OtterWasser GmbH

OtterWasser
GmbH
Engelsgrube 81
D-23552 Lübeck
☎ (+49) 0451-70 200-51
-52
info@otterwasser.de
www.otterwasser.de

Final cost calculation report for the demonstration project "Sanitation Concepts for Separate Treatment of Urine, Faeces and Greywater " (SCST)

financed by: *Kompetenzzentrum Wasser Berlin gGmbH*
Berliner Wasserbetriebe
Anjou Recherche

co-financed by: the European Commission
(LIFE 03ENV/D/000025)

Cost Calculations

Dr.-Ing. Martin Oldenburg
(Managing Director)

March 2007

Table of Contents

1 Introduction

The discussion of sanitation concept differing from the conventional one, i.e. systems with one sewer system and a central wastewater treatment station, is an ongoing increasing process. These new sanitation concepts have the target of saving and reuse the water as well as the nutrients. The approach of being a more appropriate technology can be demonstrated by life cycle analysis (Peter-Fröhlich et al, 2007). Due to the lack of implementation and long time experiences detailed cost comparison are not available yet. First estimations have been done and have shown a tendency, but detailed investigations have been missing.

The results of the SCST-project, which represents an experience of four years implementation and operation of a new sanitation concept, will be used for a cost comparison of different sanitation systems.

It is obvious that the prerequisite for a successful implementation beside the technical applicability is the demonstration of the systems benefits. These new sanitation systems will receive only acceptance, when economical benefits or other significant benefits will support their introduction. Therefore studies of cost comparisons are necessary and an important issue.

2 Results of the Cost Calculations of the previous project phase

The first cost comparison has been made at the projects beginning and was a rough calculation basing on many assumptions. This study included a cost comparison between two new sanitation concepts with gravity and vacuum separation toilets and the conventional system. It could be demonstrated that the new sanitation concepts have not only ecological advantages but can also have economical advantages (Peter-Fröhlich et al, 2004).

Different sanitation systems have been compared with various cost levels for two different sizes of the housing estate.

In the Figure 1 only the sanitation concept with gravity separation toilets is significantly cheaper than the conventional system for the chosen housing estate of 672 inhabitants. With an increasing number of inhabitants, shown in Figure 2, both new sanitation concepts are cheaper compared to the conventional system after 3 and 9 years, respectively.

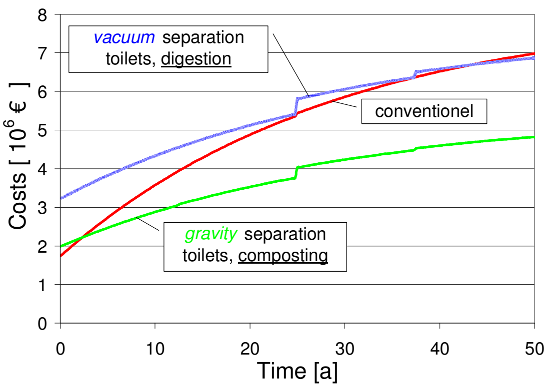

Figure 1: Total project costs for the conventional and the new sanitation concepts (672 inhabitants); cost basis: local company

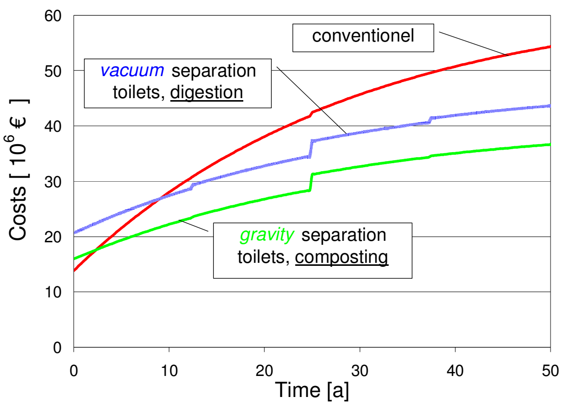

Figure 2: Total project costs for the conventional and the new sanitation concepts (*5,000* inhabitants); cost basis: *local company*

Also the investigation of other much lower cost levels for the fees of water and wastewater has shown benefits for the new sanitation concept especially for a larger size (Figure 3).

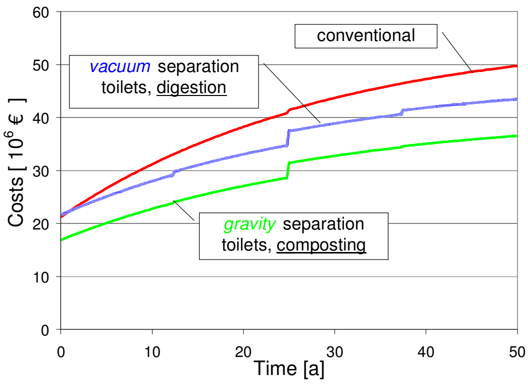

Figure 3: Total project costs for the conventional and the new sanitation concepts (*5,000* inhabitants); cost basis: *Berliner Wasserbetriebe*

Already in this phase of the project it was obvious that the result of the cost calculation is mainly depending the specific conditions of the housing estate.

Basing on the experience received from the installation and operation of the new sanitation concepts during a period of four years the cost calculations are made once again. With a much higher approach concerning details and with the knowledge from own operation the results will become more reliable.

3 Objectives

The cost calculations have to be made for an existing example otherwise there will be a lot of assumptions that weakens the cost calculations. The objective of the cost calculation is the comparability of the cost calculations for different sanitation concepts and the identification of the main influencing factors. Advantages and disadvantages of the different variants and their cost relevance will be investigated.

Beside these aspects the cost calculations should deliver information concerning the following issues.

- Due to the use of the same data frame for the ecological as well as economic investigation receiving a comparable level.
- Detailed information due to use of the costs received from the projects experience received from four years of operation.
- Receiving of reliable data for statements concerning the economical advantage and disadvantage of new sanitations concepts
- Confirmation of the results received from the former investigations.
- Identification of factors, which are very sensitive for the economical view.
- Support for the future introduction and application of new sanitation concepts.

4 Methods

4.1 Methodology

4.1.1 Specification of the chosen area

For the cost comparison an existing real estate area, Berlin Nicolassee, have been chosen. For this area data from a GIS-based system and data of the existing sewer system were available.

Table 1:Main data of the investigated area

Area	126 ha
Inhabitants	4,891
Single houses	649
Semidetached houses	98
Terraced houses	123
Multi storey buildings	130
No of units	1,000

A map of the area is shown in Figure 4 in which the project area is marked with the yellow colour. For the investigations this area which its known characteristics is treated as an independent working area, influences from the outer boundaries (buildings, roads etc.) have been neglected.

It is obvious that this is a low densely populated area typical for modern urban areas with single houses. Due to the lack of information public buildings installed in this area were not taken into consideration; the area has been reduced to a “living area”.

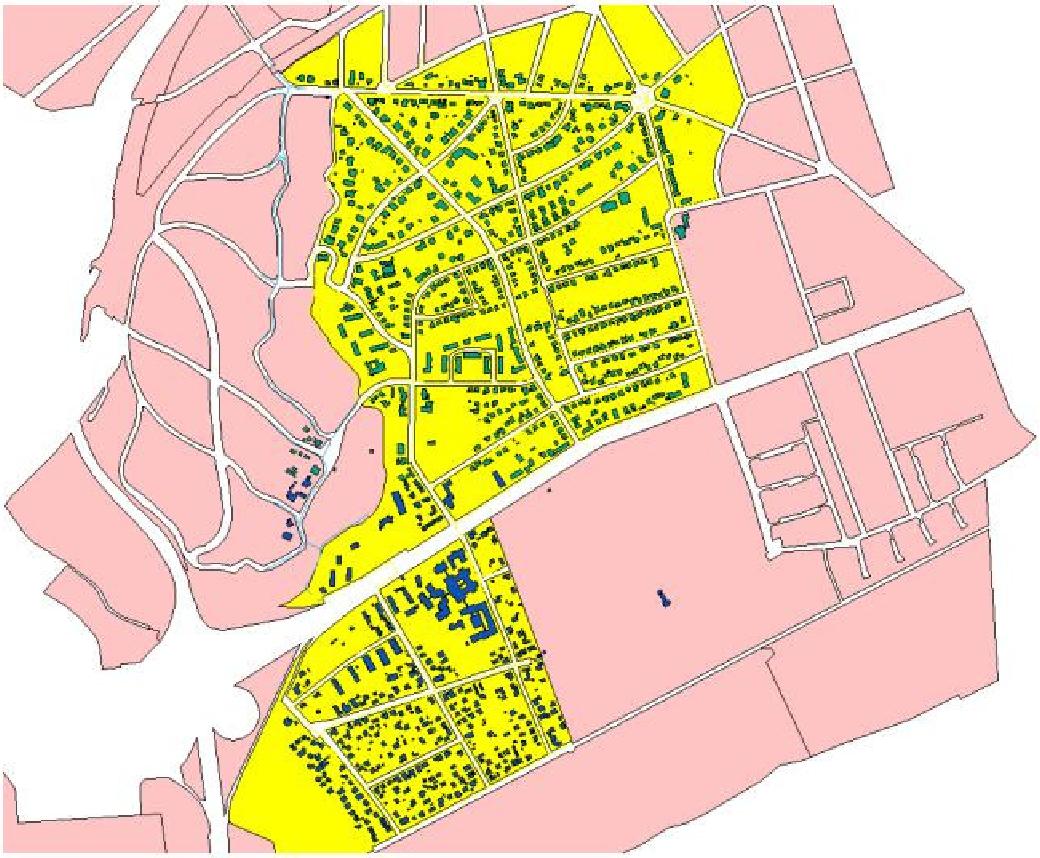

Figure 4: Map of the area Berlin-Nicolassee

For these area different sanitation systems have been planned and the cost for these systems have been calculated.

Due to the fact, that new sanitation concepts have also a significant impact on installation inside the houses, these were taken also in consideration. The framework of the investigation has been chosen from the source (toilet) the transport systems (pipes in the houses and outside of the houses) to the treatment station. Installations are not included which are the same for all systems or belonging to other technical areas like:

- Water supply network
- Rainwater management, treatment and/or utilisation
- Household appliance like washing machines, dish washers
- Sinks, showers, bathtubs
- Combined heat and power units (CHPU)

For each system the quantities of installations have been evaluated in detail like length and dimension of the pipes inside the houses as well as the size and depth of the sewers transporting the different flows of the various sanitation systems. For the quantities an appropriate price per unit have been chosen and used for the cost calculation. The similar way was taken for the treatment stages, here with the division in construction, machinery and electrical installation. For each item a specific lifetime has been given, this is the prerequisite for the dynamic cost calculation.

The basis of the specific prices have been the experience from this project during the construction phase in the apartment house and the office building, from other projects and from literature. Details are given in the annex.

All the data and assumption are chosen in accordance with the life cycle assessment investigation. With this assumptions the economical investigations are supported by the life cycle investigations.

In addition to the investment calculations the operation costs are also used in the investigations. The operation costs are in detail:

- Salaries for the personnel
- Maintenance costs for the sewer systems
- Costs for precipitants
- Costs for the regular analysis of the treated wastewater and its discharge fees in accordance to the "Abwasserabgabengesetz"
- Costs for the collection of organic and biowaste and its transport
- Costs for the sludge disposal and treatment
- Revues for other valuable outputs (compost, fertilizer, energy etc. – see chapter 4.1.3

4.1.2 Description of the investigated sanitation system

Six different sanitation systems have been investigated. The systems will be explained more in detail, a comprehensive survey of the systems is given in Table 2.

Variants 1 – 3 have also been investigated in the life cycle assessment. In opposite to the ecological investigation constructed wetlands have not investigated in detail by the economical evaluation. The reasons for this is the large area demanded for the treatment of the flows on the level of 5.000 inhabitants. This leads to unrealistic areas, which can be used better for living purposes than for the treatment of wastewater especially in urban conditions where the demand for construction plots are ever given. Therefore only the technical treatment stations for the treatment are taken into consideration.

The different variants will be described by words and a table and figure in which all important flows and treatment stages are shown.

<u>Variant 1: Conventional sanitation system</u>

The variant 1 is the reference system represents the conventional wastewater system. The houses are equipped with normal sanitation installations and the wastewater flows in a gravity sewer system to a pumping station from where the water is pumped to the treatment station. As a treatment a SBR (Sequencing Batch system) is foreseen. The treatment station is designed as a treatment station for the residential area only. Other houses are not connected to the system. The water consumption and wastewater volume is calculated as 101 litres per person and day.

Variant		1	2	3	4	5	6
YellowWater		Gravity sewer, wastewater, 1 SBR	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Vacuum sewer, Biogas	Collection Container
Brown Water			Grav. + press. sew., Sep., Compost	Vacuum sewer, Biogas	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR
Grey Water			Grav. sewer, 1 SBR	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR	

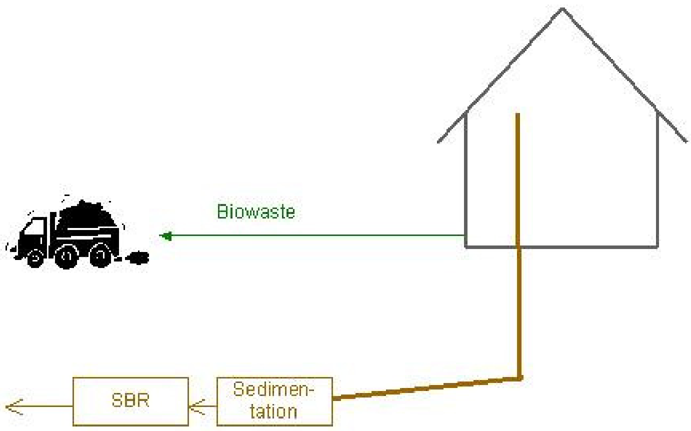

Figure 5: Scheme of the conventional sanitation system – Variant 1

The biowaste of the houses is collected in a bin system and will be treated in the public biowaste system.

This system is representative for a small wastewater system, which is not uncommon for villages in this range.

Variant 2: 3-flow gravity system

The second sanitation system is a system with three different sanitation flows. With the use of gravity separation toilets Yellow water (urine undiluted with water) is separated from the brown-water (faecal matter with flush water). Both flows were transported in gravity pipe systems outwards the house. Due to the high concentration solid concentration of the brown water and the possibility of clogging of the pipes during the transport for the brown water transport over long distances a pumping station with a cutting wheel pump an a pressure pipe system is foreseen.

Grey water from the kitchen is also separated by an use of an own pipe system. For this separation purpose a three-pipe system has to be installed inside and outside of the houses. Due to the same direction of the pipes a common installation in common trench is foreseen and results in a cost saving due to reduced digging works.

The yellow water is stored in underground storage tanks, which are distributed over the area (4 places with 3 tanks each with 11 or 12 m³). The storage time for the urine is calculated as 3 – 5 weeks, depending from the number of connected houses. These tanks are emptied regularly and transported for the use as fertilizer to the agricultural land, where seasonal storage takes place before the use. The transport distance was chosen to 20 km as a medium distance.

The brown water is transported to a treatment station. The first treatment stage is a separation of liquid and solids. This separation unit is not described in detail but it is assumed that the technology will be available for a reasonable investment. The solids will be treated aerobically together with the collected organic waste in a composting unit and the product compost is sold as a product as soil conditioner or fertilizer.

The first stage of the grey water treatment is a sedimentation unit. The liquid phase from the grey water sedimentation is treated together with the filtrate from brown water filtration in a SBR treatment stage.

Variant		1	2	3	4	5	6
YellowWater			Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Vacuum sewer, Biogas	Collection Container
Brown Water		Gravity sewer, wastewater, 1 SBR	Grav. + press. sew., Sep., Compost	Vacuum sewer, Biogas	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR
Grey Water			Grav. sewer, 1 SBR	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR	

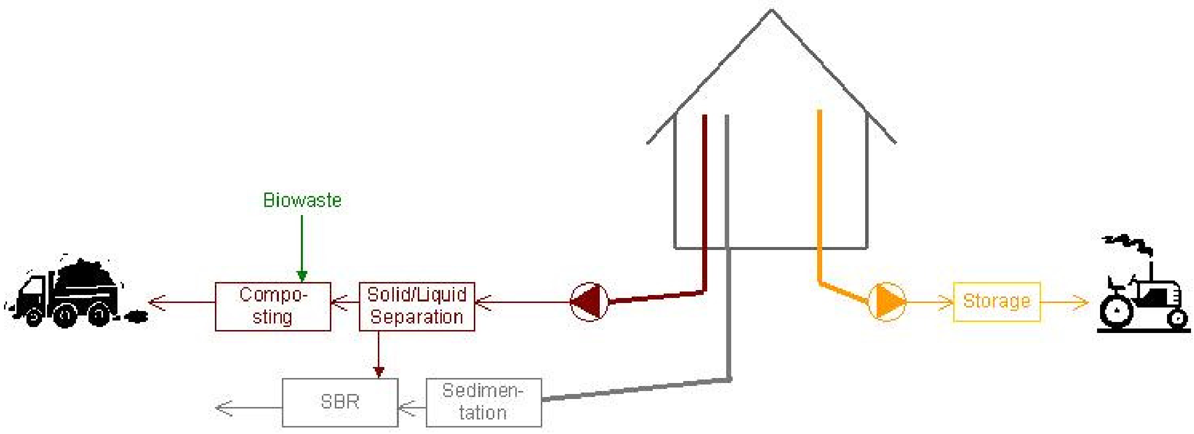

Figure 6: Scheme of the 3-flow gravity system – variant 2

<u>Variant 3: 3-flow vacuum system</u>

The third system is also a 3-flow system, but in opposite to the variant 2 the brown water is collected by vacuum toilets with a water flush use of 1 litre per flush and its transport in a vacuum sewer system. Three vacuum stations for the production of the low pressure in the sewer system are distributed over the area. Due to the low dilution rate the brown water can be treated anaerobically together with the grinded organic biowaste in a biogas plant. The biogas is be used for the process and for energy production. After the treatment in a biogas plant a thickener is installed and the liquid phase of this process is treated together with the grey water. The sludge from the thickener is used as an organic fertilizer in the agriculture.

