Faeces Thesis

- closing the nutrient cycle with an architecture of extroversion

Author: Otto Malmkvist
Supervisor: Anita Ollár
Examiner: Krystyna Pietrzyk

Institution: Chalmers School of Architecture, Department of Architecture & Civil Engineering

Course: ACEX35, Marster's thesis, Spring semester 2020

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CHALMERS

Master thesis spring semester 2020

Institution:
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Chalmers University of Technology

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Master's program:
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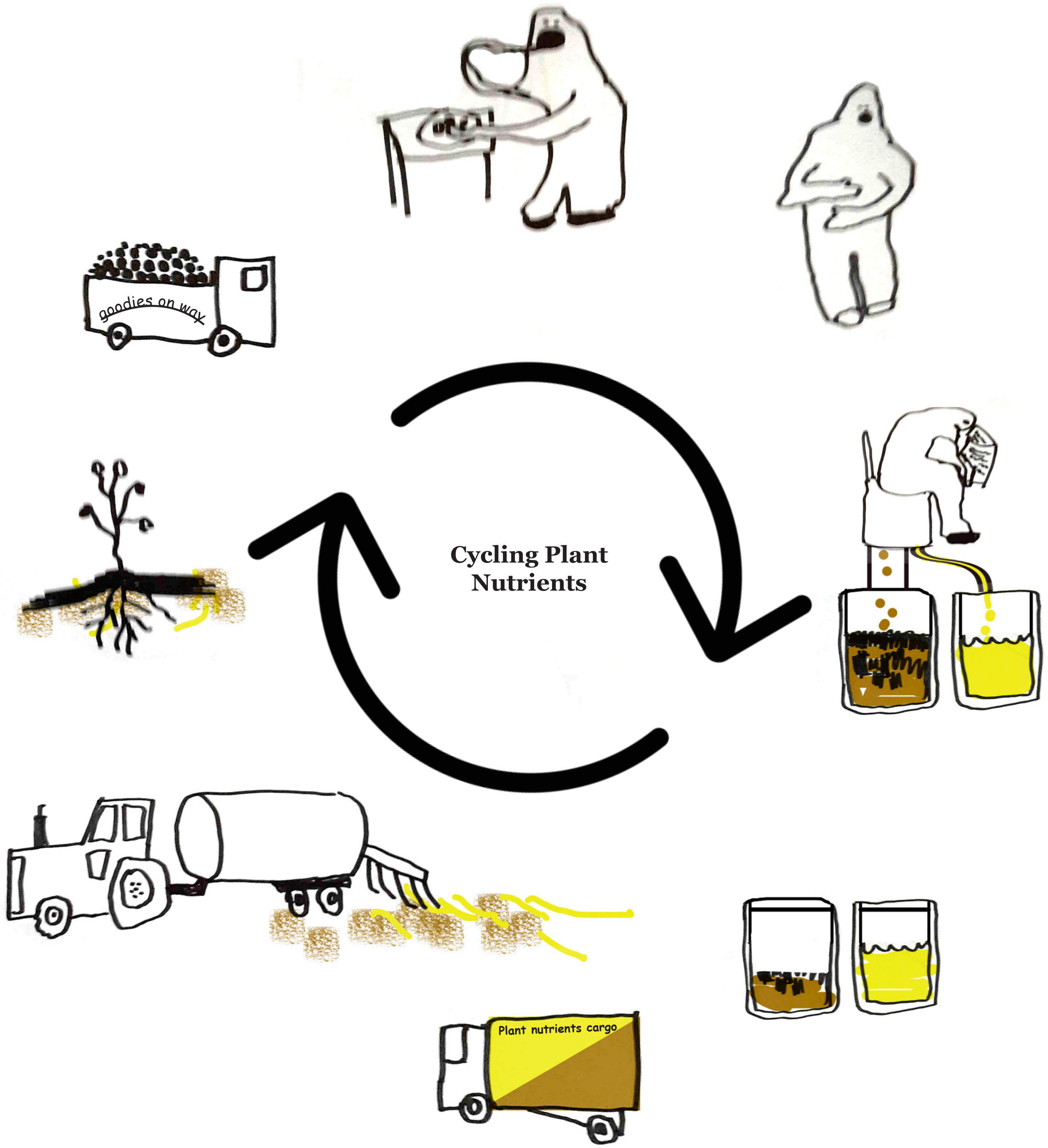

Abstract

One task for architects in the 2020s, a decade for climate crisis action, is to find sustainable recycling-systems that reduce the amount of waste and maximize the benefits of given resources. Sound and safe, resilient food production that feeds the growing population of this planet is a challenging task that architects may not solve but may help utilize the tools for the solution. Efforts have been made to source separate household waste, but when it comes to the cycling of plant nutrients from human urine and faeces, very little has happened. Agriculture is depending on synthetic fertilizer, which is not only an unsustainable product but also degenerates the soil's natural capacity to cycle nutrients and binding carbon. The use of drinking water as a means of transport for human waste is a massive waste of resources and complicates the recycling of plant nutrients. This project aims to explore the societal, mental, and spatial obstacles of a recycling toilet system. It intends to present a functional and socially accepted recycling toilet house. Through a collection of prototype user experience data in a student housing building, informed design strategies may be worked out. Which, in turn, will be put in practice within the design task. This thesis's primary research question is: -How can a small toilet house be a tool to raise awareness about the N and P nutrient cycles. What has been evident in the project is that alternative toilet systems raise much attention and emotions, enthusiasm, and doubt. The intimate and private nature of the act of going to the toilet cannot be underestimated. Functional technical and user-friendly solutions for recycling toilets exist. There are ongoing projects in Sweden that explore big-scale implementation today. Still, there is little written about the perspective of architecture in the field of recycling urine and faeces, although it is a recognized relevant field. To find long-term sustainable solutions, an unassuming dialogue between users, technicians, and designers are fundamental. That is what this thesis wants to explore.

Keywords:
recycling toilet, plant nutrients, compost, nutrition loop, source separation, resource management, ecosan

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Jessica Byström
Daniel Bävernäs

Victor Hugo in Les Miserables, 1867

*"The present system does harm in attempting to do good. The intention is good, the result is sad.
Men think they are purging the city; they are emaciating the population…
A sewer is a mistake."*

Table of Content

Reading instructions:

This booklet is divided into chapters as stated above; there are sub-paragraphs that goes into more detail in some chapters. It starts with an introduction, method and background chapters, here one can read about previous research in the field, relevance of the topic, and practical experience from built examples. The following chapters; In real-life testing and Recycling Toilet Showcase Pavilion, is describing the design process with its preparatory prototyping executed in this thesis.

Words, expressions, and abbreviations:

Recycling Toilet- a toilet that enables local recycling of plant nutrients

WC- the term used for business-as-usual water flushed toilet

WWTP- Wastewater treatment plant

UDDT- Urine diverting dry toilet

Composting Toilet- misleading term, most toilets do not in themselves create compost

N- nitrogen P- phosphor K- potassium

HSB ll- HSB Living Lab

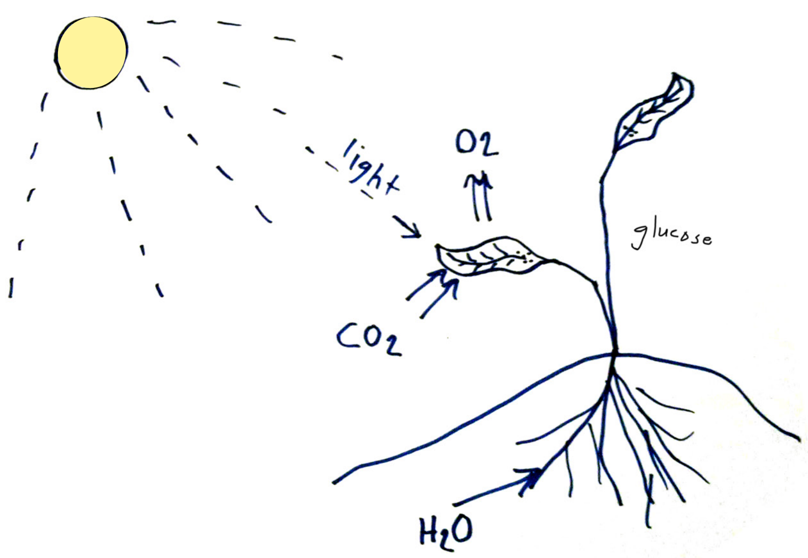
Introduction:

Problem statement
It begins with N and P

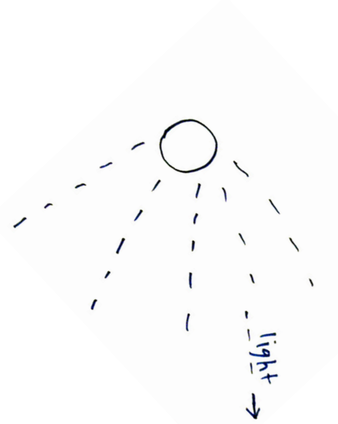
One might say that the original energy source on this planet is the sun. Through photosynthesis, this energy is harvested. Sunlight, water, and CO2 become O2 and glucose; this is how the chemical flow is usually explained. However, if one looks a little closer into the photosynthetic process, one sees that N and P play an essential part too. They work as distributors of energy, and without them, there would be no plant growth and no energy harvesting.

PHOTOSYTNTHESIS as it is often depicted

SUN



A more complex system



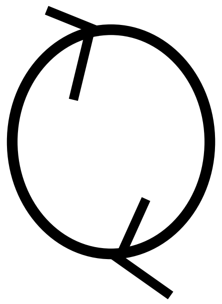
sun light excites the molucyles in the leaves

: Nitrogen and Phosphorus is required

enables conversion of solar energy to glucose

becomes charged:

ADP and NADP->->->->->->->->->ATP and NADPH



Using the energy from those two molecules, the Calvin-Benson cycle makes three-carbon sugar phosphates from atmospheric carbon dioxide

Nitrogen and Phosphorus in Crisis

Stockholm Resilience Centre is clearly stating that the flow of P and N are overexploited resources, as shown in the diagram below.

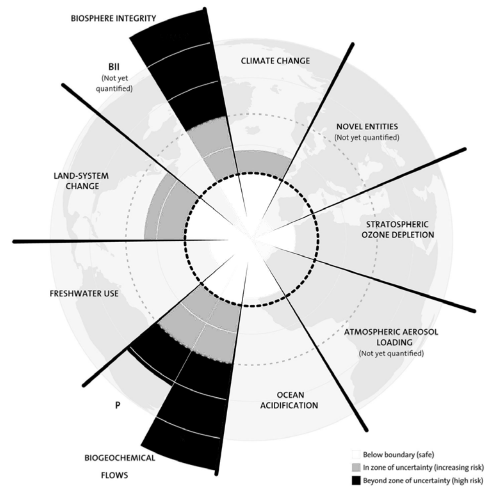


Image No.1 Planetary Boundaries

Energy in crisis

The use of fossil fuels has been, from a historical perspective, a kind of "doping" to the economy that has driven an unprecedented economic, industrial, and innovative boom over the last 100 -150 years (Aleklett, 2016). It has, not only brought massive emissions of CO_2 to the atmosphere but also enabled the incommensurable change in agriculture through synthetic fertilizer (Smil, 2005). Global warming, extreme weather, and natural disasters are increasing in frequency and are getting worse due to the emissions of greenhouse gases from human activity (Bush, 2020, p50). Human societies around the planet face climate change in one way or another, it is fair to call it a global climate crisis. The 17 UN 2030 sustainability goals state the problems and the actions needed to be taken in order to prevent an escalation of the crisis in the global climate crisis (United Nations [UN], 2015).

Architecture, Agriculture, food production and fertilizer

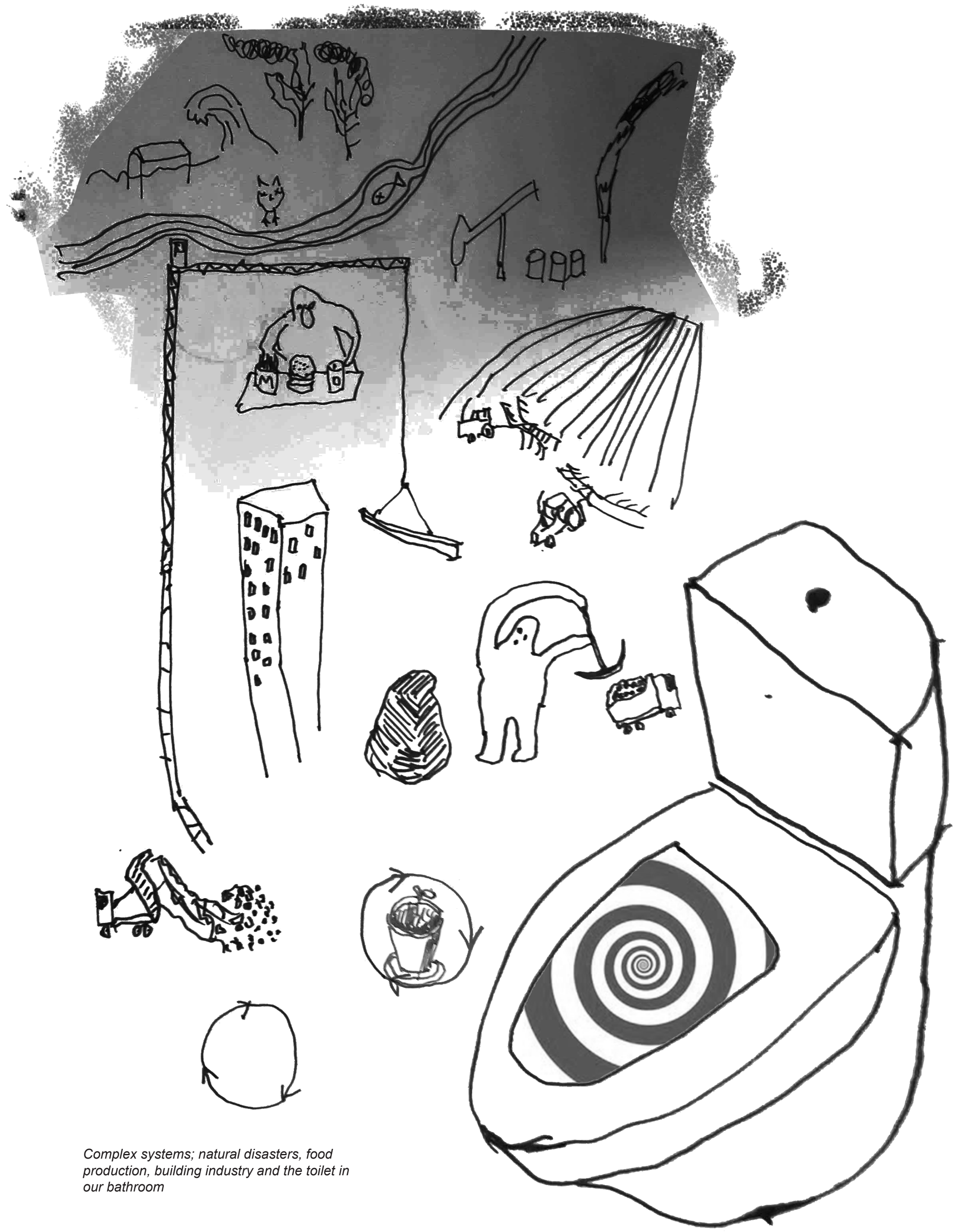
The 17 UN 2030 sustainability goals and planetary boundaries give a framework for this thesis wherein the work of architecture may play a role in the transition towards a sustainable future. Goals no2, zero hunger, no6, clean water, no9, industry, innovation and infrastructure, and no12, responsible consumption and production are four goals this thesis is touching in one way or another. To reconnect a mental bond between people and the food they eat is a delicate and peculiar challenge. According to Cordell (2013), this reconnection has to be safe, functional, clean, usable, accepted, and local. To find ways to, in a systematic manner, recycle plant nutrients back from human waste is a question the planners, engineers, and architects have to deal with in one way or another.

Sanitary-recycling and sewage systems

Urban sanitation with WC and pipes to a WWTP is a delicate way to disguise an unpleasant problem. Creating an illusion; as by a stroke of a magic wand, making waste disappear, and leaves the user at peace at heart, with the sound of pouring water in the ears. Nevertheless, we're creating an even bigger problem when we mix all kinds of wastes and collect it into the WWTP (Cordell 2013). It is hard to clean out all different sorts of dirt and chemicals from the water. The sewage treatment plants are designed to take out solid waste, typically carbon in the form of toilet paper and faeces, phosphorus, and nitrogen. Only a fraction of the total N and P are recycled as plant nutrition. The process of cleaning out nitrogen is to turn it to N_2 gas to the atmosphere. The carbon is often rotted in a reactor chamber to extract biogas as a fuel. Phosphorus is recycled from the rotted sludge as a soil conditioner. The sludge is, however, often highly contaminated by metals such as cadmium. (F. Persson, personal communication, Mars 9, 2020). This method does not provide satisfactory cycles for N and P and leaves us dependent on chemical fertilizer, which, in turn, is based on finite and fossil recourses. This thesis, therefore, looks to explore new sanitary systems that enable closed loops of nutrients from the toilet and back to agriculture.

