Socio-technical evaluation of urine diversion in Linköping and Norrköping

Master of Science Thesis in the Master's Programme Infrastructure and Environmental Engineering

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ABSTRACT

In this report, the urine diverting systems in Norrköping and Linköping have been evaluated from a socio-technical perspective. The focus has been placed on values and barriers of the systems. The values are divided into a) economic values and b) ideological values. The barriers are divided into a) technical barriers, b) organizational barriers and c) user-related barriers. The aim is to examine which values and barriers that the different actors of the system experience and to calculate an actual (monetary) value of the systems. This is done by interviewing different actors and using literature as complementing material. From these interviews, experienced values and barriers are found. Values and barriers that are possible to assign a monetary value are used to perform a cost-benefit analysis using the Excel-based tool VeVa.

The results show the actors experience both ideological and economic values. The most common are the ideological values of nutrient recycling and environmental protection, as well as the economic values of reduced maintenance cost for the household users and a well-working collaboration between the actors. Common barriers are technical problems related to the toilet, as well as, the technical problem that the urine solution is too diluted. Another barrier is that very few new installations are made today, which is believed to be because of the high investment costs, as well as, that the system demands a change of user-habits. The cost-benefit analysis shows that a system with urine diversion and an infiltration bed is more beneficial than a system with a mini-wastewater treatment plant and a phosphorus trap or a infiltration bed and a phosphorus trap. Urine diversion systems are expected to create a greater value when used in a larger scale. To gain wider acceptance for urine diversion on a large-scale, research on consequences of medical residues on cropland is needed.

Key words: urine diversion, source separating wastewater systems, nutrient recycling, on-site wastewater systems

Socio-teknisk utvärdering av urinseparering i Linköping och Norrköping

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SAMMANFATTNING

I denna rapport har de urinsorterande systemen I Norrköping och Linköping utvärderats från ett socio-tekniskt perspektiv. Fokus har varit på värden och barriärer i systemen. Värdena delas in i a) ekonomiska värden och b) ideologiska värden. Barriärerna delas in i a) tekniska barriärer, b) organisatoriska barriärer och c) användarrelaterade barriärer. Målet är att undersöka vilka värden och barriärer som de olika aktörerna i systemen upplever och att beräkna det faktiskt (monetära) värdet av systemen. Detta görs genom att intervjua olika aktörer och komplettera detta material med information från litteratur. Upplevda värden och barriärer identifieras med hjälp av dessa intervjuer. Värden och barriärer som kan tilldelas ett monetärt värde används för att utföra en kostnads-nytta-analys i det Excel-baserade verktyget VeVa.

Resultaten visar att aktörerna uppdeler både ideologiska och ekonomiska värden. De mest vanliga värdena är de ideologiska värdena näringsämnesåtervinning och skydd av miljön samt de ekonomiska värdena minskade driftkostnader för brukarna och ett välfungerande samarbete mellan aktörerna. Vanliga barriärer är tekniska problem med toaletterna liksom det tekniska problemet att urinen är för utspädd. Ett annat problem är att få installerar dessa system idag, vilket tros bero på de höga investeringskostnaderna samt att det krävs ändrade vanor. Kostnads-nytta-analysen visar att system med urinsortering och markbädd är mer lönsam än ett system med minireningsverk och fosforfälla eller markbädd och fosforfälla. Urinsorteringssystem förväntas skapa större värden om de används i större skala. För att öka acceptansen för urinsorteringssystem på en större skala behövs forskning om konsekvenserna av läkemedelsrester på åkermark.

Nyckelord: urinsortering, urinseparering, källsorterande avlopp, kretslopp, enskilda avlopp

Contents

Preface

I would like to thank my supervisor Jennifer McConville for all the help and support. Also thank you to my second supervisor Britt-Marie Wilén for helpful feedback. Most importantly, I would like to thank everyone that participated in the interviews: Linköping Municipality, Norrköping Municipality, Tekniska Verken, Biototal, SITA, Stångåstaden, politicians in Norrköping, LRF, the farmer in Norrköping and household users in Linköping. Also thank you to everyone else who provided helpful information or simply pointed me in the right direction.

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Maria Nilsson

1 Introduction

The wastewater systems in Sweden have changed throughout the years. In the beginning, the main purpose of the systems was to create a healthy environment for humans (Hjelmqvist, et al., 2012). For this reason, latrines were replaced by water closets in the beginning of the 20th century (Gårdstam, et al., 2013). At first the wastewater was not being treated. But as problems with pollution grew, the need for wastewater treatment was acknowledged. Because of this, municipal wastewater treatment plants were built all over Sweden, starting in the 1950s.

In recent years, the idea of recycling nutrients from the wastewater has become relevant. One reason for this is that phosphorus, which is present in wastewater, is a finite resource (Cordell, et al., 2009). Another reason is that the production of mineral fertilizers is an energy consuming process which could be replaced by using recycled nutrients from wastewater (Hjelmqvist, et al., 2012). The motivation has arisen to shift the focus from what can be removed from wastewater to what can be recovered (Guest, et al., 2009). Possible resources to recover are water, energy and materials. The materials that are usually focused upon are fertilizers. A way to achieve resource recovery of materials within conventional wastewater treatment is to reuse the sludge produced at a wastewater treatment plant as fertilizer. A problem with this is that heavy metals or other unwanted substances can end up in the sludge.

An option for avoiding contamination with heavy metals and other unwanted chemicals is to separate nutrient-rich sewage fractions from the rest of the wastewater (Hjelmqvist, et al., 2012). This can for example be done by using urine diversion. Urine contains 80 % of the nitrogen and at least 50 % of the phosphorous found in wastewater (Johansson, et al., 2000). Since urine makes up a small fraction of the total volume of wastewater the nutrients are quite concentrated. This makes it suitable to use urine as a fertilizer. Separation of urine at the source also means that the rest of the wastewater contains less nutrients. This means that urine diversion decreases the risk of releasing nutrients through the wastewater and thereby causing eutrophication in the recipient (Hjelmqvist, et al., 2012).

Source separating systems differ from conventional wastewater treatment. This means that potential problems need to be overcome in order for the system to function: for example different technology has to be used, user habits have to change and the management organization needs to be structured differently. This could be a reason why source separating systems are only used in a small scale in Sweden today.

In this master thesis, the two Swedish municipalities Linköping and Norrköping, where urine separation has been implemented, will be analyzed using case study methodology. Wastewater systems are socio-technical systems, consisting of technology, organization and individual users (Storbjörk & Söderberg, 2003). This means that not only the technology is important for the function of a system, but also how the system is organized and how the users act in the system. The technology is in this case the urine diverting toilets as well as the treatment of the urine. The organization consists of municipal departments as well as sub-contractors and farmers. The users are the household users of the toilets. All these subsystems will be taken into account when evaluating the systems.

This report supports a bigger research project by Dr. Jennifer McConville at Chalmers which aims to identify barriers to using source separating systems on a larger scale and potential pathways for system development.

1.1 Aims and goals

The aim of this master thesis is to evaluate cases where urine diversion are or have been used in two Swedish municipalities, Linköping and Norrköping. The focus is on identifying the motivations for using the systems and challenges that have been encountered. These two aspects are important as they affect how well the systems functions both from a technical perspective, as a well as, an organizational perspective. For example Johansson et al. (2000), states that the amount of urine collected is an indicator for the proper use of the toilets, which correlates to the motivation of the users. The motivation of users is expected to be related to how they value the system and view problems within it. Values and barriers are also expected to reflect the overall value of continuing the system. Many barriers should imply a system that is not working very well and few/weak values should imply that there the motivation of using the system is minimal. On the other hand, a system with strong values could motivate an expansion of the system.

Potential values of the system are considered to be of two different types; (a) economic, for example that a usable fertilizer product is produced, and (b) ideological, for example that the different actors find a value in using a sustainable system.

Also when considering challenges and barriers to the system, this can be categorized in the following categories: (a) technical, for example difficulties with clogging of the pipes or (b) organizational, for example that the users have not been properly informed on how to use the toilets or (c) user-related, for example that the users do not want to use the toilets the way they should be used.

The following questions should be answered:

- What values did the different actors of the systems experience? Were these economic or ideological values?
- What are the actual values produced by the system?
- What barriers were encountered? Why do these barriers exist?

1.2 Limitations

This report focuses on urine diversion. Other source separating systems, for example blackwater separation, will only be mentioned briefly and are not the target of the case study. Only two cases will be studied. This limits the possibilities for drawing general conclusions. This weakness will be compensated to some extent by the use of relevant literature throughout the report. Only water-borne systems are included in the case study since these systems are the ones that the two municipalities manage. This makes these systems comparable to other on-site systems such as mini-wastewater treatments plants.

2 Background

The world’s growing population puts higher demands on food production. To increase the amounts of nutrients in the ground and thereby increase the yield, fertilizers are commonly used in agriculture. There are two main types of fertilizers: Organic and mineral fertilizers. Organic fertilizers are for example animal excrement and urine, industrial waste or sludge from wastewater treatment plants (Granström, 2014). Organic fertilizers, especially human and animal excreta, were the main fertilizers used until the end of the 19th century (Cordell, et al., 2009). At this time water closets were introduced which decreased the amount of human excreta available for agriculture. The use of mineral fertilizers increased and continued to increase during the 20th century (Cordell, et al., 2009). Mineral fertilizers are artificially produced fertilizers that usually consist of nitrogen, phosphorous and/or potassium (Granström & Hubendick, 2014). Today, these types of fertilizers dominate agricultural practice and in forestry solely mineral fertilizers are used (Granström, 2014).

The main source of phosphorus for mineral fertilizers is phosphate rock, which is a finite resource. It is estimated that current known reserves will be depleted in 50-100 years (Cordell, et al., 2009). It is however believed that problems with availability will arise earlier than that, when all reserves of high quality and easy accessibility have been used. At this point “peak phosphorus” will occur, which is the maximum production of phosphate rock. Since high quality reserves will be used up at this point, the remaining reserves will be more uneconomical to use, which will decrease the amount produced. This point could be reached by 2033 (Cordell, et al., 2009).The availability of phosphate rock is also sensitive to politics since the remaining reserves are located in just a few countries including USA, Morocco and China (Cordell, et al., 2009).

The use of phosphate fertilizers also raises other environmental concerns related to energy consumption and pollution. Phosphate fertilizers are transported all over the world which, together with the processing of phosphate rock, leads to high energy consumption (Cordell, et al., 2009). When phosphate rock is being mined the toxic by-product phosphogypsum is also produced. This by-product has high radiation levels which stops it from being used in most countries. There is also a risk for groundwater contamination where it is stored. Phosphate rock can also contain cadmium or other heavy metals.

Unlike phosphorus fertilizers, the raw material for nitrogen fertilizers is not a finite resource; nitrogen from the air is used. However, the process of turning gaseous nitrogen into forms available for plants is an energy consuming process (Beal, et al., 2007). If fossil fuels are used the production leads to high emissions of greenhouse gases.

This implies that the high use rate of mineral fertilizers is not sustainable in the long term. Other sources of nutrients will be needed. As already mentioned, animal excrement and urine are widely used in agriculture. However, human excrement and urine is a source of nutrients which is used to a much lower extent; it is estimated that globally about 10 % of human excreta is returned to the agriculture or aquaculture (Cordell, et al., 2009). The potential is however quite big; Cordell et al (2009) estimate that globally 3 million tons of phosphorus can be found in human excreta every year, which corresponds to about 20 % of the global use of phosphorus fertilizers. Tidåker (2007) estimated how much nutrients could be found annually in urine and feces from all Swedish inhabitants: 37 000 respectively 5 000 tons of nitrogen and 3 300 respectively 1700 tons of phosphorus. The amount of nutrients found in urine corresponds to about 23 % of the yearly use of mineral fertilizers for both nutrients.

One problem with reusing nutrients from human excreta is that in the conventional wastewater system all wastewater fractions are mixed and treated together. This means that relatively pure nutrient-rich wastewater fractions (urine and feces) are mixed with nutrient-poor polluted wastewater fractions (greywater, stormwater and industrial wastewater). The resulting sludge, which could potentially be reused, may therefore also be polluted. Another way to achieve nutrient recycling of human excreta is to implement source separating wastewater systems; by separating the nutrient-rich fractions at the source a relatively pure nutrient solution can be obtained.

