Separate collection and treatment of domestic wastewater in Norway

A research into the establishment and performance of non-conventional sanitation systems at the sites “Kaja” and “Torvetua”

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Preface

As part of my Master of Science degree in Environmental Sciences at the University of Life Sciences in Wageningen I have performed a thesis for the Urban Environment Group. This research discusses two ecological sanitation systems in Norway. This research focuses on two ecological sanitation (ECOSAN) sites in Norway. This thesis is part of the project “Global Sanitation Assessment” of the Urban Environment Group of the University of Life Sciences in Wageningen, the Netherlands.

For this thesis I have spoken to many actors that were or are involved with the ecological sanitation sites. These actors helped me with gathering knowledge. Without these actors this research would not be possible. I would like to thank all the actors that helped me with my thesis.

I especially would like to thank:

- Prof. Petter D. Jenssen from the University of Life Sciences in Ås (Norway) for his time, cooperation and hospitality;
- The family Flo, who live in the research site in Bergen. I would like to thank them for my stay at their home and the quality time they have given me.

Finally I would like to thank my supervisors, Adriaan Mels and Okke Braadbaart, for the possibility to do this thesis, their feedback and assistance.

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Summary

The current treatment of domestic wastewater in the Netherlands is not very efficient. All wastewater streams, including rainwater, are put together and flushed to a central wastewater treatment plant which is most of the times situated a couple of kilometres away. The treatment of domestic wastewater consumes a lot of water and energy, but it meets the needs of its primary functions: protection of public health and protection of surface water and environment.

Based on new developments in the wastewater chain new concepts for domestic wastewater are developed. These concepts are based on separate collection and treatment of the domestic wastewater streams. The streams involved are black water (water from toilets), grey water (water from kitchen, shower, bath and washing) and rainwater. There are also systems on the market which separate black water by urine collection (yellow water) and faeces collection (brown water).
The aim of these concepts is to develop a more efficient system for the domestic wastewater chain (STOWA, 2005-13).

For this research two ecological sanitation sites in Norway were investigated, namely “Kaja” in Ås and “Torvetua” in Bergen. Next to these sites the conventional wastewater management system in Norway is discussed. The research objective is to gain insight in the drivers and barriers that were applicable for these two Norwegian sites and to assess if the implemented technology has a future or not by evaluating the performance, maintenance, costs and user perception.

This research is part of the “Global Sanitation Assessment” of the Urban Environment Group of the University of Life Sciences in Wageningen, the Netherlands. The objectives of this research project are to collect, evaluate and disseminate practical international experiences with non-conventional urban sanitation strategies.

The main research questions of this study are:

- What are the main drivers and barriers for the implementation of an ecological sanitation site in Norway?

- Is there a future for the technology as implemented at the two Norwegian ecological sanitation sites?

Results
The main drivers for the implementation of the separate collection and treatment of flows at the two sites were the positive feeling about environmental behaviour, water saving, reduction of water emissions, protection of surface water and the recycling of nutrients. Besides these main drivers the protection of ground water, the quality of neighbourhood landscaping, the involvement in the sanitation process and improving the quality of living were also important at Torvetua. Further the big governmental subsidy program for natural & ecological sanitation projects was also an important driver.
The main barrier at both sites was and still is the conservative attitude of the employees of the municipalities. At both sites the employees of the municipalities were not eager to cope with the projects, but they had to because the politicians were in favour. This kind of situation has, especially for Torvetua, resulted in slack behaviour of the municipal employees.
Comparing the drivers and barriers with results obtained in the Netherlands by Van Betuw (2005), it is noticed that water saving and reduction of water emissions were important drivers for applying non-conventional sanitation systems in the Netherlands as

well. Contrary, the recycling of nutrients did not act as a driver for the Dutch situations, while it was a main driver for the two Norwegian sites. None of the mentioned barriers in Norway acted as a barrier at the Dutch non-conventional sites.

The answer to the second main research question is divided in the technical aspects, performance and robustness, costs, public health, and user perception

The vacuum transport system seems to be a good technique for transporting concentrated black water and could have a good future provided that the vacuum system is properly installed. The advantage of the vacuum transport system is its water saving feature. The results of this investigation show that a proper installation is very important when a vacuum technique is used. Most of the problems present at Kaja and Torvetua are most likely caused by installation mistakes (90° bends, the ability of pipes to freeze during winter, too little considering of the geographical situation). Another bottleneck appears to be that no or hardly any information was provided to the people that are using the vacuum toilets and that misuse of the vacuum toilets seems to have occurred as well. The installation mistakes and lack of user information are causing the main blockages that are still occurring at both research sites. Proper installation and improved information to the users will lead to a considerable reduction in the amount of blockages and might even solve all.
The most important drawback of the black water systems as installed at both research sites is the lack of a final solution for the black water that includes reuse of components. Now at both cases it is collected by truck and transported to a regular wastewater treatment plant. This collection results in a major financial drawback, because the collection costs are a considerable part of the total operation and maintenance costs.

Besides the collapse of the physical structure of one of the grey water systems at Torvetua, the grey water systems at both research sites have performed well and have shown to be robust. The effluent concentrations fulfil the legal discharge requirements and little maintenance is necessary. Due to the good performance, robustness and little maintenance requirement, the grey water systems seem to have a good future.

The yearly energy consumption per student apartment (2 persons) in Kaja is estimated at 65 kWh and per household (3.25 persons) in Torvetua 138 kWh.

The information about the installation costs could be partially retrieved for Kaja and could not be retrieved for Torvetua. At this moment the installation costs of the implemented technology at both research sites are expected to be relatively higher than the costs for the conventional wastewater management system. The difference in installation costs in relation to the connection fee for Kaja is estimated at € 1129 per apartment. Because the installation costs from Torvetua could not be retrieved, no difference could be assessed.
The yearly operating and maintenance costs are higher at both research sites than with the conventional wastewater management system based on the data that was retrieved.. The extra yearly costs per student apartment (2 persons) in Kaja is € 648 and per household (3.25 persons) in Torvetua € 491
At both research sites the main costs for operating and maintenance are related to the blockages in the vacuum system. The blockages are most likely related to improper installation of the vacuum system and the lack of user information.

The black water systems have a (small) potential health risk during and after the collection of the black water by the trucks. The collection may lead to some spillage of black water. Especially in the case of Torvetua, where the collection is done close to the common playground of the neighbourhood, a potential health risk is present. This potential health risk would diminish if the collection tank would be replaced away from the common playground or if an appropriate end-solution will be installed, which eliminates

the current collection and eliminates the potential chance of getting into direct contact with the black water.
The grey water systems do not cause a public health risk due to their good removal efficiency, robust operation and nil chance of coming into direct contact with the grey water.

The reliability of the implemented technology is closely related to how users perceive the systems. From the interviews held with the students and households the biggest obstacle at both research sites is the unreliability of the black water system. The reliability has to improve for having a future perspective. Another comment made by the students and households is about the noise level of the vacuum toilet. About half of the interviewed people mentioned that the vacuum toilet produced an annoying noise. The implementation of the improved Vacuum On Demand (VOD) system in combination with pneumatic valves at new non-conventional projects could solve the problem of the annoying noise level.
The grey water systems are in general well accepted by the students and households, which gives it a good future perspective.

Final conclusion

Based on the current situation it has to be concluded that the investigated systems do not offer a complete solution yet, because there is no end-solution for the black water.
The vacuum technique itself seems to have a good future perspective and is advised to install when new non-conventional projects would arise provided that the system is not dependent on the collection of black water by trucks and is properly installed. The vacuum technique has a considerable water saving feature in relation to conventional toilets.

The results of the investigation show that the investigated systems are not yet cost competitive and a large number of failures is present with the vacuum system. Proper installation and improved information to the users will considerable decrease the amount of blockages and might even solve all. Less blockages will likely result in a better user acceptance. The future of the implemented black water systems in Kaja and Torvetua is dependent on its improvements and needs to be further researched.

The grey water system is a well-functioning technology, is robust in operation, requires little maintenance and has a good user acceptance. Nowadays available grey water systems have improved and are more compact in comparison to the ones implemented at both research sites, which results in an even better future perspective.

1. Introduction

1.1. Research background

The current treatment of domestic wastewater in the Netherlands is not very efficient. All wastewater streams, including rainwater, are put together and flushed to a central wastewater treatment plant which is most of the times situated a couple of kilometres away. At the wastewater treatment plant the water is purified and discharged to surface water. This way of treatment is conventional in the Netherlands.
The current system consumes a lot of water and energy, but it meets the needs of its primary functions: protection of public health and protection of surface water and environment.

There are a lot of developments in the wastewater chain. For instance a lot of sewerage pipes have to be renovated within a couple of years and it is wanted by the Dutch government that the amount of sewage overloads, which is discharged directly to the surface water, is reduced. Also there are new upcoming EU standards on effluent quality (Stowa, 2005-12). Due to these developments it is expected that the costs for the wastewater chain in the Netherlands will increase with at least 25% for this decennium, excluding inflation (STOWA, 2005-12).

Based on the developments in the wastewater chain new concepts for domestic wastewater are being developed. These concepts are called Ecological Sanitation systems or short wise ECOSAN systems. They are also referred as DESAR systems, which stands for DEcentralized Sanitation And Reuse. Currently the terms new sanitation systems and/or modern sanitation systems are more and more used. In this report the term ecological sanitation is used to refer to these concepts.

These concepts are based on separate collection and treatment of the domestic wastewater streams. The streams involved are black water (water from toilets), grey water (water from kitchen, shower, bath and washing) and rainwater. There are also systems on the market which separate black water by urine collection (yellow water) and faeces collection (brown water).
The aim of these concepts is to develop a more efficient system for the domestic wastewater chain (STOWA, 2005-13). Ecological sanitation systems enhance recycling of wastewater and reduce the potential for contamination by toxic chemicals (www.nlh.no).

In countries like the Netherlands, Germany, Sweden and Norway several types of projects are known. Most of the projects in the Netherlands are based on local grey water treatment and local infiltration of rainwater, while black water is removed and treated in the conventional way. It has to be said that the amount of black water is in most cases less due to water saving toilets. Urine separation is not yet applied on neighbourhood scale. In two cases black water is treated with composting toilets.

For this research two ecological sanitation sites in Norway are discussed, namely “Kaja” in Ås and “Torvetua” in Bergen. Next to these sites the conventional wastewater management system in Norway is discussed. This research is part of the project “Global Sanitation Assessment” of the Urban Environment Group of the University of Life Sciences in Wageningen, the Netherlands. The reason of this research was the international development of source-separated collection and local treatment of domestic wastewater in urban areas. The “Global Sanitation Assessment”-project describes the

technical functions, the history and the actors involved at the implementation of ecological sanitation sites.

The aim of the project is to collect and compare practical experiences with the various ecological sanitation technologies. This includes an assessment on operational performance, user acceptance and costs. Also the parties that were involved in technology selection are contacted (if possible) in order to detect the ‘drivers’ and ‘barriers’ of implementing ecological sanitation systems. Drivers are aspects that have encouraged implementation of the ecological sanitation systems and barriers are aspects that have hampered the implementation of the ecological sanitation systems.

The ultimate aim of the “Global Sanitation Assessment”-project is to provide better information for technology selection to interested parties.

1.2. Research objective

The research objective is to gain insight in the drivers and barriers that were applicable for the two Norwegian ecological sanitation sites “Kaja” in Ås and “Torvetua” in Bergen; and to assess if the implemented technology has a future or not by evaluating the performance, maintenance, costs and user perception.

1.3. Research questions

Main research questions

1) What are the main drivers and barriers for the implementation of an ecological sanitation site in Norway?

2) Is there a future for the technology as implemented at the two Norwegian ecological sanitation sites?

Sub-research questions

Sub-research questions for the first main research question:

- What were drivers at the implementation of the ecological sanitation systems?
- What were barriers at the implementation of the ecological sanitation systems?
- Are the drivers and barriers different in comparison to the Netherlands?

Sub-research questions for the second main research question:

- What is the conventional wastewater management system in Norway?
- What are the costs of the conventional treatment per household?
- Which actors were involved in the decision-making process of the two selected sites?
- Have the ecological sanitation systems satisfied the restriction qua performance and are the ecological sanitation systems robust?
- What are the costs of the ecological sanitation systems per household?
- Is public health safeguarded?
- How do users perceive the visible part of the system?

1.4. Research objects

The research objects are:

- all actors that were actively involved in the decision-making process and realization of the ecological sanitation sites “Kaja in Ås and “Torvetua” in Bergen;
- the actors still involved nowadays with the ecological sanitation sites “Kaja in Ås and “Torvetua” in Bergen;
- the students who live in “Kaja” / the households who live in “Torvetua”.

1.5. Outline of the report

In the next chapter the research design is presented. Chapter 3 discusses the conventional wastewater management in Norway. Chapter 4 and 5 present successively the research site “Kaja” and the research site “Torvetua”. Chapter 6 presents the conclusions and discussion. In the last chapter recommendations are presented.

2. Research design

2.1. Introduction

This chapter presents the research design. Paragraph 2.2 presents the selected sites with their location. The following paragraphs (2.3 – 2.5) show how the data is obtained for the selected research sites. Paragraph 2.6 shows in which way data is obtained for the conventional wastewater management system.

2.2. Selected research sites

The selected Norwegian research sites are:
- “Kaja” : 24 student apartments in Ås;
- “Torvetua” : suburban area with 40 households in Bergen.

Figure 1 shows the geographical location of the two research sites.

Figure 1. Location of the two research sites.

2.3. Drivers and barriers

To gain insight into the decision-making process and the implementation of the ecological sanitation system interviews are held with the people who were involved with the technology choice. This insight is gained with the help of a standardized “drivers and barriers”-interview. This interview contained the following “drivers and barriers”-aspects:
- Environmental and public health;
- Legal and regulatory;

- Social/technical;
- Financial;
- Social and managerial.

Besides these aspects, questions are asked about the design phase and the actors involved, and about the current and future status of the system. Appendix 1 presents the standardized “drivers and barriers”-interview.

2.4. Performance and costs

The performance and costs of the selected sites are assessed by three different kinds of interviews, namely:
- system owner-interview;
- operation and maintenance-interview;
- sanitation expert-interview.

The different interviews are related to the different actors involved with the ecological sanitation system. Each interview is divided in the following aspects:
- Sanitation system description;
- Performance dimension: invisibility and user comfort;
- Dimension: system robustness;
- Dimension: impact on eco-system.

The operation and maintenance-interview and the sanitation-expert interview have the following aspects as well included:
- Dimension: public health;
- Dimension: surface and groundwater management.

The three standardized interviews are successively presented in appendix 2, 3 and 4.

Besides the three mentioned interviews held, the performance of the selected sites is investigated by a literature review as well.

2.5. User perception

The user perception is investigated with the help of a standardized interview as well. To assess the user’s perception the interview is divided in the following aspects:
- Household descriptors;
- Sanitation system description;
- Performance dimension, invisibility and user comfort
- Dimension system robustness;
- Dimension public health;
- Background questions on user perspective.

The user perception-interviews held were not exactly the same for both research sites. Because “Kaja” houses students and “Torvetua” has households, the user perception-interviews differed slightly from each other. The held user perception-interview for “Kaja” is presented in appendix 5 followed by the user perception interview for “Torvetua” in appendix 6.

2.6. Conventional wastewater management system

To gain insight into the conventional wastewater management system in Norway a general literature research has been done in order to retrieve information about the organisation, laws and regulations, and costs. The wastewater management system in Vinterbro is also visited that receives part of the domestic wastewater from Ås. From this visit performance data and costs are obtained for that specific treatment plant.
Besides the literature research and the visit in Vinterbro, interviews are held with the municipality of Ås and Bergen to retrieve (additional) information about organisation, laws and regulations, and costs. No conventional wastewater management system is visited in Bergen due to lack of available time.

3. Conventional wastewater management system in Norway

3.1. Introduction

This chapter presents the conventional wastewater management system in Norway. First some background information is presented about the situation in Norway (paragraph 3.2). Paragraph 3.3 discusses the organisation followed by the laws and regulations (paragraph 3.4). In paragraph 3.5 the costs are discussed. The last paragraph (paragraph 3.6) discusses the visited conventional wastewater management system Nordre Follo Renseanlegg in Vinterbro.

3.2. Background

Norway is divided in 19 counties. Appendix 7 presents the names of the counties.
In 2003 there were 1 991 sewerage treatment plants and 558 direct discharges with a capacity of more than 50 p.e. registered in Norway (1 p.e. is 250 l hydraulic capacity). The types of treatment per county are presented in appendix 7 as well.

The partitioning concerning the types of purification in Norway is summarized presented in table 1.

Table 1. Partitioning of the amount of treatment plants concerning the types.

Type of sewage purification	Amount
Mechanical	1029
Chemical	250
Biological	133
Chemical-biological	296
Other treatment	283
Total	**1991**

The amount of treatment plants per county varies widely, as can be seen in figure 2.

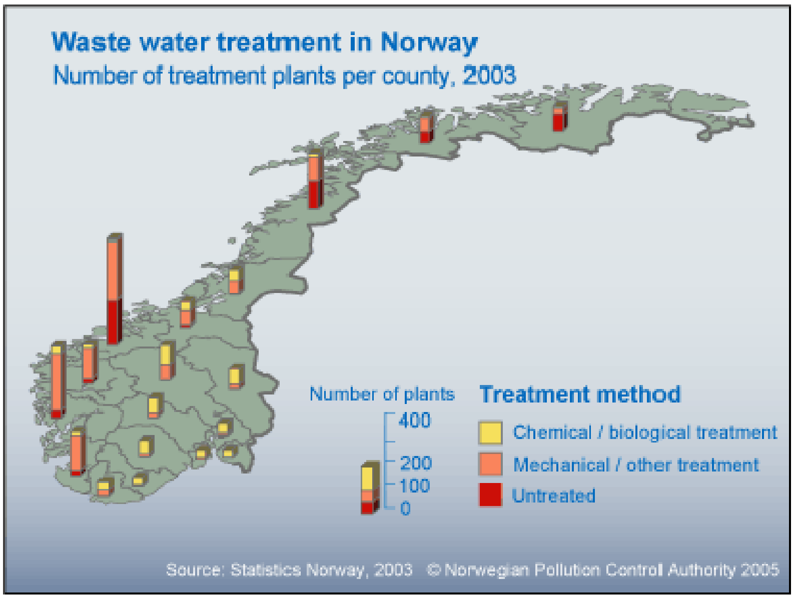

Figure 2. The amount of treatment plants per county, 2003 (source: www.environment.no).

The amount of treatment plants per county is not necessarily related to the proportion of wastewater treated. In general the average treatment capacity per plant is low in counties that have a large amount of treatment plants and high in counties that have few treatment plants.

Besides the bigger treatment plants (> 50 p.e.) 368 330 small treatment plants (< 50 p.e.) were registered in Norway in 2003.

3.3. Organisation

Wastewater management is one of the tasks of the Ministry of the Environment of Norway. Figure 3 presents the environmental agencies of the Ministry of the Environment of Norway.

Issues that have to do with pollution are the responsibility of the Norwegian Pollution Control Authority. The Norwegian Pollution Control Authority is responsible for providing the professional basis for decisions qua pollution issues for the Ministry.
The Norwegian Pollution Control Authority is authorized to provide instructions to the County Departments for Environmental Affairs.

In Norway, the collection and purification of wastewater is one of the tasks of the municipality. The municipality owns the sewerage system and the wastewater treatment plants and is responsible for their exploitation. Almost every treatment plant is run by the municipal service.

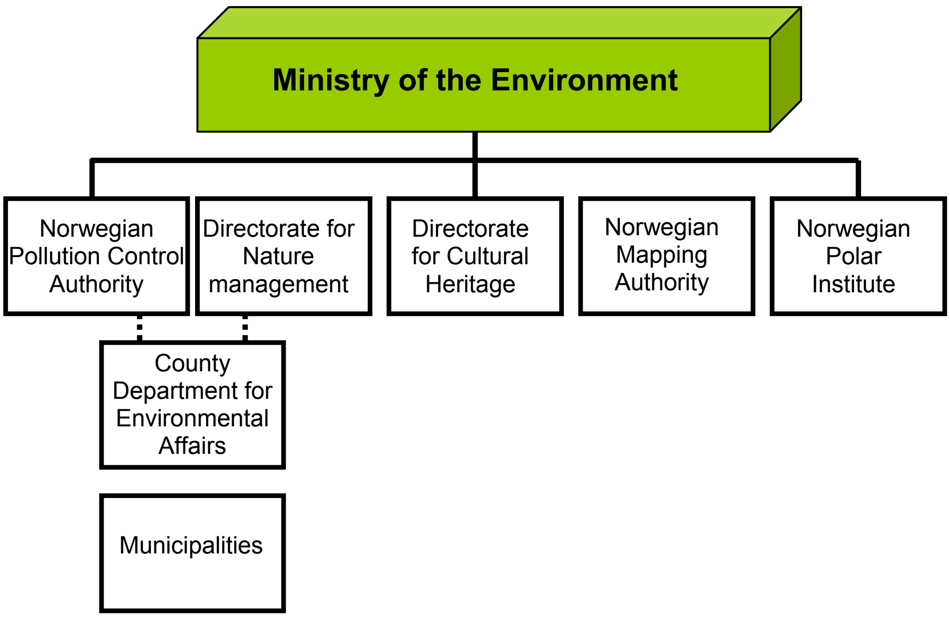

Figure 3. Environmental agencies in Norway (source: www.sft.no).

As mentioned in the previous paragraph, Norway consists of 19 counties. Each county provides the discharge permits to the municipalities. Since the first of January 2001 the municipalities are allowed to provide permits for wastewater treatment plants with a capacity of less than 1000 population equivalent (p.e.). Before 2001 only the county was allowed to provide the discharge permits

The municipalities have to finance the investments for the wastewater treatment plants themselves. Only in the case of nitrogen removal a subsidy is granted by the government.

The consumers are charged for the total drink water supply and the treatment of the wastewater. It is assumed that 1 m^3 water into the house is equal to 1 m^3 sewage out. So the fee for the wastewater treatment is based on the drink water usage. Most municipalities do not have drinking water meters installed at the households. The fees are then based on the amount of constructed area per household.
The level of the fee for the part of the wastewater treatment is stipulated by dividing the total exploitation costs by the total number of connected consumers. The costs for exploitation of the sewerage system are supposed to be covered by the drinking water fee, the wastewater treatment fee and the connection fee (interview with Skadberg, employee of municipality of Ås). The connection fee is the fee that needs to be paid when a household wants to connect their private pipes to the main municipal sewerage system. In some areas the infiltration into the sewerage system is substantial which can result in big fee differences between municipalities.

3.4. Laws and regulations

Norway does not have generally applied effluent demands. The wastewater treatment is regulated via the Pollution Control Act (Act of 13 March 1981 No.6 concerning protection against pollution and concerning waste, most recently amended by Act of 20 June 2003 No.45).

Generally speaking, phosphorus-removal is demanded for the wastewater treatment plants that discharge their effluent on the inland waterways and for the wastewater treatment plants in the south of Norway that discharge on the North Sea. The reason for this phosphorus-demand was eutrophication of the surface water, especially the Oslofjord, in the 1970's. For this reason the emphasis has been on chemical phosphorus-removal. Due to the specific composition of the wastewater in Norway the BOD purifying efficiency with pre-precipitation is high (about 80%). This purifying efficiency is enough for most discharging points due to the fact that most rivers have a high flow (STOWA, 2001).

When phosphorus-removal is demanded, the effluent demand is dependent on the method used for phosphate-removal and on the capacity of the wastewater treatment plant. Demands for average and maximum effluent concentration are formulated, see table 2.

Table 2: Effluent demands for phosphorus (source: STOWA, 2001)

Capacity wastewater treatment plant	Method for phosphorus-removal	Average concentration (mg/l total-P)	Maximum concentration (mg/l total-P)
< 1 000	Mechanical-chemical	0.6	1.2
	Simultaneous	0.8	1.5
	Post-precipitation	0.5	1.0
1 000 – 10 000	Mechanical-chemical	0.5	1.0
	Post-precipitation	0.4	0.8
10 000 – 20 000	Mechanical-chemical	0.4	0.8
	Post-precipitation	0.3	0.6
> 20 000	Mechanical-chemical	0.3	0.6
	Post-precipitation	0.25	0.5

In the north of Norway only mechanical wastewater treatment is demanded.

The North Sea declaration and the Convention for the Protection of the Marine Environment of the North-East Atlantic (known as the "OSPAR Convention") have resulted in nitrogen removal requirements for certain treatment plants, plus supporting the requirements for phosphorus removal.

Nitrogen removal is only demanded for the wastewater treatment plants that discharge on the Inner Oslofjord and on the Gramma river. The Inner Oslofjord and the Gramma river are sensitive areas. The effluent demands for nitrogen are in accordance with the EU-guideline (91/271/EEG).

Nowadays it is obliged to at least separate rain water from the black water and grey water (interview with Steinsholt).

In Norway the largest part of sewage sludge is disposed in agriculture or is used for soil improvement. Since 1995 the regulation for distribution of sludge on land is sharpened.

The most important criteria are (STOWA, 2001):

- The maximum amount of applied sludge is dependent of the application: agriculture or parks and green spaces. Table 3 presents the allowed quality of heavy metals by application.

Table 3. Maximum allowed heavy metal loads through sewage sludge addition on agricultural land, parks and green spaces (source: report STOWA, 2001).

Metal	Application in agriculture (mg/kg dry matter)	Application in parks and green spaces (mg/kg dry matter)
Cd	2	5
Pb	80	200
Hg	3	5
Ni	50	80
Zn	800	1500
Cu	650	1000
Cr	100	150

- Since the first of January 1998 sludge needs to be disinfected and stabilised. The criteria for disinfection are:
    - no Salmonella present in 50 grams of sludge;
    - no eggs of maggots;
    - less than 2500 faecal coliforms per g dry matter.
- The following methods are allowed to disinfect sludge:
    - Dosage of quick lime (calciumoxide);
    - Composting;
    - Thermophilic aerobic stabilisation;
    - Two stage thermophilic aerobic/anaerobic stabilisation;
    - Pre-pasteurisation, followed by anaerobic stabilisation;
    - Anaerobic stabilisation, followed by thermophilic drying.

General standard demands are applicable for odour and noise, the same demands as for industries. Most of the wastewater treatment plants are covered due to the climate in Norway. The odour containing ventilation air is treated in biofilters or in gas scrubbers.

The municipalities are responsible for sampling and analyses of the wastewater. The frequency of sampling is determined by the county. Every year the results need to be

reported to the county. Exceeding the requirements does not lead to a fine or other form of punishment. The county will enforce compliance by means of consultation.

3.5. Costs

In general it can be said that the biggest part of the investment in the municipal wastewater sector is for the sewerage networks and a small percent of the investment is for the wastewater treatment plants. The exact percent figures for Norway in the period from 1993 - 2003 can be obtained from appendix 8 where the investment in wastewater treatment plants and sewerage network are presented (source: www.ssb.no*). Table 4 shows the exact percent figures.

For the period 1993 – 2003 it can be seen that 24% of the total investment costs is for the wastewater treatment plants and 76% is for the sewerage networks. An average of 1 615 million NOK per year is invested in the period from 1993 – 2003.

As mentioned in paragraph 3.3, there can be big fee differences per county.
In appendix 9 an overview is presented of the average fees in Norway per county in 2003. In this appendix the water fees are calculated for a dwelling of 120 m^2. An area of 120 m^2 for a dwelling is considered to be an average in Norway. It can be seen that there are big differences per county.

Table 4. Derivation of exact percent figures.

Year	Wastewater treatment plants		Sewerage networks		Total investment (NOK million)
	Investment (NOK million)	**Percentage of total investment**	**Investment (NOK million)**	**Percentage of total investment**	
1993	347	26	964	74	1311
1994	392	27	1044	73	1436
1995	313	22	1118	78	1431
1996	279	21	1066	79	1344
1997	196	14	1229	86	1424
1998	471	26	1337	74	1807
1999	601	31	1362	69	1963
2000	503	29	1256	71	1759
2001	436	26	1250	74	1686
2002	338	19	1407	81	1745
2003	401	22	1456	78	1857
Average per year	**389 (≈ € 49 million)***	**24%**	**1226 (≈ € 155 million)***	**76%**	**1615 (≈ € 204 million)***

* Based on current exchange rate: € 1 ≈ NOK 7.9

To clarify the different approaches, the fees of the municipality of Ås and the municipality of Bergen are discussed. These two municipalities are chosen as the research site Kaja is in Ås and the research site Torvetua is in Bergen. There is a distinction made between the connection fee and the water and sewage fees (yearly costs).

Municipality of Ås

Connection fee

The connection fee is (as mentioned earlier in paragraph 3.3) the fee that needs to be paid when a household wants to connect their private pipes to the main municipal sewerage system. This fee is only paid once. If a household enlarges the house afterwards an extra connection fee has to be paid for the extra square metres.
There are two rates at Ås, namely a low rate and a high rate. Low rate is for households that have already contributed by paying the costs if these costs were already included in the building site. For example if a new housing estate with pipelines is build and the costs are added to the price of the building site or the costs for the pipelines are included in the price of the building site, then they have already paid some of the costs for applying the pipelines. These buyers have to pay a low connection fee.
High rate is for households that have not yet paid/contributed to any of the costs connected to the establishment of the pipelines.

The rates for connection to water and sewage pipes without tax are presented in table 5.

Table 5. Connection rates without tax (2005).

Rate	Water (NOK/m^2)	Sewage (NOK/m^2)
Low	120	135
High	240	270

In table 6 the connection to water and sewage pipes including tax is presented.

Table 6. Connection rates including tax (2005).

Rate	Water (NOK/m^2)	Sewage (NOK/m^2)
Low	150	168.75
High	270	303.75

The municipality of Ås charges the low rate with a tax of 25%. The high rate is charged with 25% of the amount that equals the low rate. Because the high rate is the double of the low rate it seems like the high rate is charged with 12.5%. This is a decision made by the local government (for Akershus region).

