New initiatives in sanitation systems

Comparative assessment of the implementation process and actual performance of the Casa Vita project (Deventer) and the Flintenbreite project (Lübeck)

Author:
Joost van den Bulk
Wageningen University

Supervisors:
Dr. ir. Adriaan Mels
Wageningen University
Department of environmental sciences,
Landscape centre, Urban Environment Group

Claudia Marcela Agudelo Vera
Wageningen University
Urban Environmental Group

Preface

This research was done as part of my Master of Sciences degree in Environmental Sciences at the University of life sciences in Wageningen, Netherlands. The research was performed at the Urban Environmental group under supervision of Dr. ir. A. R. Mels.
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Joost van den Bulk

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Summary

Over the last decade more and more projects have been realized in which non-conventional sanitation systems are implemented. Non-conventional sanitation systems are defined here as systems that are (partially) different than the current systems of water-flushed toilets, sewerage and wastewater treatment plants, as applied in most European conditions. They are generally designed to be an environmental friendly answer on the current wastewater system which is very energy and capital intensive.
In this research two projects in which non-conventional sanitation systems were implemented are analyzed. The collected data from these two projects are compared with the user acceptance experiences of conventional sanitation systems. The two projects which were analyzed are the Flintenbreite project in Lübeck (Germany) and the Casa Vita project in Deventer (Netherlands). In the Flintenbreite project a grey water system, consisting of a constructed wetland, and a black water system consisting of a vacuum toilet system combined with an anaerobic digester, are implemented. In the Casa Vita project a black water system which exists out of a vacuum toilet system combined with discharge to the municipal sewerage system is implemented. The user experience data from these two projects are compared with experiences of people that use a conventional sanitation in the neighbourhood Noord-West in Wageningen (Netherlands).

The objective of the research is to make a comparative assessment of the performance and user experiences of the implemented technologies. An other important aspect of the research is to identify the drivers and barriers during the implementation process of the technology. This objective is motivated by the fact that for further improvements and larger scale implementation it is important to systematically monitor and analyse these aspects. The necessary data have been collected by performing interviews with stakeholders in the projects, doing literature research and performing a household survey among inhabitants of the projects.

The research is part of a larger research project within the EU project SWITCH (Sustainable Water management Improving Tomorrow's Cieties' Health) that has a research component aimed at analysing the adoption and performance of non-conventional sanitation systems. In chapter 6 the data that are collected in this research are compared to data from previous researches concerning the implementation of non-conventional sanitation systems in projects.

The main drivers for the implementation of a black water system in the Casa Vita project were water saving aspects, environmental considerations and advantages in the construction of the apartments. When constructing a sanitation system the vacuum toilet system from JETS is more flexible than a conventional system because the pipes have a smaller diameter and the toilet can be placed anywhere in the house. This gives much more freedom for the buyer of the house to determine the inside of the house themselves. Except for the higher costs of the vacuum toilet system there were not much barriers in the Deventer project.
The most important drivers in the Flintenbreite project were the reduction of water emissions, recycling of nutrients, reduction of energy use, quality of neighbourhood landscaping and reduction in energy and operating costs. The most important barrier was the acceptance of the constructed wetland by the municipality because the municipality had some negative experiences with poorly constructed wetlands in the past.
The Flintenbreite and Casa Vita project show big differences with respect to system performance. The differences are mainly caused by differences in the set-up of the system. The system which is realized in the Flintenbreite project is far more complex and experimental than the system of the Casa Vita project. In the Casa Vita project the

households are equipped with vacuum toilets that are connected to a centrally installed vacuum pump (and a back up vacuum pump) which is located in the basement of the apartment complex. When the toilet is flushed a small motor opens a valve and the black water is sucked to the vacuum pump. From the vacuum pump the black water is directly discharged on the municipal sewage system.
In the Flintenbreite project the households are equipped with vacuum toilets that are connected to a small reservoir on household level. When the toilet is flushed the black water enters the reservoir. After 6 flushes the reservoir is full and the content is automatically sucked to the central vacuum pump. From the central vacuum pump the black water is treated further to kill pathogens and finally mixed with organic waste and anaerobic digested to produce bio gas. The resulting black water is stored in a tank and transported to local farmers that use it for agricultural purposes.
The JETS vacuum toilet system which is used in the Casa Vita project appears not very vulnerable to failures/blockages if it is installed and used properly. The disadvantage of the system is that it does not provide an onsite solution for the produced black water. The black water is simply flushed to the sewage system at the moment. In theory the black water system which is installed in the Flintenbreite neighbourhood offers a more environmental friendly solution by digesting the black water for the production of bio gas and re-use of the final product for agricultural purposes. But, in practice the majority of the black water reservoirs that were installed in the households of the Flintenbreite project were removed because too much failures/blockages occurred. Now the blackwater is sucked directly into the vacuum sewer network when flushed. The digester and related fertilizer production process is still not in operation because the amount of produced black water is too small. Officially much more houses should have been built but the construction company went bankrupt in 2001 and nowadays the black water flow is still not sufficient for the digester to be operated. Experiments performed by the university of Hamburg show that the process will run without problems (Otterwasser 2005). At the moment (2007) new houses are being built in the Flintenbreite neighbourhood and it is expected that sufficient black water will be produced when these houses are connected to the black water system.
The energy use per inhabitant of the black water system in Flintenbreite is higher than the energy use of the Casa Vita project. The higher energy use could be caused by the longer distance over which the black water is transported, leakages and differences in system set-up. A remark has to be made that the energy use in the Flintenbreite project is actually monitored while the energy use of the Casa Vita system is based on estimations.
The costs per inhabitant of the black water system in the Flintenbreite project are much higher then the Casa Vita costs. This is caused by:

- A more complex system set-up (collection reservoirs, digester)
- Implementation of the system in apartment complex vs familiy houses
- Different system manufacturer

In both the projects no human health risks exist because the systems are closed to prevent contact between humans and pathogens.

The household survey which was performed at the Casa Vita project shows that the inhabitants were satisfied with the vacuum toilet system. The majority would recommend the toilet system to other households and they would like to have the same toilet system if they moved to an other house. According to the households the main disadvantages of the system are the loud noise and the lack of a back-up system in case of a system failure. Because of system failures/blockages the inhabitants of the Flintenbreite project are less positive about the vacuum toilet system. These blockages are mainly linked to the small reservoir, this is the reason for the switch-off of these units. They are very positive about the theory behind the system but in practice they are facing too much problems. These problems need to be solved before the system can be implemented on a bigger scale. The Flintenbreite households are very positive about the grey and rain water system because they run without problems, are environmental friendly, look nice and save costs.

An important statement that needs to be made is that the Flintenbreite project is already running for 7 years while the Casa Vita project was only recently finished. There is always the possibility that the black water system of the Casa Vita project will face more problems in the future. In that case the results of the household survey could show differences with the current results.

The analyzed projects have shown that vacuum toilet systems can be a proper alternative for conventional toilet systems if implemented properly. Efforts need to be undertaken to decrease the amount of failures/blockages of the vacuum toilet system before it can be implemented on a larger scale. A lot of failures are still caused by misuse of the households such as flushing big objects through the toilet. Households should be informed more regularly and more specific about the proper use of the vacuum toilet system.
Furthermore lessons need to be learned from these pilot projects to prevent old mistakes in the future and to optimize the systems further.
In general the households of the different projects which have been analyzed are positive about the implemented black, grey and rain water systems. Despite the failures, blockages and starting-up problems the majority of the households believe that these systems have a good future if improved. Important points of attention are:

- reduction of noise production of the vacuum toilets
- proper installation of the pipes (without sharp hooks)
- installation of robust components that are not sensitive for failure
- proper management of urine stone in pipes

More research is necessary to find the optimal solution for treatment of the final concentrated black water flow from the vacuum toilet system. The concentrated black water can be digested under anaerobic conditions together with organic waste to produce bio-gas. After digestion the resulting black water can be treated further and used as a fertilizer on agricultural land but it is also possible to recover the valuable components from the black water.
Finally efforts need to be made to implement non conventional sanitation systems, especially the vacuum system technology, in law and regulations. Non conventional sanitation systems should be integrated in modern policy making in order to implement them on a larger scale. Construction companies, policy makers and consumers should become aware of the advantages that these systems can offer and legal and regulatory barriers have to disappear.

1. Introduction

1.1 Background

The treatment of our wastewater is not an easy discussable topic. People flush the toilet and usually do not bother about the process which is necessary to treat the produced wastewater. After all, why would you mind about a system such as the system which has shown its effectiveness over the past century?
The conventional sewer system exists out of a structure of big sewer pipes to which most of the Dutch households are connected. The wastewater from the households which can be divided in black water (toilet water) and grey water (water from kitchen, shower, bath and washing) enters the big pipes. The big sewer pipes transport the wastewater to wastewater treatment plants (wwtp's) which are usually located far from the cities because of the big surface which is needed and the odour production. In the wwtp an energy and capital intensive process treats the wastewater and finally the treated water is discharged on the surface water (*Stowa, 2006*).
The conventional wastewater treatment system is a system which has shown its effectiveness in reducing human health risks, treating the big amounts of human wastewater and protecting the surface water (*Lenntech, 2007*). The problems with the conventional system are the high inputs of capital and energy because the system requires a big infrastructure and an energy intensive treatment process. On household level the human waste is largely diluted with water (black and grey water) and flushed in the sewer system. Because of the big amounts of wastewater big sewer pipes are necessary to transport the wastewater. When the wastewater reaches the wwtp an energy and capital intensive process is necessary to remove the largely diluted contaminants out of the wastewater again (*Stowa, 2006).*
It took a long time before discussions about the effectiveness of the conventional sewer system started to be taken serious. The first improvements were the separated sewer systems for rainwater and wastewater from households. In these sewer systems wastewater from the households is no longer mixed with the rainwater because the rainwater is transported in other pipes. This separate collection of rainwater and human wastewater prevents the dilution of the wastewater from the households with rainwater. In the wwtp's less energy and capital is necessary to treat the wastewater because it is less diluted.
The past few years more and more efforts are made to change the conventional sanitation system on more aspects. Principles such as DESAR (decentralized sanitation and reuse) are used to start pilot projects in which wastewater is treated more locally, less fresh water is used and valuable components reused.
In this report two cases are described where the DESAR principle is put into practice. The aim of this study is to identify whether DESAR technologies can be an alternative for the conventional sanitation system. The two cases that are analyzed are equipped with vacuum-toilet systems in which air pressure is used to suck the excreta to a central vacuum pump. Only a relative small amount of water is necessary to flush the vacuum-toilets. From the central vacuum pump the black water can be either treated locally or transported to the communal sewer system.

1.2 Research objective and research questions

The objective of this research is to determine the drivers and barriers that occurred during the implementation of the Casa Vita and Flintenbreite project and to assess the performance of the implemented technology by performing interviews with stakeholders and households. The first objective of the research is to identify the drivers and barriers during the implementation process of the new sanitation technologies in the projects Casa Vita and Flintenbreite. The second objective is to make a comparative assessment of the performance and user experiences of the implemented technologies in both projects. Both objectives are motivated by the fact that for further improvements and larger scale implementation it is important to systematically monitor and analyse these aspects.

The research questions are:

- *Which main drivers and barriers for the implementation of vacuum-toilet systems in new urban developments can be identified?*
- *What is the performance of the sanitation systems in Deventer and Lübeck compared to the performance of a conventional sanitation system?*
- *What is the performance of the sanitation systems in Deventer and Lübeck compared to the performance of other projects where non-conventional sanitation systems have been implemented?*

2. Research methodology

In this chapter the different aspects of the research are described. The different aspects can be divided in

- description of the two research sites
- drivers and barriers at the specific research sites
- performance and costs of the sanitation systems
- user perception of the households that use non conventional sanitation systems
- user perception of households with conventional sanitation systems
- Comparison of different cases

Description of research sites
During this research two different research sites were analyzed:

- Casa Vita, Deventer, 38 apartments
- Flintenbreite, Lübeck, 26 houses + 4 apartments (Ger)

In addition also a conventional toilet system in the neighbourhood 'Noord-West' in Wageningen was analyzed to compare the results with the results of the two cases.

Drivers and barriers
After describing the research site, the drivers and barriers which showed up during the decision making and implementation process of a certain sanitation system were identified by performing 'drivers and barriers interviews' *(appendix 2)*. Different stakeholders of the implementation process of the sanitation system were interviewed. The goal of the interviews was to identify the typical drivers and barriers of a certain implemented sanitation system. The drivers and barriers have several aspects:

- Environment and public health
- Legal and regulatory
- Social and technical
- Financial
- Social and managerial

Performance and costs
To assess the actual performance and costs of an implemented sanitation system, detailed information is necessary. Usually it is not possible to retrieve all the necessary information from literature sources so it needs to be gathered by interviewing stakeholders. Different stakeholders can be system owners, people responsible for the operation/maintenance of the system and sanitation experts. Standardized interviews for each of these 3 stakeholders are designed *(appendix 3, 4, 5)*.
The aspects which are included in the interviews are:

- description of the sanitation system
- invisibility and user comfort of the system
- system robustness
- impact on ecosystems
- public health (not included in system owner interview)
- surface and groundwater management (not included in system owner interview)

user perception of the households
The chapter about the user perception deals with the opinion of households about their sanitation system. The opinions of the users are gathered by performing standardized questionnaires among the householders (*appendix 1*). The questionnaires deal with different aspects:

- household description
- description of the sanitation system

- invisibility and user comfort of the system
- system robustness
- public health
- background questions on user perspective

The questionnaires were performed personally by talking directly with people from the households.
In this research the opinion of people that use non-conventional sanitation systems will be compared with the opinion of people that use a conventional sanitation system. A survey research among 20 households in the neighbourhood Noord-West in Wageningen (Netherlands) (*appendix 6*) will be done to identify how people that use a conventional sanitation system judge their system.
The results of the Wageningen survey are compared with the results from the household survey among 20 households that I performed in the Casa Vita and Flintenbreite project.

Comparison of different cases
In this chapter several projects, with implemented non-conventional sanitation systems, that have been analyzed over the years by students of the University of Wageningen are compared to each other. The goal of this comparison is the identification of the strong and weak aspects of the implemented sanitation systems. The performance, costs, operation and maintenance, health risks and energy consumption of the different systems are compared *(table 31)*.
The operation and maintenance of the black water system consists out of the amount of failures of the vacuum toilet and system, the average downtime of the vacuum system in hours per year and the usage of microbe cleaner.
The health risks consist out of the possibility of having contact with the wastewater and the chance on chemical hazards if inhabitants have access to chemicals in the sanitation system.
The energy use of the sanitation system consists out of the energy use of the grey and black water system. In grey water systems electricity is necessary to run the pump that transports grey water to a constructed wetland or to run the grey water treatment installation, e.g. membrane bioreactor. A black water system such as a vacuum toilet system needs electricity to run the vacuum pump and other installations. The performance of the grey water system is measured by determining the influent and effluent concentration of COD, N and P. The total costs of the sanitation system consist out of costs related to the black water system, grey water system, installation, operating and maintenance costs.

3. Research site Wageningen

3.1 Conventional wastewater system in the Netherlands

A specific description of the Dutch wastewater treatment system is not necessary in this chapter because it has been described in detail in multiple sources before (*van Betuw, 2005).* Despite the detailed description of the system itself not much research concerning the user perception of the conventional sanitation system has been done yet. The goal of this research is to identify how people that use a conventional toilet judge their sanitation system. This is done by performing a survey among randomly chosen households with a relatively new conventional toilet system.

3.2 Household survey Wageningen

A survey among households in the neighbourhood 'Noord-West' is performed to identify how people that use a conventional toilet judge their sanitation system. In total 20 households were surveyed in this relatively new neighbourhood.

What kind of house do you have?
The majority (55%) of the interviewed householders lives in an apartment. The rest of the householders lives in a family house (40%) and free-standing house (5%).

How many persons are living in this household?
The average amount of persons per household is 2,5 *(table 1)*.

Table 1: Amount of persons per household

Amount of persons in household	Total	Total %
1	6	30%
2	5	25%
3	5	25%
4	2	10%
5	1	5%
6	1	5%

What is the composition of the household?
In 6 households live singles, 9 households are two-parent families, 3 households are married but don't have kids, 1 household is a single parent family and in 1 household they live together but are not married.

How many persons are not at home during daytime (school, work)?
From the total of 50 people that are living in the households that I interviewed 33 persons spend the day outside their house, which is equal to 66%.

How many persons are spending the night at home at least 5 night per week?
All of the 50 persons are spending at least 5 nights per week at home.

What is the highest education that you finished?
In 6 cases the highest education was university, in 10 cases HBO, in 2 cases MBO, in 1 case an education in between HBO and MBO and in 1 case an old version of MBO.

What kind of toilet system do you have?
The majority (85%)of the households has a conventional, water saving, toilet. The other households (15%) have a conventional toilet which is not water saving.

To what extend are you satisfied with the toilet system?
The majority of the interviewed households (85%) is satisfied or even very satisfied with their toilet system. A smaller part of the households (10%) was neutral about the system and only 1 household (5%) was dissatisfied with the system *(table 2)*.

Advantages concerning the (water saving) conventional system which are mentioned are:
- water saving (2x)
- no failures (1x)
- works properly (4x)

Disadvantages which are mentioned are:
- waste of fresh water
- not everything is flushed away

Table 2: Satisfaction with toilet system

Satisfaction	Number of households	%
Very satisfied	7	35%
Satisfied	10	50%
Neutral	2	10%
Dissatisfied	1	5%
Very dissatisfied		

Is the toilet easily kept clean?
In this case 17 of the households (85%) answers that the toilet is easily kept clean, 2 households (10%) answer that it is not very good kept clean and 1 household (5%) answers that it is poorly kept clean.

How often do you clean the toilet?
Fifteen out of the twenty households (75%) clean their toilet between 1 and 8 times per month, 3 households (15%) cleans their toilet between 10 and 15 times per month and in 1 household the toilet is cleaned 30 times per month.

What is your opinion about the noise that the toilet produces when flushing?
The opinions about the noise production of the toilet differs. The majority (75%) experiences no hindrance. A smaller amount of people considers it annoying (25%) *(table 3)*.

Table 3: noise production of toilet

noise	Number of households	%
Hard		
Annoying	5	25%
No hindrance	15	75%

Does the toilet of the neighbours cause noise nuisance?
The majority (80%) of the households never experiences noise nuisance from the toilet of the neighbours. A smaller group (20%) sometimes experiences noise nuisance from their neighbours toilet.

What do you consider important aspects when choosing a toilet?
A majority of the people (70%) consider saving water and other environmental aspects important when choosing a toilet.

Did you ever consider to replace your toilet for another toilet (for instance vacuum toilet)?
From the 20 households 2 household considered to replace their toilet for another one.

If you would move to another house would you prefer a conventional or alternative toilet system?
The majority (60%) wants to keep the same toilet if they would move to another house. Four households want a more environmental friendly toilet system, one household wants a demonstration of the vacuum toilet system before making a decision, two households want a vacuum system and one household wants a conventional system with more water per flush.

Which grade would you give to your toilet system?
Three households gave a grade lower then 6. On average the toilet scores a 7,05 *(table 4)*.

Table 4: Grade of the toilet system

Grade	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Amount of households	1		2	3	4	8	2	
%	5%		10%	15%	20%	40%	10%	

Did you ever have a problem (failure/blockage) with your toilet?
If yes, how often?
Only one household experienced blockages of the toilet.

Did you ever experience a failure of the total toilet system?
If yes, how often?
No one ever experienced a blockage of the total toilet system.

Which part of the wastewater system failed? What was the problem? When and how does it happen? How was the problem solved and by who?
Not relevant because no significant failures took place.

When the system fails how long does it take on average until it is fixed again?
Not relevant because no significant failures took place.

Questions about environmental awareness
Do you consider yourself environmental aware?
The people from the surveyed households are moderately environmental aware *(table 5)*.

Table 5: Environmental awareness of households

Environmental aware	Number of households	%
Always	1	5%
Often	6	30%
Sometimes	9	45%
A bit	3	15%
No	0	

Do you have doubts about the sustainability of the conventional toilet system?
A relative big group of respondents (45%) has doubts about the sustainability of the current toilet system. The commonly heard arguments were the amount of water which is flushed through the toilet and the quality of the water (drinking water) which is flushed away.

Do you expect a good future for the vacuum system?
Fifteen households (75%) thinks the vacuum system has a good future. Four households don't think that the vacuum system has a good future and one household does not have an opinion. Arguments in favour of the vacuum system are the water saving aspects, practical use and the possibility to connect it with a bioreactor.

4. Research site Casa Vita, Deventer

4.1 General

In this chapter the research site 'Casa Vita' in Deventer is described *(figure 1)* which exists out of 38 apartments where vacuum toilets from the company Jets are installed. The apartments have been bought by the households. The Casa Vita project is build by 'Klaassen Woonstijl B.V.' that developed the so called 'Casa Vita concept'. This concept is based on the use of wood as main material for the structure of the house. The wooden structure of the building creates possibilities to build with standardized sizes of 4,80 by 4,80. The standardized size makes it possible to pre-fabricate a lot of components resulting in the reduction of costs.

Figure 1: Drawing of Casa Vita project, Deventer (Klaassen)

Because wooden structures are less strong than structures from concrete and steel an alternative for the heavy conventional toilet system (water reservoirs, big pipes) has been chosen.
After a period of orientation Klaassen Woonstijl B.V. decided to install vacuum toilets. Altogether there are multiple arguments to (not) choose for vacuum toilet systems, but some of the arguments to install them in Deventer were:

- the smaller pipes of the vacuum toilets (50 mm) save weight and make it possible to place the toilets anywhere in the house
- the smaller pipes occupy less space in the building
- freedom for the costumer to design the inside of the house themselves
- instead of 6 litres per flush the vacuum toilets only uses1,2 which results in environmental profits and less dynamic forces on the structure
- a vertical piping system is possible

(Klaassen, 2007)

Implemented technology
The technology that is implemented in Deventer consists out of vacuum toilets that are connected to a central vacuumarator *(figure 2)* that is installed in the basement of the apartment complex. All 38 apartments in the Casa Vita project are connected to the vacuum toilet system. The vacuum toilets in the apartment complex are connected with each other by central pipes. The central pipes are connected to a vacuumpump *(figure 3).*
Because of the difference in air pressure in the pipeline before and behind the sewage the mixture of water and sewage is sucked towards the vacuumarator. The vacuumarator has the combined function of grinding the particles in small pieces, creating the vacuum in the system (vacuumpump) and pumping the wastewater towards the sewer system. Although one vacuumarator is sufficient, two have been installed in the basement of the complex to prevent a system fall out in case of a failure of one of the vacuumarators. The vacuumarator

is constructed and patented by the company JETS. In the Casa Vita project two vacuumarators of the 25MBA model (50 Hz) with a power consumption of 3 kW are installed next to each other *(Appendix 16)*. Because the vacuum pump works only one hour per day the electricity consumption per person is not very high.
The collected black water in the Casa Vita project is discharged on the municipal sewer system.
A big advantage of the vacuum toilet system is that when someone flushes the toilet only 1,2 litres of water will be used for flushing. Together with the water an amount of 60 litres of air is 'sucked' through the piping system, creating a powerful flush.