Relevance

There are many ways recycling sanitation could be done, and there are already working examples. What could not be found in the written sources was a source exploring the recycling toilet systems from an architecture point of view. How are the buildings going to be adapted to this new reality, and how does human interact with ditto. This thesis is an overarching investigation that touches on technology, engineering, and planning but wants to focus on architecture and the user experience. It aims to discuss why this recycling toilet waste raises such great feelings among many, feelings of disgust towards the essential natural life-giving cycle, that of; nitrogen phosphorus and potassium. Later in this thesis, there will be given examples of where alternative sanitation systems have been executed in Sweden and elsewhere.



Complex systems; natural disasters, food production, building industry and the toilet in our bathroom

Personal statement

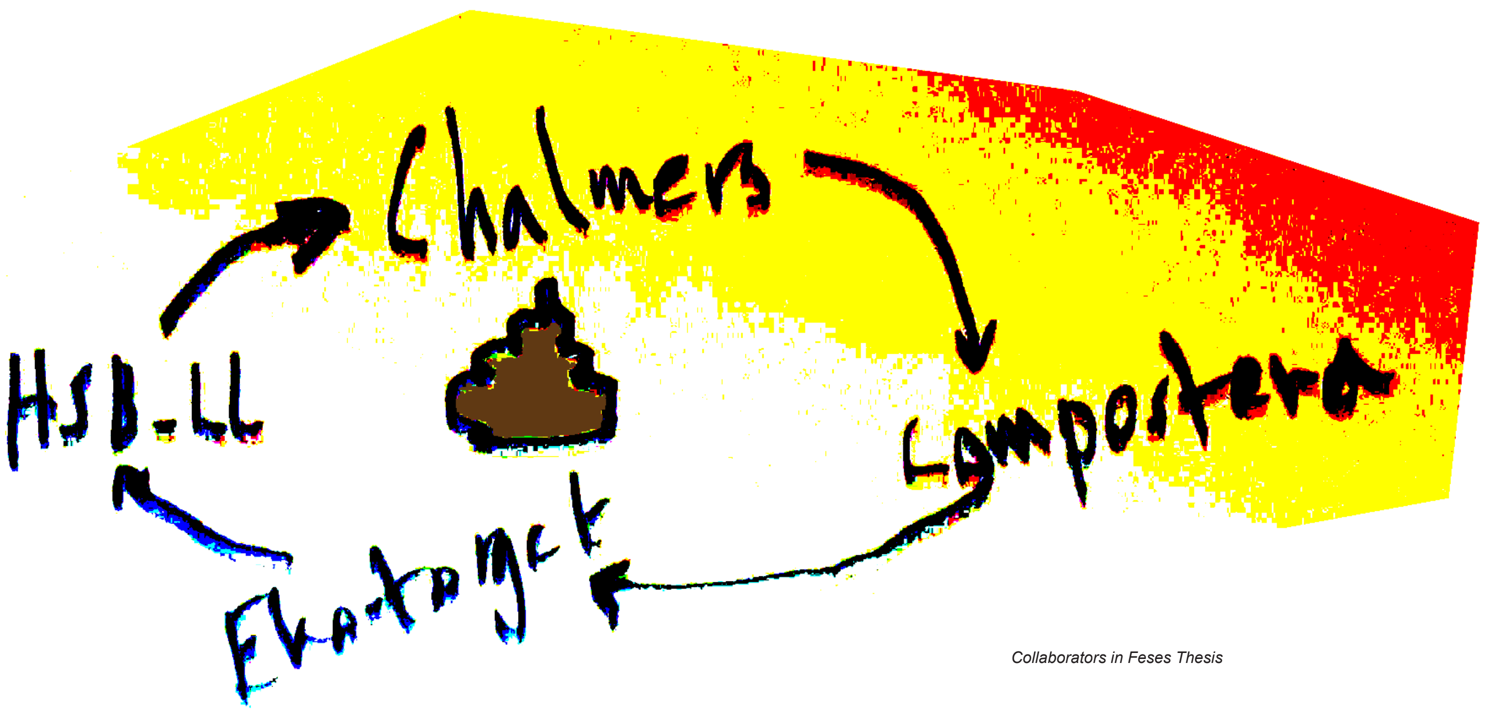
The world is facing one of the biggest threats to human life as we know it in climate change. All over the planet, there are consequences of climate change that can altogether be called nothing but a global climate crisis. This situation is challenging and questioning. It is, in many ways disqualifying our ways of leading our lives in a capitalistic society. It is a complex problem, we have created, and therefore, it can only be dealt with on a big scale. Every attempt to nudge and tweak towards sustainability within business-as-usual is like treating the symptoms but feeding the illness. Local cycling of nutrients from human feces and urine back to agricultural land is a way both to increase the resilience in food production but also a way to enhance the biological diversion in the soil itself and consequently multiply the soil's ability to bind CO_2 from the atmosphere.

Aim and Purpose

This thesis wants to explore the recycling toilets potential as a functional, educational, and curious piece of architecture. One that makes people more aware of the cycle of N and P. Hopefully; this can illustrate the connection between architecture, local food, plant nutrient, urine, faeces, and sustainable N and P cycles.

Main research question:
-How can a small toilet house be a tool to raise awareness about the N and P nutrient cycles.

Secondary research questions:
-How does the Recycling Toilet affect the user experience, and how can it be emphasized?
-In what way must the architecture be adapted to the chosen recycling technology?
-What is an adequate design of a recycling toilet in terms of fulfilling the expectations of the user?



Collaborators in Feses Thesis

Method

Architecture of Extroversion
Through a collaboration between an Ecological-product-expo called Eko-torget in Ockelbo, the compost toilet company Compostera, an innovative student housing in HSB living lab, and the Chalmers University of Technology,(represented by the author,) this thesis wants to practice an extrovert method of architecting. Extroversion means a compassionate and responsive to the different stakeholders and future users method. Trough curiosity and openness towards a variety of interests, a compound whole is created, which aims to make the project more substantial and more resilient over time.

A broad, unexplored, multidisciplinary field
According to the literature searches, it seems like the field of circular N and P and architecture is, to some extent, an unexplored niche in academic research. Consequently, the scope of this thesis became broad. The subject's interdisciplinary nature covers microbiology, sewage treatment technology, history of ideas, the social sciences, and design and architecture. In order to overview this field, a variety of methods were executed: case studies, historical studies, explorations of current technical solutions, prototyping, and real-life design.

Faeces Thesis covers a variety of research phases:

-Theory and Historical background
This investigation intended to understand how the WC came to dominate human waste management and how other types of toilets utilized N and P loops. Further, this chapter wants to give an overview of recent research in the field. In order to anchor the design project to the research and explore what the researchers are saying needs more attention.

-Examples
To get to know how recycling toilets systems are implemented today. There are several examples from Sweden and one from China with Swedish connections.

-Architecting
By designing a small public toilet house in Wij Gardens, Ockelbo, this thesis aims to find a suitable sanitary solution that showcases and promotes recycling of N and P from human urine and faeces. It wants to make people aware of the problems of wasted recourses in a WC and evoke interest in recycling toilets. The location in a famous garden and a mixed uses program helps to tie the parts together.

-Prototyping
Due to limited relevant research, the thesis must include a prototyping phase of it's own. To collect user experience data and get hands-on experience of one type of recycling toilet, a prototype that can be integrated into a typical bathroom was developed. Collaborating with Compostera, designing a smaller version of their toilet, and installed it at HSB ll. This prototype is intending to collect feedback from users and to get the opportunity to test the interface. Data collection from interviews and questionnaires are the methods.

-Delimitations
This master thesis is limited to the exploration of the enabling of safe recycling of N and P from human urine and faeces. The user experience of the recycling system is a critical factor in this exploration. It is not the aim to evaluate or develop different technical recycling systems, though understanding the basic principals and underlying logic is essential for this projects' successful execution. It is not in the scope of this thesis to explore how to apply the urine and faeces safely on agricultural land; it is neither intended to explore strategies on how to save or clean up water.

SWEDISH WASTE DATA:

466 KG HOUSEHOLD WASTE PERSON/YEAR

11000 L (KG) WATER FLUSHED DOWN THE TOILET PERSON/YEAR

500 L (KG) URINE FLUSHED DOWN THE TOILET PERSON/YEAR

50 KG FAECES FLUSHED DOWN THE TOILET PERSON/YEAR

source:
Avfall sverige, https://www.avfallsverige.se/kunskapsbanken/avfallsstatistik/hushallsavfall/
Svenskt vatten, https://www.svensktvatten.se/fakta-om-vatten/dricksvattenfakta/

Theory and Historical background

What is the current state of relevant research?

The field of eco sanitation and nutrient recovery is well established in research. For the most part, it goes into the field of biology, environmental sciences, and chemistry. Subjects commonly covered are; tweaking of business-as-usual WWTP, source separating systems, UDDT and dry toilets, hygienising of source-separated urine and faeces and how to apply it in agriculture and the concerns about the over-fertilized Baltic sea. Some research has been done regarding behavioral patterns and user-attitudes towards alternative toilet systems. In the following paragraphs, a few research examples are briefly explained:

In order to explain where the current research in eco sanitation is going Simha and Ganesapillai (2016) explain it like a shift of focus "from the split-stream collection and reuse- to the split-stream collection, resource recovery, and safe reuse..." The research is moving towards how to hygienize the diverted urine, to enable safe recycling, instead of just implementing diversion, claims Simha and Ganesapillai (2016) in their literature study. An ideal toilet system to them would be an automatic system that safely recovers the nutrients from urine, but at the same time, reduce drug residues and pathogen contamination. Lastly, they stress that the tools that come out of this recycling method-development must not be technological but low-tech, straight forward, and adaptable to a design people can appreciate.

Cordova and Knuth (2005) describe a successful process of implementation of dry sanitation in different peri-urban sites in Mexico. Here they are talking a lot about the social acceptance of the dry toilet systems. The factor that was most important to the user experience was that the users themselves were involved in the process of choosing a sanitary system and did themselves take both the initiative to prospect an alternative toilet system and the final decision to install the toilet. To feel that one is in control and that there is an active choice to have a dry toilet meant a lot to these people. Consequently, the implementation of the new toilets happened over many years. The only place where the users were not as satisfied was where they did not get to choose.

McConville, Kvarnström, Jönsson, Kärrman, and Johansson (2016) is writing an article and gives an overview of where Sweden is positioned in these questions. They claim that there is a lack of interaction between business, entrepreneurial experimentation, and academia. Lack of interest might have to do with the fact that the price of fertilizer is still low.

Design and user perspective are neglected

The author of this thesis has not found many specific writings of sustainable sanitation from an architectural point of view. That is a pity because the user interface and design of a recycling toilet may very well be a key to its successful implementation, function, and social acceptance. The common conclusion one can draw from the three texts is that technology is just one half of the solution; user acceptance through design and usability may be equally important.

Choice of words

It is confusing to read about this matter because there is no consensus in the words and names that describes a toilet that enables the recycling of human urine and excrement. There is the broader concept of EcoSan, short for Ecological Sanitation that most often refers to projects in developing countries. The names used for the toilet itself are Composting Toilet, Dry Toilet, Urine Diverting Dry toilet, Dry Sanitation. Hill, Baldwin, and Vinnerås (2012) is discussing whether the more common term in America, Composting Toilet is a misleading name since most toilets do not compost the urine and excrement at all. Instead, the faeces need to be after composted in a separate container in order to get rid of pathogens. They claim the British name dry toilet is a fairer name to what the toilet performs. This thesis is not happy with any of these names and has a name suggestion. The name is Recycling Toilet. Recycling is a strong word that gives positive connotations and points out that it enables recycling of nutrients. Toilet connotates safe and dignified sanitation. Hopefully, using this name, circular use of P and N can go together with the broader concept of a circular economy.

Peaking phosphorus and leaking nitrogen

A major achievement of the industrialization era was how to produce synthesized ammonia used as fertilizer and in bombs. The so-called Haber- Bosch- process fixate nitrogen from the atmosphere and make it accessible in ammonia liquid (Smil, 2005). Combined with pesticides and refined crops, it has made modern agriculture the mega rationalized industrial business as we know it. It is not big machines that made the difference that enabled the food-producing part of the population to drop from 50% to 2% in a century, but the nutrient doped soil. Subsequently, the human population has grown exponentially in this same period. Now we are facing some serious problems regarding this unrestrained growth. The phosphorus used in Europe is mainly mined in awful opencast mines located in, by Morocco occupied, West Sahara. It is a finite resource and will eventually their. This scenario is called peak phosphorus, and scientists argue whether it will happen in 10 or 50 years. What is clear is that mined phosphorus will not last forever, while recycled phosphorus most probably will. The nitrogen that is extracted from the air, at the expense of extensive amounts of natural gas, without it, almost nothing can grow. However, if used too generously, it may leak into sensitive biotopes and upset the biological balance. In other words, it is not good to continue using fertilizer the way we do today.

Already back in 1971, Professor R.A. Olson was a little bit concerned about nitrogen leaking out in nature (SIDA, & Food and Agriculture Organization of the United Nations (FAO). 1971). Olson underlines the great benefits of the new farming methods, how it helps to feed more people in developing countries; this is an example of how naive experts where. Today it has been proved that this was not the whole story; the transition to fertilizer farming with associated crops has sometimes resulted in a reduction of the food production and sometimes led to growing of crops for export instead of for the domestic market. The need to find local loops for plant nutrients is urgent. In this sense, food production, human urine and faeces, and the production of architecture are interconnected and highly political.

Resilient food production demands decentralized sanitation systems

According to Cordell (2013), is phosphorus the secret ingredient that makes plants grow. Isaac Asimov put it like: phosphorus is “life's bottleneck.” For phosphorus, there is neither substitute nor replacement, says Cordell (2013). By this, Cordell underlines the severe situation peak phosphorus is bound to be. Therefore Cordell is lastly addressing the issue of wasted nutrients flushed away in the WC. She claims that to reach secure phosphorus cycling, a high recovery rate will be required of about 3 million tonnes P per year (Cordell,2013). To achieve this, she states that the most effective way is to create decentralized sanitation systems.

Gothenburg's 19th century recycling system

The sanitarian situation was horrible in the city of Gothenburg, from its very foundation in 1621 until the middle of the 19th century. There were no central systems for managing neither waste nor toilet waste. Both fractions were dumped in the channel, which sadly also served as a water reserve for the town's inhabitants. However, in the mid-19th-century, things began to change for the better. The understanding of the importance of hygiene in order to limit the spreading of diseases paved the way for some organizing up in the handling of waste in Gothenburg. An intricate recycling system was developed, ambitious in its scope of turning waste into a resource (Wetterberg & Axelsson, 1995). The faeces and urine where collected in standardized dry toilets. It featured a pull-out collection vessel with rails to facilitate smooth emptying. Everything was transported to a plant by Gullbergsvass, where the material was dried and ground. After the refining process, the old shit was sold as plant nutrients under the product name Pudrett.

The ideology of WC and the Wizzard of crap

When the Swedish welfare state was built in the early 20th century, the authorities found the idea of recycling very outdated. Recycling was not as profitable as they first thought it would have been. The belief in progress, technology, and economic growth was enormous, Sweden lifted itself to an industrialized nation. It was a great achievement which helped many people to get better lives. Consequently, the view on nature was that it existed for man to exploit it, and the best way to handle waste in that scenario is to dump it out of sight. The sewage system was expanded, and the WC was approved in Gothenburg 1917 (Göteborgs Stad, 2020). The waste ran again, unfiltered out into the river Göta älv. Big dumps outside of the city where established. This reckless exploiting of nature goes hand in hand with the logic of everlasting growth, where the WC makes the waste go away, as by the stroke of a magic wand (Shizek, 2009). The “Wizard of Crap” was invented. The visual illusion of hygiene and sterile cleanliness got in the way of recycling.

“Carbonic acid, water, and ammonia contain the elements necessary for the support of animals and vegetables. The same substances are the ultimate products of the chemical process of decay and putrefaction.” -Justus von Liebig, 1843

The biochemical cycle

The “father of the fertilizer industry” Von Liebig (1843) was one of the first who already in the mid-19th century begun to give a coherent image of the biochemical cycle (Smil, 2005). The understanding of how chemical elements work in the biological cycle came hand in hand with how they can be manipulated to achieve a much-in-creased plant growth. The discoveries of von Liebig are explained in the somewhat alchemic quotation above. The mysterious connection between decay and rebirth that von Liebig discovered is implicitly telling us that human urine and faeces through the natural process of composting becomes the ultimate life-giving plant nutrient. Urine and faeces can, through the natural processes of composting, be purified from pathogens, and provide a safe and long-term sustainable plant nutrient needed to feed a growing population.

Examples

In order to understand what is, and has been, going on recently in this business, a few different cases of alternative, recycling enabling, sanitation systems where examined and analyzed. It is mainly from a Swedish context since it feels like a small boom here, although it is one example from China but with Swedish collaborators.

Hölö hygienization plant, Södertälje Kommun

The Baltic Sea suffers from overfertilization, so it has been the case for a long time. Dead seabed's spreads over vast areas. According to WWF (2020), the greatest thief is agriculture but also small sewage systems. Södertälje Municipality that is located in between a big lake and the coast decided they wanted to do something about this problem, especially since the many small houses and summer cottages around the rural areas and the archipelago have septic tanks that are leaking N and P into the sea (Kärrman, Kjer-stadius, Davidsson, Hagman, & Dahl, 2017). Therefore the municipality declared 2009 a local policy to promote recycling toilet systems in the places where now individual sewage was in use. They gave the task to the local municipal energy company, Telje Nät, to prospect the building of a recycling plant somewhere in the municipalities' rural area. The chosen technique was a separation and collection system where the toilet waste, through a vacuum system, was stored locally in closed septic tanks, separated from greywater, in the individual house properties. The tanks are emptied with a sludge vehicle and transported to the plant. The plant was located on a farm. The toilet water was cleaned from vectors, such as E. coli, through a hygienization reactor that combines bacterial wet-composting, stirring, and chemical urea treatment. The process takes about 14 days. The treated toilet water is used locally on the farm as plant nutrition. The toilet water treatment plant handles 1500m3 a year, and the system is built to serve about 100 households and approximately 500 people. This plant is a small one and was realized through external governmental funding. It provides a medium-sized farm, of 40ha cereals, with plant nutrients. The individual house owner had to pay around 200000kr for the toilet-system, according to Dackebro (2012).