The two other flows yellow water and grey water are treated like in variant 2.

Variant		1	2	3	4	5	6
YellowWater			Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Vacuum sewer, Biogas	Collection Container
Brown Water		Gravity sewer, wastewater, 1 SBR	Grav. + press. sew., Sep., Compost	Vacuum sewer, Biogas	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR
Grey Water			Grav. sewer, 1 SBR	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR	

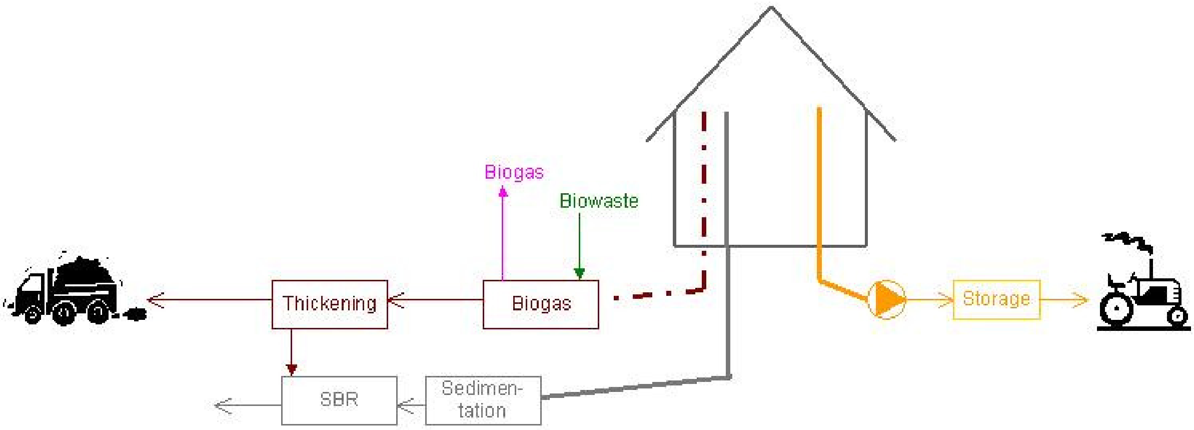

Figure 7: Scheme of the 3-flow vacuum system – variant 3

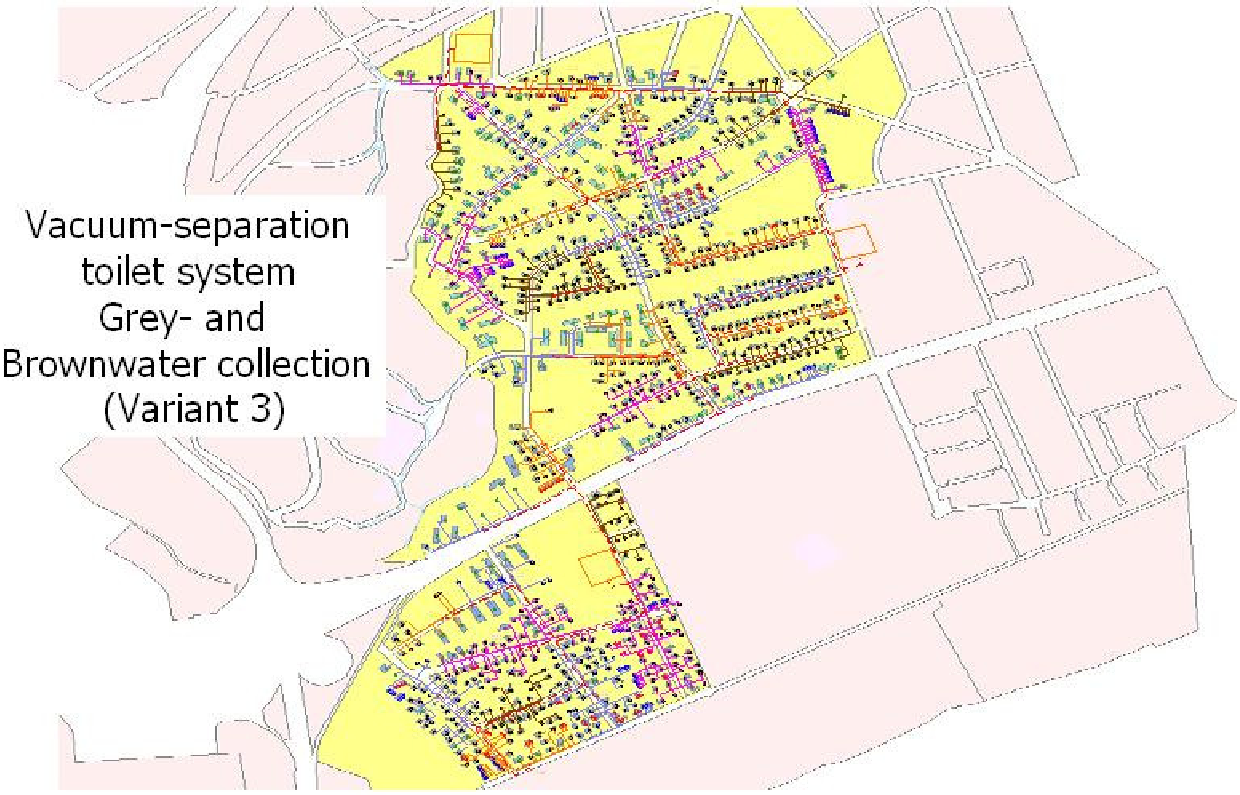

Figure 8: Sewer system as an example for the evaluation for the sewer pipe quantities

As an example for the detailed planning the design of the different pipes installed in the public areas is shown in Figure 8. Although details cannot be seen due to the low scale the figure should demonstrate the detailed planning as a prerequisite for the cost estimation.

Variant 4: 2-flow system with urine separation

The variant 4 shows a system in which the effort for the pipe and sewer system has been reduced by the use of a 2-pipe system. Yellow water keeps separate and is treated as described in the variants 2 – 3 above.

Brown and grey water are transported in the same pipe towards an aerobic treatment plant, here as an SBR plant. This is similar to variant 1 but the nutrient rich yellow water is separated, therefore the efforts for nutrient removal by the treatment stage can be reduced significantly. The sludge of the liquid-solid separation is treated in a common manner with the biowaste

Variant		1	2	3	4	5	6
YellowWater			Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Vacuum sewer, Biogas	Collection Container
Brown Water		Gravity sewer, wastewater, 1 SBR	Grav. + press. sew., Sep., Compost	Vacuum sewer, Biogas	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR
Grey Water			Grav. sewer, 1 SBR	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR	

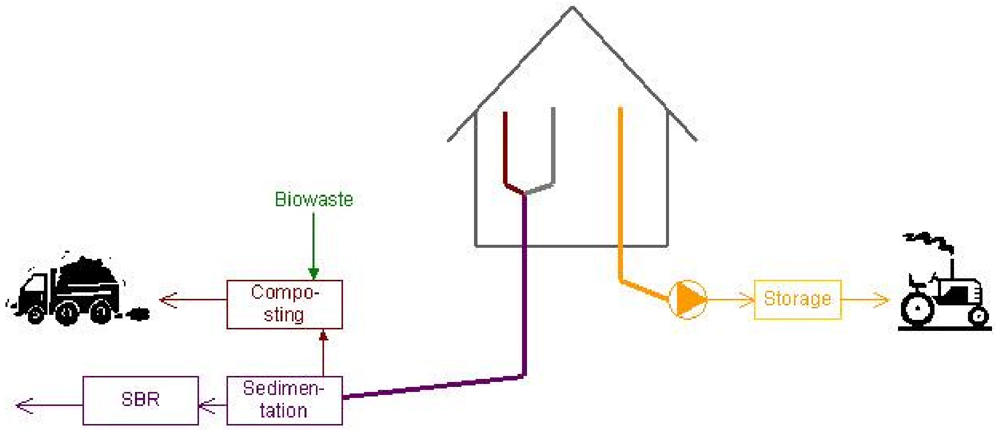

Figure 9: Scheme of the 2-flow system with urine separation – variant 4

Variant 5: 2-flow blackwater system

The variant 5 is also a 2-flow system but without urine separation. Brown water and yellow water is flushed as black water in a vacuum separation toilet via a vacuum pipe system and treated together with the grinded biowaste in a biogas plant. Due to the use of a vacuum pipe system the effort for digging works can be reduces and saves costs for the installation.

The grey water is treated separately like in the variants 2 – 4, the sludge from the pre-treatment stage is given to the biogas plant. Like in variant 3 the sludge from the biogas plant is used as a fertilizer because the nutrients from the urine can be used by this way.

Variant		1	2	3	4	5	6
YellowWater		Gravity sewer, wastewater, 1 SBR	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Vacuum sewer, Biogas	Collection Container
Brown Water			Grav. + press. sew., Sep., Compost	Vacuum sewer, Biogas	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR
Grey Water			Grav. sewer, 1 SBR	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR	

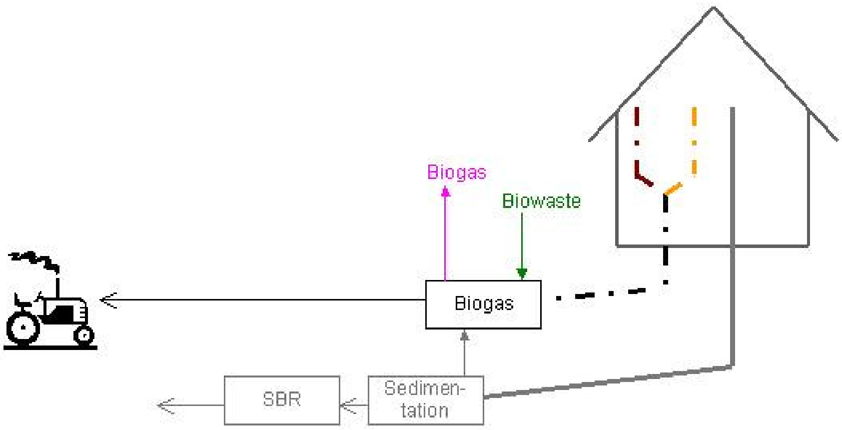

Figure 10: Scheme of the 2-flow blackwater system – variant 5

Variant 6: 2 flow system with on-site urine collection

Variant 6 is similar to variant system 4 with the difference in the way of transport of the separated and collected urine (yellow water). Instead of using an own sewer system for the transport of urine and the storage in semi-centralised urine storage tanks small tanks are installed on every plot with a volume of 0,5 m³ per unit. From here the urine is sucked of by a special sucking lorry regularly, a service similar to the waste bin collection in densely populated areas. So the urine sewer system is replace by smaller storage units, which results in a larger storage volume than the storage units in the other variants with the separation of yellow water.

Variant		1	2	3	4	5	6
YellowWater		Gravity sewer, wastewater, 1 SBR	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Vacuum sewer, Biogas	Collection Container
Brown Water			Grav. + press. sew., Sep., Compost	Vacuum sewer, Biogas	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR
Grey Water			Grav. sewer, 1 SBR	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR	

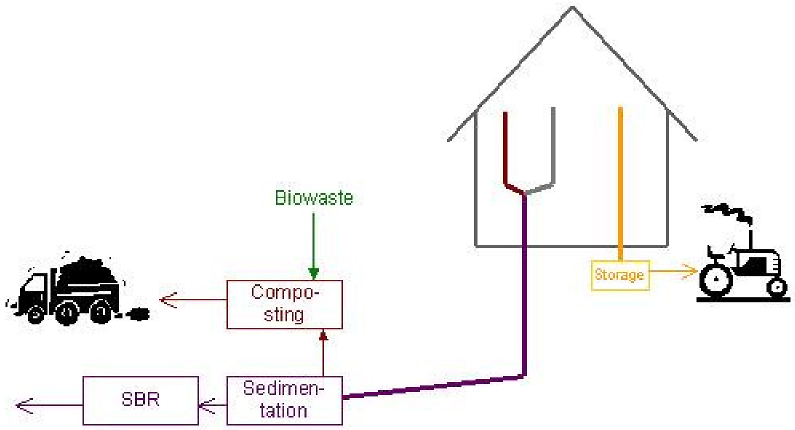

Figure 11: Scheme of the 2-flow system with on-site urine collection – variant 6

Variants 1 – 3 have also been investigated in the life cycle assessment. In opposite to the ecological investigation constructed wetlands have not investigated in detail by the economical evaluation. The reasons for this is the large area demanded for the treatment of the flows on the level of 5.000 inhabitants. This leads to unrealistic areas, which can be used better for living purposes than for the treatment of wastewater especially in urban conditions where the demand for construction plots are ever given. Therefore only the technical treatment stations for the treatment are taken into consideration.

The survey of the variants investigated for the cost calculations are given in Table 2.

Table 2: Survey of the different sanitation systems

<table>
<tr><th>System</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>6</th></tr>
<tr><th>Name / Flow</th><th>Conventional</th><th>3- flow gravity system</th><th>3- flow vacuum system</th><th>2 flow system urine sep.</th><th>2 flow blackwater system</th><th>2 flow system, on-site Urine coll.</th></tr>
<tr><td>Urine</td><td rowspan="3">Gravity sewer system, aerobic treatment</td><td>Gravity + pressure sewer system, collection and transport to the farmland</td><td>Gravity and pressure sewer system, collection and transport to the farmland</td><td>Gravity and pressure sewer system, collection and transport to the farmland</td><td rowspan="2">Vacuum sewer system, anaerobic treatment with biowaste, use of the sludge as fertilizer</td><td>Decentralized collection in small tanks, transport to the farmland</td></tr>
<tr><td>Brownwater</td><td>Gravity + pressure sewer system, aerobic treatment (liquid), composting(solids)</td><td>Vacuum sewer system, anaerobic treatment with biowaste, use of the sludge as fertilizer</td><td rowspan="2">Gravity + pressure sewer system, aerobic treatment,</td><td rowspan="2">Gravity sewer system, aerobic treatment</td></tr>
<tr><td>Greywater</td><td>Gravity sewer system, aerobic treatment</td><td>Gravity sewer system, aerobic treatment</td><td>Gravity sewer system, aerobic treatment</td></tr>
</table>

4.1.3 General assumption for all variants

For the cost calculations different assumptions have been made which are valid for all the variants:

- In future separation and vacuum toilets are available as a mass product and the price is much lower than today.
- The separation efficiency concerning the separation of urine and faeces operates with a separation rate of 75 %.
- All treatment technologies are technically feasible and available
- Urine and compost are accepted as a product for fertilizing and can be used on the farmlands

In the discussion of new sanitation concepts the use of the products are ever seen as one of the main advantages. The link of this use on an economical level is difficult, because even for the urine the calculation of the economical value is difficult because due to the low volumes and the legal restriction the urine doesn't have any market value at the moment.

Therefore the value of the urine is calculated in the framework of this study.

The composition of the urine is take from the Table 3 for the economical as well as for the ecological evaluation.

Table 3: Composition of the urine

Nutrient	Concentration [kg/m³]	Application by a rate of 10 m³/ha [kg/ha]
N	6.0	60
P	0.8	8
K	1.5	15

Basing on this composition a value for the urine is calculated compared to the use of mineral fertiliser. For both fertilisers the effort for its application is calculated and the difference can be seen as the value of the urine (Table 4).

For the application of mineral fertiliser fertilisers with a value of 52.13 €/ha have to be bought by the farmer. For the application on the field done by a enterprise the farmer would have to pay approx. 12.57 €/ha. The effort for the application of the urine is much higher (45.41 €/ha) due to the high dilution of the urine and the higher transport necessities. Although there is a difference of 19.29 €/ha for the urine application which can be seen as the urines value of 1.93 €/m³ by an application rate of 10 m³/ha.

Table 4: Calculation of the value of the urine for the application as fertiliser

Minderal Fertiliser 1):					
39 kg/ha	DAP	325 €/t			12.68 €/ha
115 kg/ha	Urea	270 €/t			31.05 €/ha
30 kg/ha	Kali 60	280 €/t			8.40 €/ha
					52.13 €/ha
Effort for the application of mineral fertiliser 2),3) (0.5 h/ha)					
Tractor 41 – 48 KW			11.90 €/h	0.5 h/ha	5.95 €/ha
Distributor 600 l			3.30 €/t	0.19 t/ha	0.62 €/ha
Wages for enterprises			12.00 €/h	0.5 h/ha	6.00 €/ha
					12.57 €/ha
Effort for the application of the urine 2),3) (1.0 h/ha):					
Tractor 60 – 74 KW			16.41 €/h	1.0 h/ha	16.41 €/ha
Transporter for urine 15 m³			0.40 €/m³	10 m³/ha	4.00 €/ha
Distributor 9.0 m		1.30 €/m³	10 m³/ha	13.00 €/ha	
Wages for enterprises			12.00 €/h	1.0 h/ha	12.00 €/ha
					- 45.41 €/ha
				Differences	**19.29 €/ha**
				for 10 m³/ha	**1.93 €/m³**

1) Sächsisches Ministerium für Umwelt und Landwirtschaft
2) KTBL Maschinendatenbank 3) Maschinenring Oberland

For the following calculations the urine is connected with an economical benefit of 1.93 €/m³. For the compost a market value of 60 €/m³ could be evaluated by a small market survey.

4.2 Financial calculation

The cost analysis is made in accordance to the German Guideline of dynamic cost calculations (LAWA, 1998) for a lifetime of 50 years. For this period the total project costs, caused by the costs for investment, reinvestment and the operation are calculated. The operation costs are subdivided in the personnel costs, material costs (maintenance, material for repairs etc.), costs for electricity, water, vehicles etc, and revenues for the products of each system (sale of the fertilizer from urine and compost, biogas, electricity produced with the biogas etc.).