Figure 2: schematic drawing of vacuum toilet and vacuumarator (Jets)

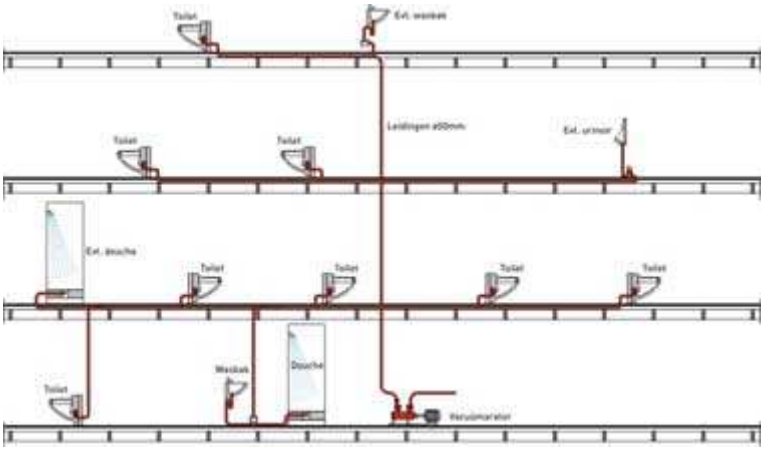


Figure 3: Schematic example of the installation of vacuum toilets in an apartment complex *(not Casa Vita project) (Bouwwereld)*

4.2 Interviews

4.2.1 Stakeholders

The relevant stakeholders in the project were interviewed in order to gather as much information as possible. The different stakeholders in the project were:

Actor	Representative	Role / responsibility
Klaassen Woonstijl B.V.	Harry Vieregge	Building company, initiator of using the vacuum toilets
Domus V.V.E. Beheer	Rudie de Haan	Operation and maintenance company
TAUW b.v.	Paul Telkamp	Analyzing the water and energy use
Jets		Supplier of vacuum toilets and repairing system failures/blockages

The stakeholders were interviewed with different questionnaires:
- Klaassen Woonstijl B.V. → Drivers and barriers interview, sanitation expert interview
- Domus V.V.E. Beheer → Operation and maintenance interview, system owner interview
- Tauw B.V. → Informal conversations and email contact
- Jets → Email contact

4.2.2 Drivers and barriers interview

Description of sanitation system
Harry Vieregge is responsible for the Casa Vita projects within the 'Klaassen Groep'. These Casa Vita projects include wood structure buildings and vacuum toilet systems. The 'Klaassen Groep' was the first commercial construction company in the Netherlands that integrated a vacuum toilet system in new houses. The main argumentation to implement a vacuum toilet system was the freedom for the customer to design the inside of the house himself but also the environmental aspects played a role.
The households are the owner of the complete sanitation system. The association of owners of the 38 households within the Casa Vita project is responsible for the maintenance. The association of owners consists out a few representatives from the household community. This year (the first year) the 'Klaassen Groep' is paying the maintenance costs of the Casa Vita project but from next year on the households have to pay these costs themselves. The 'Klaassen Groep' contracted 'Domus VVE Beheer' in a one year contract for all the maintenance work on the Casa Vita project, including the vacuum toilet system. The maintenance includes providing the ecological cleaning agent Biocompact to the households because normal bleach can affect the pipes of the vacuum system. Biocompact is also necessary because it brakes down urine stone, which can cause blockages in the pipes. The Klaassen company will not give any guarantee on the vacuum system when it breaks down because of improper usage.

Harry Vieregge was not involved in the process leading to the integration of vacuum toilet systems in the Casa Vita projects. The decision to integrate a vacuum toilet system was taken by the direction of the 'Klaassen Groep'. The former director of the 'Klaassen Groep', Mr. Warner Doorneweerd, was convinced by the vacuum system concept and convinced the direction to integrate it in the Casa Vita projects. The decision to integrate the vacuum system can be defined as a consensus decision among the direction. Harry Vieregge himself agrees with the decision of the direction to integrate a vacuum system in the Casa Vita projects and considers it a practical solution that has grown over time. The 'Klaassen Groep'

decided to use a vacuum system from the company Jets because it is a big company which has proved to produce robust systems and service.

Environmental drivers
The main environmental drivers were the positive feeling about environmental friendly behaviour, water saving and reduction of water emissions *(table 6).*

Table 6: Environmental drivers

Environmental aspect	Unimportant				Important
	0	1	2	3	4
Positive feeling about environmental friendly behaviour					x
Water saving					x
Prevention of drying out of soil	x				
Reduction of water emissions					x
Recycling of water	x				
Protection of surface water	x				
Protection of groundwater	x				
Recycling of nutrients	x				
Reduction of energy use	x				
Quality of neighbourhood landscaping	x				
Other……					
Other……					

Although no measurements considering water use were done until now it is assumed that these environmental drivers were realised in practice because the vacuum toilets only use 1,2 litres of water per flush. The implementation of the vacuum system in the Deventer Casa Vita project did not cause any legal, environmental or human health barriers.
The implementation of a vacuum toilet system in the Casa Vita projects is the result of a process in which the most practical sanitation solution for these projects was developed. The vacuum toilet system provides the opportunity for the customer to place the toilet anywhere in the apartment. The pipes of the vacuum system are much smaller in diameter (5cm) than conventional toilet pipes (10cm) which offers the possibility to integrate them in the floors instead of leading them through/along walls. According to Harry Vieregge the main advantage of the vacuum toilet system, and the Casa Vita project in general, is the big freedom for the customer to design the inside of the house (location of walls, toilet, etc).

Environmental and public health barriers
Environmental and public health barriers are of none relevance in the Deventer Casa Vita project because it only involves a black water vacuum system. This system is directly connected with the sewer system and inhabitants of the Casa Vita project do not come into contact with the black water because it is a closed system. The risks are estimated the same as with a conventional system.

Financial drivers and barriers
Financially the vacuum toilet system is less interesting than a conventional toilet system. Not only the toilets themselves but also the vacuumarator are a relatively big expense. Harry Vieregge estimates the total costs for the implementation of a conventional toilet system on 500 € per apartment and 1645 € for a vacuum system *(table 7).* Due to the relative high costs the financial aspect was one of the main barriers during the implementation of the vacuum toilet system. The expected operational and energy costs are low and the water saving aspect was considered a driver because it saves a considerable amount of money yearly. The ‘Klaassen Groep’ did not integrate more advanced technology such as a digestion system for the concentrated black water in the Casa Vita project because this would increase

the costs even more. The Casa Vita projects are meant for starters with a relatively small budget.

Table 7: Investment costs for the vacuum toilet system in Deventer

	Vacuum toilet	**Conventional toilet**
Toilet	470 €	
Vacuumarator	365 €	
Pipes	795 €	
Small materials	15 €	
Price per apartment (with one toilet)	**1645 €**	**500 €**

(Email contact with Harry Vieregge from 'Klaassen Woonstijl BV')

Social and managerial drivers and barriers
In this project social and management drivers/barriers were not considered relevant. Harry Vieregge emphasises again that the main drivers for the 'Klaassen Groep' were:

- the opportunity for customers to design the inside of their house themselves
- the water saving and related money saving aspect

The system has not been adapted/modified since it was installed in February 2007 and it is not expected that adaptations are necessary.
Harry Vieregge mentioned that more efforts should be made to promote the vacuum toilet system. These efforts need to be made by both building companies and government. Building companies should develop a more open/active attitude towards innovations on sanitation level. Governments from their side should develop regulations and/or subsidy programs in order to stimulate environmental friendly sanitation options which have proven their effectiveness.

4.2.3 Sanitation expert

The expected lifetime of the vacuumarator and pipes is 30 to 50 years but according to Harry Vieregge the system is so robust that it could easily be more then 50 years. Besides the two system failures *(table 8)* the 'Klaassen Groep' did not receive complaints about the vacuum toilet system. Harry Vieregge expects that the inhabitants are satisfied with their toilet system.

Table 8: Vacuum system failures

Part of sanitation system	**Problem**	**When**	**How often**	**Solution**	**Solved?**
Pipes + connections	No vacuum production because leakage of air	Feb 2007	2x	Proper installation of rubbers at connections	yes
Vacuumarator	Blockage of a grinder led to a total system breakdown	September 2007	1x	Removing the blocking parts out of grinder and resetting the system	yes

It is not possible to determine the total amount of m^3 necessary for the toilet system but compared to a conventional system less space is necessary because the pipes are much

thinner. Some additional space is necessary for the vacuumarator but this is only a minor amount of m^3(In the case of Deventer 1 m^3 for the 2 vacuumarators which serve 38 apartments). The exact amount of noise produced by the vacuum toilets is not known by Harry Vieregge.
The average water use per person in the Netherlands is 123,8 litres per day (Klaassen Groep). The vacuum toilet system should be able to reduce the wastewater production per person by 10.000 litres per year which is equal to 27,4 litres per day. By using a vacuum toilet system the daily water consumption would be reduced to 123,8 – 27,4 = 96,4 litres per day.
When referring to future projects the 'Klaassen Groep' wants to contract a technician for the vacuum toilet system that lives more in the neighbourhood. At the moment the Jets technician has to travel all the way from Rotterdam to Deventer when a problem with the vacuum toilet system occurs. This takes a lot of time and according to Harry Vieregge a local technician is also capable of fixing (small) problems with the vacuum toilet system.
The energy use of the vacuum system is not measured but can be estimated by assuming that the central vacuum pump runs for 1 hour a day. The pump has a power output of 3 kWh which means that 3 kW is used daily. On a yearly base this means an energy use of 1095 kWh. Divided by 65 inhabitants this means a yearly energy use of 16,8 kWh per person. The valve of the JETS toilet opens by a small electromotor and on a yearly base it is estimated that this motor uses 0,16 kW per person *(Roelofse 2006)*. On average a Dutch person in a household existing out of two persons uses 1547,5 kWh per year (*Milieucentraal*). In that case the use of a vacuum toilet system would increase the total energy use with 1,1%.

4.2.4. Operation and maintenance and system owner interview

Description of the system
The operation and maintenance interview was performed with Mr. R. de Haan from 'DOMUS v.v.e. beheer' which is responsible for the operation and maintenance of the neighbourhood. Rudie de Haan explains that the second vacuum system breakdown in Deventer could have been caused by a total system switch-off when one of the pumps was blocked.
During the household interviews In Deventer I found out that the inhabitants are not completely informed about the proper maintenance of their vacuum toilet. At the moment the inhabitants face problems with the maintenance of the toilet because the special cleaning agent (Biocompact) is finished in some cases and not renewed. Other cleaning agents such as bleach are used but this can negatively affect the pipes of the vacuum system. Inhabitants are not aware how these problems can be solved.

Rudie de Haan explains that a jerrycan of Biocompact has been ordered and placed in the basement of the Casa Vita project in Deventer. Inhabitants don't have access to this basement but they can ask the cleaner who comes weekly to fill their empty Biocompact bottles. A different approach in the distribution of the biocompact is considered because apparently inhabitants are not aware of the fact that they can fill their empty Biocompact bottles. The expected use of Biocompact is 2 litres per apartment per year.
The expected maintenance costs for the complete vacuum toilet system are not higher than 200 – 300 € per year. The reason for these relative low costs are the robustness of the system and the small amount of failures/blockages. According to Rudie de Haan only 4 hours of maintenance work needs to be done yearly plus 2 hours of work for solving system failures. So far the amount of complaints received by Domus concerning the vacuum toilet system is very limited. There have been only a few complaints which were related to the vacuum system failures in February and September. Domus can be contacted 24 hours a day by telephone because a telephone centre takes over when the office closes. The telephone centre is instructed to contact Jets in Rotterdam when a vacuum system failure occurs.

There is no monitoring system for water and electricity use installed in the Casa Vita project in Deventer. A monitoring system can provide valuable information concerning the effect of a vacuum toilet system on water and energy use. Tauw b.v., a company that works in the environmental advice sector, is working on a monitoring system for water and energy use in the Casa Vita project in Deventer and expects to install it in short term.
The time that it takes for Domus to solve a failure in the vacuum system depends largely on the time that it takes before someone contacts Domus. The first problems with the vacuum system took about 24 hours to repair because of the complexness to locate the leakage of the vacuum system. This failure can be judged as starting-up problems and it is not expected that long failures like this will happen often in the future. The blockage of the vacuum system in September was repaired much quicker, 3 to 4 hours from the moment that Domus received the phone call.
Domus organises a meeting with the inhabitants of the Casa Vita project once a year. During this meeting the vacuum system is not a topic on the agenda but Rudie de Haan agrees that it could be a good initiative to integrate the vacuum system in the meeting.

4.2.5 Other information

Additional data concerning the project came from Paul Telkamp from the company TAUW b.v. The contact with Paul Telkamp from TAUW b.v. was usually informal and focussed on the aspects:

- noise production of vacuum toilets
- water and energy use in Casa Vita project, Deventer

The noise production of the vacuum toilets in Deventer was measured and can be compared with the noise levels of other (vacuum) toilets *(table 9).* Up to now no measuring equipment for water- and energy use is installed in Deventer so it is not possible yet to draw conclusions about these aspects.

Decibel measurements Deventer
According to the household survey that I performed in Deventer the noise production of the vacuum toilets was considered high and annoying by a relatively large amount of inhabitants. Decibel measurements were performed by the Dutch company TAUW b.v. to determine the noise productions of different toilets *(table 9).* A Jets toilet in Deventer which, is closed when flushed, produces 91 dB(A) (with echo correction). This is 8 dB(A) more than a closed conventional toilet which produces 83 dB(A) *(table 9).* The advantage of vacuum toilets is the fact that the flushing takes much shorter and no noise is produced by water flowing in a reservoir. According to Paul Telkamp, TAUW b.v. is working on innovations to further reduce the noise production of vacuum toilets.

Table 9: Decibel production of different toilets when flushed

Results in dB(A)		$L_{W, Amax}$, with echo correction	$L_{W, Amax}$, without echo correction
vacuum	Deventer, JETS closed	91	94
	Deventer, JETS open	95	98
	Sneek, EVAC closed	93	99
	Sneek, EVAC open	97	103
	Sneek, ROEDIGER closed	102	105
	Sneek, ROEDIGER open	104	107
	Sneek, JETS closed	95	101
	Sneek, JETS open	99	105
	Sneek, ROEDIGER + damper closed	89	91
	Sneek, ROEDIGER + damper open	93	95

Convention neel	Deventer, CONV. Plateau closed Deventer, CONV. Plateau open	80 87	82 89
	Deventer, CONV. without plateau closed Deventer, CONV. without plateau open	83 85	84 87
		Average	**Standard deviation**
Vacuum toilet average with dispersal Conventional toilet average with dispersal		96 84	5 3

P. Telkamp, TAUW bv, 2007, financed by WUR SWITCH project

4.3 Survey

4.3.1 Results from survey

A survey research among the households of the Casa Vita project at the Boxbergerweg 140 in Deventer was performed to identify their opinion about the vacuum toilet system that they are using. Twenty from the thirty eight apartments were surveyed. I was present when the people were filling in the survey to clarify questions, ask questions about their answers and support people to give as much relevant information as possible.
The survey was divided in the aspects:

- information about household
- background questions
- functioning of vacuum system, invisibility and user comfort
- robustness of the system
- questions about environmental awareness

The different aspects are subdivided in the following questions:

Information about household

What is your age?
The majority of the people that I interviewed has an age between 20 and 40 years (90%). For a lot of people this was their first house (starters). Only in two households I spoke to a person of 40 years or older.

How many persons are living in this household?
In the majority of the apartments live 1 (8 times) or 2 (11 times) persons (95%). Only In one household there were 3 persons living *(table 10)*. Probably this has to do with the relative small size of the apartments.

Table 10: Amount of persons per household

Amount of persons in household	Total	Total %
1	8	40%
2	11	55%
3	1	5%

What is the composition of the household?
In 8 households live singles, 8 households are living together and don't have kids and 4 households exist out of a 2 parent family.

How many persons are not at home during daytime (school, work)?

In total 33 persons live in the households that I interviewed. From these 33 persons, 27 spend the day outside their apartment, which is equal to 81,8 %.

How many persons are spending the night at home at least 5 night per week?
All of the 33 persons are spending at least 5 nights per week at home.

Did you choose this apartment especially because of the vacuum toilets?
Nobody from the surveyed persons choose the apartment especially because of the vacuum toilets. One household was not aware that vacuum toilets were installed.

Background questions

What is the highest education that you finished?
One person graduated at university level, 11 at HBO level, 7 at MBO level and one at LBO level.

Functioning of the vacuum system, invisibility and user comfort

To what extend are you satisfied with the vacuum system?
The majority of the households (67,5%) is satisfied or even very satisfied with the vacuum toilet system. A smaller part of the households (27,5%) was neutral about the system and only 1 household (5%) was dissatisfied with the system *(table 11)*.
Advantages which are mentioned are:

- water saving/environment (6x)
- possibility to flush immediately afterwards (1x),

Disadvantages which are mentioned are:

- reliability (6x),
- noise production(3x)
- need to flush multiple times (1x)

Table 11: Satisfaction with vacuum system

Satisfaction	Number of households	%
Very satisfied	2	10%
Satisfied	11,5 *	57,5%
Neutral	5,5 *	27,5%
Dissatisfied	1	5%
Very dissatisfied		

* One household was in between satisfied and neutral

Is the vacuum toilet easily kept clean?
In this case 13 of the households (65%) answers that the vacuum toilet is easily kept clean, 6 households (30%) answer that it is not very good kept clean and 1 household (5%) answers that it is poorly kept clean.
Disadvantages which are mentioned are the small amount of water which flushes through the toilet, the need to flush multiple times before everything is gone, the water flushes not through the whole toilet (e.g. not through the front) and only certain cleaning agents are allowed to use.

How often do you clean the toilet?
Sixteen out of the twenty households (80%) clean their toilet between 4 and 8 times per month, 2 households (10%) clean their toilet between 10 and 15 times per month and in 1 household the toilet is cleaned 30 times per month.

What is your opinion about the noise that the vacuum toilet produces when flushing?
The opinions about the noise production of the vacuum toilet differs. The majority (50%) considers the sound hard. A smaller amount of people considers it annoying (20%). And a minority (30%) does not have hindrance of the sound *(table 12)*.
An advantage which is mentioned is that the sound only takes a short while.

Table 12: noise production of vacuum toilet

noise	Number of households	%
Hard	10	50%
Annoying	4	20%
No hindrance	6	30%

Does the toilet of the neighbours cause noise nuisance?
The majority (50%) of the households never experiences noise nuisance from the toilet of the neighbours. A group which is almost as big (45%) sometimes experiences noise nuisance from their neighbours toilet. Only one household experiences often noise nuisance from their neighbours toilet.

What do you consider important aspects when choosing a toilet?
A small majority of the people (55%) consider saving water and other environmental aspects important when choosing a toilet.

Did you ever consider to replace the vacuum toilet for an other toilet?
From the 20 households only 1 household ever considered to replace the vacuum toilet for a conventional one.

Are you informed about how to use the vacuum toilet?
All of the households were taught how to use the vacuum toilet. One time it was mentioned that the provided information could have been more elaborate.

Are there other aspects which are related to the vacuum toilet that you would like to mention?
The different aspects that are mentioned can be divided in the categories:

Failures
- Reliability of the system should be improved 2x
- No solution in case of system failure 1x
- Warning light in toilet when system is down 1x

Operation
- Hygiene (more water flushing through toilet) 3x
- Information about proper usage of toilet lacks 1x
- Problems with distribution Biocompact 3x
- Flush button could be placed higher 1x

Nuisance
- Noise nuisance 3x

User freedom
- Only one type of toilet / toilet seat 1x

Environmental
- Water saving 1x
- Environmental friendly 1x

A big disadvantage which is mentioned in previous questions is that no back-up system is available if the vacuum system fails. People don't have any possibility anymore to go to the toilet. Improvements should be made to assure that a second pump is always available if a failure occurs.

One person mentioned that the pressure of the showering water gets lower when someone flushes the toilet which would indicate an error such as an improper connected joint.

Would you recommend the vacuum toilet to households in other neighbourhoods?
The majority of the households (65%) would recommend the vacuum toilet system to households in other neighbourhoods. From these 65% everyone mentions the environmental aspects as most important in recommending it to other people. Four households think improvements are necessary before recommending it to other people. Three households don't have an opinion. Most people recommend the system because of environmental aspects.

If you would move to an other house would you prefer a vacuum toilet or a conventional one (or other option)?
The majority (60%) wants to keep the same toilet if they would move to an other house. Two households want a vacuum toilet but with a reduced noise production. Five households would choose a conventional toilet and one household doesn't have an opinion.

Which grade would you give to the vacuum system?
Two households gave a grade lower then 6. On average the toilet scores a 7,15 *(table 13)*.

Table 13: Grade of the vacuum system

Grade	**5**	**6**	**7**	**8**	**9**	**10**
Amount of households	2	2	9	5	2	
%	10%	10%	45%	25%	10%	

Did you notice any differences in your water/energy bill since you are using a vacuum toilet?
The households did not receive a water/energy bill yet so people could only guess. It is assumed that the water bill will be lower because of the small amount of water which is flushed through the toilet. The energy bill could be higher because of the energy necessary for the vacuum system.

Robustness of the vacuum system:

Did you ever have a problem (failure/blockage) with your vacuum toilet?
If yes, how often?
No one ever experienced a blockage of the vacuum toilet itself.

Did you ever experience a failure of the total vacuum system?
If yes, how often?
Seven people answered that they experienced a blockage of the vacuum system one time. Ten people answered that they experienced a blockage of the vacuum system two times and three people never experienced a blockage of the vacuum system. The two blockages took place in March and October 2007.

Only answer if 1, or both, answers of the previous 2 questions where higher then 0

Which part of the wastewater system failed? What was the problem? When and how does it happen? How was the problem solved and by who?
In both cases the failure took place at the central vacuum pump. The failure in October was caused because a person flushed something through the toilet which got stuck at the vacuum pump. The failure happened at night and the people were not able to reset the pump because they could not reach it. Because of some reason also the second pump stopped

working and the whole system broke down. The failure got solved in the afternoon by a mechanic.

When the vacuum system fails how long does it take on average until it is fixed again?
There have been only two failures and the first failure took much longer to fix than the second one. Ten people (50%) answer that it takes between 4 to 8 hours to fix the failure, One person answers that it takes on average 12 hours and three people answer that it takes on average 24 hours. Six people don't know how long it takes to fix the failure.

What is your opinion about the safety of the sanitation system in relation to contact with pathogens or other physical risks?
Everyone except for one household answered that the risks are the same as with a conventional toilet.

Questions about environmental awareness

Do you consider yourself environmental aware?
The people from the surveyed households are moderately environmental aware *(table 14)*.

Table 14: Environmental awareness of households

Environmental aware	Number of households	%
Always	3	15%
Often	6	30%
Sometimes	7	35%
A bit	2	10%
No	1	5%

Did the vacuum system increase your environmental awareness?
In 5 of the 20 cases (25%) the vacuum system has increased the environmental awareness.

Do you expect a good future for the vacuum system?
Thirteen households (65%) immediately thinks the vacuum system has a good future. Five households think that improvements should be made before implementation on a bigger scale.

