HAMBURG UNIVERSITY OF TECHNOLOGY
INSTITUTE OF WASTEWATER MANAGEMENT AND WATER PROTECTION

MASTER THESIS:

ECONOMIC FEASIBILITY STUDY OF THE NEW SANITATION SYSTEM IN BUILDING 1 IN THE GTZ HEADQUARTERS

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Affirmation

Hereby, I declare that this work has been accomplished independently with the use of solely referenced sources. The thoughts of other authors used directly or indirectly have been properly quoted or cited. This study has not been passed or published before in this or similar content.

Andrés Lazo Páez

Hamburg, 28.09.10

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List of Abbreviations

Abbreviation	*Meaning*	*Unit*
DPC:	Dynamic project costs,	€/m³
DPC2:	Dynamic project costs per use of the sanitation facility,	€/use
F:	Service fee,	€/m³
GTZ:	German Technical Cooperation Agency,	-
L:	Service life of a component,	yr
M:	Monthly maintenance frequency,	times/month
P:	Price of an item, a facility or a service,	€
R:	Reinvestment,	€
RC:	Running costs,	€
SANIRESCH:	Sanitary Recycling Eschborn,	-
T:	Timeframe used for an analysis,	yr
TPC:	Total project costs,	€
U:	Amount of uses,	uses
t:	Time required for a maintenance task,	h
Δ:	Related to the difference between two values,	-

Subscript

1:	Related to the initial state of a variable
2:	Related to the final state of a variable
C:	Related to a *conventional* sanitation installation
E:	Related to an *ecological* sanitation installation
i:	Related to an unitary value
PA:	Related to pipelines and accessories
SD:	Related to sanitary devices
Si:	Related to a sanitary installation
x:	Related to the spare parts of a facility

Superscript

‘:	Related to the adjusted value of a reinvestment
‘’:	Related to the readjusted value of a reinvestment

1 Summary

Based on the guidelines published by the Länderarbeitsgemeinschaft Wasser (LAWA, 2005), this study evaluated the economic performance of part of the system for the treatment and recycling of the urine, brown- and greywater collected at the headquarters of German Technical Cooperation (GTZ) GmbH in Eschborn, Germany. The section of the facility analyzed as part of the SANIRESCH (Sanitary Recycling Eschborn) project comprised only the in-house sanitation installation.

In addition to the economic evaluation of the existing separate wastewater collection and transport facility, a comparison with a *conventional sanitation* system in the same conditions was done. Further possible effects of potential changes in the environmental conditions that could affect the project's conditions were also considered. As a last point of the analysis, an example of the same kind of sanitary installation was done for a hypothetic larger sanitary installation.

In order to do a comparison of the *conventional* and the *Ecosan system* considered in this study, three parameters for the year 2010 were calculated. These parameters were: the *yearly costs*, the *total project costs* (*TPC,* its *net present value*), and the *dynamic project costs (DPC)* of the yellow-, brown- and greywater collection and transportation system. The main financial parameters considered for the data analysis were: the *devices' service life* (25-35 years), the *real interest rate* (3%) of the basis year of the analysis (2010), and a *timeframe* for the study (50 years).

Under the conditions assumed for the economic evaluation, the average project costs for GTZ's sanitary installation were €0.088/use, while the corresponding costs for a *conventional sanitation* installation were €0.069/use. Additionally, the net present value of the TPC required for GTZ's *ecological sanitation* installation was €651,800. It was determined that the main condition that influences the cost gap between both sanitation approaches is a combination of an increase in the amount of uses of the system with an eventual decrease of the cost of the sanitary devices (toilets and urinals). Finally, it was found out that even if there is a reduction in the average project costs, if the project is done on a larger scale, it does not necessarily mean a reduction of the economical gap between the sanitation technologies.

2 Ecological Sanitation as a sustainable sanitation option

Nowadays, a big concern around the world is to find appropriate ways to treat and dispose the waste produced by human activities. In the wastewater management field this is even considered as a critical situation that does not have a standardized solution, applicable to every country. Furthermore, even though international organizations such as the United Nations make efforts for establishing worldwide goals related to sanitation concepts (Schertenleib and Parnesar, 2008), there is a lack of sustainable tools that can safely and completely close the sanitation cycle.

Until now, a promising approach that seems to offer new solutions is the *Ecological Sanitation (Ecosan)*. This is a concept that does not follow the traditional construction and operating principles of *conventional sanitation*. In fact, it proposes the implementation of techniques to recover nutrients by separating wastewater streams, with an additional focus on water saving. However, even though there are low-tech as well as high-tech solutions developed and known, their economic consequences still remain very often unclear. Here a lot of research is still needed.

2.1 Basic concepts

According to von Münch et al (2009), the *Ecosan* approach does not focus on a specific technology, and is based more on adaptation to the resources locally available in a region for finding the area's appropriate solution. In fact, the variety of possible applications ranges from low-tech urine diversion dehydration (UDD) toilets to high-tech vacuum systems and even biogas reactors. Therefore, the success factor of the *Ecosan* approach is the lack of universal solutions.

However, it is necessary to go beyond *Ecosan*'s technological approach. Schertenleib and Parnesar (2008) indicate that "*...the main objective of a sanitation system is to protect and promote human health by providing a clean environment and breaking the cycle of disease*". Hence, it is necessary to analyze what makes *ecological sanitation* and other similar approaches sustainability oriented ideologies. In this respect, Schertenleib and Parnesar (2008) suggest considering the aspects presented in Figure 2.1.

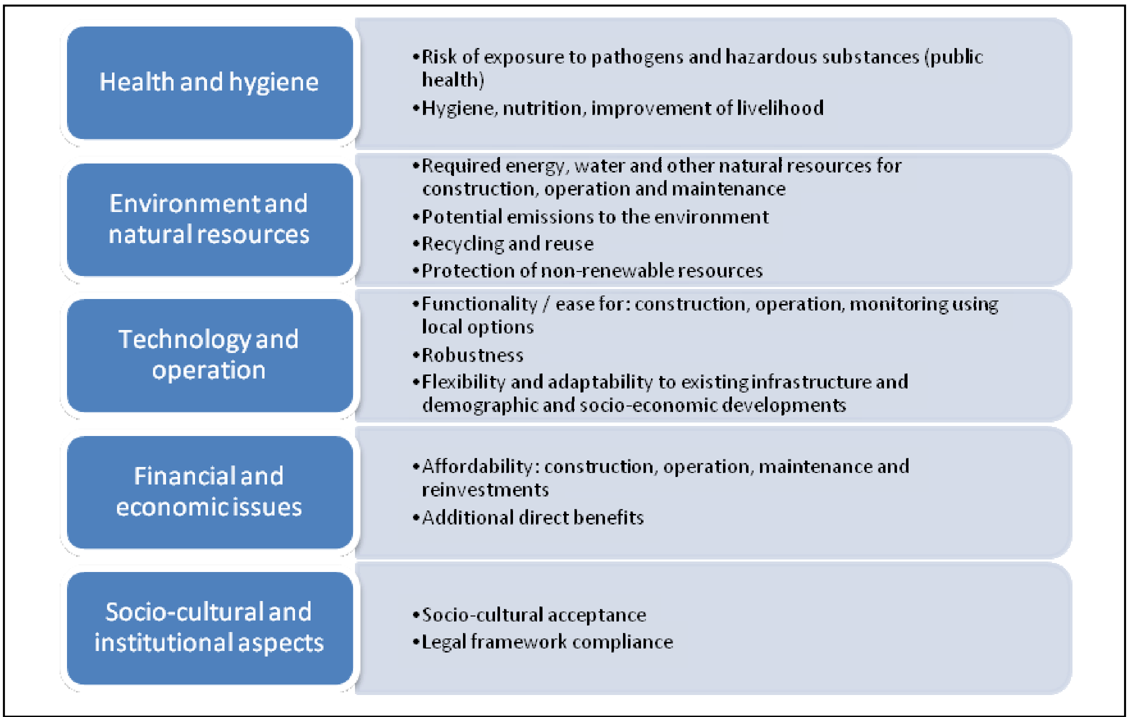

Figure 2.1 Sustainability criteria for sanitation solutions (Schertenleib and Parnesar, 2008)

The first component of a sustainable sanitation system is related to health and hygiene. This indicates that a sustainable sanitation option such as *Ecosan* should be able to improve aspects such as life expectancy, through the reduction of the exposure to pathogens and hazardous substances. However, the achievement of such condition cannot be done at all cost. There is a balance between the natural resources, environment, and the living conditions of the human being that should be maintained.

As an example, Schertenleib and Parnesar (2008) indicate that it is necessary to count with local resources (energy, water, construction materials, etc) to guarantee a good performance of the system. This implies also a reduction of potential emissions to the environment through techniques such as recycling or reuse of materials. For instance, the possibility of wastewater recycling is an option that could minimize the depletion of other sources of water.

Additionally, a sanitation system must be robust enough to guarantee a continuous service. Nevertheless, this must not have an impact on the ease of operation and maintenance of the system, with local resources. Moreover, in order to guarantee a successful short term as well as a long term performance the sanitation system should present options for adaptation to demographic or economic changes.

Last but not least, it is important to mention the balance between the affordability of the system, which sometimes can be a problem, and the social and legal acceptance. Even if a system would be completely developed, its success is conditioned to the satisfaction of the people using it. Additionally, the approach must meet the local legal requirements, so that the final link between technology, economics, social-acceptance, and policy making can be established.

2.1.1 Common variants

As a further step in order to unify different criteria in the field of *Ecosan* and other sustainable sanitation concepts, the *German Association for Water Management, Wastewater and Waste (DWA),* published in 2008 a classification based on the byproduct streams generated in different processes (Table 2.1).

Table 2.1 Classification of Sanitation Installations (DWA, 2008)

#	*Group of systems*	*Separation*	*Streams*	*Treatment goal*
1	1-Stream system	None	Wastewater	Transportation and elimination Recovery and use
2	Blackwater 2-Stream system	Greywater Rest-wastewater with lowered load and flow	Greywater Blackwater	Recovery and use
3	Urine separation 2-Stream system	Yellow water Rest-wastewater with lowered load	Yellow water Brown-/Greywater	Recovery and use
4	Urine separation 3-Stream system	Yellow water and Greywater Rest-wastewater with lowered load and flow	Yellow water Greywater Brownwater	Recovery and use
5	Feces 2-Stream system (dry toilets)	Greywater Concentrated feces No Rest-wastewater	Greywater Feces	Recovery and use

Table 2.1 (cont.) Classification of Sanitation Installations (DWA, 2008)

#	*Group of systems*	*Separation*	*Streams*	*Treatment goal*
6	Urine separation 3-Stream system (dry toilets)	Yellow water and Greywater Dry feces No Rest-wastewater	Urine Greywater Dry feces	Recovery and use

For each category presented in Table 2.1, the DWA (2008) includes in its report *Novel Sanitation Systems* a further description of the basic principles involved with the different approaches. The concepts are explained based on the minimal required water quality, the location of the collection and further usage in a common household, the name of the streams and their conduction at home, the corresponding treatments, and the eventual by-products to be obtained after the treatment. Further detailed information regarding treatment alternatives can be found in the same report.

According to the information introduced in Table 2.1, the sanitation system installed in the GTZ headquarters (to be described in chapter 3) can be considered as part of the variant 3. However, the economic analysis to be done does not consider the recovery and use component. The analysis presented in this study is focused on the separation step.

2.2 Success factors and limitations in comparison to conventional sanitation concepts

Since more than 70 years, *conventional systems* have been the prioritized sanitation alternative around the world. Nevertheless, even today in the 21st century, it is possible to observe that the efforts done relying on *conventional technologies* have not reached everyone. Even in regions where its implementation is massive, it can be observed that the sustainability offered by these alternatives is not enough for protecting and managing the world's water resources accordingly.

In 2007 in Mexico, the percentage of the population served with options for safe excreta disposal in urban areas (predominantly *conventional systems*) was around 94.5% (WSP-LAC, 2007). On the other hand, Archundia (2010) indicates that the authorities in Mexico's capital city expect one of the worst water scarcity crises during the year 2010. Additionally, Archundia (2010) indicates that the recommendation of the government to face this problem is to reduce 20% the overall water consumption. This offers a case where the water resources management does not seem to go along with the sanitation practices implemented so far.

It is important to consider that even if several drawbacks of the *conventional sanitation* can be named, it does not mean that the system should not be used any more. There are scenarios in which it is the only way to proceed and it is only a matter of applying the concepts with the most sustainable conditions possible. In the case of *Ecosan*, despite the success factors surrounding the experiences available until now, it is not exempted from certain limitations (Figure 2.2).

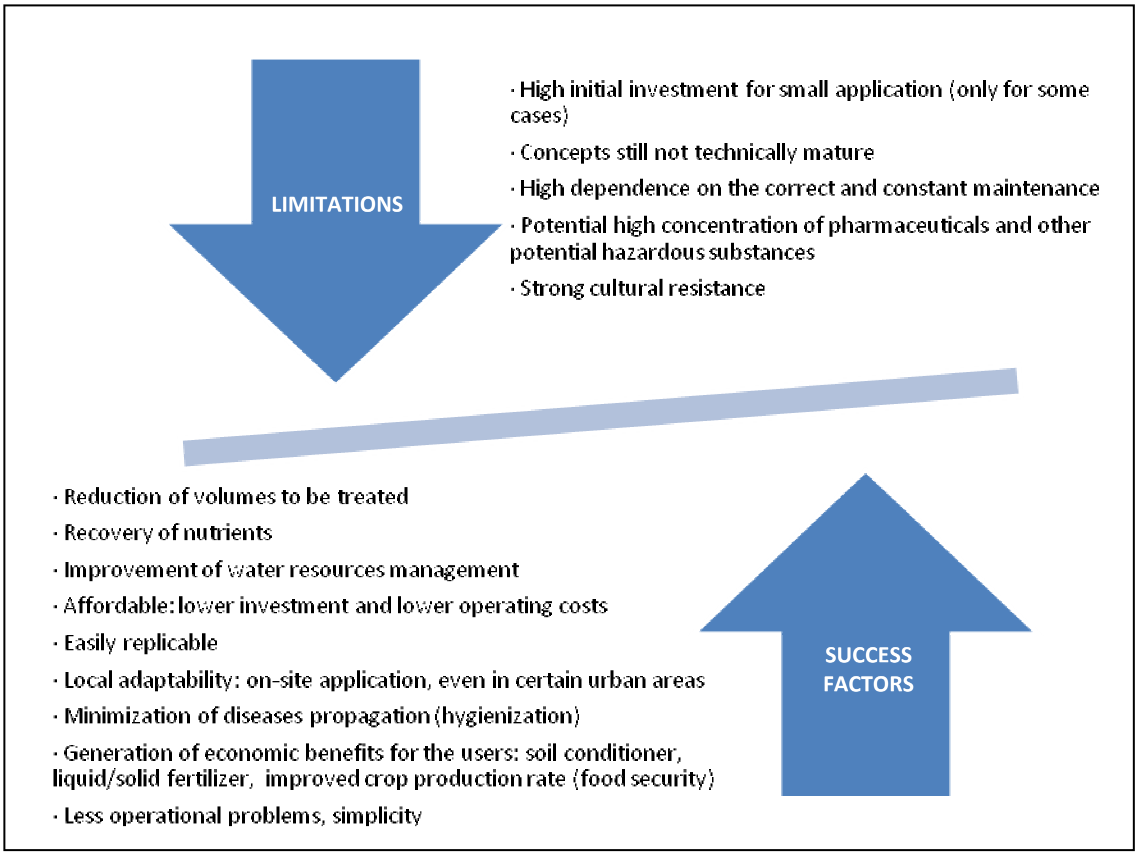

Figure 2.2 Success factors and opportunities for improvement in *Ecological Sanitation* (Gulyas, 2009; Schertenleib and Parnesar, 2008)

As it can be observed in Figure 2.2, the benefits experienced so far with *Ecosan* are overcoming remaining difficulties. However, some of these challenges are really critical for the future success of sustainable sanitation options, and they represent a barrier for the implementation of the main concepts. For example, the degree of acceptance of a urine diversion system may not be good enough yet, as indicated by Ulrich (2009b).

In terms of economic viability for small projects, there are cases in which the initial investment is still a limiting factor. For instance, Shrestha (2007) published a case study for a community in Nepal for which double toilets were found to be less costly than the corresponding *Ecosan* devices. This may be linked to the conditions of the local market, providers of accessories, etc, but that scenario is the only one available for the inhabitants of such a community.

Other drawbacks such as the lack of maturity of the sanitation devices used for some *ecological sanitation* installations (Ulrich, 2009b) as well as the potential danger of highly concentrated pharmaceuticals or hazardous substances (Gulyas, 2009) require more research and development. Nevertheless, other challenges for *Ecosan* such as the cultural resistance mentioned in Figure 2.2 and indicated by Blume and Winker (2010) can be overcome with simple solutions. For example, Blume and Winker (2010) indicate that the simple provision of disinfection devices could minimize the resistance of the users to sit down on the toilets.

2.3 Ecosan projects implemented worldwide

A successful technology needs more than a good scientific background. Demonstration projects, pilot plants and even big-scale installations (beyond a pilot plant) are often the best way to gain credibility and, at the same time, to continuously improve a concept. According to von Münch et al (2009), the aim of pilot projects is to develop and adapt E*cological Sanitation* technologies, organizational schemes and reuse concepts, and to find best-practice examples for demonstration, training and up scaling. In fact, the German Agency for Technical Assistance (GTZ) developed a database with the main *Ecosan* projects in the world (GTZ, 2010b).

According to the information mentioned in the previous paragraph there are projects in every continent and the total amount of users of these systems is close to 6 million people. Furthermore, it is important to mention that there are several projects in Europe, even though *Ecosan* is sometimes considered as just suitable for low-income conditions or rural areas (Otterpohl, 2009). That situation indicates that the concept has offered satisfactory results in different contexts so far, achieving value for its users.

3 The new sanitation system in GTZ headquarters

For several years, GTZ has been promoting *Ecosan* as sustainable sanitation solutions. Nevertheless, high-tech options, which are currently being developed and tested in research institutions still need to reach technical maturity before they can be implemented on a bigger scale. Therefore, GTZ decided to become a direct participant of its worldwide promoted policies, with a new sanitation system it its headquarters.

The initiative is called *Sanitary Recycling Eschborn (SANIRESCH)*, and investigates the treatment and recycling of the urine, brown- and greywater collected at GTZ, in Eschborn, Germany (Winker, 2010b). Additionally, Winker (2010b) indicates that technologies for the treatment of wastewater streams such as Magnesium-ammonium-phosphate (MAP) precipitation and membrane bioreactors will be applied. Furthermore, the byproducts' reuse in agriculture is part of the focus points of the whole project (Winker, 2010b).

According to Winker (2010b), further aspects investigated within the project are:

- System's operation and maintenance
- User acceptance
- Environmental and health risks of the reuse
- Economics and resource efficiency
- Legal conditions related to this kind of applications
- Transferability of such technologies to other countries

3.1 Background information

According to GTZ (2009), the main building in GTZ's Headquarters (House 1) offers office facilities for approximately 650 employees, including a canteen, several meeting rooms and an auditorium. Due to the company's profile several visitors come daily to the building, what represents a big number of potential users of the sanitation facilities. The installations were originally built in 1976 and everything was renovated between 2004 and 2006.

Even though it is difficult to determine the number of persons using the sanitation system, it is roughly estimated that around 240 persons per working day use the system (Stein and Winker, 2010). Additionally, based on the experiences of these 240 users and other GTZ workers that may have access to the sanitation facility, the project expects to investigate technical as well as social aspects. It is expected to get an impression of the acceptance of the system during all the stages of the project. Internal studies have shown so far a partially good acceptance but there are still opportunities for improvement (Blume and Winker, 2010).

3.2 Project's description

The renovation of the sanitary facilities at GTZ's House 1 is a project consisting of two main phases. The first one of them is related to the installation of the devices, pipelines and accessories (fixtures) necessary for the collection of excreta, and the second one deals directly with the treatment and further use or disposal of the different wastewater streams. The construction of the second phase is currently being done (Interview with Winker, 2010a).

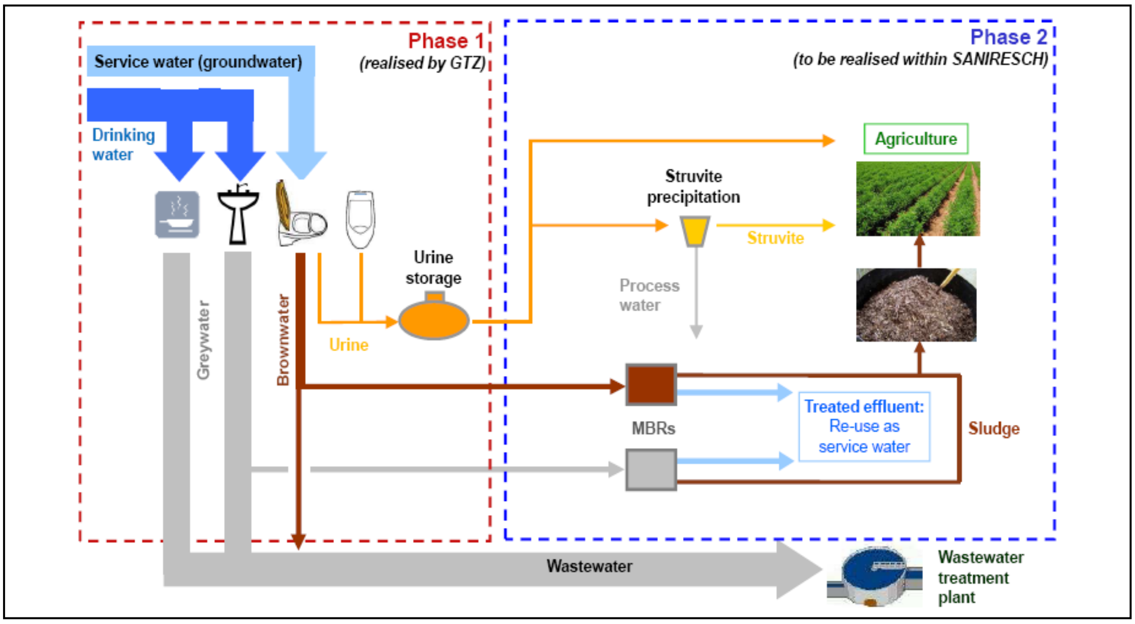

Figure 3.1 *Ecosan* system in GTZ House 1 (Winker, 2010b)

A general sketch of the whole project is presented in Figure 3.1. According to Ulrich et al. (2009), the components of the urine separation and storage system installed during *Phase 1* consist of the following components:

- 23 Waterless Urinals
- 50 Urine-diversion flush toilets
- A separate piping system for undiluted urine collection
- 4 Urine storage tanks

Additionally, Ulrich et al. (2009) indicate that due to the high water table existing in the area where the building (House 1) is, groundwater is pumped out every day. Part of this stream is used as flushing water (service water) for the sanitary installation. From the toilets and urinals two main streams are generated: the brownwater and the yellow water.

