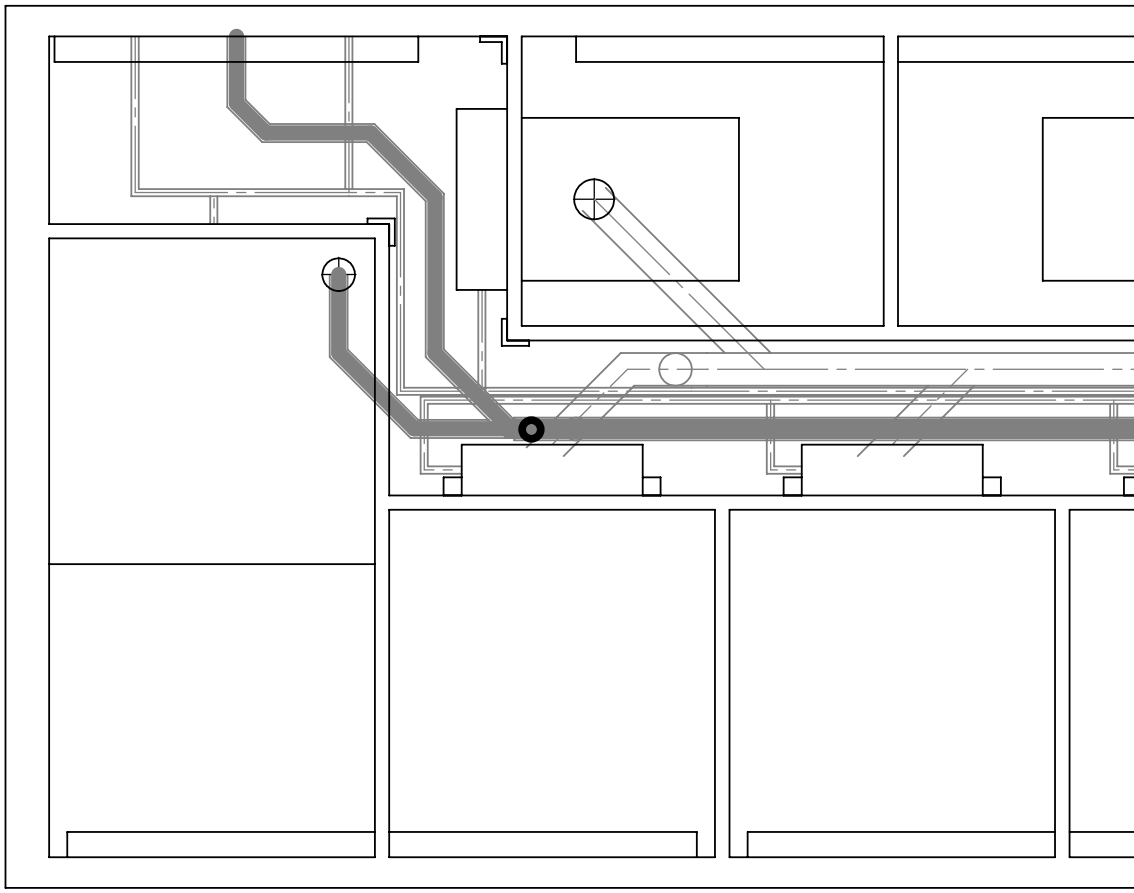


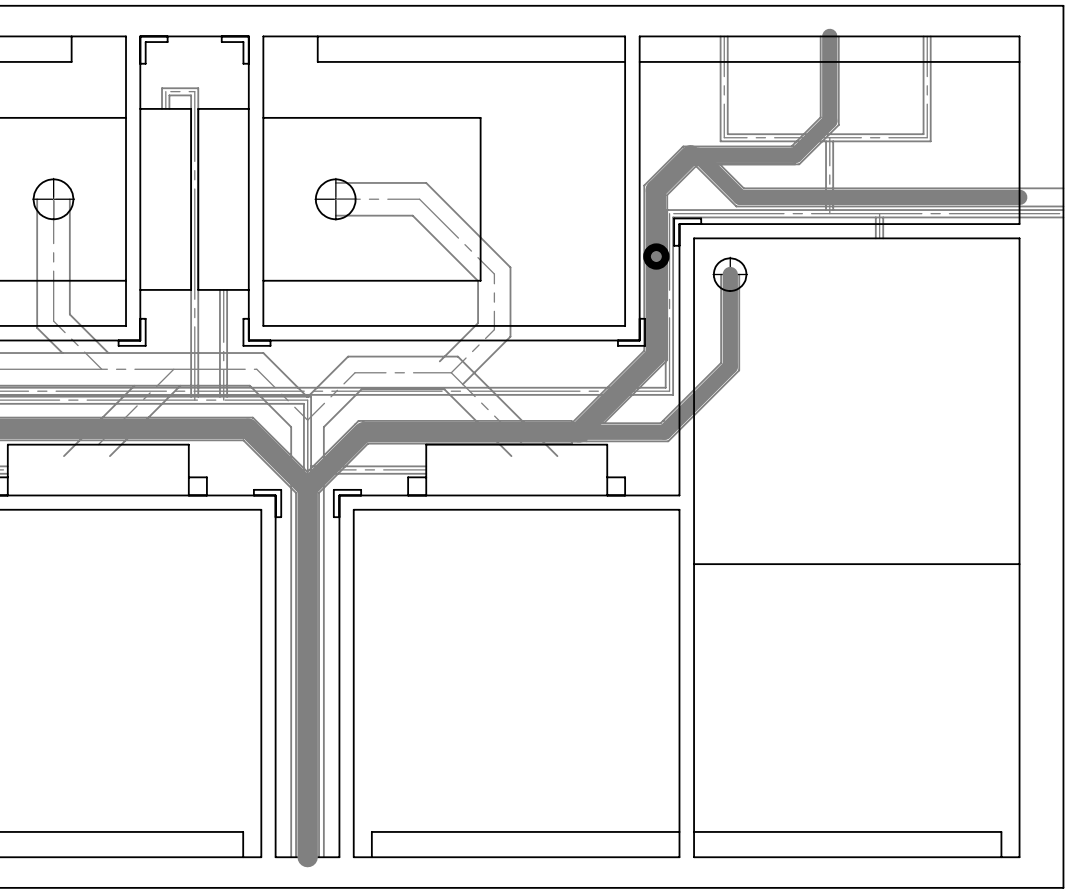


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBURR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE				TITLE:	
DRAWN								
CHK'D								
APPV'D								
MFG								
Q.A				MATERIAL:			DWG NO.	A3
				WEIGHT:			SCALE:1:50	SHEET 1 OF 1