Reflections:

The system enables local recycling of plant nutrients, but a vacuum system is costly for the individual house owners. The straightforward hygienization method does not use many chemicals, but mostly natural bacterial digestion. The hygienization is relatively fast. The dialogue with the house owners seems not to have been optimal. The cost for them was way higher than to install a small-scale chemical nitrogen precipitate filter. The safe, local recycling of N and P is prioritized, and the introduction of a vacuum toilet only affects the bathroom's user experience.

Image No.2 Hölö compost reactor

Munga, Västerås

The municipality of Västerås formulated 2013 a policy towards promoting circular sewage solutions, recycling nitrogen, not only phosphorus, in the situations where it was technically and economically viable. The first case this came in question was Munga; it is a summerhouse area that is turning in to more and more permanent settlements. The too many individual sewages in a too-small area threatened to contaminate the drinking water. The municipality considered connecting the area to the central sewage system but decided to try another solution. In contrast to Hölö, Munga choose not to change the bathrooms with vacuum toilets but instead install pump stations at every property. This intervention resulted in a so-called low-pressure system. It is separate pipes for toilet water and greywater, which makes collecting toilet water possible. The area consists of 279 properties and is considered a comprehensive project (Kärrman et al., 2017).

Reflections:

The system with double pipes and pump-stations at every property became expensive for the homeowners. They paid for the system to a large extent themselves. There were no changes inside the bathroom, which made the implementation smoother, and the user cannot tell the difference from before. This system is not saving water but enables the recycling of plant-nutrients on a community level. The toilet-water is not treated in any other way than storage; they let it sit in a pit for one year before using it on the fields. The similarities between Hölö and Munga are the circumstances, but the choice of technical solution sets them apart. Hölö has a high-tech approach with vacuum toilets and a wet-compost reactor treatment plant, Munga keeps the WC and uses an old-style manure tank for treatment. The former saves water, is faster, and gets a more concentrated plant nutrient liquid, while the later assumably holds a lower initial investment cost for the treatment facilities. The Hölö system needs emptying now and then, while Munga has close to unlimited capacity.

Image No.3 Munga manure tank

Ordos, China

In the Noth of China, in the region Inner Mongolia, there is a city called Ordos. It was finding itself in a coal mining boom in the early 2000s and was subsequently building plenty of new housing. Inner Mongolia is in a high inland condition, arid climate, cold winters, with a scarcity of drinking water. This basis leads the way to the idea of constructing a water-saving eco-residential area. Swedish scientists from the Stockholm Environmental Institute got involved in the project and suggested a UDDT system, inspired by the Gebers co-housing example. The project went wrong already in the construction phase because the workers did not have enough competence to execute the intentions of the dry toilet system. The whole time, from 2006-2009, there were problems with smell and lacking ventilation. The project was covering some 800 apartments in four and five-story buildings—the dry toilets utilized vertical shafts with separate pipes for urine, faeces, and ventilation. Later, everything was collected, composted, and used as plant nutrition. After all the trouble, most apartments got WC. Only a few got a small bucket-kind-of dry toilet, which worked better. The booming economy transformed the poor old Ordos into one of the wealthiest cities in China, and the dry toilets were not a great fit into the image of the newly rich. In the end, the government built a 170km pipe from the yellow river to provide the city with water, which further decreased the interest in alternative toilet systems (Han, Rosemarin, 2013).

Reflections:

The project was too big for experimenting; the workers lacked experience in this kind of construction because something similar had never been built before. It is better to start with something small-scale to prove the functionality first. The local recycling of plant nutrition did work, though; the farmers were more than happy with the manure. According to Scott Chen, the agricultural produce where many times increased (PRI, 2011).

Image No.4 Ordos multi story compost toilet building

Daniel Bävernäs

Outside of Alingsås, in the rural woodland, Daniel and his partner have built their own house according to permaculture ideals. They grow much food and tries to do it in line with natural biological processes. The house itself is insulated with straw and finished with clay. In this house of natural materials and processes, nothing is going to waste, and therefore Daniel has installed UDDT in his bathroom. After one and a half years of usage, Daniel is altogether happy with the choice of a toilet. The most significant flaws he can mention is the occasional appearance of flies in the toilet, and at times, the urine diversion has not worked as intended. Daniel has now changed the urine diversion system, so it does not leak, and also changed the emptying door to make emptying more convenient. The first emptying from the toilet into an after-compost bin happened recently; it may stay for at least one year. Then it is ready to be used in the garden. Daniel says he is pleased with his toilet, and he thinks that urine diversion is the best way to go if one wants to recycle plant-nutrition (personal communication, D, Bävernäs, April 15, 2020).

Reflections:

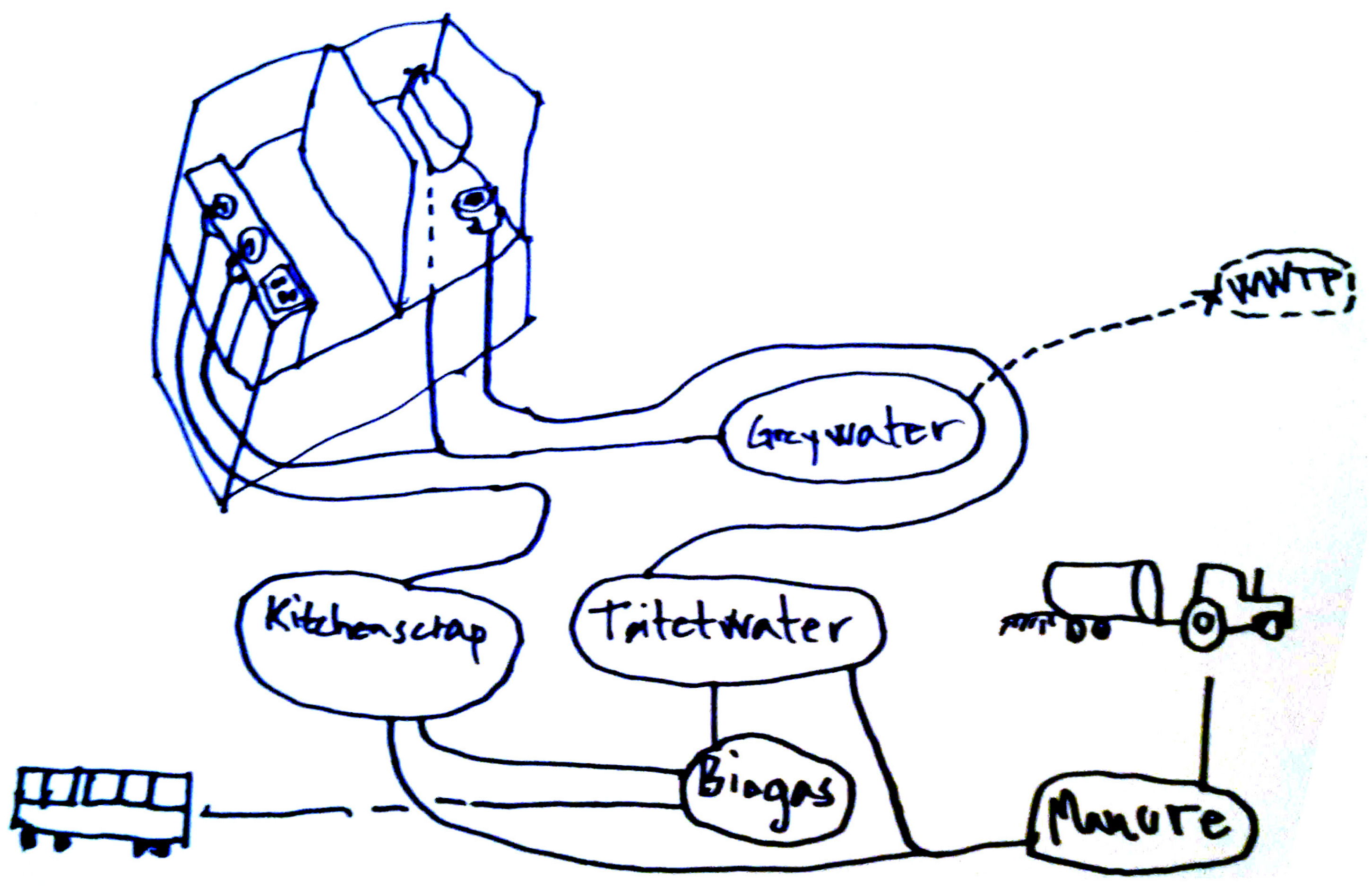
Out of all the innovative and alternative methods this house is constructed out of, such as rammed earth, clay, straw, and permaculture design, the most radical device to many people is the choice of the recycling toilet, according to Daniel. Again, it seems like it takes a dedicated individual to manage this kind of system. The incitements for a push towards a broad implementation of recycling toilets are not there yet.

H+, Helsingborg

The Helsingborg H+ city developing project is one example among many typical waterfront development projects in Sweden. However, there is one exception that makes H+ unique. They have chosen to invest in a high-tech three pipes sewage system instead of the conventional single pipe system. This type of investment is unusual and brings to the inhabitants' features like; bathrooms with vacuum toilets, in-pipe-kitchen grinders for food- and bio-waste, and ultimately the heat energy in the greywater is harvested through a heat-exchanger. Source separation gives a more manageable waste that is easier and more effective to use. According to Kärrman et al. (2017), does this separating system reduce N and P emissions to nature, mainly because the volume of toilet contaminated water is reduced. It makes cleaning much more effective. Which, in turn, raises the potential for safe reuse of nutrients in agriculture. The blackwater and biowaste are treated in a biogas reactor that produces biogas and compost. Kjerstadius (2017) stresses two aspects of this system; first, it produces more biogas. Secondly, the composted residue is a healthier soil improvement for agriculture than what the conventional WWTP produces. In this digesting process, plant nutrients become mineralized, which means they become accessible for plants. The mineralization is a crucial factor to reduce leakage of nutrients says Naturvårdsverket (2013, p14)

Reflections:

This type of infrastructure demands an initial higher investment but pays off eventually in terms of saved water and increased recycling of nutrients. The users need to adapt to the vacuum toilet but, at the same time, benefit from a kitchen grinder; they no longer need to go out with the bio-waste in paper bags. If a whole new residential area is planned, it seems to be an excellent and ambitious way to go.



H+ tree pipes

Gebers, Stockholm

Gebers is a former convalescent home is located in a picturesque setting by a small lake in the southern part of Stockholm city. It is since 1997 transformed into collective eco-housing. They have UDDTs. According to Kvarnström, Emilsson, Richert Stintzing, Johansson, Jönsson, Af Peters, Schönning, Christensen, Hellström, Qvarnström, Ridderstolpe, & Drangert (2006) there has been both positive and negative feedback from the users. Saving water is highlighted by most users as a desirable feature of the toilet system. Smell has not been a problem since the electrical fan is continuously sucking the air out through the toilet. In the case of a power failure, there might be a problem with smell. The problem that has occurred occasionally is flies. The fecal bins were emptied more often, to get the flies at bay, and ash was sprinkled over the faeces fractions to make it drier. Another problem reported by Kvarnström was the routine of cleaning the toilets. There was a strive to use little water, and therefore some users found it hard to keep the toilet clean. Other than these problems, the users were satisfied with the toilets. The maintenances routine they had to do themselves stretched to emptying the faeces bin once or twice a month. Urine is collected in a central container and used by a local farmer.

Reflections:

In order to make this toilet system work, it takes dedicated users. They maintain the emptying of the bins themselves. The people who live in Gebers have an earnest conviction to lead a sustainable life according to environmental concerns. Still, the system has been in use for more than twenty years and seems to be robust in that sense that it, in all its simplicity, works as an enabler of local plant-nutrient recycling. The system saves water since it only flushes a tiny bit of water in the urine bowl.

Gebers have a long drop toilet UDDT

Image 5. Gebers urine tank

Image 6, Gebers Faeces bin

Susedalen, Falkenberg

Between Falkenberg and Halmstad, along E4 motorway, on the west coast of Sweden, there is a service area called Susedalen. It is a water protection area where they installed dry toilets in order to save water and recycle plant nutrients. The system they choose resembles of the Compostera toilet. The faeces and urine go to the same container and are separated by a bed of peat and wood chips. This system did not work in this condition because it was under-dimensioned (Jansson & Magnusson, 2000). The police destroyed the filter bed since they dug around in it when they were looking for dumped evidence. Then the filtration did not work, and vectors were contaminating the urine. Later, when the filter bed was rebuilt, the vector contamination was low. The biggest problem with this layout was that there was no proper system for the recycling of urine and faeces. The idea was that a local farmer should use it, but it did not work, and, in the end, everything was transported to a WWTP.

Reflections:

The planning of the execution of the project was poorly planned and led to unnecessary disturbances in the implementation of the project. The uneven distribution of uses proved to be a weak spot for this type of toilet. The filter-bed is another sensitive aspect of the toilet that was not bulletproof; there is always a risk of mixing urine and faeces. Still, the toilet has many pros; water usage is zero, and when urine and faeces go in the same hole makes it easier to use; for example, there is no risk that things go in the wrong hole as it may in a UDDT.

Image 7, Susedalen toilet house

Image 8, Susedalen compost container

Public toilet in Susedalen

Conclusion Examples

A few essential principals on how to make a recycling toilet project work are articulated from the experience from the examples. These principals will later inform the design project of this thesis.

It demands extra effort, finance, and dedication to proceed with a recycling toilet project, regardless of its' scale.

A low-tech system may be resilient and safe, but it takes dedicated users to maintain it. It is therefore not realistic to think of it as a solution for the larger masses.

An important factor is the users' motivation and understanding of the benefits of a recycling toilet.

Closing the loop must be taken into consideration from the beginning. Collecting urine plus faeces, treatment, as well as agricultural application, are equally important parts. A plan how to handle the collected fractions is prioritized.

There is nothing that says that big-scale projects are not possible. However, there is a risk. Cutting edge projects is ongoing, but the scope of this thesis is better suited to evoke awareness. Lift the hippie toilet to the archi-drawing-room.

Wet composting is a useful method when it comes to transition towards recycling strategies. Ultimately, the use of water as a means of transportation may be unnecessary. In the design project, water will not be used to instead focus entirely on the N and P recycling.

Homeowners are generally positive about recycling and care of nature interventions but do not want to pay for the extra cost of a recycling system. Subsidies and public investments could be a way forward.

The high-tech solutions exist, like H+, but are still not common in use because of the high investments. They play an essential role as beacon projects, leading the way towards recycling.

This thesis does not have the competence nor the time to explore cutting-edge technology; therefore, it aims to focus on the soft aspects of recycling toilets, such as the user experience and user acceptance of recycling toilets.

HSB ll

In real life testing

The experience from the examples and the literature is useful in order to make informed and valid design decisions, but architecture is something that needs practical exploration. It was not much to hang in the Christmas tree from before; it seems like architects have not paid much attention to recycling toilets. There was a need to go out testing things in reality and talking to people about the matter. The built space is better explored built than imagined. Therefore this thesis one day trotted into HSB ll and started building. The overarching reason is to get as much data as possible before designing the Ockelbo showcase recycling toilet.

Now there might be a new wave upcoming of eco-sanitation that is in line with climate action. Many things are about to happen in Sweden regarding eco-sanitation, e.g H+. So since the consumer eco-toilet alternatives on the market are mainly targeting off-grid solutions or public installations, there is a lack of serious residential alternatives. Before one knows there might be a high demand.

Comostera is a company that produces a longterm composting toilet. The company was prompted because it is one of the few companies that communicate their product as a residential one. Efforts have as well been made to improve the user interface. For example, they have customized lights to eliminate faeces visibility, heated toilet seats, and a stool that resembles a WC-stool, i.e., close to the things that interest this thesis. It was agreed upon collaboration.

To ground this thesis in reality, a collaboration with business, was desirable. Compostera suggested a design project in Ockelbo, Gästrikland. An Eco-orientated display garden wanted a small toilet house where they could showcase the cycle of nutrients.

The focus of this thesis is the user perspective. With that in mind, it was decided to produce a prototype before settling for the final design. Therefore HSB-living lab was contacted and asked if they were interested in testing a toilet in their laboratory apartments. They were positive about the idea. The prototype was installed in a student housing corridor. Later a toilet was installed on a balcony. The Compostera toilet had to be heavily customized to fit in these applications. This particular toilet system had never before been tested is a multi-story apartment building.

Poster to tenants

Prototyping 1.0

One important reason to do this prototype was to get a deeper understanding of how the Compostera toilet works; what is the typical installation, and how can it be adapted? In dialogue with Maria and Carl, who work with the company, an idea of a downsized version of the long-term composting toilet took form. The system is a dry toilet, no flushing, and gravity to separate fluids from solid matter. It uses biological processes to slowly reduce the size of the faeces and convert the urine to a plant-nutrient liquid. The urine is collected in a separate container and needs to be emptied. The poop is collected in a big container and does not need emptying in many years, up to 30 years emptying intervals. The faeces are through composting reduced significantly in size.