The amount of square meters is based on the living surface. The living surface is every floor where the height is more than 1.9 metres.

Yearly costs

Soon all households in the municipality of Ås will have installed water meters. Most of the households in Ås already have water meters and they pay for each cubic metre water and sewage they use and produce per year.
As mentioned in paragraph 3.3, it is assumed that 1 m^3 water into the house is equal to 1 m^3 sewage out. The households have to pay for a minimum of 50 m^3 per year.
The price for water is 8.20 NOK/m^3 + 25% tax is 10.25 NOK/m^3 water.
The price for sewage is 13.30 NOK/m^3 + 25% tax is 16.625 NOK/m^3 sewage.

For the households that do not have water meters installed yet the municipality charges them by square metre, see table 7.

Table 7. Charged costs for water and sewage per year based on amounts of m^2 (2005).

Amount of m^2	Water (NOK/year)	Sewage (NOK/year)
<100m^2	820,00	1.330,00
101-140m^2	984,00	1.596,00
141-180m^2	1.312,00	2.128,00
181-220m^2	1.640,00	2.660,00
221-260m^2	1.968,00	3.192,00
261-300m^2	2.296,00	3.724,00
301-350m^2	2.665,00	4.322,50
351-400m^2	3.075,00	4.987,50
401-500m^2	3.690,00	5.985,00
501-600m^2	4.510,00	7.315,00

Municipality of Bergen

Connection fee

The municipality of Bergen has one rate for the connection fee. The connection fee per m^2 is 22 NOK for water and 22 NOK for sewage. Including the tax of 25% the fees are 27.5 NOK. The amount of square metres is based on exactly the same way as at the municipality of Ås. Thus the inhabitants are charged for the living surface. The connection fee of the municipality of Ås is much higher than the connection fee of the municipality of Bergen. According to Ivar Kalland (head of the sewage and water works department of the municipality of Bergen) Bergen has one of the lowest connection fees of the country.

Yearly costs

The yearly costs in the municipality of Bergen is, in contradiction to the municipality of Ås, divided into subscription costs and consumption costs.

The subscription costs are based on the amount of living surface, see table 8.

Table 8. Subscription costs for water and sewage (2005).

	Water (NOK/m^2)	Sewage (NOK/m^2)
Excluding tax	3.36	4.58
Including tax of 25%	4.20	5.725

The consumption costs are based on the amount of cubic metres used. As mentioned in paragraph 3.3 it is assumed that 1 m^3 water into the house is equal to 1 m^3 sewage out. Table 9 presents the consumption costs.

Table 9. Consumption costs for water and sewage (2005)

	Water (NOK/m^3)	Sewage (NOK/m^3)
Excluding tax	3.88	4.95
Including tax of 25%	4.85	6.1875

If a household does not have a water meter installed the municipality of Bergen charges the household based on the living surface with a stipulate figure of 1.3 for water and sewage. So a household of 120 m^2 without a water meter is charged for the consumption of water like this: 120 m^2 x 3.88 x 1.3 = 466.9 NOK/year (excluding tax).

3.6. Site Nordre Follo Renseanlegg, Vinterbro

The wastewater treatment plant Nordre Follo Renseanlegg (NFR) in Vinterbro receives wastewater from three municipalities, namely Ski, Oppegoård and part of Ås.
NFR purifies wastewater from approximately 40 000 inhabitants, which results in 4 million cubic metres of wastewater per year.

Implemented technology

Appendix 10 presents the flow scheme of the NFR in Vinterbro. The wastewater is first sieved by a screen for extracting the big particles. These big particles are dewatered and incinerated off-site. After screening, polymers and lime are added to the wastewater and the wastewater flows into a sedimentation unit. In this sedimentation unit the smaller particles, like sand, are separated from the water, see figure 4. The small particles are directly discharged to the sludge treatment.

Figure 4. Sedimentation unit

After the sedimentation the wastewater is pumped to the nitrogen removal unit. This is a so called Moving Bed™ Biofilm Reactor (MB™BR) from the company Kaldnes. Phosphorus and BOD-values are as well decreased by this process. Figure 5 presents the principle of the MB™BR-process.

In the sixth tank of the MB™BR a carbon source is added. At NFR the de-icing fluid that is used at the airport of Oslo for de-icing the planes is used. This is an advantage of both sides. The airport needs to get rid off this "wastewater" and the NFR can use it. The NFR gets this "wastewater" free of discharge including transport to the plant. When the amount of de-icing fluid is not enough then methanol is added.

After the MB™BR process the wastewater is pumped to the flotation unit, while in the mean time poly-aromatic hydrocarbons and polymers are added.
At the flotation unit the sludge is separated from the water. The water is "clean" now and is pumped through a pipeline to the Oslofjord where it is discharged.

The sludge is pumped to the sludge treatment. At the sludge treatment the sludge, together with the small particles from the sedimentation, is hygienised/desinfected. The process requires a temperature of 60 °C. The hygienisation unit is heated by the gas that is produced at the digester. This is a self-sustaining process.

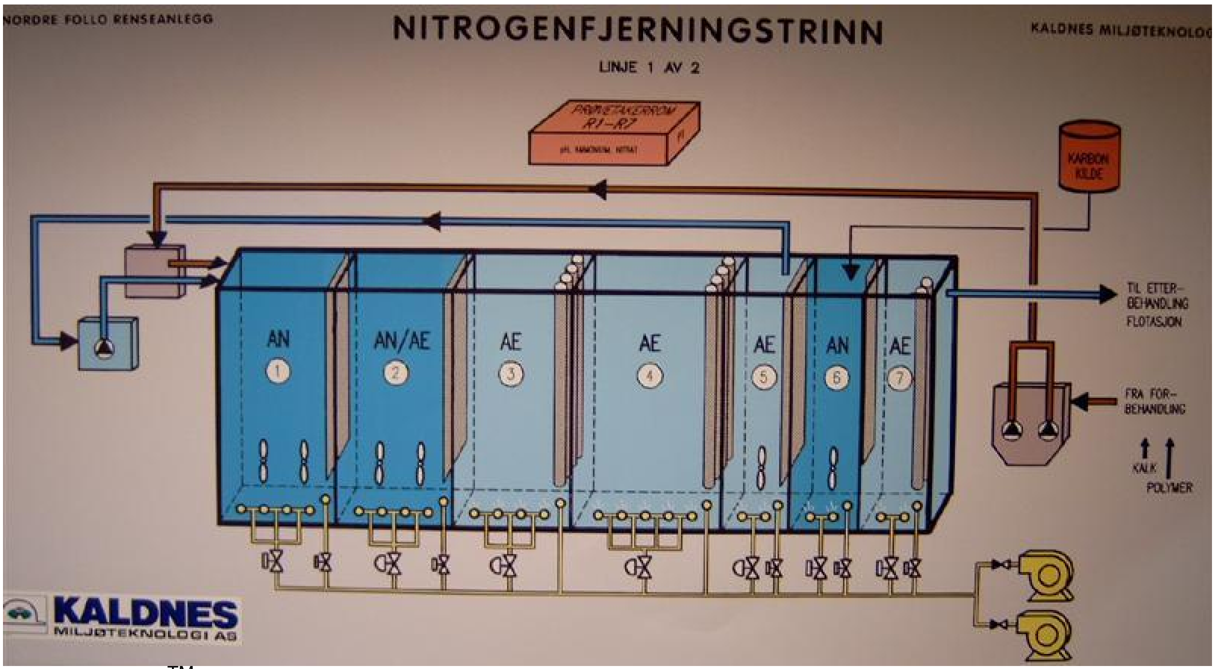

Figure 5. MB^{TM}BR-process

Once the sludge and the small particles are hygienised, it is disposed free of charge to farmers who are willing to receive the hygienised sludge. There are no obligations for farmers to receive the sludge.

Legislation

For phosphorus the NFR needs to remove at least an average of 90% on yearly basis. The allowed maximum concentration of phosphorus is 0.6 mg/l. The average phosphorus concentration should be 0.3 mg/l.

As the NFR discharges the effluent at the Inner Oslofjord, the plant has to fulfil an effluent requirement for nitrogen as well. The NFR needs to remove at least 70% of nitrogen on yearly basis (no concentration demands).

For BOD the requirement is to fulfil at least 90% removal.

Performance

Table 10 presents the results for phosphorus and nitrogen for the years 2003 - 2005. It can be seen that the treatment efficiencies and the effluent concentrations for phosphorus fulfil the effluent demands.

Table 10. Results phosphorus and nitrogen for the years 2003 - 2005.

	2003		**2004**		**2005**	
	Phosphorus	**Nitrogen**	**Phosphorus**	**Nitrogen**	**Phosphorus**	**Nitrogen**
Removal efficiency	93%	73%	92.3%	74.5%	95.2%	71.9%
Average concentration	0.25	-	0.26	-	0.20	-
Maximum concentration	0.55	-	0.47	-	0.36	-

Table 11 presents the BOD-efficiencies for the years 2003 - 2005.

Table 11. BOD-efficiencies for the years 2003 - 2005.

	2003	2004	2005
BOD-efficiency	97%	90%	97%

Table 11 shows that the BOD requirement of at least 90% BOD-removal is fulfilled.

In table 12 the results for heavy metals in sludge for the years 2003 – 2005 are presented.

Table 12. Results heavy metals in sludge for the years 2003 – 2005 in mg/kg total solids.

Metal	2003	2004	2005
Cd	0.92	0.83	0.84
Pb	21	23	18
Hg	1.07	0.78	0.83
Ni	19	21	20
Zn	373	363	383
Cu	215	208	213
Cr	28	28	29

By comparing these values for heavy metals with the values required for application in agriculture (paragraph 3.4) it can be seen that the values for heavy metals at NFR are much lower than the demands. This is due to the fact that little industry is connected to the treatment plant (interview with Buller, responsible for daily management of NFR).

In 2006 new EU-guidelines will be implemented. The NFR already fulfils these new EU-guidelines, so nothing has to be changed at the NFR.

Costs

The total operating costs for the wastewater treatment in 2004 were 10 000 000 NOK. This results in 250 NOK per households per year.

4. Research site Kaja

4.1. Introduction

In 1996 24 student apartments with ecological sanitation were build in the neighbourhood Kaja in Ås. Each apartment is shared by 2 students, thus 48 students in total are connected to the ecological sanitation system. The student apartments were ready in 1997.

This chapter discusses the research site Kaja. First the reason for the implementation of the ecological sanitation system is presented in the background (paragraph 4.2). Paragraph 4.3 presents the implemented technology. The actors with their roles and responsibilities are presented in paragraph 4.4. This paragraph contains the actors that were involved in the decision-making process and the actors that are still involved with Kaja. Paragraph 4.5 discusses the drivers and barriers. and is followed by the performance and evaluation of the sanitation system (paragraph 4.6). Paragraph 4.7 discusses the maintenance and costs. Finally paragraph 4.8 presents the user's perception.

4.2. Background

At the campus of the University of Life Sciences of Norway in Ås, the student union Sias takes care of the housing of students. The student union had a project running for building new student apartments in the neighbourhood Kaja in 1995.

Halvor Holtestaul was the director of Sias at that time and was in charge of the project. Via Petter H. Heyerdahl of the University of Life Sciences in Ås (who Mr. Holtestaul knew private) Mr. Holtestaul came by coincidence into contact with Prof. Petter D. Jenssen of the same university (interview with Holtestaul).

Prof. Jenssen was, and still is, working on ecological sanitation. Prof. Jenssen was looking at that time for an opportunity to try out a whole ecological sanitation system in practical use. As single elements (black and grey) everything was already tried out, but never on a practical scale like this.

Through the contact between Mr. Holtestaul and Prof. Jenssen a new plan arose: Kaja with ecological sanitation. Mr. Holtestaul and Prof. Jenssen found this an interesting project, because Kaja is situated next door to the office of Prof. Jenssen and Prof. Jenssen's students could also follow the project (interview with Holtestaul).
It should be mentioned that at that moment the building was already designed on paper, including wastewater discharge through a conventional pipe system. According to Mr. Holtestaul the main job of Sias was to build student houses. The ecological aspects at Kaja were just an addition and were meant as an experiment to test this type of ecological sanitation (interview with Holtestaul).
Mr. Holtestaul set some conditions from the beginning namely:

- all costs that had to do with the experiment had to be covered from other sources than Sias, because the students rent in the future should not be affected;
- Sias could not afford any delay of the finishing date of the student apartments.

The application of ecological sanitation at Kaja was an initiative of Prof. Jenssen. At the moment of developing the plan for Kaja there was a big funding program of the government to stimulate natural & ecological sanitation projects. Prof. Jenssen contacted local politicians about the plan to implement ecological sanitation at Kaja, because he needed the support from the municipality. It took some meetings to convince them all, but finally all politicians were in favour of the plan.
The county could have stopped the whole project, but they did not do that because of the experimental nature of Kaja.

After all the student apartments were constructed without delay and were ready in 1997.

4.3. Implemented technology

The sanitation system at Kaja consists of separation between black, grey and rain water.

Grey water

The applied grey water system at Kaja consists of a septic tank followed by an aerobic biofilter combined with a constructed wetland. In figure 6 a commercially available aerobic filter with a constructed wetland is presented. The system at Kaja differs slightly from figure 6. At Kaja a three-stage septic tank is used instead of a septic tank followed by a pump/siphon and the level control/sampling port is smaller. Initially the grey water system was the same as the ones used at research site Torvetua (see chapter 5), but Prof. Jenssen changed the grey water system at Kaja after one year after it was taken in use to a more improved one (with domes). The design with the domes was not available at the time of the first implementation.

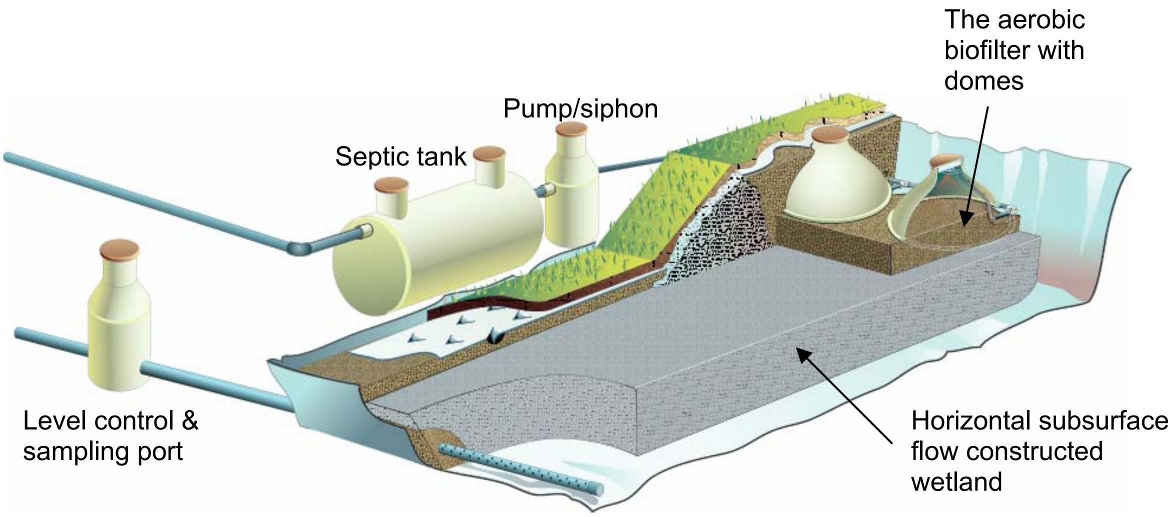

Figure 6. The latest generation of constructed wetlands for cold climate with integrated aerobic biofilter in Norway (source Jenssen et al. 2003).

The 3-stage septic tank is installed for the pre-treatment of the grey water. From the septic tank the grey water is pumped to the aerobic biofilter discontinuously.
The biofilter is covered by a dome which facilitates spraying of the grey water over the biofilter surface. At the single pass biofilter the grey water is aerated which reduces BOD and bacteria. The standard depth of the biofilter is 60 cm (Jenssen and Vråle, 2003).

Light weight aggregates (LWA) of 2 – 4 mm are used at Kaja, see figure 7. Light weight aggregates are clay pallets. The light weight aggregates are used as filter media and the light weight aggregates sorp phosphorus as well, Successful operation of the biofilter is dependent on uniform distribution of the grey water over the aggregates and intermittent dosing (Jenssen and Vråle, 2003).

Figure 7. Top view of dome – nozzle and aggregates

From the aerobic filter the grey water flows to the horizontal subsurface constructed wetland. The horizontal subsurface flow constructed wetland is vegetated with reed, see figure 8. Zhu (1998) and Mæhlum and Stålnacke (1999) showed that the roots of the reed had a positive effect on N-removal, but no significant effect on P and BOD removal.

The recommended depth of the horizontal subsurface flow constructed wetland is at least 1 m in Norway according to the Norwegian guidelines. The reason for this recommendation is the cold climate. In Norway the grey water systems are designed in such a way that the upper 30 cm of the grey water system can freeze while still leaving sufficient hydraulic capacity to transport the grey water below the frozen zone (Jenssen et al., 2004).

The septic tank is placed below ground level and has a volume of 10 m^3.
The total surface of the grey water system is 100 m^2. The biofilter needs a surface of 3 m^2 and is 60 cm in depth. The constructed wetland is 1 m deep below ground level. The level control/sampling port is 0.3 m^3 and is below ground level.

Figure 8. Left picture: the horizontal subsurface flow constructed wetland with reed
Right picture: detail picture of wetland with aggregates

The effluent of the grey water system is not reused and is discharged to the municipality's rain water sewage pipe. This municipal rain water sewage pipe transports the rain water to a lake nearby. The lake is about 3 km long and 500-800 m wide. The treated grey water is not reused, because:

- there was/is no use in using it for the vacuum toilets (black water system) as they only consume 0,5 – 1 litres of water
- it would probably be more expensive as the price for clean water is relatively low in Norway.

Possible grey water sludge will be discharged to the municipal wastewater treatment.

Black water

At Kaja vacuum toilets from the company JETS are installed (see figure 9). These toilets use 0.5 to 1 litre per flush. The vacuum toilets at Kaja are fitted with electrical valves.

Figure 9. Left picture: Vacuum toilet of JETS
Right picture: the vacuum generator of JETS in basement

The vacuum toilets require less space in the apartments than a conventional toilet. The volume that is needed for the vacuum generator is 5 m^3. The volume of the storage tank (below ground level) is 10 m^3.

The vacuum is generated by a central vacuum pump that is placed in the basement (see figure 9). This vacuum system is under constant vacuum. The black water is transported to a storage tank of 10 m^3. At the beginning the black water was collected by truck and transported to a farmer in Aremark (100 km from Ås) who has a liquid composting unit. The compost made with a liquid composting unit is used in agriculture. Because the transport costs to Aremark are very high, the black water is now collected by the municipality and is transported to the conventional sewage treatment plant of the municipality. This is just a temporary solution. Prof. Jenssen wants to have an end solution for the black water in Kaja. The kind of end solution to apply is yet unknown.

Rain water

The sanitation system at Kaja does not evacuate rain water. The rain water is discharged directly to the rain water sewage pipe of the municipality. The average rain intensity in Ås is 700 mm per m^2/year.

4.4. Actors and their roles & responsibilities

The main actors involved in the decision-making process at Kaja are presented in table 13.

Table 13. Main actors in decision-making process

Actors	Representative of actor	Roles & responsibilities
University of Life Sciences of Norway	Prof. Petter D. Jenssen	Initiator, sanitation expert and responsible for design
Sias (student union)	Mr. Halvor Holtestaul, director in 1995	Owner of the building / Responsible for final technology choice
	Mr. Harald Hansen, employee	Responsible for operation and maintenance of the system / practical input technology choice
JETS	Mr. Kaare A. Haddal, managing director	Responsible for supplying vacuum toilets and dimensioning of vacuum pump
County of Akershus	unknown*	Approved the project → provided a discharging permit
Politicians of municipality	Mr. Arne Hillestad** Mr. Håvard Steinsholt**	Helped encouraging project

* The name of the person involved on behalf of the county could not be retrieved
** There were more politicians involved.

The amount of meetings is difficult to retrieve. According to Prof. Jenssen they had many meetings. In general it can be said that the actors had a meeting twice a month. The technology selection was done by Prof. Jenssen. He was responsible for the choice of the implemented wastewater transport and treatment system.

The student union is the owner of the student apartment and therefore had to approve the selected technology. For the rest Sias was not involved in the technology choice.
Operation and maintenance of the black and grey water system is the responsibility of Harald Hansen from the student union Sias.
Prof. Jenssen is still involved with Kaja. He is responsible for the monitoring of the grey water system.

The county provided a discharge permit for Kaja. At the time of development of Kaja the municipality was not allowed to give discharge permits (when more than 7 households were involved it was a county matter). Since 2001 law and regulation changed; nowadays the municipality is allowed to provide permits and also decides on the effluent demands. Nowadays the county only gets involved when more than 1000 people are involved (see 3.3).
The municipality of Ås gives a discount on the sewage fee and supported Kaja with a once-only money amount. The municipality had no influence on the technology selection process.

Table 14 presents the currently involved actors at Kaja.

Table 14. Current actors at Kaja

Actors	Representative of actor	Roles & responsibilities
University of Life Sciences of Norway	Prof. Petter D. Jenssen	sanitation expert/ responsible for monitoring of grey water system
Sias (student union)	Mr. Eindride Berg, director	Owner of the building
	Mr. Harald Hansen, employee	Responsible for operation and maintenance of the system

4.5. Drivers and barriers

The standardized drivers and barriers interview was held with Prof. Jenssen. Prof. Jenssen was the main actor involved with the realization of Kaja. As mentioned earlier, he was the initiator and was responsible for the technology choice of the sanitation system.

Besides the interview held with Prof. Jenssen, the drivers and barriers of Mr. Holtestaul, the politicians and the municipality are presented. These drivers and barriers were not obtained with the help of the standardized interview, but from other interviews held.

The first part concerns Prof. Jenssen's part, followed by the drivers and barriers mentioned by Mr. Holtestaul. Finally the drivers and barriers of the politicians and municipality are presented.

Petter D. Jenssen, University of Life Sciences of Norway, initiator and sanitation expert

The drivers and barriers for Prof. Jenssen's part are divided in *environmental and public health*, *legal and regulatory*, *social/technical*, *financial* and *social and managerial* drivers and/or barriers. The drivers and barriers obtained during other interviews with Prof. Jenssen are also integrated in this part.

Environmental and Public Health

As can be seen in table 15 *reduction of water emissions* and *recycling of nutrients* were important drivers when Prof. Jenssen was selecting the ecological sanitation system. These aspects are still one of the motives nowadays for Prof. Jenssen. *Positive feeling about environmental behaviour, water saving* and *protection of surface water* were rated on importance scale 3. *Recycling of water* and *reduction of energy use* were of neutral importance. *Prevention of drying out of soil*, *protection of ground water* and *quality of neighbourhood landscaping* were unimportant drivers. Prevention of drying out of soil and protection of groundwater were unimportant, because there is a lot of water/rain in Norway. The quality of neighbourhood landscaping was unimportant, because the student apartments itself are just regular apartments. The student apartments are not built with any ecological aspects besides the ecological sanitation system (see figure 10).

Table 15. Environmental drivers when selecting system

Environmental drivers when selecting system					
Environmental aspect	Unimportant		Neutral		Important
	0	1	2	3	4
Positive feeling about environmental behaviour				**X**	
Water saving				**X**	
Prevention of drying out of soil	**X**				
Reduction of water emissions					**X**
Recycling of water			**X**		
Protection surface water				**X**	
Protection of ground water	**X**				
Recycling of nutrients					**X**
Reduction of energy use			**X**		
Quality of neighbourhood landscaping	**X**				

Figure 10. The student apartments at Kaja

The importance of the aspects realised are exactly the same as the ones at selecting the sanitation system, see table 16.

Table 16. Environmental drivers that are realised

Environmental drivers that are realised					
Environmental aspect	Unimportant		Neutral		Important
	0	1	2	3	4
Positive feeling about environmental behaviour				**X**	
Water saving				**X**	
Prevention of drying out of soil	**X**				
Reduction of water emissions					**X**
Recycling of water			**X**		
Protection surface water				**X**	
Protection of ground water	**X**				
Recycling of nutrients					**X**
Reduction of energy use			**X**		
Quality of neighbourhood landscaping	**X**				

As can be seen in table 17 the aspect *health risks* was rated as neutral. This aspect has been rated neutral as this aspect has been mentioned in some discussions, but has never been an issue.
The aspects *flood risks, chemical hazards* and *physical injury from students' access to equipment* were not important as a barrier. The aspect *physical injury from students' access to equipment* was rated as unimportant, because of the fact that the students do not have to do any maintenance at the sanitation system and the sanitation system is properly installed.

Table 17. Environmental and public health barriers

Environmental and public health barriers					
Environmental/public health aspect	Unimportant		Neutral		Important
	0	1	2	3	4
Health risks			**X**		
Flood risks	**X**				
Chemical hazards	**X**				
Physical injury householders access to equipment	**X**				

Legal and Regulatory

The Norwegian pollution law called "Forurensingsloven" acted as a barrier. The discharge permit for the treated grey water had to be approved by the county. The engineer at the county was not enthusiastic about the project Kaja and could have stopped the project. The engineer did not stop the project probably because of the information that was provided to him in written form and orally by Prof. Jenssen.

Social/Technical

The way of treating grey water with a biofilter and constructed wetland is chosen, because at the time of developing there were no other treatment techniques that could fit at Kaja (interview with Jenssen). Another reason for applying this grey water system is that the student union Sias wanted a low maintenance grey water system. As Jenssen already had experience with this system and knew about the low maintenance, it was the best option at that time (interview with Jenssen).

The grey water system was very difficult to implement because of the fact that the grey water system was not an approved system in 1998 (interview with Jenssen).

According to Prof. Jenssen the implementation of the vacuum toilet system was a barrier to the janitor and the administration of the student union Sias. Another matter of concern was if the system would work properly. To other actors it was indifferent. For Prof. Jenssen the implementation of a vacuum system was a driver.
After all, the vacuum toilet system was not a big problem to implement (interview with Jenssen).
The vacuum toilet system was chosen, because

- Prof. Jenssen was interested in liquid black water, as Sweden was already testing with urine separation Prof. Jenssen found it more interesting to test another system than Sweden did. Liquid composting was motive.
- Applying composting toilets required more architectural changes.

Financial

The financial aspects were rated as neutral by Prof. Jenssen, see table 18. The main costs of the vacuum system (installation) and grey water system have been mainly covered by the project of the university. The costs of the in-house grey water piping have been covered by the student union Sias. The company JETS has supplied the vacuum toilets, vacuum generator and the vacuum storage tank free of charge. For these reasons the costs have not been a big issue. The budget was known from the beginning, but played a neutral role in the system choice.
When Kaja was designed there was a big funding of the government (half billion NOK per year) for natural & ecological sanitation projects. This funding was not for building the sanitation system, but for follow up research. This funding of the government was an incentive to implement ecological sanitation.

Table 18. Financial drivers and barriers

Financial drivers and barriers					
Financial drivers and barriers in the design					
	Driver		Neutral		Barrier
	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**		
Applying vacuum toilets			**X**		
Reduced drinking water consumption (lower bills)			**X**		
To what extent financial driver of barrier played a role					
	Unimportant		Neutral		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**		
Applying vacuum toilets			**X**		
Reduced drinking water consumption (lower bills)			**X**		

Social and Managerial

The social and managerial drivers were all rated of neutral importance, see table 19. These aspects were rated neutral, because Kaja houses students. Students do not explicitly choose to live at Kaja. Generally speaking students are satisfied as long as the systems functions well.

The aspect *difficult technology* was quite an important barrier (importance scale 3) at the implementation of the sanitation system. The aspect *ownership unclear* was of neutral importance, because the student union Sias was going to be the owner of the system.
The aspects *maintenance responsibilities unclear* and *maintenance burden on householders* were rated on importance scale 1. It was rated 1, because the student union Sias once thought that a certain issue was the responsibility of the university, while it was not the case. This issue has been solved.

Table 19. Social and managerial drivers and barriers

Social and managerial drivers and barriers					
What social aspects were important					
	Unimportant		Neutral		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. E.g. water saving, reducing emissions			**X**		
Improves quality of living			**X**		
What social and managerial considerations hampered implementation of non-conventional elements in the design					
	Unimportant		Neutral		Important
	0	1	2	3	4
Difficult technology				**X**	
Ownership unclear			**X**		
Maintenance responsibilities unclear		**X**			
Maintenance burden on households		**X**			

Halvor Holtestaul, former director of student union

The drivers for Mr. Holtestaul for implementing an ecological sanitation system were that Kaja is situated next door to Prof. Jenssen's office and there were no extra costs for student union Sias. Mr. Holtestaul dared to do this project, because he knew the contractor and the architect very well. In any other case he would not have done it because of the risk of costs and losing money (interview with Holtestaul).

According to Mr. Holtestaul the only barrier for the student union Sias was the unwillingness of the employees of the municipality to cooperate. Employees of municipality were not willing to drop the connection fee. Mr. Holtestaul asked for this drop, because the students at Kaja do not discharge black water on the municipal sewage pipes and only discharge the effluent of the grey water system on the municipal rain water pipe. The employees were against, as they said that the costs for the connection and sewage fees were already calculated in for maintaining the old sewage pipes in Ås. This problem was solved by the politicians (see paragraph 4.7).