2.1 Current dominant systems

In order to understand potentials for expanding source-separated systems, an understanding of how the existing system functions is essential. Therefore, the current dominant system will be briefly presented. This consists mainly of wastewater networks connected with pipes to wastewater treatment plants. However, it also includes systems that are not connected to the piped wastewater network, on-site systems.

2.1.1 Waste water treatment within municipal wastewater network

The development of wastewater treatment systems is a process that has been dominated by the need to solve urgent, often unforeseen and/or temporarily ignored, problems. Waterborne diseases in the 19th century created the need to transport the wastewater out of the cities – which was the reason why underground wastewater pipes were built. In the beginning of the 20th century water closets began to replace traditional latrines (Bernes & Lundgren, 2009).

The water closet solved urgent problems related to human health. However, it broke the circle of nutrients that had existed between the cities and the agriculture. Nutrient recycle from human excreta had been practiced in many countries before water closets were introduced (Bracken, et al., 2007). The most famous historical system for collecting and reusing human excreta existed in China, where this was practiced already 2500 years ago (Lüthi, et al., 2011). This enabled the agriculture to achieve higher yields, which in turn allowed for the development of a densely populated country.

In the beginning, the new wastewater system did not manage nutrient flows. The wastewater was simply lead away from the cities to a lake or watercourse (Bracken, et al., 2007). It was believed that no treatment was needed since the pollution was being diluted and that the water had the ability to clean itself (Söderholm, 2007). But soon there were problems in the recipients with stench and oxygen deficit (Bernes & Lundgren, 2009). To solve this problem, wastewater treatment plants were gradually built. At first they only treated the wastewater mechanically (Höglund, 2001). In the 1950s some Swedish municipalities began to also treat the wastewater biologically in order to reduce nutrient concentrations, particularly nitrogen, in the effluent (Bernes & Lundgren, 2009). However, both of these treatment steps created a nutrient-poor sludge which was therefore generally disposed in landfills or dumped in the ocean.

As problems with eutrophication grew, due to releases of nutrients to the recipients, chemical treatment was also applied, primarily to capture phosphorus. Chemical treatment increased the nutrient-concentration in the sludge which could have made it possible to use in agriculture (Bernes & Lundgren, 2009). However, the interest in Sweden was quite low, probably due to costs related to treatment, storage and transport of the sludge (Bernes & Lundgren, 2009). There was also a risk that the sludge contained unwanted substances such as heavy metals. At the end of the 1980s less than half of the sludge was used in agriculture (Bernes & Lundgren, 2009).

Even today, only a small part of the recycling-potential of nutrients in wastewater is utilized. Every year 6000 tons of phosphorus can be found in sludge from Swedish wastewater treatment plants, which is equivalent to about one third of what is needed in Swedish agriculture (Bernes & Lundgren, 2009). Despite limits and guideline values for pollutants in sludge that is spread on agricultural land, only 15 % of the sludge was spread in 2006 (Bernes & Lundgren, 2009). In 2008, a certification system, REVAQ, was implemented to further improve the quality of the sludge (Svenskt Vatten, u.d.). Today, 25 % of all sludge produced in Swedish wastewater treatment plants is spread on cropland (Naturvårdsverket, 2013).

In the EU nearly 40 % of all produced sludge is estimated to be used in agriculture (Milieu Ltd, 2010). There are however great differences between the member states; for example the Netherlands recycled less than 1 % in 2003 while France used as much as 70 % in 2007 (Milieu Ltd, 2010).

However, there is still some controversy concerning the use of sludge in agriculture and some oppose it strongly. For example, the Swedish Society for Nature Conservation wants to stop the use of sewage sludge in agriculture, as well as, in forestry because of the unwanted substances that the sludge also contains, for example cadmium and organic compounds (Hansson & Johansson, 2012). The Federation of Swedish Farmers (LRF) has also had an active role in the debate about the use of sewage sludge in Sweden. Two times, in 1988 and 1999, they discouraged their members to use sewage sludge (Augustinsson, 2003). Today they have a more pragmatic view; they neither encourage nor discourage their members to use sludge on their crops. But if the members choose to use sludge they only recommend to use sludge certified according to REVAQ. They have also been very active in the development of REVAQ (LRF, 2010).

2.1.2 On-site wastewater systems

Not all houses are connected to the municipal sewage system. These houses have their own wastewater systems. The number of on-site wastewater treatment systems in Sweden is about 900 000 (Hjelmqvist, 2012). About 660 000 of these are water closets, and out of these more than 470 000 are installed in permanent housing (Hjelmqvist, 2012). They account for only 11% of the total number of households in Sweden (about 4 176 000) (SCB, 2013), but it is still an important area to work on since many of these individual systems do not properly treat the wastewater (Hjelmqvist, 2012). In total, on-site wastewater systems release 287 tons of phosphorus and 2 900 tons of nitrogen per year, based on numbers from 2009 (Ek, et al., 2011). This can be compared to 267 tons of phosphorus and 17 419 tons of nitrogen from municipal wastewater treatment plants in 2010 (Naturvårdsverket & SCB, 2012). When looking at releases of phosphorus and nitrogen to the Baltic Sea that is caused by human activity, on-site wastewater systems contribute with 2 % of the nitrogen releases and 13 % of the phosphorus releases (Naturvårdsverket, 2009).

Regulations have been made to improve the situation regarding individual wastewater treatment. For an on-site wastewater system it is now forbidden in Sweden to have a septic tank[1] as the only treatment step (SFS 1998:899). Despite this, 20 % of individual systems have no further treatment of their wastewater after the septic tank, which makes this the second most common treatment technology in Sweden (Hennlock, et al., 2013). The most common treatment is a drain field[2] and the third most common treatment technology is to collect the toilet fraction separately, for example blackwater separation (Hennlock, et al., 2013).

In 2006, the Swedish Environmental Protection Agency published general guidelines based on relevant legislation for on-site wastewater treatment (NFS 2006:7). These give guidance on how to appropriately interpret the legislation. In these guidelines, the terms *high protection-level* and *normal protection-level* are introduced. *High protection-level* applies to for example areas where the water is expected to affect protected areas, drinking water reserves or areas that for other reasons are considered sensitive. *High protection-level* requires for example higher reduction of phosphorous (90 % instead of 70 %) and nitrogen (50 %, not stated for *normal protection-level*). The guidelines also state that the municipalities should make it possible to reuse wastewater fractions, unless this is technically too difficult for the individuals or there is no long-term solution for how to use of the fractions.

2.2 Urine diversion

As mentioned in Chapter 2.1.1, efforts have been made to try to close the nutrient-cycle in conventional wastewater treatment through sludge recycling, but there is a lot of debate surrounding this topic. Another way to close the cycle is to separate wastewater fractions that are nutrient rich already at the source. This can be done by separating all the three fractions urine, feces and greywater or by only separating one fraction from the rest of the wastewater (Münch, et al., 2010) . The two most common source separating systems for water-borne systems in Sweden are urine separation and blackwater separation, where urine respectively blackwater (urine, feces, and flushing water) are collected separately (Hjelmqvist, et al., 2012).

The idea is to separate fractions containing the largest amounts of nutrients to enable more efficient reuse of these. The toilet fraction contains most of the nutrients but makes up a very small part of the total wastewater volume, see Figure 1 (Naturvårdsverket, 1995). The majority of heavy metals in household wastewater is found in the greywater (Vinnerås, 2001). Industrial wastewater and stormwater are other sources of pollutants in wastewater. Thus by separating the toilet-fraction a purer nutrient-solution is achieved.

[1] In a septic tank, grease and solids are separated from the wastewater (Naturvårdsverket, 2008).
[2] In a drain field the wastewater infiltrates through the natural soil layers into the groundwater (Naturvårdsverket, 2008).

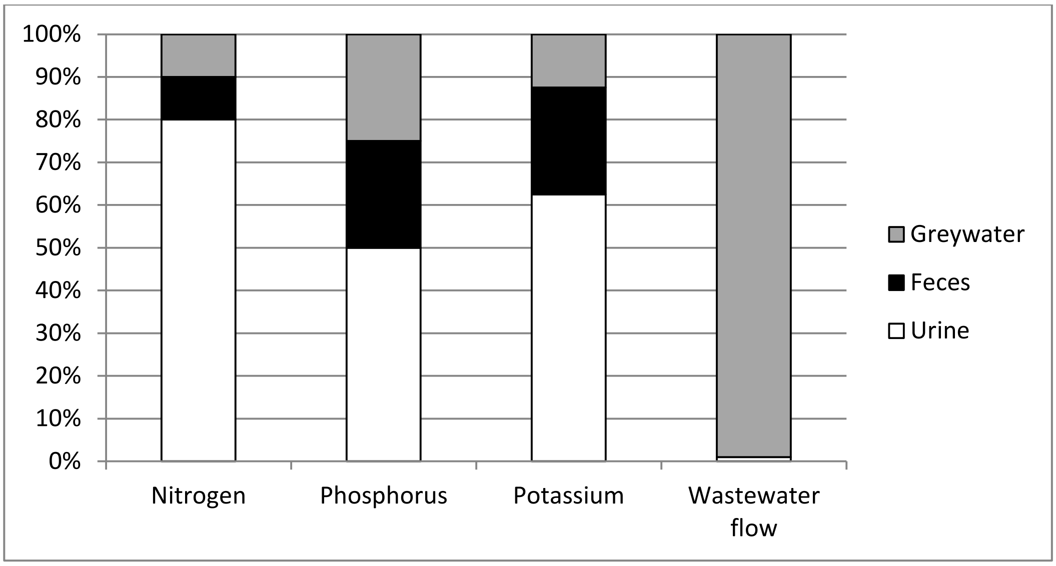

Figure 1 Nutrient-content and volume of greywater, faeces and urine in domestic wastewater. Based on Naturvårdsverket (1995).

This report focuses on urine diversion. Urine is a quite small fraction of household wastewater, representing about 1 % of the total wastewater volume (Naturvårdsverket, 1995). However, it is the wastewater fraction that contains the most nutrients; at least 50 % of the phosphorus and approximately 80 % of the nitrogen (Johansson, et al., 2000). About 60 % of the potassium can also be found in the urine (Naturvårdsverket, 1995). This makes it a relatively concentrated nutrient solution. In addition, urine normally has very low concentrations of pathogens and heavy metals (Jönsson, et al., 2000).

All phosphorus and nitrogen from the food an adult human eats passes the body without being absorbed, which means that it leaves the body with the urine and the feces (Richert Stintzing, et al., 2001). After storage, the bulk of both of these nutrients are in mineralized form, which means that they are available for plants. The relation between nitrogen, phosphorus and potassium in urine corresponds to the need for these nutrients in grains (Richert Stintzing, et al., 2001).

2.2.1 History of urine diversion

Urine diversion has been used for a long time. At the end of the 19^{th} century it was common in Swedish cities that urine was diverted from latrines to prevent them from smelling, which made it possible to build the latrines inside (Drangert & Löwgren, 2005). It also prevented the latrines from filling up too quickly since urine makes up about 90 % of the toilet fraction. However, the urine was not used but poured into the wastewater system. In Denmark, urine was used as detergent for washing clothes during the 19^{th} century (Höglund, 2001). Urine has also been used to produce gunpowder.

2.2.2 Urine diversion in Sweden in modern time

Sweden can be seen as pioneers for modern urine diversion. The interest for this technology originates from growing environmental concerns in the 1980s and 1990s (Vinnerås & Jönsson, 2013).