The senses

The user experience of the toilet is thought through: The visible view of the faces inside the container is limited through a black fall-down, black container, and a small, upward facing, LED-lamp just behind the toilet seat enhances the blackness of the inside. The smell is managed through ventilation; the whole bathroom could be vented through the toilet. Touch is dealt through a heated seat; in case the toilet room is not heated, there is at least a warm seat. The sound is a slight hum from the vent fan ventilating the toilet, no pouring water.

In order to fit the toilet inside the bathroom, the bulky Compostera toilet required a makeover. A bench mounted toilet over a waste bin sized container could do the trick and avoid a total blow out of the bathroom. Both the containers of faeces and urine could fit under the bench. This type of toilet, naturally, needs to be emptied more often than the big one. To fit the bathroom of HSB ll, it had to be a maximum of 1x1x1m, high, width, and depth. The test period would last for about three months, and Maria from Compostera assumed a container of this size would be enough. The high seat requires a couple of steps for people to access the toilet, this is not good for wheeled people, but a compromise had to be done. The materials used were mainly recycled and reused building materials. For example, the faeces container was a second-hand standard trash bin. The choice of ceramic tiles and a ceramic toilet seat was made to enhance the feel of a clean and hygienic bathroom. The ventilation was plugged into the existing system. Everything worked very fine, and the toilet worked just as intended. It proved that it is possible to build recycling enabling local human waste treatment systems enclosed inside any bathroom. The problem was that the tenants were very skeptical and did not accept the toilet at all. No one used the toilet, and it had to be removed. This fact underlines the importance of a functioning user experience and a willingness, open mindset, and cultural acceptance of this subject.

Building a toilet

Container of choice
Used waste bin

Geotextile bag
to make a darker inside
reduce view of faeces

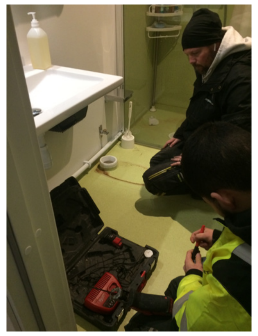
Bilge pump
Cusomized to fit in the bottom
of the container to pump urine

Used toilet
Sawed because only the rim
was used

Cover up box with
WC-rim

Tiles for freshness

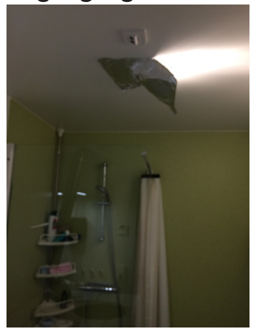
Remove WC and
Plugging the sewage



The box in place

Putting tiles upp

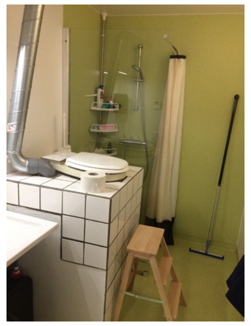
Managing light



Urine container

Plugging in on
existing ventilation

Finished recycling toilet

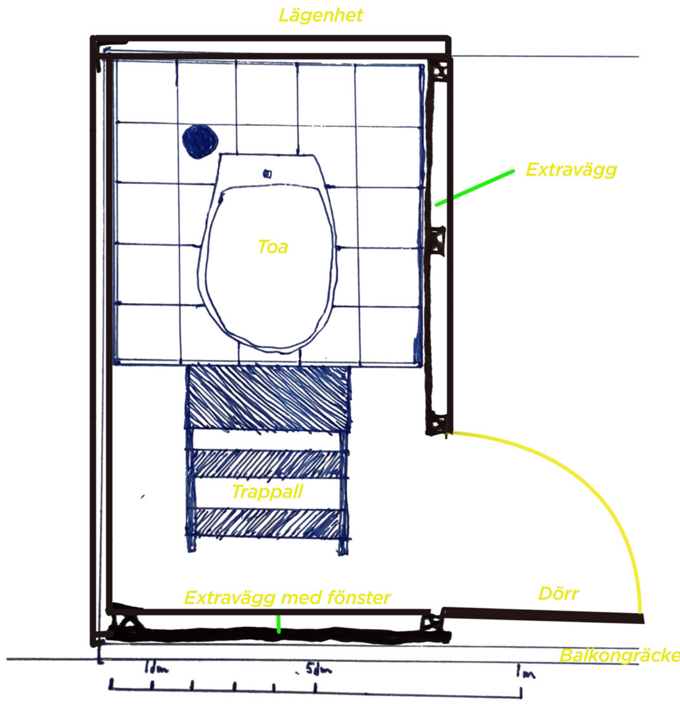


UNDERSTANDING THE TOILET
ADJUSTMENTS;
-INDOOR CONTAINER
-MORE COMPACT
-INTEGRATED PUMP
-ELIMINATE SIGHT
-VENTILATE THROUGH EXISTING SYSTEM

Initial ideas, communicated to tenants

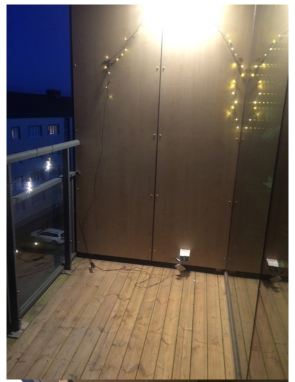
Prototyping 2.0

The second try at HSB Living Lab, the toilet, was relegated to the balcony of an apartment, which was about to get its bathroom done. This time thorough preparation and information were given to the tenants before starting. In interviews, they gave their view of how they wanted their toilet and gave input on how they preferred the design of the small privy on the balcony. They were naturally positive about the toilet since it prevented them from going to another apartment, on another floor, every time going to the bathroom. The first idea was to build a tent structure, but the tenants did not like that idea; instead, they wanted a solid structure that did not rattle in the wind. Hence the design was changed into a more classical privy-style, but with a window. This build used the same toilet as prototyping 1.0. A small structure was built around it; com-posed out of old and new material, the window, for example, was from an old boat. A questionnaire was given out to collect data from the users before the installation. An interview was executed when the toilet had been used for some months. With this information, the intention is to develop design strategies for how to proceed with a recycling toilet project in order to increase the recycling potential.



Developed proposal,communicated to tenants

Balcony toilet



The tenants decorated the toilet; cozy.

Summarizing Prototyping
The feedback collected in interviews can digest into something like; The toilet worked very well. It was smooth not to have to go down to another apartment to g to the toilet. Still, it has been a slight hassle and feeling of unease when there have been people outside on the street that could see when one goes to the toilet. Many people on the street have been curious about the “thing” on the balcony. Sometimes the users have chosen to wait five minutes in order for people to get off the street before they go to the toilet. The cold has as well been a discomfort though the heater has been a help. It has worked best when it has been on for a more extended period.

The act of not flushing was a bit strange in the beginning. It is something the users got used to, but they say that it still would feel natural to do something to “get rid of” the waste—for example, a crank or at least some bedding to throw after oneself. A more convenient way to put on the heater from inside would be appreciated, and the seat was too high. Space is a bit tiny, and the step was somewhat small was some of the comments.

The overall impression of the toilet is very fresh. It was only occasionally a bad smell, and it was probably due to strong wind that was too strong for the under-pressure in the vent pipe to handle. The waste has been visible for the users, and the intention to make it more invisible through the light setup and dark interior of the container has not helped. The tenants think it would be better if the waste could be more invisible, maybe through the use of bedding.

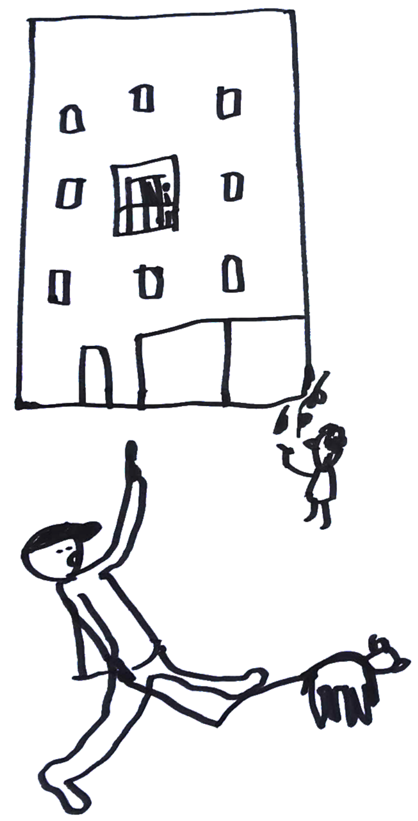
The most significant sacrifice was not to be able to wash with water and soap immediately after being on the toilet.

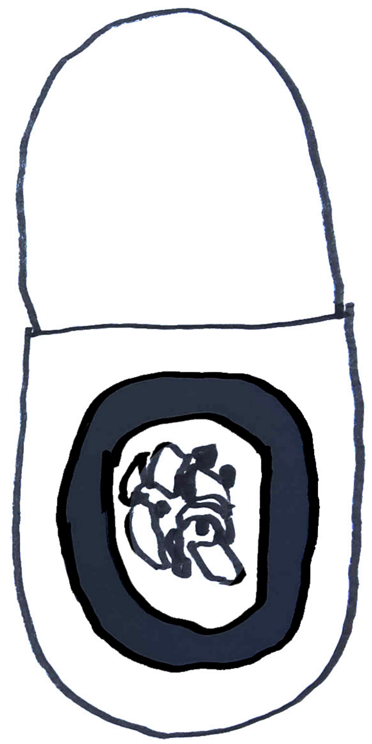
They appreciate the ceramic tiles on the toilet and the seat. It made the toilet more like a WC and gave a solid impression.

Feeling of exposure on the balcony and the lack of washing hands possibilities was the worst. Not have to go down to the other apartment was the best.

If someone else takes care of the waste and if it were part of a considerable investment for the whole neighborhood or a whole town, it would make more sense, which would be OK for the users.

One crucial motivation factor is what happens with the waste after it has been source-separated and collected; if one knows it comes to use, it is much easier to accept the extra effort, says one user.





Experienced inconvenience

Conclusion Prototyping

The conclusion is: the primary function, the faeces and urine collecting, aspects of the toilet worked well. Although the filter bed did not work as intended, the urine came out and did smell much old urine, not like the Compostera company claimed that it would be an odorless fluid. The smell inside the privy was not a problem, while insight was prominent. The balcony toilet was a compromise, and it was not good from a privacy point of view, it was cold, but it worked, partly because the users were very accommodating. Still, it does not replace the WC. It takes a dedicated user in order to execute a project like this. The pee was easy to get to use in cultivation. For the most part, used to load biochar, to apply it as a soil amendment. The use of char takes away the smell almost instantly. The shit is a bit trickier to handle. But it will stay in the bin for about one year with the sole addition of worms. Then it will compost completely, out-side in compost and after another year it can be used on the growing beds.

What to bring forward from the prototyping?

The down-sized Compostera-toilet did not work as intended; maybe it is better to have a urine-diverting toilet seat in this small scale application. One cannot stress enough on how the hand-washing capability is essential to the experienced level of comfort. The exposure of the entrance of the toilet is as well a key feature. The most crucial factor is the understanding of the users' perspective; most people have an understanding and a will to improve the ways we live, and to act against climate change, the only thing is that one needs to know why one is doing some things. The sacrifice might be worth it. Only one knows where, how, and in what way it makes a difference. Then it makes sense to make an effort.

What to do with the faeces and urine? Diverting or mixed?

The urine collected in the toilet did smell bad. The conclusion is that the filter mass was too small in order to clean the liquid properly. In the case of a small scale implementation, it is therefore suggested to use a UDDT. Where a bigger tank is suitable, it is recommended because it is more convenient for many people not to have to think about peeing and pooping in the right place.

Urine was used to load bio-char.

It is easier to accept something one understands

Recycling Toilet Showcase Pavilion

Understanding nutrient loop through play, education, and, architecture.

Design proposal for a toilet building at Wij Trädgårdar, Ockelbo

Cycle of plant nutrient, cycle of water, and, cycle of carbon.

Recycling Toilet Showcase Pavilion

The conclusions drawn from the research and prototyping imply that a source diverting toilet system is a way forward to obtain resilient cycles of N and P. Simultaneously, it is clear that more understanding, among many people, is needed before more general use of recycling toilets would make sense. To get there, architects, planners, and builders must understand why recycling is important and how the individual act of recycling benefits society as a whole. The toilet itself must reach an equivalent level of comfort as of a WC. Ideally, a recycling toilet adds architectonic quality, such as light and materiality. In order to implement this, the architect must not alienate the user. The user must feel that he/she is in control, and not forced to use recycling toilet.

Context

Eko-torget is an expo for eco-friendly products and building materials at Wij Gardens. Last year they exhibited the Compostera toilet and was impressed. Now when the municipality wants to build a new toilet house by the garden, they decided to go for the Compostera toilet. A dialogue with Yngve from Eko-torgen and Maria from Compostera followed about the needs and possibilities. Due to its location in the garden, it was agreed that the toilet-house had the potential to showcase the whole cycle of recycling plant nutrients. It seems like a garden is an ideal place for physically connect the growing of the edible plants with the toilet. The aim is to make children and adults aware of how safe plant nutrient recycling can be done and why it is important for food security.

Today the garden provides educational activities for pre-school groups, where they learn about cultivation. One idea is to include this recycling toilet as a pedagogical tool for explaining the cycle of nutrients. Therefore, Yngve, Maria, and Faeces Thesis came up with the idea to build a small greenhouse beside the toilet house. The cycle of water, nutrients, and plants can be showcased to the children in a very concrete way, during educational activities.

Ockelbo- Wij Gardens

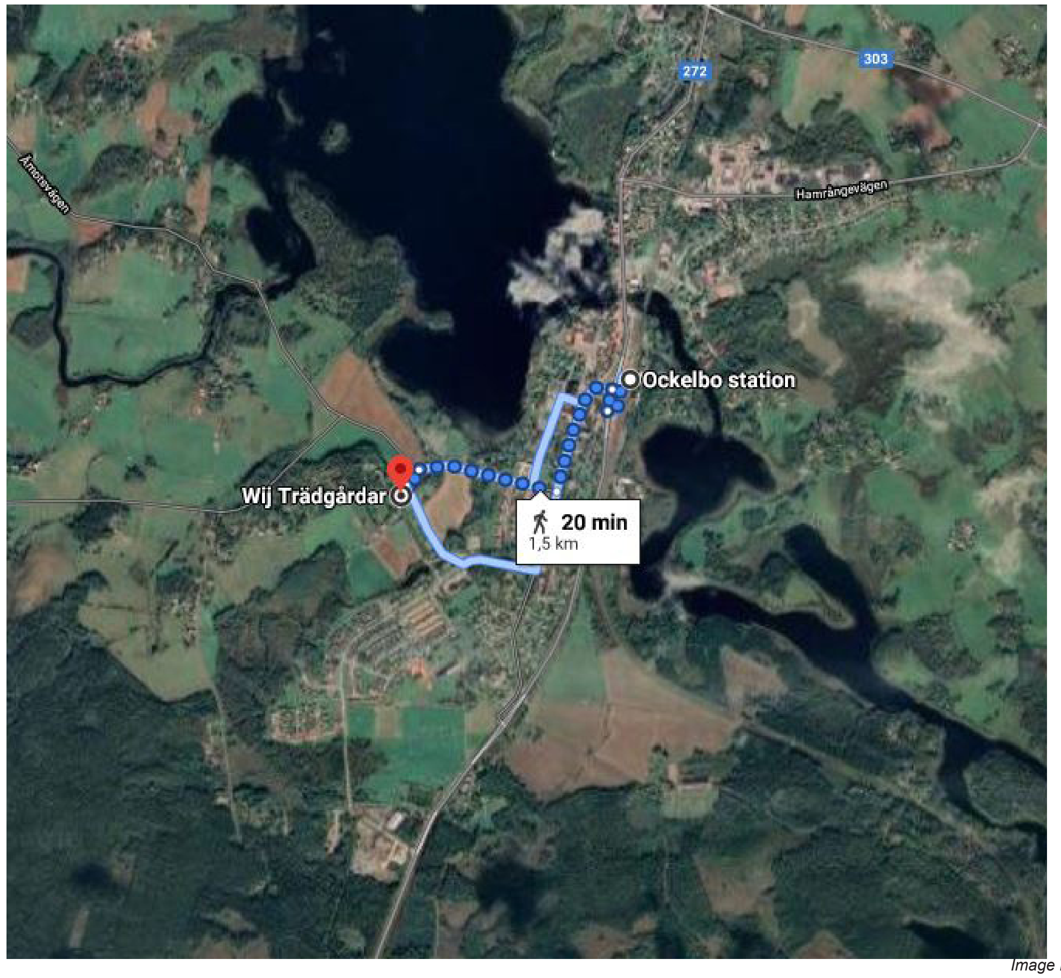


Image No9 Map Ockelbo

Location

Ockelbo is a small village in the county of Gästrikland. There is sometimes much snow in the wintertime. Situated a 20-minute walk from the train station is Wij Trädgårdar, the main attraction of Ockelbo. It is an old manor with a garden open for visitors.

Image No10 Map Sweden

Ockelbo, Gästrikland, Mid Sweden

main attraction; Wij Gardens.