To demonstrate the way of calculation the data for the variant 3 are given in Annex 1 in which all position of the variant are listed. To all positions a specific price is given and the amount is calculated. Furthermore each position is linked with its lifetime, mainly for construction parts 40 – 50 years, machinery parts 12.5 years and electrical parts also 12.5 years. After this time the parts have to been replaced and the costs for it are listed than at reinvestment costs. All parts get also a percentage rate for operation and maintenance, which covers replacement during the normal operation part.

Basing on this date the investments and the reinvestment costs for replacing the parts which lifetime has run out are calculated.

In addition operation costs are calculated. Also for the operation costs the calculation is given for variant 3 as an example in Annex 2. The operation costs are divided into:

- Personal equipment
- Maintenance
- Water and wastewater
- Electricity
- Others equipment

For the calculations furthermore the following conditions have been taken:

- Lifetime of the project: 50 years
- Real interest rate: 3 % per year

Using the three cost groups of

- Costs of the investment
- Costs of the reinvestment
- Operation costs

the Total Project Cost have been calculated. The Total Project Costs can be explained as the sum of money which has been taken today for the installation and operation of the project over the whole projects lifetime.

The calculations have been realised with the German guideline "Dynamische Kostenvergleichs-rechnung" (dynamic cost comparison calculation) published by the "Länderarbeitskreis Wasser LAWA", a working group of all federal countries in Germany concerning water management) (LAWA, 1998). This method can also named as a economic lifecycle analysis.

Relating on a cubic meter of water the dynamic primetime costs (DCP - €/m³) can be calculated and are a comparable cost. With new sanitation concepts that achieve to lower water consumption the calculation value of household costs would be much better than a value, which relates on the consumption and will be lower by higher consumption rates.

5 Results

5.1 General explanation

The results of the cost calculations are given mainly as the Total Project Costs (TPC) with which the different variants are compared to each other. This TPC are subdivided into the costs for investment, reinvestment and operation. The results of the calculation will be explained and discussed in detail and will be treated as a reference for the sensitivity analysis of the systems.

5.2 Basic scenarios

The results of the cost calculation of the variants described before are given in Table 5 and are also shown in Figure 12.

Table 5: Result of the cost calculation comparing the different variants

Variant		1	2	3	4	5	6
Yellow Water		Gravity sewer, wastewater, 1 SBR	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Vacuum sewer, Biogas	Collection Container
Brown Water			Grav. + press. sew., Sep., Compost	Vacuum sewer, Biogas	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR
Grey Water			Grav. sewer, 1 SBR	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR	
Personal	[Pers.]	0.61	1.12	1.23	0.89	1.23	1.15
Electricity consumption	[kWh/a]	115,457	129,298	265,770	102,296	293,925	101,616
Electr. Cons. With savings	[kWh/a]	115,457	129,298	81,044	102,296	81,044	101,616
Water usage	[m³/a]	180,307	180,307	152,100	180,307	152,100	180,307
Urine	[m³/a]		2,008	2,008	2,008		2,008
Compost	[m³/a]		325		325		325
Biogas	[kWh€/a]			184,726		184,726	
Investment	[€]	11,346,925	18,322,549	18,518,996	15,598,064	14,889,346	14,089,710
Reinvestment	[€]	6,591,731	7,969,859	10,408,930	8,458,691	9,179,043	7,749,926
Yearly Investment	[€/a]	528,764	800,459	833,189	709,372	680,741	641,661
Operation Costs	[€/a]	787,793	689,029	679,583	668,068	670,726	651,194
Sum Yearly Costs	[€/a]	1,316,557	1,489,489	1,512,772	1,377,440	1,351,467	1,292,855
Investment	[€]	11,346,925	18,322,549	18,518,996	15,598,064	14,889,346	14,089,710
Reinvestment	[€]	2,781,226	3,128,045	4,060,407	3,445,531	3,606,628	3,151,506
Operation Cost	[€]	20,269,717	17,728,563	17,485,521	17,189,232	17,257,614	16,755,055
Total Project Costs	[€]	34,397,868	39,179,157	40,064,925	36,232,827	35,753,588	33,996,271
DPC	[€/m³]	3.75	4.28	5.17	3.95	4.61	3.71
	[€/inh.]	7,033	8,010	8,192	7,408	7,310	6,951

The cost for the investment as well as for the reinvestment are higher for all new sanitation concepts except of variant 6. The reason is the higher effort for the pipe and sewer installation (Table 7), for the systems with the three pipes 2.4 times more pipes have to be installed than in the reference system, while the two pipe systems need only 1.75 times more. This can also be seen in the cost calculation (Figure 13) in which the investment for the treatment is for variant 2 – 5 lower than for the reference. Because the urine tanks in variant 6 are integrated into the treatment, the costs for the treatment are higher. Significant are the much higher investment costs for the 3-pipe-systems, which is obvious. It is also obvious that the costs for 2-pipe-systems are lower again. The cost for the treatment stages are – except variant 6 – nearly all in the same range.

Although the new sanitation concepts need more personal the operation costs for the new sanitation costs are lower than for the conventional sanitation system (reference) (Figure 14). Looking for the details in Table 5 benefits on different levels can be identified. The total consumption of the variants 3 and 5 is less to the reference system due to the production of energy by the biogas use. For these two variants also the water consumption is approx. 16 %

lower due to the installation of water saving vacuum toilet systems. The benefit from the sold of compost or urine can produce a revenue of 2,008 €/year, from the compost only 325 €/year are calculated. The revenue from the energy production of biogas is much higher, here 12,561 €/year can be received by the production of electrical energy.

Variant		1	2	3	4	5	6
Yellow Water		Gravity sewer, wastewater, 1 SBR	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Vacuum sewer, Biogas	Collection Container
Brown Water			Grav. + press. sew., Sep., Compost	Vacuum sewer, Biogas	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR
Grey Water			Grav. sewer, 1 SBR	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR	

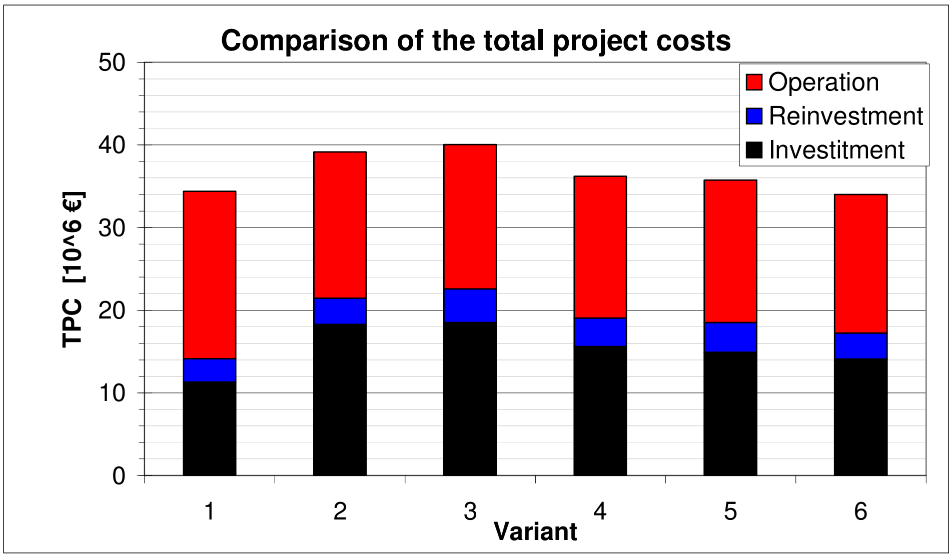

Figure 12: Total project costs of the six system variants

Due to the different flows a higher effort for the installation of the different pipes in the houses is necessary. In Table 6 the specific pipe length per person is given. While for the conventional system only 8.7 m pipe per person has to be installed in the houses for the 3-flow systems 15.7 m per person are necessary, the 2-flow need only around 12 m per person. Obviously these installations cause more costs for installation and investment.

Table 6: Pipe length per person for the in-house installation

Variant		1	2	3	4	5	6
Installation inhouse	[m/pers]	8.7	15.7	15.7	12.4	12.0	12.4

Table 7: Pipe lengths for the six system variants

Variant		1	2	3	4	5	6
Yellow Water		Gravity sewer, wastewater, 1 SBR	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Grav. sewer, press. sewer, collection	Vacuum sewer, Biogas	Collection Container
Brown Water			Grav. + press. sew., Sep., Compost	Vacuum sewer, Biogas	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR
Grey Water			Grav. sewer, 1 SBR	Grav. sewer, 1 SBR		Grav. sewer, 1 SBR	
Installation inhouse	[m]	42,713	76,989	76,989	60,871	58,831	60,871
Connection pipes	[m]	10,000	30,000	30,000	20,000	20,000	10,000
Sewer	[m]	13,805	51,055	47,512	31,963	29,354	13,805
Sum	**[m]**	**66,518**	**158,044**	**154,501**	**112,834**	**108,185**	**84,676**

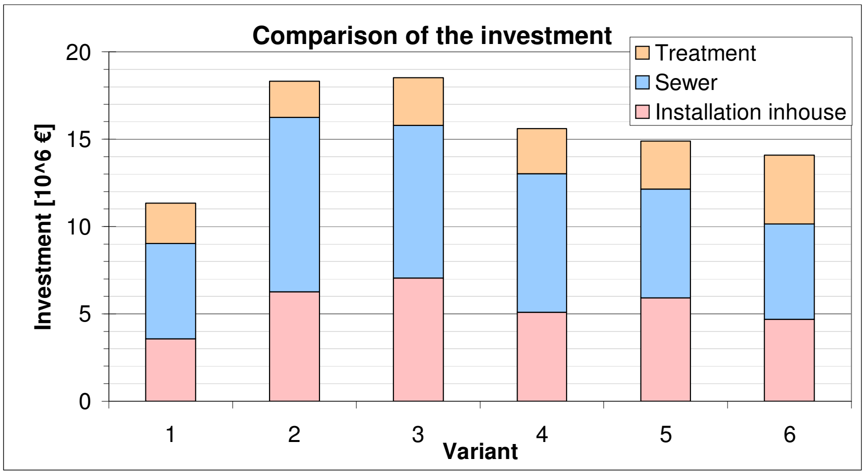

Figure 13: Investment divided in different fields

It can be recognized, that variant 2 – 3 have higher costs due to the 3 pipe installation systems. The variant 4 and 5 have only low higher costs, the specific cost for each person are only 5 % (7,401 €/pers) resp. 3,9 % (7,310 €/pers) higher than the reference system (7,033 €/pers). The variant 6 has slightly lower costs (6,951 €/pers.). Regarding the inaccuracies due the way of calculations and the assumption used for the calculation it can be stated that a few systems are more expensive than the reference system, but there are also new sanitation systems which don't cause more expenses.

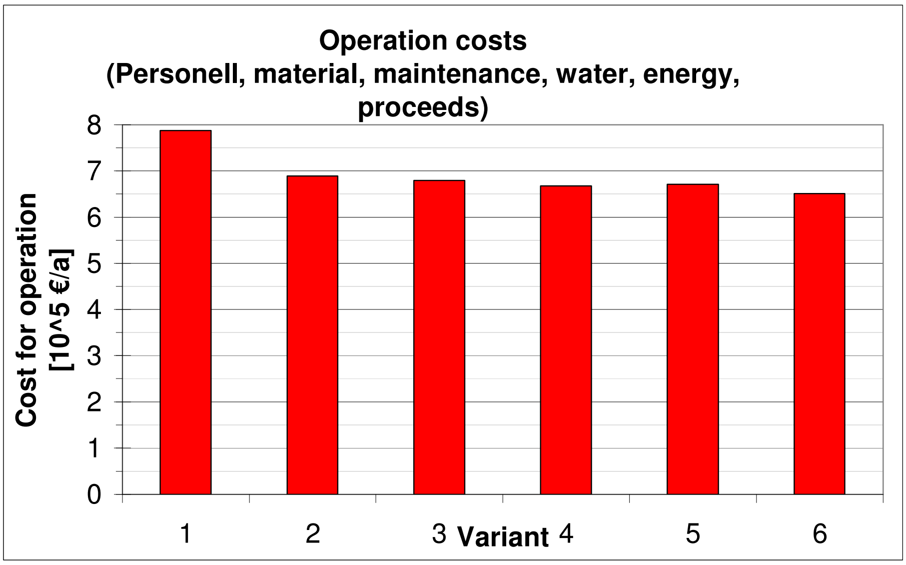

Figure 14: Operation costs of the six system variants

Furthermore it can be stated, that the Total project costs are mainly caused by the investment costs, the operation costs of the new sanitation costs are 13 – 17 % lower than for the conventional system. The revenues for the products (urine as well as compost) are negligible positions in the cost calculation

Basing on this calculation the sensitivity analysis by varying the conditions of the calculation is made. In the following figures the results of this first calculation are used as a basis scenario and also named as this.

5.3 Calculation without in-house installations

Public or private suppliers have their task normally not on private areas; their area of responsibility start mainly at the manholes installed near the houses, extend over the connection to the sewer line and the main sewer line. The installations in the houses are normally done by the construction companies of the houses and are covered by the cost of the houses. The sensitivity analysis starts with the calculation of the costs excluding the house installations but beginning with the manholes on the private areas (Figure 15).

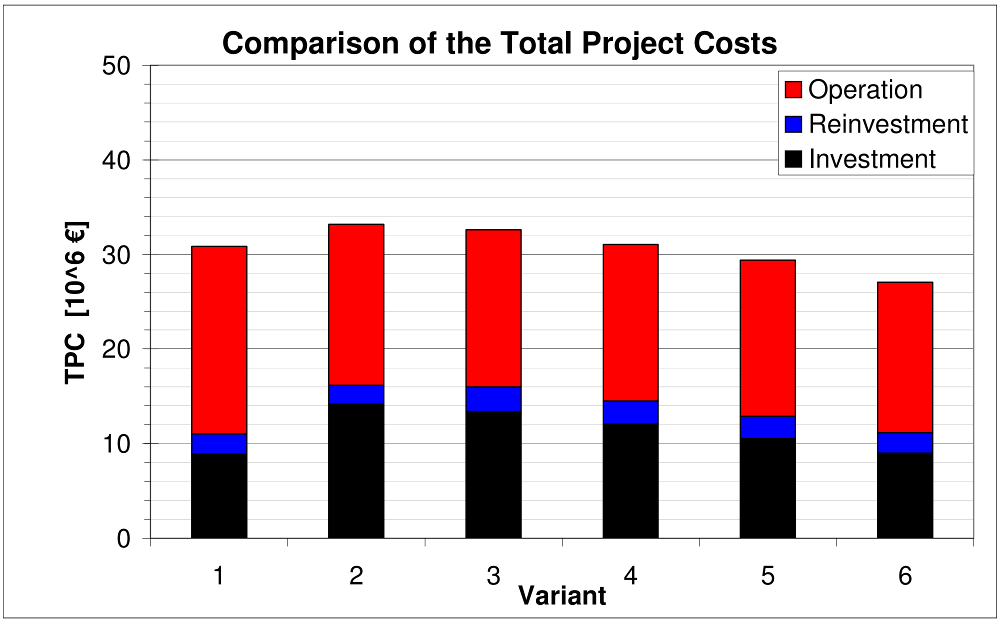

Figure 15: Total Project Costs without the in-house installations

The TPC are higher for the 3-pipe variants (variant 2 – 3) but are in the same range for the other variants compared to the reference. The two pipe systems variant 5 and 6 have also lower TVC values. Although the investment costs are slightly higher for the new variants the TPC are lower due to the lower operation costs.

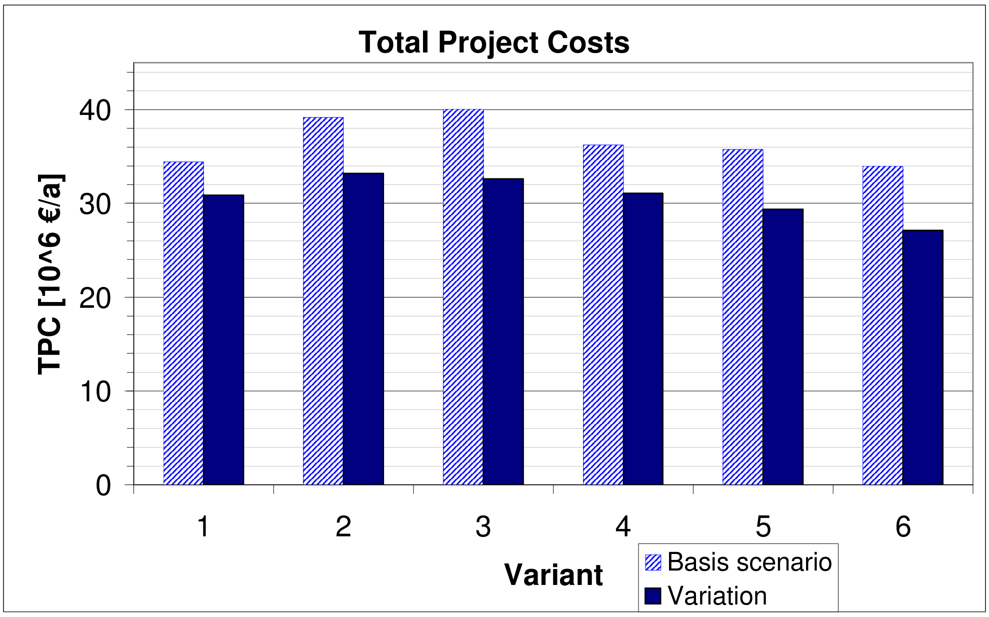

Figure 16: Total Project Costs without the in-house installations compared to the reference

Compared to the basic scenario the Total Project Costs are for lower than the reference in a range of 10 – 20 % (Figure 16). Of course the difference is greater for the 3-pipe variants than for the others. It is obvious that the largest differences can be noticed for the 3-pipe systems.