In the first stages of SANIRESCH, the yellow water was partly used for the demonstration of its benefits as fertilizer and other research goals. However, now the whole amount of urine collected is processed in the treatment facility located in the same building. In the case of the brownwater and greywater streams, they were initially directly discharged into the city's sewers but now it is intended to be processed (partially in the case of greywater) in the installation being built as part of *Phase 2*.

In the case of *Phase 2*, the brownwater and a greywater stream generated in small kitchens, sinks and other similar devices will be treated separately in Membrane Bio-Reactors (MBRs). Additionally, two urine treatment options will be investigated (Ulrich et al, 2009):

- Prolonged storage in order to produce a material suitable for direct application to fields
- Precipitation of phosphorous and nitrogen by addition of magnesium oxide, in order to produce crystal magnesium-ammonium-phosphate (MAP), also called Struvite

At the last stage of the system the material recovered from urine is expected to be used in agriculture, and the treated effluent of the brownwater and greywater streams will be used as service water. The solids obtained from these two last streams will also be applied in agriculture-related experiments. In this respect, it is important to consider that even though the current German regulations do not allow the direct use of urine as fertilizer, the experience to be developed by this system is expected to generate important scientific information to back-up a proposal for modifying this limitation (Ulrich et al., 2009). Additionally, the generation of experience in the operation of this kind of high-tech treatment systems will be a crucial point of this and future related projects.

3.3 Experiences and perspectives

Up to now the only part of the facility that is used is the installation described for *Phase I* and the MAP reactor from *Phase II*. For *Phase I*, according to Ulrich et al. (2009), an internal survey carried out in 2008 indicated that the majority of people like the idea of separately collecting urine and faeces in GTZ's House 1, for the application as fertilizer in agriculture. Additionally, a big group (71%) would even buy products fertilized with human excreta.

Conversely, less than half of the people involved in the survey would eventually support the use of urine as fertilizer for organic farming. As part of a more personal question, only 48% of the survey's participants would move in an apartment with urine-diversion toilets. These results seem contradictory, due to the fact that the people like to use the system at work but would not like it some much at home. This behavior could reflect the way of thinking of users in an urban context.

On the technical side, several challenges have come up with the operation of the system. Many are related to the daily operation of the units and some of them refer even to the design of some accessories. Among the main drawbacks being faced, the ones presented in Figure 3.2 can be mentioned.

Operation and maintenance

- Need to replace rubber odor seal due to improper maintenance
- Need to replace urine diverting valve due to imporper maintenance

Technology

- Trade-off between flushing strength (water consumption / toilet seat drops) and toilet paper – feces elimination (UD toilets)
- Small part of the urine carried out with brownwater (UD toilets)
- Low ammonium content in the yellow water (whole system)

Acceptance

- Reluctance to sit on the sanitary devices (women, UD toilets)
- Regulations against urine as fertilizer (urine reuse)

Economics

- No cost-effectiveness (economy of scale)

Figure 3.2 Main drawbacks faced during the operation and maintenance at GTZ, Eschborn (Ulrich et al., 2009)

Until now a big part of the challenges have been overcome but some critical ones still remain as opportunities for improvement (Ulrich et al., 2009). Research is still taking place in order to solve pending issues. However, the economic feasibility of projects related to *Ecosan* is usually highly questioned. The lack of economies of scale for the producers of the components as well as the lack of product development of the different *ecological sanitation* devices play an important role in the initial investment of an *Ecosan system.* Hence, in the present report it is expected to analyze, which the financial situation of the sanitation system in Eschborn is, and which are the main factors influencing it.

3.4 Objectives of the present study

Ecological sanitation systems have potential to minimize drawbacks of *conventional sanitation* systems. However, depending on the specific characteristics of the system and the conditions where it is installed, there could be differences regarding the economic resources required for installation, operation and maintenance (running costs), monitoring and reinvestment. For instance, Oldenburg (2007) indicates that "…*new sanitation concepts are not more or much more expensive than conventional systems…*" This affirmation can be considered as remarkable, considering that an *ecological* *sanitation* system as the ones studied by Oldenburg (2007) require more pipelines and even toilets that are more expensive than the *conventional* ones (Rüster, 2010).

An additional important fact mentioned by Oldenburg (2007) is that according to specific conditions, the costs of two streams separating systems may be even (in cost ranges) similar to the ones of large *conventional systems*. Moreover, even though there are some improvements still required for *Ecosan* approaches, its running costs in certain projects have been found to be lower than in the large scale sanitation options. For instance, Lechner and Langergraber (2003) indicate that for a project conceived for rural villages in Austria, the running costs for a *conventional system* reach €1,300 /house. Meanwhile, the running costs for an *ecological sanitation* system are €411.73/house.

The present analysis for the urine and brownwater separation project at GTZ evaluates the economic performance of the in-house sanitation installation (wastewater streams collection and transport) in comparison with a *conventional sanitation* system in the same conditions. In other words, the intention is to compare the system installed at GTZ in 2006 (section 3.2) with an identical facility built as a *conventional sanitation* system. None of the systems to be compared include the treatment and final disposal component.

In the case of the *Ecosan* installation, the set of collection tanks are part of the SANIRESCH project, and are therefore, also considered in the economic analysis. Additionally, the effects of potential changes in the environmental conditions that could affect the project are also considered within the guidelines published by Länderarbeitsgemeinschaft Wasser (LAWA, 2005). In general, it is expected to determine, for GTZ's conditions:

- Economic performance of both sanitary systems: initial investment, yearly running costs, reinvestment costs, average project costs, and total project costs
- Economic gap expressed as average project costs between the *Ecosan* and the *conventional sanitation* options
- Sensitivity of the average project costs to dynamic environmental conditions

4 Methodology

In order to prepare an economic analysis of a project it is always necessary to make certain assumptions. They allow the implementation of methodologies able to link the conditions existing in real life with the theoretical models commonly used in scientific working fields. The first working step in economic analyses is to determine whether a static (earnings comparisons, profitability comparisons, amortization calculations) or a dynamic methodology is the most appropriate for the analysis.

The static approach ignores the course of time and calculates an average value of the different payments, investments, expenses and earnings involved in a project during the whole timeframe analyzed. Conversely, a dynamic cost comparison refers every data to a base year, increasing the validity of analyses for longer timeframes (Wildt, 2008). Therefore, even though static procedures could be a good approximation for the economic performance of a project, the dynamic are considered as the most exact approaches (Prager, 2002). For example, for the project to be analyzed at GTZ, the present year (2010) is used as the reference point.

In the present study, the guidelines established by LAWA (2005) are presented as the dynamic cost comparison methodology to be followed for the economic evaluation of the sanitation installation at GTZ. The following sections introduce basic concepts as well as some assumptions applicable for the whole study, establishing the basis of the results presented in chapters 5 and 6.

4.1 Introduction to cost terms and concepts

Costs, as they are considered for GTZ's project, represent the resources used to build, operate and maintain the desired separate in-house wastewater collection and transport system (Figure 3.1). Each resource can be an input in the form of material, human and economic contribution for the installation, operation and maintenance of the system. According to the terminology used by LAWA (2005), the different cost types can be organized as follows:

- According to the time / frequency of occurrence: investment costs, running costs and reinvestment costs
- According to their allocation in specific cost centers: cost of goods sold, overhead costs and social costs
- According to the cost behavior: fixed and variable costs

All of the organization criteria are used in several sectors, but the applicability of each one of them depends on the evaluation to be done. For example, the classification according to the different cost centers is widely used in the manufacturing industry. Meanwhile the other two approaches can also be used for the evaluation of projects related to services and non-profit activities.

In the case of the sanitation installation built at GTZ's headquarters, the cost positions can be organized by both time / frequency of occurrence and cost behavior (Figure 4.1). The organization according to cost behavior, considers variable costs as the ones that vary in direct proportion to changes in the level of activity (Kagelmann, 2010). However, the variable cost per unit or per operation is constant. In respect to fixed costs, they are the ones that remain constant regardless of changes in the level of the activity. If expressed on a unit basis, the average cost per unit varies inversely with changes in the activity (Kagelmann, 2010).

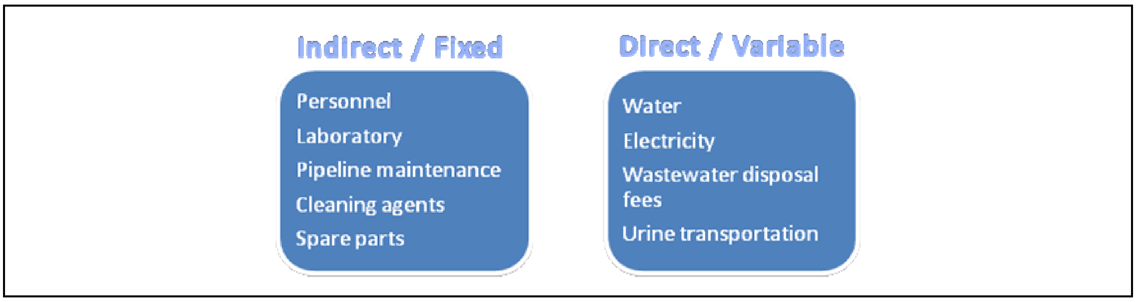

Figure 4.1 Costs classification for GTZ's new sanitation system according to *cost behavior*

According to Peters and Timmerhaus (1991), in the time / frequency of occurrence approach, direct and indirect costs can also be used as basic concepts. The main difference between them is that the direct costs can be easily traced to a specified cost object. This is mostly because these expenditures cannot be particularly (or even in average) assigned to each cubic meter of collected water or each use of the system. In the case of the variable costs, their magnitude is significantly affected by the amount of wastewater to be collected and transported.

In Figure 4.1 it can be observed that all the fixed costs in the system are considered indirect, because they do not depend on the amount of wastewater to be collected and transported or the amount of daily uses of the system. If less water is passing through the pipelines, the expense for the aspects classified as indirect would still be the same. Conversely, aspects such as water, electricity, disposal fees and eventual transportation of urine are assigned to the direct costs of the project. There is a direct dependence between the parameters and their eventual corresponding expense.

However, in order to standardize the results of this analysis according to the German context, the time / frequency of occurrence will be considered as the basic approach for the further economic analysis. This system also supports the consideration of an identical period of time for the use of the installations (*conventional* and *Ecosan*). Furthermore, the chosen system matches the conditions to be fulfilled in order to apply the guidelines published by LAWA (2005).

4.2 The LAWA methodology

The implementation of the LAWA methodology for economic feasibility analyses requires the fulfillment of specific conditions. Firstly, it is required that the variants to be compared have the same function (e.g. wastewater collection), or at least aim to solve the same problem (LAWA, 2005). Additionally, they must be compared using the same period of time; otherwise, the corresponding mathematic adjustment for meeting the correct timeframe and investment conditions must be done.

In the case of GTZ's sanitary facility installed in the year 2006, Winker (Interview, 2010a) indicates that the system is designed for the separate collection of urine and brownwater. In general, it considers urine-diversion flush toilets, waterless urinals, separate piping systems for urine, brownwater and greywater, and tanks for urine storage. Even if In the case of a conventional system the components are not exactly the same (e.g. less pipelines), the function of collection and transport to a specific point in the building is assumed to be the same.

Another condition to be satisfied by the analysis is the consideration only of the effects which have an economic impact on the evaluation. Other criteria (e.g. opportunity cost analyses) must not be taken into account, even for the final decision making process (LAWA, 2005). However, any saving possibilities that could be caused by the implementation of the alternatives to be compared must be considered (e.g. water saving opportunities).

4.2.1 Basic parameters

For comparing costs that may correspond to different points in time it is necessary to refer all the values involved to the conditions in a specific year. The main financial parameters to be considered for the data conversion are: service life, interest rate for the time in which the analysis takes place, and the considered timeframe for the study. All these values are part of the parameters that may represent variable criteria for sensitivity analyses or any other similar approaches (LAWA, 2005). Furthermore, each parameter will be presented as net present value; that means, already discounted to meet the conditions of the study's base year (2010).

The estimation of the service life of a specific item may change depending on several factors, such as: location of the project, planning, product performance, and the item's materials. Average values for these data instead of pure technical approaches (e.g. fixed duration of a material) are to be used in the calculations. Some values commonly used in sanitation applications, and that will be used in this study, are presented in Table 4.1.

Table 4.1 Service life for the main components of an in-house sanitation installation (Prager, 2002)

Item	*Service life (yr)*
Toilets, urinals and other sanitary appliances	25
Wastewater collection pipes	35
PE tanks	35
Other sanitary accessories	25

According to LAWA (2005), for the German context, it is strongly recommended to consider a yearly real interest rate of 3%, as a long term value, valid for planning and evaluation purposes. This value is based on the long term experience accumulated by different German agencies, such as the one in charge of Federal Transportation Planning (Bundesverkehrswegeplanung). Due to the fact that the reference projects for which this value was defined, deal with the development of infrastructure, the interest rate is considered as completely applicable to construction activities related to the wastewater field (LAWA, 2005).

The real interest rate mentioned by LAWA (2005) is equal to the nominal interest rate (to be paid for credits) minus a price change determining rate (also known as inflation). It gives the return of an asset, taking into account the expected monetary loss. Therefore, it also reflects a price-adjusting interest rate. Mathematically, based on perfect markets assumptions, it can be determined as the subtraction of the nominal interest rate minus the inflation rate (Anonym, 2010b).

Thus, LAWA (2005) indicates for its methodology that the prices for the project components are to be considered as constant, based on their cost in the study's reference year. The application of the real interest rate already considers changes in the value of money as one of the main influences in future price changes. In fact, the value of a component costing €1000 now and €1100 in a few years would be the same due to the fact that it was bought with different money values.

The remaining factor to be established for the economic study is its timeframe. It can be chosen according to the initial requirements established for the analysis as well as depending on the kind of project considered. The most common value for a facility such as an in-house sanitary installation is 50 years (LAWA, 2005; Prager, 2002). Therefore, this will be used as timeframe for the present analysis.

4.2.2 Costs structure

The costs structure presented in section 4.1 is an indication of the nature of the information and the way how the data can be obtained. Hence, in order to process the data for generating comparable results, LAWA (2005) defines the following details for the classification:

- Investment costs: these are the costs incurred only one time, either at the beginning of the project or in a further stage; usually corresponds to the purchase of equipment
- Running costs*:* these are costs directly related to the operation, maintenance and supervision of the installation; usually subdivided in costs of personnel and administration, materials, services, energy and maintenance required
- Reinvestment costs*:* these costs can also be considered as part of the investment costs, necessary for the replacement of specific parts of the system during the operation period

4.2.2.1 Investment costs

As already mentioned in section 3.2, the only part of the facilities included in the modernization project of House 1 (GTZ, Eschborn), to be considered in the economic analysis, is the one related to the in-house collection and transport of brownwater and yellow water, as well as the part of the greywater to be further treated in the MBR reactors (Figure 3.1). Additional accessories or parallel installations such as the water supply network or the rainwater management system are not part of the analysis. Additionally, the transport of the wastewater streams out of the building and the corresponding treatment are also out of consideration.

The components of each system are grouped in a few categories, so that the data processing and the understanding of the results become easier. This grouping step is used for the determination of the reinvestment required for each sanitation alternative. The categories that are part of this group are:

- Urinals: considers the total amount of urinals
- Toilets: considers the total amount of toilets
- Pipelines: considers the total length of pipelines installed, categorized according to their nominal diameters

- Accessories: considers the total amount of accessories (fixtures, joints, tees and other fittings) installed, categorized according to their nominal diameters
- Other accessories and materials: considers additional accessories not included in the previous classification (expansions, insulation, etc) as well as the urine storage installation (in the case of the *Ecosan system*)

Several cost approximations for the in-house sanitary installation, prepared during different stages of the modernization project exist. However, two main sources of data are chosen for the present analysis. The required initial investment for the *Ecosan* facility is determined based on the bill prepared by the company *Maßalsky* (2006) for the installation of the sanitary facility (contract 81069842, August 2006). The degree of detail presented in this document is better than in any of the other sources, and the fact that it is an actual bill, minimizes the error that may appear by using pre-calculations (based on assumptions). Additionally, this bill is among the last documents where the total costs appear summarized (Appendix B).

In the case of the *conventional sanitation* installation, the documents used for the presentation of the modernization project of House 1 to the Managers of GTZ (GTZ, 2004) are the chosen source of information. In this document, several scenarios are presented as options for the renovation of the sanitary facilities. Among them, *Scenario C* (*Modernization with conventional sanitation concepts*) is the reference estimation used for the current study. Further approximations found as part of GTZ's documentation did not offer reliable information for the analysis.

An additional factor to be taken into consideration in the determination of the initial investment is related to the price differences between the sanitary devices. The prices for the calculations of the *Ecosan system* are taken just as they are shown in Maßalsky's bill (2006). That means that there is a certain percentage for installation and profit margin that is part of the price reported in the bill. This make some numbers differ from the original price of the devices. For example, Rüster (2010) indicates that the unit price for the diverting toilets used in the project was €750 (price for 2006), instead of the €1,347 reported by Maßalsky (2006).

Nevertheless, if the information contained in the bill prepared by Maßalsky (2006) is compared with other sources, it is possible to find out that the criteria applied in Maßalsky's documentation are heterogeneous. In other words, it is not possible to determine (from the bill) a standard concept for estimating how much of the prices are actually pure installation service or profit margin. Therefore, an additional consideration is required for the cost estimation of the *conventional sanitation* system.

The information presented by GTZ (2004) does not consider the costs of labor required to install the equipment of the *conventional sanitation* system. Hence, a 30% of the price of the equipment will be considered as the additional cost of labor (Peters and Timmerhaus, 1991). It will be assumed that the profit earning is already included in the base price. In the case of the costs estimated by Maßalsky (2006), the information is taken and used as it is stated in the bill.

4.2.2.2 Running costs

In addition to the investment done for the installation of a determined facility it is important to consider the future expenses required by the system. In the case of the running costs, the main criteria considered in the analysis are:

- Disposal of the different wastewater streams
- Maintenance personnel
- Cleaning personnel and materials
- Additional cleaning substances
- Spare parts

An important condition for the analysis, related to the management of the wastewater streams of the sanitation system, deals with the water consumption in House 1. As there are no flow measuring devices currently installed in the facility, the calculations done by Stein and Winker (Interview, 2010) are used as reference for the required approximation.

According to Stein and Winker (2010), the average amount of brownwater evacuated by each toilet usage is 10.3 L/use and the corresponding amount for yellow water is 6 L/use. In the case of waterless urinals, the authors assume a generation of 250 ml of urine per toilet or urinal use. This gives a total yellow and brownwater generation of 757 m³/yr in the *Ecosan system* and 781 m³/yr in the *conventional system*.

Stein and Winker (2010) point out that the differences from the nominal values indicated by the manufacturer of the toilets are due to the fact that some users flush the toilet more than one time per use. This situation together with the fact that there are users who may use the sanitary installation more than one time per day leads to the definition of "uses" instead of "users" for further calculations. In fact, Stein and Winker (2010) assume that the amount of daily users corresponds to 240 persons, while the amount of daily uses is 676 (Table A.1).

An additional consideration for the estimation of the running costs is related to the yellow- and brownwater disposal. During the early stages of phase 1 the yellow water was temporarily used for research purposes, and therefore, transported in special containers to the required locations. Nevertheless, it is currently used in the research facility located in Eschborn (Interview with Winker, 2010a). For the purposes of this study, it is assumed that both yellow- and brownwater are disposed into the public sewerage system, at a cost of €2.08/m³ (Stadt Eschborn, 2009). Potential changes in these wastewater streams, such as the Struvite production in the MPA reactor (section 3.2), are not considered.

In the case of the greywater, its generation was determined measuring the daily flow of water on-site GTZ (2010c). The measurements took place during the months of January, February, July and August 2010. As the approach to be considered for the analysis, it is assumed that the average greywater generation during the last three months (83 m³/yr, or 377 l/d) represents the flow of this wastewater stream to be collected and further treated. Additionally, a €1.94/m³ (Stadt Eschborn, 2009) fee will be considered for the drinking water to be later sent to the public sewerage system as greywater.

More on the side of daily maintenance, Goosse and Steiner (2009) indicate that the activities to be performed as well as the time required for the cleaning and regular operation of *Ecosan systems* are comparable to the ones required for the *conventional sanitation* facility. This is supported by the statements of Neubert (Interview, 2010).

A further element to be considered is related to the cleaning personnel and materials required. According to Neubert (Interview, 2010), all the devices and manpower necessary to perform such activities are part of a contract between GTZ and the company Jacobi GmbH. Additionally, Neubert (Interview, 2010) indicates that the costs can be considered equal for both *conventional* and *ecological sanitation* installations. The parameters used for the contract's cost estimation are presented in table 4.2.

Table 4.2 Parameters for the cost estimation of the cleaning services (Interview with Neubert, 2010)

Factor	***Unit***	***Value***
Ecological sanitation restrooms' surface	m^2	260
Cleaning performance	m^2/h	100
Unit cleaning costs	€/h	14.74
Yearly working days	d/yr	220

For the calculation of the expense in cleaning services it is assumed that all the restrooms are cleaned every working day. Therefore, if the area occupied by these sanitary facilities is divided by the cleaning performance stated in the contract, the amount of daily hours required for this action can be estimated. Moreover, the price for each hour of service together with the yearly working days at GTZ gives an approach of the yearly expense in cleaning services.