casco tekeningen Kan Bud

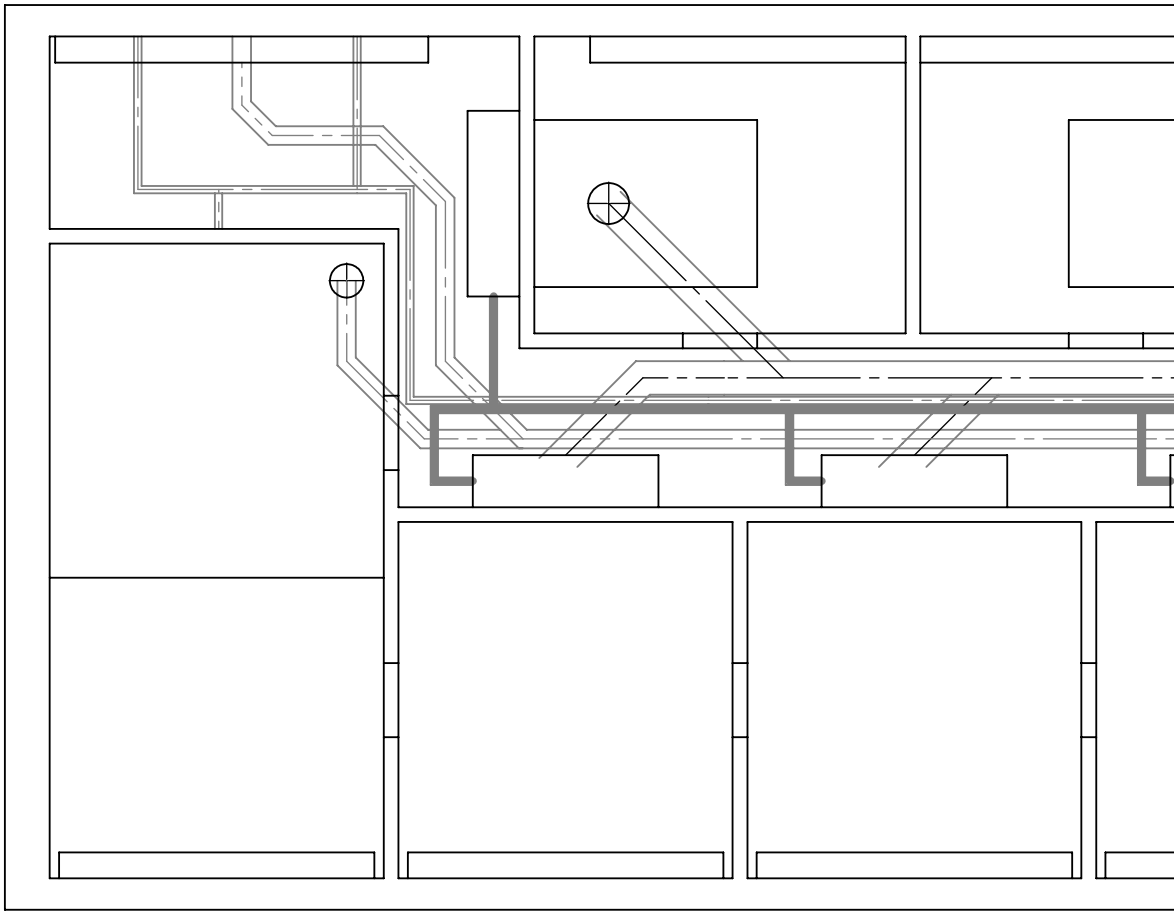
Grey water drain

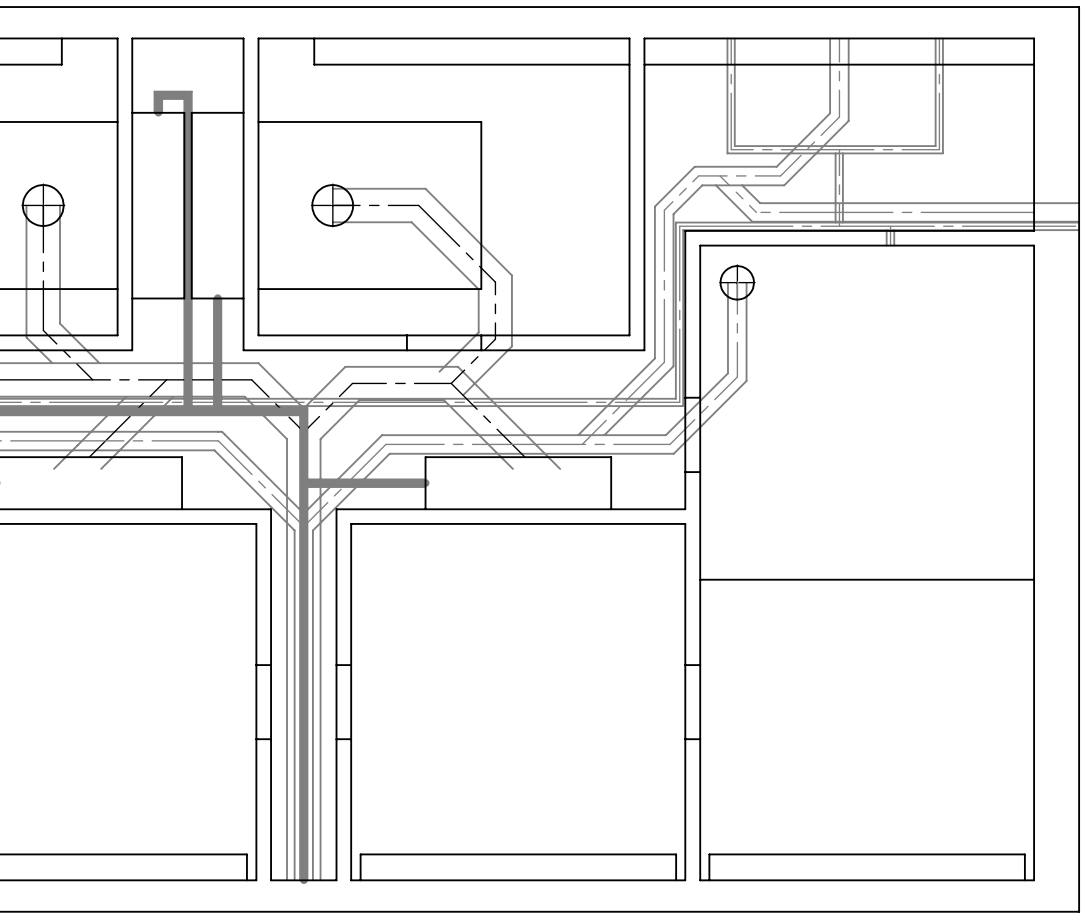




UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:			FINISH:			DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE				TITLE:	
DRAWN								
CHK'D								
APPV'D								
MFG								
Q.A				MATERIAL:			DWG NO. Afvoer tekeningen	A3
				WEIGHT:			SCALE:1:50	SHEET 1 OF 1