5.4 Yearly increase of the energy price of 3 %/a

The development of the energy price of the last years indicates a significant increase of these in future times.

Operation costs depend strongly on the price increase of the yearly expenses. In Germany the production price for electricity sold to customers has increased from the year 2000 to August 2005 about 30.3% (Statistisches Bundesamt, 2006). This is equal to a yearly increase rate of 5.4 % per year. To investigate the sensitivity of the costs a yearly increase rate of 3 %/a is implemented in the cost calculations.

Due to the high part of the investment costs of the total project cost the influence of the energy is only very low for the project area (Figure 18). For the variants with high-energy use an slight increase of the cost can be seen, the variants with energy production from biogas (variant 3 and 5) a decrease of the project costs can be calculated. The behaviour of the total project costs is only caused by the changes of the operation costs due to the increase or decrease of the energy costs (Figure 17).

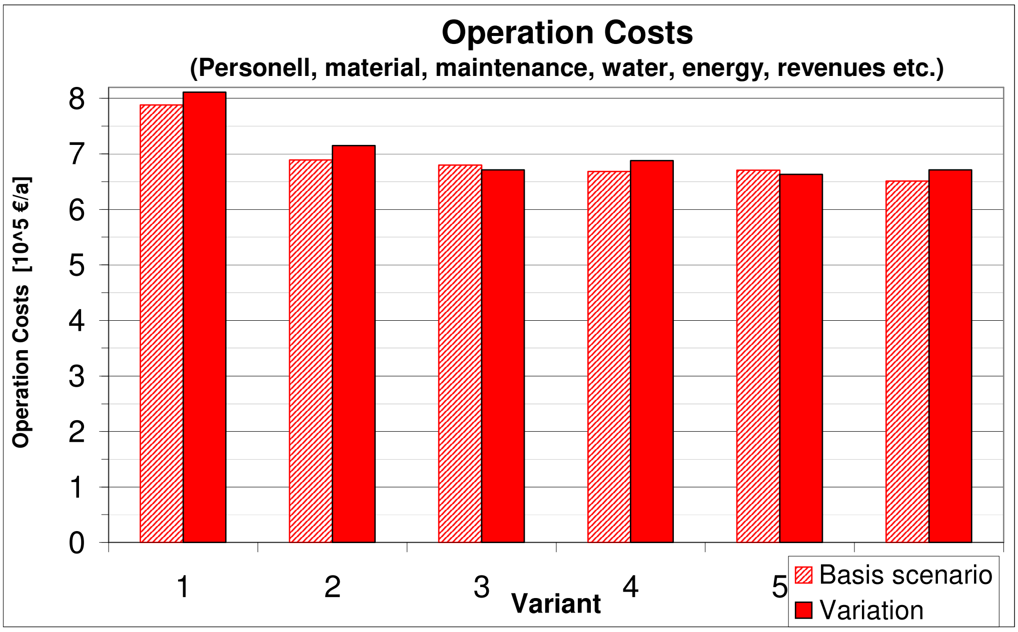

Figure 17: Yearly operation Costs with a yearly increase of the energy price of 3 %/a compared to the reference

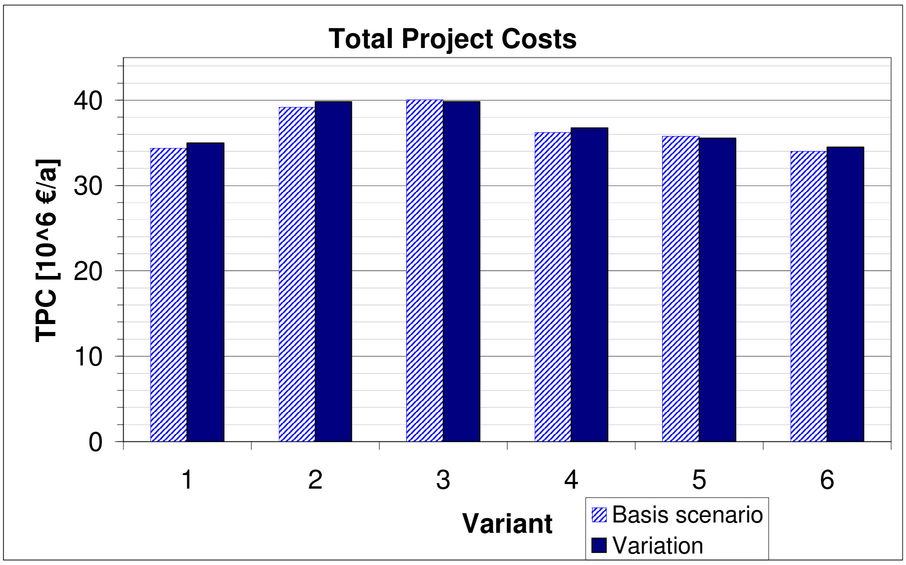

Figure 18: Total Project Costs with a yearly increase of the energy price of 3 %/a

5.5 Yearly increase of the operation costs

In future not only the increase of the energy prices have to been taken into consideration. Nevertheless it will be a realistic assumption of an increase of the operation costs in future. This is regarded by the following conditions:

- Increase of the energy price 3 % per year
- Increase of the water fees 1 % per year
- Increase of the other operation costs 0,5 % per year

These increase rates produce significantly higher operation costs (Figure 19). The operation costs for the reference are significantly higher than for the new sanitation concepts.

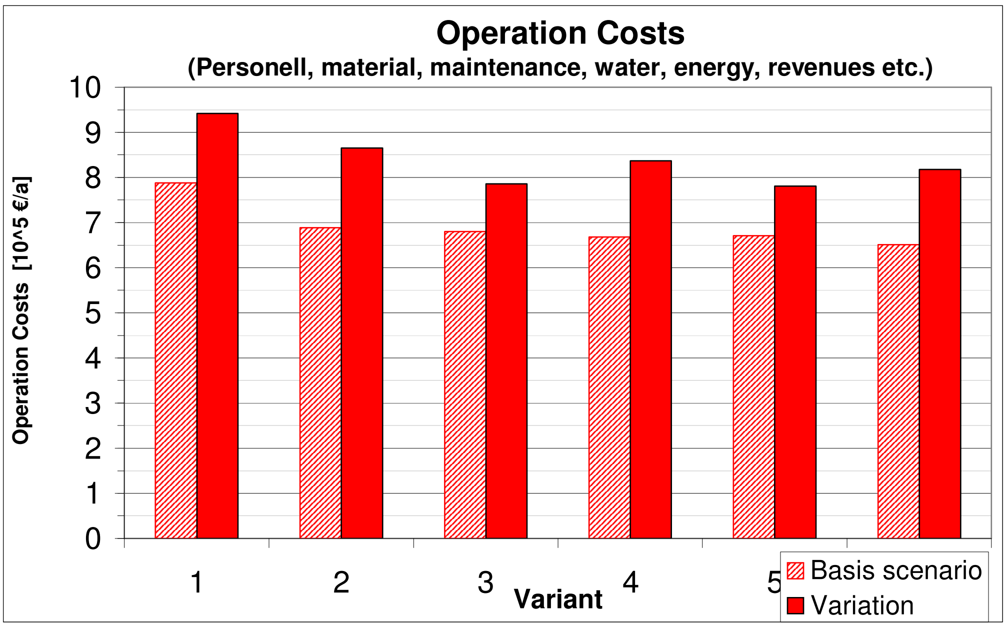

Figure 19: Yearly operation costs with a yearly increase

It is obvious that the variants with the biogas production and the substitution of energy have the lowest increase rate of the operation costs due to the own energy production. Due to the low impact of the operation costs on the Total Project Costs the effects are very low (Figure 20).

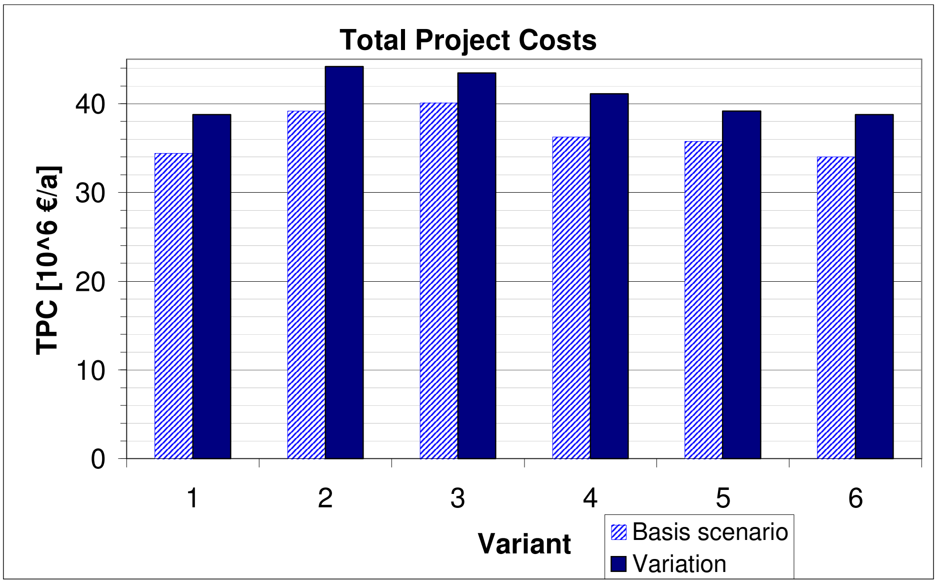

Figure 20: Total Project Costs with a yearly increase of the operation costs

5.6 Extension of the lifetime to 70 years

All the calculations were made with a project time of 50 years. These values of the lifetime are in accordance with the LAWA-Guidelines (LAWA, 1998). In reality the lifetime of sewer systems are much longer. Normally sewer systems are calculated with a depreciation time of more than 70 years. To integrate this in the sensitivity studies the project time as well as the lifetime of the sewers have been extended to 70 years. The results of this extended project time are shown in Figure 21.

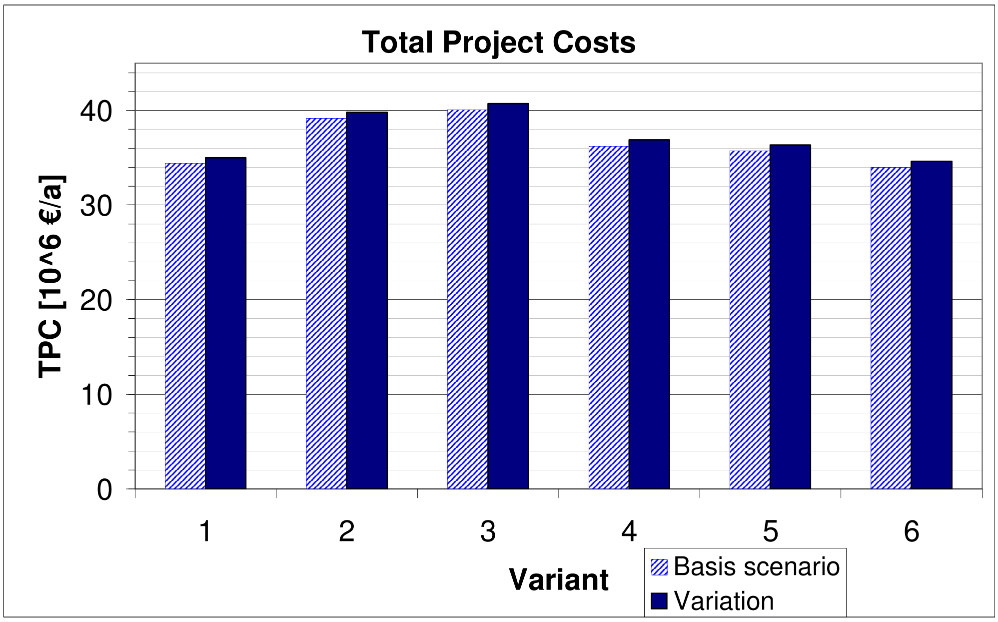

Figure 21: Total Project Costs with an extension of the project time and the lifetimes of sewers to 70 years

The impacts on the Total Project Costs are very low; for all variants an increase can be noticed. The interpretation of the results of the basis scenario (Chapter 5.2) remains.

5.7 Increasing of the population density

The chosen area has a population density rate of 38.8 inhabitants per hectare. This results also in a higher number of sewer lengths which can also expressed as specific length. This specific length is given for all variants in Table 8. Herein the specific length of 2.8 m per person for the conventional (1-pipe) installation (variant 1 and 6) is extended by the other variants. The value increases up to 10.4 or 9.7 m per person for the 3-flow installations and is less for the 2-flow installations (6.5 resp. 6.0 m per person).

Table 8: Pipe length per person for the connection pipes and sewers

Variant		1	2	3	4	5	6
Connection pipes	[m/pers]	2.0	6.1	6.1	4.1	4.1	2.0
Sewer	[m/pers]	2.8	10.4	9.7	6.5	6.0	2.8

For the evaluation of the area the population density rate is compared with values from other big cities in Europe (Table 9).

Table 9: Population density of Berlin compared with other cities in Europe (Senatsverwaltung Berlin, 2005)

	Total city area [pers./ha)]	Inner city area [pers./ha)]
Berlin	37.4	111.5
Hamburg	23.0	85.0
Frankfurt	26.4	88.6
Munich	41.2	51.8
London	46.9	89.3
Paris	213.0	213.0
Warschau	32.8	101.3

The area Nicolassee with 38.8 pers./ha hits the average value of Berlin, this can also be seen on the map (Figure 4) in which a scattered structure of the buildings can be recognizes. With this scattered kind of buildings the high value for the specific pipe lengths and its main part on the investment cost can be explained. Though the population density has also a big impact on the effort of installations.

An investigation of the systems with a higher population density will reduce the total length of the sewer pipes and the effect of the operation costs will become stronger. Therefore in this scenario the population was doubled and the buildings has been changed. It is assumed that the housings are changed to multi-storey buildings, the terraced and semi-detached houses are replaced by these multi-storey building.

This results in a higher installation effort for the in-house installations and for the treatment stages due to the higher number of flats, but the sewer system will receive only minor changes.

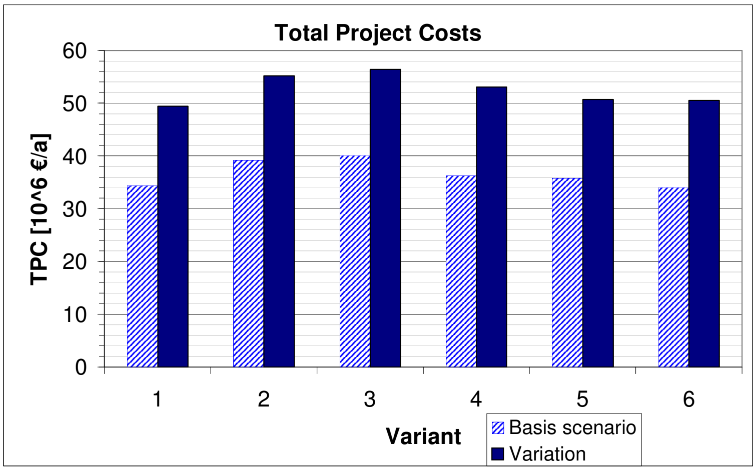

Figure 22: Total Project Costs with an extension of the project to 10,000 inhabitants

The Total Project Cost will increase significantly due to the higher installation efforts for the in-house installations and the size of the treatment stages. The result of the calculations is not significantly influence by the populations density for the area presented in the study.

5.8 Comparison with areas of higher water fee level

In the first phase of the project brief cost calculations have been made (Chapter 2). The calculations have been made for an area, for which details have not been known at that time. Furthermore the calculations were based on two different cost levels.

In the first step the calculations were made with the fee system of the Berliner Wasserbetriebe which are valid for the city of Berlin.

Here the fees are as follows:

Drinking Water fee	2.158 €/m³
Wastewater fee	2.465 €/m³

The results of the calculation, which is named as variant 0, are compared with the six variants in the figure below. Here the investment costs are caused by the house installations to the manhole. The fees for the wastewater listed above replace the investment costs for the sewer system and the treatment stage of variant 0. Therefore the operation costs are significantly higher because the fees are assigned to the operation costs.

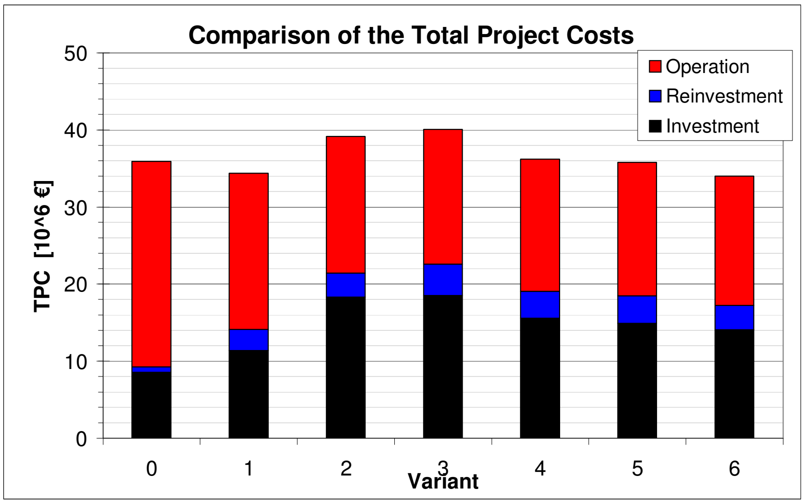

Figure 23: Total Project Costs for the six variants compared with the wastewater fees of the Berliner Wasserbetriebe (variant 0)

The variant 0 differs in the Total Project Costs only in a small range from the independently working system of variant 1.

Basic fee for water connection	61.32 €/connection
Drinking Water fee	1.50 €/m³
Basic fee for wastewater connection	142.92 €/connection
Wastewater fee	4.54 €/m³

The results of the calculations with this fee system are shown in Figure 24 as variant 0.