4.3.2 Points of attention

Some important aspects that have been mentioned by the households are:

- Biocompact should always be available for the households
- Integration of the Biocompact in the flushing water (For example a capsule in the water reservoir)
- In information sheet could be useful to inform the households which cleaning agents are allowed to be used
- Households should be aware that certain objects can not be flushed through the vacuum toilet because this will cause blockages in the pipes
- Integrate a light bulb in the toilet that starts to burn if the system is down
- A back up toilet system should be available in case of a system failure
- Make the vacuum pump accessible for (certain) inhabitants so they are able to reset the pump themselves in case of a system failure

5. Research site Flintenbreite, Lübeck

5.1 General

The construction of the Ökologische Wohnsiedlung Flintenbreite in Lübeck, Germany, has been initiated by the World exhibition of 2000 in Hamburg. In the original planning the neighbourhood existed out of 115 houses but up to now only 30 have been built *(figure 4)*. From the schematic drawing below H1 – H6, A1 – A 9, B1 – B5 and the Gemeinschaftshaus have been build. In total this means 26 houses, 4 apartments and a communal building. The planning was to accommodate 350 inhabitants but at the moment there are only living 110 persons *(Appendix 7: Realized building activites Flintenbreite).*
The goal of the project was to show that sustainable building could be successfully integrated in new neighbourhoods against reduced costs. Due to the bankrupt of the construction company IHT not much new houses have been realized since 2001. Only recently 9 new houses (E1 – E5, F1 – F4) are being built by a new construction company and which will be finished soon.

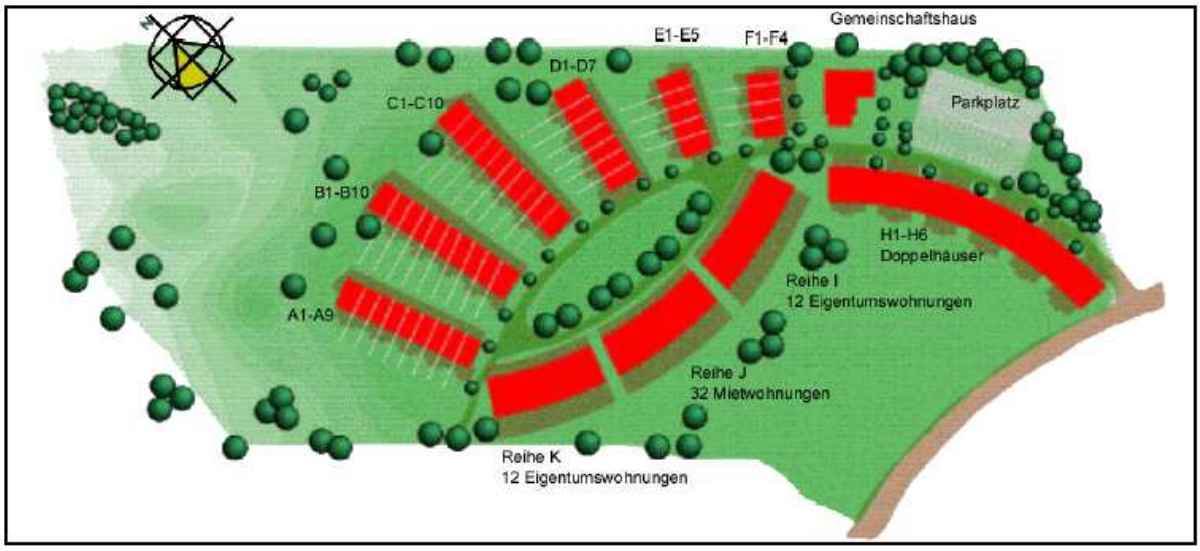


Figure 4: Schematic drawing of original Flintenbreite project (Otterwasser, 2005)

Implemented technology
The initial plan was to create a separate collection and local treatment system for black and grey water flow. The black water system would exist out of a vacuum toilet system which is connected to a digestion installation. In the digestion installation black water and kitchen garbage are mixed and biogas is produced. A combined heat and power installation (CHP) finally uses the produced biogas to create heat and electricity which is used in the households.
Up to now the black water system is only working partly. The 30 houses are equipped with vacuum toilets which are connected to a central vacuum system. The black water is sucked to the community building where the vacuum pump is located. The next step would have been to digest the black water but up to now the amount of black water is not sufficient for the digestion installation. When the new houses are finished the black water flow should be sufficient for the digestion installation to work properly. At the moment the black water is collected by truck once a month.

Black water system
Vacuum toilets (Roediger) which use only 0,7 to 1,2 litres of water per flush have been installed in the different houses. Behind the toilet a small reservoir is installed in which a total of 8 litres of black water is collected. When the storage tank is full, a valve opens and the

content is sucked through the vacuum pipeline to the vacuum pump. This is done to reduce the noise production, the energy demand and the chance on blockages in the vacuum system. From the central vacuum pump the black water first flows to a mixing tank and afterwards to a hygienisation tank. When the black water enters this tank it is heated up to 70℃ for 1 hour or up to 55 ˚C for 12 or more hour s in order to kill possible pathogens .From the hygienisation tank the black water finally flows to a collection reservoir which is emptied once a month by a truck that transports the black water to a conventional wastewater treatment plant.
In the future the concentrated black water will flow from the hygienisation tank to a digestion installation. The digestion installation is placed in the basement of the centrally located common building of the neighbourhood. During the next phase the black water sludge is digested at a temperature of 38 ˚C. In this phase biogas is produced which is transported to the CHP where the gas is turned into heat and electricity *(Appendix 8: pictures black water system*). To improve the quality of the produced biogas and to decrease the organic waste production of the neighbourhood the black water is mixed with shredded organic waste in the mixing tank. The organic waste has a relatively high carbon content which improves the quality of the biogas. It is estimated that the produced biogas will cover 5 – 10% of the energy consumption of the neighbourhood *(Stowa, 2005), (Otterwasser 2005, 2001)*.

Grey water system
The grey water which is produced by the households is transported separately from the black water flow. The grey water is transported by gravity from the houses to one of the three sedimentation tanks in which heavy particles, oils and fats are separated from the grey water. From the sedimentation tank the grey water is pumped to constructed wetland nr. 2 in which it is treated further (*figure 5: Constructed wetland Flintenbreite)*. Only one of the three originally planned constructed wetlands is active nowadays because the grey water flow is not sufficient for three filters. A constructed wetland demands a certain minimal flow of water in order to work properly *(Appendix 9: Grey water system Flintenbreite)*.
The constructed wetland exists out of a shallow pit which is filled with sand. On top of the wetland reed is growing and the sand in the filter is protected by a top layer of gravel. The bottom and sides of the constructed wetland are covered with plastic to prevent leakage of grey water in the soil. The grey water is pumped up from the sedimentation tank and enters the constructed wetland at the top. While the water flows through the wetland it is gradually cleaned by micro organisms that live in the roots of the reed. When the cleaned water reaches the bottom of the wetland it is transported out of the wetland by drainage tubes. *(Otterwasser, 2005, 2001)*

Figure 5: Constructed wetland in Flintenbreite neighbourhood (Otterwasser 2005)

Rain water

Many efforts are done to locally stimulate the infiltration of rain water in the soil. By capturing the rain water locally the water cycle is not disturbed because the rain water is able to infiltrate to the groundwater. Next to hard surfaces such as roads and roofs of houses infiltration areas are constructed where the water can infiltrate in the ground. Next to the drain-pipes of the houses an undeep, sandy trench stimulates the infiltration infiltration of rain water in the soil and next to roads a bigger, shallow trench serves the same purpose *(figure 6)*.

Figure 6: Trench for the infiltration of rainwater in the soil (Otterwasser 2005)

5.2 Interviews

5.2.1 Stakeholders

The following actors and representatives have been involved in the Flintenbreite project:

Actor	Representative	Role / responsibility
Infranova GmbH & Co KG	Dr. I.r. Martin Oldenburg	Operation, maintenance and management
Infranova GmbH & Co KG	Mr J. Nielsen	Operation and maintenance
Infranova GmbH & Co KG	Dr. I.r. Martin Oldenburg	Project development and operation
OtterWasser	Dr. I.r. Martin Oldenburg	Design wastewater system
Municipality of Lübeck		Planning authority
Infranova GmbH & Co KG	Prof. Ralf Otterpohl	Operation and maintenance work
Construction company IHT		Build houses and wastewater system → Went bankrupt in 2001

At the Infranova GmbH & Co KG represented by Dr. I.r. Martin Oldenburg is the main party in the project.

5.2.2 Drivers and barriers interview

Description of sanitation system

The drivers and barriers interview was performed with Martin Oldenburg from Infranova GmbH & Co KG. The realization of the Flintenbreite neighbourhood has been (and still is) a complex process in which a changing group of stakeholders was involved.

The initiative to construct a neighbourhood in which multiple environmental aspects are integrated goes back to 1993. In that year the first ideas started to evolve among stakeholders to construct a neighbourhood in which different sustainable aspects were integrated. At that time there was contact between Ralf Otterpohl, founder of the company Otterpohl Wasserkonzepte, an architect called R. Fleck and a designer for energy systems called E. Warnemünde. In 1994 the municipality of Lübeck decided that they wanted to construct an ecological neighbourhood. The municipality organized a competition that year to find suitable stakeholders for a new to be build neighbourhood. The above mentioned stakeholders applied for the project and were chosen as a group to perform the project development. The last party involved in the process was the construction company Trautsch Bau which was at that time located in Lübeck.

Together the stakeholders (except the construction company) founded the company Infranova GmbH & Co KG in 1996 which would be responsible for the Flintenbreite project. Before the actual building activities would start the construction company went bankrupt in 1998 and a new construction company called IHT took over the work. At that time Otterpohl Wasserkonzepte was converted to Otterwasser GmbH. Finally the 4 different stakeholders in the project were:

- IHT — Construction company
- R. Fleck — Architect
- Otterwasser GmbH — Design wastewater plan
- E. Warnemünde — Energy planner

The construction of the new to be build Flintenbreite neighbourhood began in May 1999. Nine months later in February 2000 the construction of 30 houses, the common building

(Gemeinschaftshaus), infrastructure and water system was finished. Up to today these 30 houses (26 houses and 4 apartments) are still the only houses which are finished because the construction company also went bankrupt in 2001 because of the bad situation on the house market in Germany. Since the bankrupt of the construction company Infranova GmbH & Co KG has taken over the responsibility and contracted a new construction company to build the remaining houses of the Flintenbreite neighbourhood. At the moment 9 new houses are almost finished.
The households in the Flintenbreite neighbourhood have bought their houses but the ground on which the houses are standing is still property of Infranova GmbH & Co KG. The ground is leased (possibly the ground on which the houses are standing is sold to the inhabitants in the future). The Gemeinschaftshaus which includes four apartments is property of Infranova GmbH & Co KG and the households that live in the apartments rent them. All the other ground in the Flintenbreite neighbourhood as well as the infrastructure is property of Infranova GmbH & Co KG.
Infranova GmbH & Co KG as owner of the technical infrastructure system is responsible for the operation and maintenance activities in the neighbourhood. They are responsible for providing energy, electricity, drinking water, wastewater handling, street light and other maintenance activities to the households. The households pay a single sum of money to Infranova GmbH & Co KG for all the provided services.

Environmental drivers
The main environmental drivers were the reduction of water emissions, recycling of nutrients, reduction of energy use and the quality of neighbourhood landscaping*(table 15)*. These environmental drivers were also the ones that were finally realized in the Flintenbreite neighbourhood. Aspects like water saving and the prevention of drying out of soil were considered less important but because of the vacuum toilets and the rain water infiltration system they are realized.

Table 15: Environmental drivers

Environmental aspect	**Unimportant**			**Important**	
	0	**1**	**2**	**3**	**4**
Positive feeling about environmental friendly behaviour			**X**		
Water saving		**x**			
Prevention of drying out of soil		**x**			
Reduction of water emissions				**x**	
Recycling of water	**x**				
Protection of surface water	**x**				
Protection of groundwater	**x**				
Recycling of nutrients					**x**
Reduction of energy use				**x**	
Quality of neighbourhood landscaping				**x**	
Other……					
Other……					

Environmental and public health barriers
There were no important environmental or public health barriers for the project though it was important to create a wastewater system which would not cause any health risks.

Legal and regulatory barriers
There were some legal and regulatory barriers concerning the grey water system because the municipality had bad experiences with a constructed wetland in the past. It took some time to convince the municipality that the design and performance of constructed wetlands increased a lot since that time.

No legal and regulatory barriers were faced with the black water system.

Vacuum toilet (social/technical)
The implementation of the vacuum toilet system has been a main driver in the Flintenbreite neighbourhood. From the start of the project it was clear that a vacuum toilet system would be implemented. A lot of efforts were done to maximize the social acceptance of the vacuum toilet. Reservoirs were installed behind the toilet to decrease the noise production and energy use, information concerning the proper use of the vacuum toilet system was provided to the inhabitants and a caretaker who is able to fix failures of the system lives in the Flintenbreite neighbourhood.

Financial drivers and barriers
The budget for the project was clear in advance and played no big role in the system choice. The sanitation system of the Flintenbreite project did not receive any subsidies or funding. The costs for the sanitation system is spread over the different households. An aspect such as the reuse of grey water for toilet flushing was not realized because of the relatively high costs but this aspect was also not an important driver of the project *(table 16)*.

Table 16: Financial drivers and barriers

	Unimportant				**Important**
	0	**1**	**2**	**3**	**4**
Design costs (compared to conventional system)		**x**			
Operating costs (compared to conventional system)					**x**
Energy costs (compared to conventional system)				**x**	
Reduction of water emissions			**x**		
Applying vacuum toilets		**x**			
Reduced drinking water consumption (lower bills)					

Social and managerial drivers and barriers
The most important social and managerial aspects were the involvement of the households in the wastewater system and improving the quality of living in general *(table 17)*. The goal was to make people aware of the wastewater system, the positive aspects and the way to treat it. The system should lead to an improved quality of living by creating a natural environment in the neighbourhood and reducing the costs for energy and water.

Table 17: Social and managerial drivers and barriers

	Unimportant				**Important**
	0	**1**	**2**	**3**	**4**
Intensive contact with neighbours, collaboration with neighbours	**x**				
Involvement in sanitation / taking responsibility for your household water management system				**x**	
Improved quality of living					**x**

The operation and maintenance activities in the Flintenbreite neighbourhood are the responsibility of Infranova GmbH & Co KG. Infranova GmbH & Co KG is for example responsible for the distribution of gas, electricity and drinking water but also street lights, removal of snow from the roads, repairing vacuum toilets and heating systems, etc. It is the responsibility of Infranova GmbH & Co KG to set up contracts with companies that provide the necessary services. This provides financial benefits for the households because Infranova GmbH & Co KG is able to buy the services in bulk which is relatively cheaper.

Current and future status wastewater management system

There have been some technical modifications to the vacuum toilet system. The combination of the valve and reservoir behind the toilet caused a lot of failures due to paper and other residues which got stuck in the small tubes of the valve system. In 18 of the 28 houses where such a system was installed a shortcut has been made. The reservoir and the valve do not have any use anymore and the flushed black water is sucked directly to the central vacuum pump. Due to the development made by Roediger company a newer Roediger model or models from other companies will be installed.
In the future one of the constructed wetlands which is not in operation yet will be replaced by a fixed bed system.

5.2.3. Sanitation expert interview

The sanitation expert interview was also performed with Mr. Oldenburg because he is the closest related to the Flintenbreite project. Officially certain persons of Infranova GmbH & Co KG should perform the operation and maintenance work of the Flintenbreite project but in practice Mr. Oldenburg performs these tasks.

Sanitation system description
The black and grey water system in the Flintenbreite neighborhood exists out of a lot of different components. The lifetime of the system depends on the different components:
- Pumps 10 – 12 years
- Tanks 20 years
- Pipes 50 years
- Wetland 20 years

The lifetime of the (vacuum) pumps is relatively short because they consist out of moving components which are vulnerable for wearing out. The lifetime of the tanks is much longer because there are no moving components. The lifetime of these tanks is expected to be at least 20 years. The pipes of the vacuum system are expected to have a lifetime of at least 50 years.

It is not easy to say what the average yearly costs per household are for the sanitation system. Costs that could be determined are the costs for cold, warm and wastewater per household *(table 18)*. The households have to pay the costs for the wastewater to Infranova GmbH & Co KG. From that income Infranova GmbH & Co KG pays all the necessary costs for the wastewater system. These costs are mainly caused by the maintenance work that Mr. Nielsen (the caretaker) has to do on the vacuum toilet system. On average Mr. Nielsen works 1,5 to 2 days a week on the vacuum toilet system. The households pay a certain amount of money to Infranova GmbH & Co KG for gas, water electricity etc. Infranova GmbH & Co KG does not have to pay water fees because they do not use the conventional sewer system. Probably they will have to pay a small amount of money in the future for discharging the treated grey water on the surface water. But this amount is small compared to the costs of conventional wastewater fees.

Table 18: Water costs for Flintenbreite inhabitants per household

	Basic fee (fixed)	Consumption fee	Total (excl VAT)	Total (incl VAT)
Cold water	23	79	102	109,14
Warm water (incl. heating)		49 84	133	142,31
Wastewater	151	161	312	371,28
Total	174	373	547	622,73

System performance of grey water system
The inhabitants of Flintenbreite use about 68 liter of drinking water a day which is low compared to the German average of 129 liter. There is a big difference in water consumption between the different houses in Flintenbreite (Appendix 10). At the moment only the COD and BOD of the effluent of the constructed wetland system is monitored because these measurements are obliged for small scale (>1000 p.e.) wastewater treatment plants. In the past also the N, P, TOC, NH_4N, NO_3N, PO_4P and the influent of the constructed wetland have been measured but this is not done nowadays because it costs a lot of money. The last available data concerning the influent of the constructed wetland date from 2001 *(table 19*). The data for COD, BOD_5 and TOC differ quite a lot over the different measurements. An explanation for these fluctuations could be the infiltration of rain water in the system which leads to an increased amount of relative less polluted water.
The last available data concerning N, P, NH_4N, NO_3N and PO_4P in the effluent of the constructed wetland dates from 2001. The most recent data concerning the TOC concentration in the effluent dates from 2003 and the most recent data concerning the COD and BOD_5 concentration of the wastewater dates from 2007. The surface of the constructed wetland 2 (that treat all the grey water at the moment) is 276 m^2.

Other sources *(table 20)* mention more recent data concerning the N, P, NH_4N, NO_3N and PO_4P concentration in the influent and effluent of the constructed wetland but this data is not recorded in the spreadsheets of Otterwasser *(Appendix 11)*.
Over the years the COD and BOD_5 concentration in the effluent of the constructed wetland has decreased significantly. When the wetland was build in 2000 the COD was 55 g/m^3 and this decreased to 16 g/m^3 in 2007. Martin Oldenburg assumes that the treatment efficiency of the constructed wetland has increased because of a longer retention time. Organic particles in the constructed wetland decrease the speed of the grey water flow which leads to a longer retention time and a better treatment efficiency.
The grey water system has failed only once because of a clogged pipe.
The yearly electricity use of grey water system per person is estimated to be < 2 kWh/year (The pump of 0,5 kW runs 1,11 hours a day, times 365 days a year, divided by 110 inhabitants = 1,84 kWh pp year).
The surface of the constructed wetland is > 2 m^2 per inhabitant which is more then sufficient to treat the grey water.

Table 19: Data on grey water system

	Influent constructed wetland (2001) (g/m^3)	Effluent constructed wetland (g/m^3)	Treatment efficiency
COD	359	16*	87,7% ***
BOD_5	136	2 *	93,4% ***
TOC	109	5 **	84,4% ***
N-total	11,1	3,6 ***	67,6% ***
NH_4-N	> 0,5	0,2 ***	60% ***
NO_3-N	1,2	2,4 ***	- 100% ***
P-total	5,6	3,4 ***	39,3% ***
PO_4-P	4,3	3,4 ***	20,9% ***

Otterwasser, 2007

*: data from 2007
**: data from 2003
***: data from 2001

Table 20: Data on grey water system

	Oldenburg 2002		Otterwasser 2003	
	Influent constructed wetland	Effluent constructed wetland	Influent constructed wetland	Effluent constructed wetland
COD (mg O_2 /l)	421	41	502	59
BOD (mg O_2 /l)	144	9	194	14
N-total(mg N /l)	10,1	4,0	12	2,7
NH_4-N (mg N/l)	-	> 0,5	4,5	0,9
NO_3-N (mg O_2 /l)	-	1,4	-	-
P-total (mg N /l)	5,3	4,3	8	5,7
PO_4-P	4,7	3,9	7,6	4,8

STOWA, *2005*

System performance of black water system

The black water system has faced a lot of problems since it was installed *(Appendix 12: Failures and blockages of black water system)*. A lot of problems occurred at household level with the toilet itself. The pushing button of the Roediger vacuum toilet which is used appears to be very sensitive for failures. When people flushed the toilet it happened often that the flushing did not stop which caused a continuous and increasing vacuum sound from the toilet. The reservoir and valve which are installed behind the toilets also caused lots of blockage problems. In 18 of the 28 houses where such a system was installed a shortcut has been made to bypass the reservoir and valve system. Over the years different improvements have been made to the black water system to reduce the amount of failures *(Otterwasser 2007)*. Since a shortcut in the system has been made in the majority of the houses the energy use of the vacuum system has significantly decreased *(Appendix 13: energy use of vacuum system)*. Martin Oldenburg assumes that the high energy use was caused by air leakages in the vacuum system on household level. The high concentration of pipes and connections of the reservoir and valve system is apparently vulnerable for leakage of air.
At the moment the electricity use of the black water system is 0,11 kWh per person per day which is equal to 40 kWh per person per year. Over the past months the electricity use of the black water system has decreased significantly.
The failures of the black water system are registered since 6 years and in that time a total of 537 failures took place *(Appendix 12)* which means an average of 90 failures per year. For Infranova GmbH & Co KG the failures represent repair as well as maintenance activities which are necessary at the level of the vacuum system. The majority of the failures had to do with problems in the design of the toilet itself. Only the reservoir/valve, valve at toilet level and pushing button already caused 402 from the 537 failures which is equal to 75% of the failures. On average a household experiences 2,2 times per year problems with the reservoir/valve and pushing button. Most of these failures are caused by fibres from toilet paper in the air pipe of the control unit of the reservoir. The clogging of the main vacuum pipes only occurred 13 times which means on average 2 times a year. The problems have become less over the years because the inhabitants are now better aware how to use the vacuum system. In the central vacuum unit a failure occurred 10 times of which only 1 caused a system breakdown *(table 21)*. The failures are repaired relatively fast because the caretaker is able to repair the majority of the failures himself. On average it takes about 0,5 hour to repair a failure.
A specific problem at the Flintenbreite neighborhood is the relatively high hardness of the drinking water which is caused by a high calcium content. According to Dr. I.r. Martin Oldenburg the calcium precipitates as calcium carbonate ($CaCO_3$) in the pipes and will cause blockages and a decreased flushing efficiency if not removed in time. In the Flintenbreite

project the pipes of the vacuum system have been flushed once with acid to remove the calcium carbonate scale from the pipes.
In other projects (Arbeiten&Wohnen, Torvetua) where a vacuum toilet system is implemented problems were faced with the formation of struvite ($MgNH_4PO_4$) in the pipes by precipitation of urine salts. Several tests have been performed to ensure that struvite is not causing the blockage problems in the Flintenbreite project.