The only "additional" cleaning substance required for enhancing the removal of mineral deposits in the *Ecosan* toilets is the Mellerud. It costs €126 / 25 L unit (Mellerud Chemie GmbH, 2010) and is applied with a rate of 200 ml/application, once a month. According to Winker (Interview, 2010a), due to difficulties for the correct execution of this routine with the current cleaning personnel, the GTZ decided to check this activity every time it is performed. Jacobi GmbH must apply the product on a Friday and GTZ personnel check the corresponding flushing on the following Monday.

The revision of the correct application and flushing of the Mellerud is not considered as part of the working time required for maintenance. Its magnitude when it is compared to other personnel-related expenses is low. In terms of other cleaning agents, Winker (Interview, 2010a) indicates that other products are being taken into consideration for improving or even support the current cleaning routine. However, no changes have been implemented yet.

The regular mechanical maintenance of the installation in Eschborn is done by GTZ's own staff. There is a registry where the technical problems of the sanitation facilities are documented before the corrective measures are implemented (Interview with Stein, 2010). For the entire year 2009, Stein (Interview, 2010) collected information regarding the common operational problems faced in Eschborn (Table A.7-A.8), which will be used as basis for further estimations.

Subsequently, the description of the problem, the corresponding implemented solution, and the required time for its implementation is determined. Afterwards, everything is transformed in terms of time investment per corrective measure (Tables A.9 and A.10). A combination of these time investments together with cost of the services of the personnel in charge of such tasks (Table A.9), allows the calculation of the monetary value of the time for maintenance activities.

As the *ecological sanitation* system that is part of SANIRESCH is still facing a development stage, the eventual need for spare parts and the corresponding maintenance work can be considered as key points for the evaluation of the whole installation. As it is stated by Rüster (2009) and Blume and Neuenschwander (2007) some problems that may come up in terms of spare parts are: long delivery times (more than 3 weeks), small spare parts inventory at sellers' warehouses (10 pieces), and occasional change in the parts that the sellers offer to the customers without previous notice.

In the case of *conventional sanitation*, the previously mentioned problems are less frequent because the spare parts are more standardized. The technical development of such items has been achieved through several years of operation worldwide.

Additionally, there are more companies and even specialized stores that offer availability for *conventional system's* spare parts any time.

In order to complement the information required for estimating the maintenance costs, the spare parts expenses between 2006 and 2009 for both *conventional* and *Ecosan* systems are calculated. This approximation is based on the bills received from the spare parts providers (Appendix C). The result of the costs sum for each sanitation alternative are divided by the corresponding total amount of devices (toilets and urinals), so that the yearly cost of spare parts per device (Table A.4, A.5 and A.10-A.12) can be obtained.

At this point, it is important to indicate that these yearly unit costs index, in some cases differed by even more than 300%. Hence, it was decided to choose their median instead of the average value for further calculations. This means that the costs for the years between 2006 and 2009 are considered as they are detailed in the original bills. However, the costs for the upcoming years are represented by the median value of the period 2006-2009. The average value would be highly influenced by unique situations that took place during the past few years, while the median value is less influenced by such events.

Finally, another potential cost that could be considered among the general running expenses is the electricity consumption. However, according to Neubert (Interview, 2010), there is no power requirement within the *ecological sanitation* facility. Actually, the electricity required to guarantee the water pressure in the building and to run the active aeration system of the urine storage room are neglected (Interview with Winker, 2010a). Additionally, the Neubert's (Interview, 2010) statement is further supported by the fact that GTZ's installation does not count with horizontal pumping systems. In fact, the wastewater streams flow to the collection points by gravity. An identical approach is followed for the *conventional sanitation* installation.

4.2.2.3 Reinvestment costs

In order to consider all the possible expenses that may come up as part of the sanitary installation project, the reinvestment costs are calculated according to the conditions introduced in section 4.1. The base for the estimation is the cost of each one of the items that are part of each sanitation system (Table A.3, Appendix B).

For the *Ecosan* installation, each one of the groups of items listed in Table A.2 is firstly recalculated as a net present value. For this estimation, the prices established by Maßalsky (2006) are converted from 2006 to values in the year 2010, using an interest rate of 3% (section 4.2.1). This generates, according to the assumptions presented in section 4.2.1, the base value to be discounted as part of the future reinvestment.

At this point, with the previously estimated value, the corresponding service life (Table 4.1) is assigned to each item. This allows the determination of each discounting factor. As a final step, the discounting factor is multiplied by the price of the item, and the addition of all these multiplications give part of the total value of the reinvestment. The other component is determined, in an analog way, by the spare parts already bought in the previous years, because a service life of only five years is estimated for them (Table 4.1).

In the case of the *conventional sanitation* facility, each one of the groups of items listed in Table A.6 is also recalculated as a net present value. It is important to consider that the prices established in this case (GTZ, 2004) must be converted from 2004 to the year 2010, using the same interest rate as in the previous case of 3% (section 4.2.1). The rest of the procedure is analog to the one presented in the previous paragraph (Figure 4.2).

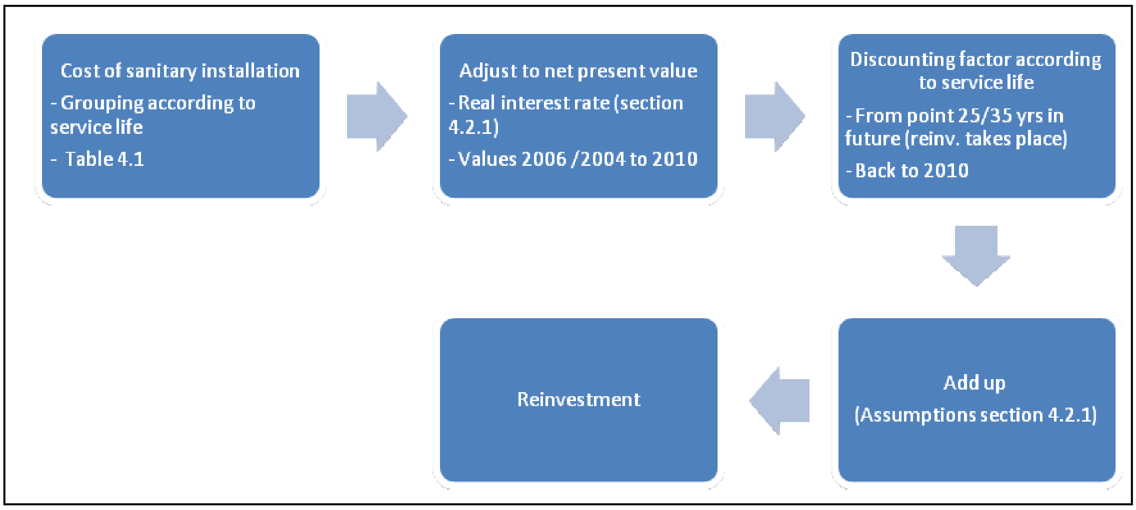

Figure 4.2 Step by step calculation of the reinvestment required for the sanitary installations. Based on information from (LAWA, 2005)

4.2.3 Costs comparison

For comparing the *conventional* and the *ecological sanitation system* considered in the case of GTZ's new installation, three comparison parameters can be used. The first of them corresponds to yearly costs, which is estimated using the corresponding capital reinvestment factor (LAWA, 2010). This factor allows the recalculation of the initial investment distributed along the whole timeframe of the project. The sum of yearly costs consists of the yearly investment added to the yearly running costs.

The second parameter is the total project costs (*TPC,* as net present value). It considers the total costs extended over the whole period of time subject to analysis. However, this calculation requires recalculating the running costs for the entire project's timeframe. This is done by grouping all the discounted yearly expenses into one big amount of money in the base year (2010), using a financial factor (LAWA, 2010). Once this is done, the addition of this total expense in running costs plus the total reinvestment costs and the initial investment, gives the final TPC of the sanitary installation.

Finally, the last comparison parameter is the dynamic project costs *(DPC)* of the collection and transportation of wastewater. It considers the TPC, number of yearly users and timeframe of the analysis. Additionally, it represents the average amount of money needed for the collection and transport of the wastewater, either per cubic meter wastewater, use, or any other adequate unit. A summary of the three cost comparison terms is presented in Figure 4.3.

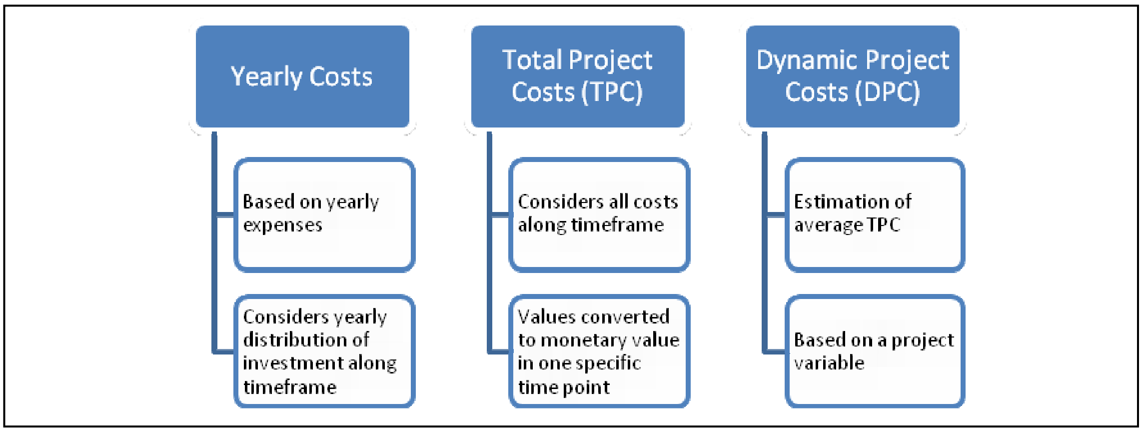

Figure 4.3 Cost comparison factors according to LAWA (2005)

In this study, the DPC will be used as the comparison parameter. The first reason for it is the low amount of digits that it usually requires, what makes it easier for any person interested in the topic to get a fast idea about the results. In the second place, it is a parameter that depends on a variable basic for the study. This allows easy data processing, considering at the same time the size of the project.

A further advantage of using the DPC as comparison value is that the parameter is useful for getting an approximation of the average effect of a modification in the system. Even for the present study, differences between two or more sanitation alternatives (expressed as DPC) can be quantified as an average TPC, facilitating the decision making process.

Nevertheless, if a DPC together with a TPC value change are calculated, it is still necessary to be able to determine whether the modification is significant or not. In this respect, the literature does not offer a fixed rule, mainly due to the fact that the budget and project conditions are different between companies. Therefore, a totally empirical rule is assumed to evaluate the significance of a TPC change. In the current study, it the change is higher than 10% of the starting TPC it will be considered as significant for the project.

4.2.4 Further scenarios

In addition to the sensitivity analysis to be introduced in section 4.2.5, two scenarios will be analyzed in advance for the project. They comprise current internal conditions, specific for the GTZ, which could eventually change and directly affect the economic performance of the facility. These scenarios differ from the ones included in the sensitivity analysis (section 5.6) in that the factors analyzed are not external (can be modified anytime by GTZ) and are not part of theoretical assumptions (e.g. timeframe for the analysis).

One of the focal points to be studied is related to the way in which the expenditure for spare parts is considered. As already mentioned in section 4.2.2.2, during the first years of operation the *ecological sanitation* installation was not optimally maintained.

Actually, there was a sudden huge expense for certain spare parts during the third year of operation. Hence, it is assumed as a potential scenario that the maintenance measures remain the same as they are nowadays (not optimal). That means that the GTZ just replaces the valves every three years during the whole timeframe considered for the analysis.

The second focal point considers a condition in which there is no availability of service water (contrary to the case of GTZ in Eschborn). Such an assumption would require the use of drinking water for flushing, causing an impact on the running costs and subsequently on the final economic performance of the system. The corresponding volumes required and other complementary conditions remain the same as in the case of the wastewater. It is considered that all the water used as drinking water will come up later as wastewater.

4.2.5 Sensitivity analysis

A sensitivity analysis is usually the complementary part of a project evaluation. Due to the fact that the economic performance of the project is partially based on assumptions (Section 4.2), the study of the effects of possible changes in these assumed conditions is recommended. This offers a broader overview of future scenarios that could be faced by the investor (in this case GTZ). It is also considered as a fundamental step, due to the nature of the investment as a non-profit activity.

LAWA (2005) suggests several factors that can be interpreted as potential sources of variation, which may affect the outcome of the project. Among them it is possible to mention: interest rate, energy costs, price of drinking/service water, price of wastewater disposal, etc. However, due to the nature of this project and further aspects to be introduced in section 5.6, the chosen criteria for the present analysis are:

I. Decrease of the price of the sanitary installation (5% rates)
II. Increase of the amount of uses (5% rates)
III. Increase of the wastewater fee (3% rates)
IV. Extension of the *timeframe* for the project consideration (5 years each)

V. Increase of the running costs (5% rates)

VI. Increase of the amount of uses and decrease of the price of the sanitary installation (I+II)

VII. Increase of the amount of uses, decrease of the price of the sanitary installation and increase of the wastewater fee (I+II+III)

A further complementary aspect for the sensitivity analysis is that the parameter to be compared is the Dynamic Project Cost based on the system's uses (DPC2) already explained in section 5.4. In each case, initial values of the DPC2 (without variation in the parameter to be analyzed) will be compared with the final DPC2 value.

5 Economic analysis

In this section, the main outcome of the economic analysis of GTZ's sanitary installation is presented. These results intend to generate the required criteria for the comparison of the project executed as an *ecological sanitation* as well as a *conventional sanitation* installation. In addition to the basic results, structured after LAWA (2005), a sensitivity analysis is done. This intends to offer a broader overview of the potential of both sanitation techniques under the consideration of several dynamic scenarios.

5.1 Investment and reinvestment

According to GTZ (2004) and Maßalsky (2006), the total investment for the *ecological sanitation* system is higher in comparison with a *conventional system* (Table A.3). As it can be observed in Table 5.1, the difference in the case of pipelines and accessories is close to €43,500, while in the case of the sanitary devices (toilets and urinals) it is €27,000. If these differences are compared to the difference in the total costs, it is possible to find out that the biggest contribution to the differentiation between both sanitation systems corresponds to the pipelines and accessories (62%).

Table 5.1 Investment required for GTZ's sanitary installation

Item	*Total Price – Conventional[a], P_C (€)*	*Total Price – Ecosan[b], P_E (€)*
Pipelines and accessories	95,300	138,800
Urinals & Toilets	57,100	84,100
Total (€)	**152,400**	**222,900**

[a] GTZ (2004)
[b] Maßalsky (2006)

If each sanitation system is considered individually, it is possible to determine that the *ecological sanitation* devices are in this case 1.5 times more costly than the *conventional* ones, representing how this technology is not yet entirely consolidated, in terms of its prices. Additionally, if the cost of pipelines and accessories is compared with the total costs of each sanitary installation, it is possible to estimate that the cost of pipelines and accessories corresponds to 63% of the total initial investment in the *conventional* concept, and 62% in the case of the *Ecosan* approach. This clearly expresses the important influence of pipelines and accessories on both sanitation options considered (more than 50%).

In order to perform the analysis according to LAWA (2005), the expected reinvestment is calculated. Using the data presented in Tables 4.1 and A.3 as the basis to determine the required reinvestment for each component, it is possible to calculate the data presented in Table 5.2 (see section 4.2.2.3). Additionally, it is important to indicate that the differentiation made between reinvestment adjusted and reinvestment readjusted is that the first one takes the original cost of the component and recalculates it for the base year of the study (2010). The term indicated as readjusted corresponds to the adjusted value financially discounted for the estimation of the required reinvestment.

Table 5.2 Reinvestment estimation for a 50 years period consideration of the *ecological sanitation* option, without already installed spare parts

Item	*Price of the installation*[a], *P (€)*	*Service life*[b], *L (yr)*	*Reinvestment, adjusted*[c], *R' (€)*	*Reinvestment, readjusted*[d], *R'' (€)*
Urinals	7,300	25	8,200	3,487
Toilets	67,400	25	75,900	32,191
Pipeline DN 50	1,500	35	1,700	533
Pipeline DN 80	5,400	35	6,100	1,919
Pipeline DN 100	9,100	35	10,200	3,234
Pipeline DN 125	4,500	35	5,100	1,599
Accessories DN 50	1,800	35	2,000	640
Accessories DN 80	8,900	35	10,000	3,163
Accessories DN 100	11,400	35	12,800	4,051
Accessories DN 125	7,900	35	8,900	2,808
Other accessories and materials	72,900	35	82,000	25,907
Total (€)	**198,100**	**-**	**222,900**	**79,500**
Total adjusted[e] **(€)**	**222,900**	**-**	**-**	**79,500**

[a] Maßalsky (2006)
[b] Prager (2002)
[c] Considers the original cost of the component and recalculates it for the base year of the study (2010)
[d] Considers the *adjusted* value financially discounted for the estimation of the required reinvestment
[e] Considers the original cost of the component and recalculates it for the base year of the study (2010)

According to the information shown in Table 5.2 and Table A.4, the reinvestment costs of the *Ecosan* facility represent approximately 40% of the total investment. For the period of time considered in the analysis this does not seem like a significant expense, taking especially into account that with a slight increase of the timeframe this cost would exceed the initial total investment. On the other hand, in the case of the *conventional sanitation* option, €83,500 is required as reinvestment, representing 55% of the initial investment. This indicates that for the context of GTZ's project, the ratio of the reinvestment costs to the total initial investment is lower for *ecological sanitation.*

5.2 Running costs

According to the assumptions presented in section 4.2.2.2 concerning the operation and maintenance of the sanitary installation in Eschborn, it is possible to determine that the running costs are higher for the *Ecosan* system. The yearly difference between the sanitation options is €1,800, about 16% if the *conventional* approach is used as reference for the calculation of the error. As it can be observed in Table 5.3, the cost advantage through water saving that is part of the *Ecosan* system is totally overcome by the expense in extra cleaning substances, spare parts, and maintenance and supervision personnel.

Table 5.3 Running costs comparison for the *ecological* and *conventional sanitation* options

Item	*Units*	*Conventional System*	*Ecosan System*
Maintenance and supervision personnel	€/yr	200	1,100
Wastewater disposal	€/yr	1,800	1,700
Cleaning personnel and materials	€/yr	8,400	8,400
Drinking water	€/yr	200	200
Cleaning substances, extra (liquid)	€/yr	0	600
Spare parts	€/yr	800	1,200
Yearly running costs	€/yr	**11,400**	**13,200**

As it is stated in section 4.2.2.2, the cleaning activity can be considered as equally costly (€8400/yr). Therefore, it does not play any role in the running costs' difference. Actually, the major contributor to the difference is the additional cleaning activity performed with the product Mellerud. This kind of cleaning is not required at all for a *conventional sanitation* installation.

In terms of spare parts, the lack of regular cleaning and maintenance of the toilet valves in the *Ecosan* system (Interview Winker, 2010a) caused a disproportionate expense in 2009, which is a unique situation specific to the conditions existing at GTZ. For example, in 2008 approximately €26/device were spent for spare parts but this expense reached €76/device in 2009. In the case of the *conventional sanitation* installation the increase was only €6/device. Therefore, a reduction of the spare parts expense requires improvement of the maintenance practices existing nowadays at GTZ. The acquisition of a stock of most-frequently damaged spare parts as well as preventive maintenance appears to be potential solutions.

Directly connected to the spare parts installation comes the time investment of the personnel in charge of this activity. As it can be seen in Table A.9, the yearly time investment for the *Ecosan* sanitation alternative is almost six times the value required for the *conventional* system. This difference comes up in terms of expenditures as €900/yr. This can be considered as consequent with the difference obtained in the case of spare parts expense (€400/yr).

The €900/yr difference in the yearly time investment could be reduced with the previously suggested measure related to preventive maintenance. However, it is necessary to reach a balance between corrective and preventive maintenance. Too much of one of them could lead to a worse condition than the current one (€900/yr difference).

The results presented in Table 5.3 show that that there are water savings around 6% in the case of the *ecological sanitation* system. The total amount of money saved due to less water consumption in the *Ecosan* installation is €100 per year. However, this sum of money may change significantly depending on the amount of uses of the system and depending on the performance of the sanitary devices (Interview with Stein and Winker, 2010).

For the *Ecosan* option, the potential reduction of the expense due to wastewater fees relies on the improvement of the design of the toilets. As it can be seen in the calculations done by Stein and Winker (2010), many users must flush the toilets more than once due to the current evacuation potential of the devices. Therefore, cooperative work with the manufacturers of the toilets appears as the first step towards a solution for the problem. Based on the approach of Stein and Winker (2010), with only one flush per use, it would be possible to go down to a wastewater generation of 576 m³/yr, instead of the current 757 m³/yr. In other words, there would be €380/yr savings, or almost 20% reduction of the total current running costs difference.

5.3 Costs comparison

Following the LAWA (2005) guidelines, the incurred costs during the project's *timeframe* (see section 4.2.1) are presented as the net present value of the total project costs (TPC). Additionally, as further optional comparison criteria, the required yearly expenses are also estimated. The main results are presented in Table 5.4.

Table 5.4 Costs comparison for the *ecological* and *conventional sanitation* options

Item	***Units***	***Conventional System***	***Ecosan System***
Investment	€	152,400	222,900
Reinvestment	€	65,700	89,300
Yearly investment	€/yr	8,100	11,300
Running costs	€/yr	11,400	13,200
Sum yearly costs	**€/yr**	**19,500**	**24,500**
Investment	€	152,400	222,900
Reinvestment	€	65,700	89,300
Running costs	€	293,319	339,633
Total project costs	**€**	**511,400**	**651,800**
DPC[a]	**€/m³**	**11.8**	**15.5**
DPC2[b]	**€/use**	**0.069**	**0.088**

[a] Amount of wastewater calculated by Stein and Winker (2010); see Table A.1
[b] Amount of uses assumed by Stein and Winker (2010); see Table A.1

There is a difference of almost €140,000 in the TPC. For the conditions of the SANIRESCH project in its first phase, this TPC difference represents the economic gap between the sanitation systems currently compared. Furthermore, as it can be seen in

Figure 5.1, the running costs considered in the analysis represent almost 1.5 times the initial investment for the *Ecosan* option, while this parameter reaches a value of 1.9 in case of the *conventional* concept.