Like in the figure above the fees are assigned to the operation costs. Therefore the operation costs of variant 0 are much higher than the other variants. Due to the high investments which have been undertaken for the installation of the sewer system and the treatment facilities have to be covered by the wastewater fees. Therefore the fee level of the surrounding countryside of Berlin is much higher than for the system in Berlin, where a wastewater system is installed which operates nowadays for more than hundred years and is replaced only part by part during the times.

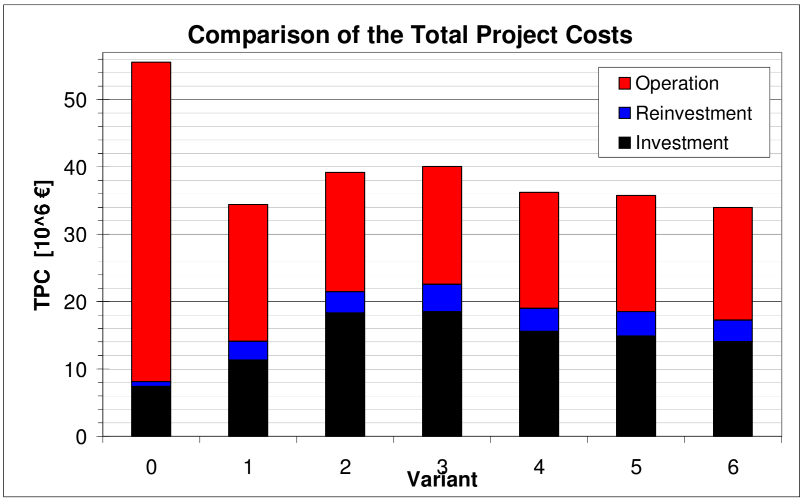

Figure 24: Total Project Costs for the six variants compared with the wastewater fees of the surrounding countryside of Berlin (variant 0)

The Total Project Costs for the variant 0 are much higher than for all the other variants. Here a very clear cost benefit for the new sanitation systems can be recognised.

6 Conclusion

The result of the cost calculation have their validity only for the investigated area, it is not possible to give a general statement concerning the cost effectiveness because the specific conditions control the result.

Basing on the investigations the following conclusions can be made:

- New sanitation concepts are not more or much more expensive than conventional systems.
- The multiple sewer systems resulting from the separation of urine, brown or grey water are responsible for higher investment costs, which control the total project costs.
- Systems with 3 flows have larger cost disadvantages than systems with 2 flows that can be in the same cost range than conventional systems.
- The operation costs for new sanitation concepts show cost benefits with regard to conventional wastewater systems
- The benefits from the products fertiliser from urine and compost produce only small revenues, energy from biogas show significantly higher benefits.
- On a long time scale the benefits for the operation costs will be reinforced especially for the systems with biogas production from wastewater and biogas due to the probable increase of costs for energy.
- The new sanitation costs have significantly cost benefits for areas with enhanced fees for wastewater

For other areas with other structures like number of inhabitants number and structure of the houses new sanitation concepts can also have cost benefits, this needs a detailed survey.

7 References

Dockhorn, T., Dichtl, N. (2004) A Desicion Support Tool for Implementing a Sustainable Resource Management in the Sector of Municipal Wastewater Treatment. . 2nd Leading-Edge Conference on Sustainability in Water-Limited Environments, 8 -10 November 2004 in Sydney, Australia

LAWA (1998) Leitlinien zur Durchführung dynamischer Kostenvergleichsrechnungen. Länderarbeitsgemeinschaft Wasser, Kulturbuchverlag Berlin GmbH.

Peter-Fröhlich, A., Pawlowski, L., Bonhomme, A. und Oldenburg, M. (2007): EU Demonstration Project for separate Discharge and Treatment of Urine, Faeces and Greywater – Results, Paper presented at IWA-conference Advanced Sanitation, Aachen 2007

Peter-Fröhlich, A., Kraume, I., Lesouëf, A. und Oldenburg, M. (2004): Separate Ableitung und Behandlung von Urin, Fäkalien und Grauwasser – ein Pilotprojekt. Korrespondenz Abwasser (51), Nr. 1, S. 38 -43.

Peter-Fröhlich, A., Kraume, I., Luck, F., Lesouëf, A. and Oldenburg, M. (2004) Demonstration Project for Separate Discharge and Treatment of Urine, Faeces and Greywater - Cost Comparison with the Conventional Wastewater System Leading Edge Conference, Prague, 2004

Senatsverwaltung Berlin, 2005; www.stadtentwicklung.berlin.de/umwelt/umweltatlas/da606_01.htm

Statistisches Bundesamt, 2006; www.destatis.de/indicators/d/vpi101ad.htm

8 Annexes

Annex 1 Table of the investment costs for variant 3

Annex 2 Table of the operation costs for variant 3

Annex Explanation of the quantities and price estimination (in German)

Annex 1 Table of the investment costs for variant 3

Realzinssatz	3,00	% p.a.	
Preissteigerung	0,00	% p.a.	für Investitionen
Projektbetrachtungszeitraum	50,00	a	

Berechnen

	Menge	Einheit	Einheits-preis	Investition (netto)	Nutzungs-dauer	Jahreskosten	Betrieb, Wartung	
			[€/E.]	[€]	[a]	[€/a]	[%]	[€/a]
Vakuumseparationstoilette inkl. Montage	2.910	Stück	600	1.746.000	40,0	75.536	1,0	17.460
Braunwasser: PE-Vakuumleitung DN 50	19.733	m	50,00	986.650	40,0	42.685	0,5	4.933
Grauwasser: HT-Leitung DN 50	13.050	m	13,26	173.043	40,0	7.486	0,5	865
Grauwasser: SML-Leitung DN 50	7.020	m	27,50	193.050	40,0	8.352	0,5	965
Grauwasser: HT-Leitung DN 70	8.048	m	14,56	117.179	40,0	5.069	0,5	586
Grauwasser: SML-Leitung DN 70	4.680	m	28,80	134.784	40,0	5.831	0,5	674
Grauwasser: HT-Leitung (Grundleitung) DN 150	6.300	m	45,00	283.500	40,0	12.265	0,5	1.418
Gelbwasser: HT-Leitung DN 50	1.740	m	13,26	23.072	40,0	998	0,5	115
Gelbwasser: HT-Leitung DN 50 mit Brandschutzmanschette	1.170	m	13,92	16.286	40,0	705	0,5	81
Gelbwasser: HT-Leitung DN 70	5.438	m	14,56	79.177	40,0	3.425	0,5	396
Gelbwasser: HT-Leitung DN 70 mit Brandschutzmanschette	3.510	m	15,29	53.668	40,0	2.322	0,5	268
Gelbwasser: HT-Leitung DN 150 (Grundleitung)	6.300	m	45,00	283.500	40,0	12.265	0,5	1.418
Hausanschluss Braunwasser	1.000	Stück	300	300.000	50,0	11.660	0,5	1.500
Hausanschluss Grauwasser	1.000	Stück	920	920.000	50,0	35.756	0,5	4.600
Hausanschluss Gelbwasser	10.000	m	32,50	325.000	50,0	12.631	0,5	1.625
Braunwasser: PE-Vakuumleitung DN 65, Tiefe 1,0 m	11.944	m	58,00	692.752	50,0	26.924	0,5	3.464
Braunwasser: PE-Vakuumleitung DN 100, Tiefe 1,0 m	1.364	m	65,00	88.660	50,0	3.446	0,5	443
Braunwasser: Vakuumstation, Baulicher Teil	3	Stück	50.000	150.000	40,0	6.489	1,0	1.500
Braunwasser: Vakuumstation, Maschineller Teil	3	Stück	40.000	120.000	12,5	11.654	2,5	3.000
Braunwasser: Vakuumstation, E-Technik	3	Stück	10.000	30.000	12,5	2.913	2,0	600
Braunwasser: Kunststoff-Druckleitung DN 65, Tiefe 1,0 m	2.241	m	58,00	129.978	50,0	5.052	0,5	650
Grauwasser: Kunststoff-Leitung DN 150, Verlegetiefe 2,0 m bis 3,0 m	8.073	m	208,48	1.683.059	50,0	65.413	0,5	8.415
Grauwasser: Kunststoff-Leitung DN 150, Verlegetiefe 3,0 m bis 4,0 m	2.718	m	293,10	796.646	50,0	30.962	0,5	3.983
Grauwasser: Kunststoff-Leitung DN 150, Verlegetiefe 4,0 m bis 5,0 m	459	m	390,37	179.180	50,0	6.964	0,5	896
Grauwasser: Kunststoff-Leitung DN 200, Verlegetiefe 3,0 m bis 4,0 m	676	m	309,59	209.283	50,0	8.134	0,5	1.046
Grauwasser: Kunststoff-Leitung DN 200, Verlegetiefe 4,0 m bis 5,0 m	334	m	410,57	137.130	50,0	5.330	0,5	686
Grauwasser: Kunststoff-Leitung DN 250, Verlegetiefe 3,0 m bis 4,0 m	270	m	334,65	90.356	50,0	3.512	0,5	452
Grauwasser: Kunststoff-Leitung DN 250, Verlegetiefe 4,0 m bis 5,0 m	375	m	439,46	164.798	50,0	6.405	0,5	824
Grauwasser: Kunststoff-Leitung DN 300, Verlegetiefe 4,0 m bis 5,0 m	164	m	469,11	76.934	50,0	2.990	0,5	385
Grauwasser: Kunststoff-Leitung DN 300, Verlegetiefe 5,0 m bis 5,5 m	206	m	559,35	115.226	50,0	4.478	0,5	576
Grauwasser: Kunststoff-Leitung DN 400, Verlegetiefe 5,0 m bis 5,5 m	530	m	624,80	331.144	50,0	12.870	0,5	1.656
Gelbwasser: Kunststoffleitung DN 150, Tiefe 2,0 m bis 3,0 m	7.667	m	104,24	799.208	50,0	31.062	0,5	3.996
Gelbwasser: Kunststoffleitung DN 150, Tiefe 3,0 m bis 4,0 m	3.441	m	146,55	504.279	50,0	19.599	0,5	2.521
Gelbwasser: Pumpstation Tiefe 2,5 m bis 3,0 m, Baulicher Teil	2	Stück	3.564	7.128	40,0	308	1,0	71
Gelbwasser: Pumpstation Tiefe 2,5 m bis 3,0 m, Maschineller Teil	2	Stück	2.310	4.620	12,5	449	2,5	116
Gelbwasser: Pumpstation Tiefe 2,5 m bis 3,0 m, E-Technik	2	Stück	726	1.452	12,5	141	2,0	29
Gelbwasser: Pumpstation Tiefe 3,0 m bis 4,0 m, Baulicher Teil	30	Stück	4.234	127.020	40,0	5.495	1,0	1.270
Gelbwasser: Pumpstation Tiefe 3,0 m bis 4,0 m, Maschineller Teil	30	Stück	2.744	82.320	12,5	7.995	2,5	2.058
Gelbwasser: Pumpstation Tiefe 3,0 m bis 4,0 m, E-Technik	30	Stück	862	25.860	12,5	2.511	2,0	517
Gelbwasser: Kunststoff-Druckleitung DN 50, Tiefe 1,0 m	7.050	m	60,00	423.000	50,0	16.440	0,5	2.115
Braunwasserbehandlung: Grundstück Vakuumstationen	300	m^2	40	12.000	50,0	466	0,0	
Braunwasserbehandlung: Grundstück Biogasanlage	1.000	m^2	40	40.000	50,0	1.555	0,0	
Braunwasserbehandlung: Bioabfallzerkleinerung, Baulicher Teil	1	Stück	10.000	10.000	40,0	433	1,0	100
Braunwasserbehandlung: Bioabfallzerkleinerung, Maschineller Teil	1	Stück	35.000	35.000	12,5	3.399	2,5	875
Braunwasserbehandlung: Bioabfallzerkleinerung, E-Technik	1	Stück	5.000	5.000	12,5	486	2,0	100
Braunwasserbehandlung: Biogasanlage, Baulicher Teil	1	Stück	524.000	524.000	40,0	22.669	0,5	2.620
Braunwasserbehandlung: Biogasanlage, Maschineller Teil	1	Stück	314.400	314.400	12,5	30.533	2,5	7.860
Braunwasserbehandlung: Biogasanlage, E-Technik	1	Stück	209.600	209.600	12,5	20.355	2,0	4.192
Grau- und Gelbwasserbehandlung: Grundstück	750	m^2	40	30.000	50,0	1.166	0,0	
Grauwasserbehandlung: Pumpstation, Baulicher Teil	1	Stück	7.500	7.500	40,0	324	1,0	75
Grauwasserbehandlung: Pumpstation, Maschineller Teil	1	Stück	6.000	6.000	12,5	583	2,5	150
Grauwasserbehandlung: Pumpstation, E-Technik	1	Stück	1.500	1.500	12,5	146	2,0	30
Grauwasserbehandlung: SBR-Anlage, Baulicher Teil	1	Stück	354.903	354.903	50,0	13.793	1,0	3.549
Grauwasserbehandlung: SBR-Anlage, Maschineller Teil	1	Stück	276.036	276.036	12,5	26.807,39	2,5	6.901
Grauwasserbehandlung: SBR-Anlage, E-Technik	1	Stück	157.735	157.735	12,5	15.318,55	2,0	3.155
Abwasserbehandlung: Schlammspeicher, Baulicher Teil	1	Stück	5.000	5.000	30,0	255	1,0	50
Abwasserbehandlung: Schlammspeicher, Maschineller Teil	1	Stück	1.250	1.250	12,5	121	2,0	25
Gelbwasserbehandlung: Urinspeicher, 11 m^3	3	Stück	10.800	32.400	40,0	1.402	0,5	162
Gelbwasserbehandlung: Urinspeicher, 12 m^3	9	Stück	11.300	101.700	40,0	4.400	0,5	509
Biotonnen 120 l für Häuser	870	Stück	50,0	43.500	20,0	2.924	0,0	
Biotonnen 240 l für Mehrfamilienhäuser	130	Stück	74,0	9.620	20,0	647	0,0	
Zwischensumme				14.782.085		672.305		108.526,05
Sonstiges	[%]	0,00		0		0		0,00
Zwischensumme gesamt				14.782.085		672.305		108.526,05
Honorare	[-]			1.182.567	50,0	45.961		
Gesamtsumme				15.964.652		718.266		108.526,05
Gesamtsumme (brutto)	[% USt.]	16,00		18.518.996		833.189		125.890,22

Annex 2 Table of the operation costs for variant 3

Eingabedaten:	Wasserverbrauch	85,2	l/(E*d)	**spezifische Daten:**	Einwohner	4.891	E
	Abwasseranfall	86,84	l/(E*d)		Wohneinheiten	2.040	WE
	Umsatzsteuer Trinkwasser	7	[%]		spez. Einwohner	2	E/WE
	Umsatzsteuer Abwasser	0	[%]				
	Umsatzsteuer Regenwasser	0	[%]				
Preise:	Grundpreis Trinkwasser	0	[€/a]	**Preissteigerungen:**	allgemeine Preissteigerungsrate r	0	% p.a.
	Wassertarif	2,158	[€/m³]		Preissteigerungsrate für Wasser/Abwasser r_w	0	% p.a.
	Grundpreis Abwasser	0	[€/a]		Preissteigerungsrate für Energie r_E	0	% p.a.
	Schmutzwasserentgelt	0	[€/m³]				
	Grundpreis Regenwasser	0	[€/a]	**variable Kostensätze:**			
					Realzinssatz i	3	% p.a.
	Strom	0,1813	[€/kWh]	**Projektbetrachtungszeitraum:**		50	Jahre

	Menge	Einheit	Einheitspreis [€/E.]	Kosten [€/a]	Barwert [€/a]	Jahreskosten [€/a]	Bemerkungen
Personalkosten							
Braunwasserbehandlung	0,34	Personen	34.000	11.560	297.436	11.560	
Grauwasserbehandlung	0,61	Personen	34.000	20.740	533.635	20.740	
Laub- und Grünschnittsammlung	0,28	Personen	34.000	9.520	244.947	9.520	
Summe				**41.820**	**1.076.019**	**41.820**	
Sachkosten							
Wartung u. Betrieb	1,00	anteilig v. Invest	108.526,05	108.526	2.792.350	108.526	
Leitungsreinigung	38.221	m	1,3	49.687	1.278.443	49.687	
Fällmittel $FeClSO_4$	4.891	Einwohner	0,33	1.614	41.529	1.614	
Laboruntersuchungen	4	Stück	150	600	15.438	600	
Abwasserabgabe	311	SE/a	35,79	11.131	286.390	11.131	
Transportkosten Urin	2.008	m³	4,0	8.032	206.661	8.032	
Schlammentsorgung Grauwasser	50	t TS	430	21.500	553.190	21.500	
Betriebsstoffe Laub- und Grünschnittsammlung	1	Stück	3.422	3.422	88.047	3.422	
Transport Schlamm eingedickt	79	Fahrt	63,32	5.002	128.707	5.002	
Summe				**209.514**	**5.390.755**	**209.514**	
Wasser / Abwasser							
Wasser							
Grundpreis Trinkwasser	1,00	Jahr	0,00	0	0	0	
Wassertarif	152.100	m³	2,16	328.232	8.445.344	328.232	
Grundpreis Abwasser	1,00	Jahr	0,00	0	0	0	
Schmutzwasserentgelt	155.028	m³	0,00	0	0	0	
Grundpreis Regenwasser	1,00	Jahr	0,00	0	0	0	
Summe				**328.232**	**8.445.344**	**328.232**	
Energie							
Strom	265.769,80	kWh	0,18	48.184	1.239.765	48.184	
Summe				**48.184**	**1.239.765**	**48.184**	
Erlöse							
Urin als Düngemittel	2.008	m³	-1,93	-3.875	-99.714	-3.875	
Biogasanlage, Verstromung von Gas	184.726	kWh/a	-0,068	-12.561	-323.201	-12.561	
Summe				**-16.437**	**-422.915**	**-16.437**	
Gesamtsumme				611.314	15.728.967	611.314	
Gesamtsumme (brutto)	[% USt.]	16,00		679.583	17.485.521	679.583	

Aggregat	Stromverbrauch Anschluß [kW]	Laufzeit [h/d]	Tage [d/y]	Stromverbrauch [kWh/a]
Gelbwasser: 32 Pumpstationen	0,04	8	365	117
Braunwasser: 3 Vakuumstationen	14,02	24	365	122.785
Braunwasser: Vergärung Aufbereitung Biomüll	3,66	24	365	32.103
Braunwasser: Vergärung Biogasanlage	4,16	24	365	36.476
Braunwasser: Vergärung Abwasserreinigung	0,84	24	365	7.336
Grauwasser: Pumpstation	1,93	6	365	4.216
Grauwasser: SBR-Anlage	7,16	24	365	62.737
				265.770

SCST-Projekt
(Anhang zum Projektbericht *cost calculation*)

Auftraggeber:

Kompetenzzentrum Wasser Berlin

Auftragnehmer:

OtterWasser GmbH
Engelsgrube 81
D-23552 Lübeck
☎ (+49) 0451-70 200-51
-52
info@otterwasser.de
www.otterwasser.de

März 2007

Sachbearbeitung:
Dipl.-Ing. C. Dlabacs

Dr.-Ing. Martin Oldenburg
(Geschäftsführer)

Inhaltsverzeichnis

9 Vorbemerkungen

Aufgrund der Verschiedenartigkeit der Hausinstallationen in den einzelnen Varianten werden auch die Kosten für die Leitungen in den Gebäuden und die Kosten für die jeweiligen Toilettentypen in allen Varianten betrachtet und miteinander verglichen.