Table 21: Vacuum system failures

Part of sanitation system	Problem	When	How often	Solution	Solved?
Reservoir + valve	Clogging of small control pipes (air)	Continuously	262	Bypass to shortcut the system	Yes, but still problems
Pushing button of toilet	Clogged or broken	Continuously	80	Cleaning or replacing the button	Yes, but still problems
Valve at toilet level	Clogged due to calcium scale or other problems	Continuously	60	Cleaned or replaced	Yes
Central vacuum station	Multiple problems		11	Repaired	Yes
Clogging of main vacuum pipe	Clogging because of tampons, toilet paper or calcium residues		13	Flushed with water or acid	Yes
Other failures			111		
Total failures			537		

In the beginning of the project a lot of problems occurred because households flushed objects (tampons) through the toilet which blocked the (main) vacuum pipes. Nowadays less problems occur because the inhabitants are better aware of the proper use of the vacuum system.
The black water system is still not in full operation because the black water flow is too small for the biogas installation to work properly. At the moment nine new houses are being constructed in the Flintenbreite neighborhood which will be connected to the black water system. According to Martin Oldenburg the black water flow will be sufficient to operate the biogas installation when these nine houses are connected. The University of Hamburg performed laboratory tests with the blackwater from the Flintenbreite neighborhood and concluded that it can be used for the production of biogas directly. Mixing it with shredded organic waste will increase the carbon value of the black water which leads to a bigger biogas production *(Otterwasser, 2005)*. After the biogas production the black water will be stored in a reservoir from which it is transported to farmers in the neighborhood that use it for fertilizing the agricultural soil. In theory 90% of the nitrogen, 60% of the phosphor and 70% of the potassium will be reused in this way.

Costs
In the Flintenbreite project a vacuum system from the company Roediger is used. At the time of building no alternative systems were available. If the 115 houses in the neighborhood are finished the total costs for the grey, black and rain water system will be 5300 € per household *(table 22)*. These costs are equal to the average costs in Germany for a connection to the wastewater system.

The additional costs for the black water systems are 3102 € per household. These costs include the costs for 2 toilets, vacuum pipes and installation. The Roediger toilets cost 650 € each. From the 5300 € investment costs per household for the grey, black and rain water system 1800 € belongs to the vacuum system.
The costs for the handling of the wastewater exist out of the wage of the caretaker (Mr. J. Nielsen) who works 1,5 to 2 days a week on repairing system failures. Yearly these costs are on average 371,3 € (151 € basic fees + 161 for water use + 19% taxes) per household. Once a month a lorry has to come to pump up the black water and transport it to a wastewater treatment plant (3600 € yearly for the total of 110 inhabitants).
The sanitation system of the Flintenbreite project did not receive any funding or subsidies from the German government. The only subsidies which were provided were related to enhanced planning activities and a relative low CO_2 production of the project in general.

Table 22: Total investment costs of grey, black and rain water system Flintenbreite (2005)

	Costs already made	Future investment costs	total
	x 1000 €	x 1000 €	x 1000 €
Rainwater infiltration constructions	21,8	50,4	72,2
Grey water			
Labour	17,9		152,5
Pipes	23,5		
constructed wetland	104,0	7,1	
Black water			
Pipes	20,2	1,3	95,6
Technical part of vacuum system	60,1		
Pipes Gemeinschaftshaus	14,0		
Biogas installation			
Tank	20,0		205,1
Technical constructions	165,1		
Control system CHP and biogas	20,0		
Total	466,6	58,8	525,4

5.2.4 Operation and maintenance interview

The caretaker of the Flintenbreite complex is Mr. J. Nielsen and it is his responsibility to solve (technical) problems when they occur. The caretaker lives in one of the apartments located above the Gemeinschaftshaus in Flintenbreite itself. This is a big advantage because the caretaker can solve problems relatively fast. There is no time lost on traveling and because the people in the neighborhood know Mr. J. Nielsen personally they do not hesitate to ask his help immediately when a failure occurs.
Mr. J. Nielsen explained me that the vacuum system in Flintenbreite has been struck by failures quite often. The major cause of the failures has been the collection reservoir behind the toilets. This reservoir, with a size of about 8 liter, is automatically emptied by a valve when it is full. This system showed to be vulnerable for clogging because the tubes that operate the automatic valve are small and get easily blocked by toilet paper.
Complete system failures do not take place often and are mainly caused by improper use of the system such as the flushing of relatively big objects.
The recent big peak *(Appendix 14)* in the energy consumption of the vacuum system is caused by a test project from the University of Hamburg with the biogas installation. Overall the electricity use of the vacuum system has decreased over the year 2007.

5.3 Household survey Flintenbreite project

A survey research among the households of the Flintenbreite project at Lübeck was performed to identify their opinion about the vacuum toilet and grey water system that they are using. Twenty from the in total thirty houses were surveyed. I was present when the people were filling in the survey to clarify questions, ask questions about their answers and support people to give as much relevant information as possible.
The survey is divided in the aspects:

- information about household
- background questions
- functioning of the vacuum system, grey water system, invisibility and user comfort
- robustness of the system
- questions about environmental awareness

The different aspects are subdivided in the following questions:

Information about household

How much persons are living in this household?
The neighbourhood exists out of 4 apartments and 26 houses. In the apartments, which differ in size, live 1 or 2 people. In only 1 of the houses live 2 people, in the rest of the houses 3 (2x), 4 (10x) or 5 (3x) persons are living (table 23).

Table 23: Amount of persons per household

Amount of persons in household	Total	Total %
1	2	10%
2	3	15%
3	2	10%
4	10	50%
5	3	15%

What is the composition of the household?
The majority of the people (12x) are married, two couples live together, and six are single (with or without kids).

How many persons are not at home during daytime (school, work)?
The majority of the people (80%) is spending the day outside the house.

How many persons are spending the night at home at least 5 nights per week?
A big majority (97%) spends at least 5 nights per week at home

Since how long are you living in this house?
On average the people are living for a relatively long time in the neighbourhood. Of all the interviewed households only 1 household lived shorter than 5 years in the neighbourhood (4 years). Two households were living for 5 years in the neighbourhood, five households for 6 to 6,5 years, nine households for 7 to 7,5 years and two households for 8 years. Because the project only exists for 8 years a lot of people are living there from the start.

Did you choose this house especially because of the ecological aspects?
The majority of the households (85%) considered the ecological aspects important when they moved to the Flintenbreite neighbourhood.

What is the highest education that you finished?
The interviewed people are relatively high educated. The majority (65%) finished the gymnasium, HBO or university.

Questions about black water system

To what extend are you satisfied with the vacuum system?

A majority of the people (55%) is satisfied or very satisfied with the black water system. Five households (25%) are neutral and 4 households (20%) dissatisfied *(table 24)*. The three households which are very satisfied with the vacuum system are all living in the apartment building.

Advantages of the system which are mentioned are the reduction in water use, better flushing results than conventional toilet and environmental aspects. The major disadvantages which are mentioned are the high amount of failures of the vacuum system and vacuum toilet, the smell in the GMH and the biogas installation that still not functions.

Table 24: Satisfaction with vacuum system

Satisfaction	Number of households	%
Very satisfied	3	15%
Satisfied	8	40%
Neutral	5	25%
Dissatisfied	4	20%
Very dissatisfied		

Points of attention which are mentioned are:

Failures

- blockages/failures (toilet paper, calcium carbonate deposition) (11x)

Operation

- much repairing work necessary (1x)
- does not always function (2x)
- toilet is cleaner than conventional toilet after flushing (1x)
- in some situations ongoing flushing, increasing noise (1x)
- flooding of toilet because a sink lacks (1x)
- biogas installation still does not function (1x)

Nuisance

- noisy (1x)
- smell of installation in GMH (1x)

Environmental

- water saving and other environmental aspects (3x)

Is the vacuum toilet easily kept clean?

The majority of the people (75%) thinks the vacuum toilet is easily kept clean. A minority (20%) thinks the toilet is moderately kept clean and only 1 household thinks the toilet is poorly kept clean. Reasons which are mentioned are the restriction in cleaning agents that can be used, the small opening and the difficulty to clean the toilet with ecological cleaning agents. Advantages which are mentioned is the absence of an edge in the toilet and the big capacity of the toilet to flush away faeces.

How often do you clean the toilet?

Six of the households clean their toilet 5 or less times a month, ten of the households between the 6 and 10 times and two households more then 10 times.

What is your opinion about the noise that the vacuum toilet produces when flushing?

The most people (55%) consider the noise production of the toilet loud *(table 25)*. Although some of the people consider the noise production of the toilet loud they do not have hindrance of the noise. A minority considers the noise as annoying.

Table 25: noise production of vacuum toilet

noise	Number of households	%
Loud	11	55% *
Annoying	3	15% *
No hindrance	9	45% *

** exceeding 100% because some households picked multiple answers*

The households explain that the noise is considered loud when compared to conventional toilets. Especially if the households are visited by family or friends with children they need to be informed about the noise production of the toilet. In some cases (2x) it happened that the vacuum toilet did not stop flushing and the noise level kept on increasing.

Does the toilet of the neighbours cause noise nuisance?
The most households (85%) do not experience any noise nuisance from their neighbours toilet. Only three households sometimes experience noise nuisance.

Did you experience a change in smell nuisance since you switched to a vacuum toilet?
According to a majority (70%) there is no difference in smell nuisance but a minority (30%) experiences less smell nuisance. This difference in smell nuisance is probably caused by people who compare the vacuum toilet to old model toilets where the faeces fall on a plateau. The smell difference between vacuum toilets and modern conventional toilets is not assumed to be big.

What do you consider important aspects when choosing a toilet?
A big majority (95%) considers the saving of water and other environmental aspects important when choosing a toilet.

Did you ever consider replacing the vacuum toilet for another kind of toilet?
The majority of the households (60%) never considered to replace it's vacuum toilet for another kind. A Minority (40%) did consider to replace it's vacuum toilet for a model with less failures.

Are you informed about how to use the vacuum toilet?
Everyone has been informed about the way to use the vacuum toilet. Despite the provided information the vacuum system faced a lot of failures due to improper use in the beginning. Only after multiple blockages of the vacuum pipes the households started to follow the instructions better. Nowadays problems with improper usage mostly occur during weekends when visitors which are not aware of the proper use of the system come to the neighbourhood and flush objects through the toilet which block the vacuum pipes.

Are there other aspects which are related to the vacuum toilet that you would like to mention?
Different aspects are mentioned in this question:

- Being able to fix small failures self without help op caretaker
- Sometimes the vacuum toilet doesn't stop flushing and finally overflows because a sink lacks
- There should be a vacuum toilet system which is less sensitive for failures
- Prevent 90° bends in the vacuum pipes, this will cause blockages
- Reduction of noise level (2x)
- Pump of the toilet failed a lot in the begin of the project
- According own measurements the toilet upstairs produces 80 to 85 dB when flushing

Would you recommend the vacuum toilet to households in other neighbourhoods?
Half of the people would (actively) recommend the vacuum toilet to households in other neighbourhoods. A small minority (45%) would not recommend the system without

improvements. One household doesn't know because it assumes that not all households are so patient considering a bad functioning toilet system *(table 26)*.

Table 26: Recommending the vacuum system to other households

Recommending the vacuum system	Number of households	%
Recommend actively	2	10%
Recommend	8	40%
Not without improvements	9	45%
No opinion	1	5%

If you would move to another house would you prefer a vacuum toilet or a conventional one (or other option)?
The majority (80%) of the people would again choose an (improved) vacuum system when moving to another house. The other group of households would prefer a conventional toilet system.

Which grade would you give to the vacuum system?
A minority of the people (20%) gives a grade lower then 6 to the system. The average grade that the households give to the vacuum system is a 6,6 *(table 27)*. Even if high grades are given to the system it is mentioned that too much failures occur. A lot of people give the system in theory a good grade but think that it is necessary to develop a system which is less sensitive for failures of any kind.

Table 27: Grade of the vacuum system

Grade	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Amount of households	1		1	1	1	3	4	8	1	
%	5%		5%	5%	5%	15%	20%	40%	5%	

To what extend are you satisfied with the grey water system?
Almost all the households (95%) are (very) satisfied with the grey water system. Mainly because it functions properly, saves costs and is environmental friendly. One household is not satisfied because it assumed that the smell in the GMH was caused by the grey water system.

Does the grey water system cause any unpleasant odours?
Only one household that lives next to the constructed wetland experiences odours but it is not clear whether these odours are caused by the grey water system or other water.

If so, in which months do the unpleasant odours occur?
The single household experiences odour problems in May, June, July and August.

Does the grey water system cause any noise nuisance?
The grey water system does not cause any noise nuisance.

Have the black and/or grey water system been adapted since you live in this house (if so, which changes and why)?
In 18 houses the original design of the vacuum system has been changed. The construction behind the toilet existing out of a storage reservoir which is emptied by a valve when the reservoir is full caused too many problems. The valve and the storage reservoir are now bypassed so when the toilet is flushed it is directly sucked through the pipes to the vacuum pump. The storage reservoirs were originally constructed to reduce the noise level and

energy consumption of the system. Since the bypasses are constructed the energy consumption of the system is actually reduced and the noise level not significantly increased.

Are there visible parts of the grey and/or black water system in or around your house?
Only the numbers 78 to 94 have a view on a part of the grey water system because the constructed wetland is located behind their houses.

What is your opinion about the visible parts of the black and/or grey water system?
The households have no problems with the sight of the constructed wetland and like the sight of it. One household has problems with the sight of the black water tank which is located under ground, opposite the house *(table 28)*. Only 8 households answered this question because the other households are not able to see the grey water system.

Table 28: Recommending the vacuum system to other households

Visible parts of black/grey water system	Number of households	%
Really nice	1	12,5%
Nice	3	37,5%
Neutral	3	37,55
Awful	1	12,5%

Are the visible parts of the grey and/or black water system vulnerable for failures or damage?
The visible parts are not vulnerable for failure or damage

How many times in a year do failures in the grey and black water system occur (failure of grey water system, vacuum toilet, vacuum system)?
The amount of failures differs a lot per household. Most failures occur at the vacuum toilet itself at household level. Failures which often occur are:

- pushing button does not work properly
- blockage of small pipes of valve

According to the households the vacuum system (or parts of it) fails 2 times a year. This means that one of the main vacuum pipes is blocked or that the central vacuum installation does not work. They grey water system failed only once because one of the pipes was blocked.
Exact data about the failures is collected by the caretaker.

Questions about environmental awareness

Do you consider yourself environmental aware?
The people from the Flintenbreite neighbourhood are relatively environmental aware *(table 29)*. A majority (95%) considers itself often or always environmental aware.

Table 29 Environmental awareness of households

Environmental aware	Number of households	%
Always	5	25%
Often	14	70%
Sometimes		
A bit	1	5%
No		

Did the grey and black water system increase your environmental awareness?
A small majority (55%) says that the grey and black water system increased the respondents environmental awareness.

Would you recommend the grey and black water system to neighbours or other households?
The majority (80%) would (actively) recommend the grey and black water system to neighbours or other households. Often the comment is given that only an improved version of the system would be recommended.

Which part of the water system has a good future to your opinion?
The majority of the respondents think that all parts of the system have a good future if they will be improved.

Which advantages do you experience from the grey and black water system?
The advantages which were mentioned are:

- cost reduction 7x
- water reduction 2x
- wastewater reduction 1x
- energy reduction 1x
- ecological aspects 6x
- independency 1x

Which disadvantages do you experience from the grey and black water system?
The disadvantages which are mentioned are:

- failures 6x
- dependency of caretaker 1x
- noise 1x
- restricted use of cleaning agents 1x

Which grade would you give to the black and grey water system?
The average grade for the combined black and grey water system is 7,48 *(table 30)*. In a lot of cases the respondents would have given a higher grade if the vacuum system would have worked better.

Table 30: Grade of the black and grey water system

Grade	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Amount of households	1		2	5,5	8,5	3	
	5%		10%	27,5%	42,5%	15%	

5.4 Survey research 2001

In 2005 there was also a survey research done at the Flintenbreite neighbourhood *(Otterwasser 2005)*. This research was done by mr. H. Wallbaum from the Wuppertal institute.
The goal of this survey was to identify what people at the Flintenbreite neighborhood think about the black and grey water systems which are installed in their houses. During this research the survey was sent to all the 21 households in the Flintenbreite neighborhood. In total 9 surveys were received back and these surveys were used to analyze the user acceptance of the grey and black water system (Otterwasser, 2005).
The survey from 2001 is partly complementary with the survey that I performed and some results of the research were:

Grey water system

- From ecological perspective a majority of the respondents (8 persons) considers a constructed wetland a preferred method to treat grey water but it is mentioned that it should work without failures.
- The same amount of respondents (8 persons) also considers a constructed wetland a positive technology and thinks that it makes the neighborhood more attractive.
- Some doubts exist about the hygienic perspective of the constructed wetland because 4 of the 9 respondents are not sure whether it causes bigger risks for the human health then a conventional system.
- If the respondents would move to a new house they all would like to live nearby a constructed wetland again because of environmental, economical and physical advantages.

Black water system

- A majority (8) considers the separation of black water as a positive thing because of water saving and energy producing aspects. Other positive aspects which are mentioned are the cost reduction and the independency of the conventional sewer system.
- A negative aspect which is mentioned by some of the people is the high noise level when the toilet is flushed. Other related disadvantages are the impossibility to repair to toilet yourself and the possible high energy use of the system.
- All respondents agree that the vacuum toilet system causes no more physical risks than a conventional system because both are closed systems.
- When considering the optical cleanness of the toilet a majority of the people (7) thinks that a vacuum toilet is equal to a conventional one.
- According to a majority of the respondents most visitors are in the beginning skeptical about the system and they are a bit shocked when they use the toilet for the first time. When they are informed about the system they get more positive because of the good environmental aspects of the vacuum system.
- In general six of the respondents consider the vacuum system ‘good’ against three that are still doubtful about the system because of the big noise production and the occurrence of failures.

6. Comparison of different cases

Over the years different projects have been analyzed in which non-conventional sanitation systems were implemented in neighbourhoods (*Telkamp 2006, Koetse 2005)*. To some extend these projects were comparable but on other aspects there were differences.
In this chapter the data from the different projects are compared to define the practical performance of the different systems.
The 6 different projects which were analyzed are:

- Casa Vita, Deventer, Netherlands
- Flintenbreite, Lübeck, Germany
- Kaja, Ås, Norway (*Telkamp 2006)*
- Torvetua, Bergen, Norway (*Telkamp 2006)*
- Arbeiten & Wohnen, Freiburg im Breisgau, Germany *(Koetse 2005)*
- KFW Bankengruppe, Frankfurt, Germany *(Koetse 2005)*

Kaja
The Kaja project in Ås (Norway) includes 24 student apartments in which 48 students are living. The project was finished in 1997. The apartments are equipped with vacuum toilets (Jets) and a grey water system (septic tank followed by an aerobic bio-filter combined with a constructed wetland).
Torvetua
The Torvetua project in Bergen (Norway) includes 40 houses in which a total of 130 people are living. The project was finished in 1999. The houses are equipped with vacuum toilet systems (Jets), a grey water system (septic tank followed by aerobic bio-filters combined with constructed wetlands) and a rain water system (rain water infiltrates in the turf roofs of the houses and the excess water flows in the ground).
Arbeiten & Wohnen
The Arbeiten & Wohnen project in Freiburg im Breisgau (Germany) includes 14 apartments and 4 offices. The project was finished in 1999. The houses and offices are equipped with a vacuum toilets (Roediger), a grey water system (membrane filter installation, Mall Ultra-Sept) and a rain water system (infiltration in soil).
KFW Bankengruppe
The KFW Bankengruppe project in Frankfurt (Germany) includes an innovative wastewater management system in the main office building of this bank. The project was finished 2002. The office building is equipped with a vacuum toilet system (Roediger) and a grey water system (biological treatment tanks).

System description

The different cases which were analyzed are comparable to a certain extend but there are big differences in size, system set up and some other aspects. The amount and kind of failures, downtime of wastewater system in case of a failure, costs, usage of microbe cleaner and electricity use show differing values per project *(table 31)*.
The experiences with the black water systems differ per project because it is never installed in the same way. In some project a relative big amount of failures/blockages takes place (Lübeck, Torvetua) while in other projects not much problems occur (Deventer, KFW Bankgruppe). Most of the problems with the vacuum system are caused by improper bends (> 45°), blockage problems of the reservoir behind the Roediger toilet and problems with the pushing button of the Roediger toilet.
Big differences can also be seen in the usage of microbe cleaner to prevent the precipitation of struvite in the pipes of the black water system. The Arbeiten&Wohnen and Torvetua projects have faced a lot of problems with pipes that were blocked because of struvite ($MgNH_4PO_4$) precipitation. In some projects microbe cleaner is not used at all and in other projects the quantity differs a lot. In Lübeck the microbe cleaner is not used at all but they face problems with the formation of calcium carbonate. Recently the pipes of the black water

system were flushed for the first time with acid in order to remove the calcium carbonate precipitation from the pipes. Additional research could be useful to identify whether struvite precipitation also plays a role in the Flintenbreite project . Another important research topic would be to identify if households could prevent the precipitation of struvite or calcium carbonate by regular flushing with microbe cleaner or other cleaning agents.
The electricity use of the different systems shows big differences. Especially the electricity use of the black water system in Lübeck can be considered high in comparison with the electricity use of the black water systems in other projects. This can be caused by the facts that the black water has to travel over a long distance and air leakages occur easily in the complex system of the Lübeck project. The Casa Vita project in Deventer which exists out of one big apartment building seems to be most energy efficient when referring to the black water system. The reason for the energy efficiency could be the relative short distance that the black water has to be transported. Only from the Lübeck project exact data concerning the energy use of the black water system is available. In the other projects estimations are made by multiplying the power output of the vacuum pump with the daily running time of the pump.

In general the implemented grey water systems function well because the effluent quality of the grey water systems is sufficient. The constructed wetlands (in some cases combined with bio-filters) are not sensitive for failures, have low maintenance costs and produce effluent water of sufficient quality. The membrane bioreactors also function well if properly installed. When comparing the different grey water treatment systems with each other the combination of a bio-filter and a constructed wetland shows a higher removal efficiency than a constructed wetland only. In the Lübeck project problems are faced with the removal of the high concentrations of phosphate in the grey water.
For different reasons the costs for the black and grey water systems in the different projects are not comparable with each other. In none of the projects an equal system is installed and from the majority of the projects financial data is lacking. Another problem is the difference in booking of the costs of the different projects. The costs for the construction of the grey water system are for example more specifically described in the Kaja project then in the KFW Bankgruppe project. Differences in booking and the lack of data cause uncertainty and make it impossible to compare costs with each other. In general it can be concluded that the building costs of non-conventional sanitation systems are more expensive than conventional systems. Mr. H. Vieregge from the Klaassen construction company estimated the building costs for a conventional toilet system on 500 € per toilet against 1645 € for a vacuum toilet. The black water system which is installed in the Flintenbreite neighbourhood is the cheapest because the total costs per household are lower then in the other projects. The costs for the grey and black water system in Lübeck seem relatively high.