Ockelbo is small, 6000 inhabitants

Prins Daniel was born here

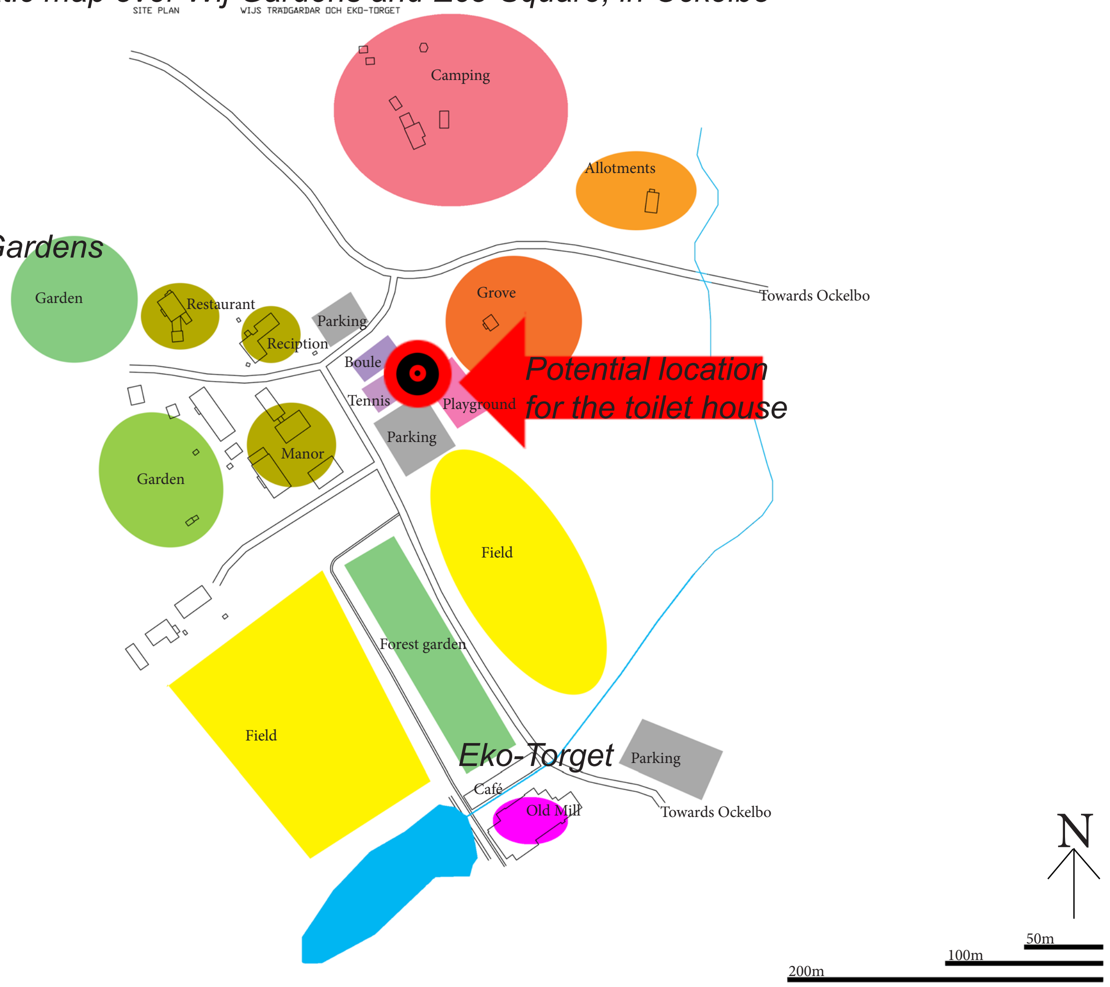
Image No11 Prins Daniel

Image No12 Wij Gardens

Closer surroundings

Wij Trädgårdar is one of Ockelbos main attractions. Except for the central garden and the forest garden, Wij also houses student gardeners. There are a restaurant and a café, and in the summer, it attracts many visitors. There are allotments and camping nearby. The toilet will serve Boules players, playground kids, garden visitors, tennis players, and the public.

Schematic map over Wij Gardens and Eco-Square, in Ockelbo



Placement

The site suggested for the toilet house is close to the tennis court, the design proposal suggests a small adjustment, about 40 meters to the south towards the playground. That way, sun-exposure is maximized, and it also allows access for service vehicles. The many big trees around will otherwise cast shadows on the greenhouse. The micro-climate is good, exposed to the sun from south- southeast, in summer from the morning throughout the day. Big trees in the north and a small hill in the northeast will provide some shelter from the cold northern winds. The place is in the center of attention in the area there is a walking path passing by, and close by there is the playground, tennis court and boules. This location will utilize users not only in the summer when the garden is open for visitors but will allow the inhabitants of Ockelbo to use the facilities all year around.

Site plan

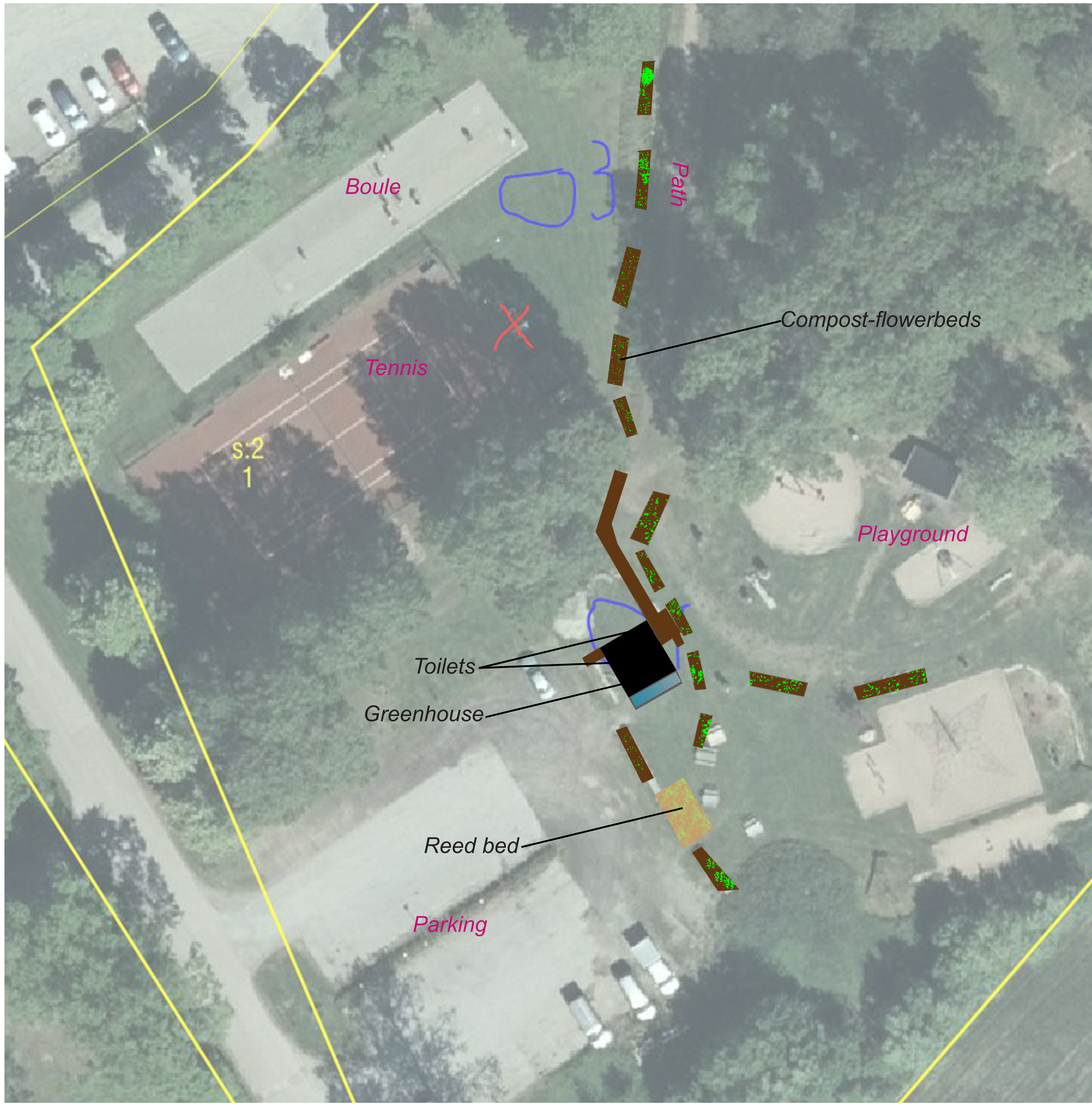
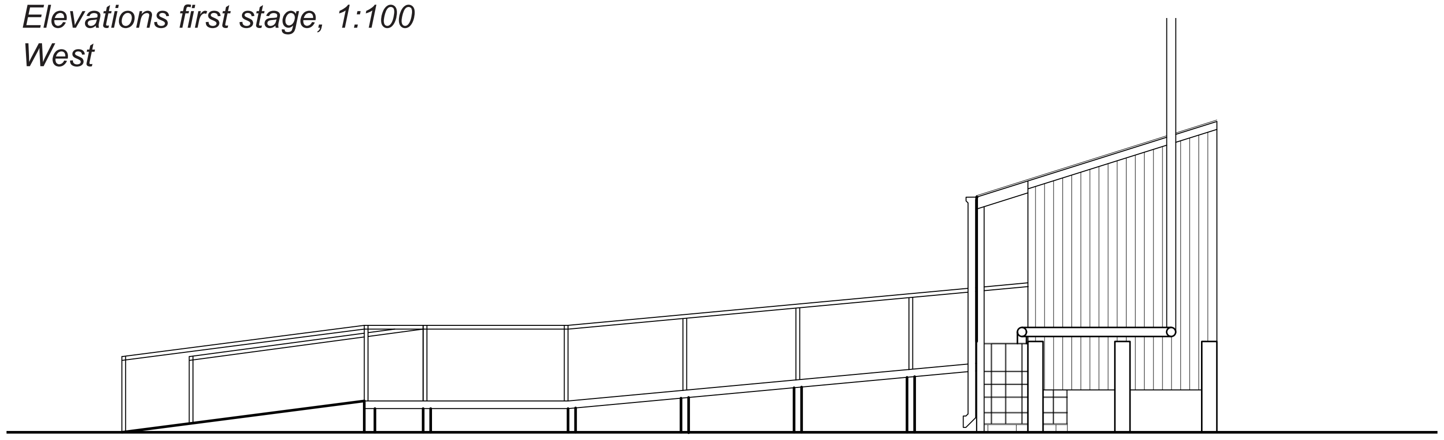