2.2.2.1 Development

Johansson et al (2009) describes the development of urine diversion in Sweden in four phases. In the first phase, environmental concerns lead to the development of so called eco-villages in the first half of the 1990s, where the aim was to find a more environmentally friendly way of living. The recycle of nutrients through on-site wastewater treatment was a central idea in these villages. Many of the eco-villages used urine diversion to achieve this (Vinnerås & Jönsson, 2013). Urine diverting insets for dry closets had developed already in the 1970's and in the early 1990's urine diverting water closets were developed (Johansson, et al., 2000). Both types of toilets were used in the eco-villages. The eco-villages organized the reuse of the urine themselves and the municipalities were mostly not involved (Vinnerås & Jönsson, 2013). During this time urine diversion was also installed in single houses and summer houses (Johansson, et al., 2009).

The second phase began in the middle of the 1990s. There was a political interest for these kinds of systems and big visions about a more environmentally friendly society (Johansson, et al., 2009). During this time the Swedish Environmental Code, which contains most Swedish laws concerning the environment, as well as the National Environmental Quality Objectives, which is the base of environmental policy in Sweden, were developed and introduced (Johansson, et al., 2009). In both of these documents support for technologies supporting nutrient recycle can be found, see Chapter 2.2.2.2. The Local Investment Program (LIP) was also started to help fund investments in sustainable buildings and projects. About 10-15 municipalities used this program to promote technologies that enabled nutrient recycle, especially urine diversion, for on-site wastewater treatment and to develop a system for the handling of the urine. Some multistory buildings also installed urine diverting toilets at this time, for example the apartment building Ekoporten in Norrköping and the museum Universeum in Gothenburg (Vinnerås & Jönsson, 2013). Some of these projects developed a system for the reuse of the urine, but many failed to do so (Johansson, et al., 2009).

The third phase began in the beginning of the 21th century. Even though there was a lot of enthusiasm about urine diversion in the 1990s, economic incentives would have been needed to enable further development of these kinds of system (Johansson, et al., 2009). This did not happen and the technology in itself did not develop at the speed that it had been expected to.

At this time, many of the pilot projects began to experience problems (Johansson, et al., 2009). The farmers were not interested in investing in storage tanks for the urine since it was still at low volumes because of few installed systems. Because of this, the rumor spread that the farmers did not want to use the urine, when in fact they were just not interested in financing the storage and spreading themselves (Johansson, et al., 2009). During this time some urine diverting systems were closed down (Johansson, et al., 2009). In some cases this was because there was no system in place for reuse of the urine. Another reason was that some of the early toilets did not work properly. Some municipal systems were also closed down, primarily because of organizational problems, for example vague division of responsibility between the actors.

The fourth and current phase of urine diversion in Sweden began around 2005 (Johansson, et al., 2009). In this phase it is possible to use legislation as incentive for developing systems for nutrient recycle from source separated systems. Examples of such legislation are mentioned in Chapter 2.2.2.2. An important progress concerning the organization of urine diversion is that it today is clear that the municipalities carry the responsibility for collecting, treating and recirculating the urine. This has led several Swedish municipalities to develop such systems.

2.2.2.2 Legal incentives

As mentioned in Chapter 2.2.2.1 there are laws and national policies in Sweden that support the use of source separation. This will be further elaborated here.

The **National Environmental Quality Objectives** are important for the environmental work in Sweden. One of the original sub-objectives was that 60 % of the phosphorus from wastewater should return to productive land by 2015 and at least half of it should be used on agricultural land (Naturvårdsverket, 2013). However, this was criticized and therefore the Swedish Environmental Protection Agency was instructed by the government in 2012 to develop a new objective and in the meantime the objective was removed. The proposal for a new sub-objective, **Sustainable reuse of phosphorus,** was presented in September 2013. In the new proposal the amount of phosphorus that should be recycled is 40% and at least 10 % should be used on agricultural land. It is also explicitly stated that this should not lead to pollution that can be harmful to humans or the environment. The government has yet to decide on if the proposal should be accepted.

Urine diversion could also help to achieve other National Environmental Quality Objectives. Since it efficiently removes nutrients from the rest of the wastewater and thus reduces the amount of nutrients in the effluent it prevents eutrophication. Therefore it contributes to the sub-objective **No eutrophication** (Hjelmqvist, et al., 2012).

The Swedish Environmental Code contains most laws concerning environmental protection. One of its main goals is to promote reuse and conservation of resources (SFS 1998:808). However, this should only be done when it can be considered economically reasonable, for example considering the costs and benefits.

As mentioned in Chapter 2.1.2 the Swedish Environmental Protection Agency has published general guidelines on how to interpret the Swedish Environmental Code and other legislation relevant for on-site wastewater systems, where an important part is the distinction between *high* and *normal protection-level.* These guidelines also states that wastewater fractions should be reused when possible. Although these guidelines gives an incentive for urine diversion and other source separating solutions it should be noted that they are only guidelines and not legally binding.

2.2.3 Urine Diversion Technology

A urine diversion system normally consists of four main steps: collection, transport, treatment and use. If the urine is used in the garden of the house several steps can be excluded since neither transport nor treatment is necessary.

2.2.3.1 Collection

In systems of urine diversion the urine is separated from the rest of the wastewater already in the toilet. This requires a urine separating toilet. They are available in different models and can be both dry closets and water closets. What they have in common is that they both have two bowls, where urine is collected in the front bowl and feces and toilet paper in the rear bowl, see Figure 2 and 3. From the front bowl a pipe leads the urine to a collection tank. The rear bowl is either connected to the rest of the household wastewater or the feces are collected separately. As mentioned in

Chapter 2.2, the first option is the most common solution for water closets, whereas urine diverting dry toilets gives three separate fractions (urine, feces, greywater). In this report, only water borne systems will be examined.


Figure 2 and Figure 3 show two different urine diverting toilet models: WC-Dubbletten from BB Innovation & Co to the left (BB Innovation & Co AB, u.d.) and EcoFlush from Wostman Ecology to the right (Wostman Ecology AB, u.d.).

The toilet can either be connected to a single collection tank, or two alternating tanks can be used. If the latter alternative is chosen, the needed storage time, see Chapter 2.2.3.3, can be achieved before the urine is transported for reuse.

Urine diverting water closets often use less flush water than traditional ones, since the urine bowl is often flushed separately with less water than the "regular" flush. How much water that can be saved depends on which model is used.

2.2.3.2 Transport

Whereas the collection of the urine is done by the house owner, transport and all following steps are the responsibility of the municipality according to Swedish law. The reason for this is that urine is seen as a household waste which is collected, treated and disposed of by the municipality (Hjelmqvist, et al., 2012). The house owners can apply for permission to take care of the urine themselves. In that case neither transport nor treatment is needed, see further Chapter 0.

The urine is generally transported by trucks to a storage tank, which is usually located at or near the farm where the urine is going to be reused.

2.2.3.3 Treatment

Urine normally has low concentrations of pathogens (Jönsson, et al., 2000). However, there is a risk of fecal contamination of the urine solution. Therefore, the urine should be treated if it is to be used as fertilizer in agriculture. The most common way to treat it is long-time storage. Jönsson et al. (2000) have made recommendations for storage-time based on what types of pathogens that could possibly remain, see Table 1. The storage times are temperature dependent because micro-organisms survive longer at lower temperature (Jönsson, et al., 2000). The same recommendations are given by the World Health Organization (World Health Organization, 2006). If urine is used on crops that are consumed raw, there are two additional recommendations for the given storage-time of six months: the urine should be spread no later than a month before harvest and the urine should be incorporated into the soil.

Table 1 Recommended storage-time for different temperatures (Jönsson, et al., 2000)

Storage-temperature	Storage-time	Possible remaining pathogens in urine solution	Recommended crops
4°C	≥ 1 month	Viruses, protozoa	Forage and food crops that are to be processed
4°C	≥ 6 months	Viruses	Food crops that are to be processed, forage crops
20°C	≥ 1 month	Viruses	Food crops that are to be processed, forage crops
20°C	≥ 6 months	Probably none	All crops

In Sweden, this is still just a recommendation and not determined by any law (Hjelmqvist, et al., 2012). It is however common that farmers do not follow these recommendations, which may be because the handling of urine is a very small part of their business (Andersson, 2008).

In 2010, Naturvårdsverket proposed the recommendations in Table 1 to the government in the proposition *Uppdatering av "Aktionsplan för återföring av fosfor ur avlopp"* (*Update of "Action plan for recirculation of phosphorus from sewage"*) (Naturvårdsverket, 2010), with the addition that urine is allowed on all crops regardless of storage temperature if it is stored for at least a year. If the proposal is accepted the recommendations would become legally binding.

2.2.3.4 Use

The urine can be spread with equipment used for more conventional fertilizers, for example farm slurry[3], which means that no extra costs for spreading arises (Petersens, et al., 2005). However, such equipment may not be available at all farms, which can lead to an extra cost for the farmer.

EU-rules about ecological production forbid human urine or feces to be used as fertilizer on ecological crops. The Swedish ecological certification system KRAV, which incorporates relevant EU rules, can therefore not allow human urine as fertilizer either (KRAV, 2013).

The house-owners can get permission from the municipality to use the urine themselves. Each municipality decides under which conditions the permission is given. In most cases they demand that the covered land belonging to the house has a certain minimum area. This rule is to prevent large amounts of urine from leaking into surrounding watercourses. No recommended storage-time is given since there are

[3] This includes animal urine, feces and sometimes added water

other more probable ways of spreading infections within a household than through the spreading of urine. It is however recommended not to spread the urine on crops that are consumed raw within a month of their harvest (Petersens, et al., 2005).

2.2.4 Frequent problems and costs

A problem that is frequently mentioned in reports about urine diversion is stoppages in odor traps (e.g. Jönsson, et al., 2000; Johansson, et al., 2000; Lindgren, 1999). In these reports, the stoppages were analyzed and in all three cases the majority of the stoppages were normal stoppages, caused by hair or similar materials. These stoppages could be removed using a mechanical snake. The rest of the stoppages were caused by precipitations of calcium and magnesium phosphates (Jönsson, et al., 2000). Unlike normal stoppages, this type of stoppage is a particular problem for urine diverting toilets. These can be removed chemically with for example a water solution of sodium hydroxide.

Another problem that is mentioned in some of the reports is a urine-odor from the toilets (Burström & Jönsson, 1998; Johansson, et al., 2000). However, in these reports it is believed that this problem is mainly related to improper installation of the systems, which caused leakage of urine. Once this was fixed the odor was reduced or disappeared completely (Burström & Jönsson, 1998).

Some reports mention that it is hard for small children to separate feces and urine correctly (Andersson, 2008; Burström & Jönsson, 1998). To solve this problem, inserts for children have been developed (Separett, u.d.).

Although urine is a quite pure nutrient solution, there is one group of substances which raises concern: pharmaceuticals and pharmaceutical residues. Not very much is known about how the environment is affected by pharmaceuticals that are spread to agricultural land. However, if the pharmaceuticals did not enter the eco-system through the spreading of urine, they would end up either in the recipients of wastewater effluent or in the sludge from wastewater treatment plants. Since there are more microorganisms in the ground than in water it is believed that there is a greater possibility that they are broken down than in an aquatic environment (Jönsson, et al., 2000). According to Andersson et al (2012), it is possible to eliminate pharmaceutical residues in urine through a method combining ozone and free radicals. This technology is however new and not yet widely used.

Urine diversion requires an extra set of pipes and a urine-tank which increases the investment costs and makes it hard to install in already existing houses. The toilets are also more expensive than traditional toilets. According to Andersson (2008) this leads to an investment cost that is 30 000-35 000 SEK higher than for the same system without urine diversion. Another added cost of urine diversion is increased vehicle transports, which also effects the environment through energy use and releases of greenhouse gases.

3 Methodology

Case study methodology is used in this study for evaluating the systems in the municipalities. According to Yin (2003) a case study is a suitable methodology when analyzing phenomena that are currently happening, where the reasons and procedures of a phenomenon should be studied and where the investigator does not affect the events to any large extent. It can be used to study complex phenomena. As already mentioned, urine diversion systems are expected to be systems consisting of many different factors. The systems are contemporary and the study has no intent to affect it. This makes a case study a suitable research method.