Table 31: Parameters of black and grey water systems

Aspect	**Research site**					
	Deventer	Lübeck	*Kaja*	*Torvetua*	*Arbeiten & Wohnen*	*KFW Bankgruppe*
Supplier of vacuum toilets	Jets	Roediger	Jets	Jets	Roediger	Roediger
Operation and maintenance (black water system)						
Failures of vacuum toilet		2,2 per household per year	18 – 22 per household per year		1 per household per year	
Failures of vacuum system + blockage of (main) vacuum pipes	2 (from Feb. 2007 until Nov. 2007)	125 in 6 y → 21 per y (problems with calcium carbonate precipitation)	2 – 3 p/y	20 - 25 p/y (problems with struvite precipitation)	1 p/y (problems with struvite precipitation)	

	Deventer	Lübeck	*Kaja*	*Torvetua*	*Arbeiten & Wohnen*	*KFW Bankgruppe*
Usage of microbe cleaner per household	2 litre per household per y (Biocompact)	none	8,33 litre per student apartment = 4,16 litre p/p y	0,625 litre per household per y		
Health Risks						
Chance of contact with wastewater or physical injury by having access to sanitation system	0%	0%	0 %	0% (some risks exist when blackwater storage tank is emptied)	0%	
Chance on chemical hazard by having access to sanitation system	0%	0%	0 %	0%		
Energy consumption						
Electricity use of grey water system (estimated)		2 kWh pp / y	272 kWh / y → 5,67 kWh pp / y	2190 kWh / y → 16,84 kWh pp / y		
Electricity use black water system vacuum pump (estimated)	16,8 kWh pp / y	40 kWh pp / y	1277,5 kWh / y → 26,6 kWh pp / y	3321,5 kWh / y → 25,6 kWh pp / y	4,1 kWh pump	6 kWh pump
Electricity use toilet valves	0,16 kWh pp / y	Not present	0,16 kWh pp / y	0,52 kWh household / y		
Performance (grey water system)						
Influent COD, effluent COD and removal eff. (mg/l)		Inf: 359 Eff: 16 %: 87,7	Inf: 130,7 ** Eff: 6,9 %: 94,7	Inf: 367 Eff: 41 %: 88	Eff: 25	Inf: 400 * Eff: 5 %: 98,8
Influent N, effluent N (mg/l) and removal efficiency		Inf: 11,1 Eff: 3,6 %: 67,7	Inf: 8,2 Eff: 2,5 %: 69,5	Inf: 7,1 Eff: 2,2 %: 60		
Influent P, effluent P (mg/l) and removal efficiency		Inf: 5,6 Eff: 3,4 %: 39,3	Inf: 0,97 Eff: 0,07 %: 92,8	Inf: 1,07 Eff: 0,2 %: 79		
Costs (investment)						
Total investment costs	1645 € per household → 62510 € in total	- vacuum system 95600 € - biogas system 205100 € - inhouse system 3102 € per house	24000 NOK → 3038 € per apartment 578560 NOK → 73235 € in total *	Can not be identified	73.516,82 DM for black water system ***	80.000 € for black water system ****
Installation costs in-house grey water piping + additional costs			97560 NOK → 12349 € *		2556,46 €	
Grey water system, including installation		152500 € in total	120000 NOK → 15190 € *		12.424,39 € ***	50.000 € ****
Vacuum toilets	470 € per toilet	650 € per toilet	3000 NOK per toilet → 380 € *	3000 NOK per toilet→ 380 € *	33.706,98 DM in total	

	Deventer	Lübeck	*Kaja*	*Torvetua*	*Arbeiten & Wohnen*	*KFW Bankgruppe*
Vacuum generator	365 € per household	60100 € (including tanks)	100000 NOK → 12658 € *		13.119,34 DM + 3499,28 DM for installation	
Vacuum tank			25000 NOK → 3165 € *			
Installation + pipe tubing vacuum system	795 € per household + 15 € for small materials	34200 €	158000 (estimated) → 20000 € *		11.173,98 DM + 12.017,25 DM in total	
Building costs per household		1800 € (including toilets)	24000 NOK (2 persons) → 3038 € *			
Costs (operation and maintenance)						
Emptying black water storage tanks		3600 € a year	5000 NOK x 11–13 y → 7595 € / y *			
Maintenance costs per household	10 € per household per year	371,3 € per household per year	15000 – 20000 NOK y → 79 – 106 € per household per year *		12 hours per household per year	90 hours per y blackwater + 30 hours per y for grey water
Total operating costs	none	3600 € / y in total	100000 NOK y → 12658 € *	450000 NOK y → 56962 € / y *(also includes streetlight, snow removal etc)	4652,76 € in first year for monitoring grey water	1550 € / y for black water system
Operating costs per household	none	94,7 € per household / y	4200 NOK (2 person) / y → 532 € /y *	9600 – 12000 NOK per household y → 1215 – 1519 € / y*	30 € per household per year for blackwater system	
Removal of struvite from system			unknown	250000 NOK → 31646 € *		

* NOK divided by 7,9 to create value in Euro *(Telkamp 2006, wisselkoersen.nl)*
** BOD7
*** Combination of offices and houses
**** Bank office, so no households included

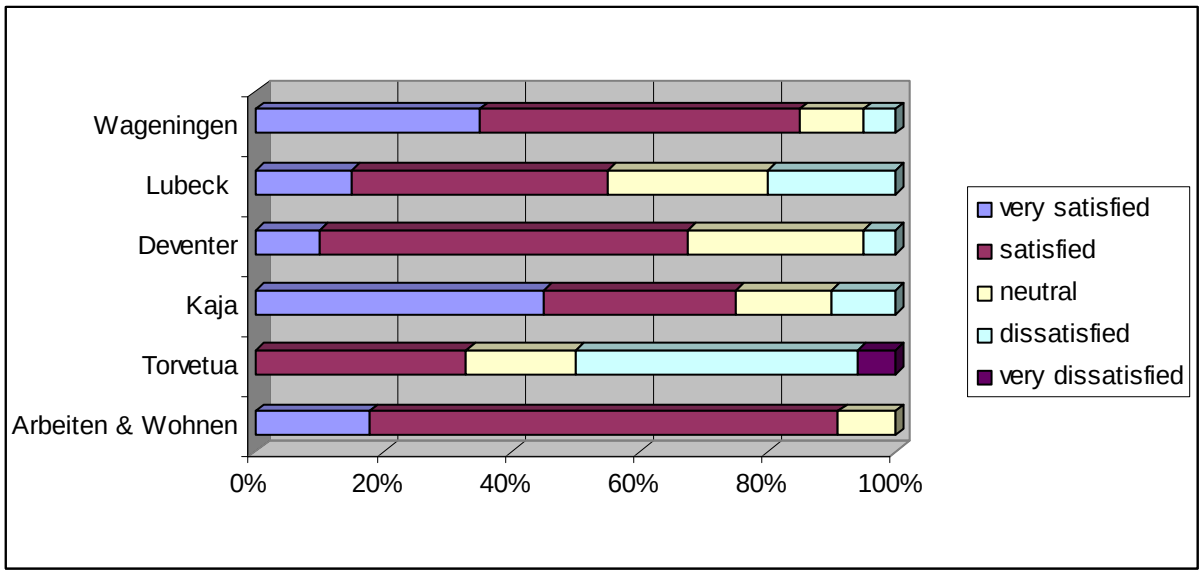
User perception

To identify how the users of the different projects judge their grey and black water systems a user perception survey has been included in the different researches. Information from the KFW Bankgruppe project in Frankfurt is not available because only one user perception survey has been performed which is not sufficient. User perception information from the Wageningen survey has been included in order to compare the scores of non-conventional systems with a conventional one. The 6 different surveys were compared with each other to identify the differences in user perception between the projects *(Appendix 15: Results from user perception surveys)*.

In general people with a conventional toilet system are more satisfied with their system than people with a vacuum toilet system. In Wageningen 85% of the inhabitants is (very) satisfied

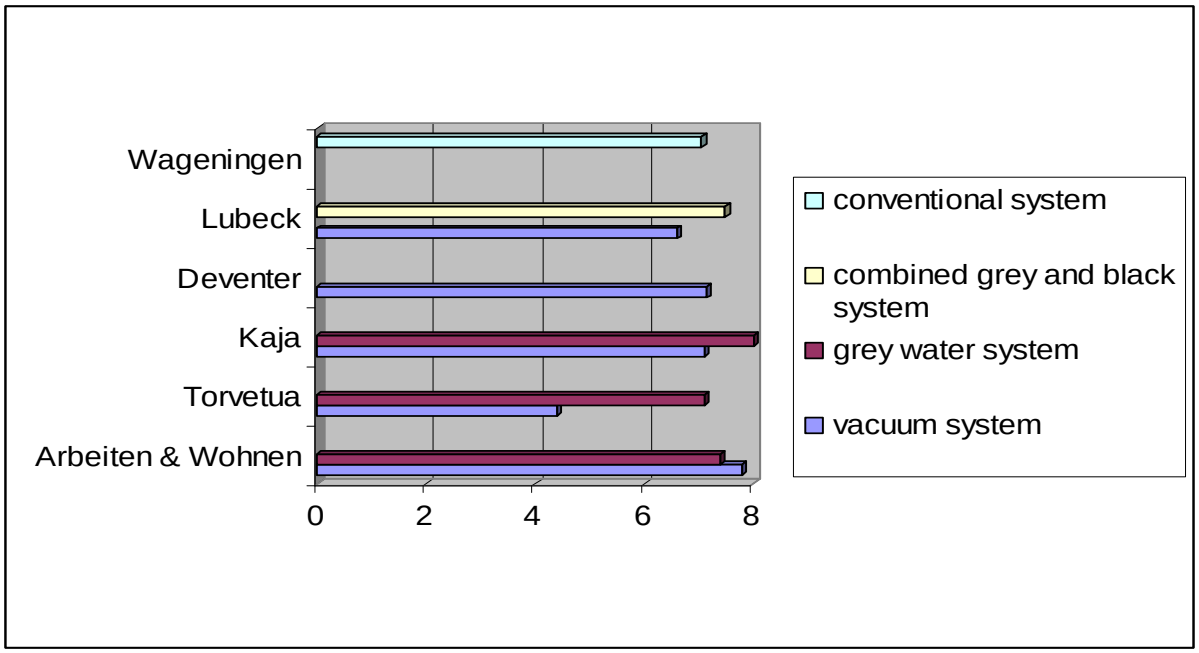
with their toilet system against 91% in the Arbeiten & Wohnen project (only 11 interviews), 75% in Kaja, 67,5% in Deventer, 55% in Lübeck and 50% in Torvetua *(figure 7:)*.

Figure 7: Satisfaction with toilet system



Although the inhabitants are not always satisfied they give a relative high mark for their toilet system *(figure 8)*. Mainly this is due to the fact that the inhabitants feel very positive about the principle of the toilet system but have some problems with the failures/blockages that occur (often). The mark for the grey water system in Lübeck differs slightly from the marks of the other projects because in Lübeck the households were asked to give a mark for the combined sanitation system instead of the grey water system alone.

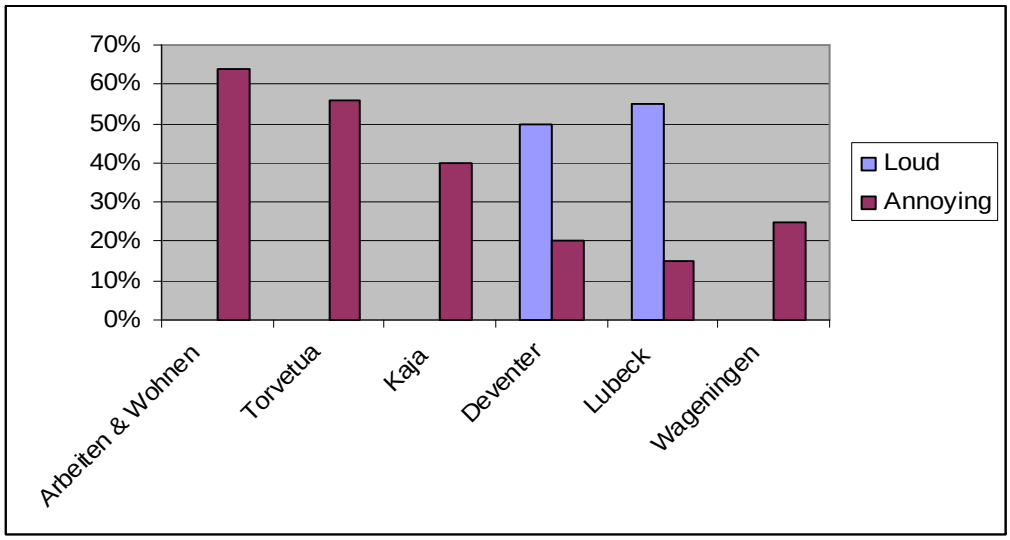
Figure 8: Marks for the vacuum and grey water systems



In comparison with conventional toilet systems the inhabitants of the projects consider the noise production usually loud and/or annoying *(figure 9)*. The noise nuisance is one of the most commonly mentioned disadvantages of the vacuum toilet system although it is mentioned that people get used to the sound of the toilet. The biggest problem seems to be

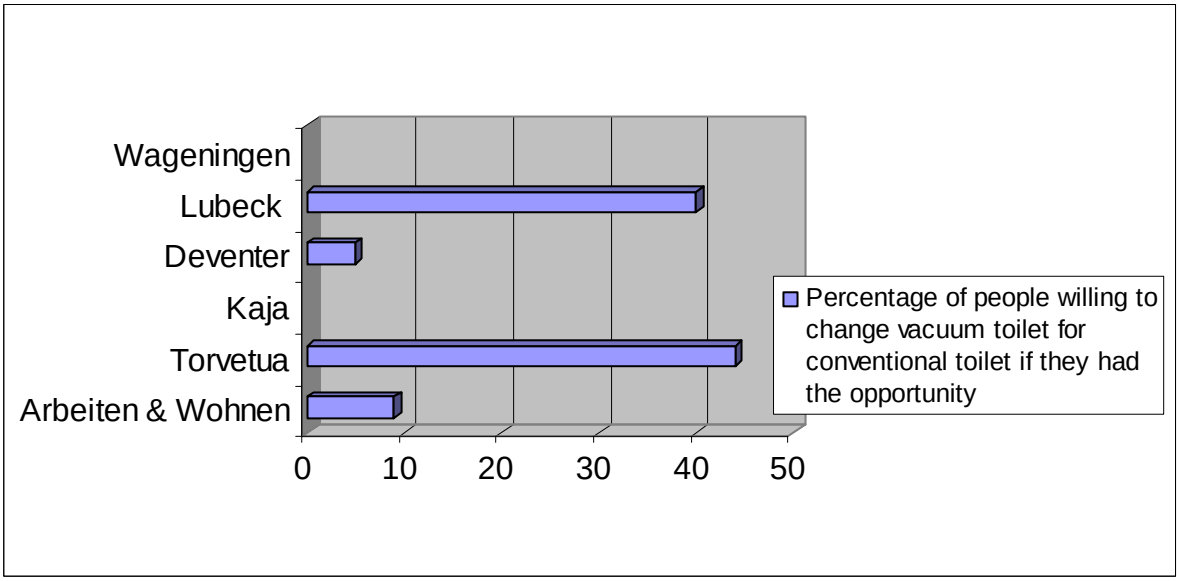
the amount of noise that the toilet produces (loud) but the kind of noise (annoying) is also mentioned by a part of the households. In the Lübeck and Deventer project the separation between loud and annoying noise was made for the first time. For the Kaja, Torvetua and Arbeiten & Wohnen project households only had the opportunity to describe the noise as annoying.

Figure 9: Perception of the noise production of vacuum toilet systems: percentage of people that consider the noise that their toilet produces loud/annoying



A clear relation exists between the amount of problems with the vacuum system and the way that inhabitants judge the system. In the projects where the inhabitants have been confronted with a lot of problems (Lübeck, Torvetua) they are much more willing to change their vacuum toilet for a conventional system then in projects where less problems occurred (Deventer, Arbeiten & Wohnen) *(figure 10)*. From the Kaja project there were no data available concerning these questions. The opinions about the different grey water systems which are implemented are positive because they work properly, have less environmental impact and look nice. In the Torvetua and Arbeiten & Wohnen projects some problems considering the grey water system have been faced but they are all solved nowadays.

Figure 10: Percentage of respondents that would consider to replace their vacuum toilet system with a conventional toilet system if they had the opportunity



7. Discussion and conclusion

7.1 Introduction

The goal of this research was to answer the following research questions:

- *Which main drivers and barriers for the implementation of vacuum-toilet systems in new urban developments can be identified?*
- *What is the performance of the sanitation systems in Deventer and Lübeck compared to the performance of a conventional sanitation system?*
- *What is the performance of the sanitation systems in Deventer and Lübeck compared to the performance of other projects where non-conventional sanitation systems are implemented?*

In chapter 7.2 the first research question concerning the drivers and barriers in the vacuum system implementation process will be answered.
In chapter 7.3 the second and third research question about the performance of the analyzed vacuum toilet systems will be described.

7.2 Drivers and barriers

Deventer
The most important driver for the 'Klaassen Groep' to implement a vacuum toilet system in the Casa Vita projects was the freedom that it provides to customers to design the inside of their house themselves. The vacuum toilet system enables the construction company to place the toilet anywhere in the apartment because smaller pipes are used that can be integrated in the floor instead of the wall. Also the positive environmental aspects played a role in the technology choice because the vacuum toilet system saves a lot of water.
Harry Vieregge considers 'positive feeling about environmental friendly behaviour', 'water saving' and 'reduction of water emissions' the most important environmental drivers.
The other environmental drivers such as 'recycling of nutrients' and 'protection of groundwater' are not relevant because the vacuum toilet system is directly connected to the sewer system and no grey water system is involved.
The relative high costs of the vacuum toilet system were the main barrier during the implementation process. The total costs per apartment (1 toilet) were 1645 € which is far more than the 500 € that a conventional toilet system costs. The Klaassen company decided not to implement a more complex black water system because this would increase the costs even further.
The Klaassen company did not face any 'environmental and public health barriers' because the black water is flushed directly from the toilets to the vacuumarator and further to the sewer system. There is no chance on physical contact with the black water or chance that the black water enters the surface water untreated. There were also no 'social and managerial barriers' involved because the black water is discharged on the sewer system and not treated locally.

Lübeck
The Flintenbreite neighbourhood was developed as a project in which multiple ecological aspects were integrated. The goal of the project to was to show that ecological systems are a proper alternative for conventional systems because they are able to reduce the water and energy consumption, recycle nutrients and provide cost reducing aspects. When considering the water system a vacuum system, grey water system and rain water infiltration system have been realized.
The most important environmental drivers to realize the water system were the reduction of water emissions, recycling of nutrients, reduction of energy use and quality of neighbourhood

landscaping. Especially the recycling of nutrients was a main point of attention and this is realized in practice by building a black water system that produces a fertilizer for the farmers in the area.
The only legal and regulatory barriers that were faced concerned the construction of the constructed wetland in the Flintenbreite neighbourhood. The municipality had problems with the wetland because they experienced problems with a wetland that had been constructed in the past. It took some time to convince the municipality that the wetland in the Flintenbreite project would not cause problems because it is an improved version.
To increase the user acceptance of the vacuum system efforts have been done to reduce possible problems with the system. The inhabitants have been informed about the proper use of the vacuum system, a caretaker who is able to solve most of the problems lives in the neighbourhood and a reservoir has been installed behind the toilet to reduce noise level and energy consumption.
From the start the budget for the Flintenbreite project was known and the most important financial aspect was to keep the operating costs as low as possible in order to compete with a conventional wastewater system.
The operation and maintenance company Infranova GmbH & Co KG is responsible for the biggest part of the service that are provided in the neighbourhood. The inhabitants pay a sum of money to Infranova GmbH & Co KG for the provision of gas, (warm) drinking water, electricity, the handling of wastewater, repairing and maintenance activities and other services such as street lights and the removal of snow from the streets. The advantage of this construction is the reduction of paperwork for the inhabitants and the cost advantages because Infranova GmbH & Co KG buys the electricity, gas and water in larger amounts which causes cost benefits.
In the beginning of the project the vacuum system experienced a lot of failures/blockages but some adjustments improved the functioning. Furthermore increasing the awareness of households on how to properly use the vacuum toilet system reduced the amount of failures/blockages further. In the future more adjustments will be made to the system to improve the functioning even more. At the moment the amount of black water is too small to properly operate the biogas installation but 9 new houses are under construction. When these new houses are connected to the vacuum system the amount of black water is sufficient to start the biogas installation.

7.3 Performance

The performance of the vacuum toilet system is analyzed by combining the collected data from the household surveys, sanitation expert, system owner and operation and maintenance interview. These interviews and surveys include technical aspects, performance and robustness, costs, public health and user perception issues.

Technical aspects, performance and robustness Deventer
The technology which is used in the Casa Vita project is not extremely complicated. The toilets are connected to two central vacuumarators that discharge the black water on the sewer system. The complete system which includes toilets, pipes and the two vacuumarators are from the company JETS which operates already for a long time in the vacuum business. The system appears robust and only some minor problems have occurred since the installation of the system in February 2007. The first problems were due to improper installation (air leakage at pipe connections) but these problems have been fixed in a short period of time. The system failure in September was due to improper use of the vacuum toilet system because a household flushed something through the toilet which should not have been flushed.
For the ‘Klaassen Groep’ it is important to construct robust and reliable systems because they are a commercial company that wants to sell their Casa Vita projects. In order to do so they can not use negative publications about the functioning of their vacuum toilet systems.

The system itself works well and households do not have any complaints about the actual functioning of the system. Some drawbacks of the system which are mentioned by inhabitants are the noise production and the lack of a back-up toilet system in case of a system failure.

Technical aspects, performance and robustness Lübeck
The wastewater system that is installed in the Flintenbreite neighbourhood in Lübeck is much more complicated than the system in Deventer. The black water is transported from the households by a vacuum system. On household level the black water system exists out of Roediger vacuum toilets that use only 0,7 – 1,2 litre water per flush. When the toilet is flushed the black water enters a reservoir behind the toilets and from there it is sucked to a central vacuum pump. From the central vacuum pump the black water first flows to a mixing tank and afterwards to a hygienisation tank to kill pathogens. From the hygienisation tank the black water finally flows to a collection reservoir which is emptied once a month by a truck that transports the black water to a conventional wastewater treatment plant.
In the future the concentrated black water will flow from the hygienisation tank to a digestion installation where biogas is produced. The gas is transported to the combined heat and power installation (CHP) where the gas is turned into heat and electricity. To improve the quality of the produced biogas and to decrease the organic waste production of the neighbourhood the black water is mixed with shredded organic waste in the mixing tank. The organic waste has a relatively high carbon content which improves the quality of the biogas.

The grey water from the households is transported to a sedimentation tank where the heavy particles, oils and fats are separated. From the sedimentation tank the water is pumped to a vertical flow, constructed wetland in which the grey water is treated further by bacteria. The treated grey water ends up at the bottom of the constructed wetland and is transported out of the wetland by drainage pipes. To stimulate the infiltration of rainwater in the ground multiple infiltration beds are constructed too reach a maximum infiltration of rainwater in the neighbourhood.