Politicians and municipality

There were several reasons for the local politicians to implement an ecological sanitation system at Kaja, namely:

- According to the local politician Håvard Steinsholt there was a already for a long time a desire at the municipality to implement some kind of ecological sanitation within the municipality, but nothing was done about it up to then (interview with Steinsholt);
- Also the municipality would like to cooperate with the university. Kaja meant a chance for cooperation between the municipality and the university (interview with Steinsholt);
- Kaja consists of student apartments. If the ecological sanitation system would fail it would be easier to move students than to move "normal citizens". Moreover, Kaja is situated near conventional pipelines. If the system would fail completely then they could easily be connected to the conventional sewage pipe within days / a week. All together, there was a low risk (interview with Steinsholt);
- The lower water consumption was also a motive for the local politician Arne Hillestad. Moreover, Norway has many areas were conventional treatment is not possible. Mr. Hillestad considered it interesting to see if this form of ecological sanitation would work and if it was feasible to use in other situations (interview with Hillestad).

According to Prof. Jenssen politicians are more open to new ideas and more likely willing to corporate with this kind of projects.

The employees of the municipality were not very eager to cooperate with Kaja according to Mr. Steinsholt. This had to do with the conservative attitude at municipality and county level.

4.6. Performance and evaluation

The students at Kaja use about 2 000 m^3 of drinking water per year (interview with Hansen). This is about 83 m^3 per student apartment per year. According to Søyland (1998) 7 litres of black water and 112 litres of grey water are produced each day per student at Kaja. This results in a grey water fraction of 94% of the wastewater volume due to the used vacuum toilets.

Grey water system

Table 20 presents the average concentration and treatment performance of the grey water system during the fall of 1998 and spring of 1999.

The WHO drinking water standard for nitrogen is 10 mg/l. From the table it can be seen that the effluent from the septic tank already fulfils this standard (Jenssen and Vråle, 2003). According to Pell and Nyberg (1985) 5 – 20 % removal of nitrogen and phosphorus may occur in the septic tank.
The total phosphorus concentration in the effluent of the septic tank is already rather low. This probably has to do with the use of phosphate free detergents in Norway. The majority of the sold cloth- and dishwashing detergents in Norway are phosphate free.
The total phosphorus and total nitrogen concentration in the effluent of the biofilter are very low (Jenssen and Vråle, 2003).

The horizontal subsurface flow wetland is needed in order to reduce BOD 7 to below 10 mg/l and to meet the requirements with respect to indicator bacteria in swimming water (<1000 TCB's/100ml).

Table 20. Average concentration and treatment performance (in %) during fall of 1998 and spring of 1999 (n = 11) (from Jenssen and Vråle, 2003)

Parameter	Average effluent values of each unit				Percent removal in %		Total removal in % of biofilter and wetland
	Unit	Effluent Septic tank	Effluent Biofilter	Effluent Wetland	Biofilter	Wetland	
pH		6.72	6.78	7.43			
Total phosphorus	mg P/l	0.97	0.32	0.07	67.0	78.1	92.8
Ortho phosphate	mg P/l	0.56	0.10	0.04	82.1	60.0	92.9
BOD 7*	mg O/l	130.7	38.2	6.90	70.8	81.9	94.7
Total nitrogen	mg N/l	8.2	5.0	2.50	39.0	50.0	69.5
Ammonium	mg N/l	3.2	2.4	2.3	25.0	4.2	28.1
Nitrate	mg N/l	<0.03	<0.03	<0.03			
Thermotolerant Coliform Bacteria (TCB)	TCB/ 100ml	10^6	10^3 - 10^5	0 - 10^3			

* a 7-day BOD is standard in Norway

The wetland has a 6-7 day retention time (Gulbrandsen, 1999). Because of this relatively long retention the fluctuations in the effluent concentrations are expected to be small (Jenssen and Vråle, 2003; interview with Jensen). The probability that a batch of final treated grey water will fail to comply with the former standards (no standards are set anymore, see text below) is considered nil (interview with Jensen).

Table 21 presents the average effluent concentrations and treatment performance over a period of 6 years.

Table 21. Average effluent concentrations and treatment performance over a period of 6 years (from Jenssen and Vråle, 2003).

Parameter	Effluent concentration (mg/l)	Treatment performance (%)
Total phosphorus	0.05	94
Total Nitrogen	2.6	70
COD	15.8	94
BOD 7*	5.6	94
TCB	swimming water quality**	

* a 7-day BOD is standard in Norway
** <1000 TCB/100ml

The county of Akershus provided a permit for discharging the effluent of the grey water systems on the rain water sewage pipe in 1997. This permit was valid for 5 years. As mentioned earlier, since 2001 the municipalities are responsible for providing discharge permits. The system has proven to be a robust system. Because the system has proven to be robust and the effluent of the grey water system is being monitored by the University of Life Sciences of Norway in Ås, the municipality of Ås has not set any effluent requirements for discharging to the municipal rain water sewage pipe since 2001.

Comparing the average effluent concentrations of the grey water system with the requirements set for the wastewater treatment plant NFR in Vinterbro (paragraph 3.6), it can be concluded that the effluent concentrations fulfil the requirements.

The sorption of phosphorus by the light weight aggregates in the grey water system is expected to last for 25 - 30 years. If combined wastewater (grey and black) would be treated with the help of aggregates the sorption can be expected for 10-15 years.

The service life of the pump of the grey water system is expected to last for 15 years (interview with Hansen, interview with Jenssen). The rest of the grey water system is expected to last 30 years.

The amount of grey water sludge produced per year is not known. So far there has never been the need to empty the septic tank, because of sludge production. The septic tank has once been emptied, but that had to do with an experiment of Prof. Jenssen.

The maximum particle size the grey water system can handle is everything that fits through the pipelines to the septic tank. Most particulate material will be removed in the septic tank by either settling or flotation.

There are about 10 -15 failures with the grey water system per year. The failures are just blockages in the pipelines. These are normal blockages according to Harald Hansen. It is the same amount of blockages as with the conventional way. The grey water system itself (septic tank/biofilter/constructed wetland) has never failed.

Black water system

The expected useful service life of the vacuum generator is 15 - 20 years (interview with Hansen, interview with Jenssen). The lifetime of the pipes and storage tank is expected to be 100 years theoretically (interview with Flo). The formation of urine stone (struvite) in the pipes might however decrease the useful service life considerably.
The maximum particle size the vacuum system can handle is everything that fits through the pipelines.

In the beginning there were a lot of teething problems with the vacuum system. After Mr. Hansen established a direct cooperation with the supplier JETS most problems were solved (interview with Holtestaul).
In about 1999 the valves of the toilets has changed. The vacuum was built up too slow. This caused a lot of blockings of toilet paper at the toilet itself (interview with Hansen).

Nowadays there are about 20-25 failures each year at Kaja with the vacuum system. 90% of those failures are at a vacuum toilet itself and 10% concerns the whole vacuum system (interview with Hansen). So at toilet level there are 18 – 22 failures per year. This is about 10 – 15% more in comparison to conventional toilets (interview with Hansen). The student union Sias has supplied the students with an regulation paper with what they are forbidden to flush down the toilet (see appendix 11).

The student union Sias applies JETS microbe cleaner in the toilets every week since 2002. This microbe cleaner decreases the formation of urine stone. The microbe cleaner safety data sheet is presented in appendix 12. Every year 200 litres of JETS microbe cleaner is used. This results in 8.33 litres per student apartment per year.

Now after 8 years the pipelines of the vacuum system probably have to be cleaned. The student union Sias thinks they have a problem with urine stone. The student union Sias will probably do camera surveillance in the summer of 2006 to see how much urine stone is present.

General

The chance that the students may come into direct contact with the wastewater is 0 %.

It is not likely that:

- the students using the sanitation system will fall ill due to a system failure or other causes;
- the students will sustain physical injury, because they are not allowed to access the sanitation equipment.

No part of the sanitation system represents a chemical hazard to the households.
Nutrients from the wastewater streams are not recovered and recycled. Also water is not recycled.

The electricity use of the sanitation system is difficult to retrieve.
The theoretical amount of kWh can be estimated with a calculation. The grey water system contains a pump with half an horsepower and runs for two hours a day (interview with Jensen). 1 horsepower is 0.746 kWh. The amount of kWh per year for this pump is then 2 * 0.373 * 365 is 272.3 kWh. So 272 kWh per year is used for the grey water pump.
The energy usage of the black water system could not be retrieved and is also assessed by a calculation. It is known that the vacuum pump installed is slightly over dimensioned and is less energy efficient (older type) than the pumps supplied at Torvetua. Comparing the kW consumption with the consumption of the pumps installed at Torvetua (see paragraph 5.6), it is assumed that the vacuum pump installed at Kaja has a power output of about 3.5 kW and runs an hour per day. This power output results in a yearly energy consumption of 1 277.5 kWh.
The electrical valves placed in the vacuum toilets consume 36 W during flushing and discharge. The flushing time including discharge time is 7 seconds. It is assumed that each person flushes the toilet 6 times per day, including an occasional extra flush and cleaning. Based on 6 flushes per day per person, the energy consumption for the electrical valve is 0.16 kWh per person on a yearly basis. Per student apartment this results in an energy consumption of 0.32 kWh per year. No energy is recovered from the sanitation system.

4.7. Maintenance and costs

When Kaja was designed there was a big funding of the government (half billion NOK per year) for natural & ecological sanitation projects. This funding suddenly stopped to exist at 1998, right at the time that Kaja was ready. This funding was not for building the sanitation system, but for follow up research. So Kaja was ready, but there was no money anymore for sampling, teething troubles, research and improvements. Intensive sampling and research was planned, but could not be done due to lack of money. Nowadays there is no funding anymore.

At this moment the grey water system in not analyzed on a frequent basis. In general it can be said that twice a year samples are taken and analyzed. This sampling is dependent on a funding.

As mentioned in the background one of student union Sias conditions was that all extra costs that had to do with the experiment had to be covered from other sources than Student union Sias. Prof. Jenssen had to find other sources for supporting the experiment.

The costs for the student union were 16 790 078 NOK, inclusive 97 560 NOK that was paid in advance for some costs concerning ecological sanitation. This 97 560 NOK should have been refunded to the student union Sias, but the student union Sias never got that back, because the funding suddenly stopped to exist.

The exact costs for the ecological sanitation could not be retrieved, because Prof. Jenssen for instance used people and resources that were paid by the university. Table 22 presents the costs that Prof. Jenssen was able to remember.

Table 22. Construction costs of the sanitation system in Kaja in 1998

Part	Costs	
Installation costs in-house grey water piping + additional costs concerning ecological aspects*	97 560 NOK	Paid by student union Sias
Grey water system incl. installation	120 000 NOK	
26 vacuum toilets 3 000 NOK each	78 000 NOK	Delivered free of charge by company JETS
Vacuum generator	100 000 NOK	
Vacuum tank	25 000 NOK	
Installation + pipe tubing vacuum system	Costs could not be retrieved. Based on costs made at the project Öko-technik-park in Hannover (Germany), it can be expected that these costs would probably be about € 20 000 (is about 158 000 NOK based on current exchange rate) (STOWA, 2005-13).	
Total	**578 560 NOK**	

* It is unknown what kind of aspects.

The company JETS supported Kaja as Kaja was also an experiment for them. The company JETS had a special programme at that time and delivered the vacuum system at Kaja free of charge. The company JETS paid for the vacuum toilets, vacuum generator and vacuum tank. The installation of the vacuum system and the grey water system (including installation) is paid by the university. The costs of the in-house grey water piping have been covered by the student union Sias. The costs of the in-house grey water piping together with some additional costs concerning ecological aspects were 97 560 NOK. The data about what kind of aspects were included within these costs, could not be retrieved. Based on the total building costs for the ecological sanitation system, the building costs per student apartment are about 24 000 NOK. The municipality of Ås has supported Kaja with NOK 100 000.

The costs for the grey water system could be lower as it is built twice as big as it could be for safety reasons. The student union Sias did not want to take the risk of being only dependent on the vacuum toilet system. If the vacuum toilet system would completely fail it is possible to transport the black water to the grey water system. Because of the double function of the grey water system it was necessary to use cast iron pipes at the grey water system which are more expensive than plastic pipes. Plastic pipes could be used if the grey water system had been built only for grey water.

There is no operation or maintenance activity that has to be done by the students. When a failure/blockage occurs, the average down time of the vacuum system is less than half an hour according to Mr. Hansen.

11 to 13 times per year the black water storage tank needs to be emptied. This emptying costs 5 000 NOK each time. Maintenance takes about 2 to 4 hours per week, which results in a maintenance cost (hours) of 15 000 to 20 000 NOK.
As all apartments in Kaja houses tenants, there has been no up-front investment per apartment and the students did not invest any money in the sanitation system.
The total average yearly operating costs are about 100 000 NOK. The annual operating costs per student apartment (two students) is then about 4 200 NOK.

As mentioned in chapter 3 you have to pay for the connection to the municipal pipelines and for sewage treatment in Norway. Mr. Holtestaul asked the municipality of Ås if they could drop the costs for the connection and give a discount for the sewage fee. Mr.

Holtestaul asked this, because the student apartments at Kaja are not completely connected. In first instance the employees of the municipality did not want to adapt. According to the employees of the municipality the student union had to pay the regular connection and sewage fees as those cost were already calculated in for maintaining the old sewage pipes in Ås. The politicians were able to solve this problem.

The student union first had to pay for the connection fee, but they got that back retroactively. Also the student union got a discount on the sewage fee. The student apartments are charged for 25% of the sewage fee, because the effluent of the grey water system is discharged on the municipality's rain water sewage pipe.

4.8. User perception

The interview for obtaining the user perception is divided into *household information items*; *performance, dimension, invisibility and user comfort*; *dimension system robustness*; *dimension public health* and *questions on user perspective*. These headings are used in this paragraph. In total 20 students are interviewed. To increase the reading friendliness the questions that were asked to the students are mentioned before the answers.

Household information items

Do you often spend the day outside home (school, work)? Answer: yes/no.

- From the 20 students interviewed 17 students (85%) often spend the day outside their room.

Do you spend the night at home at least 5 days per week? Answer: yes/no.

- All students at Kaja spend the night at their room at least 5 days per week.

For how long do you already live here? Answer: number of months/years

- The amount of time that the students already live at Kaja is very different. 4 out of 20 students (20%) live at Kaja for a period longer than 1½ year, while the other 16 students live at Kaja for a period shorter than 6 months. The average period of housing, including the 4 students who already live a longer time at Kaja (≥1½ year), is 8.7 months. Excluding the 4 students who live a longer time at Kaja, the average is 4.875 months. In general it can be said that most students have a short experience with the ecological sanitation system.

Were you aware of the ecological aspects of these apartments? Answer: yes/no.

- 7 out of 20 students (35%) were not aware of the ecological sanitation system at Kaja when they moved in.

Performance dimension, invisibility and user comfort

Black water system → vacuum toilets

Are you satisfied with the black water system? The answer to this question was rated on a 5-point rating scale with 0 being "very satisfied" and 4 "very dissatisfied".

- Table 23 presents the satisfaction rates of the students for the black water system.

Table 23. Satisfaction for the black water system.

Satisfaction	Number of students
Very satisfied – 0	9
Satisfied – 1	6
Neutral – 2	3
Dissatisfied – 3	2
Very dissatisfied – 4	0

As can be seen from table 23 none of the student has given a 4 for the vacuum system. Two students (10%) have given a 3 at the satisfaction scale. The reason for this dissatisfaction is that the vacuum toilets are too noisy and are more smelly than a conventional toilet. The latter aspect has probably to do with the fact that the students are not allowed to use any chemicals for cleaning the toilets. 3 students (15%) have rated their satisfaction with neutral. All other students (75%) have rated their satisfaction with 0 or 1. Table 24 presents the satisfaction rates for this question clustered by apartment complex. The answers are clustered to see if there are differences per complex.

Table 24. Satisfaction rates for the black water system clustered by apartment complex.

Complex A	Complex B	Complex C	Complex D
Average 0.17	Average 1.25	Average 1.5	Average 0.75
1	0	1	0
0	2	3	0
0	2	1	3
0	1	2	0
0		1	
0		1	

The average rate for satisfaction is 0.9. In general the students are satisfied with the black water system.

Is the vacuum toilet easily kept clean? Answer: yes/no.

- 14 out of 20 students (70%) said that the vacuum toilet is easily kept clean. 6 students (30%) did not agree. The main problem mentioned is the need to sometimes flush more than once (in some cases 5 times) to clean.

Does the vacuum toilet produce any annoying noise in your opinion? Answer: yes/no.

- 12 out of 20 students (60%) said that the vacuum toilet does not produce any annoying noise in their opinion. Some of those 12 students mentioned that they can hear their neighbours flush the toilet. Especially at night some of them mentioned it is quite disturbing. It seems like that they do not find the noise of their own toilet annoying, but the noise of the toilet from the neighbours.

Are there any other comments in relation to the vacuum toilet system that you would like to mention? Descriptive answer.

- No other comments were given that are not discussed within the interview.

Can you recommend the vacuum toilet system to other households in other neighbourhoods? The answer was rated on a 5-point rating scale (see below).

- Table 25 presents the recommendation rates of the students for the black water system.

Table 25. Recommendation rates for the black water system.

Recommendation	Number of students
Yes I will actively recommend it – 0	1
Yes I will – 1	13
Do not know – 2	3
Not without improvement – 3	3
Not at all – 4	0

As can be seen from table 25 none of the students has given a 4 as an answer. 3 students (15%) would not recommend the vacuum toilet system without improvement. What they mentioned as improvements were less blockages/failures, less noise and the toilet should smell better. 14 students (70%) said they will (actively) recommend it (rating scale 0 and 1). Table 26 presents the recommendation rates clustered by apartment complex.

Table 26. Recommendation rates for the black water system clustered by apartment complex.

Complex A	Complex B	Complex C	Complex D
Average 1.17	Average 1.5	Average 1.67	Average 1.25
3	1	1	1
0	3	3	1
1	1	2	2
1	1	2	1
1		1	
1		1	

The average recommendation rate is 1.4.

If you would move to another place/house would you like to have the vacuum system or would you prefer the conventional way or another system? Answer: vacuum system/conventional way/another system.

- 13 of the 20 students (65%) would like to have the vacuum toilet system if they would move. Some of the 13 students mentioned that they would only like to have the vacuum toilet system if it has the same costs (or cheaper) in comparison with a conventional system. The other 7 student (35%) chose for the conventional toilet. Some of the points mentioned by them for not choosing the vacuum toilet system has to do with the reliability. 1 of those 7 students mentioned that the conventional toilet never overflows or refuses to flush. Another mentioned that he thought that the vacuum toilet system is quite vulnerable. None of the students mentioned another system. This is probably due to the lack of knowledge about non-conventional systems.

What mark would you give the vacuum system as it is now? The answer was rated on a rating scale from 10 to 1. 10 represents the highest grade and 1 the lowest.

- The grades given differed between 3 and 9. Table 27 presents the grades given. The answers are clustered by apartment complex.

Table 27. Grades for the black water system clustered by apartment complex.

Complex A	Complex B	Complex C	Complex D
Average 7.33	Average 7	Average 7.17	Average 6.75
5	8	8	8
8	5	5	7
8	8	6	3
8	7	8	9
8		8	
7		8	

The average grade is 7.1. In general the students are satisfied with the black water system.

Grey water system

9 out of the 20 students (45%) were aware of the presence of an ecological grey water system. The 11 students (55%) not being aware of the presence of an ecological grey water system can be seen as a good sign for the invisibility of the grey water system. As only 9 students were aware, the questions about the grey water system are only answered by these 9 students.

Are you satisfied with the grey water system? The answer to this question was rated on a 5-point rating scale with 0 being “very satisfied” and 4” very dissatisfied”.

- Table 28 presents the satisfaction rates of the students for the grey water system.

Table 28. Satisfaction for the grey water system.

Satisfaction	Number of students
Very satisfied – 0	7
Satisfied – 1	1
Neutral – 2	0
Dissatisfied – 3	1
Very dissatisfied – 4	0

As can be seen from table 28 none of the students has given a 4 for the grey water system. 1 of the 9 students (11%) has given a 3 at the satisfaction scale. The reason for this dissatisfaction is that the involved student finds the grey water system smelly. This student lives in apartment complex D. Apartment complex D is the apartment that is closest to the grey water system (distance per complex from most far to closest to grey water system is from apartment complex A to apartment complex D). The other 8 students (89%) were all (very) satisfied. Table 29 presents the satisfaction rates clustered by apartment complex.

Table 29. Satisfaction rates for the grey water system clustered by apartment complex.

Complex A	Complex B	Complex C	Complex D
Average 0.2	Average 0*	Average 0	Average 3*
0	0	0	3
0		0	
0			
0			
1			

* No real average as n = 1

From the table it can be seen that almost all students that were interviewed from apartment complex A know that there is a grey water system present in the area (5 out of 6 students (83%)).
The average rate for satisfaction is 0.44. In general the students are (very) satisfied with the grey water system.

Does the grey water system produce unpleasant odours in your opinion? The answer to this question was rated on a 5-point rating scale with 0 “not at all” and 4 “always”.

- Table 30 presents the odour production rates for the grey water system.

Table 30. Odour production of the grey water system.

Odour production	Number of students
Not al all – 0	7
A little bit – 1	0
Sometimes – 2	2
Very often – 3	0
Always – 4	0

As can be seen from table 30 none of the 9 students has answered this question with a 3 (very often) or a 4 (always). 2 of the 9 students (22%) has answered that the grey water system sometimes (scale 2) produces unpleasant odours. The other 7 students (78%) have answered with “not at all”. Table 31 presents the answers to this question clustered by apartment complex.

Table 31. Rates qua odours for the grey water system clustered by apartment complex.

Complex A	Complex B	Complex C	Complex D
Average 0	Average 0*	Average 1	Average 2*
0	0	0	2
0		2	
0			
0			
0			

* No real average as n = 1

From this table it can be seen that the apartment complexes C and D experience some problems with smell. As the amount of answers is small for apartment complex B, C and D these figures are not reliable. The answers given by the two students from apartment complex C and D could be an indication that there might be some odour production from the grey water system. Further research needs to be done to prove if that is really the case.
The average rate qua odours is 0.44. In general the students are (very) satisfied with the grey water system.

If unpleasant odours occur, in which months? Answer: Jan - Dec

- The 2 students (22%) who had experienced some problems with smell, could not point out a certain month for the odour occurrence. 1 student thought that the unpleasant odour occurred most of the times in Augustus and September, while the other student mentioned that the odour occurrence had nothing to do with a certain month, but with a weather change.

Does the grey water system produce any annoying noise level in your opinion? The answer to this question was rated on a 5-point rating scale with 0 “not at all” and 4 “always”.

- All 9 students said that the grey water system did not produce any annoying noise level at all.

What do you think of the visible part of the grey water system near your apartment? *The answer was rated on a 5-point rating scale with 0 being “beautiful” and 4 “really awful”.*

- 1 student (11%) detests the visible part and rated it on scale 4 meaning really awful. This student is the student who lives in apartment complex D, so is closest to the grey water system. The students who live in apartment complex D can see the grey water system from their window. 5 students (56%) mentioned that the visible part is not disturbing. The other 3 students (33%) like the visible part of the grey water system. Table 32 presents the answers to this question clustered by apartment complex.

Table 32. Rates for the visible part of the grey water system clustered by apartment complex.

Complex A	Complex B	Complex C	Complex D
Average 1.6	Average 2*	Average 1	Average 4*
1	2	0	4
2		2	
1			
2			
2			

* No real average as n = 1

The average rate for the visible part of the grey water system is 1.78. In general the students think that the visible part of the grey water system is not disturbing.

Can you recommend the grey water system to other households in other neighbourhoods? The answer was rated on a 5-point rating scale (see below).

- Table 33 presents the recommendation rates of the students for the grey water system.

Table 33. Recommendation rates for the grey water system.

Recommendation	Number of students
Yes I will actively recommend it – 0	2
Yes I will – 1	4
Do not know – 2	2
Not without improvement – 3	1
Not at all – 4	0

As can be seen from table 33 none of the students has given a 4 as an answer. 1 student (11%) would not recommend the grey water system without improvement. That is the student who lives in apartment complex D. 2 students (22%) did not know if they would recommend it. The other 6 students (67%) said that they will (actively) recommend it. Table 34 presents the recommendation rates for this question clustered by apartment complex.

Table 34. Recommendation rates for the grey water system clustered by apartment complex.

Complex A	Complex B	Complex C	Complex D
Average 1	Average 1*	Average 1	Average 3*
0	1	1	3
2		1	
0			
1			
2			

* No real average as n = 1

The average recommendation rate for the grey water system is 1.22. So in general the students will recommend the grey water system.

If you would move to another place/house would you like to have the same grey water system or would you prefer the conventional way or another system? Answer: same grey water system/conventional way/another system.

- 8 out of 9 students (89%) would like to have the same grey water system if they would move. The other student (from apartment complex D) would prefer the conventional way. None of the students mentioned another system. This is probably due to the lack of knowledge about non-conventional systems.

What mark would you give the grey water system as it is now? The answer was rated on a rating scale from 10 to 1. 10 represents the highest grade and 1 the lowest.

- The grades given differed between 1 and 10. Table 35 presents the grades given clustered by apartment complex.

Table 35. Grades for the grey water system clustered by apartment complex.

Complex A	Complex B	Complex C	Complex D
Average 8.4	Average 10*	Average 9.5	Average 1*
10	10	10	1
9		9	
7			
8			
8			

* No real average as n = 1

The average grade is 8. In general the students are satisfied with the grey water system.

Complete system

Have you made any adaptations to the sanitation system as originally installed? Answer: yes/no.

- None of the 20 students has made any adaptations. This answer was expected, because the students are tenants and are not allowed to make any adaptations.

Dimension system robustness

How many times per year does a failure/blockage occur with your vacuum toilet? Answer in failures per year/month.

- 4 out of 20 students (20%) have experienced a failure/blockage with their own vacuum toilet.
  One of those 4 students lives at Kaja longer than 1½ year and mentioned that a failure/blockage with the vacuum toilet itself in general occurs 1 to 2 times per year. Most of the time, it is a leakage of the valve in the vacuum toilets. Due to this leakage of the valve the vacuum generator sucks away the water from the toilet. When there is no in the vacuum toilet, the toilets starts to sizzle. Often this problem can be solved by flushing the toilet several times.
  2 of the other 3 students, who experienced a problem with their vacuum toilet, live at Kaja for 6 months and already had 2 problems. The other student had 1 failure/blockage in 4 months.

How many times per year does the complete vacuum system fails/blocks? Answer in failures per year/month.

- 5 out of 20 students (25%) have not experiences a failure/blockage of the complete system. 2 of the 20 students (10%) did not know and filled in a question mark.
  The other 13 students (65%) have experienced failures/blockages. The amount of failures/blockage differs. All 4 students who live longer at Kaja than 1½ year have experiences failures/blockages. The difference between these 4 students is even quite big. 3 of these 4 students mentioned a failure/blockage occurs 1 to 2 times per year, while the other student mentioned 20 failures/blockages per year. 1 of the 3 students, who mentioned a failure/blockage occurrence 1 to 2 times per year, is most of the times at his/her apartment. What could have happened is that the student who answered 20 failures/blockages per year misunderstood the question and mentioned the sum of all failures that occurred since he/she moved in.

  The difference of the amount of failures/blockages between the students who live longer than 1½ year at Kaja and the student who live at Kaja less than 6 months is also different. Because the students who live at Kaja for less than 6 months could not give the amount of failures/blockages per year, an average is calculated on a monthly basis. About 1 failure/blockage occurs in 2 months. It seems like the students who live at Kaja for less than 6 months experience more problems with failures/blockages.
  It is not necessary that the complete system will be down when a failure/blockage occurs. What can happen is that just a part of the vacuum system has a failure or a blockage. All students interviewed from apartment complex D have experienced failures/blockages. Apartment complex D is the apartment complex that is the most far away from the vacuum generator. It could also be that the students who live at Kaja less than 6 months experience more failures/blockages, because they are not familiar with the vacuum system yet. Maybe they flush things down the toilet that they are not allowed or are experimenting with the vacuum system. This comment could be the case, because the student union once found a towel in the pipeline of the vacuum system.

Which part if the vacuum system failed/was out of order? What was the problem? When and how often does it happen? How did you solve it and who did it? (This question is only asked if one or both last questions was/were higher than 0 failures per year)

- This question could not be answered completely by the students. When a failure occurs the students call the student union Sias.

When the sanitation system fails, what is the average down time in hours? Answer in hours per failure.

- 5 out of 20 students (25%) have never experienced a failure/blockage which consequent results in no answer. 4 of the 15 students (27%) who did experience (a) failure(s) were not able to answer this question as they had no idea of the time it took. From the other 11 students, 10 students (91%) mentioned an answer that was between 1.5 and 5 hours of down time and one other student mentioned a down time of 24 hours. This latter student lives at Kaja for already 2 years and has only experienced 1 failure/blockage in that time. If this 24 hours down time was really the case is hard to tell, because this student is the only student that gave a down time of 24 hours. Table 36 presents the down times mentioned by the students who did experience a failure and mentioned a down time. The answers are clustered by apartment complex.

Table 36. Down time in hours clustered by apartment complex.

Complex A	Complex B	Complex C	Complex D
Average 4.25	Average 24*	Average 2.1	Average 3
5	24	3	2
3.5		2	3
		2	4
		1.5	
		2	

* No real average as n = 1

The average down time, including the 24 hours mentioned by 1 student, is 4.72 hours. Excluding the 24 hours mentioned by 1 student the average down time is 2.8 hours. This average is still higher than the average down time mentioned by Mr. Hansen from the student union Sias. According to him the average down time is less than half an hour. If the actual down time is less than half an hour is difficult to prove, but the students experience it otherwise.

Dimension public health

What is the chance that you could come into direct contact with untreated or partially treated wastewater? Answer in %.

- All students mentioned a 0% chance of coming into direct contact with untreated or partially treated wastewater.

Have you suffered some kind of illness due to the ecological sanitation system? Answer: yes/no.

- None of the students have suffered some kind of illness due to the ecological sanitation system.