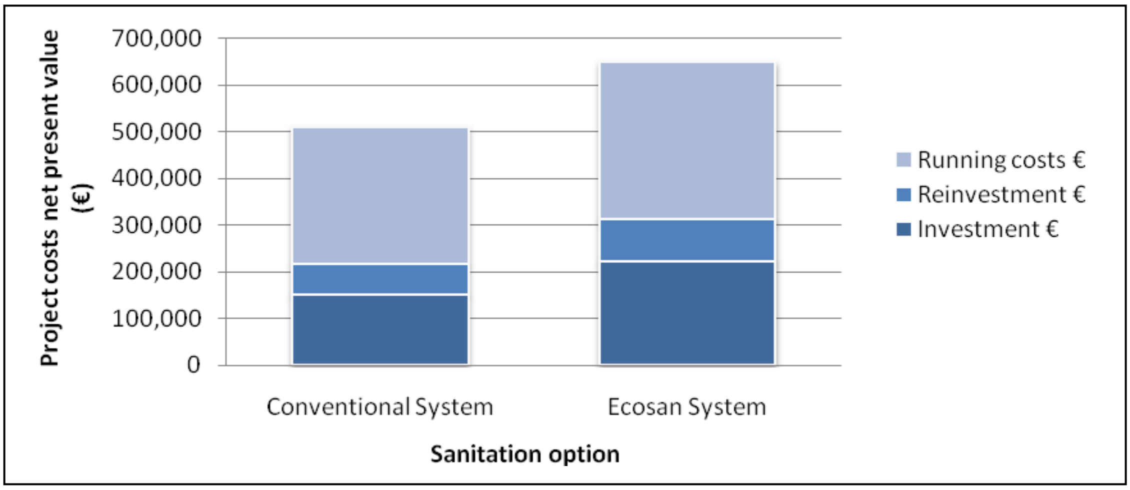

Figure 5.1 Costs comparison for the sanitation installation in Eschborn (GTZ)

If only the magnitude of the values calculated for the running costs of the two sanitation systems is considered, it seems like the running costs for the *Ecosan system* are higher than for the *conventional sanitation* installation. However the previously calculated ratios (1.9 *conventional* and 1.5 *Ecosan*) indicate that the running costs are actually higher for the *conventional option*. These results mean, for example, that for each euro invested it is necessary to spend less for the operation of an *ecological sanitation* facility than for a *conventional* one. Nevertheless, it is important to consider that this behavior could change if the initial investment changes.

Based on the yearly costs of the systems (Table 5.4), it can be observed that the costs difference between the alternatives is €5,000. This situation confirms the previously commented cost advantage of the *conventional sanitation* installation also expressed by the TPC. Simultaneously, the information from Table 5.4 indicates that on a yearly basis the biggest contribution comes from the side of the running costs and not the investment. Furthermore, this contribution is higher for the case of the *conventional* system (58%) than for the *Ecosan* system (55%). These percentages are a confirmation of the bigger influence of the initial investment on the total costs of the *ecological sanitation* installation.

As an additional analytical tool, the value of the dynamic project cost (DPC, €/m³) is also presented in the calculations (Table 5.4). In this case, the average cost for the in-house collection and transport of wastewater using a *conventional approach* is €11.8 /m³. Additionally, the value corresponding to the *Ecosan approach* is 1.3 times higher (€15.5/m³) than the result for the *conventional sanitation*. This is mainly caused by the higher initial investment of *Ecosan*, in comparison with the *conventional* system. The difference in the amount of wastewater transported by the sanitary installations (25 m³/yr) does not play a significant role, as it causes only €0.4/m³ of the total €3.7/m³ difference.

However, in order to increase the comparability of the calculations, another DPC index is also implemented. Due to the variable water consumptions presented by each of the sanitation options analyzed, and based on the assumption that the amount of uses would be the same for any option, regardless of the technology, an index based on the amount of uses (DPC2, €/use) is considered as more representative. Thus, this second approach is the basic parameter to be compared in further sensitivity analyses.

On a yearly basis, the information presented in Table 5.4 indicates that there is a difference of €0.019/use in the cost of collecting and transporting the wastewater in House 1, Eschborn. The *ecological sanitation* cost estimated, under the conditions presented as the main assumptions (chapter 4), is €0.088/use. Even though the number may seem small, it is important to consider that it is based on the amount of yearly uses, which are 148,720 uses, if 676 daily uses are considered during 220 days working time (Stein and Winker, 2010).

5.4 Further potential scenarios

In order to estimate the effect of other potential and realistic scenarios, some further assumptions are made. They comprise current internal conditions, specific for the GTZ, which could eventually change and directly affect the economic performance of the facility. These scenarios differ from the ones included in the sensitivity analysis (section 5.6) in that the factors analyzed are not external (can be modified anytime by GTZ) and are not part of theoretical assumptions (e.g. timeframe for the analysis).

One of the focal points to be studied is related to the way in which the expenditure for spare parts is considered. As already mentioned in section 5.3, during the first years of operation the *ecological sanitation* installation was not optimally maintained. Actually, there was a sudden huge expense for certain spare parts during the third year of operation. Hence, it is assumed as a potential scenario that the maintenance measures remain the same as they are nowadays (not optimal). That means that the GTZ just replaces the valves every three years during the whole timeframe considered for the analysis.

The second focal point considers a condition in which there is no availability of service water, as in the case of GTZ in Eschborn. Such an assumption would require the use of drinking water for flushing, causing a certain impact on the running costs and subsequently on the final economic performance of the system. The corresponding volumes required and other complementary conditions remain the same as in section 5.4.

5.4.1 Cyclic replacement of toilet valves (Ecosan)

In case of considering a 3-year cycle for replacing all the toilet valves of the *Ecosan* system (Table A.14 and Table A.15), the corresponding current yearly expense for spare parts is eliminated. However, this is not done for the *conventional* system because the assumption does not apply to it. A change in the reinvestment required and the running costs exclusively of the *Ecosan* installation are expected. The main results are presented in Table 5.5.

Table 5.5 Effect of a 3-year cycle for replacing all the toilet valves on the economic performance of the sanitary installation

Criteria	***Option without 3-year replacement cycle***	***Option with 3-year replacement cycle***	***Difference, ΔDPC2 (%)***
DPC2 Ecosan, (€/use)	0.088	0.095	8.0
DPC2 Conventional, (€/use)	0.069	0.069	0.0

According to information presented in Table 5.5, there is an 8.0% increase in the average cost of the *ecological sanitation* facility. Additionally, in order to determine how significant the DPC2 change is, the result obtained can be expressed as an amount of money of the TPC. In this case, a change of €0.007/use represents almost €52,000 difference in terms of the Total Project Costs (TPC). Therefore, due to the fact that this value does not reach 10% (section 4.2.3) of the total values presented in Table 5.4, it can still be considered as a minor influence for the study.

The fact that the change in the average project costs is not higher is caused mainly by the elimination of the yearly spare parts expenses. There is a compensation effect between the accumulated effect of the 3-year cycle and the elimination of money expenditure during that 3-year period. Hence, the strategy of following this cycle for the maintenance of the *ecological sanitation* system would be more costly that the current approach existing at GTZ (yearly constant maintenance).

5.4.2 Drinking water as flushing water

As it can be observed in Table A.16, the only change after incorporating the drinking water consumption into the analysis comes up as part of the running costs. In the case of the *conventional sanitation* system there would be a yearly drinking water consumption equivalent to €1700, while the *Ecosan* approach would require €1600. In order to determine whether the drinking water consumption causes a significant effect on the economic performance of the project, the values obtained for each option are presented in Table 5.6.

Table 5.6 Effect of considering drinking water usage on the economic performance of the sanitary installation

Criteria	***Option with service water***	***Option with drinking water***	***Difference, ΔDPC2 (%)***
DPC2 Ecosan, (€ /use)	0.088	0.092	5.7
DPC2 Conventional, (€/use)	0.069	0.074	7.2

As it can be seen in Table 5.6, the relative effect of the drinking water consideration is higher for the *conventional* installation. However it is necessary to check this with the actual magnitude of each percentage (Table 5.6). In this case, there is a change of €0.004/use (*Ecosan option*) that represents approximately €30,000 difference in terms of TPC. For the case of the conventional alternative (€0.005/use) the increase represents approximately €37,000. The cause for this €7,000 difference is that the *ecological sanitation* installation consumes only 25 m³/yr less than the *conventional* alternative.

As both values are below 10% of the TPCs presented in Table 5.4, they can be considered as minor differences that would not considerably affect the outcome of the alternatives. Nevertheless, an improvement of the water saving profile of the *Ecosan* sanitary installation can be considered as a potential for improvement for the system installed in Eschborn. In fact, either a further improvement of the water saving capabilities or an increase in the amount of uses of the *Ecosan* system (more drinking water for flushing required), may further reduce the cost gap between the sanitation systems analyzed.

5.5 Sensitivity analysis

A sensitivity analysis is done in order to determine the potential changes in the outcome of the analysis presented in section 5.4 due to dynamic environmental conditions. In this case, the parameter to be compared is the Dynamic Project Cost based on the system's uses (DPC2) already explained in section 5.4. Additionally, considerations proper of the methodology as well as external factors are the main concepts used as variables for the calculations:

I. Decrease of the price of the sanitary installation (5% rates)
II. Increase of the amount of uses (5% rates)
III. Increase of the wastewater fee (3% rates)
IV. Extension of the *timeframe* for the project consideration (5 years each)
V. Increase of the running costs (5% rates)
VI. Increase of the amount of uses and decrease of the price of the sanitary installation (I+II)
VII. Increase of the amount of uses, decrease of the price of the sanitary installation and increase of the wastewater fee (I+II+III)

In each case, the initial value of the DPC2 is presented for both sanitation alternatives, and the corresponding variation in the parameter to be analyzed is done stepwise in sequential tracts. As there is no rule for setting the amount of analysis points to be examined for each variable, five tracts will be calculated initially. However, if significant changes in the DPC2 are observed, a more detailed analysis for the specific case will be done. Additionally, it is important that for a deeper analysis of each case as well as for comparison purposes, the final value of the DPC2 is considered as the basis.

5.5.1 Decrease of the price of the sanitary installations

One of the main limitations faced by the *ecological sanitation* concepts is the cost of the required piping systems and sanitary devices. Therefore, an eventual decrease in the cost of sanitary devices, due to eventual economies of scale or other similar conditions, is considered as a potential scenario. Progressive decreases of 5% in the costs of all the sanitary installation are considered for the analysis presented in Table A.17-A.18 and Figure 5.2. Due to the already existing economies of scale linked to the *conventional sanitation*, the cost conditions for it are not changed.

The general 25% decrease of the sanitary devices' price is considered as realistic, due to the actual price condition that can be found in the market. In the case of this study, the price of the urine diverting toilets reported by Rüster (2006) is less than half of the price reported by Maßalsky (2006). A discussion of these differences was already presented in section 4.2.2.1.

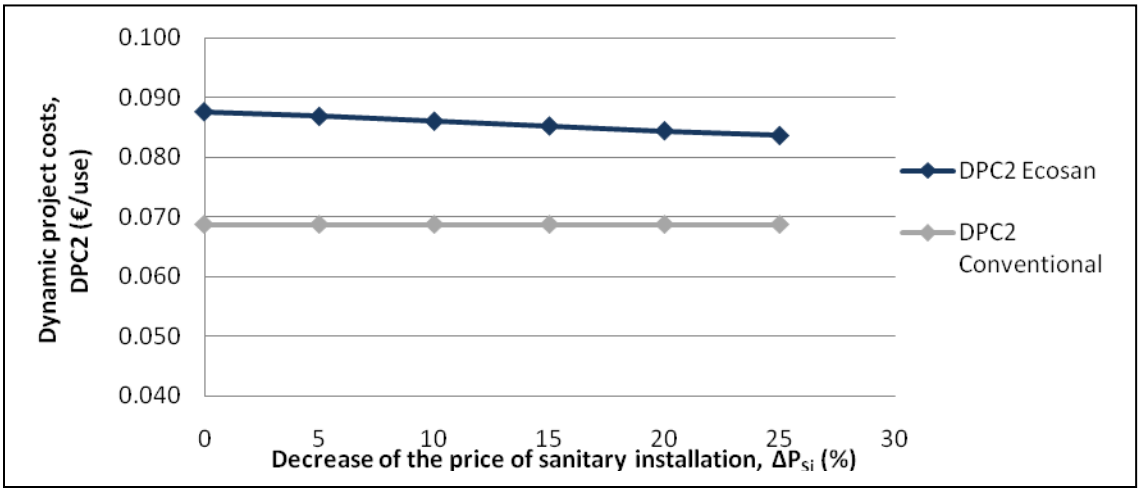

Figure 5.2 Sensitivity analysis for a decrease of the price of the sanitary installation

As it can be observed in Figure 5.2, the DPC2 for the *ecological sanitation* ($DPC2_E$) option without considering any changes is €0.088/use. On the other hand, the DPC2 for the *conventional sanitation* ($DPC2_C$) remains at a value of €0.069/use. As the decrease in the price of the sanitary installation becomes more significant, the $DPC2_E$ starts to decrease too, down to €0.084/use.

The difference between the initial and final $DPC2_E$ for this scenario does not represent more than 5% change in the starting value. Additionally, this would represent an average cost difference of €30,000, which does not reach even 10% of the initial TPC for the *Ecosan* alternative. Hence, a 25% decrease of the price of the sanitary devices does not generate a significant change in the $DPC2_E$.

In terms of the costs gap between *conventional* and *ecological sanitation*, there is a reduction of €0.004/use (around €30,000 on a TPC basis). This represents less than 10% of the total project costs. Therefore, the reduction of the cost gap between the sanitation alternatives is not significant either.

The change in the initial investment and reinvestment necessary for the project causes the change in the DPC2 value directly. In the specific situation, a 25% decrease of the price of the sanitary devices means €21,000 (from the prices of toilets and urinals) acting on €651,800 (TPC). Therefore, the influence on the TPC is still not big enough. Perhaps the effect could be more significant if the whole sanitation installation's price would change (€56,000), but that is not realistic as the pipes are not a product in research stage (as the *Ecosan* sanitary devices).

Additionally, if the price reduction is assumed to be higher than 50%, the costs equilibrium between *ecological sanitation* and *conventional sanitation* would still not be reached. Furthermore, if the reduction in the costs would be applied also to the piping systems and accessories, a price reduction higher than 50% would be required, in order to equal the cost of both sanitation alternatives. However, this condition is mostly due to the fact that the *Ecosan system* requires more pipelines and accessories than the *conventional option* (section 5.2). Hence, under the current conditions, it is not likely to reach the degree of economic feasibility of the *conventional sanitation*.

5.5.2 Increase of the amount of uses

An additional factor that could influence the economic feasibility of the sanitary installation is the amount of daily uses of the system. As a starting point, a total amount of 676 daily uses (Interview with Stein and Winker, 2010) is considered, and progressive increments of 5% in this parameter are also part of the analysis presented in Table A.19-A.20 and Figure 5.3. This condition represents 169 more daily uses than the ones considered so far.

According to Wolf (2009), between 2006 and 2008, the amount of employees in Eschborn including external workers and interns increased almost in 300 persons (approx. 23% increase). Furthermore, according to the assumptions from Stein and Winker (2010), it is possible to estimate that these new employees represent 900 potential uses per day. That would mean that at least 19% of these potential uses should take place in House 1's new sanitary installation, even though it is not stated by Wolf (2009) where the new employees are located.

Assuming that the new employees are equally distributed among the three biggest buildings in Eschborn, it would be possible to have at least 33% of the new employees in House 1, or at least eating in the company's cafeteria every day. Hence, a total eventual increase of up to 25% in the number of uses (169 daily uses) is considered as possible in the upcoming years.

Conversely to the case of section 5.6.1, both sanitation alternatives are taken into account for the condition studied. Higher values of potential uses of the systems are not assumed (25% increase previously discussed), in order to maintain the conditions as realistic as possible. Additionally, it is not indicated how long it could take to reach the 25% increase in the amount of employees at Eschborn, because this parameter is influenced by both internal (policies) and external factors (market behavior).

As it can be observed in Figure 5.3, without considering any changes, the $DPC2_E$ is €0.088/use. On the other hand, the $DPC2_C$ presents an initial value of €0.069/use. As the increase in the amount of uses becomes more significant, the $DPC2_E$ decreases, even more strongly than in the case of scenario I. An increase of 25% of the amount of uses used for the basic calculation causes the $DPC2_E$ to reach a value of €0.071/use (19% reduction).

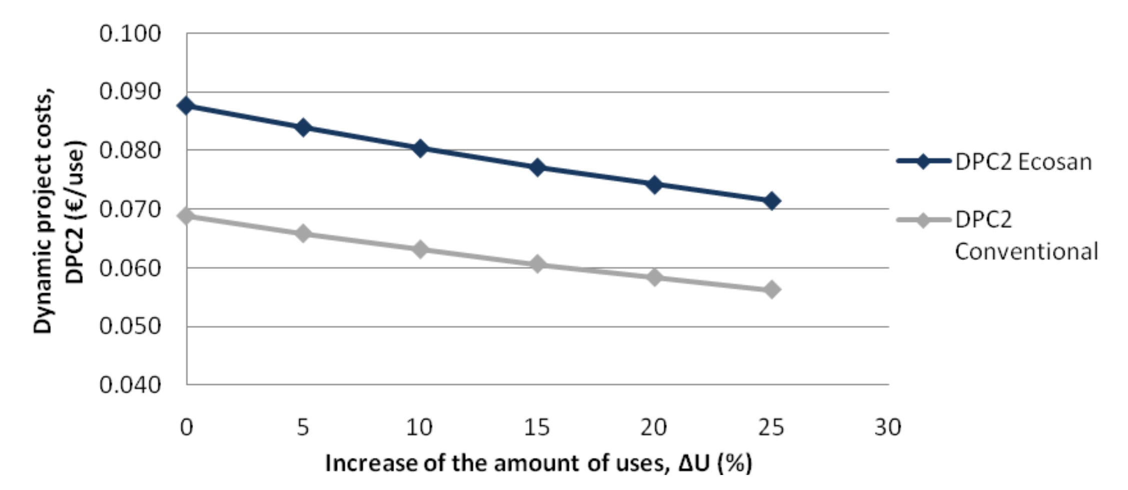

Figure 5.3 Sensitivity analysis for an increase of the amount of uses

The same change considered for the *conventional sanitation* option causes a decrease of the $DPC2_C$ down to €0.056/use (19% reduction). Even though the percentages of change are almost the same, a comparison of the final values obtained with the initial conditions indicates that there is a more significant effect of the scenario's condition on the *ecological sanitation* (€0.017/use versus €0.013/use decrease). These values expressed as TPC mean that the *ecological sanitation* option would have a costs reduction of €126,000, and the *conventional sanitation* installation would face a reduction close to €97,000.

As the costs reductions for each parameter ($DPC2_C$ and $DPC2_E$) overcome the 10% TPC established as the limit for determining the significance of the change (section 4.2.3), it can be stated that both sanitary alternatives change significantly when the amount of uses increases 25%. However, this is still not enough for the *Ecosan* alternative to reach the average costs of the *conventional option*.

In terms of the costs gap between the sanitation options, there is a total reduction of €0.004/use (around €30,000 on a TPC basis). This represents less than 10% of the total project costs. Therefore, the reduction of the cost gap between the sanitation alternatives is not significant.

The dynamic project costs, as reference value for the cost comparison, are directly dependent on the amount of uses. Hence, a reduction in the average project costs was expected. Additionally, due to the fact that the only running cost affected by a change in the amount of uses is the final wastewater fee to be paid, the scenario does not influence negatively the DPC2 (reducing it). The amount of wastewater collected and transported is still too low and does not allow significant running cost changes.

Even if more uses would be assumed for the system installed, what would not be realistic, the situation would remain the same. In fact, the difference between both DPC2 values does not change in more than €0.004/use with every 5% that is considered in the sensitivity analysis. This is 7% of the starting TPC. Therefore, according to the conditions of scenario II, it is not likely to reach the degree of economic feasibility of the *conventional sanitation*.

5.5.3 Increase of the wastewater fee

Another factor that influences the economic feasibility of the different sanitation installations is the fee charged for the disposal of the wastewater collected and transported in the in-house facility. Progressive increases of only 3% (approx. €0.06/m³) on the current fee are considered for the analysis presented in Table A.21-22 and Figure 5.4. This is considered as a possible scenario due to the fact that big increases in this concept have not occurred since 2006 in Eschborn (Stadt Eschborn, 2009).

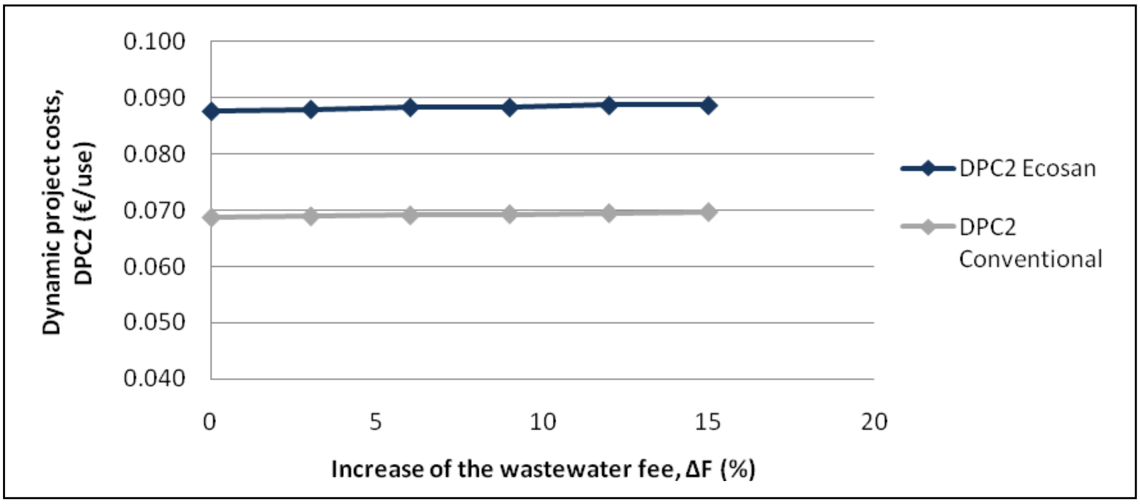

Figure 5.4 Sensitivity analysis for an increase in the wastewater fee

The $DPC2_E$ without considering any changes is €0.088/use, as it is the initial condition for the analysis. For the case of the *conventional sanitation*, the DPC2 presents an initial value of €0.069/use. As the wastewater fee is increased, the $DPC2_E$ increases as well. However, even after an increase of 15% of the fee, the total change of DPC_E is only €0.001/use. This represents an impact of barely 1%, in comparison with the TPC.