Grey water supply

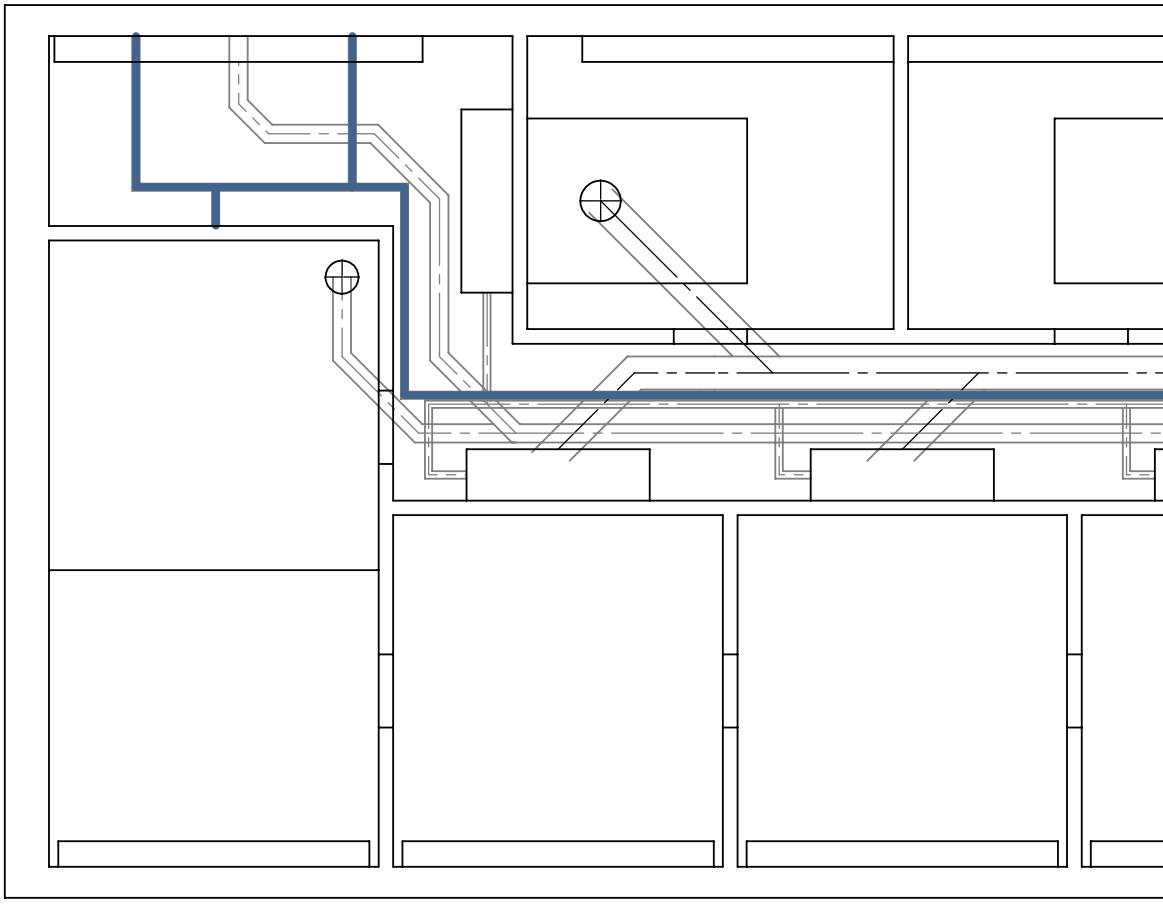


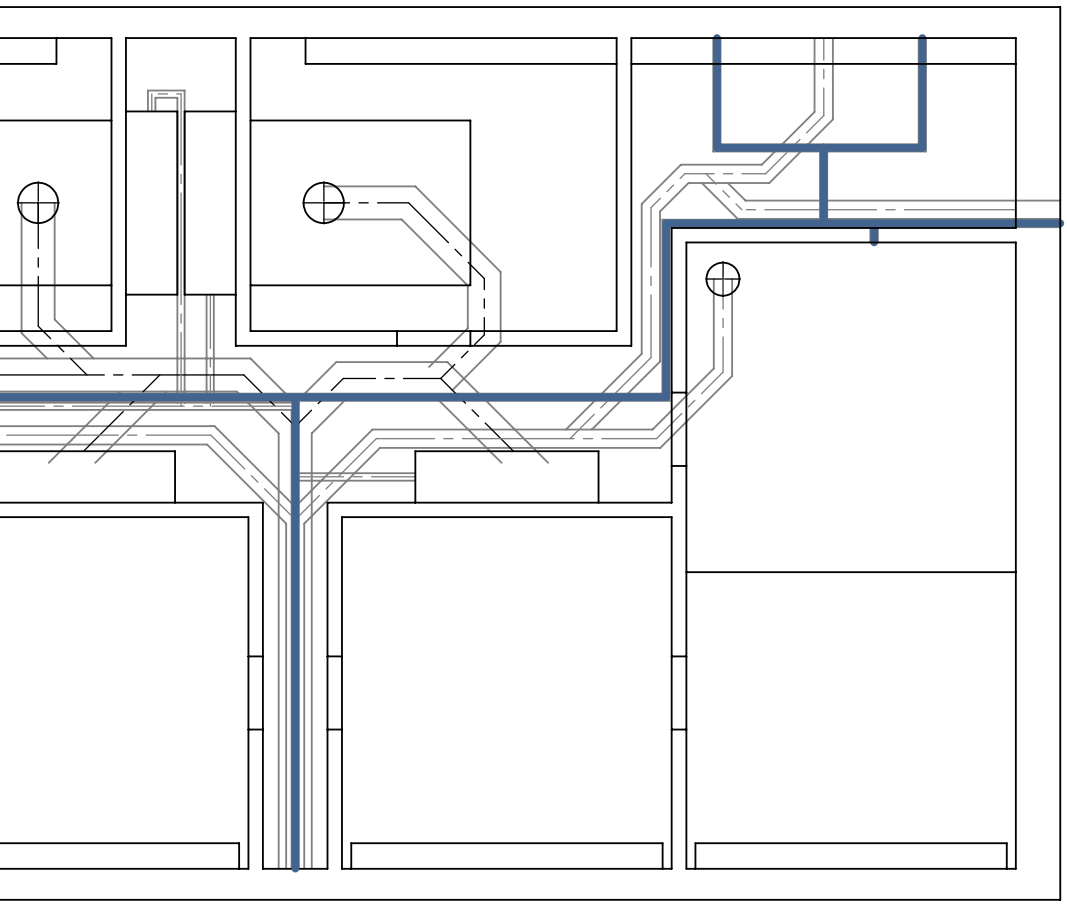


UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:			DEBURR AND BREAK SHARP EDGES	DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A2
				WEIGHT:		SCALE:1:50	SHEET 1 OF 1