Die Abflusswerte bei der KA des konventionalen Systems und bei den Pflanzenkläranlagen der Separationssysteme sollen identisch sein [7]

In allen Varianten wird die Abwasserbehandlung mit Stickstoff- und Phosphorelimination vorgesehen. Ablaufwert PO_4-P = 1 mg/l [7]

10 Variantenvergleich

Für Kostenvergleich nicht relevant, da in allen Varianten identisch:

- Trinkwassernetz
- Regenwassernutzung / -behandlung
- Haushaltsgeräte
- Waschbecken, Dusche und Badewannen
- BHKW

Alle spezifischen Kosten als Nettopreise ohne Umsatzsteuer.

10.1 Allgemeines

10.1.1 Gebietskenndaten

Gebiet Nikolassee, Daten basieren auf GIS [1]

Tab. 1: Gebietskenndaten

Einwohnerzahl	[E]	4.891
Anzahl der Gebäude	[Stk.]	1.000
Wohneinheiten	[WE]	2.040
Einwohner pro Wohneinheit	[E/WE]	2,4

Lageplan mit Markierung der Gebäudeart

10.1.2 Gebäude

Feststellung der Gebäudetypen über GIS

Nur die Wohngebäude werden betrachtet. Öffentliche und gewerbliche Gebäude wurden aus der Betrachtung herausgenommen.

Tab. 2: Gebietskenndaten

Gebäudeart	Anzahl	Wohneinheiten
	[Stk.]	[WE]
Einfamilienhaus	649	649
Doppelhaus	98	98
Reihenhaus	123	123
Mehrfamilienhaus	130	1.170
Summe	1.000	2.040

In einem Mehrfamilienhaus befinden sich neun Wohnungen (Wohneinheiten).

10.2 Variante 0, Konventionelles System – Zentraler Anschluss an bestehendes System der BWB (1 Strom)

Entwässerung des Regen- und Abwassers im Trennsystem über Schwerkraft

In diesem Fall wird das Gebiet an die bestehende Kanalisation der BWB angeschlossen. Diese Variante ist nicht vergleichbar mit den anderen, da schon vorhandene Strukturen genutzt werden.

Errichtung und Betrieb durch BWB

10.2.1 Investitionskosten Variante 0

10.2.1.1 Im Gebäude / bis Hausanschlussschacht

Trinkwassernetz, Haushaltsgeräte, Waschbecken, Duschen und Badewannen sind für den Kostenvergleich nicht relevant, da diese in allen Varianten identisch sind

Sanitärobjekt:	WC mit 6,0 l Spülkasten als Vorwandinstallation 2 Stück pro Haus, 870 Häuser = 1.740 Stück 1 Stück pro Wohnung, 1.170 Wohnungen = 1.170 Stück Insgesamt 2.910 Stück a 300 € = 873.000 €
Leitungen im Gebäude:	HT-Rohrleitung DN 50, 12.180 m, 13,26 €/m [12] → 161.507 €
	SML-Rohrleitung DN 50, 7.020 m, 27,50 €/m [12] → 193.050 €
	HT-Rohrleitung DN 100, 10.875 m, 18,23 €/m [12] → 198.251 €
	SML-Rohrleitung DN 100, 6.338 m, 34,65 €/m [12] → 219.612 €
	HT-Rohrleitung DN 150 (Grundleitung), 6.300 m, 45,00 €/m → 283.500 €

10.2.1.2 Hausanschluss

Kosten gemäß Gebühren der BWB

Anschlussgebühr und Baukostenzuschuss finanzieren Hausanschlussleitung und Kanalisation

Grundpreis Hausanschluss:	Insgesamt 1000 Hausanschlussleitungen [1] Grundpreis je Hausanschluss = 1.960,00 €/Haus [2] Grundpreis für 1000 Hausanschlüsse = 1.960.000 €
Preis für Hausanschlusslänge:	Mittlere Hausanschlusslänge je Haus = 10 m/Haus [1] Hausanschlusslängen insgesamt = 10.000 m Preis pro m-Hausanschlusslänge = 200 €/m [2] Preis für 10.000 m Hausanschlusslänge = 2.000.000 €
Baukostenzuschuss:	Mittlere Frontlänge je Haus = 17 m Frontlängen insgesamt = 17.000 m Preis pro m-Frontlänge = 55 €/m [2] Preis für 17.000 m Frontlänge = 935.000 €

10.2.1.3 Kanalnetz

Kosten über Anschlussgebühr und Baukostenzuschuss

10.2.1.4 Abwasserbehandlung

Keine, da Anschluss an das vorhandene Abwassersystem und an die vorhandene Abwasserbehandlung der BWB

10.2.2 Laufende Kosten Variante 0

10.2.2.1 Personalkosten

Durch Schmutzwasserentgelt bezahlt

10.2.2.2 Wasser / Abwasser

Trinkwasserverbrauch= 101 l/(E*d) [7]
darin enthalten 21 l/(E*d) Spülwasser (1* 6l und 5*3l) [7]
80 l/(E*d) Grauwasser
Wassertarif 2,158 € /m³ [3],
4.891 Einwohner, 365 Tage im Jahr = 389.102 €/a
Umsatzsteuer 7 % [3] → 416.339 €/a

Abwasseranfall= 101 l/(E*d) Trinkwasserverbrauch, 1,5 l Urin/(E*d), 0,14 l Fäkalien/(E*d) → 102,64 l/(E*d)
Schmutzwasserentgelt 2,465 €/m³ [3],
4.891 Einwohner, 365 Tage im Jahr = 451.673 €/a
keine Umsatzsteuer [3] → 451.673 €/a

Kein monatlicher Grundpreis [3]

10.2.2.3 Sachkosten

Durch Schmutzwasserentgelt bezahlt

Laub- und Grünschnittsammlung: Ab der Varianten 3 wird Laub und Grünschnitt mitverwertet. Beim konventionellen System verursacht die Laub- und Grünschnittsammlung Kosten

120 l Biotonne, Quartalsentgelt 32,40 € → 129,60 €/a
870 Häuser → 111.012 €/a

240 l Biotonne, Quartalsentgelt 32,40 € → 139,60 €/a
130 Mehrfamilienhäuser → 16.848 €/a

10.2.2.4 Energie

Durch Schmutzwasserentgelt bezahlt

10.2.2.5 Erlöse

Keine

10.3 Variante 1, Konventionelles System – Siedlungseigenes Behandlungssystem für Schmutzwasser (1 Strom)

10.3.1 Investitionskosten Variante 1

10.3.1.1 Im Gebäude / bis Hausanschlussschacht

Identisch mit Variante 0

Sanitärobjekt: WC mit 6,0 l Spülkasten als Vorwandinstallation
2 Stück pro Haus, 870 Häuser = 1.740 Stück
1 Stück pro Wohnung, 1170 Wohnungen = 1.170 Stück
Insgesamt 2910 Stück a 300 € = 873.000 €

Leitungen im Gebäude: HT-Rohrleitung DN 50, 12.180 m, 13,26 €/m [12] → 161.507 €

SML-Rohrleitung DN 50, 7.020 m, 27,50 €/m [12] → 193.050 €

HT-Rohrleitung DN 100, 10.875 m, 18,23 €/m [12] → 198.251 €

SML-Rohrleitung DN 100, 6.338 m, 34,65 €/m [12] → 219.612 €

HT-Rohrleitung DN 150 (Grundleitung), 6.300 m, 45,00 €/m [12] → 283.500 €

10.3.1.2 Hausanschluss

Annahme jedes Gebäude hat einen eigenen Hausanschlussschacht, 100 % sind an das konventionelle Netz angeschlossen. [7]

Hausanschlussschacht: 1.000 Hausanschlussschächte, Beton, Schachttiefe 2,0 m

Hausanschlussleitung: 1.000 Hausanschlussleitungen, DN 150
Leitungsmaterial Steinzeug, Verlegetiefe 2,0 m
Leitungslänge pro Hausanschluss = 10 m [1]
Leitungslänge insgesamt = 10.000 m

Komplett: 1.000 Anschlüsse, 920,00 € pro Anschluss → 920.000 €

10.3.1.3 Kanalnetz

Leitungsnetz nach Kanalnetzberechnung. Entwässerung in Richtung Kläranlage

Steinzeug-Rohrleitung [7] DN 150, Tiefe 2,0 m bis 3,0 m, 8.073 m, 238,39 €/m → 1.924.522 €

Steinzeug-Rohrleitung [7] DN 150, Tiefe 3,0 m bis 4,0 m, 2.718 m, 323,14 €/m → 878.295 €

Steinzeug-Rohrleitung [7] DN 150, Tiefe 4,0 m bis 5,0 m, 459 m, 420,79 €/m → 193.143 €

Steinzeug-Rohrleitung [7] DN 200, Tiefe 3,0 m bis 4,0 m, 676 m, 369,15 €/m → 249.545 €

Steinzeug-Rohrleitung [7] DN 200, Tiefe 4,0 m bis 5,0 m, 334 m, 470,90 €/m → 157.281 €

Steinzeug-Rohrleitung [7] DN 250, Tiefe 3,0 m bis 4,0 m, 270 m, 430,51 €/m → 116.238 €

Steinzeug-Rohrleitung [7] DN 250, Tiefe 4,0 m bis 5,0 m, 375 m, 536,60 €/m → 201.225 €

Steinzeug-Rohrleitung [7] DN 300, Tiefe 4,0 m bis 5,0 m, 164 m, 582,88 €/m → 95.592 €

Steinzeug-Rohrleitung [7] DN 300, Tiefe 5,0 m bis 5,5 m, 206 m, 673,88 €/m → 138.819 €

Steinzeug-Rohrleitung [7] DN 400, Tiefe 5,0 m bis 5,5 m, 530 m, 757,73 €/m → 401.597 €

342 Kontrollschächte [1], wie Ist-Situation, aus Beton, im Abstand von 40,36 m sind in den Kosten der Leitungen enthalten

10.3.1.4 Abwasserbehandlung

Das Abwasser der fiktiven, durchschnittlichen Wohnsiedlung wird in einer Kläranlage behandelt. Die Kläranlage liegt an der Potsdamer Chaussee, am westlichen Rand des betrachteten Gebiets. Tatsächlich ist in diesem Bereich ein Autobahnkreuz.

Grundstück : 1.500 m²; 40,00 €/m² → 60.000 €

Pumpstation: Q_{10} = 0,004 l/sec bei 4891 E = 19 l/sec → 20.000 € [5]
Aufteilung der Kosten: Baulicher Teil 50 % [6] = 10.000 €
Maschineller Teil 40 % [6] = 8.000 €
E-Technik 10 % [6] = 2.000 €

Siebrechen: 120.000 € [6]
Aufteilung der Kosten: Baulicher Teil 15 % [6] = 18.000 €
Maschineller Teil 65 % [6] = 78.000 €
E-Technik 20 % [6] = 24.000 €

SBR-Anlage: bei 4891 E; 325 €/E [6] → 1.589.575 €
Aufteilung der Kosten: Baulicher Teil 45 %=715.309 €
Maschineller Teil 35 %= 556.351 €
E-Technik 20 %= 317.915

Schlammspeicher: 300 m³, 62.000 € [6]
Aufteilung der Kosten: Baulicher Teil 80 % [6] = 50.000 €
Maschineller Teil 20 % [6] = 12.500 €

10.3.2 Laufende Kosten Variante 1

10.3.2.1 Personalkosten

Abwasserbehandlung: 90 h/Monat → 0,61 Personen
34.000 €/(Person*a) [M 271, Sept. 1998] → 20.740 €/a

10.3.2.2 Sachkosten

Laub- und Grünschnittsammlung: Identisch mit Variante 0

Leitungsreinigung: 13.805 m, 1,3 €/m → 17.947 €

Fällmittel $FeClSO_4$: Elimination von 1,5 g P/(E*d), 0,55 € /(E*a) bei einer Elimination von 1 g P/(E*d) [11]→ 0,83 €/(E*a)
4891 E, 0,83 €/E*a → 4.060 €/a

Laborkosten: 4 Untersuchungen pro Jahr, 150 €/Untersuchung → 600 €/a

Abwasserabgabe: 404 SE/a , 35,79 €/SE [8] → 14.459 €/a

Schlammentsorgung: Verbrennung des Primär- und Sekundärschlammes (Eindickung, Faulung, Entwässerung, Verbrennung)
Entscheidung für die Verbrennung aufgrund des Trends zur Verbrennung in Deutschland [7]
Feststoffanfall bei 5.000 E = 91 t TS/a [11]

Kosten Transport mit LKW = 30 €/t TS [10]
Kosten maschinelle Entwässerung = 150 €/t TS [10]
Kosten Verbrennung = 250 €/t TS [10]
Gesamtkosten 430 €/t TS → 39.130 €/a

10.3.2.3 Wasser / Abwasser

Trinkwasserverbrauch= 101 l/(E*d) [7]
darin enthalten 21 l/(E*d) Spülwasser (1* 6l und 5*3l) [7]
80 l/(E*d) Grauwasser
Wassertarif 2,158 € /m³ [3],
4.891 Einwohner, 365 Tage im Jahr = 389.102 €/a
Umsatzsteuer 7 % [3] → 416.339 €/a

Abwasseranfall= 101 l/(E*d) Trinkwasserverbrauch, 1,5 l Urin/(E*d), 0,14 l Fäkalien/(E*d) → 102,64 l/(E*d)

Kein Abwasserentgelt, da die Abwasser- und Schlammbehandlung kalkuliert wird.

Kein monatlicher Grundpreis [3]

10.3.2.4 Energie

Trinkwasserbereitstellung: 10,29 kW, 24 h/d, 365 d/a → 90.153 kWh/a
18,13 Ct/kWh → 16.345 €/a

Abwasserreinigung: 13,18 kW, 24 h/d, 365 d/a → 115.457 kWh/a
18,13 Ct/kWh → 20.932 €/a

10.3.2.5 Erlöse

Keine

10.4 Variante 2: Urinseparation, Braunwasserableitung und –behandlung, Grauwasserbehandlung in einer technischen Anlage (3 Teilströme)

10.4.1 Investitionskosten Variante 2

10.4.1.1 Im Gebäude / bis Hausanschlussschacht

Sanitärobjekt: Schwerkraftseparationstoilette inkl. Montage
Herstellung in großen Stückzahlen
Insgesamt 2910 Stück a 450 € = 1.309.500 €

Leitungen im Gebäude: Entlüftung der Grau- und Gelbwasserleitung über Anschluss an die Entlüftungsleitung der Braunwasserleitung

Braunwasser:

HT-Rohrleitung DN 100, 10.875 m, 18,23 €/m [12] → 198.251 €

SML-Rohrleitung DN 100, 6.338 m, 34,65 €/m [12] → 219.612 €

HT-Rohrleitung DN 150 (Grundleitung), 6.300 m, 45,00 €/m
→ 283.500 €

Grauwasser:

HT-Rohrleitung DN 50, 13.050 m, 13,26 €/m [12] → 173.043 €

SML-Rohrleitung DN 50, 7.020 m, 27,50 €/m [12] → 193.050 €

HT-Rohrleitung DN 70, 5.438 m, 14,56 €/m [12] → 79.177 €

SML-Rohrleitung DN 70, 3.510 m, 28,80 €/m [12] → 101.088 €

HT-Rohrleitung DN 150 (Grundleitung), 6.300 m, 45,00 €/m
→ 283.500 €

Gelbwasser:

Leitungsmaterial: in den Mehrfamilienhäusern in Kunststoff mit Brandschutzmanschetten [7]

HT-Rohrleitung DN 50, 1.740 m, 13,26 €/m [12] → 23.072 €

HT-Rohrleitung DN 50 mit Manschette, 1.170 m, 13,92 €/m [12]
→ 16.286 €

HT-Rohrleitung DN 70, 5.438 m, 14,56 €/m [12] → 79.177 €

HT-Rohrleitung DN 70 mit Manschette, 3.510 m, 15,29 €/m [12]
→ 53.668 €

HT-Rohrleitung DN 150 (Grundleitung), 6.300 m, 45,00 €/m [12]
→ 283.500 €

10.4.1.2 Hausanschluss

Annahme jedes Gebäude hat einen eigenen Hausanschlussschacht, 100 % sind an das Netz angeschlossen. [7]

Braunwasser:

Hausanschlussschacht:: 1.000 Hausanschlussschächte, Beton, Schachttiefe 2,0 m

Hausanschlussleitung: 1.000 Hausanschlussleitungen, DN 150
Leitungsmaterial Steinzeug, Verlegetiefe 2,0 m

Leitungslänge pro Hausanschluss = 10 m [1]
Leitungslänge insgesamt = 10.000 m

Komplett: 1.000 Anschlüsse, 920 € pro Anschluss → 920.000 €

Grauwasser:

Verlegung in gleichen Schacht und gleichen Rohrgraben wir Braunwasser → Kosten für Grauwasserhausanschluss um 50 % reduziert

Hausanschlussschacht:: Mitnutzung des Hausanschlussschachtes für Braunwasser

Hausanschlussleitung: 1.000 Hausanschlussleitungen, DN 150
Leitungsmaterial Kunststoff, Verlegetiefe 2,0 m
Leitungslänge pro Hausanschluss = 10 m [1]
Leitungslänge insgesamt = 10.000 m

Komplett: 1.000 Anschlüsse, 460 € pro Anschluss → 460.000 €

Gelbwasser:

Keine Hausanschlussschächte, dafür Revisionsöffnung im Gebäude

Verlegung in gleichem Rohrgraben wie Braunwasser → Kosten für Gelbwasserhausanschluss um 50 % reduziert

Hausanschlussleitung: 1.000 Hausanschlussleitungen, DN 150
Leitungsmaterial Kunststoff, Verlegetiefe 2,0 m
Leitungslänge pro Hausanschluss = 10 m
Leitungslänge insgesamt = 10.000 m
32,50 €/m → 325.000 €

10.4.1.3 Kanalnetz

Braunwasser:

Leitungsnetz entspricht teilweise dem Gelbwassernetz. Fest-Flüssig-Trennung auf dem Gelände der Bodenfilter.