On the other hand, the same change considered for the *conventional sanitation* option causes an increase of the DPC_C up to €0.070/use (less than 2% increase). In terms of TPC, this value means also that there is almost a negligible effect of the wastewater fee on both sanitation alternatives. However, it may be possible that with a different water saving profile (not more than one toilet flushing per use, for example) the *ecological sanitation* option may have a slight cost advantage. In terms of the costs gap between *conventional* and *ecological sanitation*, there is practically no change.

Even if a further increase of the wastewater fee would take place, the ratio between the average costs of both sanitation alternatives would remain almost the same. The difference between both DPC2 values does not change more than €0.001/use with every 3% increase of the wastewater fee. Therefore, within a realistic possible range, it is not likely that the *Ecosan option* reaches the degree of economic feasibility of the *conventional sanitation*. In other words, an increase in the wastewater fee alone is not enough to make the technologies economically comparable.

5.5.4 Extension of the timeframe for the project consideration

As part of the methodology for the analysis, it is determined how a consideration of longer *timeframes* could influence the economic feasibility of the sanitation facility. In this case, the reinvestment costs as well as the final estimation of the dynamic project cost depend directly on this time-based parameter. Progressive increases of 5 years in the period of time are considered for the analysis presented in Table A.23-24 and Figure 5.5.

As indicated in Figure 5.5, the $DPC2_E$ without considering any changes is €0.088/use. On the other hand, the $DPC2_C$ presents an initial value of €0.069/use. As the increase in the *timeframe* becomes more significant, the $DPC2_E$ decreases, even more significantly than in the case of the change analyzed in the sections 5.6.1 to 5.6.3. The final $DPC2_E$ is €0.062/use and the corresponding total $DPC2_E$ change is €0.026/use (30% reduction).

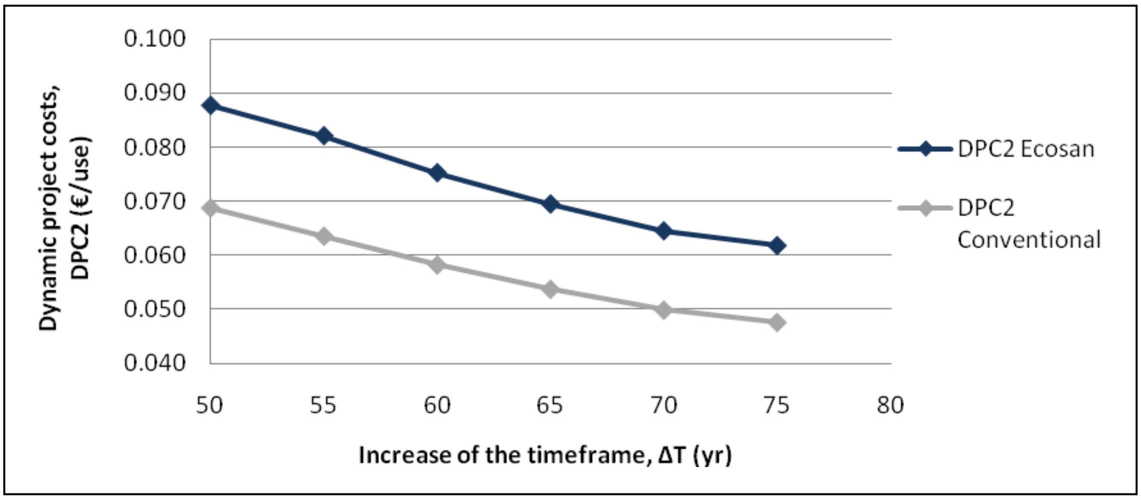

Figure 5.5 Sensitivity analysis for an increase of the *timeframe* considered for the project

In the case of the *conventional sanitation* option, the *timeframe* extension causes a decrease of the $DPC2_C$ down to €0.048/use (30% difference). A comparison of the final DPC2 values obtained with the initial conditions indicates that there is a slightly bigger effect of the scenario's condition on the *ecological sanitation* (€0.026/use Vs €0.021/use). In fact, both changes can be considered as significant in terms of the TPC variation that they represent.

In terms of the costs gap between *conventional* and *ecological sanitation*, there is a reduction of €0.005/use (around €37,000 on a TPC basis). This represents less than 3% of the total project costs. Therefore, the reduction of the cost gap between the sanitation alternatives is not significant in this case. Even though there is a significant reduction of the individual costs, it is not enough to reach the average costs of the *conventional option*.

If a longer *timeframe* is considered, the ratio between the average costs of both sanitation alternatives remains almost the same. The difference between both DPC2 values remains in an interval between €0.014/use and €0.019/use with every increase in *timeframe* considered. Nevertheless, even if this scenario shows a slightly more significant effect on the average costs than in the considerations presented in sections 5.6.1-5.6.3, it is not likely either in the long or short term that the *Ecosan* option can reach the degree of economic feasibility of the *conventional sanitation*. This is valid for the conditions of the current analysis.

5.5.5 Yearly increase of running costs

An additional factor that could affect the balance of the system is the one related to the running costs. This is directly related to the constant changes faced in the cost of living that also affect companies in their daily activities. Even if it is clear that the dynamic project costs will increase as well, it is important to determine how significant the effect in each option is. Progressive increases of 5% rates in the running costs are used for the analysis presented in Table A.25-26 and Figure 5.6.

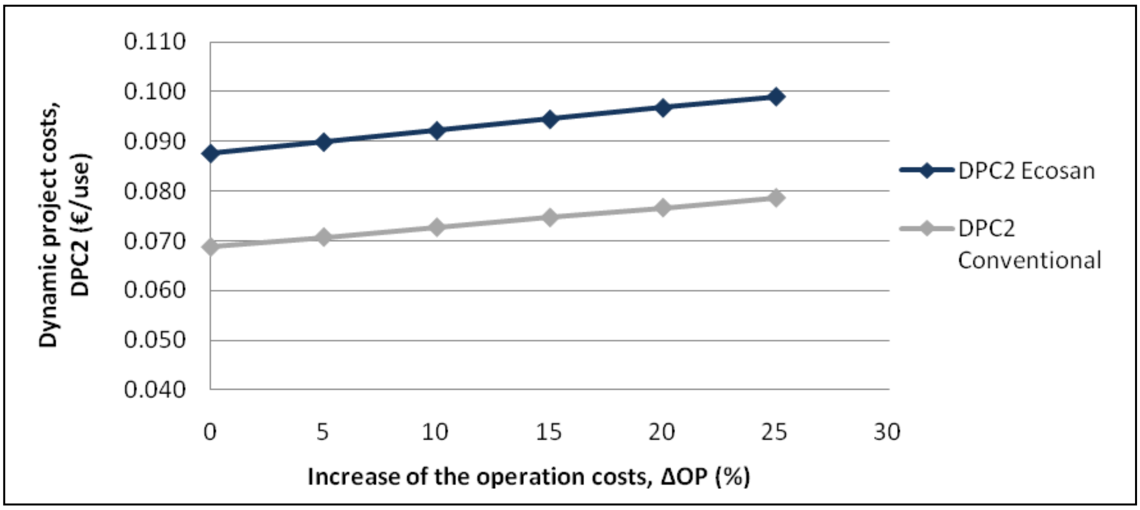

Figure 5.6 Sensitivity analysis for an increase of the running costs considered for the project

The initial values for the $DPC2_E$ and the $DPC2_C$ are €0.088/use and €0.069/use, respectively. Every increase in the running costs means a raise of the $DPC2_E$ as well. After a 25% increase of the running costs (€3,300/yr), the $DPC2_E$ reaches a value of €0.099/use, meaning a change of €0.011/use (13% increment).

In contrast, the same change considered for the *conventional sanitation* option (€2,850/yr) causes an increase of the DPC_C up to €0.079/use (13% more). A comparison of the final values obtained with the initial conditions indicates that there is similar effect on both sanitation installations. Actually, this change expressed as total project costs, represents around €75,000 (*conventional*) and €82,000 (*Ecosan*) on a TPC basis. This indicates that higher running costs would significantly influence the financial performance of both sanitation installations by making them more expensive.

However, even if there is an important influence on the individual DPC2 values, the gap between the average costs of both sanitation concepts remains practically constant. A difference of €0.001/use (of the cost gap) would be the maximum value to be expected, which is not a condition that means a significant reduction of the costs gap. Hence, for the specific case analyzed, within a realistic possible range, it is not likely that the *Ecosan option* reaches the degree of economic feasibility of the *conventional sanitation*.

5.5.6 Increase of the amount of uses and decrease of the price of the sanitary installation

After scenario IV, the only two conditions that represent a decrease in the average costs of both sanitary options, and at the same time a costs gap reduction, are the ones presented in scenarios I and II. Furthermore, a price decrease of the *Ecosan* sanitary devices can be considered as an expected situation in the following years, due to possible economies of scale and/or progress coming from research and development projects. Additionally, an increase in the amount of uses of the system by either expansion of the sanitation facility, or just simple acceptance of the public, is also a condition that may occur in the future.

Due to the previously stated reasons, a combination of these two scenarios is considered as an important further scenario to be analyzed. Progressive decreases of 5% in the prices of all the sanitary installation as well as increases of 5% in the amount of uses are considered for the analysis presented in Table A.27-28 and Figure 5.7. It is expected to have a change in the investment and reinvestment necessary for the project, together with a modification in the running costs. Additionally, in order to keep an appropriate degree of plausibility, the cost of the *conventional sanitary* installation is not changed.

The initial values for the $DPC2_E$ and the $DPC2_C$ are €0.088/use and €0.069/use, respectively. As it can be observed in Figure 5.7, as the present scenario's conditions are applied (lower cost and more uses), the $DPC2_E$ starts to decrease until it reaches a value of €0.068/use (23% reduction). On the other hand, the same changes considered for the *conventional sanitation* option cause a decrease of the $DPC2_C$ down to €0.056/use (19% reduction).

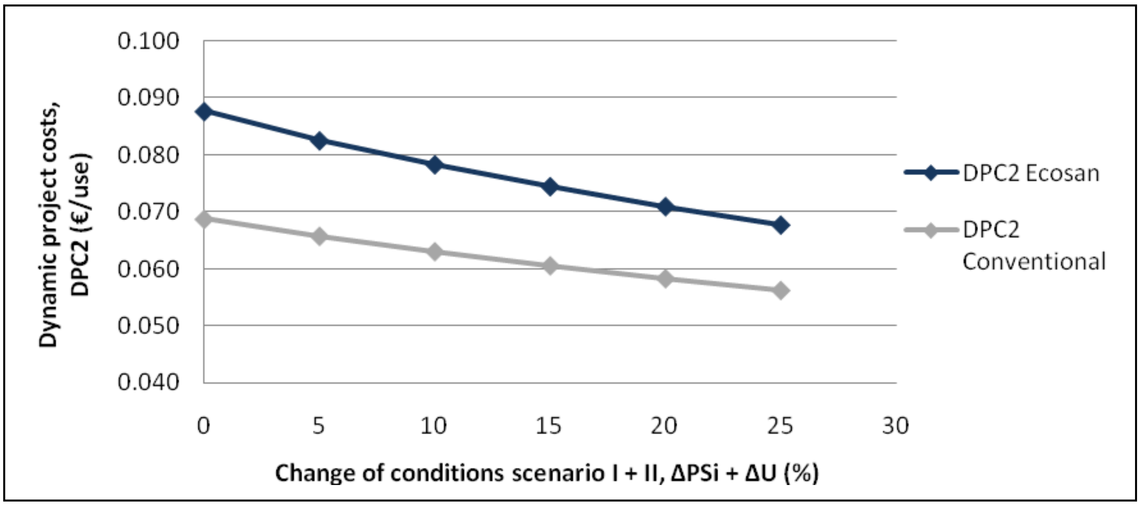

Figure 5.7 Sensitivity analysis for a decrease of the price of a sanitary installation, and an increase in the amount of uses

According to this data, there is a higher effect of the conditions on the *ecological sanitation* installation. In fact, the change in the average costs reaches €0.020/use, which represents approximately €149,000 (significant). On the side of the *conventional sanitation* the reduction (€0.013/use), the costs decrease can also be considered as significant, as it represents a value of €97,000.

In terms of the costs gap between *conventional* and *ecological sanitation*, there is a reduction of €0.011/use (around €82,000 on a TPC basis). This represents less than 10% of the total project costs. Therefore, the reduction of the cost gap between the sanitation alternatives, despite of the significant decrease of the specific dynamic project costs, is not significant.

If a further application of the conditions is done beyond 25% decrease of the sanitary devices' price and 25% increase of the number of uses, the ratio between the average costs of both sanitation alternatives decreases. However, even after a hardly achievable condition of 60% change in both number of uses (1080 instead of 676 daily uses) and price of sanitary devices (€33,640 instead of €84,100), it is not possible to find a realistic point where the difference between the sanitation options approaches zero. Therefore, within a realistic possible range of the analyzed conditions, it is not likely that the *Ecosan option* reaches the degree of economic feasibility of the *conventional sanitation*.

5.5.7 Increase of the amount of uses, decrease of the price of the sanitary installation and increase of the wastewater fee

In order to determine how an entirely negative condition could affect the economic performance of both sanitation alternatives analyzed in the scenario presented in section 5.6.6, the additional effect of an increase of the wastewater fee is taken into account. This scenario may be considered as possible on a long term, due to the need that the three changes are valid for a certain point in time. No other external or indirect influences are taken into account.

Progressive decreases of 5% in the prices of all the sanitary installation, increases of 5% in the amount of uses, as well as 3% yearly increases in the price of the wastewater fee are the main conditions for the results presented in Table A.29-30 and Figure 5.8. It is expected to have a change in the investment and reinvestment necessary for the project, together with a modification in the running costs. Once again, as already done in sections 5.6.1 and 5.6.6, the cost changes of the sanitary installation are not considered for *conventional sanitation* option.

As it can be observed in Figure 5.8, the $DPC2_E$ without considering any changes is €0.088/use and the $DPC2_C$ is €0.069/use. As the conditions are applied (lower cost, higher fee, more uses), the $DPC2_E$ starts to decrease until it reaches a value of €0.069/use (22% reduction). In the case of the *conventional sanitation* option, the same change indicates a decrease of the $DPC2_C$ down to €0.057/use (17% reduction).

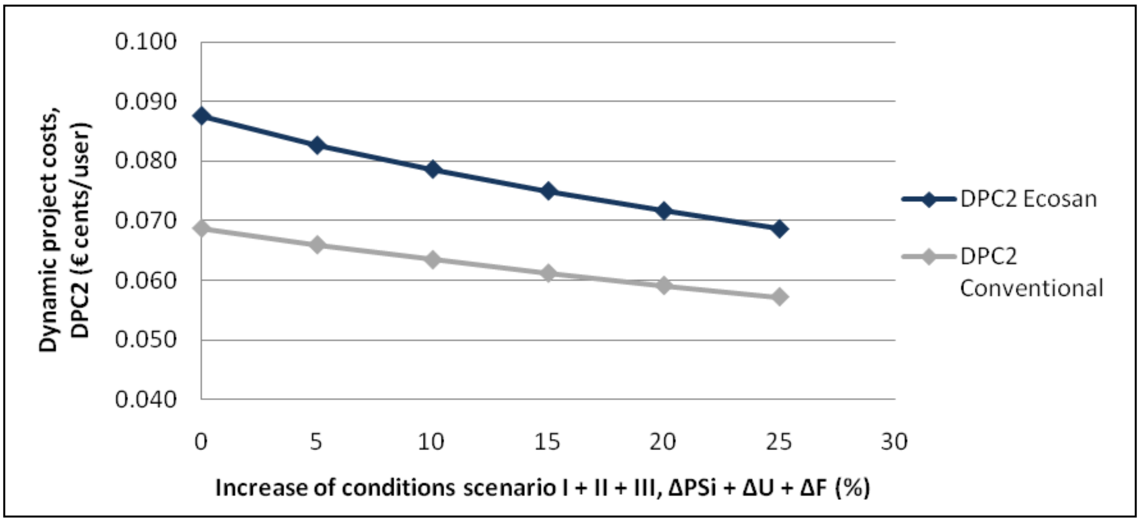

Figure 5.8 Sensitivity analysis for a decrease of the price of a sanitary installation, an increase in the amount of uses and an increase in the wastewater fee

A comparison of the final values obtained with the initial conditions indicates that there is a higher effect on the *ecological sanitation* installation. Similar to the result for section 5.6.6, the change in the $DPC2_E$ reaches €0.019/use, which represents in average €141,000. This is more than 20% of the TPC, and can be considered as a significant reduction.

Nevertheless, once again, the costs gap between the alternatives is not closed completely. Even a further application of the conditions up to values corresponding to 80% change (totally unrealistic) would not generate a full cost gap reduction. Hence, this scenario does not show the required conditions by the *Ecosan option* in order to reach the degree of economic feasibility of the *conventional sanitation*.

5.5.8 Summary of the sensitivity analysis

A sensitivity analysis gives an idea of the robustness of a project concept, even if sources of uncertainty start to influence the environment in which the project takes place. According to the information presented in sections 5.6.1 to 5.6.7, several factors may affect the outcome of the economic feasibility directly. A summary of the main results is presented in Table 5.7. In this Table, the initial DPC2 values represent the starting point for each scenario and sanitation option. Meanwhile, the final DPC2 values indicate the result for the last condition evaluated in each scenario.

If the results obtained for both sanitation alternatives are compared, it is clear that the *conventional sanitation* always reaches a lower dynamic average cost value. Some scenarios such as II show a final *Ecosan* DPC2 value (€0.071/use), which is close to the same as the initial *Conventional* DPC2 (€0.069/use). Nevertheless, what counts is the comparison with the final *Conventional* DPC2 (€0.056/use). In other words, the average cost of the *Ecosan* sanitary installation project does not show lower values than the *conventional* system, in any of the cases considered as part of the sensitivity analysis. This is valid for the conditions at GTZ and the assumptions presented in chapter 4.

Table 5.7 Outcome summary of the sensitivity analysis

#	*Scenario*	*Initial DPC2 Ecosan (€/use)*	*Final DPC2 Ecosan (€/use)*	*Initial DPC2 Convention. (€/use)*	*Final DPC2 Convention. (€/use)*
I	Decrease of the price of sanitary installations	0.088	0.084	0.069	0.069
II	Increase of the amount of uses	0.088	0.071	0.069	0.056
III	Yearly increase of wastewater fee	0.088	0.089	0.069	0.070
IV	Extension of lifetime	0.088	0.062	0.069	0.048
V	Yearly increase of running costs	0.088	0.099	0.069	0.079
VI	II + I	0.088	0.068	0.069	0.056
VII	III + II + I	0.088	0.069	0.069	0.057

Statements considering magnitudes such as the ones presented in Table 5.7 are not enough to determine the sensitivity of the sanitation options. The fact that *conventional sanitation* values are lower than other ones does not necessarily mean that the degree of sensitivity in the case of the *ecological sanitation* is lower. Actually, the representation that indicates the real sensitivity of each alternative is the change in the variable, not the magnitude.

Table 5.8 Effect of the scenario conditions on the outcome of the sensitivity analysis

#	*Scenario*	*Change DPC2 Ecosan*		*Change DPC2 Conventional*	
		(€/use)	*(%)*	*(€/use)*	*(%)*
I	Decrease of the price of sanitary installations	-0.004	-5	0.000	0
II	Increase of the amount of uses	-0.017	-19	-0.013	-18

Table 5.8 (cont.) Effect of the scenario conditions on the outcome of the sensitivity analysis

#	*Scenario*	*Change DPC2 Ecosan*		*Change DPC2 Conventional*	
		(€/use)	*(%)*	*(€/use)*	*(%)*
III	Yearly increase of wastewater fee	0.001	1	0.001	1
IV	Extension of lifetime	-0.026	-30	-0.021	-31
V	Yearly increase of running costs	0.011	13	0.010	14
VI	II + I	-0.020	-23	-0.013	-18
VII	III + II + I	-0.019	-22	-0.012	-17

In Table 5.8, the change in the dynamic project costs is expressed as both Euros per use as well as percentages. From the information presented in Table 5.8, the effect of an extension of the *timeframe* considered for the project (scenario IV) causes the biggest change in the DPC2 variables. The variation is actually a 30% decrease of the DPC2 for the case of the *ecological sanitation* and 31% in the case of *conventional sanitation*.

According to the conditions of scenario IV, the existing reduction indicates that the average project costs would be lower in the long term. This would be the case mainly due to the increasing ratio between running costs and the initial investment as well as reinvestment related factors. In the case of scenarios VI and VII, the effect on the DPC2 values is due to the combination of two effects, which reduces the average costs for both alternatives.

Besides the merely financial consideration of the project's *timeframe* (scenario IV), scenarios VI and VII are the ones showing the biggest sensitivity. According to the initial and final values of DPC2, the changes range between 17 and 23%, representing TPC differences of €89,000 and €149,000 respectively. This implies that the change is not only important but also significant, because it is higher than 10% of the total project costs.

According to the numbers presented in Table 5.7, the differences commented in the previous paragraph have two components. In fact, by observing the 18%-19% reduction produced by scenario II, it is possible to state that the major influencing factor on the DPC2 and TPC differences (scenarios VI and VII) is the number of uses of the system.

The complementary condition to this behavior corresponds to eventual changes in the price of the *Ecosan* devices (scenario I).

In practical terms, an increase of the amount of uses (scenario II) would mean more wastewater to be collected and transported without investing additional money in an expansion of the facility. This behavior is based on the fact that more brown- and yellow water would be transported, with the same initial investment. From the mathematical point of view, the costs of the whole system are just divided by a bigger number of uses. On the other hand, scenario I's conditions are completely depending on what happens in the market of the sanitary devices (external effect).

From the information presented in Table 5.8 it is also possible to observe that the DPC2 change is a relative parameter. In other words, it is a calculation based on the initial state of the DPC2 of each sanitation alternative. Hence, it is important to determine, in addition to the previous calculations, the effect of the different sensitivity analyses on the cost gap between *ecological* and *conventional sanitation*.