Questions on user perspective

Background question

- *What kind of study do you do? This question could be answered by marking one of the six kinds of education (see below).*

  Possible answers:
  Economics - 0
  Agricultural sciences and Forestry - 1
  Engineering - 2
  Planning - 3
  Landscape architecture - 4
  Natural Sciences - 5

  Table 37 presents the partitioning of the kinds of education over the 20 interviewed students.

Table 37. The partitioning of the kinds of education over the 20 interviewed students.

Kind of education	Amount of students
Economics	3
Agricultural sciences and Forestry	3
Engineering	2
Planning	3
Landscape architecture	2
Natural Sciences	7

Involved questions

Do you feel environmentally concerned? The answer was rated on a 5-point rating scale with 0 being "always" and 4 "not at all".

- Table 38 presents the rate for feeling environmentally concerned for the 20 students.

Table 38. The feeling environmentally concerned rate for the 20 students.

Feeling environmentally concerned	Amount of students
Always – 0	3
Very often – 1	10
Sometimes – 2	6
A little bit – 3	0
Not at all – 4	1

The average feeling environmentally concerned rate for the 20 students is 1.3. In general the students are very often feeling environmentally concerned.

Did the sanitation system make you more environmentally concerned? Answer: yes/no.

- 3 of the 20 students (15%) mentioned that the sanitation system has made them more environmentally concerned.

Which aspect(s) of the ecological sanitation system do you think has/have a good future? Descriptive answer.

- 2 students (10%) have not answered this question. The 9 students that were aware of the grey water system all think that the grey water system has a good future. The students who were not aware of the grey water system have in generally not mentioned anything about the grey water system. It is expected that the latter students will think that the grey water system has a future based on the invisibility.
  16 of the 18 students (89%) who answered this part of the interview think that the vacuum system has a good future, but there are some comments made. There is a good future for the vacuum system:
    - If the vacuum system is good maintained (1 student);
    - If the design improves of the vacuum toilet (1 student);
    - If an end-solution arises for the black water (1 student);
    - In countries that do not have a lot of water (1 student);
    - If it has less problems and is more reliable (2 students).

  The other 2 students (11%) do not think that the vacuum system will have a good future, because of the noise produced. In general the students like the idea of the ecological sanitation.

What kind of benefits of the ecological sanitation system do you experience? Descriptive answer.

- 2 of the 20 students (10%) have not answered this question and 10 of the 20 students (50%) mentioned no benefits. The other 8 students (40%) that had mentioned benefits, mentioned benefits related to the vacuum system. The following benefits were mentioned:
    - Use of less water (3 students);
    - Feeling that they are doing something right for the environment (2 students);
    - Not the need to wait for the tank to fill after a flush like with conventional toilet (1 student);
    - The speed of flushing. Black water disappears much quicker than with a conventional toilet (2 students). 1 of these 2 students said that the vacuum toilet makes less noise. This student mentioned that the noise of the vacuum toilet is louder than conventional toilet, but the noise is much shorter than conventional toilet.

What kind of drawbacks of the ecological sanitation system do you experience? Descriptive answer.

- 2 of the 20 students (10%) have not answered this question and 8 of the 20 students (40%) did not mention any drawbacks. The drawbacks mentioned by the other 10 students (50%) were related to the vacuum system and most of the drawbacks were mentioned before in the interview. The mentioned drawbacks were:
    - Failures of the vacuum system;
    - Noisy;
    - Smell related to the emptying of the storage tank;
    - Not always nice to have the people of student union Sias in the apartment every week for applying the JETS microbe cleaner.

5. Research site Torvetua

5.1. Introduction

In 1997 40 houses with ecological sanitation were build in the neighbourhood Torvetua in Bergen. Two of the 40 houses have an extra apartment beneath their house. In total about 130 people are connected to the ecological sanitation system. All houses were ready in 1999.

This chapter discusses the research site Torvetua. First the reason for the implementation of the ecological sanitation system is presented in the background (paragraph 5.2). Paragraph 5.3 presents the implemented technology. The actors with their roles and responsibilities are presented in paragraph 5.4. This paragraph contains the actors that were involved in the decision-making process and the actors that are still involved with Torvetua. Paragraph 5.5 discusses the drivers and barriers. and is followed by the performance and evaluation of the sanitation system (paragraph 5.6). Paragraph 5.7 discusses the maintenance and costs. Finally paragraph 5.8 presents the user's perception.

5.2. Background

In 1995 Arne Sande AS, a big building company, wanted to build 70 houses in the area of Torvetua, which at that time was a nature area. Kurt Oddekalv (environmental activist in Norway) did not want that to happen. He could not let the building company - in his words - "destroy" that area. Mr. Oddekalv was not against building in that area, but against the number and the type of houses the building company had planned. He had the idea of building houses in that area that would "fit" in the nature of the area.

Mr. Oddekalv approached the politicians of the municipality of Bergen to talk about his idea. The politicians of the municipality were on his hand and he got permission to buy the area to build an environmentally appropriate neighbourhood. Mr. Oddekalv contacted Prof. Petter D. Jenssen of the University of Life Sciences of Norway to inquire what kind of sanitation systems could be used.

Mr. Oddekalv wanted to show with this project that it is possible to build within the normal frame (regular building techniques) and include ecological aspects. His aim was to build the houses at Torvetua for '85% environmentally correct'. He would have liked to close the water system completely, but that was too costly.

Mr. Oddekalv asked architect Bjørn Eik to draw a plan according to Oddekalv's ideas. During later stages of the planning process this architect tried to get the whole project in his hands. Mr. Oddekalv however, did not permit that to happen and this issue resulted in a lawsuit that Mr. Oddekalv won. Mr. Eik was withdrawn from the project.

According to Mr. Oddekalv the building company Block Watne got involved quite hasty with the project (the building company Block Watne has been no part of the planning process) and has eventually build the houses in Torvetua.

5.3. Implemented technology

The sanitation system at Torvetua consists of separation between black, grey and rain water.

Grey water

As Torvetua is an big area (60 are) and mountainous, two grey water systems are installed (see appendix 13).
The applied grey water systems at Torvetua consist of septic tanks, followed by aerobic biofilters combined with constructed wetlands. Both systems have the same dimensions. This system is slightly different than the system at Kaja. The Kaja system uses domes for spreading the grey water over the biofilter, whereas the system at Torvetua does not have these domes. Originally the design of the grey water system at Kaja was the same as the ones used at Torvetua. The grey water system at Kaja has been changed to a more improved system.

The grey water is first collected in a septic tank for pre-treatment. From the septic tank the grey water flows to the pump/siphon. From the pump/siphon the grey water is pumped discontinuously to the aerobic biofilter where the grey water is divided among three pipelines. Each pipeline has installed nozzles at the bottom. Through these nozzles the grey water is sprayed on the biofilter. The system is clarified in figure 11 and 12.

The rest of the flow scheme is exactly the same as at Kaja (see paragraph 4.3).
In Torvetua filtralite-P^{TM} (aggregates) is used in the constructed wetland. Filtralite-P^{TM} has a higher calcium content in comparison with regular filtralite and consequently has a much higher ability to adsorb phosphorus.

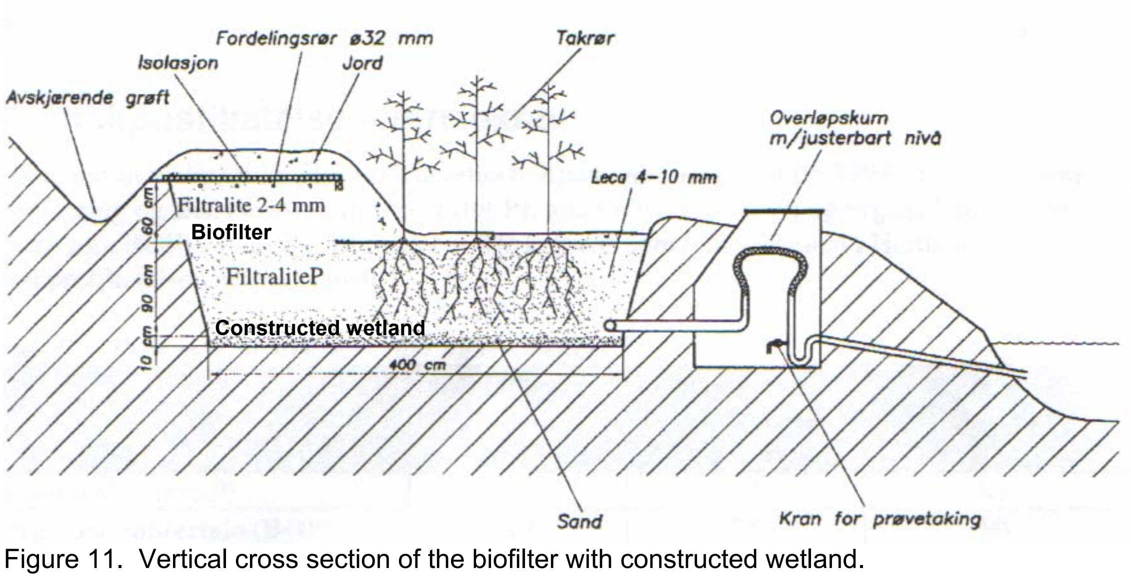

Figure 11. Vertical cross section of the biofilter with constructed wetland.

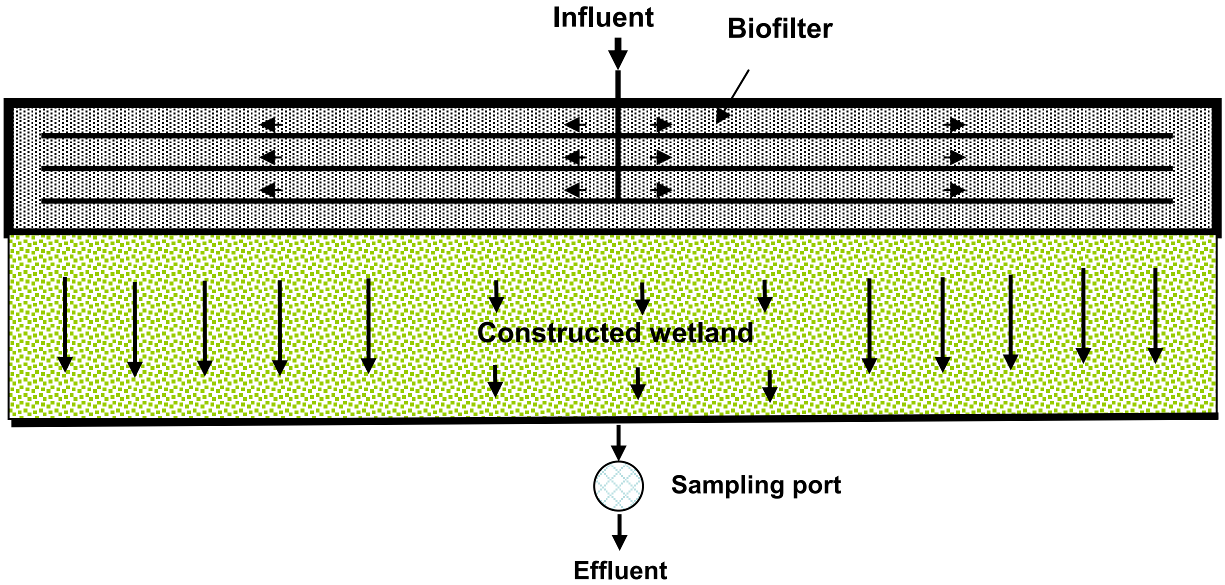

Figure 12. Top view of the biofilter with constructed wetland.

The septic tanks are placed below ground level and have a volume of 21.4 m^3 each. The total surface of the grey water systems is 160 m^2 each. The biofilters have a surface of 60 m^2 and is 60 cm in depth. The constructed wetlands have a depth of 1 m. Because the constructed wetlands are partially below the biofilters (see figure 11), the volumes of the constructed wetlands result in 160 m^3 each. The level control/sampling ports are 1 m^3 each and are placed below ground level.

The effluent of the grey water systems is not reused and is discharged to the lake next to the neighbourhood (see appendix 13).

Possible grey water sludge will be discharged to the municipal wastewater treatment.

Black water

Prof. Jenssen together with Mr. Oddekalv have chosen for implementing vacuum toilets at Torvetua. Prof. Jenssen also tested a modified composting unit, but the vacuum toilets were considered more interesting and a more proven technology with a lower risk.
Likewise Kaja at Torvetua vacuum toilets from the company JETS are installed (0.5 to 1 litre per flush). The vacuum toilets at Torvetua are fitted with electrical valves.

The vacuum toilets require less space in the houses than a conventional toilet. The vacuum is generated by a central vacuum pump that is placed in a pump house (above ground level) of 14 m^3 (see appendix 13 and figure 13). This vacuum system is under constant vacuum. The black water is transported to a storage tank of 14 m^3 below ground level.

Figure 13. Central vacuum pump in pump house

The storage tank is emptied every tenth day by a truck of the municipality of Bergen and is transported to one of the conventional sewage treatment plants of the municipality. The transport unit that is recently installed consumes 2 m^3 below ground level.

Rain water

The sanitation system at Torvetua does not evacuate rain water. Most of the rain water that falls on the roofs of the houses is used for maintenance of the roofs, because all houses at Torvetua are fitted with turfed roofs, see figure 14. Water is needed to maintain the roofs. The rest of the rain water is infiltrated into the ground by drains. At Torvetua the amount of paved area is minimized to provide a good infiltration of rain water. The average rain intensity in Bergen is 2 250 mm per m^2/year.


Figure 14. The turfed roofs of the houses at Torvetua.

Drinking water

A special facility at Torvetua is that the drinking water is obtained from a well in the neighbourhood and is treated in a special facility. The raw well water is rich in calcium (90 mg/l) and needs to be treated to prevent damage to household equipment.
It is treated by ion-exchange. The water is pumped up and is flushed through a filter of gel-based material that has a large specific surface. The surface of the gel-particles contains adsorbed Na^+-ions. The Ca^{2+}-ions in the raw water are thus exchanged with the Na^+-ions. To recover the ion exchange capacity, the filter is back flushed every third night with a saturated salt brine (NaCl). This back flush takes 1 hour. About 300 kg's of salt is used every month.

The drinking water facility consumes 15 m^3 below ground level and 15 m^3 above ground level at Torvetua. This could be about 15 m^3 in total, but the building company had to replace the facility (see text below). Besides these volumes there are two storage tanks for the drinking water below ground level of 12 m^3 each.

Recently a new drinking water facility is built (see figure 15). The old drinking water facility was placed below ground level and did not comply with nowadays regulations. The new facility is placed above ground level and also includes an UV-installation. The pump of the old water facility is still used for extracting the water.

Figure 15. Drinking water facility

5.4. Actors and their roles & responsibilities

Table 39 presents the main actors involved in the decision-making process at Torvetua.

Table 39. Main actors in decision-making process

Actors	Representative of actor	Roles & responsibilities
Green Warriors of Norway	Mr. Kurt Oddekalv, environmental activist	Initiator and responsible for final technology choice
University of Life Sciences of Norway	Prof. Petter D. Jenssen	Sanitation expert and responsible for design of the grey water system
JETS	Mr. Kaare A. Haddal, managing director	Responsible for supplying vacuum toilets and dimensioning of vacuum pump
County of Hordaland	unknown*	Approved project → provided discharging permit
Politicians of municipality	unknown**	Helped encouraging project

* The name of the person involved on behalf of the county could not be retrieved.
** The name of the politicians involved on behalf of the municipality could not be retrieved.

The actors had about 15 - 20 meetings in total (interview with Oddekalv). In the beginning they met very often. The technology selection was done by Prof. Jenssen and Mr. Oddekalv. Mr. Oddekalv was responsible for the final technology choice.

The building company Block Watne is still owner of the sanitation system (complete sanitation system until household level), although they are not eager to admit that. The intension was that the board of Torvetua inhabitants' association would have been the system owner from the beginning, but Block Watne did not fulfil the requirements that were set by the board. The board represents the inhabitants and consists of six inhabitants that live in the neighbourhood. Generally speaking the board has a meeting once a month.

The board of Torvetua is willing to accept the responsibility to be system owner after the following requirements are fulfilled (interview with Samsonsen, current leader of the board):

- Block Watne should provide an operation & maintenance manual that is accepted by the department of sewage and water works of the municipality of Bergen. So far (after 7 years of operation) there is not an operation & maintenance manual. In addition, the inhabitants still do not know what is forbidden to flush down the toilet and what types of compounds are forbidden to discharge to the grey water system.
- The black water & grey water system have to run perfectly for at least 1 year.

Block Watne does not feel responsible for the sanitation system at Torvetua. E.g., if there is a blockage in the pipelines the building company sends a plumber, but the bill is sent to the board of Torvetua. Officially Block Watne has to pay this bill as they are still the system owner. However, since Block Watne refuses to pay these bills, the board of Torvetua decided to pay these bills itselves in order to be sure that problems are solved when blockages occur. These problems however, have resulted in various conflicts between the board of Torvetua and Block Watne. Both parties have assigned lawyers already for several years.

The Torvetua inhabitants' association had a technical group that was headed by Knut G. Flo who is a professional plumber. This technical group stopped to exist two years ago. The time inputs for operation & maintenance activities got too high. Mr. Flo was called whenever something was wrong with the sanitation system, it did not matter what time it was. These activities next to a fulltime job got too much (interview with Flo).

Nowadays when blockages occur the company VITEK is called in most cases. VITEK uses a high water pressure system to unblock the pipes. In other cases the plumbing company Henry Gjøen is called. This plumbing company has a service contract with the building company Block Watne.
Prof. Jenssen is still involved with Torvetua. He is responsible for analyzing the grey water samples.

Table 40 shows the actors that are currently involved with the sanitation system of Torvetua.

Table 40. Current main actors at Torvetua

Actors	Representative of actor	Roles & responsibilities
Building company Block Watne	Mr. Torbjørn Holgersen	Technically still owner of the sanitation system
Board of Torvetua inhabitants' association	Mr. Øystein Samsonsen	Current chairman of the board
	Mr. Svein Linga	Responsible for the finances
	Mr. Kjetil Helle	Responsible for taking grey water samples
	Mr. Niels B. Jensen	Responsible for drinking water

Plumbing company Henry Gjøen, has service contract with Block Watne.	Mr. Johnny Eide	Operation & Maintenance, responsible for black water system & grey water system
VITEK	Mr. Ole Kårtveit	Operation & Maintenance, solves most blockages since 2 years
University of Life Sciences of Norway	Prof. Petter D. Jenssen	Responsible for analyzing grey water samples
Ex-member board of Torvetua, head of technical group (does not exist anymore)	Mr. Knut G. Flo	Is still involved, at background level

5.5. Drivers and barriers

The standardized drivers and barriers interview was held with Mr. Oddekalv. Mr. Oddekalv was the main actor involved with the realization of Torvetua. He was the initiator and was responsible for the final selection of the sanitation system.

Besides the interview held with Mr. Oddekalv the drivers and barriers of the politicians and municipality are presented. These drivers and barriers were not obtained with the help of the standardized interview, but from other interviews held.

The first part presents Mr Oddekalv's part, followed by the drivers and barriers of the politicians and municipality.

Kurt Oddekalv, Green Warriors of Norway, land owner and initiator

The drivers and barriers for Mr. Oddekalv's part are divided in environmental & public health, legal & regulatory, social/technical, financial and social & managerial drivers and/or barriers.

Environmental and public health

As can be seen in table 41 six environmental drivers were important for Mr. Oddekalv when he was selecting the ecological sanitation system. *Prevention of drying out of soil* and *recycling of water* were unimportant to him, because Norway has enough water/rain. The recycling of nutrients were considered neutral and *reduction of energy use* was considered on importance scale 3.

The importance of environmental aspects realised are similar to the importance of the environmental aspects when Mr. Oddekalv was selecting the system, see table 42. There is only one difference. While he was selecting the system *prevention of drying out of soil* was unimportant for him. After the realisation Mr. Oddekalv rated the importance of *prevention of drying out of soil* neutral. This has to do with the fact that the effluent of the grey water systems is discharged to a lake. So by this way the soil is prevented from drying out.

Table 41. Environmental drivers when selecting system

Environmental drivers when selecting system					
Environmental aspect	Unimportant		Neutral		Important
	0	1	2	3	4
Positive feeling about environmental behaviour					**X**
Water saving					**X**
Prevention of drying out of soil	**X**				
Reduction of water emissions					**X**
Recycling of water	**X**				
Protection surface water					**X**
Protection of ground water					**X**
Recycling of nutrients			**X**		
Reduction of energy use				**X**	
Quality of neighbourhood landscaping					**X**

Table 42. Environmental drivers that are realised

Environmental drivers that are realised					
Environmental aspect	Unimportant		Neutral		Important
	0	1	2	3	4
Positive feeling about environmental behaviour					**X**
Water saving					**X**
Prevention of drying out of soil			**X**		
Reduction of water emissions					**X**
Recycling of water	**X**				
Protection surface water					**X**
Protection of ground water					**X**
Recycling of nutrients			**X**		
Reduction of energy use				**X**	
Quality of neighbourhood landscaping					**X**

Flood risks and *physical injury from households' access to equipment* were important barriers for Mr. Oddekalv, whereas *health risks* and *chemical hazards* were unimportant, see table 43.

Table 43. Environmental and public health barriers

Environmental and public health barriers					
Environmental/public health aspect	Unimportant		Neutral		Important
	0	1	2	3	4
Health risks	**X**				
Flood risks					**X**
Chemical hazards	**X**				
Physical injury householders access to equipment					**X**

Legal and regulatory

According to Kurt Oddekalv the municipality's regulations are an important barrier, but he mentioned that those regulations are not a barrier when someone is experienced in moving around in the political system.

Social/Technical (Vacuum toilets)

Kurt Oddekalv rated the importance of applying vacuum toilets on importance scale 3. It was kind of a barrier, because of the general sceptic towards a new technique. The social/technical considerations played a neutral role in the system choice.

Financial

Because Torvetua has been built within the normal frame (regular building techniques) Mr. Oddekalv rated the financial aspects neutral, see table 44.

Table 44. Financial drivers and barriers

Financial drivers and barriers					
Financial drivers and barriers in the design					
	Driver		Neutral		Barrier
	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**		
Applying vacuum toilets			**X**		
Reduced drinking water consumption (lower bills)			**X**		
To what extent financial driver of barrier played a role					
	Unimportant		Neutral		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**		
Applying vacuum toilets			**X**		
Reduced drinking water consumption (lower bills)			**X**		

Social and managerial

The *intensive contact with neighbours / collaboration with neighbours* was of neutral importance according to Mr. Oddekalv, see table 45. *Involvement in sanitation / taking responsibility for your household water management system* was important for realising a non-conventional design. Although this was important for realising a non-conventional design it is not implemented like Mr. Oddekalv had planned. Mr. Oddekalv is convinced that the building company Block Watne has ruined those aspects. The houses at Torvetua were sold quite quickly. Block Watne did not put any emphasis on the ecological function of the houses (see also Støa, 2004). Block Watne was afraid that if the emphasis would be on the ecological function that they would not be able to sell the houses.

The *difficulty technology* and *ownership unclear* were no important barriers that hampered implementation of the non-conventional elements. The aspect *maintenance responsibilities unclear* was quite an important (importance scale 3) barrier, whereas the *maintenance burden on households* was of neutral importance.

Table 45. Social and managerial drivers and barriers

Social and managerial drivers and barriers					
What social aspects were important					
	Unimportant		Neutral	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. E.g. water saving, reducing emissions					X
Improves quality of living					X
What social and managerial considerations hampered implementation of non-conventional elements in the design					
	Unimportant		Neutral	Important	
	0	1	2	3	4
Difficult technology		X			
Ownership unclear	X				
Maintenance responsibilities unclear				X	
Maintenance burden on households			X		

Politicians and municipality

According to Mr. Oddekalv the politicians of the municipality of Bergen favoured his ideas and had faith in him to build ecologically and the politicians believed that the municipality of Bergen needed a good ecological example.

The employees of the municipality were not very eager to cooperate with the project Torvetua. According to Mr. Oddekalv this has to do with the conservative attitude at the municipality (see also the research site Kaja) and the reputation he had.

According to Ivar Kalland of the Sewage and Water Works Department of the municipality of Bergen they were not against the implemented sanitation system, but against the fact that this system is applied in that specific area. According to Mr. Kalland the ecological method is a good method to incorporate in more rural areas, but not in a big city like Bergen. Mr. Kalland mentioned that the municipal sewerage pipes were within a range of 100 metres of Torvetua and was sure that connection to the municipal sewerage pipes was the best option.
As the implemented technology was quite new Mr. Kalland was also a bit scared about if the technology would fail. Since Torvetua is in an suburban area public health could be at stake.

5.6. Performance and evaluation

The households at Torvetua use about 5 900 m^3 of drinking water per year (interview with Jensen). This is about 147 m^3 per household per year.

Grey water system

Table 46 presents the concentrations of phosphorus and nitrogen in the effluent of the septic tank at Torvetua.

Table 46. Concentrations of phosphorus and nitrogen in the effluent of the septic tank (from Jenssen and Vråle, 2003).

Phosphorus	Nitrogen
1.07 mg/l	7.1 mg/l

The concentrations of phosphorus and nitrogen in the effluent of the septic tank are already rather low. The nitrogen concentration in the effluent of the septic tank already fulfils the WHO drinking water standard (Jenssen and Vråle, 2003).
It is assumed that the retention time of the grey water systems at Torvetua is the same as at Kaja i.e. 6-7 days. Because of this relatively long retention the fluctuations in the effluent concentrations are expected to be small (Jenssen and Vråle, 2003; interview with Jensen). The probability that a batch of final treated grey water will fail to comply with the standards is considered nil (interview with Jenssen).

Table 47 presents the average effluent concentrations and treatment performance of both grey water systems over a period of 5 years.

Table 47. Average concentrations in the effluent and treatment performance over a period of 5 years (from Jenssen and Vråle, 2003).

Parameter	Effluent concentration (mg/l)	Treatment performance (%)
Total phosphorus	0.2	79
Total Nitrogen	2.2	60
COD	41.0	88
BOD 7*	5.5	97
TCB	swimming water quality**	

* a 7-day BOD is standard in Norway
** <1000 TCB/100ml

The total phosphorus and total nitrogen concentration in the effluent of the biofilter are, as was the case in Kaja, very low.

Since 2002 there is no official permit anymore for discharging the effluent of the grey water systems on the lake. The municipality of Bergen did not want to have the project Torvetua, which appears to have resulted in some slack behaviour of the municipality.

Table 48 presents the former effluent requirements for the grey water system.

Table 48. Former effluent requirements for grey water systems.

	Average concentration (mg/l)	Maximum concentration (mg/l)	Treatment performance (%)
Total phosphorus	0.2	0.5	95
Total nitrogen	-*	-*	50
BOD 7	10	25	90

* no concentration requirement

Because the effluent concentrations of the septic tank are already rather low, the phosphorus en BOD 7 concentration did not need to fulfil the performance in percentages, but had to fulfil the concentrations. No requirements were set for the parameters COD and TCB. From table 47 it can be seen that the effluent concentrations fulfil the former requirements.

Similar to Kaja, the sorption of phosphorus by the light weight aggregates in the grey water system is expected to last for 25 - 30 years.
The service life for the pumps of the grey water system is expected to be 10 - 20 years. The lifetime of the pipes is expected to be 100 years theoretically (interview with Flo).

The amount of grey water sludge produced per year is not known. So far the septic tanks have never been emptied.

The maximum particle size the grey water system can handle is everything that fits through the pipelines to the septic tank. Most particulate material will be removed in the septic tank by either settling or flotation.

The county of Hordaland provided a permit for discharging the effluent of the grey water systems to the lake next to Torvetua in 1998. This permit was valid for 5 years.
The permit states that the effluent quality of the grey water systems has to be analyzed 12 times a year. The municipality of Bergen has to pay for the analyses and has reduced the frequency to 4 times per year to save costs (interview with Jensen).

The biofilter part of the grey water system that is situated in the south side of the neighbourhood collapsed in 2004. This collapse was probably due to a weak construction in combination with bad maintenance. The founding father of plumbing company Henry Gjøen was responsible for operation and maintenance from the beginning, but he unfortunately passed away a few years ago. Because of the fact that all information about Torvetua was not written down, there has been some miscommunication. Johnny Eide, employee at the plumbing company Henry Gjøen, was not told that there was a second grey water system. So the collapsed grey water system has had a period without maintenance.
Besides the collapse of the involved grey water system, the grey water systems have never had a system failure.

The board of Torvetua inhabitants' association made the decision to reconstruct the grey water system as it was, but with some extra support to prevent a second collapse.
The board of Torvetua considered to implement the more improved grey water system (as at Kaja), but chose to have the same system. The reason for implementing the same system is that the extra costs for building the improved version were considered to be too high and that they were satisfied about the performance of the old system.

The reconstruction of the collapsed grey water system is not yet finished as can be seen in figure 16.

Figure 16. Reconstruction of the grey water system

Black water system

The amount of black water produced per day is about 1 m^3 for the whole neighbourhood (interview with Flo).

The expected useful service life of the vacuum generator is 10 - 20 years. The pipes and storage tank are expected to last for 100 years theoretically (interview with Flo). The formation of urine stone in the pipes might however decrease the useful service life considerable. The maximum particle size the vacuum system can handle is everything that fits through the pipelines.

After three years of operation the households of Torvetua started to apply JETS microbe cleaner in the toilets. The households should apply this microbe cleaner in the toilets every week. The microbe cleaner decreases the formation of urine stone. The households started to use it after some years, because they were not aware from the beginning that urine stone could be a problem. About 100 litres of the cleaner is used since the households at Torvetua started to use it (December 2005). This is an average use of 25 litres of JETS microbe cleaner per year. Per household the average use is 0.625 litres per year. This is a lot less than what is used at Kaja per student apartment (8.33 l/year).
A new vacuum generator was installed in 2002, because the previous vacuum generator had a lot of problems and appeared to have been under dimensioned. The new vacuum generator is running perfectly since 2002.