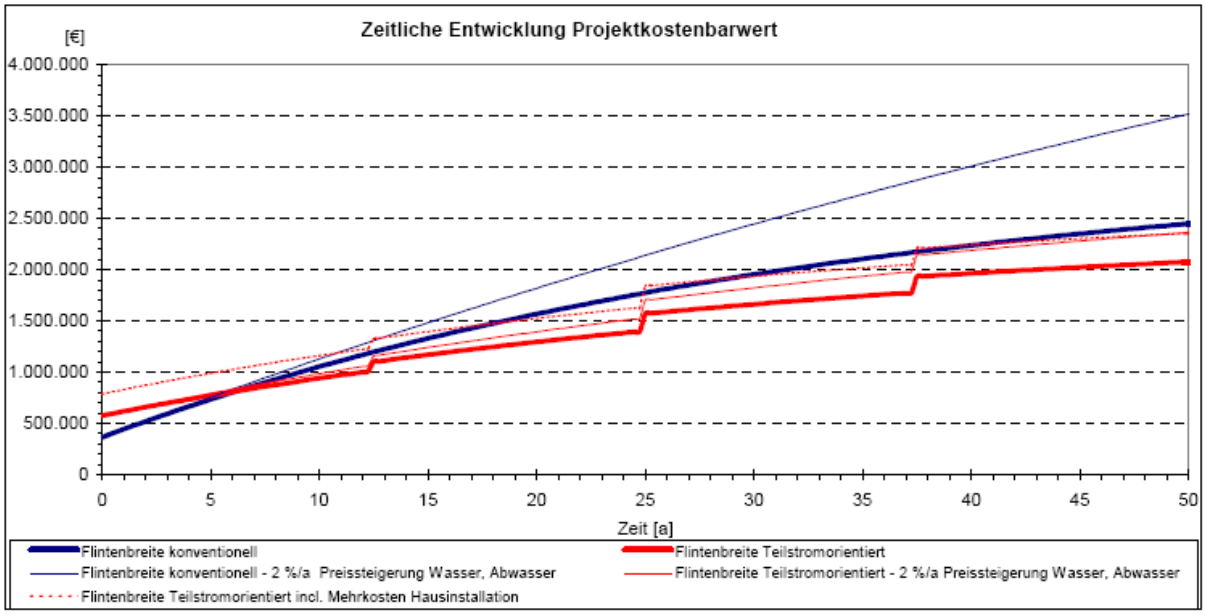
Especially the black water system has faced a lot of problems since the start-up. A wide variety of failures has occurred but the majority had to do with small problems on toilet level. Since 2001 some adjustments have been made on household level to reduce the amount of failures. The caretaker that lives in the Flintenbreite neighbourhood is necessary because he is able to repair the majority of the failures of the vacuum system in a short period of time. The user acceptance of the black water system would be much lower if no caretaker was available to solve problems. The biogas installation in the Flintenbreite neighbourhood is still not in operation because the black water production of the neighbourhood is too small to properly operate it (the installation was dimensioned for a black water flow of over 300 persons but at the moment only 110 people live in the neighbourhood due to a bankruptcy of the construction company in 2001). At the moment 9 new houses are being constructed and when they are inhabited the black water flow will be large enough to operate the biogas installation. Tests from the Hamburg University have shown that the quality of the black water is sufficient to properly operate the biogas installation. The addition of shredded organic waste will improve both the quantity and quality of the biogas.

Costs Deventer
According to Harry Vieregge the total costs of the vacuum toilet system were 1645 € per household. Compared with a conventional system this is much more expensive because these systems cost on average 500 € per household. For the ‘Klaassen Groep’ the advantages of the vacuum toilet system outweighed the higher costs but they consider it one of the major barriers of the vacuum toilet system. There are reasons to believe that the costs of vacuum toilet systems will decrease in the future because of an increased production and improvements in the design of the vacuum toilets *(Telkamp 2006)*.

Up to now the maintenance and operation costs are low because not much blockages and/or failures appeared. The general maintenance on the complete vacuum system only takes 4 hours a year (Rudie de Haan, Domus) and an additional 2 hours are necessary for fixing blockages/failures.
An important notice is the cost reduction caused by the relative low water use of the vacuum toilet. In comparison with a conventional toilet a total amount of 10 m^3 water is saved on a yearly basis per person when a vacuum toilet is used (Klaassen). With a current water price of 1,34 € per m^3 (*Milieucentraal*) this means a reduction in the drinking water price of 13,4 € per person per year. A household with 3 persons saves about 40 € yearly.
A unique aspect of the Casa Vita project is the independency of subsidies or funds. No financial help from the government or other organisations was necessary to realise the vacuum toilet system. This is an important aspect because it shows that the vacuum toilet system can be a full alternative for the conventional toilet system in the market sector.

Costs Lübeck
The total costs for the wastewater system outside the houses in the Flintenbreite neighbourhood are 525.400 €. These costs are divided by the total amount of households and an additional 3.102 € per household has to be paid for the in-house black water system (toilets, reservoir, pipes). If the costs are spread equally over the 30 households this means that each household has to pay 20.615 € for the wastewater system. Yearly the households have to pay a certain amount of money to Infranova GmbH & Co KG for operation and maintenance services. These costs are 371,3 € per household and mainly exist of the wage of the caretaker. Once a month the black water reservoir has to be emptied by a truck which costs 3600 € on a yearly base which is spread equally over the households. The black and grey water systems are not connected to the central sewer system and offers cost advantages because no fees have to be paid for the wastewater discharge. Another cost advantage is the relative low water use of 68 litre per person instead of 129 litre which is average in Germany. This low water use is mainly caused by the vacuum toilets because they save up to 6 litres of water per flush.
Long term calculations have been made by Infranova GmbH & Co KG that show the cost benefits of the wastewater system installed in the Flintenbreite neighbourhood. With an expected rise of the wastewater and drinking water fees, combined with a longer lifetime of the system, cost benefits appear in the coming 50 years *(figure 7)*.

Figure 7: Cost development Flintenbreite



7.4 User perception

One of the most important factors determining the success of a (newly) implemented technology is the way in which the users perceive the technology. When a system causes too much problems and frustrations for the users it will not be implemented on a larger scale. During the research I performed a household survey among 20 households in the Casa Vita and 20 households in the Flintenbreite project to identify their opinion about the grey and black water system. The results were compared with the results of a household survey that I performed in Wageningen where 20 households where surveyed about their conventional toilet system.

In general the inhabitants of the Casa Vita project are quite content with their vacuum toilet system and give it a higher grade than the grade for conventional toilets of the survey in Wageningen. The higher grade is mainly caused by the positive environmental aspects of the vacuum toilet system. Other advantages which are mentioned are the short time that the flushing takes and the absence of a water reservoir and related noise production. There are also some disadvantages such as the relative big noise production and the absence of a back-up system in case of a system failure. Despite the disadvantages most households would again choose a vacuum toilet system if they would move to an other house. This is an interesting fact because the people that live in the Casa Vita are only moderately environmental aware. The vacuum toilet system shows to be a proper and accepted alternative for the conventional toilet system.
Compared with the system in Deventer the system implemented in the Flintenbreite neighbourhood in Lübeck is more vulnerable to failures and blockages. Due to the failures the households in Lübeck are less satisfied with the black water system. In general the households in Lübeck are very enthusiastic about their wastewater system but to their opinion improvements are necessary before it can be implemented on a larger scale. The inhabitants also mention that the black water system would not be accepted if the caretaker was not available to solve the failures relatively fast. An explanation for the fact that the acceptance of the vacuum toilet system system in Lübeck is still high could be related to the relative high environmental awareness (95%) of the inhabitants.
The inhabitants of the Flintenbreite neighbourhood are very enthusiastic about the grey water system because it is reliable, does not produce any noise or smell, looks nice and is better for the environment.

7.5 Final Conclusion

The sanitation system of the Casa Vita and Flintenbreite projects have been analyzed on the aspects drivers&barriers, operation&maintenance, health risks, performance, costs and user perception. The most important results of the research were:

Drivers

- Vacuum toilet system gives big freedom for consumers to design the inside of their house themselves
- Positive environmental aspects (water and energy saving)
- Reduction of water emissions
- Positive feeling about environmental friendly behaviour'
- reduction of water emissions
- Recycling of nutrients
- Reduction of energy use
- Quality of neighbourhood landscaping

Barriers

- Relative high costs of non conventional sanitation system
- Objections from the municipality against the implementation of a constructed wetland

Operation and maintenance

- In comparison with the Roediger system which is implemented in the Flintenbreite project the JETS system in Casa Vita project appears more robust although it is only functioning for a short period of time (2006)
- The Flintenbreite sanitation system is more complex and advanced than the Casa Vita sanitation system because it includes a grey water system and an on-site solution for the produced black water.
- The vacuum pipes of the JETS and Roediger system both get blocked if people flush big objects through the toilet
- The blockage of vacuum pipes by formation of precipitates should be prevented by flushing the pipes with a proper cleaning agent (Biocompact)
- The pushing buttons and reservoirs behind the Roediger toilets cause a lot of failures and possibly also a higher energy use in the Flintenbreite project
- The caretaker in the Flintenbreite project is necessary to keep the sanitation system running in case of a system failure

Health risks

- In both projects there is no contact between inhabitants and the black or grey water
- It is not possible that inhabitants come in contact with chemicals or other harmful compounds that are used in the sanitation system

Performance

- Despite the relative high phosphate content in the effluent of the constructed wetland of the Flintenbreite project the constructed wetland treats the grey water properly and cost efficiently
- Although not yet in operation, laboratory tests performed by the University of Hamburg indicated that the black water from the Flintenbreite neighborhood be used for the production of biogas directly
- The addition of shredded organic waste will improve both the quantity and quality of the biogas

Costs

- The construction costs of both non-conventional sanitation systems are much higher than the construction costs of conventional sanitation systems
- The operation costs of non-conventional sanitation systems can be lower because of a lower water use, decreased wastewater production and a reduction in wastewater fees.
- The maintenance costs of non-conventional sanitation systems are higher than the maintenance costs of conventional sanitation systems because they are more vulnerable for blockages/failures.

User perspective

- In general the users of the non-conventional sanitation systems are satisfied
- Advantages that are mentioned are the positive environmental aspects, short time that the flushing takes and the absence of a water reservoir and related noise production
- Disadvantages that are mentioned are the noise production, absence of a back-up system in case of a system failure, big amount of system failures, dependency on caretaker to solve problems
- According to the households an improved vacuum toilet system, which is less vulnerable for failures, would be preferred above a conventional toilet system

The vacuum toilet system implemented in the Casa Vita project in Deventer seems a proper alternative for a conventional toilet system. The user comfort of the system is high, it is clean,

robust, there are no interactions with pathogens and it safes a lot of water. Furthermore it provides several advantages for construction companies and house buyers.
The robustness of the system black water system is very important because households demand a reliable system without failures and/or blockages. In the Flintenbreite project the robustness of the black water system has been a problem because of misuse, the reliability of certain components, the high calcium content of the water and possibly the long distance over which the black water is transported. Vacuum toilet systems still have a few disadvantages which are hard to solve such as the relative big noise production and the lack of a back-up system in case of a system failure.
Despite the disadvantages the vacuum toilet system is an interesting alternative for building companies and households because it increases the freedom for the households to determine the interior of their houses and saves a lot of water.
An important notice is the information which is provided to the households that use the vacuum toilet system. The inhabitants should be completely aware of the proper toilet maintenance, such as the cleaning (which cleaning agents and why) and the things which are prohibited to flush through the toilet. Most of the system failures in the Casa Vita project and a lot of failures in the Flintenbreite neighbourhood are caused by improper use. The lifetime of the system is largely increased by proper use and maintenance.
A notice made by Harry Vieregge from the ‘Klaassen Groep’ is that the vacuum toilet system should be promoted by the government. Building companies should be pushed to implement vacuum toilet systems in their building projects.
The next step is to develop a robust, reliable and more sustainable method to treat the concentrated black water flow. A method which is already applied in other projects such as the Flintenbreite neighbourhood and a project in Sneek *(Stowa 2007)*.
This method exists out of the anaerobic digestion of the concentrated black water. During this digestion process biogas (methane), which can be used for energy production, is produced. An advantage of the digestion system is the possibility to add shredded green waste which will lead to an increased biogas production. After the digestion process the wastewater and sludge should be treated further to retrieve the nutrients and remove the heavy metals, hormones and medicine residues.
The system which is installed in the Flintenbreite neighbourhood should produce a valuable fertilizer which can be easily transported and used for regional agricultural purposes. The system which is installed in Sneek should be able to produce effluent water with a quality that can be discharged on the surface water directly. Such systems can be a complete alternative for the conventional wastewater system because a sewer system and wastewater treatment plant are not necessary anymore.
Especially in apartment and office buildings that are newly constructed it seems to be rewarding to implement a complete vacuum toilet system. In comparison with normal neighbourhoods the black water has to be transported over a shorter distance. This provides advantages such as a lower energy use and less blockages. Another advantage is the possibility to group all the necessary equipment in for example the basement of the building. All the devices necessary for the vacuum system can be grouped together to optimize energy and cost aspects.

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Appendices

1. Appendix 1: Survey questionnaire for households
2. Appendix 2: drivers and barriers interview
3. Appendix 3: System owner interview
4. Appendix 4: Operation and maintenance interview
5. Appendix 5: Sanitation expert interview
6. Appendix 6: Survey questionnaire for households with conventional toilet system
7. Appendix 7: Realized building activities Flintenbreite
8. Appendix 8: Pictures of black water system
9. Appendix 9: Grey water system Flintenbreite
10. Appendix 10: Drinking water use Flintenbreite
11. Appendix 11: Grey water quality spreadsheet
12. Appendix 12: Failures and blockages of black water system
13. Appendix 13: Energy use of black water system
14. Appendix 14: Electricity use
15. Appendix 15: Results user perception surveys
16. Appendix 16: Vacuumarator Casa Vita project Deventer

Appendix 1: Survey questionnaire for households

Survey onderzoek naar de gebruikerservaringen van huishoudens met vacuümtoiletten

Uw mening over het functioneren van het vacuümsysteem is belangrijk voor dit onderzoek.
Het interview zal ongeveer 10 minuten duren.
Alle informatie die u geeft zal vertrouwelijk worden behandeld en niet voor anderen openbaar worden gemaakt.

Enquête nr:…….....Datum:……

Naam geïnterviewde: ……Leeftijd:…….

Geslacht:……...

Adres: Straat……Nr……..

Informatie over huishouden:

1. Hoeveel personen telt uw huishouden?

   ……..personen

2. Hoe ziet de samenstelling van uw huishouden eruit?

   O alleenstaand
   O één-ouder familie
   O twee-ouder familie
   O Getrouwd (geen kinderen)
   O Samenwonend (geen kinderen)

3. Hoeveel leden van het huishouden zijn overdag buitenshuis (school, werk)? …….personen

4. Hoeveel leden van het huishouden slapen tenminste 5 nachten per week thuis?

   ……personen

5. Bent u speciaal vanwege de vacuümtoiletten in dit complex komen wonen?

   O ja - 0
   O nee - 1
   O niet bewust van - 2

Functioneren van het vacuumsysteem, onzichtbaarheid en gebruikersgemak:

6. Is uw huishouden tevreden over het vacuümsysteem? (leg uit)
    - o Erg tevreden - 0
    - o Tevreden - 1
    - o Neutraal - 2
    - o Ontevreden - 3
    - o Erg ontevreden - 4

    omdat……
    ……

7. Is het vacuümtoilet gemakkelijk schoon te houden?
    ……
    ……

8. Vindt u dat het vacuümtoilet een hard geluid maakt?
    ……
    ……
9. Vindt u het geluid ook irritant/hinderlijk?
    ……
    ……

10. Heeft u ooit overwogen om het vacuümtoilet te vervangen voor een ander toilet?
    ……
    ……

11. Bent u ook geinformeerd over het gebruik van het vacuumtoilet?
    ……
    ……

12. Zijn er andere aspecten van het vacuümtoilet waar u een opmerking over zou willen maken?
    ……
    ……
    ……

13. Zou u het vacuümtoilet aanraden aan huishoudens in andere buurten?

O Ja, ik zou het ten zeerste aanraden – 0
O Ja ik zou het aanraden – 1
O Ik weet het niet – 2
O Niet zonder verbeteringen – 3
O Helemaal niet – 4

Commentaar……
……

14. Wanneer u zou verhuizen naar een ander huis zou u dan graag opnieuw een vacuümtoilet willen hebben of heeft u de voorkeur voor een conventioneel toilet (of andere optie).

O Zelfde toilet
O Conventioneel toilet
O Ander toilet, namelijk……..

Commentaar……
……

15. Welk cijfer zou u het vacuümsysteem geven?

O 10
O 9
O 8
O 7
O 6
O 5
O 4
O 3
O 2
O 1

Omdat:……
……
……

Degelijkheid van vacuümsysteem:

16. Heeft u al een keer een probleem (uitval/verstopping) gehad met uw vacuümtoilet?
    Zo ja, hoe vaak is dit gebeurt?
    ……

17. Is het gehele vacuümsysteem al een keer uitgevallen?
    Zo ja, hoe vaak is dit gebeurt?
    ……

Alleen beantwoorden als 1, of beide, antwoorden van de vorige 2 vragen hoger waren dan 0 uitvallen/jaar.

18. Welk onderdeel van het afvalwatersysteem viel uit? Wat was het probleem? Wanneer en hoe vaak gebeurt het? Hoe loste u het probleem op en wie deed het?

Onderdeel van het systeem	Probleem	Wanneer? (Datum)	Hoe vaak? (t/m /j)	Oplossing	Opgelost

19. Wanneer het vacuümsysteem uitvalt hoe lang duurt dit dan gemiddeld?

……uren/uitval

Achtergrond vragen

20. Welke vorm van middelbare school heeft u gevolgd?

    O VMBO (voorheen MAVO)
    O HAVO
    O VWO
    O anders, namelijk……

21. Heeft u ook hoger onderwijs gevolgd?

O nee
O Ja, LBO
O ja, MBO
O ja, HBO
O ja, Universiteit
O ja, anders, namelijk……

Vragen over milieubewustzijn

22. Heeft u het gevoel dat u milieubewust bent?

O Altijd –0
O Vaak –1
O Soms –2
O Een beetje –3
O Helemaal niet –4

23. Heeft het vacuümsysteem u milieubewuster gemaakt?

O Ja
O Nee

24. Verwacht u dat het vacuümsysteem een goede toekomst heeft?

……
……
……

25. Welke voordelen ondervindt u van het vacuümsysteem?

……
……
……
……

26. Welke nadelen ondervindt u van het vacuümsysteem?

……
……
……
……
……

Het interview is voorbij. Bedankt voor het beantwoorden van de vragen.

Appendix 2: drivers and barriers interview

Uw mening over het functioneren van het vacuümsysteem is belangrijk voor dit onderzoek.
Het interview zal ongeveer 10 minuten duren.
Alle informatie die u geeft zal vertrouwelijk worden behandeld en niet voor anderen openbaar worden gemaakt.

Interview nr:…….....institutie:……

Datum…… Naam geïnterviewde::……

Adres: Straat……Nr……..

Vragen over het design

Beschrijving van het sanitaire systeem

1. Kunt u de technische en management eigenschappen van het sanitaire systeem beschrijven (eigenaar, process train, management, grootte, aantal aangesloten huishoudens, etc)?
   ……
   ……
   ……
   ……
   ……
   ……

2. Had u een aandeel in de keuze van de sanitaire technologie die momenteel in de wijk geïnstalleerd is?

   O ja
   O nee

3. Wanneer is het systeem gebouwd en hoe lang duurde de bouw?

   ……..
   …… jaar

4. Welke actoren waren betrokken in de keuze van de sanitaire technologie en wat was hun rol?

Actor	**Rol**

5. Op welke manier werden beslissingen genomen (consensus of autoritair)?

O consensus
O autoriteit

6. Was u het eens met het beslissingsproces?

O ja
O nee, want
……
……..

7. Wie had het laatste woord met betrekking tot de keuze van het sanitaire systeem / technologiekeuze?
……
……..

8. Hoe vaak pleegde u overleg met de andere actoren die betrokken waren bij de systeemkeuze?
……keer per maand

Milieu drivers

9. Welke milieu aspecten van het sanitaire systeem waren belangrijk voor u en de andere actoren toen u een systeem aan het selecteren was?

Milieu aspect	Onbelangrijk				belangrijk
	0	1	2	3	4
Positief gevoel over milieubewust gedrag					
Water besparen					
Tegengaan van verdroging van de bodem					
Reduceren van water emissies					
Recycling van water					
Beschermen van oppervlaktewater					
Beschermen van grondwater					
Recycling van nutrienten					
Reduceren van energieverbruik					
Kwaliteit van het landschap in de woonwijk					
Anders nl……..					
Anders nl……..					
Anders nl……..					

10. Welke milieuaspecten van het sanitaire systeem zijn uiteindelijk gerealiseerd toen het gebouwd werd?

Milieu aspect	Onbelangrijk				belangrijk
	0	1	2	3	4
Positief gevoel over milieubewust gedrag					
Water besparen					
Tegengaan van verdroging van de bodem					
Reduceren van water emissies					
Recycling van water					
Beschermen van oppervlaktewater					
Beschermen van grondwater					
Recycling van nutrienten					
Reduceren van energieverbruik					
Kwaliteit van het landschap in de woonwijk					
Anders nl……..					
Anders nl……..					
Anders nl……..					

Milieu en volksgezondheid barrières

11. Welke barrières waren er toen u non-conventionele elementen in het systeem wilde implementeren?

Milieu aspect	Onbelangrijk				belangrijk
	0	1	2	3	4
Gezondheidsrisico's					
Overstromingsgevaar					
Chemische risico's					
Fysieke risico's doordat de gebruiker toegang heeft tot het systeem					
Anders nl…….					
Anders nl…….					
Anders nl…….					

Wettelijke en regelgeving barrières

12. Welke wet en regelgeving verhinderde de implementatie van welk non-conventioneel element in het originele design (specifiek)?

	Wet of regelgeving	**Gevolg voor non-conventioneel element in het systeem**
1		
2		
3		
4		
5		

Vacuum toilet (sociaal/technisch)

13. Was het idee om vacuümtoiletten in het systeem te implementeren een driver of een barrière?

Driver		neutraal		barriere
0	1	2	3	4

Toelichting
……
……
……

14. Tot op welke hoogte speelden sociaal/technische afwegingen een rol bij de systeemkeuze?

onbelangrijk		neutraal		belangrijk
0	1	2	3	4

Toelichting
……
……
……

Financiële drivers en barrières

15. Welke financiële afwegingen waren een driver dan wel barrière bij het implementeren van non-conventionele elementen in het systeem?

	driver				barrière
	0	1	2	3	4
Kosten van design (vergeleken met conventioneel systeem)					
Operationele kosten (vergeleken met conventioneel systeem)					
Energie kosten (vergeleken met conventioneel systeem)					
Toepassen van vacuümtoiletten (financieel)					
Verminderde drinkwater consumptie (lagere rekening)					
Anders nl……..					
Anders nl……..					
Anders nl……..					

16. Tot op welke hoogte speelden de volgende afwegingen een rol in de systeemkeuze?

	onbelangrijk				belangrijk
	0	1	2	3	4
Kosten van design (vergeleken met conventioneel systeem)					
Operationele kosten (vergeleken met conventioneel systeem)					
Energie kosten (vergeleken met conventioneel systeem)					
Toepassen van vacuümtoiletten (financieel)					
Verminderde drinkwater consumptie (lagere rekening)					
Anders nl……..					
Anders nl……..					
Anders nl……..					

17. Was het budget voor het systeem vanaf het begin bekend?

O ja
O nee

18. Tot op welke hoogte speelde het budget een rol in de systeemkeuze?

onbelangrijk		neutraal		belangrijk
0	1	2	3	4

Sociale en management drivers/barrières

19. Welke sociale aspecten van het sanitaire systeem waren belangrijk voor u en de andere actoren bij het realiseren van een non-conventioneel systeem?

Aspecten	Onbelangrijk				belangrijk
	0	1	2	3	4
Intensief contact met de buren / samenwerking buren					
Betrokkenheid bij het sanitaire systeem					
Toegenomen kwaliteit van leven					
Anders nl……..					
Anders nl……..					
Anders nl……..					

20. Welke sociale en management afwegingen verhinderde het integreren van non-conventionele elementen in het design?

aspecten	onbelangrijk				belangrijk
	0	1	2	3	4
Ingewikkelde technologie					
Onduidelijkheid over eigendom					
Onduidelijkheid over verantwoordelijkheid voor onderhoud					
Onderhoudstaak voor huishoudens					

Anders nl……..					
Anders nl……..					
Anders nl……..					