casco tekeningen Kan Bud

Fresh water supply





UNLESS OTHERWISE SPECIFIED: DIMENSIONS ARE IN MILLIMETERS SURFACE FINISH: TOLERANCES: LINEAR: ANGULAR:		FINISH:		DEBURR AND BREAK SHARP EDGES		DO NOT SCALE DRAWING	REVISION
	NAME	SIGNATURE	DATE			TITLE:	
DRAWN							
CHK'D							
APPV'D							
MFG							
Q.A				MATERIAL:		DWG NO.	A3 A
						casco tekeningen Kan Bud	
				WEIGHT:		SCALE:1:50	SHEET 1 OF 1

Appendix H: Shipping components

Object	Amount	Measurements [cm]
Cashier's desk	1	140 x 125 x 245
High fences	19	6 x 250 x 203
Low fences	13	6 x 250 x 80
High poles	17	6 x 6 x 283
Low poles	8	6 x 6 x 160
Mens door	1	6 x 200 x 200
Womens door	1	6 x 200 x 300
Urinal wall	1	95 x 200 x 255
Part A solar panel construction urinal	2	220 x 275 x 10
Part B solar panel construction urinal	4	4 x 4 x 450
Part A solar panel construction container	4	250 x 37 x 10
Part B solar panel construction container	8	4 x 4 x 320
Part A solar panel cashier's desk	2	130 x 19 x 10
Part B solar panel cashier's desk	4	4 x 4 x 200
Solar panels	25	10 x 100 x 170
Booster pump	4	50 x 50 x 30
Submersible pump	1	19 x 30 x 35
Garbage bins	3	51 x 53 x 85
Towel dispenser	5	10 x 28 x 36
Soap dispenser	1	11 x 11 x 27
Outside lights	12	20 x 20 x 14

Appendix J: Project brief

DESIGN FOR our future

TU Delft

IDE Master Graduation

Project team, Procedural checks and personal Project brief

This document contains the agreements made between student and supervisory team about the student's IDE Master Graduation Project. This document can also include the involvement of an external organisation, however, it does not cover any legal employment relationship that the student and the client (might) agree upon. Next to that, this document facilitates the required procedural checks. In this document:

- The student defines the team, what he/she is going to do/deliver and how that will come about.
- SSC E&SA (Shared Service Center, Education & Student Affairs) reports on the student's registration and study progress.
- IDE's Board of Examiners confirms if the student is allowed to start the Graduation Project.

USE ADOBE ACROBAT READER TO OPEN, EDIT AND SAVE THIS DOCUMENT
Download again and reopen in case you tried other software, such as Preview (Mac) or a webbrowser.

STUDENT DATA & MASTER PROGRAMME
Save this form according the format "IDE Master Graduation Project Brief_familyname_firstname_studentnumber_dd-mm-yyyy".
Complete all blue parts of the form and include the approved Project Brief in your Graduation Report as Appendix 1 !

family name: Berg 4718
initials: P.J. given name: Koos
student number: 4457269
street & no.:
zipcode & city:
country:
phone:
email:

Your master programme (only select the options that apply to you):
IDE master(s): ★ IPD ○ DfI ○ SPD
2nd non-IDE master:
individual programme: - - (give date of approval)
honours programme: ○ Honours Programme Master
specialisation / annotation: ○ Medisign ○ Tech. in Sustainable Design ○ Entrepeneurship

SUPERVISORY TEAM **
Fill in the required data for the supervisory team members. Please check the instructions on the right !

** chair: Jan Carel Diehl dept. / section: SDE/DfS
** mentor: Marian Loth dept. / section: HCD
2nd mentor: Peter Scheer
organisation: Semilla
city: Breda country: Nederland

comments (optional)

Chair should request the IDE Board of Examiners for approval of a non-IDE mentor, including a motivation letter and c.v..

Second mentor only applies in case the assignment is hosted by an external organisation.

Ensure a heterogeneous team. In case you wish to include two team members from the same section, please explain why.

Procedural Checks - IDE Master Graduation

TU Delft

APPROVAL PROJECT BRIEF

To be filled in by the chair of the supervisory team.

chair Jan Carel Diehl date 12 - 02 - 2021 signature jdi ehl Digitally signed by jdiehl Date: 2021.02.12 10:50:42 +01'00'

CHECK STUDY PROGRESS

To be filled in by the SSC E&SA (Shared Service Center, Education & Student Affairs), after approval of the project brief by the Chair.
The study progress will be checked for a 2nd time just before the green light meeting.