The study objects that have been chosen are municipalities where the municipality has taken some kind of responsibility for the systems. These cases offer more opportunities for generalization and recommendations with wider impacts. Other types of initiatives, for example an eco-village, are expected to attract people that have a high motivation and willingness to overcome challenges as a starting point, which would not give a representative view of public attitudes and potential problems. However, two pilot projects, which could be viewed as eco-initiatives, have been used in this study. This is because they were located in urban areas and is therefore believed to bring complementary experiences since the main systems are only used in the country-side.

Another criterion considered was that there is relatively little (up-to date) documentation of these cases, which makes them more interesting than other well documented cases. The results from this study can then be compared with these other studies.

3.1 Sources of Information

According to Yin (2003) the strength of case studies is that it enables the use of many different sources of information. He stresses the importance of data triangulation. This means that the facts in the case study should be supported by more than one source of information. The six main sources of information for a case study are archival records, participant-observation, physical artifacts, documentation, interviews and direct observation. The three latter were used in this study.

Interviews are considered the main source of information for this study. In order to get a diverse understanding of the problems and motivations of the urine diversion systems, the views of people from different parts of the system were taken into account. Municipal management, individual users, sub-contractors and farmers are considered to be key actors with different perspective on the topic. Interviews with persons representing these groups were done. The interviews were done as so called *semi-structured interviews*. This means that the questions are specific but the interviewee is rather free to answer the questions as he/she wants to (Bryman, 2004). In addition, the interviewer may ask questions that she/he had not planned, for example follow-up questions to clarify something said by the interviewee. According to Bryman (2004), all questions should be asked but not necessarily in the planned order. The phrasing should however be similar in all interviews. However, in this case, different types of actors of the system have been interviewed. This makes it unsuitable to ask them exactly the same questions, since for example the users will probably not know how well urine works as a fertilizer and the farmers will have little insight to the technical problems related to the toilets. To still have some consistency, first sub-research questions were formulated and then interview questions were formulated to be able to answer these questions (Appendix 1). The sub-research questions are the same but the interview questions differ depending on which actor is interviewed (Appendix 2a-f). All actors do not have interview-questions covering all sub-research questions.

Some problems were encountered when planning the interviews. In Norrköping, the municipality did not want to give out any contact details to households with urine diverting toilets for legal reasons. To compensate for this, this study used a household-questionnaire performed a couple of years ago by the municipality itself. In Linköping a similar problem was encountered when the sub-contractor that handles the contact to the farmers did not want to give out contact information. Representatives of the Federation of Swedish Farmers (LRF) were interviewed to partly compensate for the fact that only one farmer was interviewed in the study. It was also difficult to get in contact with people who had knowledge about the process of implementing the systems, because they had been in place for over a decade and many people have retired or changed jobs. Due to time-limitations, this led to only two interviews being performed with politicians, who both were/had been active in Norrköping.

The interviews were recorded and transcribed in order to achieve good material for the analysis. The interviewees have had the opportunity to read the transcript in case they want to add or take back any statements. Yin (2003) points out that even though interviews are important sources of information, they also bring problems such as preconceptions the interviewee. Therefore the use of other sources is also important.

In connection to the interviews, direct observations of the actors of the system have been done. This is to complement what they are saying as to how engaged they seem to be. Originally, direct observations of the facilities were also planned. This was however not possible since the only participating farmer declined to host a visit.

When it comes to documentation, as much material as possible has been collected from the municipalities and other sources. This material includes documents such as previous reports, policy documents and results from a household-questionnaire. Easily accessible material were read and analyzed before the interviews to create an insight in the systems and prepare for the interviews. Other materials were collected in connection to the interviews (with help from the interviewees) to give additional information on the topic, that may or may not confirm what has been said in the interviews. This information was mainly used for background information about the systems, as well as complimentary information where the interview-material was not sufficient. All data sources used can be found in Table 2.

Table 2 Data sources used for the case studies

Type of data source	Norrköping	Linköping
Interviews	Employee at environmental office	Employee at environmental office
	Former employee at environmental office (at the time of implementation)	
	Employee at technical office	Employee at department of waste and recycling at municipal company
	Two politicians	
	Sub-contractor SITA	Sub-contractor Biototal
		Household users (6)
		Project leader for urine-separating tenement house
	Farmer	
	Representatives from the Federation of Swedish Farmers LRF[1]	Representatives from the Federation of Swedish Farmers LRF[1]
Direct observation	Observations during interviews	Observations during interviews
Documentation	Household-questionnaire (Carlsson, 2011)	
	Report about urine-separating tenement house (Norberg, 2002)	
	Policy and guidelines (Norrköping Municipality, 2011) (Norrköping Municipality, 2013c) (Norrköping municipality, 2013a)	Policy and guidelines (Linköping Municipality, 2011)
	Documents where the system in Norrköping has been mentioned (Andersson, 2008) (Arvidsson & Andersson, 2009)	
	Statistics (SCB, 2014) (Ek, et al., 2011)	Statistics (SCB, 2014) (Ek, et al., 2011)
	Report about historical background (Drangert & Löwgren, 2005)	Report about historical background (Drangert & Löwgren, 2005)
Personal correspondence	Investigator for rental company that owned tenement house with urine diversion	Farmer with own urine-diverting system

[1]Two regional representatives were interviewed that are expected to have insight in the situation in both municipalities

When all the information had been collected it was analyzed and used to answer the questions posed under aims and goals. This has been done in two different types of analysis: Coding typology for qualitative data and a Cost-Benefit-Analysis, which are both described below.

3.2 Analytical framework for coding typology for qualitative data

This analysis examined data from the interviews, but also some complementing material: a report and a household-questionnaire. To make the analysis more structured a framework was developed. This framework is based on relevant literature, as well as what was expected to be found in the case studies.

Since the aim of this report is to identify values and barriers of the systems the first step is to find these in the interviews. As mentioned in Chapter 1.1, the values are expected to be either ideological or economic and the barriers are expected to be technical, organizational or user-related. Values and barriers have been divided into these categories and are then further categorized into functional criteria that are expected to be important for the systems to work properly. These functional criteria are described in Chapter 3.2.2. Exactly what is meant by values and barriers in this report is defined in Chapter 3.2.1.

The analysis has been performed for four different groups of actors:

1. Actors of the current system in Linköping
2. Actors of the current system in Norrköping
3. Actors of former urine-diverting residential houses (pilot projects)
4. Politicians and representatives from the Federation of Swedish Farmers LRF (political input)

Group 1 and 2 are considered to deal with the main focus of this study, which are the current systems of urine diversion for individual systems in both cities. Group 3 is expected to give additional experience on how urine diversion systems functions in more urban environments and early problems with urine diversion. Group 4 consists of actors that have less insight to the systems but can give a more theoretical input about the values and barriers from a political standpoint.

3.2.1 Values and barriers

Since this report focuses on the values and barriers of the system it is important to clarify what exactly is meant by values and barriers.

Values are defined as factors that motivate the use of a specific system. The values are divided into *economic* and *ideological* values. *Economic* values are values that show if there are any monetary motivations for using the system, for example a decreased cost for water because of decreased water-use. *Ideological* values concern what ideological motivations people see in the system. These are values that the actors do not necessarily gain anything from themselves, but that still brings them satisfaction because they correlate to their own ideological values. In this study, these are mostly about ecological values. It should be noted that all values depend on the actors seeing it as a value themselves; if a system is environmental-friendly will not be motivating unless the actors recognizes that it is and find it important.

Values are in some cases only values for one type of actor. For example, there can be an economic value for the user because the fee for emptying the urine tank is free, but this is not a value to the municipality since they still have to finance it. The values identified in this study are not necessarily representative for the system as a whole, but are the sum of all values for different actors.

In addition to these experienced values from the interview study, a cost-benefit analysis will be done to try to calculate the actual value of the system, see Chapter 3.2.2.

Barriers are defined as factors that affect the value of a system in a negative way, and thereby decrease the value. There does not need to be a value directly corresponding to a barrier, as a barrier can affect the overall operation and hence value of the system. Barriers do not necessarily need to be detected by the actors; barriers detected by an external observer are still expected to affect the values of the system to some extent.

Barriers are divided into *organizational*, *user-related* and *technical* barriers. *Organizational* barriers are related to the organization and its different actors, for example high costs for the municipality or lack of knowledge within the organization. *User-related* barriers are related to the users of the system, which are the house owners or tenants. Such barriers are for example the need to change behavior or high costs for the users. *Technical* barriers are related to how the system works technically, for example technical problems with the toilet or uncertainties regarding the content of the urine.

From these definitions it can be concluded that values and barriers are defined in different ways and are not each other's direct opposites. This means that not all parts of the framework are used for both values and barriers, see Chapter 3.2.2.

3.2.2 Functional criteria

Several other reports have developed functional criteria to examine technological systems. These criteria are expected to be critical for a system to work well, which in turn is expected to reflect the values and barriers of the system. Some of these were used in this report in order to find relevant topics of investigation for the case studies.

Bergek et al. (2008) define functions that can be used for analyzing a technological innovation system. A technological innovation system is defined as "a socio-technical system focused on the development, diffusion and use of a particular technology (in terms of knowledge, product or both)" (Bergek, et al., 2008). These functions include Knowledge development and diffusion, Influence on the direction of Search, Entrepreneurial experimentation, Market formation, Legitimation, Resource mobilization and Development of positive externalities. Storbjörk & Söderberg (2003) defines seven criteria that should be considered when planning sustainable urban water management. Such criteria include for example shared values among actors and division of responsibility and risks.

Based on these reports, as well as the Multi-Layer Perspective presented by Geels and Shot (2007), the functional criteria **Resource Mobilization, Legitimation, Stakeholder Arena, Breadth and Depth of Support Network** and **Access to Knowledge** were chosen. These criteria are relevant to this study because they concern parameters that may influence the *values* (economic as well as ideological) or different kinds of *barriers* (organizational, user-related or technical). Here follows a brief description of each criterion and why they are relevant to this study.

Resource Mobilization concerns the financial resources that needs to be mobilized for the technology to be implemented (Bergek, et al., 2008). The lack of ability to finance the technology can be a barrier (Storbjörk & Söderberg, 2003). A high resource demand is also expected to be barrier of the system. Both these barriers can be either organizational or user-related, depending on who covers the costs. This criterion is used to determine the *actual economic value*.

Legitimation is about social acceptance of a technology and that relevant actors find it useful and applicable (Bergek, et al., 2008). In this report Legitimation is merged with the closely related criterion "influence on the direction of search" which is connected to incentives for using the technology (Bergek, et al., 2008). Social acceptance is expected to be greater if a *value* is perceived by the different actors. Thus, perceived legitimation is defined as the values the actors spontaneously connect with the system. The actor's beliefs in growth potential are expected to reflect if they see any value of the system. Complications occurring due to *technical problems*, which thereby decrease the social acceptance, are expected to be discovered when analyzing this criterion. Political support and alignment with current legislation are other important factors. In the cost-benefit-analysis, see Chapter 3.2.2, an attempt will be made to calculate the *actual ecological value* which would represent a possible *ideological value* in this category.

Stakeholder Arena is a combination of criteria concerning the stakeholders and how they collaborate. A well working collaboration is considered to be an *economic value* since it is expected to lead to more efficient work. Storbjörk & Söderberg (2003) empathize for example the importance of a clear division of responsibilities. This criterion is relevant to see if there are any *user-related barriers* or *organizational barriers* caused by for example insufficient communication.

Breadth and Depth of Support Network concerns the power and enthusiasm of the involved actors (Storbjörk & Söderberg, 2003). Geels & Schot (2007) also mention the importance of powerful actors. Powerful and enthusiastic actors are expected to be needed to have the capacity to implement the system. This criterion is expected to reflect the attitudes of the actors, which could be a factor that could cause *organizational* or *user-related problems*, as well as *ideological values.*

Access to Knowledge concerns what knowledge the actors of the system has access to, for example scientific knowledge or experiences from similar systems (Storbjörk & Söderberg, 2003). A lack of knowledge is expected to lead to *organizational problems.* According to the definition of values the fact that they possess knowledge is not a value in itself and is not counted as a value in the analysis. Yet, possession of knowledge can influence what values a stakeholder sees in the system. In this case, knowledge will affect how stakeholders see the legitimacy of the system and influence values identified under Legitimation.