Table 5.9 Costs gap for each scenario in the sensitivity analysis

#	*Scenario*	*Initial DPC2-Gap (€/use)*	*Final DPC2-Gap (€/use)*	*DPC2-Gap Change (%)*
I	Decrease of the price of sanitary installations	0.019	0.015	-21
II	Increase of the amount of uses	0.019	0.015	-21
III	Yearly increase of wastewater fee	0.019	0.019	0
IV	Extension of lifetime	0.019	0.014	-26
V	Yearly increase of running costs	0.019	0.020	5
VI	II + I	0.019	0.011	-42
VII	III + II + I	0.019	0.011	-42

Table 5.9 presents the behavior of the costs gap between the alternatives, according to each scenario's assumptions. Scenarios VI and VII are the ones that reduce the most the cost differences between the sanitation options. From an initial value of €0.019/use, the DPC2 goes down to values around €0.011/use, representing 42% reduction. According to this average project costs decrease, that would mean a reduction of approximately €60,000 in terms of TPC. Hence, this result together with the observations presented in

sections 5.6.1 to 5.6.6 confirms that no environmental changes can reduce the cost gap significantly.

In terms of reduction of the costs differences existing between *Ecosan* and *conventional sanitation,* it is possible to indicate that scenarios VI and VII are the most favorable. Therefore, a theoretical approach for a large-scale sanitary installation is investigated in chapter 5. It is assumed that the whole sanitary facility in House 1 at GTZ is changed to an *Ecosan* system. Moreover, this new installation is compared again to a corresponding *conventional sanitation* system. Any costs comparison will be referred to the facility analyzed in the present chapter in terms of small-scale installation.

6 Ecological sanitation in a larger scale at GTZ

The analysis presented in chapter 5 indicates that, according to the existing conditions of the sanitation system at GTZ, the *conventional sanitation* system has lower Total Project Costs and also Dynamic Project Costs. However, after the sensitivity analysis presented also in section 5.6, it seems like a project executed in a larger scale, with more daily toilet uses, may offer a better economic performance. Therefore, an analysis of a hypothetical renovated sanitary installation in the whole House 1 at GTZ is presented.

6.1 General considerations

Due to the fact that the sanitary installation studied in the previous section is only a part of the whole facility modernized in House 1 (GTZ, Eschborn), a new analysis is done assuming that the whole sanitary installation is replaced. That is actually the reason why this expansion is denominated as project in a large scale. The in-house collection and transport of brownwater, yellow water, and greywater remains as the system's objective, leaving other eventual parallel systems (rainwater, etc) also out of consideration. Additionally, it is expected to evaluate the effect of an increase of the installation's daily uses, together with the investment required for this expansion.

Based on the information used for the estimations done in section 5, new parameters are calculated (Table 6.1). The total amount of toilets and urinals in House 1 is already known from the plans prepared for the whole modernization project (Peterson & Ahrens Ingenieur-Planung GmbH & Co. KG, 2006), for both sanitation options. However, due to the difficulty concerning the estimation of the exact requirement of pipelines and corresponding accessories, three main concepts are used as references.

Firstly, similar to the approach followed by Oldenburg (2007), the length of pipelines installed for the existing sanitary installation is expressed as an equivalent length per user, for each nominal diameter installed. Secondly, the amount of accessories required for the installation highly depends on the restrooms' location inside the building, but from the detail present in the plans, it is not possible to determine an exact requirement.

Therefore, the investment for accessories per meter pipeline is used as a further parameter (own assumption).

As there is another group of components which are slightly heterogeneous and may not be linked with the characteristics of the installation, it is considered that they are an investment per user of the system. This assumption intends to make the estimation as logical and plausible as possible. Additionally, a similar approach is presented in Table A.32 for the *conventional sanitation* option.

Table 6.1 Parameters for the study of alternative sanitation in a bigger scale at GTZ

Category	*Base value units*	*Base value*[a]	*Scaling factor's units*	*Scaling factor*	*Scaled value*[c]	*Approximate cost*[b]
Urinals	urinals	23	Urinals	45	45	14,196
Toilets	toilets	50	Toilets	74	74	99,693
Pipeline DN 50	m	100	m/user	0.15	270	4,251
Pipeline DN 80	m	300	m/user	0.44	809	14,638
Pipeline DN 100	m	400	m/user	0.59	1,078	22,332
Pipeline DN 125	m	200	m/user	0.30	539	14,164
Accessories DN 50	€	1,800	money/m	18.00	4,853	4,853
Accessories DN 80	€	8,900	money/m	29.67	23,993	23,993
Accessories DN 100	€	11,400	money/m	28.50	30,733	30,733
Accessories DN 125	€	7,900	money/m	39.50	21,297	21,297
Other accessories and materials	€	72,900	money/user	107.84	196,526	196,526
Total (€)						**446,676**

[a] Maßalsky (2006)
[b] Considers the upscaled cost of the elements already adjusted for the base year of the study (2010)
[c] The units for these factors correspond to the base value units

Together with the installation itself, the potential water consumption in House 1 is a critical factor to be considered in the analysis. Assuming that the eventual amount of users is equivalent to the occupation of the whole building (Braum, 2009), and following the methodology proposed by Stein and Winker (Interview, 2010a), the consumption of service water can be determined (Table A.31).

In this case, the comparison of the economic feasibility for a *conventional* and an *alternative sanitation* installation for the whole building (House 1) is presented. Additionally, a comparison of these results with the ones obtained for the smaller scale project (chapter 5) is done. A sensitivity analysis for the big scale project is also presented, pointing out the main aspects where a significant difference in regard to the small scale case can be found.

6.2 Investment and reinvestment

Based on GTZ (2004) and Maßalsky (2006), the total investment for the large scale *ecological sanitation* system is higher in comparison with a *conventional system* (Table A.3). According to the information presented in Table 6.2, the difference in the case of pipelines and accessories is close to €117,700, while in the case of the sanitary devices (toilets and urinals) it is €30,000. Furthermore, taking the difference in the total costs as basis, it is possible to find out that the biggest contribution to the differentiation between both sanitation systems corresponds to the pipelines and accessories (80%).

Table 6.2 Investment required for the large scale sanitary installation

Item	***Total Price – Conventional[a], P_C (€)***	***Total Price – Ecosan[b], P_E (€)***
Pipelines and accessories	256,900	374,600
Urinals & Toilets	98,200	128,200
Total (€)	**355,100**	**502,800**

[a] GTZ (2004)
[b] Maßalsky (2006)

In comparison with the small scale system presented in chapter 5, the investment in pipelines and accessories increased 2.7 times. The reason for this is the corresponding increase in the amount of toilets and urinals (up to 45 and 74 respectively). Additionally, it is important to consider that more pipelines and accessories are required due to the fact that the system has to be extended to the wings of House 1. The current system is located only in the central section of the building; meanwhile the large scale sanitary installation is for the whole building.

Considering each sanitation system individually, it is possible to determine that the large scale *ecological sanitation* devices are 1.3 times more costly than the *conventional* ones. This behavior remains similar to the one observed in section 5.2 (1.5 ratio for the small scale installation), with a small variation due to the increase in the amount of urinals in comparison to the toilets. As the urinals are less expensive than the toilets (Table 6.3) the ratio of the large scale system cannot be higher than or equal to the one for the small scale system (chapter 5).

Table 6.3 Reinvestment estimation for a 50 years period consideration of the large scale *ecological sanitation* option, without already installed spare parts

Item	***Price of the installation[a], P (€)***	***Service life[b], L (yr)***	***Reinvestment, adjusted[c], R' (€)***	***Reinvestment, readjusted[d], R'' (€)***
Urinals	14,200	25	16,000	7,642
Toilets	99,700	25	112,200	53,587
Pipeline DN 50	4,300	35	4,800	1,706
Pipeline DN 80	14,600	35	16,400	5,828
Pipeline DN 100	22,300	35	25,100	8,920
Pipeline DN 125	14,200	35	16,000	5,686
Accessories DN 50	4,900	35	5,500	1,955
Accessories DN 80	24,000	35	27,000	9,595
Accessories DN 100	30,700	35	34,600	12,296
Accessories DN 125	21,300	35	24,000	8,529
Other accessories and materials	196,500	35	221,200	78,611
Total (€)	**446,700**	**-**	**502,800**	**194,400**
Total adjusted[e] (€)	**502,800**	**-**	**-**	**194,400**

[a] Maßalsky (2006)
[b] Prager (2002)
[c] Considers the original cost of the component and recalculates it for the base year of the study (2010)
[d] Considers the *adjusted* value financially discounted for the estimation of the required reinvestment
[e] Considers the original cost of the component and recalculates it for the base year of the study (2010)

From the point of view of contributions, if the cost of pipelines and accessories is compared with the total costs of each large scale sanitary installation, it is possible to estimate that the cost of pipelines and accessories corresponds to 72% of the total initial investment in the *conventional* concept, and 75% in the case of the *Ecosan* approach. The ten percent increase with respect to the small scale facility matches the behavior explained in the previous paragraph, regarding the increase in the costs of pipelines and accessories of both sanitation options.

As a further step in the analysis, the reinvestment calculation according to LAWA (2005) is presented in Table 6.3. The methodology introduced in section 4.2.2.3 is the basis for processing the data presented in Tables 4.1 and 6.1. Similarly to the conditions presented in chapter 5, a differentiation must be made between *reinvestment adjusted* and *reinvestment readjusted*, so that the first one takes the original cost of the component and recalculates it for the base year of the study (2010). Moreover, the term indicated as *readjusted* corresponds to the *adjusted* value financially discounted for the estimation of the required reinvestment.

In terms of the reinvestment required, Table 6.3 and Table A.3 show how it reaches 42% of the initial investment for both, the *ecological* and the *conventional sanitation*. A big part of the reinvestment comes from the side of the sanitary devices, especially due to the different service life and financial factors assumed. Hence, as the pipelines and accessories' contribution increases with the project scale's change, the role of the devices to be discounted first (after 25 years) to the reinvestment costs decreases. Therefore, as long as the contribution of the sanitary devices to the total investment keeps decreasing, the ratio of the reinvestment costs to the initial investment will go down too (see Table 6.5 and Table A.3).

6.3 Running costs

Regarding operation and maintenance, the costs for the large scale estimation are based on the assumptions used for the calculation of the small scale project (section 5.3). As part of the only differences considered for the big scale's calculations, it can be stated that the unit costs presented in Table A.12 are the basis for the consideration of "previously bought" spare parts. In the case of the calculation of the future spare parts to be bought for the big scale approach, the same factors introduced in Table A.12 are used. However, a correction factor using the total amount of sanitary devices is used. Hence, the amounts showed for this cost term (Table 6.4) are higher than the ones presented in Table 5.4.

Furthermore, the cleaning activities are assumed to have the same value as in the small scale analysis. The contract with the cleaning company is not expected to be modified according to the sanitation system, as it was indicated by Neubert (Interview, 2010). Additionally, the corresponding adjustments are done for the requirement of Mellerud (Mellerud Chemie GmbH, 2010) as cleaning agent (Table A.13).

Table 6.4 Running costs comparison for the large scale *ecological* and *conventional sanitation* options

Item	*Units*	*Conventional System*	*Ecosan System*
Maintenance and supervision personnel	€/yr	300	1,800
Wastewater disposal	€/yr	4,600	4,200
Cleaning personnel and materials	€/yr	8,400	8,400
Drinking water	€/yr	200	200
Cleaning substances, extra (liquid)	€/yr	0	900
Spare parts	€/yr	2,100	3,100
Yearly running costs	€/yr	**15,600**	**18,600**

According to the information presented in Table 6.4, the large scale running costs are higher for the *Ecosan* system. The yearly difference between the sanitation options is €3,000, about 19% if the *conventional* approach is used as reference for the calculation of the error. Additionally, as in the case of the small scale system (Table 5.3), the cost advantage through water saving that is part of the *Ecosan* system (€400/yr) is totally overcome by the expense in extra cleaning substances, spare parts, and maintenance and supervision personnel.

For the case of the large scale sanitary installation, the expense in maintenance and supervision personnel is the major contributor (€1,500/yr) to the whole difference in running costs (€3,000/yr). This is totally dependent on the assumptions done for the calculation of this expense. In fact, the magnitude of these personnel costs seems plausible if it is considered that the amount of toilets and urinals increased.

The other factors that are part of the large scale running costs contribute to the total difference in a similar way as they do in the case of the small scale approach. However it is important to consider the wastewater disposal expense more in detail. In this case, Table 6.4 shows that that the *ecological sanitation* allow more water savings (9%) than in the case of the small scale facility (6%). The total amount of money saved due to less water consumption in the large scale *Ecosan* installation is €400 per year.

However, as in the case analyzed in chapter 5, this sum of money may change significantly depending on the amount of uses of the system and depending on the performance of the sanitary devices (Interview with Stein and Winker, 2010). Based on the approach of Stein and Winker (2010), with only one flush per use (see section 5.3), it would be possible to go down to a wastewater generation of 1,552 m³/yr, instead of the current 2,040 m³/yr. In other words, there would be €1,015/yr savings, or around 34% reduction of the total current running costs difference.

6.4 Costs comparison

Following the LAWA (2005) guidelines, the incurred costs during the project's *timeframe* (see section 4.2.1) are presented as the net present value of the total project costs (TPC). Additionally, as further optional comparison criteria, the required yearly expenses are also estimated. The main results are presented in Table 6.5.

Table 6.5 Costs comparison for the large scale *ecological* and *conventional sanitation* options

Item	*Units*	*Conventional System*	*Ecosan System*
Investment	€	355,100	502,800
Reinvestment	€	149,000	210,300
Yearly investment	€/yr	19,300	24,800
Running costs	€/yr	15,600	18,600
Sum yearly costs	**€/yr**	**34,900**	**43,400**
Investment	€	355,100	502,800
Reinvestment	€	149,000	210,300

Table 6.5 (cont.) Costs comparison for the large scale *ecological* and *conventional sanitation* options

Item	*Units*	*Conventional System*	*Ecosan System*
Running costs	€	401,384	478,574
Total project costs	**€**	**905,500**	**1,191,700**
DPC[a]	**€/m³**	**7.8**	**11.1**
DPC2[b]	**€/use**	**0.045**	**0.059**

[a] Amount of wastewater calculated by Stein and Winker (2010); see Table A.1
[b] Amount of uses assumed by Stein and Winker (2010); see Table A.1

There is a difference of almost €286,200 in the TPC. For the conditions of the SANIRESCH project in its first phase, this TPC difference represents the economic gap between the sanitation systems currently compared. Furthermore, as it can be seen in Figure 6.1, the running costs of both options represent almost the same amount of money required as initial investment. The differences are around €24,200 for the *Ecosan* option, and €46,300 in the case of the *conventional sanitation*.

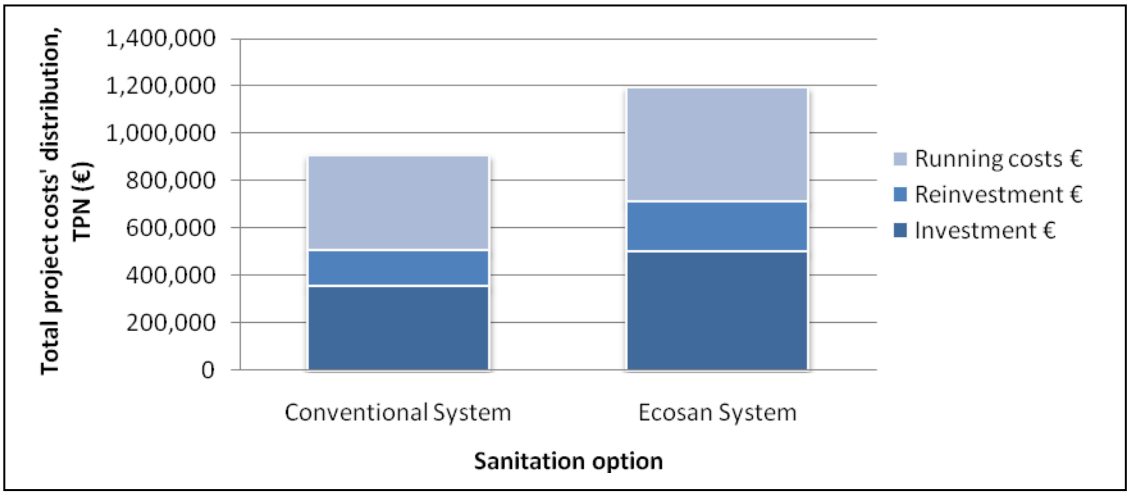

Figure 6.1 Costs comparison for the large scale sanitation installation case (GTZ)

The reduction of the ratio between running costs and initial investment is caused by the way how the running costs come up. There are certain expenses that increase as the whole installation is scaled up, such as the wastewater disposal expense. Nevertheless, there are other parameters that remain constant, such as the cost of the cleaning activities (Table 6.5). Additionally, the growth in dimension of a sanitary installation does not have a 1:1 proportionality with its operational costs. For example, the fact that the initial investment for the large scale *conventional sanitation* installation is 2.3 times the cost of a small scale installation does not necessarily mean the same increase in the amount of wastewater to be produced or the required personnel for cleaning and maintenance. Therefore, this initial investment Vs running costs behavior is considered as realistic.

Another comparison criterion, the yearly costs of the systems (Table 6.5), indicates a difference of €8,500 between the sanitation alternatives, where the *conventional system* has the lowest yearly costs. This result confirms the previously commented cost advantage of the *conventional sanitation* installation also expressed by the TPC. Moreover, a similar condition can be also confirmed with the estimation of the DPC2 of the sanitation options currently evaluated.

On a yearly basis, the information presented in Table 6.5 indicates that there is a difference of €0.014/use in the cost of collecting and transporting the wastewater in House 1, Eschborn. The *ecological sanitation* cost estimated, under the conditions presented as the main assumptions (chapter 4), is €0.059/use. Even though the number may seem small, it is important to consider that it is based on the amount of yearly uses, which are 400,840 uses, if 1,822 daily uses are considered during 220 days working time.

6.5 Sensitivity analysis

In order to determine the eventual influence of the factors analyzed in section 5.5 on the results presented in section 6.4, a sensitivity analysis is done. The corresponding details related to the calculations and intermediate results are included in Table A.33 and the electronic file *LAWA Thesis – Andres Lazo.xlsx*. The main results of the sensitivity analysis of the big scale approach in comparison with the corresponding ones for the small scale consideration (section 5.5) are presented in Figure 6.2.

As it can be observed in Figure 6.2, the final DPC2 values obtained in the big scale approach (Table A.34) present a behavior similar to the one observed in the small scale approximation (Table 5.7). In fact, there is no condition where the DPC2 for *ecological sanitation* shows a lower value than the *conventional sanitation* evaluation. Furthermore, the most sensitive conditions are still scenarios IV, VI and VII.

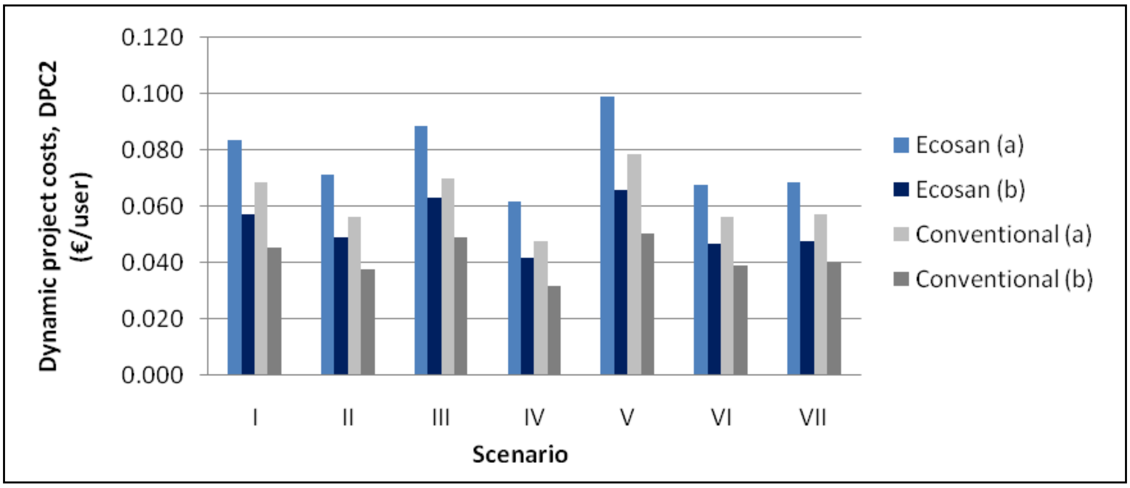

Figure 6.2 Comparison of the results of the sensitivity analysis for both (a) small scale and (b) big scale projects

The main difference between the results of the small and big scale approaches is the magnitude of their DPC2 values. Both the initial and the final value of the big scale model are always lower than in the case of the small scale approximation. This is mainly due to the higher amount of wastewater treated as well as due to the higher number of users assumed to use the system.

Table 6.6 Costs gap for each sensitivity analysis scenario of the small and big scale approaches

#	*Scenario*	*DPC2 Gap Change-Small scale (€/use)*	*DPC2 Gap Change-Big scale (€/use)*
I	Decrease of the price of sanitary installations	-0.004	-0.002
II	Increase of the amount of uses	-0.004	-0.003
III	Yearly increase of wastewater fee	0.000	0.000
IV	Extension of lifetime	-0.005	-0.004
V	Yearly increase of running costs	0.001	0.002
VI	II + I	-0.007	-0.006
VII	III + II + I	-0.007	-0.006

However, a lower cost of these alternative sanitation options (big scale case) does not necessarily mean that such an approach also minimizes the cost gap between *ecological* and *conventional* sanitation. Hence, the effect of the different sensitivity analyses on the cost gap between *ecological* and *conventional sanitation* is compared. According to the information presented in Table 6.6, it can be indicated that the size of a sanitation installation does not necessarily reduce the cost gap between *ecological* and *conventional* sanitation. Actually, except for scenarios III, IV and V, the cost gap among the sanitation alternatives is even lower with a big scale installation. On the other hand, it is possible to indicate that scenarios VI and VII are the most favorable for the two project scales analyzed.