Master electives no. of EC accumulated in total: 15 EC

Of which, taking the conditional requirements into account, can be part of the exam programme 15 EC

List of electives obtained before the third semester without approval of the BoE

★ YES all 1st year master courses passed

NO missing 1st year master courses are:

name J. J. de Bruin date 16 - 02 - 2021 signature J. J. de Bruin, SPA Digitally signed by J. J. de Bruin, SPA Date: 2021.02.16 10:43:27 +01'00'

FORMAL APPROVAL GRADUATION PROJECT

To be filled in by the Board of Examiners of IDE TU Delft. Please check the supervisory team and study the parts of the brief marked **.
Next, please assess, (dis)approve and sign this Project Brief, by using the criteria below.

- Does the project fit within the (MSc)-programme of the student (taking into account, if described, the activities done next to the obligatory MSc specific courses)?
- Is the level of the project challenging enough for a MSc IDE graduating student?
- Is the project expected to be doable within 100 working days/20 weeks ?
- Does the composition of the supervisory team comply with the regulations and fit the assignment ?

Content: ★ APPROVED ○ NOT APPROVED

Procedure: ★ APPROVED ○ NOT APPROVED

- remark: no company name in title, suggestion Design of a sanitation unit

comments

name Monique von Morgen date 02 - 03 - 2021 signature

Initials & Name P.J. Berg 4718 Student number 4457269

Title of Project Semilla sanitation unit

Personal Project Brief - IDE Master Graduation

TU Delft

Semilla sanitation unit — project title

Please state the title of your graduation project (above) and the start date and end date (below). Keep the title compact and simple. Do not use abbreviations. The remainder of this document allows you to define and clarify your graduation project.

start date 11 - 02 - 2021 — 11 - 07 - 2021 end date

INTRODUCTION **

Please describe, the context of your project, and address the main stakeholders (interests) within this context in a concise yet complete manner. Who are involved, what do they value and how do they currently operate within the given context? What are the main opportunities and limitations you are currently aware of (cultural- and social norms, resources (time, money,...), technology, ...).

Stakeholders and their main interests

Koos Berg
- o Work on a project I am proud of to put on my portfolio, a project I feel motivated and happy to spend my time on.

Semilla sanitation Netherlands: The company I will do my internship.
- o Having a complete plan for a sanitation unit, a finished sanitation unit is ready to be placed in Ghana by the end of the project.

Nijhuis Industries: A company Semilla works with closely, Semilla is situated inside Nijhuis.
- o Nijhuis provides the tools and manpower to work on the unit and helps realizing it physically, besides that they have a lot of knowledge about water filtration.

Semilla sanitation Ghana: The Ghanaian partner company on location.
- o By the end of the project have a sanitation unit that can go into production directly so around 5 can be made and tested in the real environment.

Good sanitation Ghana: Will exploit the sanitation unit in Techiman in Ghana (a town of around 68.000 people) on a market with 3.000 – 5.000 visitors (Bono East).
- o Their main interest is to make sure the units are clean and people will pay to go in.

Greenlink Solar: Provides the solar panels on top of the sanitation unit.
- o The more units are placed the more panels they sell. Make sure the panels can't get stolen from the top of the unit.

TU Delft
- o Make sure the project matches the academic guidelines to keep the level of graduates high

Opportunities
At Semilla I have the opportunity to rebuild a container into a sanitation unit. So besides making the design I can make a true to size prototype of a unit. According to the client, if my design is good Semilla will take it into production, this is a big opportunity to make impact in Ghana with my design.

Limitations
The biggest limitation is that user and context research will be very difficult since there will be no possibility for me to travel to Ghana and see the context with my own eyes. However via Semilla Sanitation Ghana I can get answers to my questions regarding the local context. Sanitation is something very private and therefore heavily context specific. Therefore it is best to search for a part of the design that is less heavily context specific to focus on.