The vacuum piping system still has problems. About 20 – 25 times per year the system or a part of the system has a blockage/failure. These blockages/failures can be/are caused by several factors:
- households may flush other things down the toilets besides urine and faeces that may cause blockages/failures;
- the piping system has several 90° bends. Although this is denied by the building company Block Watne, several households confirm that these 90° bends exist as they have seen them in their own houses. According to JETS 90° bends should never be used, as they cause more resistance. Besides the 90° bends at house level, there has been a camera surveillance in part of the pipelines by the company VITEK. In the video a 90° bend is spotted. As the camera surveillance was just in a part of the pipelines it can be expected that more 90° bends are present;
- formation of urine stone. The camera surveillance showed that some parts of the pipelines have severe forming of urine stone, see figure 17. This urine stone could be the result of the low use of JETS microbe cleaner, but Kaare A. Haddal (managing director of company JETS) mentioned that it is quite normal to have problems with urine stone after 7 to 8 years.

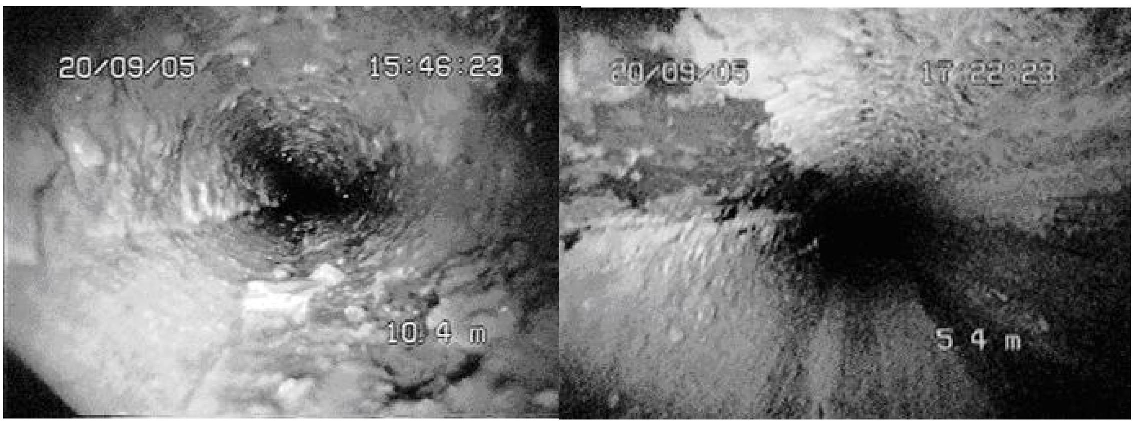

Figure 17. Urine stone formation (light coloured) in a part of the pipeline

In the report made by VITEK it is stated that there is a chance that pieces of urine stone can come off the walls, which may cause blockages/failures;
- wrong location of the vacuum generator. This generator is installed in the centre of Torvetua, which is not the lowest point in the area. The south side of Torvetua is geographically lower and has more problems with the vacuum system than the rest of the area. This problem is probably caused by the slope of the pipeline in combination with the length of the pipeline as the south side is the most far away from the vacuum generator. It seems that the vacuum generator is not able to generate enough vacuum on the long length of pipeline to suck black water from the south side to the vacuum generator (interview with Eide, interview with Flo).

A transport unit was recently installed in the pipeline at the south side. This transport unit is meant to facilitate transportation of the black water to the vacuum generator. It is not yet known whether the transport unit really decreases the amount of blockages/failures as the transport unit was just recently taken into operation.

General

The chance that the households may come into direct contact with the wastewater is in general 0 %. The emptying of the black water storage tank can create a risk especially for children. The storage tank of the black water system is situated next to the common playground of the neighbourhood. At emptying of the storage tank there is a chance of some black water being spilled next to the playground which can result in direct contact with the wastewater by especially children.

It is not likely that:
- the households using the sanitation system will fall ill due to a system failure or other causes;
- the households will sustain physical injury, because they are not allowed to access the sanitation equipment.

No part of the sanitation system represents a chemical hazard to the households.
Nutrients from the wastewater streams are not recovered and recycled. Also water is not recycled.

The electricity use of the sanitation system is difficult to retrieve. There are no separate energy meters installed for the sanitation system. There is no energy recovered from the sanitation system. There are two energy meters installed in Torvetua: one at the north side and one at the south side. The streetlighting is also connected to the energy meters. It could not be retrieved what is connected to which energy meter.

The energy meter at the south side had a total usage of 166 560 kWh, whereas the energy meter at the north side had a total usage of 77 791 kWh. There is huge difference between the amount of kWh's at the north side and south side. The reason for this big difference can not be explained clearly. Mr. Eide (from plumbing company Henry Gjøen) believes it has to do with the problems experienced with the grey water system at the south side. He thinks that the pumps from the south side's grey water system were constantly pumping, but he is not sure if that is really the case.

What also could have happened is that the energy meter at the north side is replaced when the new vacuum generator was installed in 2002. This possible replacement of the energy meter could not be confirmed.

The theoretical amount of kWh can be estimated with a calculation. The grey water systems at Torvetua contain two pumps at each grey water system. These pumps have a

capacity of 0.75 kW each. It is assessed that the grey water pumps at Torvetua will run for two hours a day. The amount of kWh per year for one grey water system is then 2 * 2 * 0.75 * 365 is 1 095 kWh. Since there are two grey water systems, the amount of kWh needs to be doubled. This means that 2 190 kWh is used for the pumps of the grey water systems on a yearly basis.
At Torvetua two of Jets' 65 MBA pumps are installed to create the vacuum for the black water. These pumps have a capacity of 30 m^3 of air per hour each at a vacuum level of -0.4 to -0.5 bar. Each pump consumes about 3.5 kW when running. Every flush of a vacuum toilet uses 60 to 100 litres of air. As mentioned before (paragraph 4.6), it is assumed that each person flushes the toilet 6 times per day, including an occasional extra flush and cleaning. Based on this information 78 m^3 of air is needed per day for Torvetua (100 litres of air * 130 persons * 6 flushes per day). To produce 78 m^3 of air the two pumps have to run 1.3 hours per day. This results in an energy consumption of 9.1 kWh per day (= 3 321.5 kWh on a yearly basis).
The electrical valves placed in the vacuum toilets consume 36 W during flushing and discharge. The flushing time including discharge time is 7 seconds. Based on 6 flushes per day per person, the energy consumption for the electrical valve is 0.16 kWh per person on a yearly basis. The average number of person per households is 3.25 in Torvetua. So on household level 0.52 kWh is used per year for the electrical valves. No energy is recovered from the sanitation system.

The municipality is currently showing more interest in Torvetua. They appear to realize that something should be done in Torvetua. After 7 years there is still no good working black water system, the grey water systems do not have a legal discharge permit anymore and the drinking water facility does not have a quality permit. As mentioned earlier the municipality nowadays is responsible for providing permits.

Officially the drinking water facility also needs to be monitored (12 times per year), but the building company Block Watne (who is technically still owner) is not doing that (interview with Jensen).

5.7. Maintenance and costs

As mentioned in the chapter on Kaja (chapter 4) there was a big governmental subsidy program for natural & ecological sanitation projects. This funding was suddenly stopped in 1998. At that time the building company Block Watne had just signed all contracts and was promised money from that subsidy. However, since Block Watne had contractual obligations this has resulted in high costs for Block Watne.
In addition, similar to the Kaja case, intensive sampling and research was planned for Torvetua. This monitoring program was also cancelled due to lack of subsidy.

Since the discharge permit expired in 2002 the effluent of the grey water systems is not sampled and analyzed anymore.

The employee of building company Block Watne who is involved with Torvetua is Torbjørn Holgersen. Mr. Holgersen was not involved since the beginning, because he started to work at Block Watne in 2000. His predecessor left to another company and was not willing to tell Mr. Holgersen anything about Torvetua. According to Mr. Holgersen he had to learn everything the hard way. He still does not know much about Torvetua.

Block Watne is not willing to give much information about the building costs and the costs they had up to now. Due to errors, changes in regulation and the sudden stop of the subsidy program the costs have been extremely high. The projects costs for Block Watne

were about two times more than they had planned originally. Some of the mistakes made and/or changes due to regulations are:

- The vacuum pumping station was too small. There was no room to do maintenance, so they had to reconstruct it;
- The drinking water facility was built below ground level without good facilities for maintenance. So they had to built a new facility above ground level;
- Some parts of vacuum pipelines were not installed deep enough below ground level, resulting in freezing of the pipes and consequent blockages/failures. Part of the vacuum pipelines had to be replaced.

Block Watne is not willing to give cost figures as they do not want other building companies to take advantage from the mistakes they made. Block Watne considers the costs as a company secret (interview with Holgersen).

The costs for the vacuum toilets were 3 000 NOK per toilet according to Kaare A. Haddal (managing director of company JETS). The costs of the vacuum generator and vacuum tank could not be retrieved. JETS did not fund Torvetua, so the whole vacuum installation is completely paid by the households of Torvetua.

The new vacuum generator that is installed since 2002 was funded by JETS. JETS has paid the pump and the building company Block Watne paid the costs for installation. The total costs including installation were 250 000 NOK.

The Norwegian State Housing Bank has supported the project with a subsidy. The board of Torvetua received an amount of 1 000 000 NOK (25 000 NOK per house) from the Norwegian State Housing Bank. This funding was meant as a back-up in case the sanitation system would fail and the municipality of Bergen would demand connection to the conventional sewer system.

Because both the wastewater and the drinking water are completely decentralised, the households of Torvetua do not have to pay anything to the municipality for these services. The households pay a monthly fee to the Torvetua inhabitants' association. The yearly operating costs for the households in Torvetua is about 9 600 – 12 000 NOK.
The exact amount of costs differs per year. These costs are based on the costs the board has planned. Up to now the operation costs vary between 800 to 1000 NOK each month. Except for the water services, these costs also include items like electricity needed for the streetlighting, improvement of living surroundings and removal of snow from the roads by a company. The improvement of living surroundings includes things like playground facilities or a green plan. The households of Torvetua have to pay for snow removal from the roads, because the roads are private owned.
The average yearly operating costs for whole Torvetua is about 450 000 NOK per year. In appendix 14 the composition of the income and expenses are clarified for the years 2000 to 2004.

The households do not have to execute any operation and maintenance activity for the sanitation system. Some volunteers of the association have a responsibility in relation to the sanitation system (see table 40). The only maintenance activity of the households is to apply the JETS microbe cleaner every week.

The operation and maintenance is done by Johnny Eide from plumbing company Henry Gjøen and by VITEK. The main point of criticism Johnny Eide and the company VITEK have about the vacuum system is the difficulty to access the piping system. There are no special openings installed in the vacuum system. If they have to access the vacuum pipelines they have to dismantle a vacuum toilet in someone's household.

The costs per failure are about 3 000 NOK on weekdays and 6 000 NOK on Sundays. The average down time of the vacuum system (or part of the vacuum system) is 2 hours. During weekends the down time is usually longer (5 – 8 hours) (interview with Samsonsen).

Torvetua inhabitants' association has budgeted 50 000 NOK for operation problems with the vacuum system for 2005. Appendix 14 shows that the costs budgeted for solving operational problems were much lower in earlier years. The reason of the current increase is of course the termination of the technical group of the board and the consequent need to call Johnny Eide or VITEK. The costs for operation problems with the vacuum system were already 76 500 NOK at the end of November 2005.

The costs to remove the urine stone are estimated at 250 000 NOK. This amount is not in the budget. In order to remove the urine stone, phosphoric acid needs to be recycled/flushed through the vacuum system for 24 hours. Consequently, the whole vacuum system will have to be down for 24 hours. It might be possible to treat the pipelines in separate parts, but this is not known yet.

The maintenance for the drinking water facility is 1 hour per month for checking system and half an hour per month for renewing salt. So the total maintenance for the drinking water facility is 1½ hours per month.

5.8. User perception

The interview for obtaining the user perception is divided into *household information items*; *performance, dimension, invisibility and user comfort*; *dimension system robustness*; *dimension public health* and *questions on user perspective*. These headings are used in this paragraph. In total 18 households are interviewed. To increase the reading friendliness the questions that were asked to the households are mentioned before the answers.

Household information items

How many people does your household have? Answer: number of people

- The number of people per household varies between 2 to 6. The average number of people per household is 3.47.

How many members of the household spend the day outside home (school, work)? Answer: amount of people.

- All members of the interviewed households spend the day outside home.

How many persons are spending the night at home at least 5 days per week? Answer: amount of people.

- All members of the interviewed households spend the night at home at least 5 days per week.

For how long do you already live in the neighbourhood? Answer: number of months/years

- 14 out of the 18 households (78%) already live in Torvetua from the beginning (7 years). The other 4 households (22%) live at Torvetua for 2, 3, 4 and 6 years. The average amount of years is 6.05.

Do you own or rent the house? Answer: own/rent.

- All households are owner of the house.

Did you come to live here especially for the ecological aspects of the neighbourhood? Answer: yes/no.

- 5 of the 18 households (28%) came to live at Torvetua especially for the ecological aspects.

Performance dimension, invisibility and user comfort

Black water system → vacuum toilets

Is your household satisfied with the black water system? The answer to this question was rated on a 5-point rating scale with 0 being "very satisfied" and 4 "very dissatisfied".

- Table 49 presents the satisfaction rates of the households for the black water system.

Table 49. Satisfaction for the black water system.

Satisfaction	Number of households
Very satisfied – 0	0
Satisfied – 1	6
Neutral – 2	3
Dissatisfied – 3	8
Very dissatisfied – 4	1

As can be seen from table 49 9 out of 18 households (50%) are (very) dissatisfied with the black water system. The reason for this dissatisfaction is the fact that the vacuum system "stops" too many times. Three households (17%) rated their satisfaction neutral. The latter six households (33%) are satisfied with the vacuum system. Because the households in the south side experience more problems with the vacuum system (as mentioned earlier) than the rest of the households, a distinction is made qua satisfaction between the households in the problem part of the south side (no 67 – 85) and the rest of the households (see table 50).

Table 50. Satisfaction rates between the households in south side and the rest of the households.

Households in south side*	Rest of households*
Average 2.57	Average 1.9
3	1
3	1
4	1
3	2
1	3
3	3
1	2
	1
	3
	2

* 1 household interview is left out, because no address is mentioned in the interview.

From table 50 it can be seen that the households in the south side in general are less satisfied with the black water system than the rest of the households.
The average rate for satisfaction is 2.22.

Is the vacuum toilet easily kept clean? Answer: yes/no.

- 16 out of 18 households (89%) said that the vacuum toilet is easily kept clean. Two households (11%) did not agree. These latter two households have not mentioned a reason. It is expected that the need to sometimes flush more than once to clean (as at Kaja) is the reason.

Does the vacuum toilet produce any annoying noise in your opinion? Answer: yes/no.

- 10 out of 18 households (56%) mentioned that the vacuum toilet produces some annoying noise in their opinion.

Who is the owner of the vacuum toilet?

- All households are owner of their own vacuum toilet.

Did your household ever consider replacing the vacuum toilet with a conventional one? Answer: yes/no.

- 8 out of 18 households (44%) mentioned that they have not considered to replace the toilet. It should be mentioned that 2 of these 8 households have answered with “no”, because they knew that the vacuum toilet can not be replaced easily. So probably they did consider it once to replace the vacuum toilet, but were told it was not an option. 2 out of 18 households (11%) did not answer with a “yes” or “no”, but mentioned that this replacement was not possible and was not an option. The other 8 households have considered replacing the vacuum toilet with a conventional toilet, but they knew that it is not an option without high costs.

Are there any other comments in relation to the vacuum toilet that you would like to mention? Descriptive answer.

- 9 out of 18 households (50%) did not mention any other comments. The comments that were mentioned by the other 9 households are:
    - 1 household mentioned that it might be better to increase the amount of water per flush to reduce the number of local stops;
    - 5 household mentioned aspects about the vacuum system still not working properly. Too many failures;
    - 1 household mentioned that the valve of the toilet sometimes releases water which can result in an overflow of water in the toilet. This overflow is a danger of getting water in the house;
    - 1 household mentioned that hard water (water being rich in calcium) can cause the valve of the toilet to leak;
    - 1 household mentioned that problem of an electricity failure. Without electricity it is not possible to use the vacuum toilet.

Can you recommend the vacuum toilet system to other households in other neighbourhoods? The answer was rated on a 5-point rating scale (see below).

- Table 51 presents the recommendation rates of the households for the black water system.

Table 51. Recommendation rates for the black water system.

Recommendation	Number of households
Yes I will actively recommend it – 0	0
Yes I will – 1	2
Do not know – 2	2
Not without improvement – 3	12
Not at all – 4	2

From table 51 it can be seen that the majority of the interviewed households will not recommend the vacuum system without improvement. Table 52 presents the recommendation rates for the households in the south side and the rest of the households.

Table 52. Recommendation rates between the households in south side and the rest of the households.

Households in south side*	Rest of households*
Average 3.14	Average 2.5
3	3
3	1
4	3
3	4
3	2
3	3
3	2
	1
	3
	3

* 1 household interview is left out, because no address is mentioned in the interview.

From table 52 it can be seen that the households in the south side in general have given a lower rate than the rest of the households. In general it can be said that the households will not recommend the vacuum system to other households in other neighbourhoods. The average rate given is 2.22.

If you would move to another place/house would you like to have the vacuum system or would you prefer the conventional way? Answer: vacuum system/conventional way.

- 15 out of 18 households (83%) would prefer to have the conventional way if they would move. 3 households (17%) mentioned that they would like to have the vacuum system, but 2 of these 3 households made some comments. The comments made are:
  - 1 household would only like to have the vacuum system if it works properly, without many failures;
  - the other household would only like to have the vacuum system if there is an ecological end solution for the black water.

What mark would you give the vacuum system as it is now? The answer was rated on a rating scale from 10 to 1. 10 represents the highest grade and 1 the lowest.

- The grades given differed between 1 and 8. Table 53 presents the grades given of the households in the south side and the rest of the households..

Table 53. Grades of the households in south side and the rest of the households for vacuum.

Households in south side*	Rest of households*
Average 3.71	Average 4.8
5	1
5	7
1	2
3	3
4	8
7	4
1	5
	7
	3
	8

* 1 household interview is left out, because no address is mentioned in the interview.

From table 53 it can be seen that the households in the south side in general have given a lower grade than the rest of the households.
The average grade is 4.39. In general it can be said that the households are not satisfied with the black water system.

Grey water system

Is your household satisfied with the grey water system? The answer to this question was rated on a 5-point rating scale with 0 being "very satisfied" and 4 "very dissatisfied".

- Table 54 presents the satisfaction rates of the households for the grey water system.

Table 54. Satisfaction for the grey water system.

Satisfaction	Number of households
Very satisfied – 0	5
Satisfied – 1	9
Neutral – 2	3
Dissatisfied – 3	1
Very dissatisfied – 4	0

As can be seen from table 54 none of the households are very dissatisfied with the grey water system. 1 household (6%), who lives in the south side of the neighbourhood, is dissatisfied. The reason for this dissatisfaction is the odour level of the grey water system. This odour complaint could be related to the collapse of the grey water system in the south side in 2004. Due to the collapse the partially treated grey water was exposed and could have caused odour nuisance. As mentioned earlier in this chapter the rebuild of the grey water system in the south side is not finished, which also can cause odour nuisance. 14 households (78%) are (very) satisfied with the grey water system.
The average rate for satisfaction is 1. In general the households are satisfied with the grey water systems.

Does the grey water system produce unpleasant odours in your opinion? The answer to this question was rated on a 5-point rating scale with 0 "not at all" and 4 "always".

- Table 55 presents the odour production rates for the grey water system.

Table 55. Odour production of the grey water system.

Odour production	Number of households
Not al all – 0	1
A little bit – 1	8
Sometimes – 2	8
Very often – 3	1
Always – 4	0

As can be seen in table 55 none of the 18 households has answered this question with 4 (always). 1 household has rated the odour production on scale 3. This is the same household that also rated the previous question with a 3. The average odour production rate given is 1.5. In general it can be said that the grey water system has some unpleasant odour production at times.

If unpleasant odours occur, in which months? Answer: Jan - Dec

- No unambiguous answer could be obtained by this question. The answers given differed between January to December. 7 out of 18 households (39%) have not answered this question. The reason for not mentioning an answer for this question could be because the involved households do not know in which month(s) the unpleasant odours occur(s), but it could also be that they did not mention an answer, because the unpleasant odours can occur year-round. Further research needs to be done to prove the unpleasant odour occurrence of the grey water system.

Does the grey water system produce any annoying noise level in your opinion? The answer to this question was rated on a 5-point rating scale with 0 “not at all” and 4 “always”.

- All 18 households said that the grey water system did not produce any annoying noise level at all.

Can you recommend the grey water system to other households in other neighbourhoods? The answer was rated on a 5-point rating scale (see below).

- Table 56 presents the recommendation rates of the students for the grey water system.

Table 56. Recommendation rates for the grey water system.

Recommendation	Number of households
Yes I will actively recommend it – 0	3
Yes I will – 1	9
Do not know – 2	3
Not without improvement – 3	1
Not at all – 4	2

The reason for giving a recommendation rate of 2, 3 or 4 could not be retrieved. The 6 households (33%) probably have rated the grey water system on a lower rate due to the collapse of the grey water system in the south side of the neighbourhood. 12 households (67%) mentioned to (actively) recommend the grey water system.
The average recommendation rate for the grey water system is 1.44. It is expected that if the collapse of the grey water system in the south side would not have happened, the average recommendation rate would more tend to 1.

If you would move to another place/house would you like to have the same grey water system or would you prefer the conventional way? Answer: same grey water system/conventional way.

- 10 out of 18 households (56%) would like to have the same grey water system if they would move. In contrary to the before mentioned questions about the grey water systems, with this question there is quite a big difference between the answers mentioned by the households at the south side and the other households. 2 out of 7 households from the south side would like to have the same sanitation system, whereas 5 would prefer the conventional way. The average of the households from the south is 0.71. 8 out of the 10 other households would like to have the same grey water system. The average of these households is 0.2. It is expected that this difference is caused by the collapse of the grey water system in the south side. As mentioned earlier 1 household interview is left out, because no address is mentioned in the interview.

What mark would you give the grey water system as it is now? The answer was rated on a rating scale from 10 to 1. 10 represents the highest grade and 1 the lowest.

- The grades given differed between 3 and 9. Table 57 presents the grades given of the households in the south side and the rest of the households.

Table 57. Grades of the households in south side and the rest of the households for grey water system.

Households in south side*	Rest of households*
Average 6.43	Average 7.6
7	6
8	9
3	9
7	3
9	8
8	7
3	7
	9
	9
	9

* 1 household interview is left out, because no address is mentioned in the interview.

From table 57 it can be seen that the households in the south side have given a lower grade than the rest of the households, which is probably caused by the collapse of the grey water system in the south side.
The average grade is 7.1. In general it can be said that the households are satisfied with the grey water systems.

Complete system

Has your household made any adaptations to the sanitation system as originally installed? Answer: yes/no.

- 17 out of the 18 households (94%) has not made any adaptations. 1 households mentioned that they made an adaptation to reduce the noise of the vacuum toilet. In which way this adaptation is done could not be retrieved.

Is there a visible part of the sanitation system near your house? Answer: yes/no.

- 12 out of 18 households (67%) mentioned that there is a visible part of the sanitation system near their house.

If yes, what do you think of the visible part near your house? The answer was rated on a 5-point rating scale with 0 being "beautiful" and 4 "really awful".

- This question is only answered by the 12 households that mentioned that there is a visible part of the sanitation system near their house. 6 of these households live at the south side. Table 58 presents the rates given for the visible part divided by the households in the south side and the rest of the households.

Table 58. Rates of the households in south side and the rest of the households for visible part.

Households in south side*	Rest of households*
Average 2	Average 1.4
1	1
2	1
2	2
2	1
3	2
2	

* 1 household interview is left out, because no address is mentioned in the interview.

From table 58 it can be seen that the households in the south side in general are less satisfied with the visible part of the sanitation system than the other households, which is probably caused by the fact that the grey water system in the south side is not completely ready yet.
The average rate is 1.75. In general it can be said that the households do not mind the visible part of the sanitation system.

If yes, is the visible part of the sanitation system near your house vulnerable to damage/failure? The answer was rated on a 5-point rating scale with 0 being "not at all" and 4 "always".

- As with the latter question, this question is only answered by the 12 households that mentioned that there is a visible part of the sanitation system near their house. Table 59 presents the rates given for the vulnerability divided by the households in the south side and the rest of the households.

Table 59. Rates of the households in south side and the rest of the households for visible part.

Households in south side*	Rest of households*
Average 2.5	Average 0.6
4	0
4	0
4	1
2	1
0	1
1	

* 1 household interview is left out, because no address is mentioned in the interview.

From table 59 it can be seen that the households in the south side in general have rated the vulnerability of the sanitation system on a lower rate than the other

households, which means that the households in the south side find the sanitation system more vulnerable than the other households. As mentioned earlier, this is probably caused by the fact that the grey water system in the south side has collapsed.
The average rate is 1.5. In general it can be said that the households experience the sanitation system to be vulnerable to damage/failure.

Dimension system robustness

How many times per year does a failure/blockage occur with your vacuum toilet? Answer in failures per year.

- 12 out of 18 households (67%) have not experienced a failure/blockage with their own vacuum toilet. The 6 other households (33%) that did mention a failure/blockage of their vacuum toilet, mentioned problems with the toilet paper. It sometimes occurs that the toilet paper gets stuck between the valve and the vacuum toilet. Due to the fact the valve does not close properly anymore the water is sucked away from the toilet which results in a sizzling sound. This problem can be solved by removing the toilet paper from the valve. 1 of these 6 households also mentioned a problem that once occurred due to lime deposition on the valve. This deposition results in the same problems as mentioned with the toilet paper. The amount of times per year these kinds of problems occur differed from twice in 7 years (0.28 times per year) to 2.5 times per year.

How many times per year does the complete vacuum system fails/blocks? Answer in failures per year.

- It is expected, based on comments made by some households and from the interviews held with the involved actors, that most of the amount of failures/blockages is related to local failures/blockages and not to the complete system. For this reason answers given at the last question that were related to local stops or appeared to be related to local stops are included in this answer. Every household has experienced a failure/ blockage. The amount of failures/blockages differed between 1 to 10 times per year.
  Table 60 presents the amount of failures/blockages per year given for the vacuum system divided by the households in the south side and the rest of the households.

Table 60. Amount of failures/blockages per year for the households in the south side and the rest of the households for the vacuum system.

Households in south side*	Rest of households*
Average 6.86	Average 4.17
10	1
10	3
5	7.5
9	5
5	3.5
2.5	2
6.5	6
	7.5
	2

* 2 household interviews are left out, because at 1 interview no address is mentioned in the interview and the answer from the other interview is not representative.

From table 60 it can be seen that the households in the south side in general experience more failures/blockages per year than the other households. It is expected that the difference in amount of failures/blockages per year between the households in the south side and the other households in reality would be bigger. Probably some households (not from the south side) have mentioned that average failures/blockages per year for the whole neighbourhood instead of their own failures/blockages they experience, because they know about the amount of failures/blockages in general.
In general it is expected that 90 – 95 % are local blockages/failures instead of a complete vacuum system failure. If a local blockage/failure occurs the company VITEK or the plumbing company Henry Gjøen is called to solve the problem.
The average amount of failures/blockages per year is 5.41.

How many times per year does the grey water system fails? Answer in failures per year.

- The grey water systems have never failed since the beginning, except for the collapse of the grey water system in the south side.

Which part of the sanitation system failed/was out of order? What was the problem? When and how often does it happen? How did you solve it and who did it? (This question is only asked if one or both last questions was/were higher than 0 failures per year)

- The answers to this question are already included in the answers from last 3 questions.

When the black water system fails, what is the average down time in hours? Answer in hours per failure.

- 2 households (11%) have not mentioned an average down time? The other 16 households (89%) mentioned down times that differ from 0.5 hours to 5 hours. The average down time in hours is 2.34. Important to mention is that this average down time is based on failures/blockages that occur during week days. Failures/blockages that occur in weekends can have longer down times. The down times mentioned during weekends can differ from 10 to 20 hours.

Dimension public health

What is the chance that you could come into direct contact with untreated or partially treated wastewater? Answer in %.

The answer to this question is based on interviews held with actors and own observation. As mentioned earlier, all households have in general a 0% chance of coming into direct contact with untreated or partially treated wastewater. The emptying of the black water storage tank can create a risk especially for children.

Have you suffered some kind of illness due to the ecological sanitation system? Answer: yes/no.

- None of the households have suffered some kind of illness due to the ecological sanitation system.

Has anyone in your household ever been physically injured in using or maintaining the sanitation system? (If yes, how often, nature and cause or injury). Answer: yes/no.

- None of the households have ever been physically injured in using or maintaining the sanitation system.

Questions on user perspective

Background question

Did you do a higher education after high school/ youth school? Answer: yes, what kind of education?/no.

- All interviewed persons of the households have done a higher education after high school/youth school. 2 persons (11%) mentioned to have done “Yrkesfag” or a similar education. This education is based on work subjects and prepares someone to be e.g. a mechanic, electrician or for work in healthcare. The other 16 persons (89%) mentioned to have done “Almennfag” or a similar education. This education prepares someone to do a bachelor or master education.

Involved questions

Do you feel environmentally concerned? The answer was rated on a 5-point rating scale with 0 being “always” and 4 “not at all”.

- Table 61 presents the rate for feeling environmentally concerned for the 18 households.

Table 61. The feeling environmentally concerned rate for the 18 households.

Feeling environmentally concerned	Amount of households
Always – 0	3
Very often – 1	8
Sometimes – 2	7
A little bit – 3	0
Not at all – 4	0

The average feeling environmentally concerned rate for the 18 households is 1.22. In general the households are very often feeling environmentally concerned.