Leitungen werden im Rohrgraben der Grauwasserleitungen verlegt, daher ist die Rohrverlegung um 50 % niedriger angesetzt

Steinzeug-Rohrleitung [7] DN 150, Tiefe 2,0 m bis 3,0 m, 7.648 m, 119,20 €/m → 911.642 €

Steinzeug-Rohrleitung [7] DN 150, Tiefe 3,0 m bis 4,0 m, 3.460 m, 161,57 €/m → 559.032 €

Kontrollschächte sind in den Kosten der Leitungen enthalten.

Pumpstationen: Pumpstationen als Pauschale, Kunststoffschacht mit 2 Pumpen

Pumpstation Tiefe 2,0 m bis 3,0 m = 7.100 €
Aufteilung der Kosten: Baulicher Teil 50 % = 3.550 €
Maschineller Teil 40 % = 2.840 €
E-Technik 10 % = 710 €
insgesamt 2 Stück

Pumpstation Tiefe 3,0 m bis 4,0 m = 8.340 €
Aufteilung der Kosten: Baulicher Teil 50 % = 4.170 €
Maschineller Teil 40 % = 3.336 €
E-Technik 10 % = 834 €
insgesamt 30 Stück

Kunststoff-Druckleitung [7], DN 50, Verlegetiefe 1,0 m, 7.984 m, 60,00 €/m = 479.040 €

Grauwasser:

Grauwasser wird generell nicht wieder verwendet [7]

Leitungsnetz nach Kanalnetzberechnung. Entwässerung zu einem Standort.
Material der Leitungen in Kunststoff.

Kunststoff-Rohrleitung [7] DN 150, Tiefe 2,0 m bis 3,0 m, 8.073 m, 208,48 €/m → 1.683.059 €

Kunststoff-Rohrleitung [7] DN 150, Tiefe 3,0 m bis 4,0 m, 2.718 m, 293,10 €/m → 796.646 €

Kunststoff-Rohrleitung [7] DN 150, Tiefe 4,0 m bis 5,0 m, 459 m, 390,37 €/m → 179.180 €

Kunststoff-Rohrleitung [7] DN 200, Tiefe 3,0 m bis 4,0 m, 676 m, 309,59 €/m → 209.283 €

Kunststoff-Rohrleitung [7] DN 200, Tiefe 4,0 m bis 5,0 m, 334 m, 410,57 €/m → 137.130 €

Kunststoff-Rohrleitung [7] DN 250, Tiefe 3,0 m bis 4,0 m, 270 m, 334,65 €/m → 90.356 €

Kunststoff-Rohrleitung [7] DN 250, Tiefe 4,0 m bis 5,0 m, 375 m, 439,46 €/m → 164.798 €

Kunststoff-Rohrleitung [7] DN 300, Tiefe 4,0 m bis 5,0 m, 164 m, 469,11 €/m → 76.934 €

Kunststoff-Rohrleitung [7] DN 300, Tiefe 5,0 m bis 5,5 m, 206 m, 559,35 €/m → 115.226 €

Kunststoff-Rohrleitung [7] DN 400, Tiefe 5,0 m bis 5,5 m, 530 m, 624,80 €/m → 331.144 €

Kontrollschächte sind in den Kosten der Leitungen enthalten

Gelbwasser:

Leitungen werden im Rohrgraben der Grauwasserleitungen verlegt, daher ist die Rohrverlegung um 50 % niedriger angesetzt

Kunststoff-Rohrleitung [7] DN 150, Tiefe 2,0 m bis 3,0 m, 7.667 m, 104,24 €/m
→ 799.208 €

Kunststoff-Rohrleitung [7] DN 150, Tiefe 3,0 m bis 4,0 m, 3.441 m, 146,55 €/m
→ 504.279 €

Kontrollschächte sind in den Kosten der Leitungen enthalten.

Pumpstationen: Pumpstationen als Pauschale, Kunststoffschacht mit 2 Pumpen

Pumpstation Tiefe 2,0 m bis 3,0 m = 6.600 €
Aufteilung der Kosten: Baulicher Teil 54 % = 3.564 €
Maschineller Teil 35 % = 2.310 €
E-Technik 11 % = 726 €
insgesamt 2 Stück

Pumpstation Tiefe 3,0 m bis 4,0 m = 7.840 €
Aufteilung der Kosten: Baulicher Teil 54 % = 4.234 €
Maschineller Teil 35 % = 2.744 €
E-Technik 11 % = 862 €
insgesamt 30 Stück

Kunststoff-Druckleitung [7], DN 50, Verlegetiefe 1,0 m, 7.050 m = 60,00 €/m = 423.000 €

10.4.1.4 Abwasserbehandlung

Braunwasser:

Filtrat / Überstand der Braunwasserbehandlung wird in die Grauwasserbehandlung eingeleitet [7]

Grundstück: 250 m², 40,00 €/m² → 10.000 €

1 Kompostplatz, 500 m², 40,00 €/m² → 20.000 €

Fest-Flüssig-Trennung: Aufteilung der Kosten: Baulicher Teil = 65.000 €
Maschineller Teil = 45.000 €

Kompostplatz: Pflasterung und Überdachung → 5.000 €

Grauwasser:

Reinigung des Grauwassers über SBR-Anlagen. Filtrat / Überstand der Fest-Flüssig-Trennung des Braunwassers wird ebenfalls in den SBR-Anlagen gereinigt.

Grundstück: 400 m², 40,00 €/m² → 16.000 €

Pumpstation: Q_{10} = 0,002 l/sec bei 4891 E= 10 l/sec → 15.000 € [5]
Aufteilung der Kosten: Baulicher Teil 50 % [6] = 7.500 €
Maschineller Teil 40 % [6] = 6.000 €
E-Technik 10 % [6] = 1.500 €

SBR-Anlage: bei 4891 E; 258 €/E → 1.261.878 €
Aufteilung der Kosten: Baulicher Teil 45 %= 567.845 €
Maschineller Teil 35 %= 441.657 €
E-Technik 20 %= 252.376 €

Schlammspeicher: 96 m³/Anlage, 125 €/m³ → 12.000 €
Aufteilung der Kosten: Baulicher Teil 83 % = 10.000 €
Maschineller Teil 17 % = 2.000 €

Gelbwasser:

Urinmenge: 1,5 l Urin/(E*d) [7]

Trenngrad in den Toiletten: Es wird davon ausgegangen, dass sich die Einwohner zu 100 % in den Gebäuden aufhalten. Annahme: 75 % des Urins geht in die Urinleitung [7]

Grundstück: Stellplatz 3 Speicher a 11 m³ = 80 m², insgesamt 1 Stellplatz → 80 m²
Stellplatz 3 Speicher a 12 m³ = 90 m², insgesamt 3 Stellplätze → 270 m²
Summe 350 m², 40,00 €/m² → 14.000 €

Urinspeicher: 1 Standort mit 3 Speichern à 11 m³, Füllzeit 3 Wochen, 10.800 €/Speicher → 32.400 €

3 Standorte mit jeweils drei Speichern à 12 m³, Füllzeit 3 bis 5 Wochen, 11.300 €/Speicher → 101.700 €

10.4.1.5 Bioabfallsammlung

Anschaffung Biotonnen: Häuser 120-l-Tonnen, 870 Stück, 50 €/Stück → 43.500 €
Mehrfamilienhäuser 240-l-Tonnen, 130 Stück, 74 €/Stück
→ 9.620 €

10.4.2 Laufende Kosten Variante 2

10.4.2.1 Personalkosten

Braunwasserbehandlung: Pro Anlage 8 h/Woche → 0,23 Personen
34.000 €/(Person*a) [M 271, Sept. 1998] → 7.820 €

Grauwasserbehandlung: 90 h/Monat → 0,61 Personen
34.000 €/(Person*a) [M 271, Sept. 1998] → 20.740 €

Laub- und Grünschnittsammlung: 3 Personen à 0,4 d/Woche → 0,28 Personen
34.000 €/(Person*a) [M 271, Sept. 1998] → 9.520 €

10.4.2.2 Sachkosten

Leitungsreinigung: Braunwasserleitung identisch mit Variante 2 (11.108 m),
Grauwasserleitung identisch mit Variante 1 (13.805 m),
Gelbwasserleitung identisch mit Variante 2 (11.108 m)
→ 36.021 m
1,3 €/m → 46.827 €

Fällmittel $FeClSO_4$: In der SBR-Anlage sind 0,75 g P/(E*d) zu eliminieren.
Elimination von 0,75 g P/(E*d), 0,55 € /(E*a) bei einer Elimination von 1 g P/(E*d) [11]→ 0,41 €/(E*a)
4891 E, 0,41 €/E*a → 2.005 €

Laborkosten: 4 Untersuchungen pro Jahr, 150 €/Untersuchung → 600 €

Abwasserabgabe: 325 SE/a , 35,79 €/SE [8] → 11.632 €

Transportkosten Urin: 2008 m³ Urin/a, 4,0 €/m³ → 8.032 €

Transportkosten Kompost: 325 m³ Kompost/a, 2,6 €/ m³ → 845 €

Betriebsstoffe Laub- und Grünschnittsammlung: 3.422 €

Schlammentsorgung Grauwasser: : 50 t TS/a, 430 €/t → 21.500 €

10.4.2.3 Wasser / Abwasser

Trinkwasserverbrauch= 101 l/(E*d) [7]
darin enthalten 21 l/(E*d) Spülwasser (1* 6l und 5*3l) [7]
80 l/(E*d) Grauwasser
Wassertarif 2,158 € /m³ [3],
4.891 Einwohner, 365 Tage im Jahr = 389.102 €/a
Umsatzsteuer 7 % [3] → 416.339 €/a

Abwasseranfall= 101 l/(E*d) Trinkwasserverbrauch, 1,5 l Urin/(E*d), 0,14 l Fäkalien/(E*d) → 102,64 l/(E*d)

Kein Abwasserentgelt, da die Abwasser- und Schlammbehandlung kalkuliert wird.

Kein monatlicher Grundpreis [3]

10.4.2.4 Energie

Trinkwasserbereitstellung:	10,29 kW, 24 h/d, 365 d/a → 90.153 kWh/a 18,13 Ct/kWh → 16.345 €/a
<u>Gelbwassernetz:</u>	
Stromverbrauch Pumpstation:	32 Pumpstationen → 0,04 kW 8h, 365d → 117 kWh/a 18,13 Ct/kWh [9] → 21 €
<u>Braunwassernetz:</u>	
Stromverbrauch Pumpstation:	32 Pumpstationen → 0,39 kW 8h, 365d → 1.139 kWh/a 18,13 Ct/kWh [9] → 207 €
<u>Braunwasserbehandlung:</u>	
Fest-Flüssig-Trennung:	3 Anlagen, 3,86 kW 6 h/d, 365 d/a → 8.450 kWh/a 18,13 Ct/kWh [9] → 1.532 €
Kompostierung:	2,89 kW, 24 h/d, 365 d/a → 25.354 kWh/a 18,13 Ct/kWh [9] → 4.597 €
<u>Grauwasserbehandlung:</u>	
Pumpstation zu SBR-Anlage:	1,93 kW, 6 h/d, 365 d/a → 4.216 kWh/a 18,13 Ct/kWh [9]→ 764 €
Stromverbrauch SBR–Anlage:	10,28 kWh, 24 h, 365 d → 90.022 kWh/a 18,13 Ct/kWh → 16.321 €

10.4.2.5 Erlöse

Urin als Düngemittel:	Erlös 1,93 €/m³ 2.008 m³ Urin/a → 3.875 €/a
Kompost als Düngemittel:	125 m³ Kompost aus Schlamm, 200 m³ Kompost aus Bioabfall → 325 m³ Kompost/a 60 €/m³ → 19.500 €

10.5 Variante 3: Urinseparation, Vakuumssystem Braunwasser Biogasanlage, Grauwasserbehandlung in einer technischen Anlagen (3 ,Teilströme, 1 Standort)

10.5.1 Investitionskosten Variante 3

10.5.1.1 Im Gebäude / bis Hausanschlussschacht

Sanitärobjekt: Vakuumseparationstoilette inkl. Montage
Herstellung in großen Stückzahlen
Insgesamt 2.910 Stück a 600 € = 1.746.000 €

Leitungen im Gebäude: Entlüftung der Gelbwasserleitung über Anschluss an die Entlüftungsleitung der Grauwasserleitung

Braunwasser:

PE-Vakuumleitung DN 50, 19.733 m, 50,00 €/m → 986.650 €

Grauwasser:

HT-Rohrleitung DN 50, 13.050 m, 13,26 €/m [12] → 173.043 €

SML-Rohrleitung DN 50, 7.020 m, 27,50 €/m [12] → 193.050 €

HT-Rohrleitung DN 70, 8.048 m, 14,56 €/m [12] → 117.179 €

SML-Rohrleitung DN 70, 4.680 m, 28,80 €/m [12] → 134.784 €

HT-Rohrleitung DN 150 (Grundleitung), 6.300 m, 45,00 €/m → 283.500 €

Gelbwasser: Identisch mit Variante 2

10.5.1.2 Hausanschluss

Annahme jedes Gebäude hat einen eigenen Hausanschlussschacht, 100 % sind an das Netz angeschlossen. [7]

Braunwasser:

Keine Hausanschlussschächte

Hausanschlussleitung: 1.000 Hausanschlussleitungen (Vakuum), DN 50
Leitungsmaterial PE, Verlegetiefe 1,0 m
Leitungslänge pro Hausanschluss = 10 m [1]
Leitungslänge insgesamt = 10.000 m

Komplett: 1.000 Anschlüsse, 300 € pro Anschluss → 300.000 €

Grauwasser:

Hausanschlussschacht:: 1.000 Hausanschlussschächte, Beton, Schachttiefe 2,0 m

Hausanschlussleitung: 1.000 Hausanschlussleitungen, DN 150
Leitungsmaterial Kunststoff, Verlegetiefe 2,0 m
Leitungslänge pro Hausanschluss = 10 m [1]
Leitungslänge insgesamt = 10.000 m

Komplett: 1.000 Anschlüsse, 920 € pro Anschluss → 920.000 €

Gelbwasser: Massen und Kosten identisch mit Variante 2, Verlegung im gleichem Rohrgraben wie Grauwasser.

10.5.1.3 Kanalnetz

<u>Braunwasser:</u>

PE-Vakuumleitung DN 65, Tiefe 1,0 m, 11.944 m, 58,00 €/m → 692.752 €

PE-Vakuumleitung DN 100, Tiefe 1,0 m, 1.364 m, 65,00 €/m → 88.660 €

Vakuumstationen: Vakuumstationen als Pauschale, 100.000 €
Aufteilung der Kosten: Baulicher Teil 50 % = 50.000 €
Maschineller Teil 40 % = 40.000 €
E-Technik 10 % = 10.000 €
insgesamt 3 Stück

Kunststoff-Druckleitung DN 65, Tiefe 1,0 m, 2.241 m, 58,00 €/m → 129.978 €

<u>Grauwasser:</u> Identisch mit Variante 2

<u>Gelbwasser:</u> Identisch mit Variante 2

10.5.1.4 Abwasserbehandlung

<u>Braunwasser:</u>

Grundstück Vakuumstation: 100 m², 3 Stationen → 300 m²
40 €/m² → 12.000 €

Grundstück Biogasanlage: 1.000 m², 40 €/m² → 40.000 €

Bioabfallzerkleinerung: 50.000 €
Aufteilung der Kosten: Baulicher Teil 20 % = 10.000 €
Maschineller Teil 70 % = 35.000 €
E-Technik 10 % = 5.000 €

Biogasanlage: 2-stufige thermophile Biogasanlage
400 m³, 2620 €/m³ → 1.048.000 €
Aufteilung der Kosten: Baulicher Teil 50 % = 524.000 €
Maschineller Teil 30 % = 314.400 €
E-Technik 20 % = 209.600 €

<u>Grauwasser:</u> Kein Filtrat / Überstand aus Braunwasserbehandlung vorhanden und mitbehandelt.