Image No13 Site plan

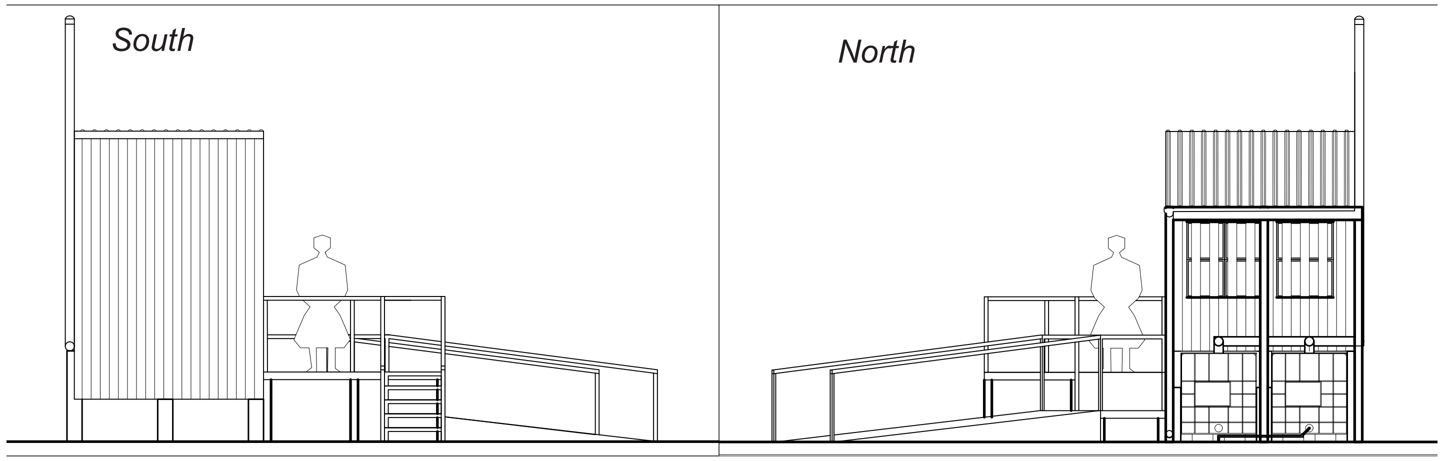
50m 30m 10m

N

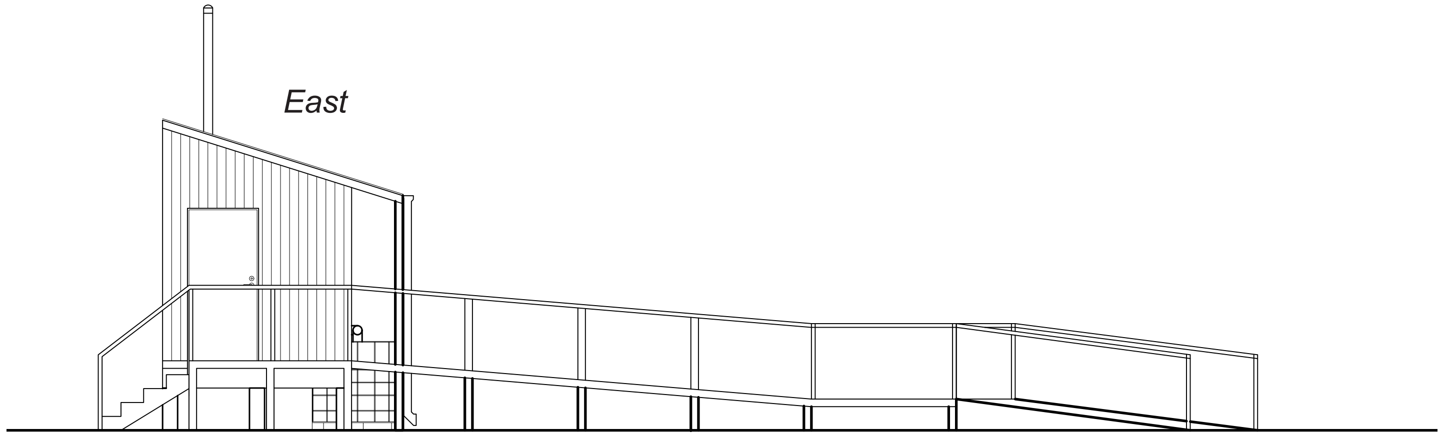
Elevations first stage, 1:100
West



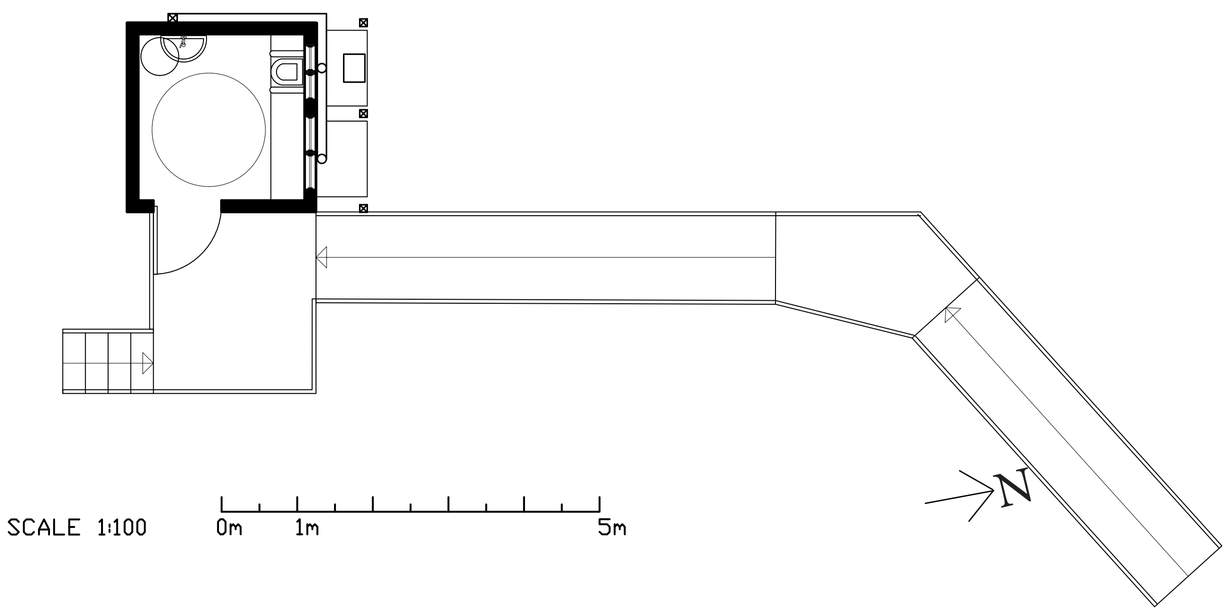
South | *North*



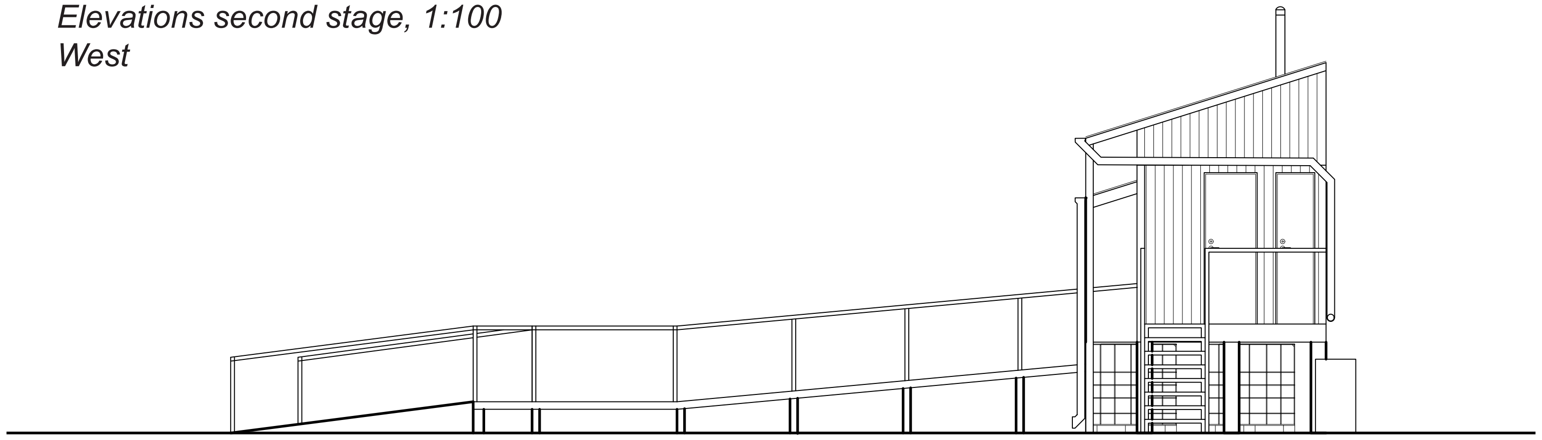
East



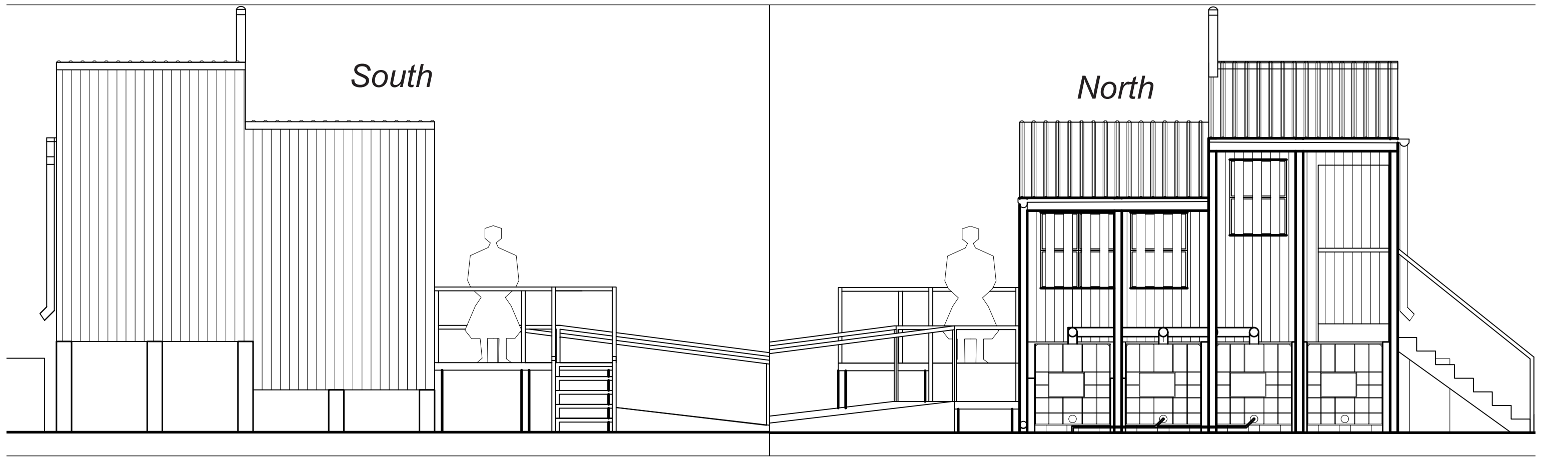
Plan



Elevations second stage, 1:100
West



South | *North*



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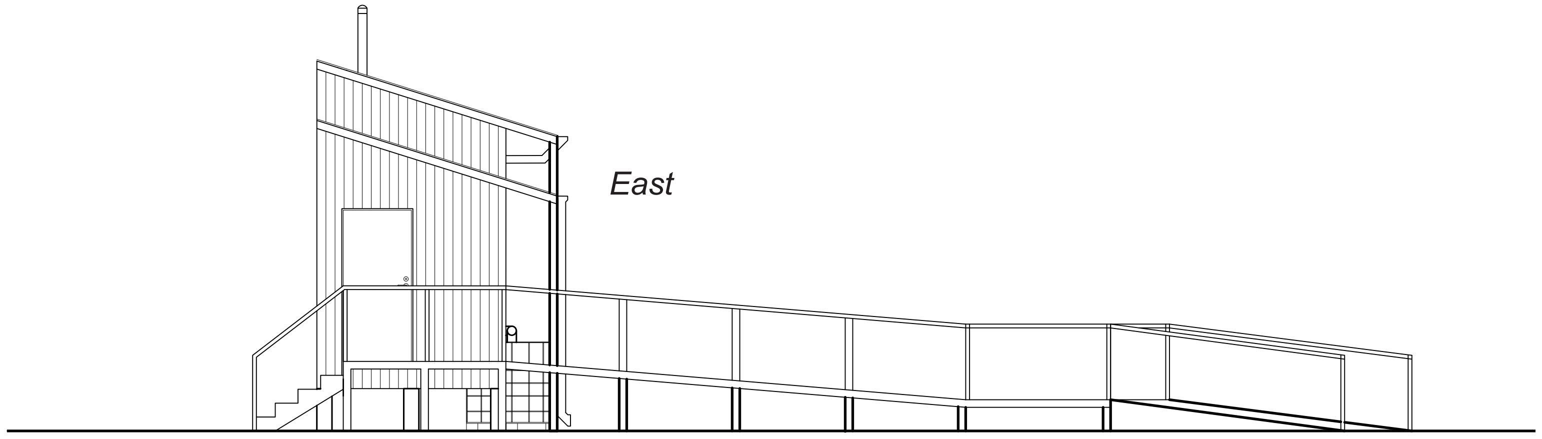
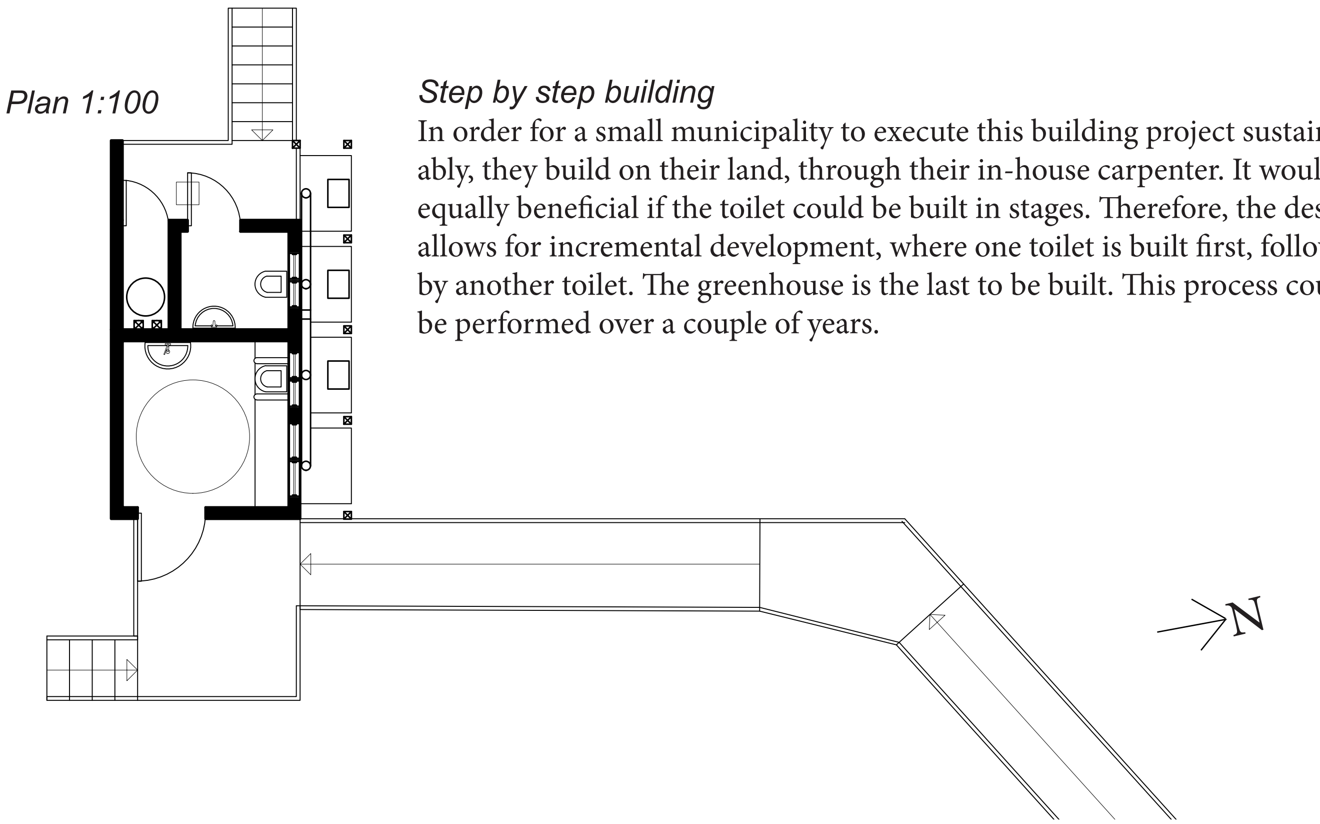


Plan 1:100



Step by step building

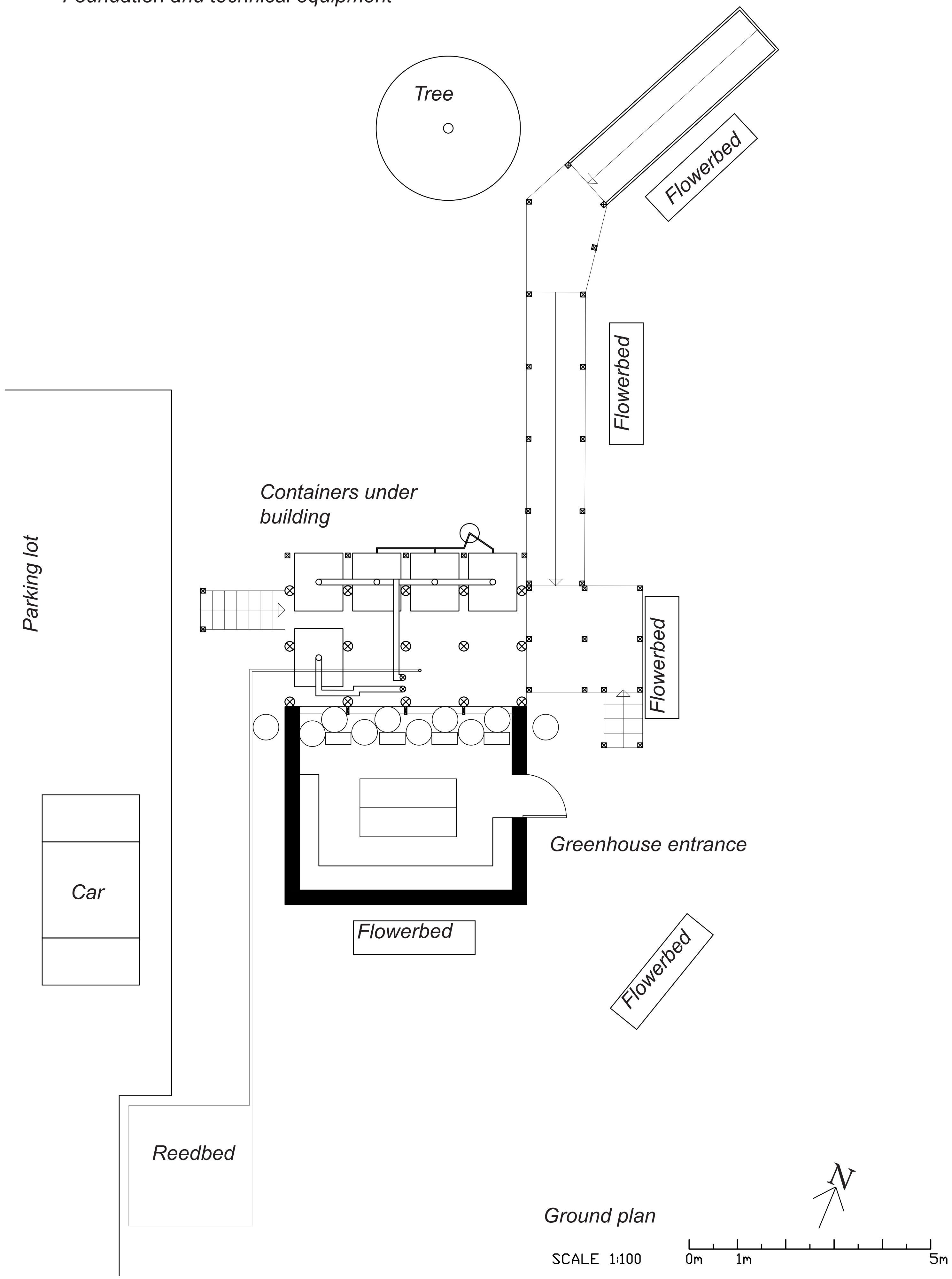
In order for a small municipality to execute this building project sustainably, they build on their land, through their in-house carpenter. It would be equally beneficial if the toilet could be built in stages. Therefore, the design allows for incremental development, where one toilet is built first, followed by another toilet. The greenhouse is the last to be built. This process could be performed over a couple of years.

Recycled building components and local material

Recycled building components and local material

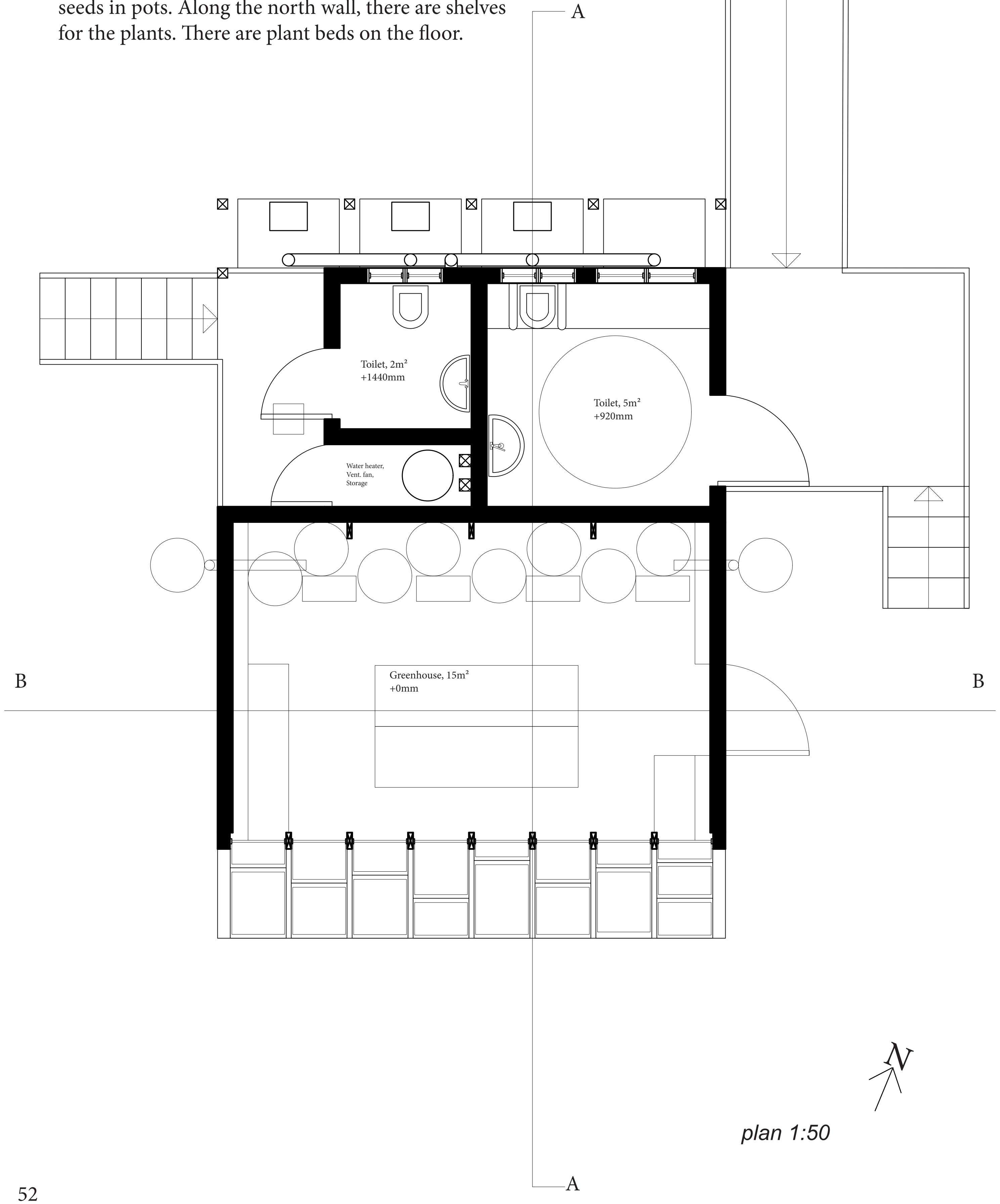
In dialogue with the carpenter and Eko-Torget, a strive to use local recourses and recycled material as much as possible emerged. The facade, structure, floor, and tresses are made from locally sawed wood. Many farmers around the area have small sawmills where good quality material is sawed at an affordable price. Windows and doors are recycled and, consequently, may wary, in size and appearance. The roof cover material will probably be used sheet metal. There are two options for the greenhouse window wall: the first option is that if there are plenty of old windows, it might be possible to make a patchwork wall out of them, although the inclination of the wall makes it unsuitable for wooden windows. Option two uses corrugated transparent sheet plastic with a second layer of building plastic underneath with a gap of air in between. This option would not be as nice looking but might be more affordable.