Did the sanitation system make you more environmentally concerned? Answer: yes/no.

- 8 of the 18 households (44%) mentioned that the sanitation system has made them more environmentally concerned.

Which aspect(s) of the ecological sanitation system do you think has/have a good future? Descriptive answer.

- 2 households (11%) have not answered this question. 6 of the 18 households (33%) think that the whole system has a good future. 4 of these 6 households made some additional comments. They only think that the whole system has a future:
    - if it works properly (2 households);
    - in areas with little water (2 households).

8 of the 18 households (44%) think that only the grey water system has a good future. 3 of these 8 households have mentioned a reason for not thinking that the vacuum system has a good future, namely:

- black water system is too unreliable (1 household);
- black water system does not solve any problem, because conventional system is getting better as well (1 household);
- black water system needs big adjustments/improvements before it has a future (1 household).

The latter 2 households only mentioned to believe in a good future of the vacuum system, but they made some comments. They only believe in a future for the vacuum system:

- in areas with little water (1 household);
- if blockages/failures are permanently solved (1 household).

It is expected that these latter 2 households also believe in a future for the grey water system, although they have not mentioned the grey water system in their answer. This expectation is based on the answers given by these 2 households to the previous questions.

What kind of benefits of the ecological sanitation system do you experience? Descriptive answer.

- 3 households (17%) have not answered this question. 9 of the 18 households (50%) mentioned to experience benefits qua ecological aspects (doing something right for nature). No personal benefits are mentioned. The other 6 households (33%) do not experience any benefits.

What kind of drawbacks of the ecological sanitation system do you experience? Descriptive answer.

- 2 households (11%) have not answered this question. 13 of the 18 households (72%) mentioned drawbacks related to the vacuum system (blockages/failures). From these 13 households 3 households also considered the smell of the grey water system to be a drawback. 1 of the 18 households (6%) only experienced the odours from the grey water system to be a drawback and did not mention anything about the vacuum system. The latter 2 households (11%) did not mention any drawbacks.

6. Discussion & Conclusions

6.1. Introduction

This chapter presents the discussion and conclusions. Paragraph 6.2 presents the answer to the first main research question "What are the main drivers and barriers for the implementation of an ecological sanitation site in Norway?" followed by paragraph 6.3 where the second main research question "Is there a future for the technology as implemented at the two Norwegian ecological sanitation sites?" is discussed.

6.2. Main drivers and barriers

Positive feeling about environmental behaviour, water saving, reduction of water emissions, protection of surface water, recycling of nutrients were important drivers for the implementation of the two ecological sanitation sites. Besides these main drivers the protection of ground water, the quality of neighbourhood landscaping, the involvement in the sanitation process and improving the quality of living were also important at Torvetua. Further the big governmental subsidy program for natural & ecological sanitation projects was also an important driver.

The main barrier at both ecological sanitation sites was and still is the conservative attitude of the employees of the municipalities. They seem to have their own "kingdom of economics" and favour the conventional wastewater management system. Expertise about ecological sanitation systems can hardly be found in municipalities (interview with Steinsholt). At both ecological sanitation sites the employees of the municipalities were not eager to cope with the projects, but they had to because the politicians were in favour. This kind of situation has, especially for Torvetua, resulted in slack behaviour of the municipal employees.

Besides the conservative attitude of the municipal employees, the difficulty of the technology acted also as a barrier for the ecological sanitation site Kaja. Flooding risks, possible physical injury by householders having access to the equipment and the unclearness of the maintenance responsibilities acted as barriers for the ecological sanitation site Torvetua.

For the Dutch situation it has been found by Van Betuw (2005) that water saving and reduction of water emissions were important drivers for applying non-conventional sanitation systems in the Netherlands as well. Contrary, the recycling of nutrients did not act as a driver for the Dutch situations, while it was a main driver for the two Norwegian sites. None of the above mentioned barriers acted as a barrier at the Dutch non-conventional sites.

6.3. Future perspective

To answer the second main research question a distinction is made between the technical aspects, performance and robustness, costs, public health, and user perception. At the end of this paragraph the final conclusion is presented.

Technical aspects, performance and robustness

Black water system

The vacuum transport system seems to be a good technique for transporting concentrated black water and could have a good future provided that the vacuum system is properly installed. The advantage of the vacuum transport system is its water saving feature. The implementation of vacuum toilets saves a considerable amount of water, because a vacuum toilet uses 0.5 to 1 litre of water per flush, while a conventional toilet uses around 4 litres of water per flush.

The results of this investigation show that a proper installation is very important when a vacuum technique is used. Most of the problems present at Kaja and Torvetua are most likely caused by installation mistakes (90° bends, the ability of pipes to freeze during winter, too little considering of the geographical situation). Another bottleneck appears to be that no or hardly any information was provided to the people that are using the vacuum toilets and that misuse of the vacuum toilets seems to have occurred as well. The installation mistakes and lack of user information are causing the main blockages that are still occurring at both research sites. Proper installation and improved information to the users will lead to a considerable reduction in the amount of blockages and might even solve all.

The most important drawback of the black water systems as installed at both research sites is the lack of a final solution for the black water that includes reuse of components. Now at both cases it is collected by truck and transported to a regular wastewater treatment plant. The collection by truck can not be seen as a durable end-solution for the black water if the system is to be applied in other (new) cases. A truck from the municipality has to come frequently (in Kaja once per month, in Torvetua every tenth day) to collect the black water. This collection results in a major financial drawback, because the collection costs are a considerable part of the total operation and maintenance costs (see appendix 15 and 16, their contents are further discussed below).

For both Norwegian sites installing a liquid composting unit has been considered by Prof. Jenssen. However, it was concluded that a liquid composting unit was not economically feasible on the small scale of both research sites. A proper end-solution is still under consideration by Prof. Jenssen. The establishment of a direct connection for the black water to the conventional sewage pipes seems to be the best solution in case no other appropriate solution comes up.

It has to be taken into account that the implementation of the vacuum technique at both research sites was an experiment, especially for the big area Torvetua. Torvetua is the only big area up to now where JETS's vacuum technique is installed according to the managing director of the company JETS. At this moment the vacuum technique is already proven on a small scale like Kaja. To prove if the vacuum technique has a future in big areas like Torvetua it has to be further improved to decrease the amount of blockages/failures.

Grey water system

Besides the collapse of the physical structure of one of the grey water systems at Torvetua, the grey water systems at both research sites have performed well and have shown to be robust. The effluent concentrations fulfil the legal discharge requirements and little maintenance is necessary. An overview of the performance is presented in table 62. This table shows a comparison between the effluent values and the performance of the system at Kaja in relation to the requirements set. For Kaja a comparison between

the effluent values and performance obtained at the investigated conventional wastewater management plant is also included. It can be seen that the grey water systems fulfil the requirements set. Most of the effluent values or removal efficiencies are close to the requirements set and in the case of Kaja close to the effluent values and performance of the conventional wastewater management plant. It has to be noted that lower influent concentrations are present at both research sites in comparison to the conventional wastewater management system. The lower influent concentrations make it more difficult to obtain high removal efficiencies.

Due to the good performance, robustness and little maintenance requirement, the grey water systems seem to have a good future. Nowadays available grey water systems have been improved and are also more compact than the ones implemented at Kaja and Torvetua, which results in an even better future perspective.

Table 62. Overview performances Kaja and Torvetua.

Parameter	Effluent Kaja compared with requirements set and effluent values obtained for the local municipal wastewater treatment system of the city		
	Requirements	**Municipal wastewater treatment plant***	**Kaja**
BOD_7	≥ 90% removal	95%	94%
Total-P	Average 0.3 mg/l Maximum 0.6 mg/l	Average 0.24 Maximum 0.46	Average 0.05 Maximum unknown
Total-N	≥ 70% removal	71%	70%
Parameter	**Effluent Torvetua compared with requirements set for Torvetua****		
	Requirements	**Torvetua**	
BOD_7	Average 10 mg/l Maximum 25 mg/l	Average 5.5 mg/l Maximum unknown	
Total-P	Average 0.2 mg/l Maximum 0.5 mg/l	Average 0.2 mg/l Maximum unknown	
Total-N	≥ 50% removal	60%	

* Averages for 2003 – 2005 calculated

** No comparison to municipal wastewater treatment system as no data was obtained in the county where Torvetua is situated. As mentioned before in chapter 3, each county has different requirements dependent on the geographical situation.

General

The estimated total energy consumption for the black and grey water treatment per year for Kaja is 1557 kWh and for Torvetua 5532 kWh. The energy consumption per student apartment (2 persons) in Kaja is then 65 kWh and per household (3.25 persons) in Torvetua 138 kWh. The relative higher energy consumption per person at Torvetua is mainly caused by the implementation of two grey water systems. Due to the geographical situation of Torvetua one grey water system was not feasible.

Costs

The information about the installation costs could be partially retrieved for Kaja and could not be retrieved for Torvetua. At this moment the installation costs of the implemented technology at both research sites are expected to be relatively higher than the costs for the conventional wastewater management system. In appendix 15 and 16 a costs and benefits-analysis is presented of both research sites. It has to be noted that the presented costs and benefits analysis is performed based on the data that could be retrieved. This costs and benefits analysis might not represent the real situation.
The costs and benefits analysis of Kaja shows the difference in installation costs in relation to the connection fee. Around € 27 000, or € 1129 per apartment, is estimated to be the extra costs (indication). It has to be noted that the costs for the grey water system at Kaja could be lower due to the fact that the grey water system is installed with a double

function (can also treat black water if necessary). This double function was installed for safety reasons.
Because the installation costs from Torvetua could not be retrieved, no difference could be assessed.

Currently experiments are done at the university of Life Sciences in Ås (Norway) with different kind of valves which could result in a breakthrough for the costs of a vacuum toilet. The current valve in a vacuum toilet is the majority of the costs of a vacuum toilet. A vacuum toilet itself is easier to produce than a conventional toilet, because the vacuum toilet consists of one piece whereas a normal conventional toilet consists of three pieces. The valve makes a vacuum toilet expensive. If the valve testing becomes successful the vacuum toilet can become as cheap, or even cheaper, than a conventional toilet according to Prof. Jenssen.

What needs to be considered with the implementation of non-conventional sanitation systems is that in Norway an average of 76% of the costs of the conventional wastewater management system is for sewage pipes and 24% is for the treatment itself (see table 4 in chapter 3). These percentages are also representative for the Netherlands (STOWA 2005-12). Due to the high percentage of costs for the sewage pipes, application of non-conventional sanitation systems seems to be most profitable compared to the conventional system in the case of remote areas where no conventional sewage system is nearby, provided that all wastewater streams are treated on-site.

As can be seen from appendix 15 and 16, the yearly costs (operating and maintenance costs) are higher than with the conventional wastewater management system based on the data that was retrieved. The extra yearly costs for Kaja are estimated at € 15 538 and for Torvetua at € 19 618. The extra yearly costs per student apartment (2 persons) in Kaja is then € 648 and per household (3.25 persons) in Torvetua € 491. The difference per site is caused by:
- the relative cheaper costs for the conventional wastewater management system for Torvetua compared to Kaja;
- the operating costs for the grey water systems of Torvetua are not considered, because these costs could not be retrieved. The operating costs for the grey water system are included for Kaja;
- the operating costs for the drinking water supply are relatively cheaper for Torvetua than for Kaja.

At Kaja the main costs for operating and maintenance are related to the blockages in the vacuum pipes. These blockages are mostly at the same place in the vacuum system, indicating a problematic area in the total vacuum system. This is most likely caused by the 90° bend just before the vacuum pump. In some cases blockages are also caused by misuse by the students.
At Torvetua the main operating and maintenance costs are caused by the blockages in the vacuum system in the south side of Torvetua (the lowest part and most far away from the vacuum pump). The blockages are most likely related to improper installation of the vacuum system. A transport unit was recently installed in the pipeline at the south side to overcome/decrease the blockages/failures. If the amount of blockages/failures can be decreased the financial profitability for the black water system will increase considerably.

At this moment projects like Kaja and Torvetua can not be cost competitive with the conventional wastewater management system without external funding. If the costs of the implemented technology would decrease and/or the water price per cubic metre would increase considerable then it would be an interesting option.

Public health

The black water systems have a (small) potential health risk during and after the collection of the black water by the trucks. The collection may lead to some spillage of black water. Especially in the case of Torvetua, where the collection is done close to the common playground of the neighbourhood, a potential health risk is present. The tube that is used has to cross the playground and during its removal some black water may drip on the playground. This potential health risk would diminish if the collection tank would be replaced away from the common playground or if an appropriate end-solution will be installed, which eliminates the current collection and eliminates the potential chance of getting into direct contact with the black water.

The grey water systems do not cause a public health risk due to their good removal efficiency, robust operation and nil chance of coming into direct contact with the grey water.

User perception and invisibility

The reliability of the implemented technology is closely related to how users perceive the systems. From the interviews held with the students and households the biggest obstacle at both research sites is the unreliability of the black water system. The reliability has to improve for having a future perspective. Another comment made by the students and households is about the noise level of the vacuum toilet. About half of the interviewed people mentioned that the vacuum toilet produced an annoying noise. According to the managing director of the company JETS new vacuum systems are developed. These new systems are called VOD-systems, which stand for Vacuum On Demand. This is contrary to the vacuum systems installed at Kaja and Torvetua where the vacuum systems are under constant vacuum. Also pneumatic valves have been developed (in Kaja and Torvetua electrical vales have been installed). The advantages of the VOD-systems and the pneumatic valves are that they use less energy and, more important, are more quiet.
The implementation of the improved Vacuum On Demand (VOD) system in combination with pneumatic valves at new non-conventional projects could solve the problem of the annoying noise level. If that would be really the case has to be proven by further research.

A general uncertainty of the current vacuum collection system is that the valves are driven by electricity. No electricity during a power failure automatically means that the vacuum toilets in Kaja and Torvetua can not be used. However, currently pneumatic valves are being developed that could solve this potential problem.

The grey water systems are in general well accepted by the students and households, which gives it a good future perspective.

Final conclusion

Based on the current situation it has to be concluded that the investigated systems do not offer a complete solution yet, because there is no end-solution for the black water.
The vacuum technique itself seems to have a good future perspective and is advised to install when new non-conventional projects would arise provided that the system is not dependent on the collection of black water by trucks and is properly installed. The vacuum technique has a considerable water saving feature in relation to conventional toilets.

The results of the investigation show that the investigated systems are not yet cost competitive and a large number of failures is present with the vacuum system. Proper installation and improved information to the users will considerable decrease the amount of blockages and might even solve all. Less blockages will likely result in a better user acceptance. The future of the implemented black water systems in Kaja and Torvetua is dependent on its improvements and needs to be further researched.

The grey water system is a well-functioning technology, is robust in operation, requires little maintenance and has a good user acceptance. Nowadays available grey water systems have improved and are more compact in comparison to the ones implemented at both research sites, which results in an even better future perspective.

7. Recommendations

7.1. Introduction

This chapter presents the recommendations for Kaja and Torvetua. Besides the recommendations presented for Kaja and Torvetua, some general recommendations are mentioned for people/actors who want to develop or are considering to develop a new ecological sanitation site.

7.2. Recommendations Kaja

The recommendations for Kaja are:
- develop end-solution for black water;
- remove the 90° bend in the basement just before the vacuum pump (problem area) and replace it by two 45° bends;
- do further research to the possible odour occurrence of the grey water system, because of complaints by some students;
- analyze the grey water system on a frequent basis in order to ensure the efficiency and to protect public health.

7.3. Recommendations Torvetua

The recommendations for Torvetua are:
- develop end-solution for black water;
- remove 90° bends as much as possible;
- do further research to the possible odour occurrence of the grey water system, because of complaints by some households;
- analyze the grey water systems on a frequent basis in order to ensure the efficiency and to protect public health;
- install automatic dosing device for JETS microbe cleaner to ensure that the vacuum piping system is well maintained;
- install access points in the vacuum piping system to do maintenance/service. This will possibly make maintenance cheaper and will cause less disturbance, because there is no need anymore to dismantle a vacuum toilet at a household to get access to the vacuum piping system;
- unless the good performance of the grey water system it is recommended to update the grey water systems to the grey water system with domes, because it is a better system (better spreading of the grey water) and is easier to maintain;
- inform households what they are and what they are not allowed to discharge on the grey water system, because there still is no guideline for the households.

7.4. General recommendations

- If you want to develop an ecological sanitation site it seems like you have to bypass bureaucracy and try to get politicians on your hand. In general the municipal engineers are very conservative and do not realise the importance of ecological sanitation and

are not willing to help you. Be aware that the municipal employees are most possibly not eager to work with ecological sanitation projects;
- Get the future inhabitants involved in the sanitation, because they are the future users of the system. Inform them on how to use the system and what they are not allowed to discharge on the system;
- Make sure you attract a dedicated contractor to prevent the mistakes made at e.g. Torvetua with the 90° bends in the vacuum piping system;
- The responsibilities should be clear from the beginning. At Torvetua not much attention has been paid to who should operate the systems. The responsibilities were underestimated at Torvetua (Støa, 2004);
- Maintenance should be done by someone who is familiar with the system to ensure the systems quality. This could be a professional or a dedicated inhabitant that has been provided a good operation and maintenance manual;
- To make the ecological sanitation system financially more attractive make sure a complete drop or a discount is obtained on the waterboard levy or taxes.

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Interviews

Interviews with Petter D. Jenssen, professor at the University of Life Sciences in Ås, on 8 November 2005, 17 November 2005 and 25 January 2006.

Interview with Halvor Holtestaul, former director of student union Sias in Ås, on 11 November 2005.

Interview with Harald Hansen, employee of student union Sias who is responsible for operation and maintenance of sanitation system, on 16 November 2005 and 24 November 2005.

Interview with Bjørn Buller, responsible for daily management of wastewater treatment plant Nordre Follo Renseanlegg in Vinterbro, on 23 November 2005.

Interview with Kurt Oddekalv, environmental activist and initiator of Torvetua, on 29 November 2005.

Interview with Øystein Samsonsen, current leader of the board of Torvetua, on 30 November 2005.

Interview with Svein Linga, responsible for economics of board of Torvetua, on 1 December 2005.

Interview with Even Gabrielsen, former leader of board of Torvetua, on 4 December 2005.

Interview with Tølbjorn Holgersen, contact person for Torvetua at building company Block Watne, on 5 December 2005.

Interview with Ivar Kalland, head of sewage and water works department of the municipality of Bergen, on 5 December 2005.

Interview with Kjetil Helle, responsible for grey water samples of board of Torvetua, on 7 December 2005.

Interview with Niels B. Jensen, responsible for drinking water of board of Torvetua, on 7 December 2005.

Interviews with Knut G. Flo, ex-member of board of Torvetua, head of technical group (does not exist anymore), in the period from 28 November till 9 December.

Interviews by phone

Interview with Håvard Steinsholt, one of politician involved with development of Kaja, on 18 November 2005.

Interview with Ingunn Skadberg, employee of municipality of Ås, on 18 November 2005.

Interview with Arne Hillestad, one of politician involved with development of Kaja, on 21 November 2005.

Interview with Johnny Eide, employee of company Henry Gjøen and responsible for operation and maintenance of sanitation system, on 7 December 2005.

Interview with Ole Kårtveit, manager of company VITEK, on 7 December 2005.

Interview with Kaare A. Haddal, managing director of the company JETS, on 1 December 2005.

Interview with Knut G. Flo, ex-member of board of Torvetua, head of technical group (does not exist anymore), on 6 February 2006.

Interviews with Petter D. Jenssen, professor at the University of Life Sciences in Ås, several times in the period from December 2005 till February 2006.

Appendices

Appendix 1 "Drivers and barriers"-interview

Analysis of Drivers and Barriers in Non-Conventional System Design Phase

The aim of this survey is to get an overview of the practical experiences of ecological projects. Your opinion about this is important to us for making this survey successful.
The interview will take us only around 30 minutes.
All the information you give will be treated confidentially and will not be shown to anyone else.

Questionnaire No:………………………………….Institution:……………………………………….
Date:…………………….Respondent name:…………………………………………Age:…………
Address: Street……………………………………………………………………….No:………….
District………………………………………..Ward:…………………………………….

Questions on design

Sanitation system description

0. Can you describe the technical and managerial features of the sanitation system (ownership, process train, management, size, number of households connected to the system, and so on)?
……………………………………………………………………………………………………
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1. Did you participate in the technology choice of the neighbourhood sanitation system?

   O Yes
   O No

2. When was the system constructed and over what period?

   ………………….
   …………years

3. Which actors were involved in the technology choice? And what was their role?

	Actor	Role
1		
2		
3		
4		
5		
6		
7		
8		

4. How were decisions made? (consensus or authority)

   O consensus
   O authority

5. Did you agree with the decision-making process?

   O Yes
   O No, because………………………………………………………………………………
   …………………………………………………………………………………………………
   …………………………………………………………………………………………………

6. Who was responsible for the final decision on the system selection / technology choice? (Which part?)

   …………………………………………………………………………………………………
   …………………………………………………………………………………………………

7. How often did you meet with other people involved in the system selection?

   ………………….times/month

Environmental drivers

8. What kind of environmental aspects of the waste water management system were important for you and other actors when you were **selecting** the system?

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

9. What environmental aspects of the sanitation system were **realised** in the sanitation system as it was constructed?

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

Environmental and public health barriers

10. What barriers stood in the way of incorporating non-conventional elements in the design?

Environmental aspect	Unimportant	Neutral		Important	
	0	1	2	3	4
Health risks					
Flood risks					
Chemical hazards					
Physical injury from householder access to equipment					
Other …………………					
Other …………………					
Other …………………					

Legal and regulatory barriers

11. What laws and regulations hampered implementation of what non-conventional elements in the original design? (specify)

	Law or regulation	Impact on non-conventional design element(s)
1		
2		
3		
4		
5		

Vacuum toilet (social/technical)

12. Was the idea of applying vacuum toilets in the project a driver or a barrier?

Driver		Neutral		Barrier
0	1	2	3	4

Explanation……………………………………………………………………………………………
……
……
………………………………………………………………………………………………………..

13. To what extent did the social/technical considerations play a role in the system choice?

Unimportant		Neutral		Important
0	1	2	3	4

……
……
……

Financial drivers & barriers

14. What financial considerations were a driver or a barrier of decision to incorporate non-conventional elements in the design?

	Driver		Neutral		Barrier
	0	1	2	3	4
Design costs (compared to conventional system)					
Operating costs (compared to conventional system)					
Energy costs (compared to conventional system)					
Applying vacuum toilets (financially)					
Reduced drinking water consumption (and lower bills)					
Other…………………					
Other …………………					
Other …………………					

15. To what extent did the considerations play a role in the system choice?

	Unimportant	Neutral		Important	
	0	1	2	3	4
Design costs (compared to conventional system)					
Operating costs (compared to conventional system)					
Energy costs (compared to conventional system)					
Applying vacuum toilets (financially)					
Reduced drinking water consumption (and lower bills)					
Other…………………					
Other …………………					
Other …………………					

16. Was the budget for the system known from the beginning?

O Yes
O No

17. To what extent did the budget play a role in the system choice?

Unimportant		Neutral		Important
0	1	2	3	4

Social and managerial drivers and barriers

18. What social aspects of the sanitation system were important for you and other actor to realise a non-conventional design?

Aspects	Unimportant	Neutral		Important
	0	1	2	3	4
Intensive contact with neighbours / Collaboration with neighbours					
Involvement in sanitation / Taking responsibility for your household water management system. E.g. water saving, reducing emissions					
Improves quality of living					
Other …………………					
Other …………………					
Other …………………					

19. What social and managerial considerations hampered incorporation of non-conventional elements in the design?

Aspects	Unimportant	Neutral		Important
	0	1	2	3	4
Difficult technology					
Ownership unclear					
Maintenance responsibilities unclear					
Maintenance burden on householders					
Other …………………					
Other …………………					
Other …………………					

Current and future status wastewater management system

20. Did you participate in the period of building until now of the neighbourhood?

    O Yes
    O No (skip next 2 questions)

21. Have there been any changes/modifications on the sanitation system from the start of using until now?

    O No
    O Yes, what and why?..
    ……………………………………………………………………………………………
    ……………………………………………………………………………………………
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    ……………………………………………………………………………………………

22. Are there any changes on the sanitation system that you think will happen in the future?

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    ……………………………………………………………………………………………
    ……………………………………………………………………………………………
    ……………………………………………………………………………………………
    ……………………………………………………………………………………………

General

23. Which aspect(s) of the sanitation system do you think has a (good) future?

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…………………………………………………………………………………………………

24. Who do you think is the most important actor in developing/initiating implementation of non-conventional systems? Why?

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25. If you could do the project over again would you do it in the same way or would you deal with it differently?

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The interview is over now. Thank you for answering these questions

Appendix 2 System owner-interview

Interview system owner

The aim of this survey is to get an overview of the practical experiences of ecological projects. Your opinion about this is important to us for making this survey successful.
The interview will take us only around 20 minutes.
All the information you give will be treated confidentially and will not be shown to anyone else.

Questionnaire No:…………………………………Institution:………………………………………
Date:……………………Respondent name:…………………………………………Age:…………
Address: Street………………………………………………………………………No:…………
District…………………………………………..Ward:……………………………………

Questions

Sanitation system description

0. Can you describe the technical and managerial features of the sanitation system (ownership, process train, management, size, number of households connected to the system, and so on)?
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Sanitation system description

1. What is the up-front investment per household in EURO of the process train?

   …………€/household

2. What is the estimated useful (service) life of the process train in years?

   …………years

3. What is the estimated annual operating cost in EURO of the process train per household?

   …………….€/household/year

Performance dimension: invisibility and user comfort

4. Are householders satisfied with the sanitation system?

   O Yes
   O No, because………………………………………...

……
……

5. How many hours per household unit per year of operations or maintenance activity does the process train require from its users?

   …………………..hours/household/year

6. What area of the above-ground indoor space on household premises does the process train equipment require expressed in m^3 per households?

   …………………..m^3/household

7. What area of the above-ground outdoor space on household premises does the process train equipment require expressed in m^3 per households?

   …………………..m^3/household

8. What area of the above-ground space in the residential area (neighbourhood) does the process train equipment require expressed in m^2?
   (What is the depth?.............)

   ………………….m^2/neighbourhood

9. What area of the under-ground space in the residential area (neighbourhood) does the process train equipment require expressed in m^3?

   ………………….m^3/neigbourhood

Dimension: system robustness

10. Is the sanitation system being monitored? How?

    ………………………………………………………………………………………………………
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    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………

11. How many times per year does **a vacuum toilet** fails/blocks?

    ……………………failures/year

12. How many times per year does the **complete vacuum system** fails/blocks?

    ……………………failures/year

13. How many times per year does the **grey water system** fails?

    ……………………failures/year

Only to be asked if one, two or all last 3 questions was/were higher than 0 failures per year

14. Which parts of the wastewater management system failed/was out of order? What was the problem? When and how often does it happen? How did you solve it and who did it?

Part of the system	Problem	When ? (Date)	often? (t/m /y)	Solution	Solved

15. When the **vacuum system** fails, what is the average down time in hours?

…………………hours/failure

16. When the **grey water system** fails, what is the average down time in hours?

…………………hours/failure

Dimension: impact on eco-system

17. What is the energy consumption per household per year for the sanitation system?

………………….kWh/household/year

18. What amount of energy is recovered from the treatment process per household per year?

………………….kWh/household/year

19. What is the volume of water recycled from the sanitation system per household per year?

………………….m^3/household/year

The interview is over now. Thank you for answering these questions

Appendix 3 Operation and maintenance-interview

Interview operation and maintenance expert

The aim of this survey is to get an overview of the practical experiences of ecological projects. Your opinion about this is important to us for making this survey successful. The interview will take us only around 30-40 minutes.
All the information you give will be treated confidentially and will not be shown to anyone else.

Questionnaire No:…………………………………Institution:………………………………………
Date:……………………Respondent name:…………………………………………Age:…………
Address: Street…………………………………………………………………………No:…………
District………………………………………..Ward:……………………………………

Questions

Sanitation system description

0. Can you describe the technical and managerial features of the sanitation system (ownership, process train, management, size, number of households connected to the system, and so on)?
……………………………………………………………………………………………………
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Sanitation system description

1. What is the up-front investment per household in EURO of the process train?

   …………€/household

2. What is the estimated useful (service) life of the process train in years?

   …………years

3. What is the estimated annual operating cost in EURO of the process train per household?

   …………….€/household/year

Performance dimension: invisibility and user comfort

4. Are householders satisfied with the sanitation system?

O Yes
O No, because…………………………………………………………………………………………

……

……

5. Have householders made adaptations to the sanitation system as originally installed?

O No
O Yes. What did they change and why?..

……

……

……

6. How many hours per household unit per year of operations or maintenance activity does the process train require from its users?

…………………..hours/household/year

7. What area of the above-ground indoor space on household premises does the process train equipment require expressed in m^3 per households?

…………………..m^3/household

8. What area of the above-ground outdoor space on household premises does the process train equipment require expressed in m^3 per households?

…………………..m^3/household

9. What area of the above-ground space in the residential area (neighbourhood) does the process train equipment require expressed in m^2?
(what is the depth?……….)

………………….m^2/neighbourhood

10. What area of the under-ground space in the residential area (neighbourhood) does the process train equipment require expressed in m^3?

………………….m^3/neigbourhood

11. How many official odour level complaints do users make per year (registered at for instance the municipality)?

…………………number/year

12. How many non-official odour level complaints do users make per year (complaint at your address)?

    …………………number/year

Dimension: system robustness

13. Is the sanitation system being monitored? How?
    ………………………………………………………………………………………………
    ………………………………………………………………………………………………
    ………………………………………………………………………………………………
    ………………………………………………………………………………………………
    ………………………………………………………………………………………………

14. How many times per year does **a vacuum toilet** fails/blocks?

    ……………………failures/year

15. How many times per year does the **complete vacuum system** fails/blocks?

    ……………………failures/year

16. How many times per year does the **grey water system** fails?

    ……………………failures/year

Only to be asked if one, two or all last 3 questions was/were higher than 0 failures per year

17. Which parts of the wastewater management system failed/was out of order? What was the problem? When and how often does it happen? How did you solve it and who did it?