space available for images / figures on next page

introduction (continued): space for images

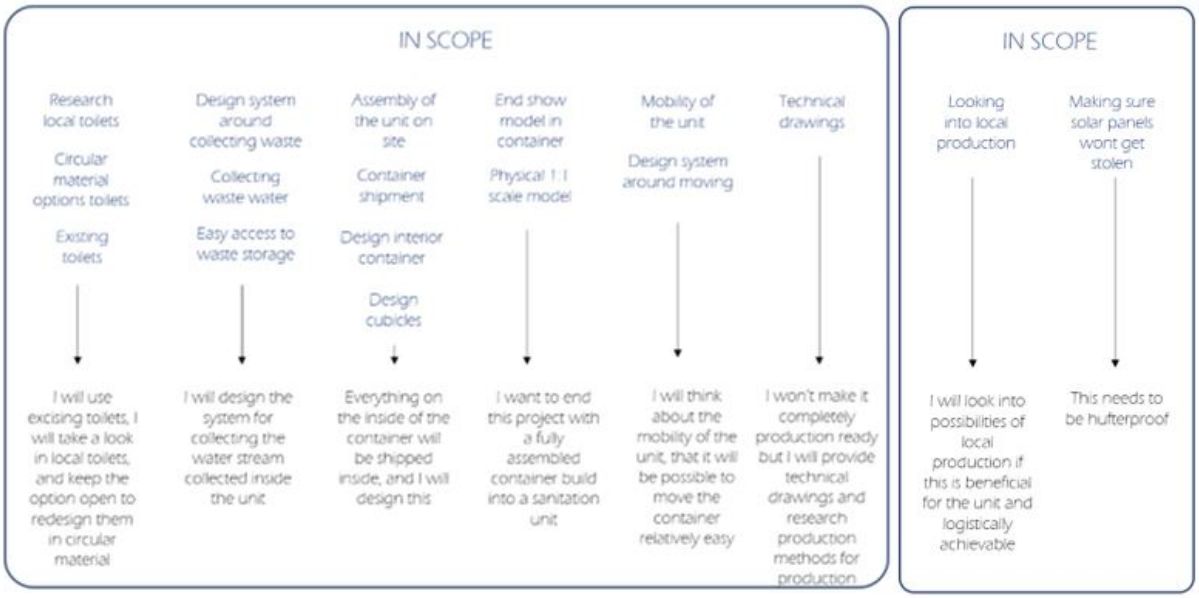


image / figure 1: Within projects scope

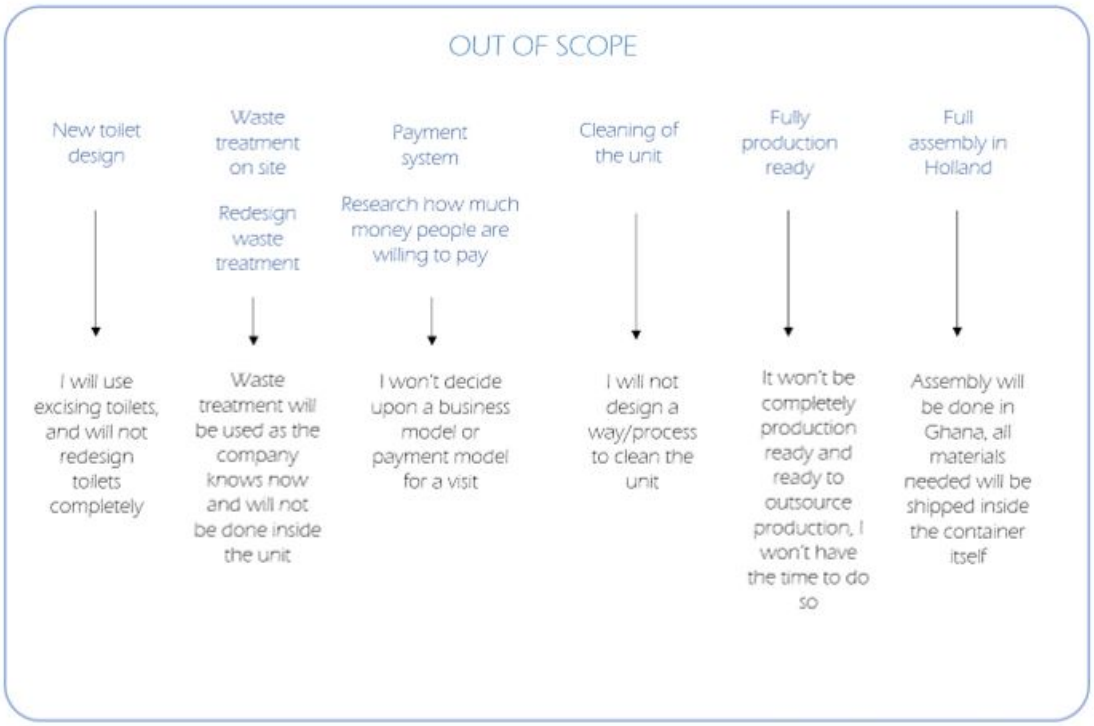


image / figure 2: Out of projects scope

PROBLEM DEFINITION **

Limit and define the scope and solution space of your project to one that is manageable within one Master Graduation Project of 30 EC (= 20 full time weeks or 100 working days) and clearly indicate what issue(s) should be addressed in this project.

The underlying problem that this sanitation unit will try to solve is the lack of clean sanitation in Ghana. In 2015 Ghana was ranked as the seventh dirtiest country by sanitation standards by the WHO with over 7.000 children dying every year from conditions like cholera and diarrhea (Dowden, R. 2020). Ghana has a sanitation coverage of only 15%. (Smith-Asante, E. 2015). Clean sanitation can prevent conditions like diarrhea.

In addition this sanitation unit will help closing the loop by turning the different water streams in for example biogas, fertilizer, or drinking water.

The techniques to filter grey, black and yellow water and to turn this into drinking water and/or fertilizer are already present. The biggest problem in Ghana now is to design the system around the cleaning and to ensure people will use it. Besides that people need to be willing to pay a small amount of money for a visit to the toilet.

I will design a sanitation unit with 1 or 2 showers, 4 toilets and 1 or 2 urinals. This unit is build out of a 20 ft container of 6,06 x 2,44 x 2,59 m. In this unit there also needs to be place for storage of grey, yellow, black and clean water. Everything needed inside of the sanitation unit, such as the doors and plates that make up the toilet cubicle, need to be transported inside the container. Besides that nothing can stick out of the container, this way it matches the regulations regarding container shipment and can it be treated like a 'normal container' on a container ship.