Plan 1:100 Recycling Toilet Pavilion
Foundation and technical equipment



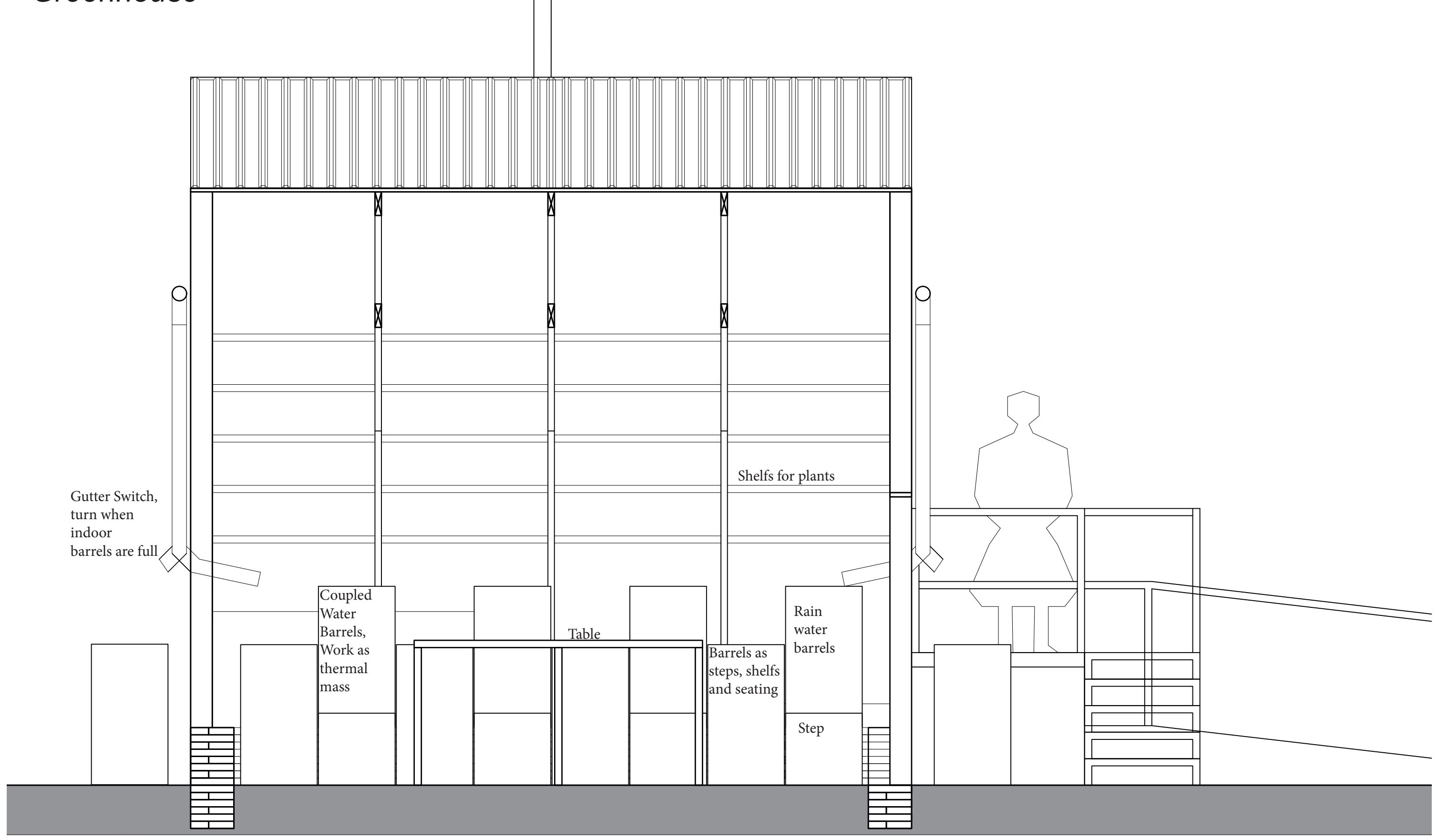
Greenhouse strategies

The greenhouse has a big south-facing glassed wall. The other walls are solid, with no windows, but slots for ventilation. Rainwater is stored in barrels and serves as a thermal mass, storing heat during the day and distribute it at night. In the middle of the room, there is a table where children and adults can plant seeds in pots. Along the north wall, there are shelves for the plants. There are plant beds on the floor.

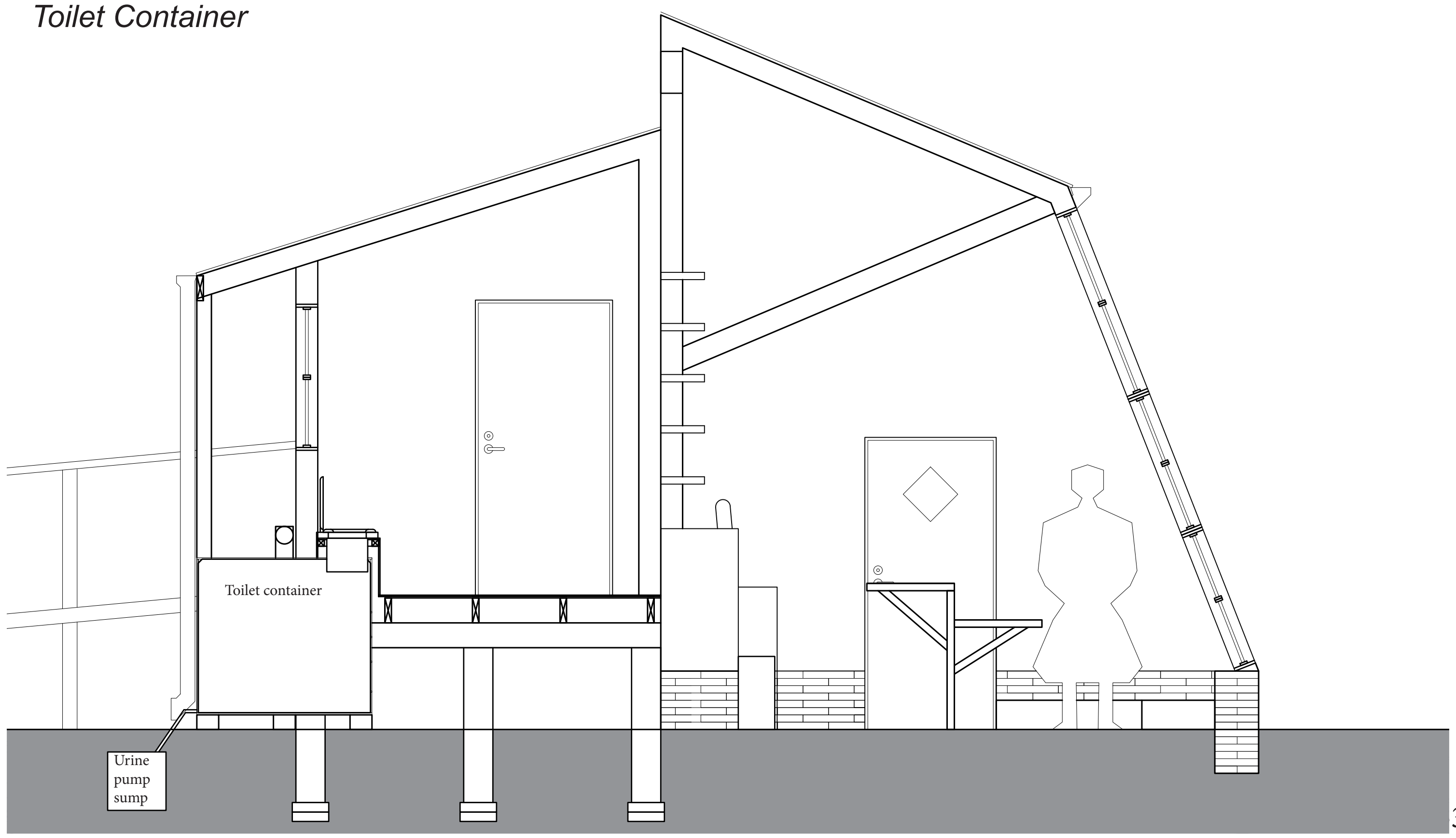


plan 1:50

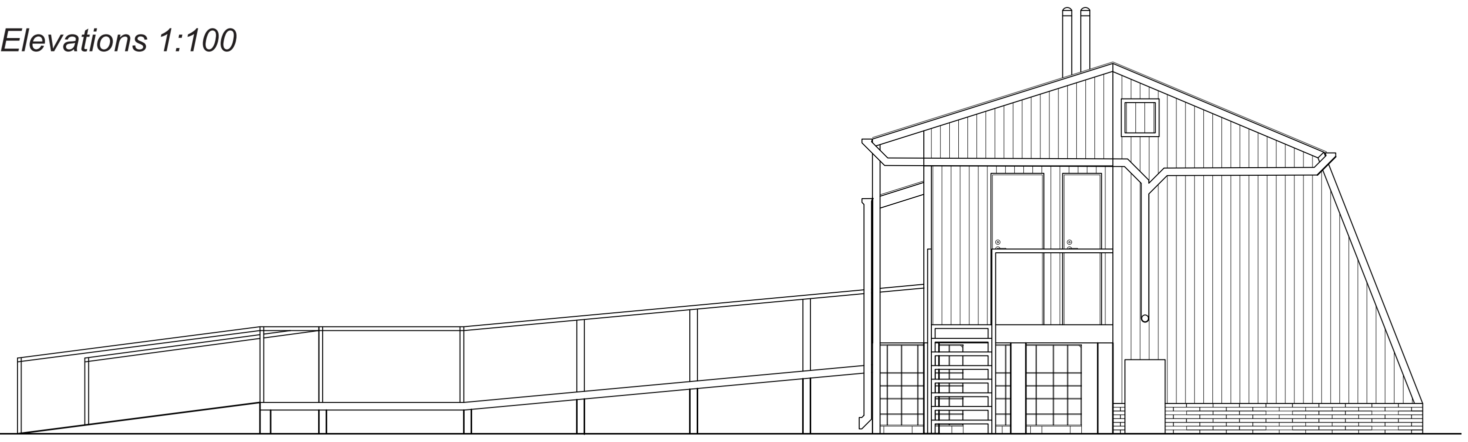
Section A-A 1:50 Recycling Toilet Pavilion
Greenhouse



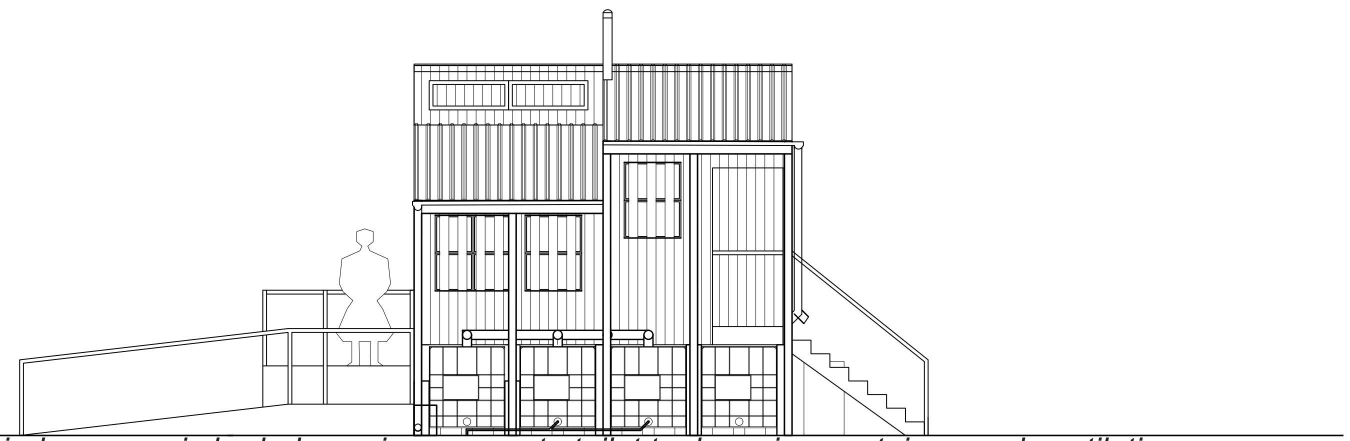
Section B-B 1:50 Recycling Toilet Pavilion
Toilet Container



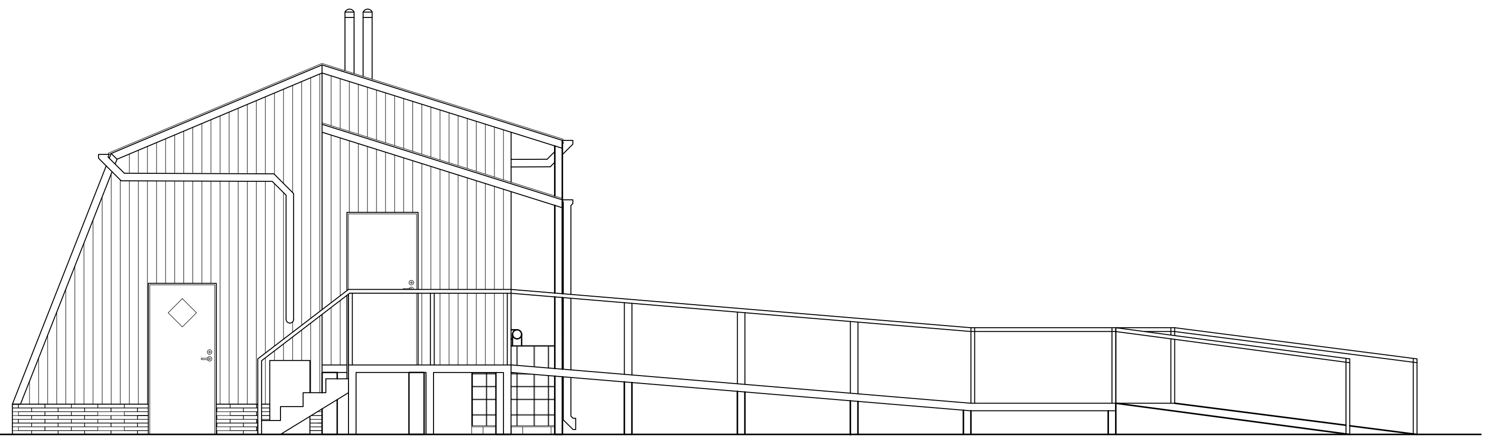
Elevations 1:100



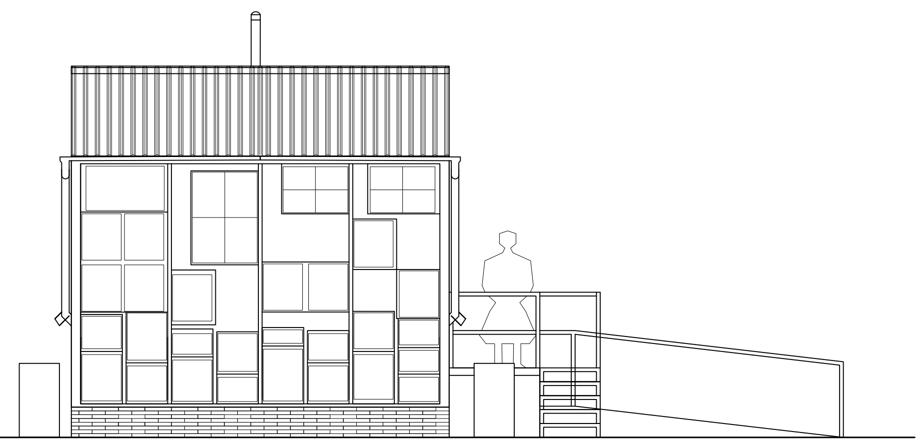
West, access to toilet.



North, windows; semi shaded, service access to toilet tanks, urine container, and ventilation.



East, access to toilet and greenhouse.



South, big windows.

Recycling toilet strategies

Minimize insight

One of the apparent disadvantages of the Compostera toilet is that there is a risk that the toilet user gets an undesired glimpse of the pile of faeces and paper down the toilet. In order to minimize this risk, the light sources need to be well planned. Lights need to not point directly down into the toilet seat. The windows are, therefore, a potential risk factor of light leakage. What is desirable from the windows is limited, even light. Thus, the north wall is a good place for the windows since light from the north is much softer and gives little contrast. Furthermore, the windows will be 50% shaded by shutters made from planks that go in line with the façade boards. These shutters also hide the irregularities that might occur with the old windows. A thin curtain is still needed in front of the windows to obliterate the last bit of insight.