Part of the system	Problem	When? (Date)	often? (t/m/y)	Solution	Solved

18. When the **vacuum system** fails, what is the average down time in hours?

…………………hours/failure

19. When the **grey water system** fails, what is the average down time in hours?

…………………hours/failure

20. What is the effect of the process to fluctuations in heavy metals in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

21. What is the effect of the process to fluctuations in pathogens in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

22. What is the effect of the process to fluctuations in oily or fatty substances in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

23. What is the effect of the process to fluctuations in medicines and hormones in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

24. What is the effect of the process to fluctuations in phosphorus or nitrogen in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

25. What is the effect of the process to fluctuations in organic materials in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

26. What is the effect of the process to fluctuations in particle size in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

27. What is the maximum particle diameter the process can treat?

……………..mm particle size

28. What is the effect of the process to fluctuations in outdoor temperature?

No effect		Effect		A lot of effect
0	1	2	3	4

29. What is the effect of the process to fluctuations in rain intensity?

No effect		Effect		A lot of effect
0	1	2	3	4

Dimension: public health

30. What is the chance of inhabitants of the neighbourhood to come into direct contact with waste water in percentages?

……………….%

31. What is the probability of a batch of final treated waste water failing to comply with official waste water quality standards in percentages?

……………….%

32. Does the final effluent water exceed official quality standards?

O Yes (go to next question)
O No (skip next question)

33. In how far does the final effluent water exceed official quality standards in percentages?

……………….%

34. Does the final sludge exceed official quality standards?

O Yes (go to next question)
O No (skip next question)

35. In how far does the final sludge exceed official quality standards in percentages?

……………….%

36. How likely is it that householders using the system fall ill due to system failure or other causes?

Not likely at all				Very likely
0	1	2	3	4

37. How likely is it that householders sustain physical injury because they have access to sanitation system equipment?

Not likely at all				Very likely
0	1	2	3	4

38. Does the system or its components represent a chemical hazard to householders?

O No
O Yes, what is a chemical hazard?...
………………………………………………………………………………………………

39. What is the treatment efficiency for pathogens removal in percentages?

………………..%

40. What is the average effluent quality of water for pathogens?

………………..mg/kg

41. What is the average effluent quality of sludge for pathogens?

……………….mg/kg

Dimension: impact on eco-system

42. What is the volume of effluent water production per household per year, by effluent type?

……………m^3/household/year

43. What is the amount of sludge production per household per year?

……………kg/household/year

44. How many kilograms of chemicals does the sanitation system use per household per year?

…………….kg/household/year

45. What is the energy consumption per household per year for the sanitation system?

…………….Kwh/household/year

46. What amount of energy is recovered from the treatment process per household per year?

…………….Kwh/household/year

47. What is the volume of drinking water usage per household per year?

……………..m^3/household/year

48. What is the volume of water recycled from the sanitation system per household per year?

   ……………...m^3/household/year

Dimension: surface and groundwater management

49. Does the sanitation system evacuate rain water?

   O No
   O Yes

50. Does the sanitation system contribute to groundwater management?

   O No
   O Yes

51. What is the average rain water intensity per year?

   ……………mm rainfall/m^2/year

52. What is the maximum intensity rainstorm the system can handle?

   ……………mm rainfall/m^2

The interview is over now. Thank you for answering these questions

Appendix 4 Sanitation expert-interview

Interview sanitation expert

The aim of this survey is to get an overview of the practical experiences of ecological projects. Your opinion about this is important to us for making this survey successful.
The interview will take us around 40 minutes.
All the information you give will be treated confidentially and will not be shown to anyone else.

Questionnaire No:…………………………………Institution:………………………………………
Date:……………………Respondent name:…………………………………………Age:…………
Address: Street…………………………………………………………………………No:…………
District………………………………………..Ward:……………………………………

Questions

Sanitation system description

0. Can you describe the technical and managerial features of the sanitation system (ownership, process train, management, size, number of households connected to the system, and so on)?
……
……
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Sanitation system description

1. What is the up-front investment per household in EURO of the process train?

…………€/household

2. What is the estimated useful (service) life of the process train in years?

…………years

3. What is the estimated annual operating cost in EURO of the process train per household?

…………….€/household/year

Performance dimension: invisibility and user comfort

4. Are householders satisfied with the sanitation system?

O Yes
O No, because………………………………………..

……
……

5. How many hours per household unit per year of operations or maintenance activity does the process train require from its users?

   …………………..hours/household/year

6. What area of the above-ground indoor space on household premises does the process train equipment require expressed in m^3 per households?

   …………………..m^3/household

7. What area of the above-ground outdoor space on household premises does the process train equipment require expressed in m^3 per households?

   …………………..m^3/household

8. What area of the above-ground space in the residential area (neighbourhood) does the process train equipment require expressed in m^2?
   (What is the depth?..........................)

   ………………….m^2/neighbourhood

9. What area of the under-ground space in the residential area (neighbourhood) does the process train equipment require expressed in m^3?

   ………………….m^3/neighbourhood

10. What is the maximum noise level produced on the household premises by the process in dB when in operation?

    ………………….dB

11. How many official odour level complaints do users make per year (registered at for instance the municipality)?

    …………………number/year

12. How many non-official odour level complaints do users make per year (complaint at your address)?

    …………………number/year

Dimension: system robustness

13. Is the sanitation system being monitored? How?
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………
    ………………………………………………………………………………………………………

14. How many times per year does **a vacuum toilet** fails/blocks?

……………………failures/year

15. How many times per year does the **complete vacuum system** fails/blocks?

……………………failures/year

16. How many times per year does the **grey water system** fails?

……………………failures/year

Only to be asked if one, two or all last 3 questions was/were higher than 0 failures per year

17. Which parts of the wastewater management system failed/was out of order? What was the problem? When and how often does it happen? How did you solve it and who did it?

Part of the system	Problem	When ? (Date)	often? (t/m /y)	Solution	Solved

18. When the **vacuum system** fails, what is the average down time in hours?

…………………hours/failure

19. When the **grey water system** fails, what is the average down time in hours?

…………………hours/failure

20. What is the effect of the process to fluctuations in heavy metals in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

21. What is the effect of the process to fluctuations in pathogens in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

22. What is the effect of the process to fluctuations in oily or fatty substances in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

23. What is the effect of the process to fluctuations in medicines and hormones in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

24. What is the effect of the process to fluctuations in phosphorus or nitrogen in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

25. What is the effect of the process to fluctuations in organic materials in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

26. What is the effect of the process to fluctuations in particle size in influent quality?

No effect		Effect		A lot of effect
0	1	2	3	4

27. What is the maximum particle diameter the process can treat?

……………..mm particle size

28. What is the effect of the process to fluctuations in outdoor temperature?

No effect		Effect		A lot of effect
0	1	2	3	4

29. What is the effect of the process to fluctuations in rain intensity?

No effect		Effect		A lot of effect
0	1	2	3	4

Dimension: public health

30. What is the chance of inhabitants of the neighbourhood to come into direct contact with waste water in percentages?

………………%

31. What is the probability of a batch of final treated waste water failing to comply with official waste water quality standards in percentages?

………………%

32. Does the final effluent water exceed official quality standards?

O Yes (go to next question)
O No (skip next question)

33. In how far does the final effluent water exceed official quality standards in percentages?

………………%

34. Does the final sludge exceed official quality standards?

O Yes (go to next question)
O No (skip next question)

35. In how far does the final sludge exceed official quality standards in percentages?

………………%

36. How likely is it that householders using the system fall ill due to system failure or other causes?

Not likely at all				Very likely
0	1	2	3	4

37. How likely is it that householders sustain physical injury because they have access to sanitation system equipment?

Not likely at all				Very likely
0	1	2	3	4

38. Does the system or its components represent a chemical hazard to householders?

    O No
    O Yes, what is a chemical hazard?..
    …………………………………………………………………………………………………

39. What is the treatment efficiency for pathogens removal in percentages?

    ………………..%

40. What is the average effluent quality of water for pathogens?

    ……………….mg/kg

41. What is the average effluent quality of sludge for pathogens?

    ……………….mg/kg

Dimension: impact on eco-system

42. What is the treatment efficiency for organic material (BOD) removal in percentages?

    ……………..%

43. What is the average effluent quality of water for BOD?

    …………….mg BOD/l

44. What is the average quality of sludge for BOD?

    ……………mg/kg dm

45. What is the average quality of water for heavy metals?

    ……………µg/l

46. What is the average effluent quality of sludge for heavy metals?

    ……………mg/kg dm

47. What is the volume of effluent water production per household per year, by effluent type?

    ……………m^3/household/year

48. What is the amount of nutrients in effluent water per household per year, by effluent type?

    ……………mg/m^3

49. What is the amount of sludge production per household per year?

    ……………kg/household/year

50. What is the amount of nutrients recovered from the waste water stream and recycled per household per year?

…………….kg/household/year

51. How many kilograms of chemicals does the sanitation system use per household per year?

…………….kg/household/year

52. What is the energy consumption per household per year for the sanitation system?

…………….Kwh/household/year

53. What amount of energy is recovered from the treatment process per household per year?

…………….Kwh/household/year

54. What is the volume of drinking water usage per household per year?

……………..m^3/household/year

55. What is the volume of water recycled from the sanitation system per household per year?

……………...m^3/household/year

Dimension: surface and groundwater management

56. Does the sanitation system evacuate rain water?

O No
O Yes

57. Does the sanitation system contribute to groundwater management?

O No
O Yes

58. What is the average rain water intensity per year?

……………mm rainfall/m^2/year

59. What is the maximum intensity rainstorm the system can handle?

……………mm rainfall/m^2

The interview is over now. Thank you for answering these questions

Appendix 5 User perception-interview "Kaja"

HOUSEHOLD SURVEY including vacuum toilets

Your opinion about the sanitation system is important to me for making my survey successful.
The interview will take around 20 minutes.
All the information you give will be treated confidentially and will not be shown to anyone else.

Questionnaire No:……………….............Date:……………………
Respondent name: ……………………………………………
Age:…………...
Gender:……….
Address: Street → Kajaveien 15 House A / B / C / D Roomnumber……………….
District:……………….……………… Ward:…………………………………..

Household information items:

1. Do you often spend the day outside home (school, work)?

   O Yes
   O No

2. Do you spend the night at home at least 5 days per week?

   O Yes
   O No

3. For how long do you already live here?

   …………years

4. Were you aware of the ecological aspects of these apartments?

   O Yes - 0
   O No - 1

Performance dimension, invisibility and user comfort:

Black water system → vacuum toilets

5. Are you satisfied with the **black water** system? (explain)
   - o Very satisfied - 0
   - o Satisfied - 1
   - o Neutral - 2
   - o Dissatisfied - 3
   - o Very dissatisfied - 4

   because………………………………………………………………………………………
   ……………………………………………………………………………………………

6. Is the vacuum toilet easily kept clean?

O Yes - 0
O No - 1

Reason,……………………………………………………………………………………………

7. Does the vacuum toilet produce any annoying noise in your opinion?

O Yes - 0
O No - 1

……………………………………………………………………………………………

8. Are there any other comments in relation to the vacuum toilet system that you would like to mention?

……………………………………………………………………………………………………
……………………………………………………………………………………………………

9. Can you recommend the **vacuum toilet system** to other households in other neighbourhoods?

O Yes I will actively recommend it – 0
O Yes I will – 1
O Do not know – 2
O Not without improvement – 3
O Not at all – 4

Comments………………………………………………………………………………………
…………………………………..……………………………………………………………
…………………………………………………………………………………………….

10. If you would move to another place/house would **you** like to have the vacuum toilet system or would you prefer the conventional way or another system?

O Same sanitation system

O Conventional way

Other comments…………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………………………..

11. What mark would you give the vacuum toilet system as it is now?

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

Reason:…………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

Grey water system

12. Are you satisfied with the **grey water** system? (explain)

- o Very satisfied - 0
- o Satisfied - 1
- o Neutral - 2
- o Dissatisfied - 3
- o Very dissatisfied - 4

because………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

13. Does the **grey water** process produce unpleasant odours in your opinion?

- o Not at all - 0
- o A little bit - 1
- o Sometimes - 2
- o Very often - 3
- o Always - 4

14. If unpleasant odours occur, in which months?

Jan – Feb – March – April – May – June – July – Aug – Sept – Oct – Nov – Dec

15. Does the **grey water** system produce any annoying noise level in your opinion?

O Not at all – 0
O A little bit – 1
O Sometimes – 2
O Very often – 3
O Always – 4

16. What do you think of the visible part of the grey water system near your apartment?

- o Beautiful - 0
- o Nice - 1
- o Not disturbing - 2
- o Annoying - 3
- o Really awful - 4

Comments…………………………………………………………………………………………
……………………………………………………………………………………………………

17. Can you recommend the **grey water** system to other households in other neighbourhoods?

O Yes I will actively recommend it – 0
O Yes I will – 1
O Do not know – 2
O Not without improvement – 3
O Not at all – 4

Comments…………………………………………………………………………………………
……………………………..…………………………………………………………………
…………………………………………………………………………………………….

18. If you would move to another place/house would **you** like to have the same grey water system or would you prefer the conventional way or another system?

O Same sanitation system

O Conventional way

O Another system, namely…………………………………………………………………….

Other comments………………………………………………………………………………
………………………………………………………………………………………………………
………………………………………………………………………………………………………

19. What mark would you give the **grey water** system as it is now?

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

Reason:……………………………………………………………………………………………
……………………………………………………………………………………………
……………………………………………………………………………………………

Complete system

20. Have you made any adaptations to the sanitation system as originally installed? (If yes, what and why)

O no

O yes

What………………………………………………………………………………………………
………………………………………………………………………………………………
Why………………………………………………………………………………………………
………………………………………………………………………………………………

Dimension system robustness:

21. How many times per year does a failure/blockage occur with your vacuum toilet?

……………………failures/year

22. How many times per year does the complete system fails/blocks?

…………………..failures/year

Only to be asked if one or both last questions was/were higher than 0 failures per year

23. Which parts of the wastewater management system failed/was out of order? What was the problem? When and how often does it happen? How did you solve it and who did it?

Part of the system	Problem	When? (Date)	often? (t/m /y)	Solution	Solved

24. When the sanitation system fails, what is the average down time in hours?

…………hours/failure

Dimension public health:

25. What is the chance that you could come into direct contact with untreated or partially treated waste water? (in %)

    …………%

26. Have you suffered some kind of illness due to the ecological sanitation system system?

    O No

    O Yes, explain.

    ....

    ....

Background questions on user perspective

Background question

27. What kind of study do you do?

    O Economics
    O Agricultural sciences and forestry
    O Engineering
    O Planning
    O Landscape architecture
    O Natural sciences
    or
    O PhD (which direction? Mark 1 of the above 6 directions)

Involved questions

28. Do you feel environmentally concerned?

    O Always – 0
    O Very often – 1
    O Sometimes – 2
    O A little bit – 3
    O Not at all – 4

29. Did the sanitation system make you more environmentally concerned?

    O Yes
    O No

30. Which aspect(s) of the ecological sanitation system do you think has/have a good future?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
…………………………………………………………………………………………………….

31. What kind of benefits of the ecological sanitation system do you experience?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

32. What kind of drawbacks of the ecological sanitation system do you experience?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Appendix 6 User perception-interview “Torvetua”

HOUSEHOLD SURVEY including vacuum toilets

Your opinion about how you experience the system is important to us for making this survey successful.
The interview will take around 20 minutes.
All the information you give will be treated confidentially and will not be shown to anyone else.

Questionnaire No:………………..............Institution:…………………………………….

Date:……………………Respondent name: ……………………………………………Age:……

Gender:………………...Role in Household………………………………………………………

Address: Street……………………………………………………….. No………………

District:…………………….…………… Ward:…………………………………..

Household information items:

1. How many people does your household have?

   …………..number

2. What is the composition of the household?

   O Single
   O One parent family
   O Two parent family
   O Married (no kids)
   O Living together (no kids)

3. How many members of the household spend the day outside home (school, work)?

   ………..persons

4. How many persons are spending the night at home at least 5 days per week?

   …………persons

5. For how long do you already live in the neighbourhood?

   ………….years (O from the beginning)

6. Do you own or rent the house?

   O Own -0
   O Rent -1

7. Did you come to live here especially for the ecological aspects of the neighbourhood?

O Yes - 0
O No - 1
O Wasn't aware of it - 2

Sanitation system description:

8. What is the estimated annual operating cost in NOK per household for the sanitation system?

……………NOK

9. Did you receive any funding assistance for the ecological aspect?

O Yes, how much?...
O No

Performance dimension, invisibility and user comfort:

Black water system

10. Is your household satisfied with the **black water** system? (explain)

- o Very satisfied - 0
- o Satisfied - 1
- o Neutral - 2
- o Dissatisfied - 3
- o Very dissatisfied - 4

because………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

11. Is the vacuum toilet easily kept clean?

O Yes - 0
O No - 1

Reason,…………………………………………………………………………………………

12. Does the vacuum toilet produce any annoying noise in your opinion?

O Yes - 0
O No - 1

Reason,…………………………………………………………………………………………

13. Who is the owner of the vacuum toilet? *(Especially important for house owners)*

…………………………………………………………………………………………………..

Next question only to be answered by house owners

14. Did you ever consider to replace the vacuum toilet with another toilet?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

15. Are there any other comments in relation to the vacuum toilet that you would like to mention?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

16. Can you recommend the **vacuum toilet** system to other households in other neighbourhoods?

O Yes I will actively recommend it – 0
O Yes I will – 1
O Do not know – 2
O Not without improvement – 3
O Not at all – 4

Comments………………………………………………………………………………

…………………………………………………………………………………………………

17. If you would move to another place/house would **you** like to have the vacuum toilet system or would you prefer the conventional way?

O Same sanitation system

O Conventional way

Other comments…………………………………………………………………………

…………………………………………………………………………………………………

18. What mark would you give the **vacuum toilet** system as it is now?

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

Reason:…………………………………………………………………………………

…………………………………………………………………………………………………

Grey water system

19. Is your household satisfied with the **grey water** system? (explain)

    - o Very satisfied - 0
    - o Satisfied - 1
    - o Neutral - 2
    - o Dissatisfied - 3
    - o Very dissatisfied - 4

    because…………………………………………………………………………………

    …………………………………………………………………………………………

20. Does the **grey water** process produce unpleasant odours in your opinion?

    - o Not at all - 0
    - o A little bit - 1
    - o Sometimes - 2
    - o Very often - 3
    - o Always - 4

21. If unpleasant odours occur, in which months?

Jan – Feb – March – April – May – June – July – Aug – Sept – Oct – Nov – Dec

22. Does the **grey water** system produce annoying noise level in your opinion?

    O Not at all – 0
    O A little bit – 1
    O Sometimes – 2
    O Very often – 3
    O Always – 4

23. Can you recommend the **grey water** system to other households in other neighbourhoods?

    O Yes I will actively recommend it – 0
    O Yes I will – 1
    O Do not know – 2
    O Not without improvement – 3
    O Not at all – 4

    Comments…………………………………………………………………………………

    ……………………………..…………………………………………………………………

24. If you would move to another place/house would **you** like to have the **grey water** system or would you prefer the conventional way or another system?

    O Same sanitation system

    O Conventional way

    Other comments…………………………………………………………………………

25. What mark would you give the **grey water** system as it is now?

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

Reason:……………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Complete system

26. Have you / your household made any adaptations to the sanitation system as originally installed? (If yes, what and why)

O no

O yes

What…………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

Why……………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

27. Is there a visible part of the sanitation system near your house?

O yes (go to next question)
O no (skip next 2 questions)

28. What do you think of the visible part of the sanitation system in or near your house?

- o Beautiful - 0
- o Nice - 1
- o Not disturbing - 2
- o Annoying - 3
- o Really awful - 4

Comments…………………………………………………………………………………

……………………………………………………………………………………………

29. Is the visible part of the sanitation system in or near your house vulnerable to damage/failure?

  o Not at all - 0
  o A little bit - 1
  o Sometimes - 2
  o Very often - 3
  o Always - 4

What is vulnerable? ……..…………………………………………………………………

…………………………………………………………………………………………………

Dimension system robustness:

30. How many times per year does a system failure/blockage occur with your vacuum toilet?

……………………failures/year

31. How many times per year does the complete vacuum system fails?

……………………failures/year

32. How many times per year does the grey water system fails?

……………………failures/year

Only to be asked if one or two or all last 3 questions was/were higher than 0 failures per year

33. Which parts of the sanitation system failed/was out of order? What was the problem? When and how often does it happen? How did you solve it and who did it?

Part of the system	Problem	When ? (Date)	often? (t/m /y)	Solution	Solved

34. When the sanitation system fails, what is the average down time in hours?

…………hours/failure

Dimension public health:

35. What is the chance that you could come into direct contact with untreated or partially treated water (in percentages)?

    ……………….%

36. Have you suffered some kind of illness due to the wastewater management system?

    O No

    O Yes, explain.

    ....

    ....

    ....

37. Has anyone in your household ever been physically injured in using or maintaining the sanitation system? (If yes, how often, nature and cause or injury)

    O No
    O Yes,

    How often………………………………………………………………………………

    Nature

    ……………………………………………………………………………………………

    ……..…………………………………………………………………………………….

    Cause

    ………………………………………………………………………………………………

    ………………………………………………………………………………………………

Background questions on user perspective

Background questions

38. Did you do a higher education after high school/ youth school?

    O No
    O Yes, Yrkesfag (or similar education) – work subjects – for work (mechanic, electrician, healthcare etc)
    O Yes, Almennfag (or similar education) – common subjects- for bachelor/master

Involved questions

39. Do you feel environmentally concerned?

O Always –0
O Very often –1
O Sometimes –2
O A little bit –3
O Not at all –4

40. Did the sanitation system make you **more** environmentally concerned?

O Yes
O No

41. Which aspect(s) of the sanitation system do you think has/have a good future?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

42. What kind of benefits of the ecological sanitation system do you experience?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

43. What kind of drawbacks of the ecological sanitation system do you experience?

……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………
……………………………………………………………………………………………………

Appendix 7 Number of municipal treatment plants, by county. 2003

Statistics Norway
Statistisk sentralbyrå

Municipal waste water treatment. Discharges, treatment efficiencies and sludge disposal

1 Number of municipal treatment plants, by county. 2003

Region	Total[1]	Direct discharges	Mechanical	Chemical	Biological	Chemical-biological	Other treatment	Small treatment plants (<50 PE)
Total 2001	**2 639**	**700**	**976**	**256**	**125**	**299**	**283**	**336 321**
Total 2002	**2 530**	**570**	**1 027**	**250**	**129**	**278**	**276**	**340 204**
Total 2003	**2 549**	**558**	**1 029**	**250**	**133**	**296**	**283**	**368 330**
2003								
North Sea counties (1-10)	653	11	38	211	31	226	136	192 090
Rest of the counties (11-20)	1 896	547	991	39	102	70	147	176 240
1. Østfold	37	-	1	10	-	23	3	19 916
2-3. Akershus og Oslo	59	4	1	26	-	18	10	22 303
4. Hedmark	92	2	-	31	3	35	21	39 495
5. Oppland	157	1	5	18	4	66	63	31 598
6. Buskerud	87	-	1	47	2	20	17	19 326
7. Vestfold	40	-	2	12	3	18	5	22 167
8. Telemark	74	-	2	34	11	17	10	14 781
9. Aust-Agder	40	-	3	17	2	15	3	11 434
10. Vest-Agder	67	4	23	16	6	14	4	11 070
11. Rogaland	201	22	136	9	6	5	23	21 236
12. Hordaland	323	31	236	1	25	12	18	30 093
14. Sogn og Fjordane	177	21	132	2	11	6	5	14 095
15. Møre og Romsdal	475	202	236	2	2	4	29	25 349
16. Sør-Trøndelag	119	10	41	7	19	14	28	23 519
17. Nord-Trøndelag	113	6	40	10	21	20	16	13 214
18. Nordland	250	125	90	2	13	2	18	29 680
19. Troms	125	54	56	4	3	3	5	11 823
20. Finnmark Finnmárku	113	76	24	2	2	4	5	7 231

1 Small treatment plants are not included.

Explanation of symbols

2005 © Statistics Norway

Source: http://www.ssb.no/avlut_en/tab-2005-01-27-01-en.html

Appendix 8 Municipal wastewater treatment. Investment, costs, fee income, and cost coverage ratio. 1993-2003. Current prices

Statistics Norway
Statistisk sentralbyrå

Municipal waste water treatment. Discharges, treatment efficiencies and sludge disposal

4 Municipal wastewater sector. Investment, costs, fee income, and cost coverage ratio. 1993-2003. Current prices

	Investment in wastewater treatment plants	Investment in sewerage network	Total investment	Maintenance, running and overhead costs	Capital costs	Annual costs	Fee income	Cost coverage ratio
	NOK million							Per cent
Total 1993	347	964	1 311	.	.	.	.	.
Total 1994	392	1 044	1 436	1 596	1 340	2 936	2 753	94
Total 1995	313	1 118	1 431	1 706	1 407	3 113	2 957	95
Total 1996	279	1 066	1 344	1 776	1 411	3 187	3 094	97
Total 1997	196	1 229	1 424	1 846	1 339	3 184	3 280	103
Total 1998	471	1 337	1 807	1 929	1 499	3 428	3 455	101
Total 1999	601	1 362	1 963	2 074	1 832	3 906	3 668	94
Total 2000	503	1 256	1 759	2 181	1 826	4 007	4 024	100
Total 2001	436	1 250	1 686	2 394	2 003	4 397	3 993	91
Total 2002	338	1 407	1 745	2 415	1 802	4 216	4 067	96
Total 2003	401	1 456	1 857	2 574	1 706	4 280	4 280	100
2003								
North Sea counties (1-10)	171	867	1 038	1 620	991	2 611	2 619	[1]100
Rest of the counties (11-20)	230	589	819	954	715	1 669	1 661	100

1 The figure was corrected 27 January 2005 at 1130.

Explanation of symbols

2005 © Statistics Norway

Source: http://www.ssb.no/english/subjects/01/04/20/avlut_en/tab-2005-01-27-04-en.html

Appendix 9 Water fees, for a private dwelling of 120 m^2. Municipal figures. 2005. NOK

Statistics Norway
Statistisk sentralbyrå

Municipal water supply - KOSTRA

1 Water fees, for a private dwelling of 120 m^2. Municipal figures. 2005. NOK

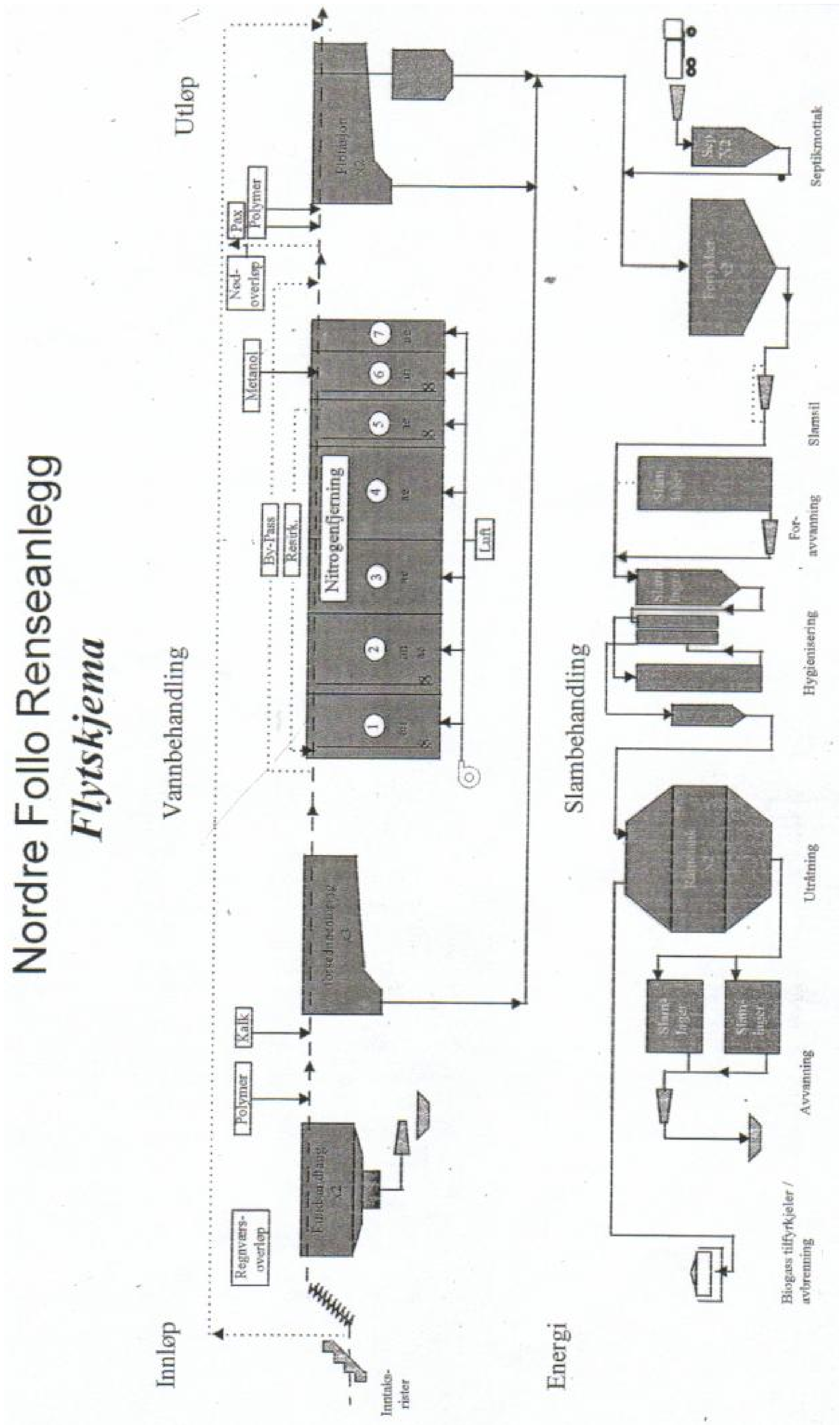
		Two-level fee system		Payment by water used		Connection fee	
	Fixed annual fee	Variable portion (per m^3 water used)	Fixed portion	Variable portion (per m^3 water used)	Minimum use charged	Lowest level	Highest level
Country average							
2003	2 055	7.04	1 044	9.08	177	7 544	10 556
2004	2 076	7.06	1 145	9.16	146	7 331	10 556
2005	2 132	7.22	1 079	8.05	149	7 596	10 828
County average							
Østfold	1 553	8.68	672	8.95	85	5 919	7 486
Akershus	1 966	10.08	821	9.42	95	9 098	18 326
Oslo	912	..	84	9.02	..	..	..
Hedmark	2 576	11.51	742	11.33	82	8 704	11 035
Oppland	2 206	10.16	855	10.92	121	6 739	12 988
Buskerud	2 414	9.50	530	11.11	104	8 413	13 249
Vestfold	1 788	5.41	823	6.07	110	10 111	13 120
Telemark	1 993	7.65	1 408	8.13	135	3 875	5 493
Aust-Agder	1 867	5.35	1 032	5.58	143	9 690	8 303
Vest-Agder	1 667	5.28	750	5.41	68	10 050	11 806
Rogaland	1 607	5.37	811	5.53	234	8 647	9 356
Hordaland	2 396	6.85	1 317	8.26	128	10 904	12 096
Sogn og Fjordane	2 447	7.00	1 340	7.67	167	6 898	9 333
Møre og Romsdal	2 143	4.08	1 398	7.41	207	6 604	9 724
Sør-Trøndelag	2 464	7.40	1 430	8.17	220	9 716	13 471
Nord-Trøndelag	2 136	7.07	1 202	8.11	164	5 714	9 685
Nordland	2 254	7.02	1 384	7.92	178	6 146	9 377
Troms	2 088	5.66	1 140	6.14	202	4 637	5 041
Finnmark Finnmárku	2 111	5.85	1 281	5.90	483	8 099	7 274