7 Conclusions

The main objective of this study was to evaluate the economic performance of the *Ecosan* sanitary installation at GTZ, with the help of a comparison with a *conventional sanitation* system in the same conditions. According to the analysis done, the average project costs for GTZ's currently installed sanitary facility are €0.088/use, while the corresponding costs for a *conventional sanitation* installation are €0.069/use. Additionally, these calculations were complemented with further observations regarding the economic performance of the system evaluated:

- The net present value of the total project costs required for GTZ's *ecological sanitation* installation is €651,800, considering a *real interest rate* of 3% during a 50 years period
- The net present value of the total initial investment required for GTZ's *ecological sanitation* installation is €222,900
- In both *conventional* and *ecological sanitary installations*, the biggest part of the initial investment corresponds to the pipelines and accessories (62-63% of the initial investment)
- For the conditions presented in the study, GTZ's *ecological sanitation* installation has slightly lower yearly operating costs/initial investment ratio (1.5), than an eventual corresponding *conventional sanitation* installation (1.9). However, in terms of magnitude, the yearly running costs are higher for the *ecological sanitation* (€13,200/yr)
- The biggest component of the operation and maintenance expenses, in both sanitation facilities, is caused by the cleaning personnel and the wastewater fees to be paid (€10,200/yr *conventional* and €10,100/yr *Ecosan*)
- The consideration of a 3-year cycle for the replacement of toilet valves in the *ecological sanitation* concept does not have a significant effect on the total project costs
- The eventual usage of drinking water as flushing water affects more significantly a *conventional sanitation* installation (7.2% increase) than an *ecological sanitation* installation (5.7%). However, these effects are still considered as minor in comparison to the total project costs

As part of the sensitivity analysis, several potential scenarios that could have affected the economic performance of the systems were analyzed (section 5.6). According to the results obtained, the scenarios where the number of daily uses (starting with 676 uses) of the sanitary installation increases, are the cases where the average project costs of the *ecological system* approach most significantly the ones from a *conventional system*. In this case, in terms of the cost gap between the sanitation alternatives considered, the scenarios VI and VII caused the biggest average costs reduction. From an initial value of €0.088/use, the $DPC2_E$ went down to €0.068/use and €0.069/use respectively.

Finally, in order to determine the effect of an increase of the project scale on its economic performance, an expansion of the installation in House 1 (Eschborn) together with an increase of the number of uses was considered. The main outcome of this analysis can be summarized by the following statements:

- The average project costs for the up-scaled GTZ's project would be €0.059/use, while the corresponding costs for a *conventional sanitation* installation would be €0.045/use
- An increase in the *urinal to toilet* ratio, with the current project conditions, means a potential lower costs ratio between *ecological sanitation* devices and the *conventional* ones (1.3 instead of 1.5, in the present study)
- The scale of the sanitation facility causes a big impact on the operating costs, meaning a reduction of the ratio between the amount of money to be spent for operation and the corresponding amount for investment

However, even if the previous statements seem quite promising, it was determined that a larger-scale project does not necessarily mean a reduction of the economical gap between the sanitation approaches.

8 Outlook

Even though the analysis of the economic performance of GTZ's sanitation system in Eschborn indicates that there is a considerable disadvantage in comparison with *conventional systems*, there are conditions that could modify this outcome. The first factor comprises the possibility to recover valuable substances from the brown- and yellow water, for their further use in agriculture, industry and other economic sectors. Secondly, the installation and operation of an on-site wastewater treatment system at GTZ may serve as a modifying factor, especially on the side of the operation costs of the whole facility. Finally, further development of the sanitary devices themselves should focus on the maximization of their water saving potential, which nowadays is highly affected, for example, by the multiple flushing problems.

A part of these factors is already part of the SANIRESCH project. However, a good cooperation between research projects and the manufacturers is required. It would not make any sense if research institutions keep on developing *ecological sanitation* installations, while the sanitary devices are not improved. This improvement should aim not only to the enhancement of the technology, as mentioned before. It should also aim at expanding the opportunities of *ecological sanitation* in order to try to generate economies of scale that can help small as well as big scale projects around the world.

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10. Appendix

10.1 Appendix A

Table A.1 Water saving profile for the modernization project in House 1, Eschborn (Interview with Stein and Winker, 2010)

System	*Unit*	*Ecosan*	*Conventional*
Urinals – yellow			
Usage per day	use/p*d	2	2
Flush water for urinals, every use	l/use	0	3,9
Male users (workers + guests)	p	120	120
Yearly working days	d/yr	220	220
Sum	**m³/yr**	**0**	**206**
Female toilets – yellow			
Usage per day	use/p*d	2	2
Average flushes per usage	flush/use	1	1
Flush water for toilets, every use	l/use	6	6
Female users (workers + guests)	P	120	120
Yearly working days	d/yr	220	220
Sum	**m³/yr**	**317**	**317**
Male toilets - brown			
Usage per day	use/p	1	1
Average flushes per usage	flush/use	1.7	1
Flush water for toilets, every use	l/use	10	6
Male users (workers + guests)	P	98	98
Yearly working days	d/yr	220	220
Sum	**m³/yr**	**220**	**129**
Female toilets - brown			
Usage per day	use/p	1	1
Average flushes per usage	flush/use	1.7	1
Flush water for toilets, every use	l/use	10	6
Female users (workers + guests)	P	98	98
Yearly working days	d/yr	220	220
Sum	**m³/yr**	**220**	**220**
Total sum	**m³/yr**	**757**	**781**

Table A.2 Grouped investment for the *Ecosan* system (Maßalsky, 2006)

Item	*Amount (#)*	*Total Price, P (€)**
Urinals	23	7,300
Toilets	50	67,400
Pipeline DN 50		1,500
Pipeline DN 80		5,400
Pipeline DN 100		9,100
Pipeline DN 125		4,500
Accessories DN 50		1,800
Accessories DN 80		8,900
Accessories DN 100		11,400
Accessories DN 125		7,900
Other accessories and materials		72,900
Total (€)		**198,100**
Total adjusted (€)		**222,900**

* Rounded price

Table A.3 Performance indicators for the system analyzed

Parameter	*Value – Small scale*	*Value – Big scale*
Difference investment in pipelines and accessories, ΔP_{PA} (€)	43,600	117,700
Difference investment sanitary devices, ΔP_{SD} (€)	27,000	30,000
Total difference, ΔP (€)	70,600	147,700
Contribution pipelines and accessories, ΔP_{PA}-ΔP (%)	62%	80%
Contribution sanitary devices, ΔP_{SD}-ΔP (%)	38%	20%
Conventional sanitation		
Investment in pipelines and accessories, P_{PA} (€)	95,300	256,900
Investment in sanitary devices, P_{SD} (€)	57,100	98,200
Total investment, P (€)	152,400	355,100
Contribution pipelines and accessories, $P_{PA\text{-}P}$ (%)	63%	72%
Contribution sanitary devices, $P_{SD\text{-}P}$ (%)	37%	28%
Reinvestment, R (€)	65,700	149,000
Total investment, P (€)	152,400	355,100
Reinvestment ratio, R-P (%)	55%	42%
Ecological sanitation		
Investment in pipelines and accessories, P_{PA} (€)	138,900	374,600
Investment in sanitary devices, P_{SD} (€)	84,100	128,200
Total investment, P (€)	223,000	502,800
Contribution pipelines and accessories, $P_{PA\text{-}P}$ (%)	62%	75%
Contribution sanitary devices, $P_{SD\text{-}P}$ (%)	38%	25%
Reinvestment, R (€)	89,300	210,300

Table A.3 (cont.) Performance indicators for the system analyzed

Parameter	***Value – Small scale***	***Value – Big scale***
Total investment, P (€)	222,900	502,800
Reinvestment ratio, R-P (%)	40%	42%
Sanitary devices ratio, P_{SD1}-P_{SD2} (€)	1.5	1.3

Table A.4 Reinvestment considered due to spare parts for the *ecological sanitation*

Item[a]	***Price of the installation***[a]***, P (€)***	***Service life***[b]***, L (yr)***	***Reinvestment, adjusted***[c]***, R' (€)****	***Reinvestment, readjusted***[d]***; R'' (€)***
Spare parts Ecosan 2006	0	5	0	0
Spare parts Ecosan 2007	500	5	546	546
Spare parts Ecosan 2008	1,900	5	2,016	2,016
Spare parts Ecosan 2009	5,500	5	5,665	5,665
Subtotal (€)	**7,900**		**8,227**	**8,227**
Taxes[e], % VAT (€) 19%	1,600		1,600	
Total (€)	**9,400**		**9,800**	**9,800**

[a] List of the items considered for each year in Appendix C
[b] Prager (2002)
[c] Considers the original cost of the component and recalculates it for the base year of the study (2010)
[d] Considers the *adjusted* value financially discounted for the estimation of the required reinvestment
[e] European Commission (2010)

Table A.5 Reinvestment considered due to spare parts for the *conventional sanitation* (GTZ, 2010a)

Item[a]	***Price of the installation***[a]***, P (€)***	***Service life***[b]***, L (yr)***	***Reinvestment, adjusted***[c]***, R' (€)****	***Reinvestment, readjusted***[d]***; R'' (€)***
Spare parts Conventional 2006	531	5	500	600
Spare parts Conventional 2007	494	5	500	500
Spare parts Conventional 2008	1,059	5	1,100	1,200
Spare parts Conventional 2009	1,530	5	1,500	1,500
Subtotal (€)	**3,614**		**3,600**	**3,800**
Taxes[e], % VAT (€) 19%	700		700	700
Total (€)	**4,300**		**4,300**	**4,500**

[a] List of the items considered for each year in Appendix C
[b] Prager (2002)

[c] Considers the original cost of the component and recalculates it for the base year of the study (2010)
[d] Considers the *adjusted* value financially discounted for the estimation of the required reinvestment
[e] European Commission (2010)

Table A.6 Reinvestment estimation for a 50 years period consideration of the *conventional sanitation* option, without already installed replacement parts

Item	***Price of the installation[a], P (€)***	***Service life[b], L (yr)***	***Reinvestment, adjusted[c], R' (€)***	***Reinvestment, readjusted[d], R'' (€)***
Pipelines and accessories	77,500	35	95,300	33,900
Urinals & Toilets	46,400	25	57,100	27,300
Total (€)	**123,900**	**-**	**152,400**	**61,200**
Total adjusted[e] (€)	**181,400**	**-**	**-**	**61,200**

[a] GTZ (2004)
[b] Prager (2002)
[c] Considers the original cost of the component and recalculates it for the base year of the study (2010)
[d] Considers the *adjusted* value financially discounted for the estimation of the required reinvestment
[e] Considers the original cost of the component and recalculates it for the base year of the study (2010)

Table A.7 Service requests for the *ecological sanitation* installation between January 2009 and February 2010 (Interview with Stein, 2010)

Problem	***Number of service requests***													
	2009											***2010***		
	Jan	***Feb***	***Mar***	***Apr***	***May***	***Jun***	***Jul***	***Aug***	***Sep***	***Oct***	***Nov***	***Dec***	***Jan***	***Feb***
Conventional														
Toilet ring defect		2												
Flushing defect, water runs continuously		2	2	1		1	1	2	1	3	1	1	2	
Toilet out of service, unknown reason				1										
Water overconsumption						1	1							
Flushing defect, water runs out						1								
Toilet cover defect			1				1							
Congestion							1	1						
Ecosan														
Maintenance required														
Urine collection bowl blocked														
Clogged toilet	1	2	1						1					2
Flushing defect, water runs continuously		1												2
Flushing mechanism out of service, water runs			2											
Pressure sensor under the toilet seat defect			1											
Not enough flushing water				1	1			1						
Bad smells					1			1						
Toilet seat broken					1									
Flushing button defect		1						1						1
Clogged urinal										1				1

Table A.8 Time effort estimated for the *ecological sanitation* installation's service requests between January 2009 and February 2010

Problem	***Yearly maintenance frequency[a], M (times/yr)***	***Task time requirement[b], t (h/time)***	***Yearly time invest. (h/yr)***
Conventional			
Toilet ring defect	2	0.5	1
Flushing defect, water runs continuously	17	0.5	8.5
Toilet out of service, unknown reason	1	1	1
Water overconsumption	2	0.5	1
Flushing defect, water runs out	1	0.5	0.5
Toilet cover defect	2	0.5	1
Congestion	2	1	2
Total			**15**
Ecosan			
Maintenance required	0	1	0
Urine collection bowl blocked	0	1	0
Clogged toilet	7	1	7
Flushing defect, water runs continuously	3	0.5	1.5
Flushing mechanism out of service, water runs	2	0.5	1
Pressure sensor under the toilet seat defect	1	1	1
Not enough flushing water	3	0.5	1.5
Bad smells	2	1	2
Toilet seat broken	1	0.5	0.5
Flushing button defect	3	0.5	1.5
Clogged urinal	2	0.05	0.1
Total			**16.1**

[a] Based on Table A.8
[b] Interview with Stein (2010)

Table A.9 Data for the maintenance expense calculation

Criteria	***Value***
Conventional sanitation installation	
Yearly time investment (h/yr)	15.0
Yearly time investment per device (h/dev*yr)	0.042
Amount of devices analyzed installation in Eschborn (dev)	73
Hourly rate for time consideration[a] (€/h)	67
Yearly cost of maintenance (€/yr)	206
Ecological sanitation installation	
Yearly time investment (h/yr)	16.1

Table A.9 (cont.) Data for the maintenance expense calculation

Criteria	*Value*
Yearly time investment per device (h/dev*yr)	0.221
Amount of devices analyzed installation in Eschborn (dev)	73
Hourly rate for time consideration[a] (€/h)	67
Yearly cost of maintenance (€/yr)	1,079

[a] Zapf (2010)

Table A.10 Toilets and urinals distributions at the GTZ Headquarters (*conventional sanitation*)

Level	*Urinals*	*Men Toilets*	*Women Toilets*
House 1			
0.	14	11	18
1.	4	2	4
2.	4	2	4
3.	4	2	4
4.	4	2	4
5.	4	2	4
6.	4	2	4
7.	4	2	3
8.	2	1	1
9.	1	1	1
Total House 1	**45**	**27**	**47**
House 2			
0.	6	6	6
1.	6	6	6
2.	6	6	6
3.	6	6	6
4.	4	4	4
Total House 2	**28**	**28**	**28**
House 3			
0.	11	13	13
1.	9	10	10
2.	9	10	10
3.	6	7	7
4.	6	7	7
Total House 3	**41**	**47**	**47**
House 4			
EG	2	2	5
1.	2	2	5
Total House 4	**4**	**4**	**10**
All Houses			
Total GTZ	**118**	**106**	**132**

Table A.11 Initial estimation indexes for the spare parts costs

Cost estimation	*2006*	*2007*	*2008*	*2009*
Unit cost spare parts for *conventional installation*, P_{xi} (€/device*yr)	7	7	15	21
Cost spare parts for *conventional installation*, P_x (€/yr)	2,589	2,409	5,162	7,464
Unit cost spare parts for *Ecosan installation*, P_{xi} (€/device*yr)	0	7	26	76
Cost spare parts for *Ecosan installation*, P_x (€/yr)	0	489	1,866	5,540

Table A.12 Final estimation indexes for the spare parts costs

Cost estimation	*Small scale*	*Big scale*
Unit cost spare parts for *conventional installation - Average*, P_{xi} (€/device*yr)	12	20
Unit cost spare parts for *conventional installation - Median*, P_{xi} (€/device*yr)	11	18
Unit cost spare parts for *Ecosan installation - Average*, P_{xi} (€/device*yr)	27	44
Unit cost spare parts for *Ecosan installation - Median*, P_{xi} (€/device*yr)	16	26
Total cost spare parts for *Ecosan installation*, P_x (€/yr)	1,200	3,100
Total cost spare parts for *conventional installation*, P_x (€/yr)	800	2,200

Table A.13 Technical information for the application of Mellerud

Data	*Unit*	*Value*
Costs Mellerud[a]	€/(25 L unit)	126
Consumption Mellerud	25 L unit/yr	21
Dosage[b]	ml/dosage	200
Yearly working days[c]	d/yr	220

[a] Mellerud Chemie GmbH (2010)
[b] Braum (2009b)
[c] Stein and Winker (2010)

Table A.14 Economic analysis outcome for the 3-year cycle spare parts replacement

Item	*Units*	*Conventional System*	*Ecosan System*
RUNNING COSTS			
Maintenance and supervision personnel	€/yr	200	1,100
Wastewater disposal	€/yr	1,800	1,700
Cleaning personnel and materials	€/yr	8,400	8,400
Drinking water	€/yr	200	200
Cleaning substances, extra (liquid)	€/yr	0	600
Spare parts	€/yr	800	0

Table A.14 (cont.) Economic analysis outcome for the 3-year cycle spare parts replacement

Item	*Units*	*Conventional System*	*Ecosan System*
MAIN OUTCOME			
Investment	€	152,400	220,900
Reinvestment	€	65,700	174,300
Yearly investment	€/yr	8,100	11,300
Running costs	€/yr	11,400	12,000
Sum yearly costs	**€/yr**	**19,500**	**23,300**
Investment	€	152,400	220,900
Reinvestment	€	65,700	174,900
Running costs	€	293,300	308,800
Total project costs	**€**	**511,400**	**706,600**
DPC	**€/m³**	**11.8**	**16.8**
DPC2	**€/use**	**0.069**	**0.095**

Table A.15 Reinvestment considered due to the 3-year cycle spare parts replacement

Item		*Price of the installation[a], P (€)*	*Service life[b], L (yr)*	*Reinvestment, adjusted[c], R' (€)**	*Reinvestment, readjusted[d], R'' (€)*
Valves replacement every 3 years		8,500	3	8,800	71,936
Subtotal (€)			**8,500**	**8,800**	**71,936**
Taxes[e], % VAT. (€)	19%		1,600	1,700	13,700
Total (€)			**10,100**	**10,500**	**85,600**

[a] GTZ, 2010a
[b] Assumption of replacement every 3 years
[c] Considers the original cost of the component and recalculates it for the base year of the study (2010)
[d] Considers the *adjusted* value financially discounted for the estimation of the required reinvestment
[e] European Commission (2010)

Table A.16 Economic analysis outcome for the drinking water as flushing water approach

Item	*Units*	*Conventional System*	*Ecosan System*
RUNNING COSTS			
Maintenance and supervision personnel	€/yr	200	1,100
Wastewater disposal	€/yr	1,800	1,700
Cleaning personnel and materials	€/yr	8,400	8,400
Drinking water	€/yr	1,700	1,600
Cleaning substances, extra	€/yr	0	600

Table A.16 (cont.) Economic analysis outcome for the drinking water as flushing water approach

Item	*Units*	*Conventional System*	*Ecosan System*
Spare parts	€/yr	800	1,200
MAIN OUTCOME			
Investment	€	152,400	222,900
Reinvestment	€	65,700	89,300
Yearly investment	€/yr	8,100	11,300
Running costs	€/yr	12,900	14,600
Sum yearly costs	**€/yr**	**21,000**	**25,900**
Investment	€	152,400	222,900
Reinvestment	€	65,700	89,300
Running costs	€	331,914	375,655
Total project costs	**€**	**550,000**	**687,900**
DPC	**€/m³**	**12.7**	**16.4**
DPC2	**€/use**	**0.074**	**0.093**

Table A.17 Economic analysis outcome for the sensitivity analysis: Scenario I; *Ecosan System*

Item	*Units*	*Conventional System*	*Ecosan System*	*5%*	*10%*	*15%*	*20%*	*25%*
RUNNING COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	1,100	1,100	1,100	1,100	1,100
Wastewater disposal	€/yr	1,800	1,700	1,700	1,700	1,700	1,700	1,700
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	200	200	200	200	200
Cleaning substances, extra (liquid)	€/yr	0	600	600	600	600	600	600
Spare parts	€/yr	800	1,200	1,200	1,200	1,200	1,200	1,200
MAIN OUTCOME								
Investment	€	152,400	222,900	218,695	214,490	210,285	206,080	201,875
Reinvestment	€	65,700	89,300	87,548	85,764	83,980	82,196	80,412
Yearly investment	€/yr	8,100	11,300	11,048	10,807	10,565	10,324	10,082
Running costs	€/yr	11,400	13,200	13,200	13,200	13,200	13,200	13,200
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**24,200**	**24,000**	**23,800**	**23,500**	**23,300**
Investment	€	152,400	222,900	218,695	214,490	210,285	206,080	201,875
Reinvestment	€	65,700	89,300	87,548	85,764	83,980	82,196	80,412
Running costs	€	293,319	339,633	339,633	339,633	339,633	339,633	339,633
Total project costs	**€**	**511,400**	**651,800**	**645,900**	**639,900**	**633,900**	**627,900**	**621,900**
DPC Ecosan	**€/m³**	**11.8**	**15.5**	**15.4**	**15.2**	**15.1**	**15.0**	**14.8**
DPC2 Ecosan	**€/use**	**0.069**	**0.088**	**0.087**	**0.086**	**0.085**	**0.084**	**0.084**

Table A.18 Economic analysis outcome for the sensitivity analysis: Scenario I; *Conventional System*

Item	*Units*	*Conventional System*	*Ecosan System*	*5%*	*10%*	*15%*	*20%*	*25%*
RUNNING COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	200	200	200	200	200
Wastewater disposal	€/yr	1,800	1,700	1,800	1,800	1,800	1,800	1,800
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	200	200	200	200	200
Cleaning substances, extra (liquid)	€/yr	0	600	0	0	0	0	0
Spare parts	€/yr	800	1,200	800	800	800	800	800
MAIN OUTCOME								
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Yearly investment	€/yr	8,100	11,300	8,100	8,100	8,100	8,100	8,100
Running costs	€/yr	11,400	13,200	11,400	11,400	11,400	11,400	11,400
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**19,500**	**19,500**	**19,500**	**19,500**	**19,500**
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Running costs	€	293,319	339,633	293,319	293,319	293,319	293,319	293,319
Total project costs	**€**	**511,400**	**651,800**	**511,400**	**511,400**	**511,400**	**511,400**	**511,400**
DPC Conventional	**€/m³**	**11.8**	**15.5**	**11.8**	**11.8**	**11.8**	**11.8**	**11.8**
DPC2 Conventional	**€/use**	**0.069**	**0.088**	**0.069**	**0.069**	**0.069**	**0.069**	**0.069**

Table A.19 Economic analysis outcome for the sensitivity analysis: Scenario II; *Ecosan System*