Hight differences

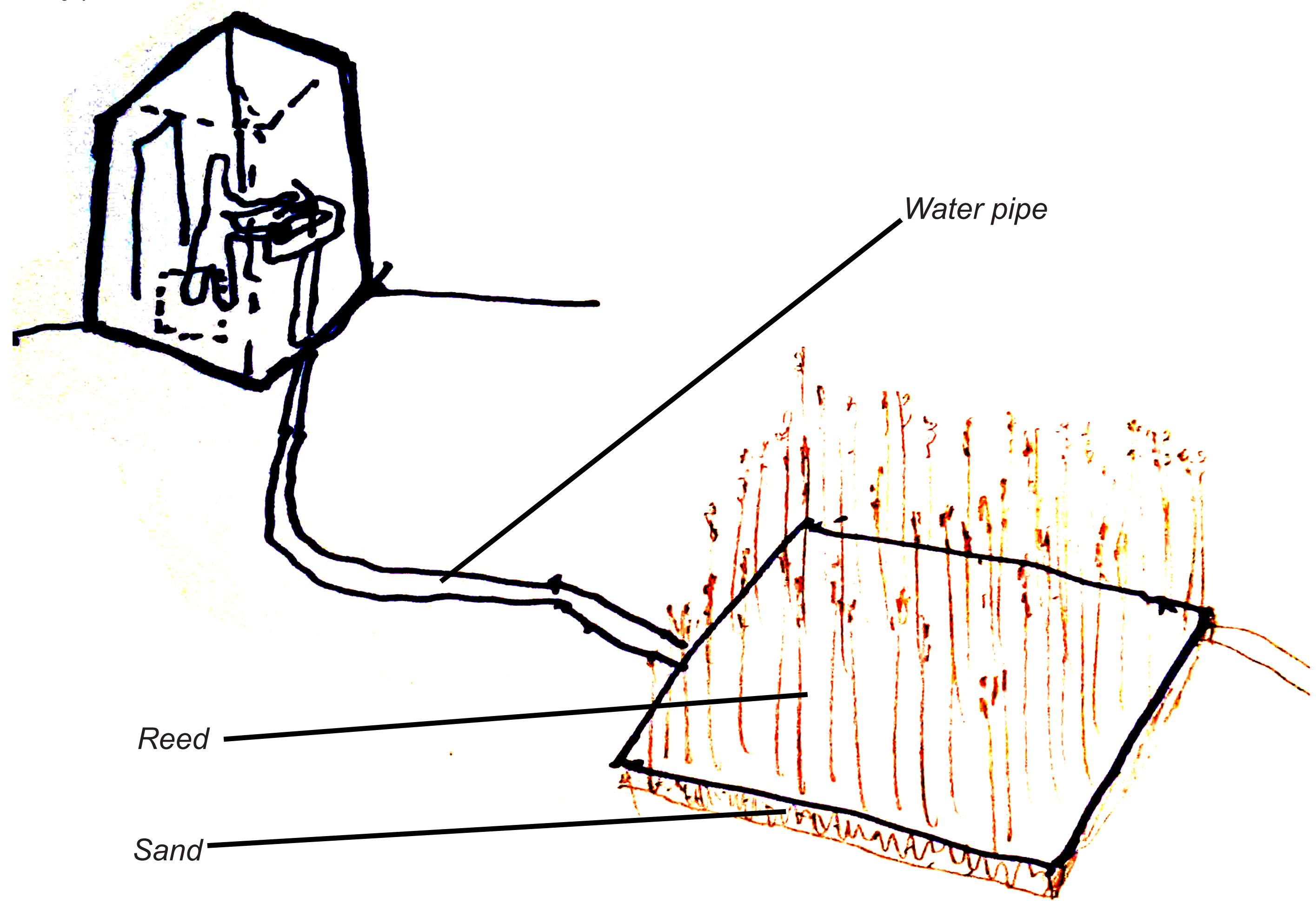
The Compostera toilet does not flush, consequently uses no water. It requires instead a steady drop for the faeces and urine to be collected by gravity. The urine is then filtered through a bed of peat and woodchips. The faeces and toilet paper stays on top of the filter bed while the urine goes into a sunken sump pump, where it is pumped to a bigger container placed on the ground. The building is small but tall, the floors of the toilets are elevated 800 respectively 1300mm above ground in order to fit the tanks under the floor. The lower room consists of a bench toilet and the higher fitted a floor-mounted toilet. These height differences require connections, and therefore stairways and a ramp are leading up to the toilets.

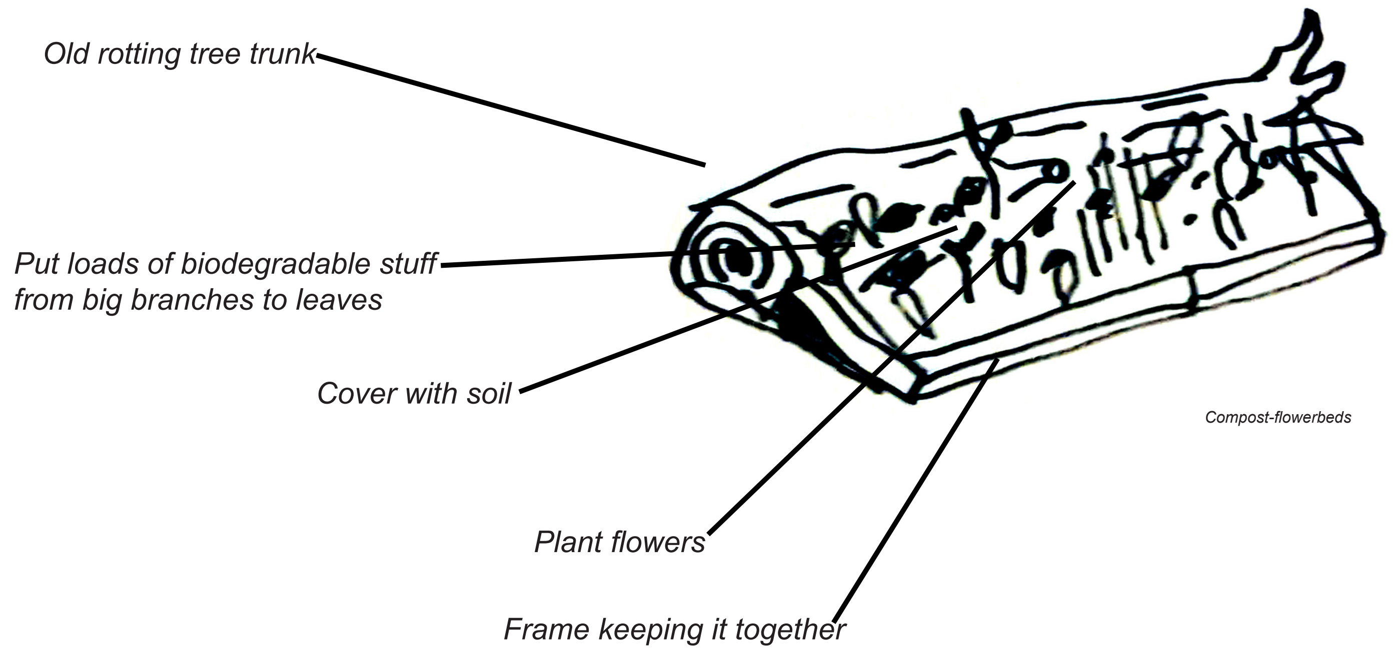
Maintenace access

The toilets need to be maintained. The pile needs to be leveled out with a rake now and again. After a couple of years, depending on the usage, the whole container needs to be replaced. For convenient access with a forklift, all the containers are accessible along the north wall, beside the parking lot. There is a space under the porch where full containers can be stored for a couple of years. Containers may be emptied when the faeces is fully decomposed. The urine is stored in a tank to the north wall and may be used as plant nutrients whenever required.

The view of the toilet house from the parking lot; containers are easily accessible for maintenance.

Reed greywater treatment bed





Compost-flowerbeds

General design strategies

Although this project focuses on the toilet part of recycling, it is necessary to address the whole picture of the recycling pavilion as an inspiring example to make the statement clear. Therefore design strategies that go beyond the actual toilet are implemented and presented but in a concise, comprehensive manner.

Reed greywater treatment bed

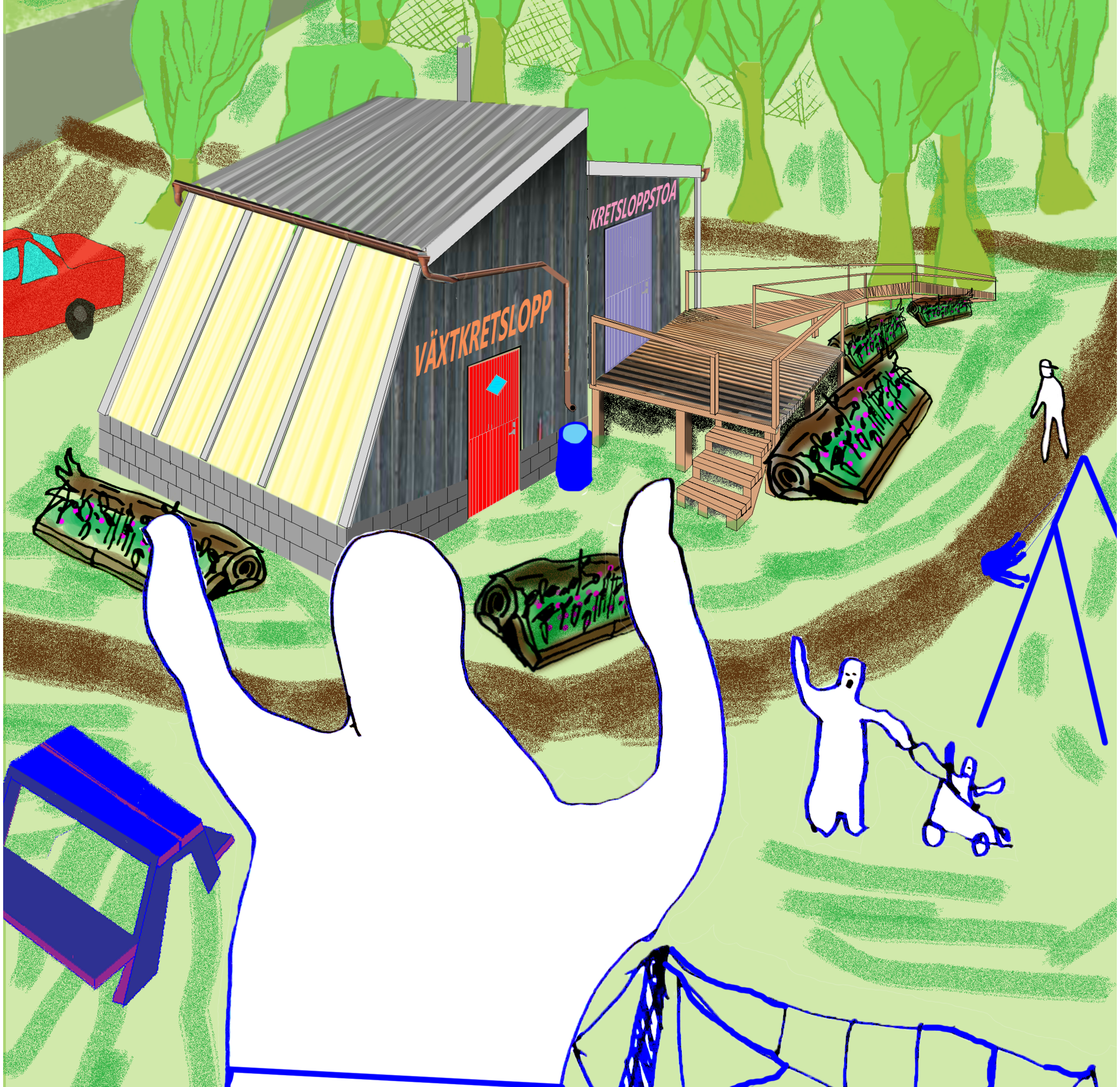
The water from the basin in the toilets must be treated in some way. Since this project aims at creating zero waste and find loops for nutrients, there is a particular strategy for greywater treatment. The greywater generates sludge, which is usually collected in a tank. However, there are also biological processes that decompose this material. This process can artificially be achieved by digging out a bed. The bed is then filled with sand in which reed is planted. The water is then lead through this plantation where the micro life at the roots of the reed processes the sludge.

Compost-flowerbeds

There are already today old tree trunks lying around the playground as dividers, as well as for climbing and seating. By adding more tree trunks, the idea is to create beautiful, easily maintained flower beds. As the trunks are slowly decomposing, they provide good microclimate supporting plants. The compost flower-beds consists of a frame along the tree trunk that will hold biodegradable matter such as branches, leaves, and grass clippings, in place. It is then covered by soil, and flowers are planted. The composting process under the flowers will not only provide nutrients but also hold beneficial humidity. The compost-flowerbeds could be placed along the path. They will then lead the way towards the Recycling Toilet, connecting the playground, sports facilities, path, and toilet by a uniform landscaping element. Eventually, the urine and faeces from the toilet can be used in these beds. This type of growing bed is called "hügelkultur".

Rainwater harvesting

The cycle of water is one that is widely known, even by kids. Water evaporates, becomes clouds, rains down on land, flows through rivers and lakes towards the sea and evaporates again. This water cycle is a symbol of a resource loop, to be compared with the cycle of plant nutrients. Rainwater is harvested from the roof; plant nutrition is harvested from the toilets. The water is stored both outside and inside in barrels. When the barrels inside are full there is a switch to direct the flow of water to the outside.



A child's perspective from the highest part of the climbing frame Highlighting the greenhouse characteristics, untreated wooden porch, board facade with grey earth paint, and compost-flowerbeds.

Discussion

Faeces Thesis has, as a part of the academia, tried to reach out to entrepreneurs, businesses, engaged people, and ordinary people. This strategy was a direct answer to what McConville et al. (2016) was requesting. To Simha and Ganesapillai (2016), one can say that this thesis has worked in their spirit. It is not the technology that has shown the way, but it has been a backdrop in a more editable form. Instead, the usability and expression of a cause greater then architecture are prioritized. A small toilet house became an image for a progressive idea of closing the nutrient loop. Built upon the assumption this thesis and others before makes; it rather seems to be a matter of social acceptance and motivation of the user, which makes an alternative toilet project resilient than the level of technology. Therefore one might suggest that in future research, more effort should be put into how to inform and alert people about the N and P matters.

Summary

This thesis has been trying to investigate the architectonic aspects of recycling toilets through a multitude of extroverted methods. It has involved communication, research, and design in the given order. Emailing and phone calls have been indispensable for the project. Engagement with other people outside of the architectural business has been part of the method. The Outcome became a small toilet house with a greenhouse that will hopefully be built in Ockelbo. There it may serve as an inspiration for increased recycling. It may as well work as a learning tool for educational activities with kids.

Conclusion

Main research question:

-How can a small toilet house be a tool to raise awareness about the N and P nutrient cycles?

There have been explorations about how to raise awareness about the N and P nutrient cycle through the Recycling Toilet Showcase Pavilion. An exploring prototyping investigation took place to find a suitable design for the toilet house. The local circumstances and the given toilet system gave a foundation for the project to grow. The circularity is repeatedly showed not only in the toilet but in the materials and the rainwater harvesting and the compost-flowerbeds. The configuration of the greenhouse is intended to counterbalance the verticality of the toilets.

-How does the Recycling Toilet affect the user experience, and how can it be emphasized?

To test this, interviews and questionnaires were undertaken, and the users said that they thought the recycling toilet was ok. The smell and visibility of faeces were not too disturbing. The location on the balcony was though relatively inconvenient. Cold temperature, lack of handwashing possibility, and exposedness to neighbors created a toilet that did not fulfill the expected level of comfort. All these negative factors were not present in prototype number one, but it was never thoroughly tested. Consequently, the design project focused on reaching a high level of comfort and making something extra pleasant for the users.

-In what way must the architecture be adapted to the chosen recycling technology?

The prototypes showed that it is possible to exchange the WC for a recycling toilet, although there is much hustle. The Compostera toilet was probably not ideal for the purpose because the filtration of the urine was not sufficient. A UDDT would have been preferred in such small scale installation. The chosen toilet is the Compostera toilet; it works with gravity, and hence one needs to dig the containers down, or the building needs to be elevated. In this situation, the containers needed to be easily exchanged; therefore, the digging was not an option. A small elevated building may be perceived as disproportionally tall. The addition of a greenhouse, leaning towards the south wall, anchors the building to the ground in a subtle way.

-What is an adequate design of a recycling toilet in terms of fulfilling the expectations of the user?

What has been evident in the process of this thesis is that architecture has no intrinsic value. To create an adequate design for a recycling toilet, one needs not only an understanding of the technical system but also understand the users' preferences and local circumstances. It is a more inclusive and more complicated process than the sole building designing. The method "architecture of extroversion" has helped to find the many times' unarticulated expectations of the users; the greenhouse and the water harvesting for example, were initially not asked for but where added through an open dialogue. The ignorant mannerisms of some architects leave the usability to its fate. Through the recycling toilet, a stive has been apparent all the way through; to include as many different kinds of angles as possible, metaphorically speaking. Architecture is nothing in itself- it needs the involvement of other people and disciplines in order to be relevant, resilient, and useful.

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