Huidige en toekomstige staat van het afvalwater management systeem

21. Neemt u deel aan het project sinds het bouwen van de woonwijk tot aan het heden?

O ja
O nee (sla de volgende twee vragen over)

22. Heeft het sanitaire systeem sinds het opstarten veranderingen/modificaties ondergaan?

O nee
O ja, welke en waarom?
……
……
……

23. Verwacht u dat het sanitaire systeem in de toekomst veranderingen zal ondergaan?
……
……
……

Algemeen

24. Wie is volgens u de meest belangrijke actor betreffende het ontwikkelen en implementeren van non conventionele systemen? Waarom?
……
……
……

25. Als u het project opnieuw zou kunnen uitvoeren zou u het dan anders aanpakken of niet?
……
……
……
……
……
……

Dit is het einde van het interview. Bedankt voor uw medewerking.

Appendix 3: System owner interview

Het doel van dit interview is om een indruk te krijgen van praktische ervaringen met alternatieve sanitatie.
Het interview zal ongeveer 20 minuten duren.
Alle informatie die u geeft zal vertrouwelijk worden behandeld en niet voor anderen openbaar worden gemaakt.

Interview nr:…….....institutie:……

Datum…… Naam geïnterviewde::……

Adres: Straat……Nr……..

Vragen

Omschrijving van het systeem

1. Kunt u de technische en management aspecten van het sanitaire systeem omschrijven (eigenaar, process train, management, grootte, aantal aangesloten huishoudens, etc)?
   ……
   ……
   ……
   ……
   ……
   ……
   ……
   ……

Systeem omschrijving

2. Hoe groot was de investering per huishouden voor de bouw van het complete sanitaire systeem (process train) ?
   ……€/huishouden

3. Wat is de verwachtte levensduur in jaren van het complete sanitaire systeem (process train)?
   ……jaar

4. Hoeveel bedragen de verwachtte jaarlijkse operationele kosten voor het complete sanitaire systeem per huishouden?
   …….€/huishouden/jaar

Onzichtbaarheid en gebruiksvriendelijkheid

5. Zijn de huishoudens tevreden met het sanitaire systeem?
   O ja
   O Nee, want…….....
   ……
   ……

6. Hoeveel uur per jaar besteden huishoudens gemiddeld aan operationele / onderhouds werkzaamheden betreffende het complete sanitaire systeem?
   ……..uur/huishouden/jaar

7. Hoeveel binnenshuis oppervlak, in m^3 per huishouden, vereist het complete sanitaire systeem (process train)?
   …….. m^3/huishouden

8. Hoeveel buitenshuis oppervlak, in m^3 per huishouden, vereist het complete sanitaire systeem (process train)?

   ……..m^3/huishouden

9. Hoeveel bovengronds oppervlak in m^2 vereist het complete sanitaire systeem in de wijk (process train)? (Wat is de diepte?.....)

…….m^2/wijk

10. Hoeveel ondergrondse ruimte in m^3 vereist het complete sanitaire systeem (process train) in de wijk?

…….m^3/wijk

Systeem robuustheid

11. Wordt het sanitaire systeem gemonitord? Zo ja, hoe?
    ……
    ……
    ……
    ……

12. Hoeveel keer per jaar raakt een vacuüm toilet verstopt/ werkt het toilet niet?
    …….verstoppingen/jaar

13. Hoeveel keer per jaar raakt het complete vacuüm systeem verstopt/ werkt het systeem niet?
    …….verstoppingen/jaar

Alleen vragen wanneer 1 of beide van de laatste 2 vragen een hogere score had dan 0 verstoppingen per jaar

14. Welk onderdeel van het sanitaire systeem werkte niet? Wat was het probleem? Wanneer en hoe vaak gebeurt het? Hoe werd het opgelost en door wie?

Onderdeel van systeem	Probleem	Wanneer? (datum)	Hoe vaak? (keer/jaar)	Oplossing	opgelost

15. Wanneer het vacuüm systeem niet werkt hoe lang duurt dat dan gemiddeld?
…….uren/buiten bedrijf

Impact op ecosystemen

16. Hoeveel bedraagt de energieconsumptie van het sanitaire systeem per huishouden per jaar?
……kWh/huishouden/jaar

17. Hoeveel bedraagt de energiehoeveelheid die teruggewonnen wordt door het sanitaire proces per huishouden per jaar?
……kWh/huishouden/jaar

18. Hoe groot is de hoeveelheid water per huishouden die jaarlijks gerecycled wordt door het sanitaire systeem?
……m^3/huishouden/jaar

Dit is het einde van het interview. Bedankt voor uw medewerking.

Appendix 4: Operation and maintenance interview

Het doel van dit interview is om een indruk te krijgen van praktische ervaringen met alternatieve sanitatie.
Het interview zal ongeveer 30-40 minuten duren.
Alle informatie die u geeft zal vertrouwelijk worden behandeld en niet voor anderen openbaar worden gemaakt.

Interview nr:…….....institutie:……

Datum…… Naam geïnterviewde::……

Adres

Vragen

Omschrijving van het systeem

1. Kunt u de technische en management aspecten van het sanitaire systeem omschrijven (eigenaar, process train, management, grootte, aantal aangesloten huishoudens, etc)?
   ……
   ……
   ……
   ……
   ……
   ……
   ……
   ……

2. Hoe groot was de investering per huishouden voor de bouw van het complete sanitaire systeem (process train) ?
   ……€/huishouden

3. Wat is de verwachtte levensduur in jaren van het complete sanitaire systeem (process train)?
   ……jaar

4. Hoeveel bedragen de verwachtte jaarlijkse operationele kosten voor het complete sanitaire systeem per huishouden?
   ……€/huishouden/jaar

Onzichtbaarheid en gebruiksvriendelijkheid

5. Zijn de huishoudens tevreden met het sanitaire systeem?
   O ja
   O Nee, want……
   ……
   ……

6. Hoeveel uur per jaar besteden huishoudens gemiddeld aan operationele / onderhouds werkzaamheden betreffende het complete sanitaire systeem?
   ……uur/huishouden/jaar

7. Hoeveel binnenshuis oppervlak, in m^3 per huishouden, vereist het complete sanitaire systeem (process train)?
   …… m^3/huishouden

8. Hoeveel buitenshuis oppervlak, in m^3 per huishouden, vereist het complete sanitaire systeem (process train)?

   ……..m^3/huishouden

9. Hoeveel bovengronds oppervlak in m^2 vereist het complete sanitaire systeem in de wijk (process train)? (Wat is de diepte?.....)
   ……m^2/wijk

10. Hoeveel ondergrondse ruimte in m^3 vereist het complete sanitaire systeem (process train) in de wijk?
    ……m^3/wijk

11. Hoeveel officiële klachten met betrekking tot stankoverlast worden jaarlijks ingediend dood gebruikers (bijvoorbeel bij gemeente)?
    ……aantal/jaar

12. Hoeveel onofficiële klachten worden jaarlijks door gebruikers ingediend (klachten aan uw adres)?
    ……aantal/jaar

Systeem robuustheid

13. Wordt het sanitaire systeem gemonitord? Zo ja, hoe?
    ……
    ……
    ……
    ……

14. Hoeveel keer per jaar raakt een vacuüm toilet verstopt/ werkt het toilet niet?
    ……verstoppingen/jaar

15. Hoeveel keer per jaar raakt het complete vacuüm systeem verstopt/ werkt het systeem niet?
    ……verstoppingen/jaar

Alleen vragen wanneer 1 of beide van de laatste 2 vragen een hogere score had dan 0 verstoppingen per jaar

16. Welk onderdeel van het sanitaire systeem werkte niet? Wat was het probleem? Wanneer en hoe vaak gebeurt het? Hoe werd het opgelost en door wie?

Onderdeel van systeem	Probleem	Wanneer? (datum)	Hoe vaak? (keer/jaar)	Oplossing	opgelost

17. Wanneer het vacuüm systeem niet werkt hoe lang duurt dat dan gemiddeld?
    ……uren/buiten bedrijf

18. Wat voor effect heeft het proces op fluctuaties in zware metalen in het influent

Geen effect		effect		veel effect
0	1	2	3	4

19. Wat voor effect heeft het proces op fluctuaties in pathogenen in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

20. Wat voor effect heeft het proces op fluctuaties in olie-/vetachtige substanties in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

21. Wat voor effect heeft het proces op fluctuaties in medicijnen en hormonen in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

22. Wat voor effect heeft het proces op fluctuaties in fosfaat en nitraat in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

23. Wat voor effect heeft het proces op fluctuaties in organisch materiaal in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

24. Wat voor effect heeft het proces op fluctuaties in deeltjesgrootte in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

25. Wat is de maximale diameter van een deeltje dat door het systeem behandeld kan worden?
……..mm deeltjesgrootte

26. Wat voor effect heeft het proces op fluctuaties in buitentemperatuur?

Geen effect		effect		veel effect
0	1	2	3	4

27. Wat voor effect heeft een fluctuerende regen intensiteit op het systeem?

Geen effect		effect		veel effect
0	1	2	3	4

Volksgezondheid

28. Hoe groot is de procentuele kans dat bewoners van de wijk in direct contact komen met het afvalwater?
……%

29. Hoe groot is de procentuele kans dat een hoeveelheid gezuiverd water niet aan de afvalwaternormen voldoet?
……%

30. Overschrijdt het effluent van het systeem officiele kwaliteitsnormen?
O ja (ga naar de volgende vraag)
O Nee (sla de volgende vraag over)

31. Met hoeveel procent overschrijdt het effluent de kwaliteitsnormen?
……%

32. Overschrijdt het uiteindelijke slib officiele kwaliteitsnormen?
O ja (ga naar de volgende vraag)
O Nee (sla de volgende vraag over)

33. Met hoeveel procent overschrijdt het slib de kwaliteitsnormen?
……%

34. Hoe groot is de kans dat gebruikers van het systeem ziek worden door storingen of andere oorzaken?

Very likely				not likely at all
0	1	2	3	4

35. Hoe groot is de kans dat gebruikers van het systeem fysiek letsel ondervinden omdat ze toegang hebben tot (onderdelen van) het systeem?

Very likely				not likely at all
0	1	2	3	4

36. Zou het systeem mogelijk chemische gevaren voor de gebruikers kunnen opleveren?
    O Nee
    O ja, wat voor soort chemisch gevaar?
    .....
    ……

37. Hoe groot is het procentuele reinigingsrendement van pathogenen?
    ……..%

38. Hoeveel pathogenen bevinden zich gemiddeld in het effluent?
    ……..mg/kg

39. Hoeveel pathogenen bevinden zich gemiddeld in het slib?
    …….mg/kg

impact op ecosystemen

40. Hoe groot is het afvalwatervolume per huishouden per jaar?
    …….m^3/huishouden/jaar

41. Hoe groot is de uiteindelijke slibproductie per huishouden per jaar?
    …….kg/huishouden/jaar

42. Hoeveel kg chemicalien verbruikt het sanitaire systeem per huishouden per jaar?
    …….kg/huishouden/jaar

43. Hoeveel energie verbruikt het sanitaire systeem per huishouden per jaar?
    …….Kwh/huishouden/jaar

44. Hoeveel bedraagt de energiehoeveelheid die teruggewonnen wordt door het sanitaire proces per huishouden per jaar?
    …….kWh/huishouden/jaar

45. Hoeveel drinkwater wordt er per huishouden per jaar gebruikt?
    …….m^3/huishouden/jaar

46. Hoe groot is de hoeveelheid water per huishouden die jaarlijks gerecycled wordt door het sanitaire systeem?
    …….m^3/huishouden/jaar

Oppervlakte- en groundwater management

47. Gebruikt het sanitaire systeem regenwater?
    O Nee
    O ja

48. Draagt het sanitaire systeem bij aan grondwater management?
    O Nee
    O ja

49. Hoe groot is de jaarlijkse neerslag?
    ……mm neerslag/m^2/jaar
50. Hoeveel neerslag kan het systeem maximal aan?
    ……mm neerslag/m^2

Dit is het einde van het interview. Bedankt voor uw medewerking.

Appendix 5: Sanitation expert interview

Het doel van dit interview is om een indruk te krijgen van praktische ervaringen met alternatieve sanitatie.
Het interview zal ongeveer 30-40 minuten duren.
Alle informatie die u geeft zal vertrouwelijk worden behandeld en niet voor anderen openbaar worden gemaakt.

Interview nr:…….....institutie:……

Datum…… Naam geïnterviewde::……

Adres

Vragen

Omschrijving van het systeem

1. Kunt u de technische en management aspecten van het sanitaire systeem omschrijven (eigenaar, process train, management, grootte, aantal aangesloten huishoudens, etc)?
   ……
   ……
   ……
   ……
   ……
   ……
   ……
   ……

2. Hoe groot was de investering per huishouden voor de bouw van het complete sanitaire systeem (process train) ?
   ……€/huishouden

3. Wat is de verwachtte levensduur in jaren van het complete sanitaire systeem (process train)?
   ……jaar

4. Hoeveel bedragen de verwachtte jaarlijkse operationele kosten voor het complete sanitaire systeem per huishouden?
   ……..€/huishouden/jaar

Onzichtbaarheid en gebruiksvriendelijkheid

5. Zijn de huishoudens tevreden met het sanitaire systeem?
   O ja
   O Nee, want…….....
   ……
   ……

6. Hoeveel uur per jaar besteden huishoudens gemiddeld aan operationele / onderhouds werkzaamheden betreffende het complete sanitaire systeem?
   ……..uur/huishouden/jaar

7. Hoeveel binnenshuis oppervlak, in m^3 per huishouden, vereist het complete sanitaire systeem (process train)?
   …….. m^3/huishouden

8. Hoeveel buitenshuis oppervlak, in m^3 per huishouden, vereist het complete sanitaire systeem (process train)?

   ……..m^3/huishouden

9. Hoeveel bovengronds oppervlak in m^2 vereist het complete sanitaire systeem in de wijk (process train)? (Wat is de diepte?.....)
   ……m^2/wijk

10. Hoeveel ondergrondse ruimte in m^3 vereist het complete sanitaire systeem (process train) in de wijk?
    ……m^3/wijk

11. Wat is, binnen het huishouden, de maximale hoeveelheid geluid in dB die geproduceerd wordt door het systeem?

12. Hoeveel officiële klachten met betrekking tot stankoverlast worden jaarlijks ingediend dood gebruikers (bijvoorbeel bij gemeente)?
    ……aantal/jaar

13. Hoeveel onofficiële klachten worden jaarlijks door gebruikers ingediend (klachten aan uw adres)?
    ……aantal/jaar

Systeem robuustheid

14. Wordt het sanitaire systeem gemonitord? Zo ja, hoe?
    ……
    ……
    ……
    ……

15. Hoeveel keer per jaar raakt een vacuüm toilet verstopt/ werkt het toilet niet?
    ……verstoppingen/jaar

16. Hoeveel keer per jaar raakt het complete vacuüm systeem verstopt/ werkt het systeem niet?
    ……verstoppingen/jaar

Alleen vragen wanneer 1 of beide van de laatste 2 vragen een hogere score had dan 0 verstoppingen per jaar

17. Welk onderdeel van het sanitaire systeem werkte niet? Wat was het probleem? Wanneer en hoe vaak gebeurt het? Hoe werd het opgelost en door wie?

Onderdeel van systeem	Probleem	Wanneer? (datum)	Hoe vaak? (keer/jaar)	Oplossing	opgelost

18. Wanneer het vacuüm systeem niet werkt hoe lang duurt dat dan gemiddeld?
……uren/buiten bedrijf

19. Wat voor effect heeft het proces op fluctuaties in zware metalen in het influent

Geen effect		effect		veel effect
0	1	2	3	4

20. Wat voor effect heeft het proces op fluctuaties in pathogenen in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

21. Wat voor effect heeft het proces op fluctuaties in olie-/vetachtige substanties in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

22. Wat voor effect heeft het proces op fluctuaties in medicijnen en hormonen in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

23. Wat voor effect heeft het proces op fluctuaties in fosfaat en nitraat in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

24. Wat voor effect heeft het proces op fluctuaties in organisch materiaal in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

25. Wat voor effect heeft het proces op fluctuaties in deeltjesgrootte in het influent?

Geen effect		effect		veel effect
0	1	2	3	4

26. Wat is de maximale diameter van een deeltje dat door het systeem behandeld kan worden?
……..mm deeltjesgrootte

27. Wat voor effect hebben fluctuaties in buitentemperatuur op het proces?

Geen effect		effect		veel effect
0	1	2	3	4

28. Wat voor effect heeft een fluctuerende regen intensiteit op het systeem?

Geen effect		effect		veel effect
0	1	2	3	4

Volksgezondheid

29. Hoe groot is de procentuele kans dat bewoners van de wijk in direct contact komen met het afvalwater?
…….%

30. Hoe groot is de procentuele kans dat een hoeveelheid gezuiverd water niet aan de afvalwaternormen voldoet?
…….%

31. Overschrijdt het effluent van het systeem officiele kwaliteitsnormen?
O ja (ga naar de volgende vraag)
O Nee (sla de volgende vraag over)

32. Met hoeveel procent overschrijdt het effluent de kwaliteitsnormen?
…….%

33. Overschrijdt het uiteindelijke slib officiele kwaliteitsnormen?
O ja (ga naar de volgende vraag)
O Nee (sla de volgende vraag over)

34. Met hoeveel procent overschrijdt het slib de kwaliteitsnormen?
…….%

35. Hoe groot is de kans dat gebruikers van het systeem ziek worden door storingen of andere oorzaken?

Very likely				not likely at all
0	1	2	3	4

36. Hoe groot is de kans dat gebruikers van het systeem fysiek letsel ondervinden omdat ze toegang hebben tot (onderdelen van) het systeem?

Very likely				not likely at all
0	1	2	3	4

37. Zou het systeem mogelijk chemische gevaren voor de gebruikers kunnen opleveren?
    O Nee
    O ja, wat voor soort chemisch gevaar?
    .....
    ……

38. Hoe groot is het procentuele reinigingsrendement van pathogenen?
    ……..%

39. Hoeveel pathogenen bevinden zich gemiddeld in het effluent?
    ……..mg/kg

40. Hoeveel pathogenen bevinden zich gemiddeld in het slib?
    …….mg/kg

impact op ecosystemen

41. Hoe groot is het procentuele reinigingsrendement voor organisch materiaal (BZV)?
    ……%

42. Wat is de kwaliteit van het effluent m.b.t. BZV?
    …….mg/BZV/l

43. Wat is de kwaliteit van het uiteindelijke slib m.b.t. BZV?
    …….mg/kg dm

44. Wat is de kwaliteit van het effluent m.b.t. zware metalen?
    …….µg/l

45. Wat is de kwaliteit van het uiteindelijke slib m.b.t. zware metalen?
    …….mg/kg dm

46. Hoe groot is het afvalwatervolume per huishouden per jaar?
    …….m^3/huishouden/jaar

47. Hoe groot is de hoeveelheid nutriënten in het afvalwater per huishouden per jaar?
    …….mg/m^3

48. Hoe groot is de uiteindelijke slibproductie per huishouden per jaar?
    …….kg/huishouden/jaar

49. Hoeveel kg chemicalien verbruikt het sanitaire systeem per huishouden per jaar?
    …….kg/huishouden/jaar

50. Hoeveel energie verbruikt het sanitaire systeem per huishouden per jaar?

…….Kwh/huishouden/jaar

51. Hoeveel bedraagt de energiehoeveelheid die teruggewonnen wordt door het sanitaire proces per huishouden per jaar?
……kWh/huishouden/jaar

52. Hoeveel drinkwater wordt er per huishouden per jaar gebruikt?
…….m^3/huishouden/jaar

53. Hoe groot is de hoeveelheid water per huishouden die jaarlijks gerecycled wordt door het sanitaire systeem?
…….m^3/huishouden/jaar

Oppervlakte- en groundwater management

54. Gebruikt het sanitaire systeem regenwater?
O Nee
O ja

55. Draagt het sanitaire systeem bij aan grondwater management?
O Nee
O ja

56. Hoe groot is de jaarlijkse neerslag?
…….mm neerslag/m^2/jaar

57. Hoeveel neerslag kan het systeem maximal aan?
…….mm neerslag/m^2

Dit is het einde van het interview. Bedankt voor uw medewerking.

Appendix 6: Survey questionnaire for households with conventional toilet system

Uw mening over het functioneren van het toiletsysteem is belangrijk voor dit onderzoek.
Het interview zal ongeveer 10 minuten duren.
Alle informatie die u geeft zal vertrouwelijk worden behandeld en niet voor anderen openbaar worden gemaakt.

Enquête nr:…….....Datum:……

Naam geïnterviewde: ……Leeftijd:……

Geslacht:……..

Adres: Straat……Nr……..

Informatie over huishouden:

1. Hoeveel personen telt uw huishouden?

   ……..personen

2. Hoe ziet de samenstelling van uw huishouden eruit?

   O alleenstaand
   O één-ouder familie
   O twee-ouder familie
   O Getrouwd (geen kinderen)
   O Samenwonend (geen kinderen)

3. Hoeveel leden van het huishouden zijn overdag buitenshuis (school, werk)? …….personen

4. Hoeveel leden van het huishouden slapen tenminste 5 nachten per week thuis?

   ……personen

   Functioneren van het toiletsysteem, onzichtbaarheid en gebruikersgemak:

5. Is uw huishouden tevreden over het toiletsysteem? (leg uit)

   o Erg tevreden - 0
   o Tevreden - 1
   o Neutraal - 2
   o Ontevreden - 3
   o Erg ontevreden - 4

   omdat……

   ……

6. Is het toilet gemakkelijk schoon te houden?

   ……

   ……

7. Vindt u dat het toilet een hard geluid maakt bij doorspoelen en vollopen van de stortbak?

   ……

   ……

8. Vindt u het geluid ook irritant/hinderlijk?

   ……

   ……

9. Zijn er andere aspecten van het toilet waar u een opmerking over zou willen maken?

   ……

   ……

   ……

Bent u bekend met vacuümtoilet systemen? Vacuümtoiletten zijn een voorbeeld van alternatieve sanitaire mogelijkheden. Wanneer deze toiletten doorgespoeld worden gebruiken ze slechts een kleine hoeveelheid water (1 liter ipv 5 – 8). Op deze manier springen ze veel zuiniger met water om.

10. Heeft u ooit overwogen om het toilet te vervangen voor een ander toilet (bijvoorbeeld vacuümtoilet)?

    ……

    ……

11. Wanneer u zou verhuizen naar een ander huis zou u dan graag opnieuw dit toilet willen hebben of heeft u de voorkeur voor een alternatief toilet (of andere optie).

    O Zelfde toilet
    O Alternatief toilet
    O Ander toilet, namelijk…….

    Commentaar…….

    ……

12. Welk cijfer zou u uw huidige toiletsysteem geven?

    O 10
    O 9

O 8
O 7
O 6
O 5
O 4
O 3
O 2
O 1

Omdat:……
……
……

Degelijkheid van het sanitaire systeem:

13. Heeft u al een keer een probleem (uitval/verstopping) gehad met uw toilet?
    Zo ja, hoe vaak is dit gebeurt?
    ……

14. Is het gehele toiletsysteem al een keer uitgevallen?
    Zo ja, hoe vaak is dit gebeurt?
    ……

Alleen beantwoorden als 1, of beide, antwoorden van de vorige 2 vragen hoger waren dan 0 uitvallen/jaar.

15. Welk onderdeel van het afvalwatersysteem viel uit? Wat was het probleem? Wanneer en hoe vaak gebeurt het? Hoe loste u het probleem op en wie deed het?