Other is a criterion for values and barriers that were found that were not expected when the framework was developed. These will be examined in the Discussion to see if they represent a criterion/criteria that could be of importance too.

Table 3 summarizes which criterions are used in this study and which values/barriers they are expected to influence.

Table 3 The functional criteria used in this study. Values and barriers that are expected to be influenced by the different criteria are marked with an X.

Functional Criteria	Ideological value	Economic value	Technical barrier	Organizational barrier	User-related Barrier
Resource Mobilization		X		X	X
Legitimation	X	X	X	X	X
Stakeholder Arena		X		X	X
Breadth and Depth of Support Network	X			X	X
Access to Knowledge				X	

For each criterion possible indicators have been suggested and from what type of source they can be found. Sub-research questions that should examine the different criteria were formulated, see Appendix 1. Where interviews are the source of information interview questions were formulated for the different groups of actors, see Appendix 2a-f. The answers to these questions were then used to answer the questions posed under aims and goals. The functional criteria, indicators and sub-research questions are shown in Table 4.

Table 4 Functional criteria, Indicators and Sub-research questions used in this report

Functional criteria	Indicators	Sub-research questions
Resource Mobilization	Financial resources used	Was there an experienced economic value? Was there an actual economic value? Were there economic barriers?
Legitimation	Visions	What was the motivation for implementing the system?
	Perceived legitimation (among actors)	Did the different actors experience any economic value? Did they find any ideological value?
	Actual ecological value	What is the (approximate) ecological value?
	Beliefs in growth potential	Do the actors believe that an expansion of the system is possible/suitable?
	Technical legitimation	Are there any technical problems?
	Political support	Is there political support for the system?
	Alignment with current legislation	Are there any legal incentives? Are there any legal barriers?
Stakeholder Arena	Division of responsibilities	Is there a clear division of responsibilities?
	Arena for participation and conflict resolution	Are there any organizational or user-related problems related to conflict resolution?
	Collaboration between actors	Are there any barriers related to the collaboration between actors?
	Communication with potential users	How well does the communication with the users and farmers work?
Breadth and Depth of Support Network	Enthusiasm of actors	What are the actor's attitudes towards the project?
	Capacity of implementing the system	How was the initial support for the system?
Access to Knowledge	Existing human capital (training of project team, experience of people involved, etc.)	Are there any barriers related to the lack of experience?

3.3 Cost-Benefit-Analysis

Based on the results from the coding typology analysis, the most important values and barriers were selected and are presented in Chapter Analysis of actual values4.3.2. There it is briefly discussed which of these values are possible to assign monetary values. For these values and barriers a cost-benefit analysis has been performed. This was done to try to determine the *actual value* of the system.

The cost-benefit analysis has been performed in the Excel-based tool, VeVa. VeVa is a tool that has been developed to enable municipalities and other decision-makers to compare different drinking water and wastewater alternatives. It has been developed by CIT Urban Water, Stockholm Vatten AB, Ecoloop AB in cooperation with the Swedish municipalities Tanum, Norrtälje, Södertälje, Uppsala and Värmdö. More detailed information (in Swedish) can be found in *Handbok för tilllämpning av VeVa* (Erlandsson, et al., 2010). The tool is also available online[4].

The tool has been used to compare urine diversion systems, where the rest of the wastewater is treated in an infiltration bed[5], with two other on-site wastewater systems: infiltration bed with phosphorus trap and mini-wastewater treatment plant with phosphorus trap. Mini-wastewater treatment plants with phosphorus traps are commonly chosen instead of urine diversion because they also fulfil the demands that both municipalities have on new on-site wastewater systems (Norrköping municipality, 2013a; Linköping Municipality, 2011). Infiltration beds with phosphorus traps are an example of a system that does not meet the requirements (Linköping Municipality, 2011). These are common systems where the discharge requirements are not as high.

In VeVa, parameters from previous investigations were already available. These figures are based on other projects or are assumptions based on literature. Calculations for urine diversion specifically are mostly based on Håkansson (2011). When possible, the parameters in VeVa have been changed to reflect the systems of the investigated cities. Since more figures could be found for Norrköping, it has been chosen to be the main focus of the cost-benefit analysis. The systems in Norrköping and Linköping are however considered to be relatively similar. For this reason, figures from Linköping have been used to complement the calculations. In some cases new assumptions have been made, either based on literature or on similar assumptions, see Appendix 3.

Some of the calculations are based on prices that are a couple of years old. However, many of the figures are based on assumptions given in a quite wide range, for example the investment cost of urine separating systems that is 30 000-35 000 SEK, according to Andersson (2008). The cost in this calculation is set to the mean value of this, 32 500 SEK, but it is also possible that the actual costs of the systems are on the upper or lower end of this interval. Inflation and deflation is expected to be negligible compared to the uncertainty with these kinds of assumptions.

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[4] Available at http://www.urbanwater.se/en/services-working-methods-and-tools/sustainability-assessment-transition-areas

[5] In an infiltration bed the wastewater in landscaped soil layers. The effluent is released to surface layer and some may also be released to the groundwater (Naturvårdsverket, 2008).

It should also be noted that these calculations contain inherent uncertainties since information about many parameters, for example transportation distances, were missing. The calculations should not be considered to produce exact numbers but rather be used to compare urine diversion with other systems. Since many assumptions concern all investigated systems, the relation between the systems is expected to be fairly accurate.

When all costs and benefits have been determined, the present value is calculated. Investment costs are assumed to be done at present, but all costs and benefits occurring in the future are calculated by multiplication with the present worth factor pwf, see formula (1). The discount rate *i* have been set to 5 %. The life length (n) of the systems are set to be that of the component with the shortest life length.

The net benefit cost ratio is then calculated according to formula (2) where C is the costs in SEK and B is the Benefits in SEK.

$$pwf = \frac{(1+i)^n - 1}{i*(1+i)^n} \qquad (1)$$

$$\frac{B-C}{C} \qquad (2),$$

4 Case Studies

The case study areas are the municipalities Linköping and Norrköping, both located in the county Östergötland in southeastern part of Sweden, see Figure 4. The municipality of Linköping has about 150 000 inhabitants and Norrköping 134 000 inhabitants (SCB, 2014). Linköping and Norrköping are the two biggest municipalities in Östergötland and make up almost 65 % of the county's population (SCB, 2014).

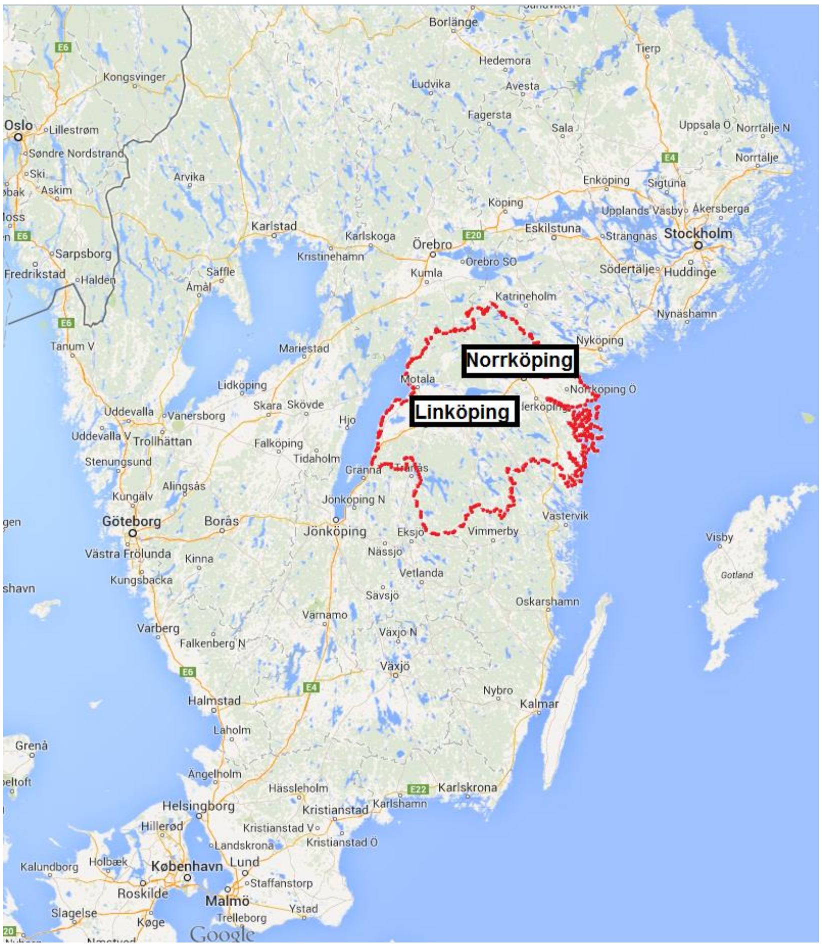

Figure 4 Map showing the location of Norrköping and Linköping. The county of Östergötland marked in red. Modified from Google Earth (2014)

The municipalities in Östergötland invested in wastewater treatment relatively early. Already in 1974, 72% of the wastewater from localities with more than 200 inhabitants was treated chemically, which can be compared to the average in Sweden which was 49 % (Drangert & Löwgren, 2005). By 1982, 99.5 % of all inhabitants living in urban areas were connected to wastewater treatment plants with biological and chemical treatment (Drangert & Löwgren, 2005).

Norrköping and Linköping were both affected by the merging of municipalities in the 1970s, which meant that more settlement areas became a part of the municipalities (Drangert & Löwgren, 2005). The municipalities had to decide how they wanted to manage the drinking- and wastewater systems in the entire municipality. Despite the geographical proximity and similar population size the wastewater systems in Linköping and Norrköping developed quite differently. In Linköping, the municipal technical company Tekniska Verken managed the production of drinking water and treatment of wastewater and played an important part in the development of these systems. The system was centralized with only one node in the city of Linköping. Linköping connected areas to the main system at a fast pace and got government grants to help finance this work. In Norrköping, the municipal administration managed the water systems and a less centralized system with three main nodes was chosen (Drangert & Löwgren, 2005).

Just like other municipalities a number of properties are not connected to municipal wastewater treatment plants. Statistics concerning this can be found in Table 5.

Table 5 Statistics for properties not connected to municipal wastewater systems in Linköping and Norrköping (Ek, et al., 2011). Figures marked with * are not included in the analysis.

	Permanent housing with WC	Holiday housing with WC	Permanent housing without WC*	Holiday housing without WC*	Total number of properties not connected to municipal WWTP
Linköping	4006	798	264	1459	6527
Norrköping	3214	720	745	2516	7195

According to Andersson (2008), 500-600 properties in Norrköping have some kind of urine diverting dry toilet, from which the property-owners almost exclusively take care of the urine themselves. As mentioned in Chapter 1.1 these are not included in this analysis.

4.1 Linköping

The municipality has worked with a system for urine diversion since around 2000 (Linköping Municipality, 2014). The municipality demands that all new on-site wastewater systems enable nutrient recycling. In the beginning, urine diversion was the only allowed water-borne technology for this, but in recent years other solutions are possible. The municipal wastewater treatment plant has been REVAQ-certified, which means that solutions where a majority of the nutrients end up in the sludge, such as mini-wastewater treatment plants, also are seen as enabling nutrient recycling (Linköping Municipality, 2011).

The municipal technical company, Tekniska Verken, is responsible for the collection of the urine and making sure that it is spread on agricultural land (Tekniska Verken, 2013). The users do not pay anything extra for this service. The collection is done by the company Renall (who did not participate in interviews) and Biototal stores the urine and makes sure it is spread.

Urine diversion has also been used by other stakeholders than the municipality in Linköping. Before the municipality started to develop a system for reuse of urine, the housing company Stångåstaden installed urine diverting toilets in connection to a renovation of an apartment building in 1996. The aim was to examine if this system was possible to maintain in a regular house with regular tenants, and the building was not marketed as an eco-house (Stångåstaden, 2014). The housing company was responsible for the entire chain and the municipality was not involved. Although there were farmers interested in using the urine, the project had problems with the transportation of the urine early on. The farmers handled the transportation in the beginning, but because of restrictions concerning these transports it became too complicated for them. Tekniska Verken offered to transport the urine to the wastewater treatment plant for treatment, but the cost they required to deliver it to the farmers was too high for the housing company. This meant that after a few years the urine was lead directly to the treatment plant. After another few years the toilets were exchanged to traditional ones.