Item	*Units*	*Conventional System*	*Ecosan System*	*5%*	*10%*	*15%*	*20%*	*25%*
RUNNING COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	1,100	1,100	1,100	1,100	1,100
Wastewater disposal	€/yr	1,800	1,700	1,835	1,922	2,009	2,097	2,184
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	200	200	200	200	200
Cleaning substances, extra (liquid)	€/yr	0	600	600	600	600	600	600
Spare parts	€/yr	800	1,200	1,200	1,200	1,200	1,200	1,200
MAIN OUTCOME								
Investment	€	152,400	222,900	222,900	222,900	222,900	222,900	222,900
Reinvestment	€	65,700	89,300	89,300	89,300	89,300	89,300	89,300
Yearly investment	€/yr	8,100	11,300	11,300	11,300	11,300	11,300	11,300
Running costs	€/yr	11,400	13,200	13,335	13,422	13,509	13,597	13,684
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**24,600**	**24,700**	**24,800**	**24,900**	**25,000**
Investment	€	152,400	222,900	222,900	222,900	222,900	222,900	222,900
Reinvestment	€	65,700	89,300	89,300	89,300	89,300	89,300	89,300
Running costs	€	293,319	339,633	343,095	345,343	347,591	349,838	352,086
Total project costs	**€**	**511,400**	**651,800**	**655,300**	**657,500**	**659,800**	**662,000**	**664,300**
DPC Ecosan	**€/m³**	**11.8**	**15.5**	**14.9**	**14.2**	**13.7**	**13.1**	**12.7**
DPC2 Ecosan	**€/use**	**0.069**	**0.088**	**0.084**	**0.080**	**0.077**	**0.074**	**0.071**

Table A.20 Economic analysis outcome for the sensitivity analysis: Scenario II; *Conventional System*

Item	*Units*	*Conventional System*	*Ecosan System*	*5%*	*10%*	*15%*	*20%*	*25%*
RUNNING COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	200	200	200	200	200
Wastewater disposal	€/yr	1,800	1,700	1,888	1,978	2,068	2,158	2,248
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	200	200	200	200	200
Cleaning substances, extra (liquid)	€/yr	0	600	0	0	0	0	0
Spare parts	€/yr	800	1,200	800	800	800	800	800
MAIN OUTCOME								
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Yearly investment	€/yr	8,100	11,300	8,100	8,100	8,100	8,100	8,100
Running costs	€/yr	11,400	13,200	11,488	11,578	11,668	11,758	11,848
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**19,600**	**19,700**	**19,800**	**19,900**	**19,900**
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Running costs	€	293,319	339,633	295,582	297,895	300,208	302,521	304,835
Total project costs	**€**	**511,400**	**651,800**	**513,700**	**516,000**	**518,300**	**520,600**	**522,900**
DPC Conventional	**€/m³**	**11.8**	**15.5**	**11.3**	**10.9**	**10.4**	**10.0**	**9.7**
DPC2 Conventional	**€/use**	**0.069**	**0.088**	**0.066**	**0.063**	**0.061**	**0.058**	**0.056**

Table A.21 Economic analysis outcome for the sensitivity analysis: Scenario III; *Ecosan System*

Item	*Units*	*Conventional System*	*Ecosan System*	*3%*	*6%*	*9%*	*12%*	*15%*
RUNNING COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	1,100	1,100	1,100	1,100	1,100
Wastewater disposal	€/yr	1,800	1,700	1,800	1,900	1,900	2,000	2,000
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	200	200	200	200	200
Cleaning substances, extra (liquid)	€/yr	0	600	600	600	600	600	600
Spare parts	€/yr	800	1,200	1,200	1,200	1,200	1,200	1,200
MAIN OUTCOME								
Investment	€	152,400	222,900	222,900	222,900	222,900	222,900	222,900
Reinvestment	€	65,700	89,300	89,300	89,300	89,300	89,300	89,300
Yearly investment	€/yr	8,100	11,300	11,300	11,300	11,300	11,300	11,300
Running costs	€/yr	11,400	13,200	13,300	13,400	13,400	13,500	13,500
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**24,600**	**24,700**	**24,700**	**24,800**	**24,800**
Investment	€	152,400	222,900	222,900	222,900	222,900	222,900	222,900
Reinvestment	€	65,700	89,300	89,300	89,300	89,300	89,300	89,300
Running costs	€	293,319	339,633	342,206	344,779	344,779	347,352	347,352
Total project costs	**€**	**511,400**	**651,800**	**654,400**	**657,000**	**657,000**	**659,600**	**659,600**
DPC Ecosan	**€/m³**	**11.8**	**15.5**	**15.6**	**15.6**	**15.6**	**15.7**	**15.7**
DPC2 Ecosan	**€/use**	**0.069**	**0.088**	**0.088**	**0.088**	**0.088**	**0.089**	**0.089**

Table A.22 Economic analysis outcome for the sensitivity analysis: Scenario III; *Conventional System*

Item	*Units*	*Conventional System*	*Ecosan System*	*3%*	*6%*	*9%*	*12%*	*15%*
RUNNING COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	200	200	200	200	200
Wastewater disposal	€/yr	1,800	1,700	1,852	1,906	1,960	2,014	2,068
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	200	200	200	200	200
Cleaning substances, extra (liquid)	€/yr	0	600	0	0	0	0	0
Spare parts	€/yr	800	1,200	800	800	800	800	800
MAIN OUTCOME								
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Yearly investment	€/yr	8,100	11,300	8,100	8,100	8,100	8,100	8,100
Running costs	€/yr	11,400	13,200	11,452	11,506	11,560	11,614	11,668
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**19,600**	**19,600**	**19,700**	**19,700**	**19,800**
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Running costs	€	293,319	339,633	294,657	296,045	297,432	298,820	300,208
Total project costs	**€**	**511,400**	**651,800**	**512,800**	**514,100**	**515,500**	**516,900**	**518,300**
DPC Conventional	**€/m³**	**11.8**	**15.5**	**11.9**	**11.9**	**11.9**	**12.0**	**12.0**
DPC2 Conventional	**€/use**	**0.069**	**0.088**	**0.069**	**0.069**	**0.069**	**0.070**	**0.070**

Table A.23 Economic analysis outcome for the sensitivity analysis: Scenario IV; *Ecosan System*

Item	*Units*	*Conventional System*	*Ecosan System*	*55*	*60*	*65*	*70*	*75*
RUNNING COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	1,100	1,100	1,100	1,100	1,100
Wastewater disposal	€/yr	1,800	1,700	1,700	1,700	1,700	1,700	1,700
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	200	200	200	200	200
Cleaning substances, extra (liquid)	€/yr	0	600	600	600	600	600	600
Spare parts	€/yr	800	1,200	1,200	1,200	1,200	1,200	1,200
MAIN OUTCOME								
Investment	€	152,400	222,900	222,900	222,900	222,900	222,900	222,900
Reinvestment	€	65,700	89,300	108,678	108,678	108,678	108,678	126,208
Yearly investment	€/yr	8,100	11,300	11,300	11,300	11,300	11,300	11,300
Running costs	€/yr	11,400	13,200	13,200	13,200	13,200	13,200	13,200
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**24,500**	**24,500**	**24,500**	**24,500**	**24,500**
Investment	€	152,400	222,900	222,900	222,900	222,900	222,900	222,900
Reinvestment	€	65,700	89,300	108,678	108,678	108,678	108,678	126,208
Running costs	€	293,319	339,633	339,633	339,633	339,633	339,633	339,633
Total project costs	**€**	**511,400**	**651,800**	**671,200**	**671,200**	**671,200**	**671,200**	**688,700**
DPC Ecosan	**€/m³**	**11.8**	**15.5**	**14.5**	**13.3**	**12.3**	**11.4**	**10.9**
DPC2 Ecosan	**€/use**	**0.069**	**0.088**	**0.082**	**0.075**	**0.069**	**0.064**	**0.062**

Table A.24 Economic analysis outcome for the sensitivity analysis: Scenario IV; *Conventional System*

Item	*Units*	*Conventional System*	*Ecosan System*	*55*	*60*	*65*	*70*	*75*
RUNNING COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	200	200	200	200	200
Wastewater disposal	€/yr	1,800	1,700	1,800	1,800	1,800	1,800	1,800
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	200	200	200	200	200
Cleaning substances, extra (liquid)	€/yr	0	600	0	0	0	0	0
Spare parts	€/yr	800	1,200	800	800	800	800	800
MAIN OUTCOME								
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	74,164	74,164	74,164	74,164	86,200
Yearly investment	€/yr	8,100	11,300	8,100	8,100	8,100	8,100	8,100
Running costs	€/yr	11,400	13,200	11,400	11,400	11,400	11,400	11,400
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**19,500**	**19,500**	**19,500**	**19,500**	**19,500**
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	74,164	74,164	74,164	74,164	86,200
Running costs	€	293,319	339,633	293,319	293,319	293,319	293,319	293,319
Total project costs	**€**	**511,400**	**651,800**	**519,900**	**519,900**	**519,900**	**519,900**	**531,900**
DPC Conventional	**€/m³**	**11.8**	**15.5**	**10.9**	**10.0**	**9.3**	**8.6**	**8.2**
DPC2 Conventional	**€/use**	**0.069**	**0.088**	**0.064**	**0.058**	**0.054**	**0.050**	**0.048**

Table A.25 Economic analysis outcome for the sensitivity analysis: Scenario V; *Ecosan System*

Item	*Units*	*Conventional System*	*Ecosan System*	*5%*	*10%*	*15%*	*20%*	*25%*
RUNNING COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	1,155	1,210	1,265	1,320	1,375
Wastewater disposal	€/yr	1,800	1,700	1,785	1,870	1,955	2,040	2,125
Cleaning personnel and materials	€/yr	8,400	8,400	8,820	9,240	9,660	10,080	10,500
Drinking water	€/yr	200	200	210	220	230	240	250
Cleaning substances, extra (liquid)	€/yr	0	600	630	660	690	720	750
Spare parts	€/yr	800	1,200	1,260	1,320	1,380	1,440	1,500
MAIN OUTCOME								
Investment	€	152,400	222,900	222,900	222,900	222,900	222,900	222,900
Reinvestment	€	65,700	89,300	89,300	89,300	89,300	89,300	89,300
Yearly investment	€/yr	8,100	11,300	11,300	11,300	11,300	11,300	11,300
Running costs	€/yr	11,400	13,200	13,860	14,520	15,180	15,840	16,500
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**25,200**	**25,800**	**26,500**	**27,100**	**27,800**
Investment	€	152,400	222,900	222,900	222,900	222,900	222,900	222,900
Reinvestment	€	65,700	89,300	89,300	89,300	89,300	89,300	89,300
Running costs	€	293,319	339,633	356,615	373,596	390,578	407,559	424,541
Total project costs	**€**	**511,400**	**651,800**	**668,800**	**685,800**	**702,800**	**719,800**	**736,700**
DPC Ecosan	**€/m³**	**11.8**	**15.5**	**15.9**	**16.3**	**16.7**	**17.1**	**17.5**
DPC2 Ecosan	**€/use**	**0.069**	**0.088**	**0.090**	**0.092**	**0.095**	**0.097**	**0.099**

Table A.26 Economic analysis outcome for the sensitivity analysis: Scenario V; *Conventional System*

Item	*Units*	*Conventional System*	*Ecosan System*	*5%*	*10%*	*15%*	*20%*	*25%*
OPERATION COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	210	220	230	240	250
Wastewater disposal	€/yr	1,800	1,700	1,890	1,980	2,070	2,160	2,250
Cleaning personnel and materials	€/yr	8,400	8,400	8,820	9,240	9,660	10,080	10,500
Drinking water	€/yr	200	200	210	220	230	240	250
Cleaning substances, extra (liquid)	€/yr	0	600	0	0	0	0	0
Spare parts	€/yr	800	1,200	840	880	920	960	1,000
MAIN OUTCOME								
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Yearly investment	€/yr	8,100	11,300	8,100	8,100	8,100	8,100	8,100
Running costs	€/yr	11,400	13,200	11,970	12,540	13,110	13,680	14,250
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**20,070**	**20,640**	**21,210**	**21,780**	**22,350**
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Running costs	€	293,319	339,633	307,985	322,651	337,317	351,983	366,649
Total project costs	**€**	**511,400**	**651,800**	**526,100**	**540,800**	**555,400**	**570,100**	**584,700**
DPC Conventional	**€/m³**	**11.8**	**15.5**	**12.2**	**12.5**	**12.8**	**13.2**	**13.5**
DPC2 Conventional	**€/use**	**0.069**	**0.088**	**0.071**	**0.073**	**0.075**	**0.077**	**0.079**

Table A.27 Economic analysis outcome for the sensitivity analysis: Scenario VI; *Ecosan System*

Item	*Units*	*Conventional System*	*Ecosan System*	*5%*	*10%*	*15%*	*20%*	*25%*
OPERATION COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	1,100	1,100	1,100	1,100	1,100
Wastewater disposal	€/yr	1,800	1,700	1,835	1,922	2,009	2,097	2,184
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	0	0	0	0	0
Cleaning substances, extra (liquid)	€/yr	0	600	600	600	600	600	600
Spare parts	€/yr	800	1,200	1,200	1,200	1,200	1,200	1,200
MAIN OUTCOME								
Investment	€	152,400	222,900	218,695	214,490	210,285	206,080	201,875
Reinvestment	€	65,700	89,300	87,548	85,764	83,980	82,196	80,412
Yearly investment	€/yr	8,100	11,300	11,048	10,807	10,565	10,324	10,082
Running costs	€/yr	11,400	13,200	13,135	13,222	13,309	13,397	13,484
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**24,200**	**24,000**	**23,900**	**23,700**	**23,600**
Investment	€	152,400	222,900	218,695	214,490	210,285	206,080	201,875
Reinvestment	€	65,700	89,300	87,548	85,764	83,980	82,196	80,412
Running costs	€	293,319	339,633	337,949	340,197	342,445	344,692	346,940
Total project costs	**€**	**511,400**	**651,800**	**644,200**	**640,500**	**636,700**	**633,000**	**629,200**
DPC Ecosan	**€/m³**	**11.8**	**15.5**	**14.6**	**13.9**	**13.2**	**12.6**	**12.0**
DPC2 Ecosan	**€/use**	**0.069**	**0.088**	**0.083**	**0.078**	**0.074**	**0.071**	**0.068**

Table A.28 Economic analysis outcome for the sensitivity analysis: Scenario VI; *Conventional System*

Item	*Units*	*Conventional System*	*Ecosan System*	*5%*	*10%*	*15%*	*20%*	*25%*
OPERATION COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	200	200	200	200	200
Wastewater disposal	€/yr	1,800	1,700	1,888	1,978	2,068	2,158	2,248
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	200	200	200	200	200
Cleaning substances, extra (liquid)	€/yr	0	600	0	0	0	0	0
Spare parts	€/yr	800	1,200	800	800	800	800	800
MAIN OUTCOME								
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Yearly investment	€/yr	8,100	11,300	8,100	8,100	8,100	8,100	8,100
Running costs	€/yr	11,400	13,200	11,488	11,578	11,668	11,758	11,848
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**19,600**	**19,700**	**19,800**	**19,900**	**19,900**
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Running costs	€	293,319	339,633	295,582	297,895	300,208	302,521	304,835
Total project costs	**€**	**511,400**	**651,800**	**513,700**	**516,000**	**518,300**	**520,600**	**522,900**
DPC Conventional	**€/m³**	**11.8**	**15.5**	**11.3**	**10.9**	**10.4**	**10.0**	**9.7**
DPC2 Conventional	**€/use**	**0.069**	**0.088**	**0.066**	**0.063**	**0.061**	**0.058**	**0.056**

Table A.29 Economic analysis outcome for the sensitivity analysis: Scenario VII; *Ecosan System*

Item	*Units*	*Conventional System*	*Ecosan System*	*5%*	*10%*	*15%*	*20%*	*25%*
OPERATION COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	1,100	1,100	1,100	1,100	1,100
Wastewater disposal	€/yr	1,800	1,700	1,890	2,037	2,190	2,348	2,512
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	0	0	0	0	0
Cleaning substances, extra (liquid)	€/yr	0	600	600	600	600	600	600
Spare parts	€/yr	800	1,200	1,200	1,200	1,200	1,200	1,200
MAIN OUTCOME								
Investment	€	152,400	222,900	218,695	214,490	210,285	206,080	201,875
Reinvestment	€	65,700	89,300	87,548	85,764	83,980	82,196	80,412
Yearly investment	€/yr	8,100	11,300	11,048	10,807	10,565	10,324	10,082
Running costs	€/yr	11,400	13,200	13,190	13,337	13,490	13,648	13,812
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**24,200**	**24,100**	**24,100**	**24,000**	**23,900**
Investment	€	152,400	222,900	218,695	214,490	210,285	206,080	201,875
Reinvestment	€	65,700	89,300	87,548	85,764	83,980	82,196	80,412
Running costs	€	293,319	339,633	339,365	343,164	347,097	351,166	355,369
Total project costs	**€**	**511,400**	**651,800**	**645,600**	**643,400**	**641,400**	**639,400**	**637,700**
DPC Ecosan	**€/m³**	**11.8**	**15.5**	**14.6**	**13.9**	**13.3**	**12.7**	**12.1**
DPC2 Ecosan	**€/use**	**0.069**	**0.088**	**0.083**	**0.079**	**0.075**	**0.072**	**0.069**

Table A.30 Economic analysis outcome for the sensitivity analysis: Scenario VII; *Conventional System*

Item	*Units*	*Conventional System*	*Ecosan System*	*5%*	*10%*	*15%*	*20%*	*25%*
OPERATION COSTS								
Maintenance and supervision personnel	€/yr	200	1,100	200	200	200	200	200
Wastewater disposal	€/yr	1,800	1,700	1,945	2,097	2,254	2,417	2,585
Cleaning personnel and materials	€/yr	8,400	8,400	8,400	8,400	8,400	8,400	8,400
Drinking water	€/yr	200	200	200	200	200	200	200
Cleaning substances, extra (liquid)	€/yr	0	600	0	0	0	0	0
Spare parts	€/yr	800	1,200	800	800	800	800	800
MAIN OUTCOME								
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Yearly investment	€/yr	8,100	11,300	8,100	8,100	8,100	8,100	8,100
Running costs	€/yr	11,400	13,200	11,545	11,697	11,854	12,017	12,185
Sum yearly costs	**€/yr**	**19,500**	**24,500**	**19,600**	**19,800**	**20,000**	**20,100**	**20,300**
Investment	€	152,400	222,900	152,400	152,400	152,400	152,400	152,400
Reinvestment	€	65,700	89,300	65,700	65,700	65,700	65,700	65,700
Running costs	€	293,319	339,633	297,039	300,948	304,996	309,183	313,509
Total project costs	**€**	**511,400**	**651,800**	**515,100**	**519,000**	**523,100**	**527,300**	**531,600**
DPC Conventional	**€/m³**	**11.8**	**15.5**	**11.4**	**10.9**	**10.5**	**10.2**	**9.8**
DPC2 Conventional	**€/use**	**0.069**	**0.088**	**0.066**	**0.063**	**0.061**	**0.059**	**0.057**

Table A.31 Water saving profile for the modernization project in House 1 (big scale), Eschborn (based on Stein and Winker, 2010)

System	*Unit*	*Ecosan*	*Conventional*
Urinals – yellow			
Usage per day	use/p*d	2	2
Flush water for urinals, every use	l/use	0	4
Male users (workers + guests)	p	324	324
Yearly working days	d/yr	220	220
Sum	**m³/yr**	**0**	**555**
Female toilets - yellow			
Usage per day	use/p*d	2	2
Average flushes per usage	flush/use	1	1
Flush water for toilets, every use	l/use	6	6
Female users (workers + guests)	p	324	324
Yearly working days	d/yr	220	220
Sum	**m³/yr**	**854**	**854**
Male toilets - brown			
Usage per day	use/p	1	1
Average flushes per usage	flush/use	2	1
Flush water for toilets, every use	l/use	10	6
Male users (workers + guests)	p	264	264
Yearly working days	d/yr	220	220
Sum	**m³/yr**	**593**	**349**
Female toilets - brown			
Usage per day	use/p	1	1
Average flushes per usage	flush/use	2	1
Flush water for toilets, every use	l/use	10	8
Female users (workers + guests)	p	264	264
Yearly working days	d/yr	220	220
Sum	**m³/yr**	**593**	**465**
Total sum	**m³/yr**	**2,040**	**2,223**

Table A.32 Reinvestment estimation for a 50 years period consideration of the (big scale) *conventional sanitation* option

Item	*Price of the installation[a], P (€)*	*Service life[b], L (yr)*	*Reinvestment, adjusted[c], R' (€)*	*Reinvestment, readjusted[d], R'' (€)*
Pipelines and accessories	208,873	35	256,900	91,300
Urinals & Toilets	79,885	25	98,300	46,900
Total (€)	**288,758**	**-**	**355,100**	**138,200**
Total adjusted[e] (€)	**355,100**	**-**	**-**	**138,200**

[a] Based on GTZ (2004)
[b] Prager (2002)

[c] Considers the original cost of the component and recalculates it for the base year of the study (2010)
[d] Considers the *adjusted* value financially discounted for the estimation of the required reinvestment
[e] Considers the total cost of the components recalculated for the base year of the study (2010)

Table A.33 Summary of the outcome of the sensitivity analysis for the modernization project in House 1, Eschborn (big scale)

#	*Analysis*	*DPC2 Ecosan Start*	*DPC2 Ecosan End*	*DPC2 Conventional Start*	*DPC2 Conventional End*
I	Decrease of the price of sanitary installations	0.059	0.057	0.045	0.045
II	Increase of the amount of uses	0.059	0.049	0.045	0.038
III	Yearly increase of wastewater fee	0.059	0.063	0.045	0.049
IV	Extension of lifetime	0.059	0.042	0.045	0.032
V	Yearly increase of operation costs	0.059	0.066	0.045	0.050
VI	II + I	0.059	0.047	0.045	0.039
VII	III + II + I	0.059	0.048	0.045	0.040

10.2 Appendix B

Maßalsky's bill (Maßalsky, 2006). See CD attached (LAWA Thesis – Andres Lazo.xlsx).

10.3 Appendix C

Spare parts bills (GTZ, 2010a). See CD attached (LAWA Thesis – Andres Lazo.xlsx).