Onderdeel van het systeem	Probleem	Wanneer? (Datum)	Hoe vaak? (t/m /j)	Oplossing	Opgelost

16. Wanneer het toiletsysteem uitvalt hoe lang duurt dit dan gemiddeld?

    ……uren/uitval

Achtergrond vragen

17. Welke vorm van middelbare school heeft u gevolgd?

    O VMBO (voorheen MAVO)
    O HAVO
    O VWO
    O anders, namelijk……

18. Heeft u ook hoger onderwijs gevolgd?

    O nee
    O Ja, LBO
    O ja, MBO
    O ja, HBO
    O ja, Universiteit
    O ja, anders, namelijk……

Vragen over milieubewustzijn

19. Heeft u het gevoel dat u milieubewust bent?

    O Altijd –0
    O Vaak –1
    O Soms –2
    O Een beetje –3
    O Helemaal niet –4

20. Heeft u twijfels over de milieubewustheid van uw huidige toiletsysteem?

    O nee
    O Ja, n.l.
    ……
    ……

21. Verwacht u dat alternatieve toiletsystemen zoals het vacuümsysteem een goede toekomst hebben?

    ……
    ……
    ……

22. Welke voordelen ondervindt uw huidige toiletsysteem?

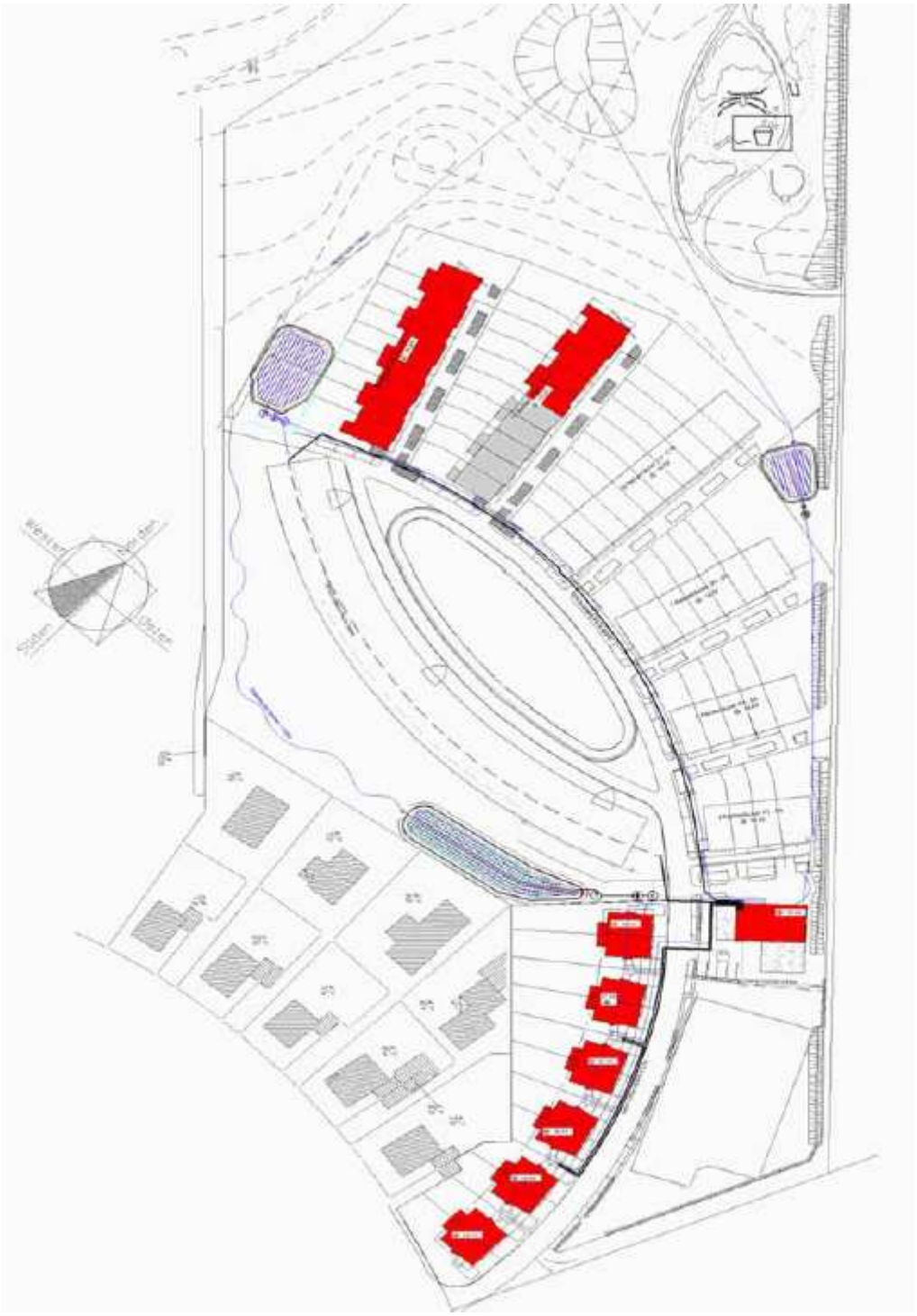
……
……
……
……

23. Welke nadelen ondervindt u van uw huidige toiletsysteem?

……
……
……
……
……

Het interview is voorbij. Bedankt voor het beantwoorden van de vragen.

Appendix 7: Realized building activities Flintenbreite



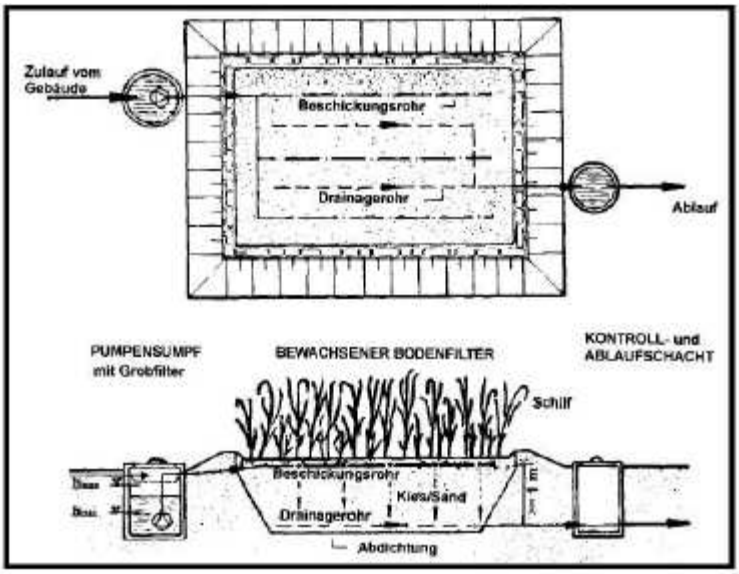
Otterwasser, 2005

Appendix 8: Pictures of black water system

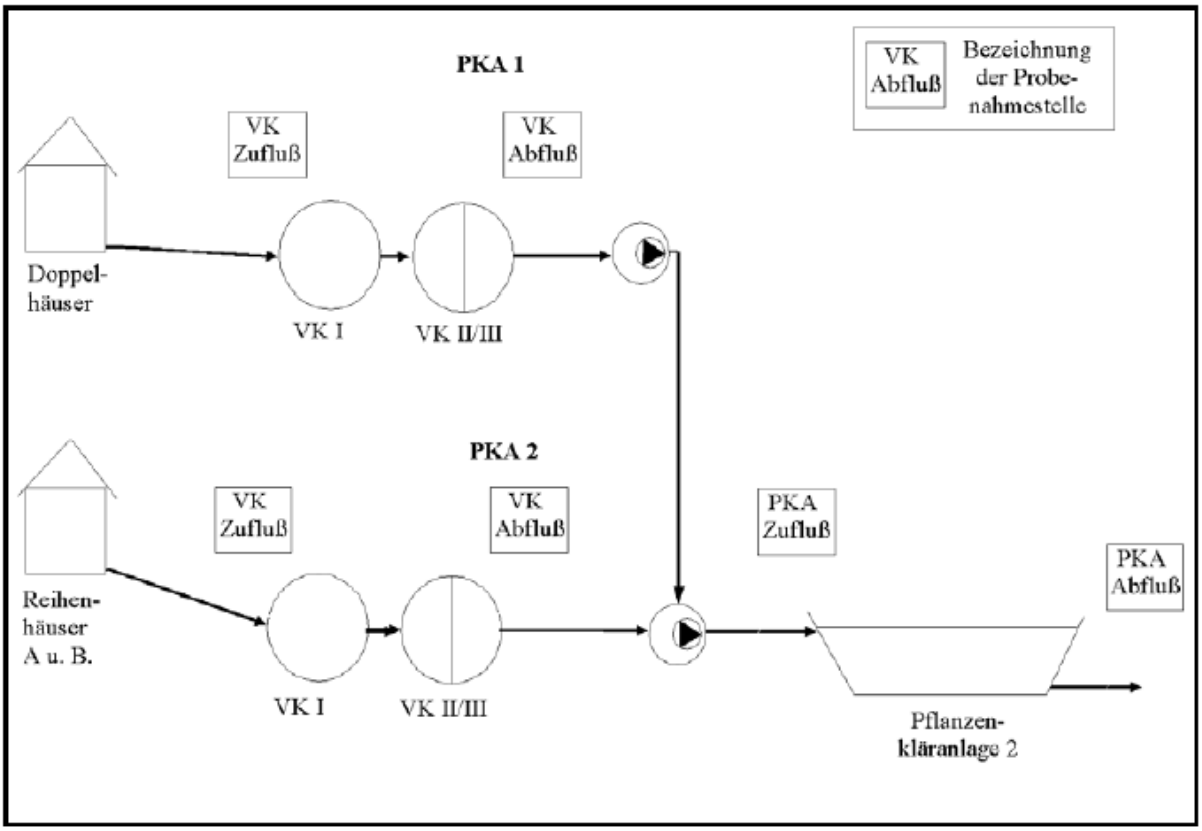
Ruhrwelle im inneren der Biogasanlage

Otterwasser, 2005

Appendix 9: Grey water system Flintenbreite

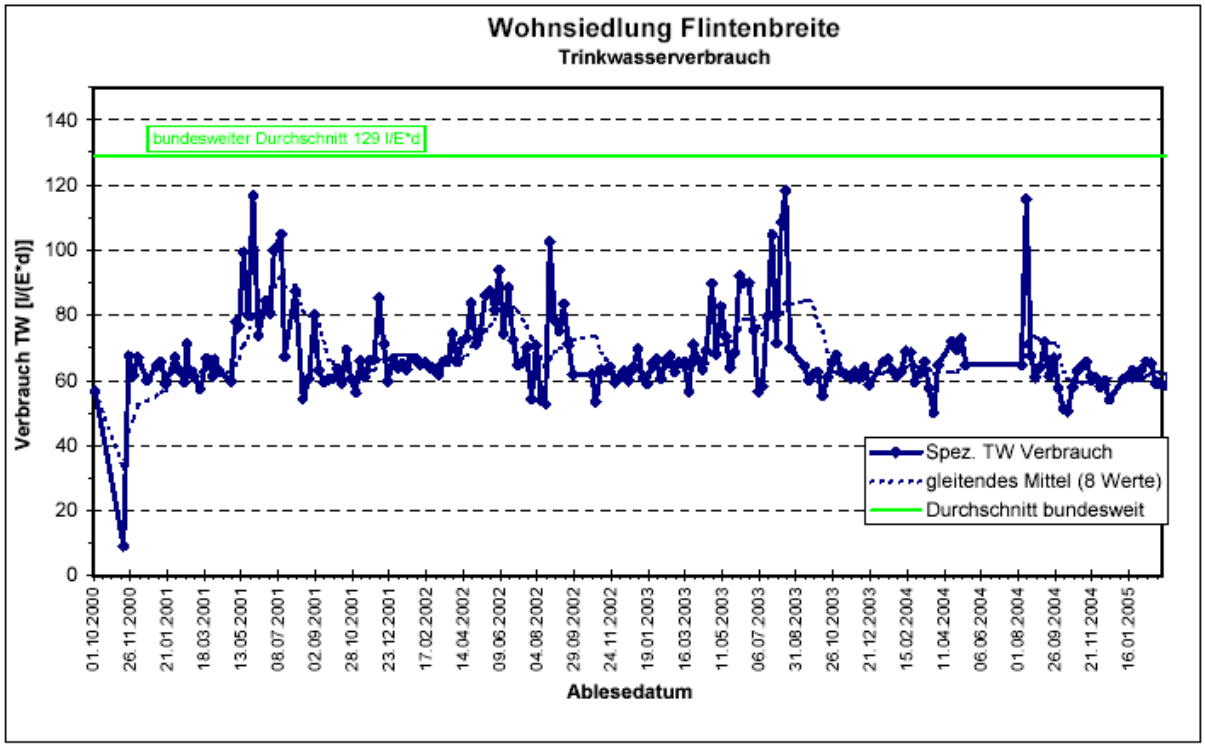


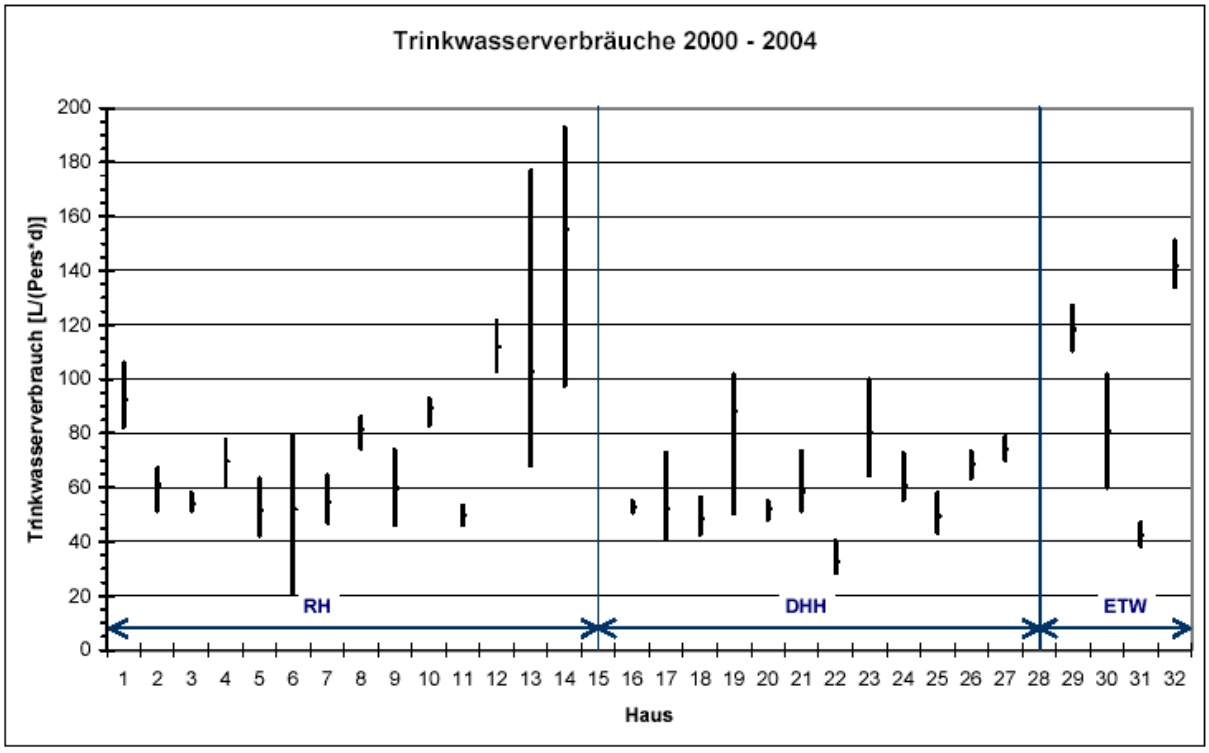
Schematic drawing of constructed wetland nr. 2 (Pflanzenkläranalage nr. 2)(Otterwasser 2005)



Schematic drawing of grey water system in Flintenbreite neighborhood (Otterwasser 2005)

Appendix 10: Drinking water use Flintenbreite





Appendix 11: Grey water quality spreadsheet

Appendix 12: Failures and blockages of black water system

Appendix 13: Energy use of black water system

Appendix 14: Electricity use

Appendix 15: Results user perception surveys

User perception of toilet system

Aspect	Wageningen	Lübeck	Deventer
Black water system			
Satisfaction with toilet system	35% very satisfied, 50% satisfied, 10% neutral, 5% dissatisfied	15% very satisfied, 40% satisfied, 25% neutral, 20% dissatisfied	10% very satisfied, 57,5% satisfied, 27,5% neutral, 5% dissatisfied
Grade for toilet system	7,05	6,6	7,15
Noise nuisance of flushing the toilet	Annoying: 25%	loud: 55% Annoying: 15% No hindrance: 45%	loud: 50% Annoying: 20%
Noise nuisance of toilet from neighbours	Sometimes: 20%	Sometimes: 15%	Often: 5% Sometimes: 45%
Is the vacuum toilet easily kept clean?		Easily: 75% Moderately: 20% Not easily: 5%	Easily: 65% Not easily: 30% Poorly: 5%
Doubts about sustainability of conventional toilet system	45%	-	-
Importance of environmental aspects of toilet system	70%	95%	55%
Adaptations made to system		Removal or shortcut of 18 of 28 reservoirs + valves (behind toilets) because they caused blockages	
Considering a replacement of the vacuum toilet for a conventional one		40%	5%
Recommending the vacuum system to other households		Directly: 50% Adapted form: 45% No opinion: 5%	Directly: 65% Adapted form: 20% No opinion: 15%
System choice if moving to other house		vacuum (adapted form or not): 80% Conventional: 20%	Vacuum: 60% Adapted vacuum: 10% Conventional: 30%
Failures / Blockages of toilet	0	402 in total (mostly small problems with valve and reservoir)	-
Failures / blockages of system		135 (blockages of pipes, failures of central vacuum station, etc)	2 (Since installation in February 2007)
Time to repair blockages/failures		< 30 minutes	4 – 8 hours
Chance on risks or illness		0%	0%
Grey water system			
Awareness of existence grey water system		100%	-
Satisfaction with grey water system		Very satisfied: 55% Satisfied: 40% Neutral: 5%	-
Unpleasant odours		Not at all	-
Noise production	-	No noise hindrance	-
Visible parts of grey water system		Really nice: 14% Nice: 43% Neutral: 43%	-
Recommending grey water system to other households		(Actively) recommend grey water system 80% (Could be higher because respondents were asked about the combined grey and black water system)	-

Aspect	Wageningen	Lübeck	Deventer
Mark for grey water system		7,48 (for combined black and grey water system)	
General			
Environmental awareness target group	Always: 1 Often: 6 Sometimes: 9 A bit: 3 No: 0	Always: 5 Often: 14 Sometimes: 0 A bit: 1 No: 0	Always: 3 Often: 6 Sometimes: 7 A bit: 2 No: 1
House choice influenced by environmental aspects?		85%	
Future perspective of vacuum toilets (or complete wastewater system)	Positive perspective: 75%	Positive perspective for all parts, if improved	Positive: 65% Positive if adapted: 25%

Aspect	Kaja	Torvetua	Arbeiten & Wohnen
Black water system		***Only 18 interviews***	***Only 11 interviews***
Satisfaction with toilet system	45% very satisfied, 30% satisfied, 15% neutral, 10% dissatisfied	Satisfied: 33% Neutral: 17% Dissatisfied: 44% Very dissatisfied: 6%	Very satisfied: 18% Satisfied: 73% Neutral: 9%
Grade for toilet system	7,1	4,4	7,8
Noise nuisance of flushing the toilet	Annoying: 40% Not annoying: 60%	Annoying: 56%	Annoying: 64% Not annoying: 36%
Noise nuisance of toilet from neighbours	Noise nuisance (no exact numbers known)		64%
Is the vacuum toilet easily kept clean?	Easily: 70% Not easily: 30% (need to flush multiple times)	Easily: 89% Not easily: 11%	Easily: 82% Not easily: 18%
Doubts about sustainability of conventional toilet system	-	-	
Importance of environmental aspects of toilet system			
Adaptations made to system			Removal of reservoir behind toilet in 3 houses because it was broken
Considering a replacement of the vacuum toilet for a conventional one		44% (maybe more but they answered 'no' because it is not possible to replace)	9%
Recommending the vacuum system to other households	Directly: 60% Adapted form: 15% No opinion: 15%	Directly: 11% Adapted form: 67% Not at all: 11% No opinion: 11%	Directly: 82% Adapted form: 9%
System choice if moving to other house	Vacuum system: 65% Conventional: 35%	Vacuum (adapted form or not): 17% Conventional: 83%	Vacuum system: 91% Adapted vacuum: 9%
Failures / Blockages of toilet	1 to 2 times a year at 20% of the households (usually toilet valve)	33% experienced failures on toilet level (toilet valve)	On average 1 failure/blockage a year
Failures / blockages of system	None: 25% 1–2 times a year: 65% Don't know: 10%	5,41 (mostly local) blockages	On average 1 failure/blockage a year
Time to repair blockages/failures	1,5 – 5 hours (students) > 0,5 hour (Sias)	2,34 hours (at weekends 10 – 20 hours)	> 3 hours
Chance on risks or illness	0%	0%	0%
Grey water system			
Awareness of existence grey water system	45% (Only these 9 persons were asked further about grey water system)		

Aspect	Kaja	Torvetua	Arbeiten & Wohnen
Satisfaction with grey water system	Very satisfied: 78% Satisfied: 11% Dissatisfied: 11%	Very satisfied: 28% Satisfied: 50% Neutral: 16,5% Dissatisfied: 5,5%	Very satisfied: 46% Satisfied: 18% Neutral: 27% Dissatisfied: 9%
Unpleasant odours	Not at all: 78% Sometimes: 22%	Not at all: 6% A little bit: 44% Sometimes: 44% Very often: 6%	Not at all: 91% Sometimes : 9%
Noise production	No noise hindrance		Not at all
Visible parts of grey water system	Nice: 33% Neutral: 56% Really awful: 11%	Nice: 36% Neutral: 55% Awful: 9%	Nice: 40% Neutral: 60%
Recommending grey water system to other households	Actively recommend: 22% Recommend: 44% Neutral: 22% Not without improvements:11%	Actively recommend: 16,5% Recommend: 50% Neutral: 16,5% Not without improvements: 6% Not at all: 11%	Recommend: 82% Don't know: 18%
System choice if moving to other house	Same system: 89% Other system: 11%	Same system: 56% Conventional: 44%	Same system: 82% Improved grey water system: 18%
Mark for grey water system	8	7,1	7,4
General			
Environmental awareness target group	Always: 15% Often: 50% Sometimes: 30% No: 5%	Always: 17% Often: 44% Sometimes: 39%	Always: 55% Often: 27% Sometimes: 18%
House choice influenced by environmental aspects?		28%	73%
Future perspective of vacuum toilets (or complete wastewater system)	Positive perspective Vacuum system: 89% Positive perspective grey water system: 100%	Positive perspective for complete system 33% Grey water: 44%	

Appendix 16: Vacuumarator Casa Vita project Deventer

Rotterdam, 30 maart 2005

Betreft: Boxbergerweg - Deventer

Mijne Heren,

Wij danken u voor uw aanvraag en bieden u vrijblijvend aan:
1 stuk Vacuüm unit Jets 5OMBA, bestaande uit:
2 vacuumaratoren Jets 25MB inch electro motor
8 trilhingsdempers
1 schakelkast
3 drukschalcelaars
1 vacuummeter
1 kogeikraan
2 kogeikraan DN 50
2 kogelkraan DN 32
2 rubber moffen DN 50
2rubbermoffenDN32
2 vloeistoftank 4,8 ltr.
1 manifold
1 fundatieframe

Bovenstaande volgens pijpschema 41781 en tekening 32154-044 idw