A farmer in a village outside of Linköping started using human urine already in 1994 and other houses in the village were connected to this system. Today 18 houses in the village use urine diverting toilets (Johansson, 2014). Every house has two tanks that are alternately filled with urine, which means that the required storage can be achieved at the individual houses and the urine is ready to be used when it is collected from the tanks. The farmer produces ecological food. He/she has been able to get an exception from KRAV to be allowed to use human urine. However, since 2010 the rules from KRAV has become stricter and therefore the exception is no longer possible. Instead another farmer in the village uses the urine as fertilizers on his/her crops. The village has formed an association for closing loops in the village. This could mean that the involved house owners are more motivated than "regular" ones, in a similar way as in an eco-village. For this reason this system is not a part of the case study.

4.2 Norrköping

In Norrköping, the municipality has worked with urine diversion since about 2003 (Norrköping Municipality, 2013b). The municipality had high demands on the treatment of on-site wastewater systems. However, the technology normally used to reach such demands, which is to use a drain field, was not possible in most of the municipality due to geological conditions (Norrköping Municipality, 2014). This meant that it was hard to get authorization to install a new water-closet with on-site wastewater treatment. Urine diversion made it possible to achieve these demands.

Today, the municipality demands nutrient recycling for all new on-site wastewater systems, which means that at least 50 % of the phosphorus and nitrogen should be recycled (Norrköping municipality, 2013a). This can be achieved by urine separation but mini-wastewater treatment plant with phosphorus trap is another option. The municipal guidelines for on-site wastewater systems state that most nutrient recycling systems also fulfil *high protection-level* as stated in the guidelines from the Swedish Environmental Protection Agency (see Chapter 2.1.2) (Norrköping Municipality, 2011).

The technical office is responsible for the collection of the urine and to make sure that it is spread (Norrköping Municipality, 2013b). SITA is the sub-contractor for the collection of the urine and they have in turn hired a trucking company to do the actual emptying (SITA, 2014). SITA also handles the contact to the farmer who stores and spreads the urine. The users of this system do not pay anything for the collection of the urine (maximum twice a year) and they also get a discount of about 30 % on the emptying of their septic tank (Norrköping Municipality, 2013c).

In Norrköping there was also an apartment building that had tried urine diversion before the municipal system was developed. It was called Ekoporten and urine diverting toilets were installed in connection to a renovation in 1995-1996 (Norberg, 2002). Apart from the urine being separated, the feces and greywater were also treated separately. The feces were separated from the flush water and composted with organic waste from the households and the greywater together with the flush water was treated on-site.

Ekoporten had problems with finding a way to reuse the urine and the urine was driven to the wastewater treatment plant for several years (Andersson, 2008). The housing area, including Ekoporten, was sold in 2004 and the new owners chose to remove the urine diverting system in 2006 (Zetterdahl, 2013).

Norrköping also considered implementing urine diversion in the city itself. A politician made a proposition to develop guidelines and an action plan for urine diversion in urban areas (Arvidsson & Andersson, 2009). However, in 2009 it was decided that this work should not continue. Since the sewage sludge from the wastewater treatment plant had been REVAQ-certified the politicians thought that there was already the possibility for nutrient recycling.

4.3 Analysis

The analysis was performed as described in Chapter 3. As described there, values and barriers have been identified. In this chapter tables with simplified presentation of the results are presented and evaluated. The categorization of the different values and barriers was sometimes obvious, but in other cases more difficult. Therefore some explanations are presented.

The results for the analysis of the actual values are also presented. The experienced and actual values will be further discussed and compared in the Discussion.

4.3.1 Analysis of values and barriers

These results are based on the performed interviews, as well as two additional documents; a report about the pilot project Ekoporten in Norrköping (Norberg, 2002) and a household questionnaire in Norrköping (Carlsson, 2011).

4.3.1.1 Linköping

Table 6 presents simplified results of the analysis. Six household users were interviewed who are counted as one actor in the table.

Table 6 Simplified results of values and barriers in Linköping. Number in parenthesis corresponds to the number of actors that mentioned the value/barrier. The total number of actors are four (4).

	Values	Barriers
Resource Mobilization	*Economic:* Free emptying of urine tank (2)	*Organizational:* Additional cost for the municipality (1) *User-related:* Large tanks (1) More pipes (1) Expensive (3)
Legitimation	*Economic:* Urine becomes a product (1) The system works well (1) Municipal demand (1) *Ideological:* Environmental protection (1) Nutrient recycling (2) Support in laws and guidelines (1) Political support (1)	*Organizational:* Inequality to other municipalities (1) *Technical:* Much flush water (1) Stoppages (2) Difficult for children (2) Smells urine (1) Leakages (1) Other cleaning routines (1)
Stakeholder Arena	*Economic:* Good collaboration (3)	*Organizational:* Coordination difficulties (1) Planning difficulties (1) User-communication problems (1)
Breadth and Depth of Support Network	*Ideological:* Good if nutrients are recycled(1) Positive to the system (1)	*User-related:* No alternatives (1)
Access to Knowledge	X	*Technical:* Uncertainties concerning for example medical residues (1) *Organizational*: Full picture is missing (1)
Other		*Organizational:* Unable to deliver required number of toilets(1) Locked into old system(1) *User-related:* Few producers means high prices(1)

In general, Legitimation is the criteria where most values and barriers are found. The barriers mainly concern technical problems with the toilets, ranging from higher demands on frequent cleaning to problems with leakages, stoppages and odors. Difficulties for children to use the toilet were also pointed out. A subcontractor also found it to be a problem that the urine solution contained too much flush water, making the nutrients quite diluted. One household user also questioned the fact that other municipalities nearby do not have the same strict demands on individual systems.

The most common value in Legitimation is the ideological value that urine diversion is beneficial for the environment. These are more or less articulated, some only state that it is "*good to separate at the source*", but the two main notions are that urine diversion allows for nutrient recycling and that it decreases the amount of nutrients entering the environment. Other values include the economic value that urine is a good fertilizer and that the system is well-functioning. A well-functioning wastewater system is expected to increase the value of the property and is therefore considered an economic value. For all interviewed household users, the reason given for installing urine diverting toilets has been to meet municipal requirements for new separate sewers. This may not seem like a value, but given that they would otherwise not have been able to install a WC at all, it is considered one. For the same reason as above it is considered an economic value. Ideological values also include that there has been political support for the system. That there is an alignment with current legislation is considered an ideological value since the municipalities have the opportunity to interpret the law differently and could have chosen an ”easier” way.

The criterion with the second most barriers is Resource Mobilization. Most of the barriers here are user-related, since they are related to increased costs for the users. It is noted that urine diversion costs more than "normal" systems for the municipality in regards to emptying and storing. An economic value in this category is the fact that the emptying of the urine tank is free of charge for the users.

In Stakeholder Arena some minor organizational problems are found, such as that it was difficult for the sub-contractor to know how much storage-capacity was needed from one year to another. Another problem was that the deadline that had been set up by Biototal for emptying of the urine was not held, which meant that the possible time-span for spreading was delayed. These problems are however said to be solved today. Under this criterion, a statement by a user is found, saying "*There is no farmer in Linköping who wants to receive the urine*". In fact, there is a farmer that receives the urine, which shows that there is a lack of communication to the users. The economic value is found that all actors (excluding the household users) think the collaboration works well.

The main barrier concerning Access to Knowledge is that individual actors do not have enough information about the system to have a complete picture. This is not necessarily considered a problem for the actors themselves but since it is mentioned as an important factor in Storbjörk & Söderberg (2003) it is noted as a potential barrier. If it really is a barrier to this system will be discussed in the Discussion. There are also uncertainties concerning what happens to medical residues in the urine.

In Breadth and Depth of Support Network ideological values are found. Half of the participating household users are positive to the system, but all under the premise that there is final use of the urine. The municipal management is also positive to the system. Under barriers in this category it can be seen that many household users objected to the system in the beginning. They felt that it was forced upon them since during a time there was no other choice when installing a water closet.

There are also some barriers that do not fit any of the categories. This includes the problem that the toilet-company could only deliver one toilet to a household that needed two (because of a deficit in the market) as well as, that a household user thinks that the high prices for urine diverting toilets is related to the fact that there are very few producers. Here a statement of the employee at the environmental office is also placed:

”I know there was an idea to install some kind of system like this in a new housing area, Djurgården (...). So there are thoughts and ideas but unfortunately we are a little locked to these [conventional] systems in the city. When it comes to Tekniska Verken and the big-scale systems, Linköpings Municipality is unfortunately a little bit locked, and I can find that a little bit sad.”

4.3.1.2 Norrköping

Table 7 presents simplified results from Norrköping. Employees at the environmental office and the technical office were interviewed at the same time and are therefore counted as one actor.

In Norrköping, the most values and barriers are found under Legitimation. The values are mostly about the environmental benefits. Here both nutrient recycling, as well as reduction of the amount of nutrients released to the recipients are mentioned. It is also mentioned that it is important to take proper care of individual systems since they contribute significantly to pollution. The fact that there is an interest from farmers to receive the urine is seen as a value. The farmer is a part of the system because of the compensation, which is an economic value. The household users, whose answers have been taken from a household-questionnaire, have not specifically mentioned any environmental effects. However, a significant percentage (about 20 %) state that they can use the urine as fertilizer in their own garden as something positive, which could be seen as an ideological value. Another value that is mentioned is that the system is practical, but it is hard to assign this to either economic or ideological value since it is not clear in what way they find it practical. Other values that are mentioned are related to political support and alignment with current legislation. Urine diversion enabled the municipality to allow installation of new toilets without having to lower their demands on the treatment, which is seen as an ideological value.

Table 7 Simplified results of values and barriers in Norrköping. Number in parenthesis corresponds to the number of actors that mentioned the value/barrier. The total number of actors are four (4)

	Values	Barriers
Resource Mobilization	*Economic:* Economically advantageous for users (3) Decreased water-use (1)	*Organizational:* Additional cost for municipality(1) High investment cost but low maintenance cost, hard to communicate to users (1) *User-related:* Expensive installation cost (3) *Technical:* Small amounts of urine (2) Difficult in existing construction(1)
Legitimation	*Economic:* Interest from farmers (1) Economical gain for farmer(1) Possible to build new WC that fulfilled high demands(1) *Ideological:* Nutrient recycling (2) Environmental protection (2) Fertilizer for the garden (1) Easier to take care of the nutrients in a separating system (1) Political support (2) *Other:* Practical (1)	*Organizational* Demand on nutrient recycling only in guidelines and not in laws (2) *User-related:* Empty tanks (1) Instruct guests (2) Inconvenient for the user (1) Suspected misuse (2) *Technical:* Noticed stoppages (1) Noticed negative about cleaning (3) Noticed smell (1) Incorrect separation by children(2) More pipes (2) Few tanks but long distances (1) Possible working environment problem (1)
Stakeholder Arena	*Economic:* Good collaboration (4)	*Organizational:* Coordination difficulties (2)
Breadth and Depth of Support Network	*Ideological:* Engaged in nutrient recycling solutions (1) Works well from a treatment + environmental perspective (1) The basic idea is good (1) Majority of users are pleased (1)	*Organizational:* Few new installations (2) No-one is driving it anymore (1) Farmer indifferent to the system (personal observation)o *Technical:* Uncertain if the small quantity of urine motivates the transports (1)
Access to Knowledge	X	*Technical:* Uncertainties about medical residues (1)
Others	*Economic:* Possible value: bigger value if larger quantities of urine(1) *Other:* Better working environment(1)	*Organizational:* Extensive commercial from mini-WWTP producers (1) *Technical:* Hard to obtain toilets(1) Dip in the market 2008-2009 (1)

The barriers under Legitimation are mostly concerned with the technical system. Different technical problems are mentioned, for example stoppages, that it is harder to clean the toilets, bad odors and difficulties for children to use the toilet in a proper way. It is also mentioned that there is a risk in having more pipes in the house since more things can go wrong. A sub-contractor mentioned that many urine tanks are empty or almost empty when they collect the urine. This is seen as a user-related problem since it indicates that the users have installed a normal toilet instead of a urine diverting toilet. Other user-related problems that are mentioned are that it is a complicated system for the user in comparison to systems that allows a regular WC. It is also seen as an inconvenience that guests have to be informed about how to use the toilet. Furthermore, it is suspected that the users might not follow the cleaning advices given at the installation, which could cause or worsen the technical problems. An organizational problem is that the demand to use nutrient-recycling systems is only stated in guidelines (see Chapter 2.2.2.2) and not in any binding laws.