ASSIGNMENT **

State in 2 or 3 sentences what you are going to research, design, create and / or generate, that will solve (part of) the issue(s) pointed out in "problem definition". Then illustrate this assignment by indicating what kind of solution you expect and / or aim to deliver, for instance: a product, a product-service combination, a strategy illustrated through product or product-service combination ideas, ... In case of a Specialisation and/or Annotation, make sure the assignment reflects this/these.

I will design a sanitation unit made out of a container containing 1/2 shower(s), 4 toilets, 1/2 urinals and enough taps to be used in Ghana. All different waterstreams need to be collected and accessible for a collecting system. Via this system the streams from different units will be collected and recycled at a separate recycle plant. The unit needs to be transportable.

I am to deliver a product, I am to end this project with a 1:1 model built in an actual container.

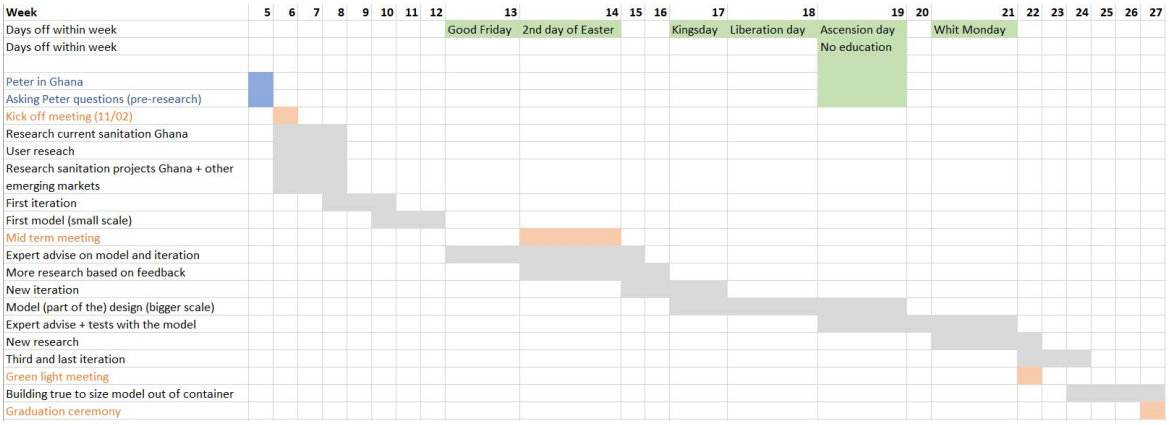
Initials & Name P.J. Berg 4718 Student number 4457269

Title of Project Semilla sanitation unit

PLANNING AND APPROACH **

Include a Gantt Chart (replace the example below - more examples can be found in Manual 2) that shows the different phases of your project, deliverables you have in mind, meetings, and how you plan to spend your time. Please note that all activities should fit within the given net time of 30 EC = 20 full time weeks or 100 working days, and your planning should include a kick-off meeting, mid-term meeting, green light meeting and graduation ceremony. Illustrate your Gantt Chart by, for instance, explaining your approach, and please indicate periods of part-time activities and/or periods of not spending time on your graduation project, if any, for instance because of holidays or parallel activities.

start date 11 - 2 - 2021 11 - 7 - 2021 end date



I would like to do 3 main iterations. Within these 3 iteration I will probably do some other small iterations with parts of the problem. To find certain solution spaces. It is hard to foresee this in advance already, but it is my aim. Besides that I would like to end with a container that I have built into a sanitation unit. This will be my end goal. Besides this I would like to think it as far though as possible, but making it production ready will not be in scope.

MOTIVATION AND PERSONAL AMBITIONS

Explain why you set up this project, what competences you want to prove and learn. For example: acquired competences from your MSc programme, the elective semester, extra-curricular activities (etc.) and point out the competences you have yet developed. Optionally, describe which personal learning ambitions you explicitly want to address in this project, on top of the learning objectives of the Graduation Project, such as: in depth knowledge a on specific subject, broadening your competences or experimenting with a specific tool and/or methodology, ... Stick to no more than five ambitions.

The main reason I set up this project is because I want to make impact in emerging markets. I do not like to work on the next coffeemachine or other luxury product. I think we already have way too many of these luxury products, and as a society we are overdesigning and overproducing these. Instead of that I want to work on projects that can make a difference for people who need it the most. Therefore I like to work on a project like this, something that facilitates people's basic needs and actually make their lives better and heathier.

In this project I want to prototype and make models, this is one of my strengths and I would like to deepen this. Besides that I really like to make models and I feel if my portfolio is filled with models I am more likely to find a job in which this is one of my responsibilities.

I often have difficulties managing a big project like this on my own. This is something I want to learn to do better as well, keeping into account all stakeholders and making decisions. Sometimes it is better to make a decision and later on change it than keep procrastinating the decision because you want to make everybody happy.

FINAL COMMENTS

In case your project brief needs final comments, please add any information you think is relevant.