Grundstück: identisch mit Variante 2

Pumpstation: Identisch mit Variante 2

SBR-Anlage: bei 4891 E; 258 €/E → 788.674 €
Aufteilung der Kosten: Baulicher Teil 45 %= 354.903 €
Maschineller Teil 35 %= 276.036 €
E-Technik 20 %= 157.735 €

Schlammspeicher: 96 m³/Anlage, 125 €/m³ → 6.250 €
Aufteilung der Kosten: Baulicher Teil 80 % = 5.000 €
Maschineller Teil 20 % = 1.250 €

<u>Gelbwasser:</u> Identisch mit Variante 2

10.5.1.5 Bioabfallsammlung

Identisch mit Variante 2

10.5.2 Laufende Kosten Variante 3

10.5.2.1 Personalkosten

Braunwasserbehandlung: 0,5 d/Woche für Abfallzerkleinerung → 0,11 Personen
1 d/Woche für Biogasanlage → 0,23 Personen
0,34 Personen, 34.000 €/(Person*a) [M 271, Sept. 1998]
→ 11.560 €

Grauwasserbehandlung: Identisch mit Variante 2

Laub- und Grünschnittsammlung: Identisch mit Variante 2

10.5.2.2 Sachkosten

Leitungsreinigung: Braunwasserleitung identisch mit Variante 4 (13.308 m),
Grauwasserleitung identisch mit Variante 1 (13.805 m),
Gelbwasserleitung identisch mit Variante 2 (11.108 m)
→ 38.221 m, 1,3 €/m → 49.687 €

Fällmittel $FeClSO_4$: In der SBR-Anlage sind 0,6 g P/(E*d) zu eliminieren.
Elimination von 0,6 g P/(E*d), 0,55 € /(E*a) bei einer Elimination von 1 g P/(E*d) [11]→ 0,33 €/(E*a)
4891 E, 0,33 €/E*a → 1.614 €

Laborkosten: Identisch mit Variante 2

Abwasserabgabe: 311 SE/a , 35,79 €/SE [8] → 11.131 €

Transportkosten Urin: Identisch mit Variante 2

Schlammentsorgung: Identisch mit Variante 2

Betriebsstoffe Laub- und Grünschnittsammlung: Identisch mit Variante 2

Transport Schlamm eingedickt: Schlamm aus Biogasanlage
79 Fahrten, 63,32 €/Fahrt → 5.002 €

10.5.2.3 Wasser / Abwasser

Trinkwasserverbrauch= 85,2 l/(E*d) [7]
Darin enthalten 80 l/(E*d) Grauwasser [7]
5,2 l/(E*d) Spülwasser (2*1,2l und 4*0,7l) [7]
Wassertarif 2,158 € /m³ [3],
4.891 Einwohner, 365 Tage im Jahr = 328.232 €/a
Umsatzsteuer 7 % [3] → 351.209 €/a

Abwasseranfall= 85,2 l/(E*d) Trinkwasserverbrauch, 1,5 l Urin/(E*d),
0,14 l Fäkalien/(E*d) → 86,84 l/(E*d)

Kein Abwasserentgelt, da die Abwasser- und Schlammbehandlung kalkuliert wird.

Kein monatlicher Grundpreis [3]

10.5.2.4 Energie

Trinkwasserbereitstellung: 8,68 kW, 24 h/d, 365 d/a → 76.050 kWh/a
18,13 Ct/kWh → 13.788 €/a

Braunwassernetz:

Stromverbrauch Vakuumstationen: 3 Anlagen, 14,02 kW
24 h/d, 365 d → 122.785 kWh/a
18,13 Ct/kWh → 22.261 €

Braunwasserbehandlung:

Vergärung Aufbereitung Biomüll: 3,66 kW, 24 h/d, 365 d → 32.103 kWh/a
18,13 Ct/kWh → 5.820 €

Vergärung Biogasanlage: 4,16 kW, 24 h/d, 365 d → 36.476 kWh/a
18,13 Ct/kWh → 6.613 €

Vergärung Abwasserreinigung: 0,84 kW, 24 h/d, 365 d → 7.336 kWh/a
18,13 Ct/kWh → 1.330 €

Grauwasserbehandlung: Identisch mit Variante 2

Stromverbrauch SBR–Anlage: 7,16 kW, 24 h, 365 d → 62.737 kWh/a
18,13 Ct/kWh → 11.374 €

10.5.2.5 Erlöse

Urin als Düngemittel: Identisch mit Variante 2

Biogasanlage: Verstromung von Gas
200.065 kWh/a, 0,068 €/kWh [GASAG] → 13.604 €/a

10.6 Variante 4: Urinseparation – Grau- und Braunwasserbehandlung in einer technischen Anlage (2 Teilströme)

10.6.1 Investitionskosten Variante 4

10.6.1.1 Im Gebäude / bis Hausanschlussschacht

Sanitärobjekt: Identisch mit Variante 2

Leitungen im Gebäude: <u>Grau- und Braunwasser:</u>
Grau- und Braunwasser wird zusammen abgeführt.
Identisch mit Schmutzwasserleitungen in Variante 1

<u>Gelbwasser:</u>
Identisch mit Variante 2

10.6.1.2 Hausanschluss

<u>Grau- und Braunwasser:</u> Identisch mit Schmutzwasseranschluss in Variante 1

<u>Gelbwasser:</u> Identisch mit Variante 2

10.6.1.3 Kanalnetz

<u>Grau- und Braunwasser:</u> Identisch mit Schmutzwassernetz in Variante 1

<u>Gelbwasser:</u> Identisch mit Variante 2

10.6.1.4 Abwasserbehandlung

<u>Grau- und Braunwasser:</u> Identisch mit Schmutzwasserbehandlung in Variante 1

<u>Gelbwasser:</u> Identisch mit Variante 2

10.6.1.5 Bioabfallsammlung

Identisch mit Variante 2

10.6.2 Laufende Kosten Variante 4

10.6.2.1 Personalkosten

Braun- und Grauwasserbehandlung: Abwasserbehandlung identisch mit Schmutzwasserbehandlung Variante 1 → 0,61 Personen
34.000 €/(Person*a) [M 271, Sept. 1998] → 20.740 €/a

Laub- und Grünschnittsammlung: Identisch mit Variante 2

10.6.2.2 Sachkosten

Leitungsreinigung: Braun- und Grauwasserleitung 13.805 m (identisch mit Schmutzwasserleitung Variante 1, Gelbwasserleitung 11.108 m

	(identisch mit Variante 2) → 24.913 m 1,3 €/m → 32.387 €
Fällmittel $FeClSO_4$:	Im Zufluss der SBR-Anlage (Grau- und Braunwasser) sind 0,9 g P/(E*d) zu eliminieren. Elimination von 0,9 g P/(E*d), 0,55 € /(E*a) bei einer Elimination von 1 g P/(E*d) [11]→ 0,50 €/(E*a) 4891 E, 0,50 €/E*a → 2.446 €
Laborkosten:	Identisch mit Variante 1
Abwasserabgabe:	325 SE/a , 35,79 €/SE [8] → 11.632 €/a
Schlammentsorgung:	Identisch mit Variante 1
Transportkosten Urin:	Identisch mit Variante 2
Transportkosten Kompost:	200 m³ Kompost aus Bioabfall 2,6 €/m³ → 520 €
Laub- und Grünschnittsammlung:	Identisch mit Variante 2

10.6.2.3 Wasser / Abwasser

Identisch mit Variante 2

10.6.2.4 Energie

Grau- und Braunwassernetz:

Abwasserreinigung:	Basiert auf Variante 1, Energiemenge wurde um Faktor 0,885 reduziert 11,66 kW, 24 h/d, 365 d/a → 102.179 kWh/a 18,13 Ct/kWh → 18.525 €/a

Gelbwassernetz:

Stromverbrauch Pumpstation:	Identisch mit Variante 2

10.6.2.5 Erlöse

Urin als Düngemittel:	Identisch mit Variante 2
Kompost als Düngemittel:	200 m³ Kompost aus Bioabfall 60 €/m³ → 12.000 €

10.7 Variante 5: Vakuumssystem Schwarzwasser Biogasanlage, Grauwasserbehandlung in einer technischen Anlagen (2 Teilströme, 1 Standort)

10.7.1 Investitionskosten Variante 5

10.7.1.1 Im Gebäude / bis Hausanschlussschacht

Sanitärobjekt: Vakuumtoilette inkl. Montage
Insgesamt 2910 Stück a 550 € = 1.600.500 €

Leitungen im Gebäude: Schwarzwasser: Identisch mit Braunwasserleitung in Variante 3

Grauwasser: Identisch mit Variante 3

10.7.1.2 Hausanschluss

Schwarzwasser: Identisch mit Braunwasseranschluss in Variante 3

Grauwasser: Identisch mit Variante 3

10.7.1.3 Kanalnetz

Schwarzwasser: Identisch mit Braunwassernetz in Variante 3

Grauwasser: Identisch mit Variante 2

10.7.1.4 Abwasserbehandlung

Schwarzwasser: Basiert auf Variante 3
Biogasanlage: 2-stufige thermophile Biogasanlage
400 m³, Kosten baulicher Teil 29 % erhöht
Aufteilung der Kosten:
Baulicher Teil = 524.000 € * 1,29 = 675.960 €
Maschineller Tei = 314.400 €
E-Technik = 209.600 €

Grauwasser: Kein Filtrat / Überstand aus Schwarzwasserbehandlung vorhanden und mitbehandelt.

Grundstück: Identisch mit Variante 2

Pumpstation: Identisch mit Variante 2

SBR-Anlage: Identisch mit Variante 3

Schlammspeicher: Identisch mit Variante 3

10.7.1.5 Bioabfallsammlung

Identisch mit Variante 2

10.7.2 Laufende Kosten Variante 5

10.7.2.1 Personalkosten

Braunwasserbehandlung: Identisch mit Variante 3

Grauwasserbehandlung: Identisch mit Variante 3

Laub- und Grünschnittsammlung: Identisch mit Variante 2

10.7.2.2 Sachkosten

Leitungsreinigung: Schwarzwasserleitung identisch mit Braunwasserleitung in Variante 4 (13.308 m),
Grauwasserleitung identisch mit Variante 1 (13.805 m),
→ 27.113 m, 1,3 €/m → 35.247 €

Fällmittel $FeClSO_4$: Identisch mit Variante 3

Laborkosten: Identisch mit Variante 3

Abwasserabgabe: 143 SE/a , 35,79 €/SE [8] → 5.118 €

Transportkosten Urin: Identisch mit Variante 2

Schlammentsorgung: Identisch mit Variante 3

Betriebsstoffe Laub- und Grünschnittsammlung: Identisch mit Variante 2

Transport Schlamm: Schlamm aus Biogasanlage
612 Fahrten, 63,32 €/Fahrt → 38.752 €

10.7.2.3 Wasser / Abwasser

Identisch mit Variante 3

10.7.2.4 Energie

Schwarzwassernetz: Basiert auf Variante 3, Energiemenge wurde um Faktor 1,29 erhöht
Stromverbrauch Vakuumstationen: 3 Anlagen, 18,08 kW
24 h/d, 365 d → 158.393 kWh/a
18,13 Ct/kWh → 28.717 €

Schwarzwasserbehandlung: Identisch mit Braunwasserbehandlung in Variante 3

Grauwasserbehandlung:

Pumpstation zu SBR: Identisch mit Variante 3

Stromverbrauch SBR–Anlage: Identisch mit Variante 3

10.7.2.5 Erlöse

Biogasanlage: Identisch mit Variante 5

Schlamm aus Biogasanlage: 12.242 m³ Schlamm, 0,32 €/m³ → 3.917 €

10.8 Variante 6, Urinseparation, Speicherung auf den Grundstücken; Grau- und Braunwasserbehandlung in einer technischen Anlage (2 Teilströme)

10.8.1 Investitionskosten Variante 6

10.8.1.1 Im Gebäude / bis Hausanschlussschacht

Sanitärobjekt: Identisch mit Variante 2

Leitungen im Gebäude:

<u>Grau- und Braunwasser:</u>
Grau- und Braunwasser wird zusammen abgeführt.
Identisch mit Schmutzwasserleitungen in Variante 1

<u>Gelbwasser:</u>
Identisch mit Variante 2

10.8.1.2 Gelbwasserspeicher

Einfamilien- und Reihenhäuser:	0,5 m³ Speicher pro Haus, 772 Stück 1.000 €/Stück → 772.000 €
Doppelhäuser:	1,0 m³ Speicher pro Haus, 98 Stück 1.500 €/Stück → 147.000 €
Mehrfamilienhäuser:	3,0 m³ Speicher pro Haus, 130 Stück 2.500 €/Stück → 325.000 €

10.8.1.3 Hausanschluss

<u>Grau- und Braunwasser:</u> Identisch mit Schmutzwasseranschluss in Variante 1

<u>Gelbwasser:</u> Identisch mit Variante 2

10.8.1.4 Kanalnetz

<u>Grau- und Braunwasser:</u> Identisch mit Schmutzwassernetz in Variante 1

<u>Gelbwasser:</u> Identisch mit Variante 2

10.8.1.5 Abwasserbehandlung

<u>Grau- und Braunwasser:</u> Identisch mit Schmutzwasserbehandlung in Variante 1

<u>Gelbwasser:</u> Identisch mit Variante 2

10.8.1.6 Bioabfallsammlung

Identisch mit Variante 2

10.8.2 Laufende Kosten Variante 6

10.8.2.1 Personalkosten

Braun- und Grauwasserbehandlung: Abwasserbehandlung identisch mit Schmutzwasserbehandlung Variante 1 → 0,61 Personen
34.000 €/(Person*a) [M 271, Sept. 1998] → 20.740 €/a

Gelbwasserbehandlung: Entleerung der Urinsammelbehälter
Einfamilien- und Reihenhaus 8,4 d/Quartal
Doppelhaus 1 d/Quartal
Mehrfamilienhaus 5 d/Quartal → 14,4 d/Quartal
Pro Jahr 58 d/ 220 Arbeitstage pro Jahr → 0,26 Personen
34.000 €/(Person*a) [M 271, Sept. 1998] → 8.840 €/a

Laub- und Grünschnittsammlung: Identisch mit Variante 2

10.8.2.2 Sachkosten

Leitungsreinigung: Braun- und Grauwasserleitung 13.805 m (identisch mit Schmutzwasserleitung Variante 1
1,3 €/m → 17.947 €

Fällmittel $FeClSO_4$: Im Zufluss der SBR-Anlage (Grau- und Braunwasser) sind 0,9 g P/(E*d) zu eliminieren.
Elimination von 0,9 g P/(E*d), 0,55 € /(E*a) bei einer Elimination von 1 g P/(E*d) [11]→ 0,50 €/(E*a)
4891 E, 0,50 €/E*a → 2.446 €

Laborkosten: Identisch mit Variante 1

Abwasserabgabe: 325 SE/a , 35,79 €/SE [8] → 11.632 €/a

Schlammentsorgung: Identisch mit Variante 1

Transportkosten Urin: Abtransport mit Sammelfahrzeug
Einsatz 58 d/a, 137,55 €/d → 7978 €

Transportkosten Kompost: 200 m³ Kompost aus Bioabfall
2,6 €/m³ → 520 €

Laub- und Grünschnittsammlung: Identisch mit Variante 2

10.8.2.3 Wasser / Abwasser

Identisch mit Variante 2

10.8.2.4 Energie

<u>Grau- und Braunwassernetz:</u>

Abwasserreinigung: Identisch mit Variante 1

<u>Gelbwassernetz:</u>

Stromverbrauch Pumpstation: Identisch mit Variante 2

10.8.2.5 Erlöse

Urin als Düngemittel:	Identisch mit Variante 2
Kompost als Düngemittel:	325 m³ Kompost aus Bioabfall 60 €/m³ → 19.500 €

11 Literatur

[1]	n.n.	GIS Nikolassee
[2]	BWB	Preisliste „Pauschalpreise für die Herstellung von Hausanschlusskanälen. http://www.bwb.de/medien/pdf/HA_Kanal_01-05.pdf Gültig ab 01.01.2005
[3]	BWB	Tarife für Wasser, Schmutzwasser, Niederschlagswasser, Fäkalwasser und Fäkalschlamm, http://www.bwb.de/medien/pdf/Tarife06.pdf Januar 2006
[4]	BWB	Allgemeine Bedingungen für die Entwässerung in Berlin ABE http://www.bwb.de/medien/pdf/ABE-06.pdf Bek. vom 15.12.2005
[5]	Ministerium für Landwirtschaft, Umweltschutz und Raumordnung	Abwasserentsorgung in Brandenburg, Orientierungswerte Jahr 2003; Aufwand für die Abwasserableitung und Abwasserbehandlung Gewässerschutz und Wasserwirtschaft März 2003
[6]	OtterWasser GmbH	
[7]	Besprechung	Besprechung am 28.03.2006 Anwesende: A. Peter-Fröhlich, C. Remy, A. Bonhomme,M. Oldenburg, C. Dlabacs
[8]	BGBl I 1976, 2721, 3007	Gesetz über Abgaben für das Einleiten von Abwasser in Gewässer, AbwAG § 9 Abgabepflicht, Abgabesatz 13. September 1976, Neugefasst durch Bek. v. 18.1.2005 I 114
[9]	Vattenfall	www.vattenfall.de Stand 02.02.2006

[10]	KA	ATV-Arbeitsbericht der Arbeitsgruppe „Kostenstrukturen der Klärschlammbehandlung und –entsorgung“ Korrespondenz Abwasser, 46. Jahrgang, Nr. 5, S. 806 – 814 Mai 1999
[11]	Wagner	
[12]	Rechnung Stahnsdorf	Kosten (inkl. Montage) zuzüglich 30 % Aufschlag für Formstücke
[13]	Lebensministerium	Nachhaltige Strategien der Abwasserentsorgung im ländlichen Raum – SUS-SAN, Forschungsprojekt Endbericht August 2005