Values under Breadth and Depth of Supporting Network are mostly ideological. Municipal employees, former as well as current, find it to be a good system for the environment. The farmer also thinks that it is a good system. 51 % of the users are pleased with the system, though it is not clear for which reason. When it comes to barriers however, the municipal employees point out that very few choose this system today. A former municipal employee expresses disappointment that this is the case and that no one is pressing the issue anymore. Another possible organizational barrier is that the farmer does not seem to be very engaged in the system (personal observation). For example, she/he said *"Honestly, I don't care if I receive it or not. I mean, I receive a small amount of money for accepting it. But if they wouldn't want to deliver it here anymore or if I wouldn't get paid, then I could might as well skip it. For me it's a non-question really"*. Another organizational problem is that a sub-contractor questions if the small volumes of urine motivate the extra transportation costs.

Under Access to Knowledge the barrier is found that one stakeholder is uncertain of what happens with medical residues when they are spread on agricultural land. This is a technical barrier because the information does not exist (within the organization or anywhere else) and thus it is an uncertainty related to the technology itself.

Under Resource Mobilization two values are found. One is that the system is economically advantageous for household users, since with urine diversion they get free urine collection and a discount on the regular septic tank emptying. In addition, 26% of the users also noted that their water use decreased with the system. Under barriers the organizational barrier is found that urine diversion means an additional cost for the municipality, because of the free collection and discount mentioned above. Another organizational barrier is that it is hard to communicate to the users that urine diversion means very low maintenance cost, since the investment cost is much higher compared to other systems and this is more directly apparent for the users. A user-related barrier is that the installation costs are high. A technical barrier is that the amounts of urine collected are relatively small, which means that the economic gain for the farmer is insignificant. Another technical barrier is that it is hard to build the system in already existing houses since two pipe systems are needed.

In Stakeholder Arena, the value is found that all actors thought the collaboration worked well. However, two of them mentioned that there had been some mistakes in the past when permits were given for where to install the urine tank. The environmental office authorized the permits but did not always remember to make sure that the tanks were easily accessible for the emptying trucks. This organizational problem is however said to be solved today.

Both values and barriers have been found that do not match any of the categories. One value is that the emptying of urine diversion tanks gives a better working environment than the emptying of regular septic tanks. A possible economic value is that the urine would have had a higher value to the farmer if the quantities had been larger. The barriers are that it is believed that users choose urine diverting systems to a very low extent partly because of the extensive commercial campaigns done by producers of mini-wastewater treatment plants. Another barrier is that there are few urine-diverting toilets available on the market. This is linked to a depression in the market around 2008 when it was very hard to get a hold of a urine diverting toilet, and at the same time the market for mini-wastewater treatment plants exploded. The market for urine-diverting toilets has not recovered since.

4.3.1.3 Pilot projects

Table 8 presents simplified results from the pilot projects. Only one actor was interviewed and one report used, which means that if the number of actors are two the barrier/value existed in both projects.

Table 8 Simplified results of values and barriers from the pilot projects. Number in parenthesis corresponds to the number of actors that mentioned the value/barrier. The total number of actors are two (2).

	Values	Barriers
Resource Mobilization		*Organizational:* Expensive (2)
Legitimation	*Ideological:* Experiment for urban environments (2) Increased experienced was a positive effect (1) Farmers wanted to use urine (1) Political support (1) No support in law but in public debate (1) Public discussion (1)	*Organizational:* Laws and restrictions (1) Big storage-demand (1) Problems with transportation (1) Problems with spreading (1) Human urine not allowed on KRAV-cropland (1) *User-related:* Decreased motivation due to no recycling (1) Other cleaning routines (2) Different use (1) *Technical:* Much flush water (1) Crystallization of the urine (1) Smell problems (1) Incorrect separation (1) *Other:* No public discussion (1)
Stakeholder Arena		*Organizational:* One stakeholder responsible for entire chain (1) The municipal technical company demanded a high fee for transporting the urine to the farmers, which was not possible for economic reasons (1) Communication problems with users (1)
Breadth and Depth of Support Network	*Economic:* Farmer was a driving force, profile as eco-farmer (1) *Ideological:* Nutrient recycling (1) Positive aspects relating to responsibility (1)	*Organizational:* Decreased motivation since urine was not used (2)
Access to Knowledge	X	
Others		*Organizational:* Transport problems easier if big scale(1)

For this analysis, the interview with the project manager from Stångåstaden in Linköping has been used as well as a report about Ekoporten (Norberg, 2002) project in Norrköping. The problem with the latter is that not only the urine was diverted but there were other unconventional solutions, such as composting of the feces and treatment of greywater and flushing water in a sand filtration bed[6]. For the analysis, it has been sought to only include aspects directly related to urine diversion to make it comparable with the other system. For the value-analysis only the values that originate from interviews performed by Norberg (2002) as well as values derived from the aim-formulation of the project can be used. Other values, such as calculations of decreased water-use and increased nutrient recycle, do not originate from actors of the system and are therefore not possible to use according to the definition in Chapter 3.2.1.

As in the other analyses most of the values and barriers are related to Legitimation. All values in this category are ideological. The ideological value is found that the project Stångåstaden[7] was started as a result of the on-going public debate about peak phosphorous and eutrophication. Since both projects were pilot projects a goal was to increase the knowledge and experience of such systems, which is reflected in the values. Both Ekoporten and Stångåstaden saw a value in examining if this system was suitable for urban environments. Stångåsstaden also saw a value in not making the house an ecological house, but to see if this kind of systems is possible in "normal" houses. Even though the system is no longer in use, the project leader of Stångåstaden thought it was a value that the knowledge about such systems had increased and that farmers were interested in using the urine. There was political support for Stångåstaden and even though there was no legal incentive at the time, there was a general opinion in public debate that supported the system.

The organizational barriers under Legitimation show that Stångåstaden had many problems with regulations and the project manager believes that regulations were the main reason that the system failed. He mentions problems like storage demand leading to the need for many tanks and that the farmer's tanker trucks that had been used to transport farm slurry[8] had to be cleaned to be used for human urine, which made it so complicated that no one wanted to do it in the end. Ekoporten also had organizational problems, but they were more about the spreading of the urine (it was not always used on cropland). The report identified the prohibition of human urine on KRAV[9]-cropland as a problem, since ecological farming is often done at a small-scale and must only use organic fertilizers, which makes human urine suitable since the volumes are still small.

There were also some user-related barriers in this category. In both projects it was noted that the toilets had to be cleaned differently from a regular toilet. In the report from Ekoporten the problem was noted that men have to sit down while urinating for the separation to work properly and that some stand up anyway. This led to a technical problem; since not all urine was separated some was led together with the

[6] This treatment is conventional for individual sewers but not for residential buildings

[7] Stångåstaden is actually the name of the housing company that built urine diversion in one of their houses in Linköping. To make it simple, the name will however be used to refer to that specific project.

[8] This includes animal urine, feces and sometimes added water

[9] KRAV is the Swedish certification system for ecological farming, which incorporates EU legislation.

flush water to the sand filtration bed, which was not dimensioned for the extra nitrogen loading, which led to higher releases of nitrogen to the recipient. Other technical problems that were noted were that the toilets smelled, that there was a crystallization of the urine which required regular clearance of the pipes and that there was a lot of flush water in the urine solution.

A barrier in Legitimation today is that there is not much discussion about this anymore, especially not peak phosphorous. This barrier could not be classified since it relates to factors outside the system. This will be further evaluated in the discussion.

In Resource Mobilization, both projects noted the organizational barrier that urine diversion is more expensive than regular systems.

Both projects also had some organizational problems related to the criteria Stakeholder Arena. One problem was that Stångåstaden had to manage the entire chain. When they could not find any farmers that wanted to collect the urine, the technical municipal company drove it to the wastewater treatment plant. To drive it to the farmers, who still were interesting in receiving the urine but could not manage the transports, they demanded a too high price for Stångåstaden. At Ekoporten there were some problems with communication to the users: the users had heard that the urine was transported to the wastewater treatment plant, and one of the interviewees had therefore stopped following the recommendations regarding acceptable cleaning chemicals. It was true that the urine had been transported to the wastewater treatment plant the previous year, but for the current year a farmer was contracted. The use of non-recommended cleaning chemicals could lead to that the urine became unusable. No values were found in this category.

Under Breadth and Depth of Support Network the ideological value is found that the project manager for Stångåstaden thought the project was good because he/she found it positive to use the urine instead of mineral fertilizers. A farmer in Linköping was also very engaged in the beginning, which the project leader of Stångåstaden believed was because he saw a way to profile himself/herself as an ecological farmer, which makes it an economic value. Two of three interviewed users in the Ekoporten-report also mentioned ideological values relating to a changed attitude among the tenants towards the environment and their own responsibility towards it. However, as a user-related barrier in this category it can be found that the third interviewee does not see any societal advantages since the urine (and compost) was not used in agriculture. This barrier also existed for Stångåstaden, where the project manager lost some motivation when the urine was not used.

One barrier that could not be divided into any of the categories is the organizational barrier that the project manager of Stångåstaden believes that a bigger system would have eased the transports, which can be seen as a barrier for smaller systems.

4.3.1.4 Political input

Table 9 presents simplified results from the pilot projects. The interviewed actors were municipal politicians and representatives from LRF.

Table 9 Simplified results of values and barriers from political input. Number in parenthesis corresponds to the number of actors that mentioned the value/barrier. The total number of actors is four (4).

	Values	Barriers
Resource Mobilization	*Economic:* Urine equated to farm slurry (1) Increase nitrogen concentration in farm slurry (1) Good fertilizer (1)	*Organizational:* Farmers probably receives small amounts (1) Expensive (2)
Legitimation	*Ideological:* Advantages compared to sewage sludge (3) Some political support for implementation in urban areas (1) Nutrient recycling (3) *Economic:* Dryer & lighter feces-fraction (1)	*Organizational:* Not allowed on KRAV-cropland (1) Restrictions (no-mix with farm slurry) (1) Recommendations for new construction prevents unconventional solutions (1) Implementation would lead to unequal competition between municipalities (1) Need to be considered early (1) *Technical:* Medical residues (1) Poor quality of the urine (1) Toilets not suitable for children (1)
Stakeholder Arena		
Breadth and Depth of Support Network	*Ideological:* All actors positive to the system (4)	
Access to Knowledge	X	
Others		*Other:* Difficult to get a hold on toilets (1) More suitable for small-scale (1)

Most values in Legitimation are ideological. Urine is compared to sewage sludge by three actors and they see values in urine compared to the sludge: it contains less unwanted substances, the nutrients are less diluted and it is believed to have higher acceptance among farmers. Other ideological values are the recycling of nutrients and that there was partly political support for implementing urine diversion also in the city of Norrköping. The economic value is found that urine diversion gives a drier and lighter feces-fraction for dry closets.

Organizational barriers in Legitimation include that KRAV-certification does not allow the use of human urine and that the urine from the staff room of a farm is not allowed to be mixed with animal urine. A representative from LRF believes that the fact that new houses in the country-side are recommended to be built close to existing houses is a barrier for urine diversion, since this is done so that they can easily be connected to the municipal water- and wastewater system. He/she believes that urine diversion is more suitable for smaller systems of maybe ten houses. Another organizational barrier is that there are different things that need to be considered already in the building stages of a house, for example that the house needs extra pipes and sufficient storage capacity. Yet another problem is that it is far between the urine tanks in the countryside, which mean that the transport distances are greater. A barrier for implementing the systems in the cities is that it not considered commercially interesting and if it was a municipal requirement it would negatively affect the house owner, which would in turn lead to uneven competition between municipalities. Technical problems that are mentioned are that the toilets are difficult to use for children, that the urine fraction would preferably be more concentrated than it is and that it is unknown what happens to the medical residues from the urine.