Explanation of symbols

2005 © Statistics Norway

Source: http://www.ssb.no/english/subjects/01/04/20/vann_kostra_en/tab-2005-06-30-01-en.html

Appendix 10 Flow scheme of Nordre Follo Renseanlegg in Vinterbro



Appendix 11 Regulation what is forbidden to flush down vacuum toilet at Kaja

Fôring og stell av ditt kretsløpsbaserte vakuumtoalett

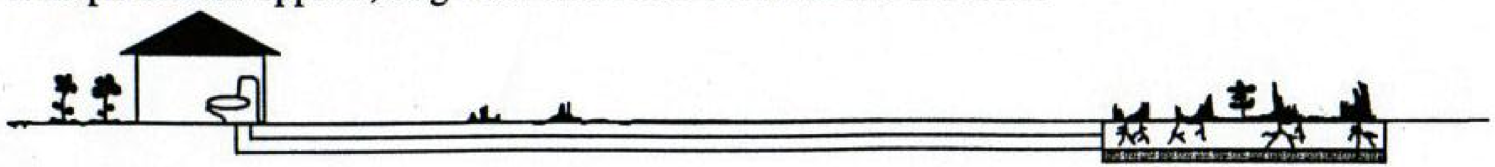
The care and feeding of your vacum toilet

"Drit med omtanke"

Det følgende må ikke spyles ned:
Forbidden to flush down the toilet:

- matavfall - *food waste*
- bind/tamponger - *sanitary napkins/tampoons*
- bomullspinner - *q-tips*
- kondomer - *condoms*
- husholdningskjemikaler og produkter, f.eks maling, klor, medisinrester
  household chemicals and products, for example paint, clorox, old medicine
- skarpe gjenstander: de kan skade gummimembranen i utløpet
  sharp objects: they can damage the rubber pipe seal
- sigarettsneiper - *cigarette butts*

* Hvis problemer oppstår, ring 7484 eller 9869 eller mobil 942 38 062



Appendix 12 JETS microbe cleaner safety data sheet

Material Safety Data Sheet
According to 2001/58/EC

Printing date: 25.11.2002 Reviewed on: 17.07.2002

1 Identification of substance:

* **Product details:**
  * **Trade name: Careclean Sewage**
    * **Application of the substance / the preparation**
      Anti-fouling agent
      Cleaning agent/ Cleaner
  * **Manufacturer/Supplier:**
    Marine Care
    Klompenmakerstraat 45A
    Hoogvliet
    The Netherlands

    Tel.: +31 - (0)10 29 50 342
    Fax : +31 - (0)10 29 50 345
  * **Informing department:** Industrial Safety Department
  * **Emergency information:**
    MARINE CARE

    Tel.: +31 - (0)10 29 50 342
    Fax : +31 - (0)10 29 50 345

2 Composition/Data on components:

* **Chemical characterization**
  * **Description:**
    Mixture of ubiquitous bacteria.
    Mixture of several enzymes.
  * **Dangerous components:** Void
  * **Additional information** For the wording of the listed risk phrases refer to section 16.

3 Hazards identification

* **Hazard designation:** void
* **Information pertaining to particular dangers for man and environment**
  The product does not have to be labelled due to the calculation procedure of the "General Classification guideline for preparations of the EU" in the latest valid version.
* **Classification system**
  The classification is in line with current EC lists. It is expanded, however, by information from technical literature and by information furnished by supplier companies.

4 First aid measures

* **General information**

Z Instantly remove any clothing soiled by the product.

No special measures required.
* **After inhalation** Not applicable.
* **After skin contact**
  Instantly wash with water and soap and rinse thoroughly.
  If skin irritation continues, consult a doctor.
* **After eye contact**
  Rinse opened eye for several minutes under running water. If symptoms persist, consult doctor.

(Contd. on page 2)

GB

Material Safety Data Sheet
According to 2001/58/EC

Printing date: 25.11.2002 Reviewed on: 17.07.2002

Trade name: Careclean Sewage

(Contd. of page 1)

* **After swallowing**
Rinse out mouth and then drink plenty of water.
In case of persistent symptoms consult doctor.

5 Fire fighting measures

* **Suitable extinguishing agents** Use fire fighting measures that suit the environment.
* **Protective equipment:** No special measures required.
* **Additional information** Cool endangered containers with water spray jet.

6 Accidental release measures

* **Person-related safety precautions:** Not required.
* **Measures for environmental protection:** Dilute with much water.
* **Measures for cleaning/collecting:**
Absorb with liquid-binding material (Oil Adsorbent, sand, diatomite, acid binders, universal binders).
Clean the accident area carefully; suitable cleaners are:
warm water
* **Additional information:** No dangerous materials are released.

7 Handling and storage

* **Handling**
* **Information for safe handling:**
No special measures required.
When diluting, always stir the product into standing water.
* **Information about protection against explosions and fires:** No special measures required.

* **Storage**
* **Requirements to be met by storerooms and containers:**
Store in cool location.
No special requirements.
* **Information about storage in one common storage facility:** Not required.
* **Further information about storage conditions:**
Protect from heat and direct sunlight.
Protect from frost.
* **Storage class**
* **Class according to regulation on inflammable liquids:** Void

8 Exposure controls and personal protection

* **Additional information about design of technical systems:** No further data; see item 7.

* **Components with limit values that require monitoring at the workplace:**
The product does not contain any relevant quantities of materials with critical values that have to be monitored at the workplace.
* **Additional information:** The lists that were valid during the compilation were used as basis.

* **Personal protective equipment**
* **General protective and hygienic measures**
The usual precautionary measures should be adhered to general rules for handling chemicals.
Take off immediately all contaminated clothing
Wash hands during breaks and at the end of the work.
* **Breathing equipment:** Not required.
* **Protection of hands:** Not required.

(Contd. on page 3)

Material Safety Data Sheet
According to 2001/58/EC

Printing date: 25.11.2002 Reviewed on: 17.07.2002

Trade name: Careclean Sewage

(Contd. of page 2)

* **Eye protection:**

R Safety glasses recommended during refilling.

9 Physical and chemical properties:

* **General Information**	
* **Form:**	Fluid
* **Colour:**	White
* **Odour:**	Sweetish
* **Change in condition**	
* **Melting point/Melting range:**	- 1°C
* **Boiling point/Boiling range:**	101°C
* **Flash point:**	Not applicable
* **Inflammability (solid, gaseous)**	Product is not inflammable.
* **Self-inflammability:**	Product is not selfigniting.
* **Danger of explosion:**	Product is not explosive.
* **Vapour pressure at 20°C:**	23 hPa
* **Density at 20°C**	1.01 g/cm3
* **Solubility in / Miscibility with**	
* **Water:**	Fully miscible
* **pH-value at 20°C:**	5.5 - 8.5

10 Stability and reactivity

* **Thermal decomposition / conditions to be avoided:**
No decomposition if used according to specifications.
* **Dangerous reactions** No dangerous reactions known
* **Dangerous products of decomposition:** No dangerous decomposition products known

11 Toxicological information

* **Acute toxicity:**
  * **Primary irritant effect:**
    * **on the skin:** No irritant effect.
    * **on the eye:** No irritant effect.
  * **Sensitization:**
  Sensitizing effect by skin contact is possible by prolonged exposure.
  No sensitizing effect known.
* **Additional toxicological information:**
The product is not subject to classification according to the calculation method of the General EC Classification Guidelines for Preparations as issued in the latest version:
When used and handled according to specifications, the product does not have any harmful effects according to our experience and the information provided to us.

GB

(Contd. on page 4)

Material Safety Data Sheet

According to 2001/58/EC

Printing date: 25.11.2002 Reviewed on: 17.07.2002

Trade name: Careclean Sewage

(Contd. of page 3)

12 Ecological information:

* **General notes:**
Generally not hazardous for water.
In accordance with the requirements of the RVO on the Act on Detergents and Cleansing Agents, tensides are biodegradable up to at least 90 %.

13 Disposal considerations

* **Product:**
  * **Recommendation**
  Smaller quantities can be disposed with household waste.
  Contact manufacturer for recycling information.

* **Uncleaned packagings:**
  * **Recommendation:** Packaging can be reused or recycled after cleaning.
  * **Recommended cleaning agent:** Water.

14 Transport information

* **Land transport ADR/RID (cross-border)**
  * **ADR/RID-GGVS/E Class:** -

* **Maritime transport IMDG:**
  * **IMDG Class:** -

* **Air transport ICAO-TI and IATA-DGR:**
  * **ICAO/IATA Class:** -

* **Transport/Additional information:** Not dangerous according to the above specifications.

15 Regulatory information

* **Designation according to EC guidelines:**
Observe the normal safety regulations when handling chemicals
The product is not subject to identification regulations under EC Directives and the Ordinance on Hazardous Materials (GefStoffV).

* **National regulations**
  * **Classification according to VbF:** Void
  * **Water hazard class:** Generally not hazardous for water.

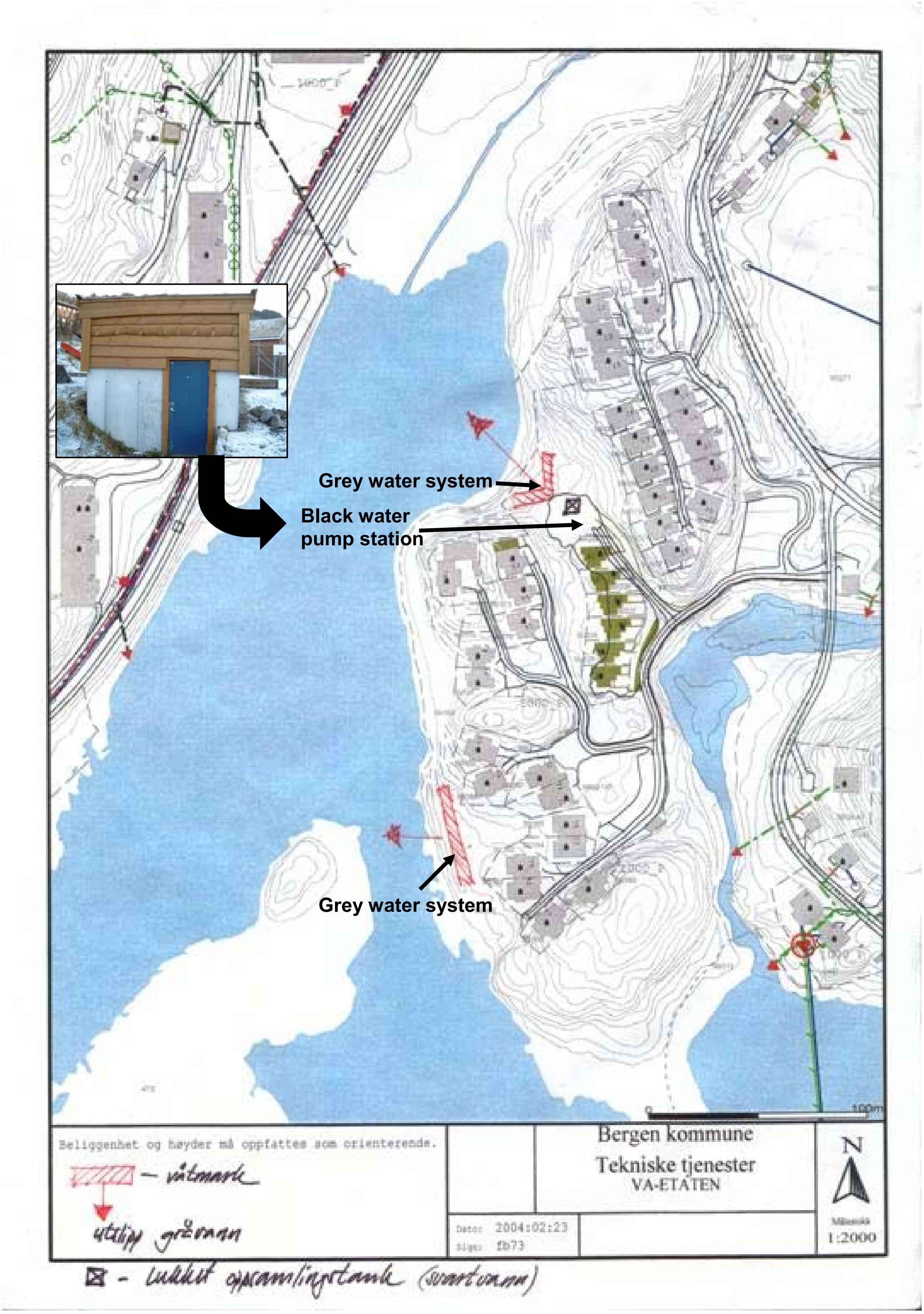
16 Other information:

These data are based on our present knowledge. However, they shall not constitute a guarantee for any specific product features and shall not establish a legally valid contractual relationship.
The chapters that have been updated are marked with an asterix (*).

* **Department issuing data specification sheet:** Quality, Environment and Safety Department
* **Contact:** Q/E/S Manager

GB

Appendix 13 Top view of Torvetua including the two grey water systems and black water pump station



Appendix 14 Economical figures of Torvetua from 2000 – 2004

Kontonavn	Aktive Konto Numre	Budsjett 2004 [kr]	Regnskap 2004 [kr]	Regnskap 2003 [kr]	Regnskap 2002 [kr]	Regnskap 2001 [kr]	Regnskap 2000 [kr]	Avvik [kr]	Avvik [%]
Possesions		**0,00**	**1.476.498,12**	**1.242.315,72**	**226.536,00**	**1.192.030,79**	**0,00**		
Bank		**0,00**	**1.460.247,12**	**1.225.169,72**	**204.000,00**	**1.178.328,79**	**0,00**	**-1.460.247,12**	0,0 %
Kbank Bedriftskonto (Brukskonto)	1110		181.605,35	4.340,23		38.808,78		-181.605,35	0,0 %
Kbank Sparekonto (Hensettelse)	1120		215.624,09	213.280,05	204.000,00	192.467,74		-215.624,09	0,0 %
Kbank Særinnskudd (VA-fond/Husbank).	1130		1.063.017,68	1.007.549,44		947.052,27		-1.063.017,68	0,0 %
Kontanter		**0,00**	**51,00**	**51,00**	**2.000,00**	**0,00**	**0,00**	**-51,00**	**0,0 %**
Pengekasse	1210		51,00	51,00	2.000,00	0,00		-51,00	0,0 %
Andre fordringer		**0,00**	**16.200,00**	**17.095,00**	**20.536,00**	**13.702,00**	**0,00**	**-16.200,00**	**0,0 %**
Fordringer	1310		16.200,00	17.095,00	20.536,00	13.702,00		-16.200,00	0,0 %
Debt		**0,00**	**134.173,73**	**20.481,00**	**98.864,00**	**24.854,05**	**0,00**	**-134.173,73**	**0,0 %**
Langsiktig gjeld		**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,00**	**0,0 %**
Kortsiktig gjeld		**0,00**	**134.173,73**	**20.481,00**	**98.864,00**	**24.854,05**	**0,00**	**-134.173,73**	**0,0 %**
Påløpne kostnader, leverandør med mer	2210		134.173,73	20.156,00	97.939,00	9.044,05		-134.173,73	0,0 %
Periodiserte kostnader	2220		0,00	0,00				0,00	0,0 %
Forskuddsbetalt husleie	2230		0,00	325,00	925,00	15.810,00		0,00	0,0 %
Income		**511.500,00**	**525.885,68**	**471.364,09**	**430.795,00**	**422.706,59**	**336.426,00**	**-14.385,68**	**2,8 %**
Husleie	3100	**480.000,00**	**480.000,00**	**438.350,50**	**390.558,00**	**404.124,00**	**325.000,00**	**0,00**	**0,0 %**
Vannavgifter	3200	**3.500,00**	**3.500,00**	**3.000,00**	**3.000,00**	**2.800,00**	**2.600,00**	**0,00**	**0,0 %**
Kapitalinntekter		**4.000,00**	**18.385,68**	**9.613,59**	**16.837,00**	**15.782,59**	**8.826,00**	**-14.385,68**	**359,6 %**
Kreditkassen [1110 Bedrift; 1120 Sparekonto]	3310	4.000,00	2.653,53	9.613,59	16.837,00	15.782,59		1.346,47	-33,7 %
Kreditkassen [1130 VA-fond/Husbank]	3330	0,00	15.732,15	0,00		60.604,00		-15.732,15	0,0 %
Andre inntekter		**24.000,00**	**24.000,00**	**20.400,00**	**20.400,00**	**0,00**	**0,00**	**0,00**	**0,0 %**
Dugnad	3410	24.000,00	24.000,00	20.400,00	20.400,00			0,00	0,0 %
Expenses		**511.500,00**	**445.132,10**	**491.703,37**	**416.296,00**	**400.010,92**	**268.241,00**	**66.367,90**	**13,0 %**
Tech facilities		**365.000,00**	**335.987,85**	**368.878,30**	**338.301,00**	**292.008,69**	**194.241,00**	**29.012,15**	**7,9 %**
Tap water fac		**40.000,00**	**5.221,72**	**39.139,25**	**45.747,00**	**20.942,35**	**31.173,00**	**34.778,28**	**86,9 %**
Operation - material	4111	10.000,00	0,00	4.259,60	7.564,00	11.332,00	13.093,00	10.000,00	100,0 %
Service - operation problems	4112	10.000,00	1.305,72	11.037,24	21.633,00		5.534,00	8.694,28	86,9 %
Servive - planned maintenance	4113	20.000,00	3.916,00	23.842,41	16.550,00	8.972,00	12.546,00	16.084,00	80,4 %
Water analyses	4114	0,00	0,00	0,00		638,35		0,00	0,0 %
Investmetn/Depreciation	4118	0,00	0,00	0,00				0,00	0,0 %
Other	4119	0,00	0,00	0,00				0,00	0,0 %
Grey water		**10.000,00**	**2.556,00**	**17.171,70**	**2.500,00**	**0,00**	**0,00**	**7.444,00**	**74,4 %**
Operation - material, emptying	4121	10.000,00	0,00	0,00	2.500,00			10.000,00	100,0 %
Service - operation problems	4122	0,00	0,00	3.943,20				0,00	0,0 %
Servive - planned maintenance	4123	0,00	2.556,00	13.228,50				-2.556,00	0,0 %
Water analyses	4124	0,00	0,00	0,00				0,00	0,0 %
Investmetn/Depreciation	4128	0,00	0,00	0,00				0,00	0,0 %
Other	4129	0,00	0,00	0,00				0,00	0,0 %
Black water		**240.000,00**	**196.935,89**	**230.153,22**	**205.952,00**	**194.085,19**	**140.963,00**	**43.064,11**	**17,9 %**
Operation - material, emptying	4131	225.000,00	175.445,89	198.774,92	193.261,00	156.655,50	104.549,00	49.554,11	22,0 %
Service - operation problems	4132	5.000,00	21.230,00	10.282,30	6.317,00	15.395,79	9.385,00	-16.230,00	-324,6 %
Servive - planned maintenance	4133	10.000,00	260,00	6.216,00	6.374,00	16.526,00	27.029,00	9.740,00	97,4 %
Water analyses	4134	0,00	0,00	0,00				0,00	0,0 %
Investmetn/Depreciation	4138	0,00	0,00	14.880,00		1.529,60		0,00	0,0 %
Other	4139	0,00	0,00	0,00		3.978,30		0,00	0,0 %
Tech maintenance		**40.000,00**	**28.525,00**	**39.346,35**	**58.844,00**	**50.259,15**	**3.928,00**	**11.475,00**	**28,7 %**
Maintenance/administration	4149	40.000,00	28.525,00	39.346,35	58.844,00	50.259,15	3.928,00	11.475,00	28,7 %
Electricity system		**35.000,00**	**102.749,24**	**43.067,78**	**25.258,00**	**26.722,00**	**18.177,00**	**-67.749,24**	**-193,6 %**
Operation - electricity ,aterials and more	4161	35.000,00	43.273,74	43.067,78	25.258,00	26.722,00	18.177,00	-8.273,74	-23,6 %
Service - operation problems	4162	0,00	0,00	0,00				0,00	0,0 %
Service - planned maintenance	4163	0,00	0,00	0,00				0,00	0,0 %
Investmetn/Depreciation	4168	0,00	59.475,50	0,00				-59.475,50	0,0 %
Other	4169	0,00	0,00	0,00				0,00	0,0 %
Other operation		**52.000,00**	**50.165,94**	**36.679,84**	**37.732,00**	**27.665,85**	**15.984,00**	**1.834,06**	**3,5 %**
Snowremoval	4220	22.000,00	31.084,10	19.482,12	19.070,00	22.506,00	11.070,00	-9.084,10	-41,3 %
Pest animals	4230	6.000,00	6.901,84	5.707,72	5.462,00	5.159,85	4.914,00	-901,84	-15,0 %
Outside maintenance by inhabitants	4240	24.000,00	12.180,00	11.490,00	13.200,00			11.820,00	49,3 %
Improving living surroundings		**30.000,00**	**25.995,31**	**35.696,23**	**14.017,00**	**27.183,28**	**49.881,00**	**4.004,69**	**13,3 %**
Arrangements/parties bbq	4510	10.000,00	3.467,00	2.099,30	5.935,00	566,00		6.533,00	65,3 %
Greenplan	4520	10.000,00	11.747,50	13.348,43	3.449,00	6.256,28		-1.747,50	-17,5 %
Playground facilities	4530	10.000,00	8.371,81	19.011,50	2.983,00	19.680,00	43.983,00	1.628,19	16,3 %
Other	4590	0,00	2.409,00	1.237,00	1.650,00	681,00	5.898,00	-2.409,00	0,0 %
Extraordinary expenses		**0,00**	**770,00**	**0,00**	**0,00**	**2.000,00**		**-770,00**	**0,0 %**
Loss on demands- no payment of bill	4890	0,00	770,00	0,00		2.000,00		-770,00	0,0 %
Administration		**64.500,00**	**32.213,00**	**50.449,00**	**26.246,00**	**51.153,10**	**8.135,00**	**32.287,00**	**50,1 %**
Board administration		**15.000,00**	**14.769,00**	**12.098,50**	**10.547,00**	45.947,50	5.385,00	231,00	1,5 %
Board administration	4911	14.000,00	14.000,00	10.789,00	10.058,00			0,00	0,0 %
Service fee	4918	1.000,00	769,00	1.309,50	489,00			231,00	23,1 %
Round-off amounts	4919	0,00	0,00	0,00				0,00	0,0 %
Honorary	4920	10.000,00	10.000,00	10.100,00	10.000,00			0,00	0,0 %
Legal help (lawyer)	4930	30.000,00	0,00	20.305,00		500,00		30.000,00	100,0 %
Accountant	4940	7.500,00	6.944,00	6.045,00	4.464,00	3.000,00	2.750,00	556,00	7,4 %
Gifts	4950	2.000,00	500,00	1.900,50	1.235,00	1.705,60		1.500,00	75,0 %

Income	511.500,00	525.885,68	471.364,09	430.795,00	422.706,59	336.426,00
Expenses	511.500,00	445.132,10	491.703,37	416.296,00	400.010,92	268.241,00
Result	0,00	80.753,58	-20.339,28	14.499,00	22.695,67	68.185,00

Appendix 15 Costs and benefits analysis of Kaja

KAJA

1 NOK is 100 Øre
45 Øre per kWh is NOK 0.45 http://ssb.no/elkraftpris_en/tab-2006-07-03-02-en.html

Expenditures			NOK	Euro	Normal costs	NOK	Euro	Extra costs	NOK	Euro
Installation costs sanitation system			**578560**	**€ 73.235**	**Connection fee******	**364500**	**€ 46.139**	**Installation**	214060	**€ 27.096**
Yearly operating costs			100000	€ 12.658				Yearly operating costs	100000	€ 12.658
Yearly energy costs	1557	kWh*	701	€ 89				Yearly energy costs	701	€ 89
Yearly costs drinking water	2000	m3	20500	€ 2.595	water costs****	26035	€ 3.296	Yearly costs drinking water	-5535	-€ 701
25% sewer water saving + 75% discount based on	1880	m3**	5860	€ 742	sewer water costs****	42228	€ 5.345	Yearly sewer water costs	-36367.2	-€ 4.603
Yearly costs collection and transport black water	12*5000	NOK	60000	€ 7.595				Yearly costs collection and transport black water	60000	€ 7.595
Yearly costs for monitoring grey water***				€ 500				Yearly costs for monitoring grey water		€ 500
Total yearly costs				**€ 24.179**			**€ 8.641**			**€ 15.538**

*The energy used is based on the kWh estimated

** 1880 m3 is derived from the fact that 6% of 2000 m3 is converted into black water. The costs for the 120 m3 of black water are included in the heading "yearly costs for collection and transport black water"

*** The monitoring of the grey water system is assumed twice a year for each system and is estimated to costs €250 per sample.

**** The costs for the connection fee is based on the average area per apartment of 50 m2 and on the costs mentioned in chapter 3. The water and sewer water costs are also obtained from chapter 3.

production of sewer water 7 l/person black water for Kaja
112 l/person grey water for Kaja

vacuum toilet 1 l per flush conventional toilet 4 l per flush
it is assumed that 15% of grey water is saved due to watersaving taps and showerheads

Increase in water consumption with conventional will be

7*4	28	zwart
112+15%	128.8	grijs
	156.8	l totaal

Increase in water amount to --> **2747** m3 per jaar
This consumption is taken into account instead of 2000 m3
difference 2747m3 and 2000m3 is **27%**

Appendix 16 Costs and benefits analysis of Torvetua

TORVETUA

1 NOK is 100 Øre
45 Øre per kWh is NOK 0.45 http://ssb.no/elkraftpris_en/tab-2006-07-03-02-en.html

Expenditures		NOK	Euro	**Normal costs**	NOK	Euro	**Extra costs**	NOK	Euro
Installation costs sanitation system		**Unknown**		**Connection fee******	**211200**	**€ 26.734**	**Installation**	**Unknown**	
				Yearly subscription costs****	47640	€ 6.030			
Yearly operating costs grey water system		Unknown					Yearly operating costs	Unknown	
Yearly operating costs black water water system*		20000	€ 2.532						
Yearly energy costs	5532 kWh**	2490	€ 315				Yearly energy costs	-45150	-€ 5.715
Yearly operating costs drinking water water system*	5900 m3	35000	€ 4.430	Yearly water costs****	32764	€ 4.147	Yearly water costs	2236	€ 283
Yearly costs collection and transport black water*		190000	€ 24.051	Yearly sewer water costs****	41800	€ 5.291	Yearly sewer water costs	190000	€ 24.051
Yearly costs for monitoring grey water***			€ 1.000				Yearly costs for monitoring grey water		€ 1.000
Total yearly costs			**€ 32.328**			**€ 15.469**			**€ 19.618**

* The yearly operating costs are based on the economical figures table from Torvetua. Averages are estimated

** The energy used is based on the kWh estimated

*** The monitoring of the grey water systems is assumed twice a year for each system and is estimated to costs €250 per sample.

**** The costs for the connection fee is based on the average area per households of 120 m2 and on the costs mentioned in chapter 3. The subscription, water and sewer water costs are also obtained from chapter 3.

production of sewer water 124.3 l/person for Torvetua

vacuum toilet 1 l per flush conventional toilet 4 l per flush, so 3 litres difference
grey water production will be the same, because there are no watersaving techniques applied at grey water system

Extra water consumption will be
7*3 **21** l extra black water production
124.3 l
145.3 l total

Increase in water amount to --> **6894** m3 per year for Torvetua
This consumption is taken into account instead of 5900 m3

diference 6894m3 and 5900m3 is **14.5%**