Under Resource Mobilization, the economic value of the urine for the farmers is found. According to a LRF-representative human urine is comparable with farm slurry and the gain is therefore the cost of animal urine minus the cost for spreading the urine. Other economic values include that urine is a good fertilizer with a higher nutrient content than farm slurry. This means that it could possibly be used to increase the nitrogen concentration in the slurry. All these values are found in Resource Mobilization because they could possibly increase the incomes/decrease the outcomes for farmers.

However, an organizational barrier is that there is probably no farmer that receives so much human urine that they could decrease their purchase of mineral fertilizers. Another organizational barrier pointed out by LRF is that it is too expensive to build urine diversion, even though the representative believes that the installation of urine diversion should be a manageable additional cost at a societal level.

There are no barriers in the category Access to Knowledge and neither values nor barriers can be found in Stakeholder Arena. This is expected since these actors are not involved in the systems themselves.

Under Breadth and Depth of Support Network the ideological values can be found that all actors think urine diversion is good. However, they have some premises; that agriculture does not end up being a dumping ground for society and that urine diversion should be taken into account early in a planning process.

There are some barriers that do not fit any of the categories; the organizational barriers that it was difficult to obtain urine diverting toilets and the belief of the LRF-representative that there is a large reliance on big scale systems when urine diverting systems might fit better on a small scale.

4.3.2 Analysis of actual values

The analysis of the actual values of the system is an extension of the results from the analysis in Chapter 4.3.1, focusing on translating the most important values and barriers to monetary benefits and costs. In order to do this, most commonly mentioned benefits (values) and costs (barriers) have been listed in Table 10. The values and barriers in Chapter 4.3.1 are sometimes closely linked and are here summarized in more general terms. For example, values such as *noticed stoppages* and *noticed smell* are all *technical problems related to the toilets*. Since the analysis concerns the current systems in Norrköping and Linköping, only benefits and costs that could apply to these systems are taken from political input and none are taken from the pilot projects. Unlike the analysis in Chapter 4.3.1, this analysis focuses on the value of the system as a whole and not values specific to individual actors. This means that for example the value *economically advantageous for users* is not included since the reduced costs for household users need to be covered by someone else.

Table 10 Most commonly mentioned benefits and costs of the systems in Linköping and Norrköping. Costs and benefits used in the cost-benefit analysis in bold.

Benefits	Costs
Nutrient recycling	**Investment costs**
Environmental protection	**Maintenance costs**
Political support	Increased transports
Practical	Technical problems with the toilets
Good collaboration	Dissatisfaction with the system
Actors are positive to the system	Change of habits by users
Good working environment	Collaboration difficulties
Advantages compared to sludge from WWTP	Lack of enthusiasm
Possible to install WC	Uncertainties concerning medical residues
Legal support	Market-related problems
	Unequal to other municipalities
	Too much flush water

Many of these parameters are however very hard to assign monetary values to. For example, a lot of them reflect qualitative factors which are hard to value in an objective way. Efforts have however been made to develop standard monetary values for environmental changes (e.g. Kinell et al, 2009). Therefore, the benefits *nutrient recycling* and *environmental protection* are evaluated. The actual monetary costs are also included, which is the *investment costs* and *maintenance costs* of the systems.

Increased transports would also be possible to put a value to, but since not enough data is available it has not been possible to do it for this analysis. Norrköping Municipality has tried to decrease the impact from this factor by only using trucks that use renewable fuels to do the collection.

When speaking of *Environmental protection*, the interviewees meant the reduced release of phosphorus and nitrogen to the environment. Kinell et al (2009) has suggested intervals and standard values for decreased releases of nitrogen and phosphorus to coastal waters. This is suitable for Norrköping since it is located near the coast.

The value for decreased release of nitrogen to coastal waters is 4-70 SEK per kilo and the suggested standard value is 31 SEK (Kinell, et al., 2009). Correspondingly, decreased releases of phosphorus are worth 127-2140 SEK per kilo, where the suggested standard value is 1023 SEK (Kinell, et al., 2009).

These standard values state the value of *decreased* releases, which means that they have to be compared to something. Most systems are expected to have been built where no water closet was installed before. However, greywater may have been used in the houses, in which case a simple septic tank is a probable treatment used. For this reason, a system of only a septic tank is chosen for the comparison of phosphorus and nitrogen releases to the recipient. It is not used any further in the analysis.

The benefit of *nutrient recycling* can be evaluated by looking at the price of mineral fertilizers for the same amount of nitrogen and phosphorus that can be found in the urine. According to Jönsson et al (2013) the price is 16.42 SEK per kilo phosphorus and 11.11 SEK per kilo nitrogen.

Other important assumptions can be found in Appendix 3. For all other parameters, values from previous evaluations in VeVa have been used.

4.3.2.1 Results

A cost-benefit analysis was performed in VeVa. Before the resulting net benefit cost ratio is presented the costs and benefits are studied. As described above, the cost-benefit analysis consists of four different parameters: *investment costs, maintenance costs, nutrient recycling* and *environmental protection*.

The environmental benefits are based on parameters regarding the reuse and removal of nitrogen and phosphorus. Figure 5 and Figure 6 show the releases of nitrogen and phosphorus to the recipient by the different systems. The reduction of these releases compared to treatment using only a septic tank was used to approximate the benefit *environmental protection.*

Figure 5 shows the releases of nitrogen. High protection level according to the guidelines from the Swedish Environmental Protection Agency is marked in the figure, which is a reduction of 50 % of the nitrogen (NFS 2006:7). As can be seen this requirement is met by the systems with infiltration bed and a phosphorus trap as well as the urine diversion system, where the urine diverting system reduces nitrogen-releases the most. The mini-wastewater treatment plant does not fulfill the requirement of high protection level.

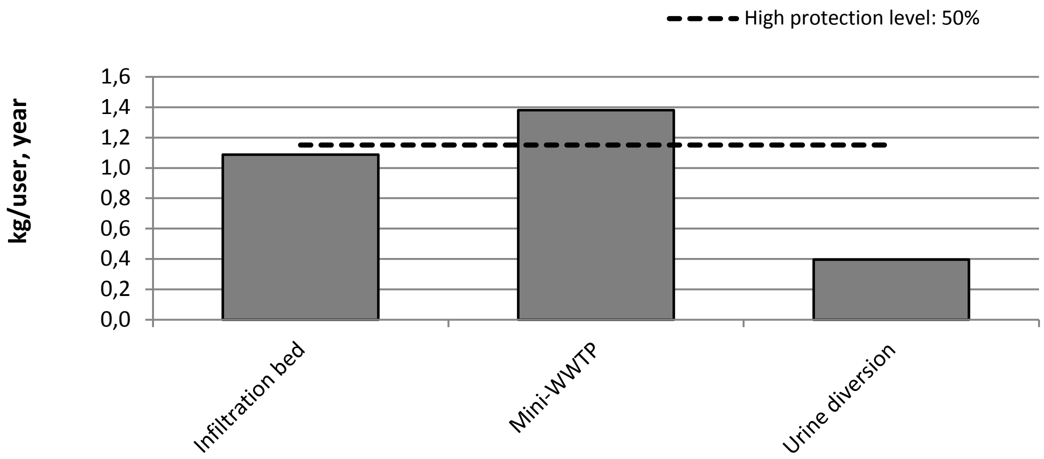

Figure 5 Releases of nitrogen to recipient

Figure 6 shows the releases of phosphorus to the recipients by the different systems. The protection levels according to the national guidelines (NFS 2006:7) are shown here too (70 % reduction of phosphorus for normal protection level and 90 % reduction for high protection level). In this case the infiltration bed and the mini-wastewater treatment plant meet both requirements but urine diversion only fulfils normal protection level. This is probably because some phosphorus is present in the feces, which in urine diverting systems are treated in a normal infiltration bed without any extra treatment for phosphorus.

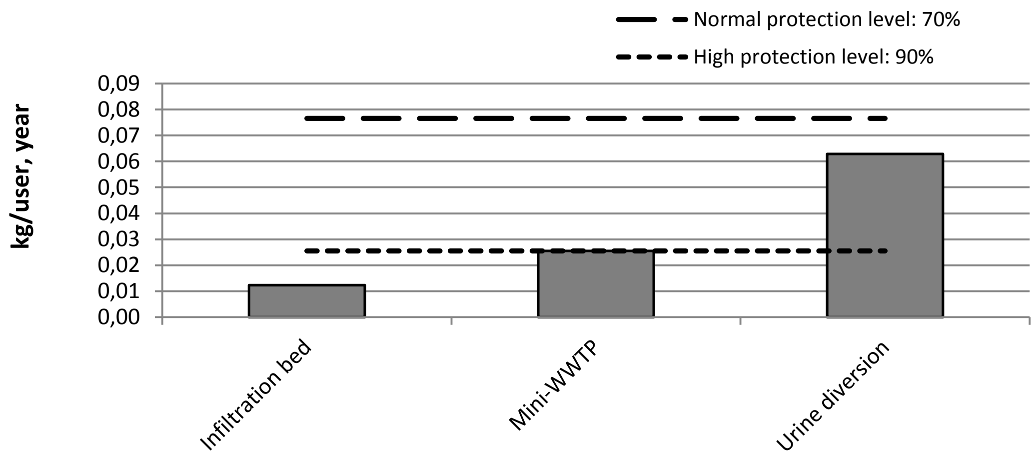

Figure 6 Releases of phosphorus to recipient

Figure 7 shows how much nitrogen and phosphorus is recycled from the different systems, which has been used to calculate the benefit of *nutrient recycling*. Mini-wastewater treatment plants and infiltration beds hardly recycle any plant-available nitrogen at all, whereas urine diversion achieves significantly more. Urine diversion also recycles the most plant-available phosphorus but the differences between the systems are not as big as for nitrogen.

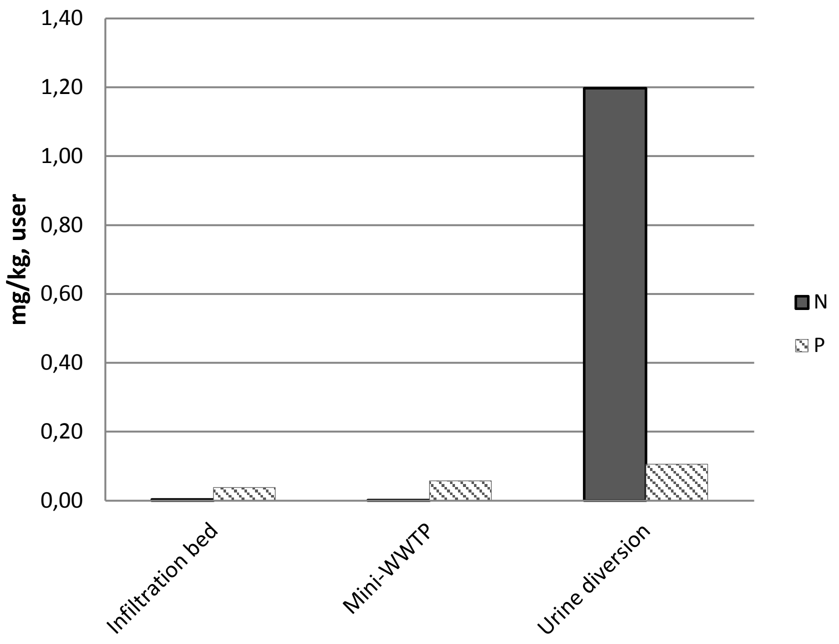

Figure 7 Nutrients recycled from the systems

Figure 8 shows the benefits of the different systems. As can be seen, urine diversion gives the highest *nutrient recycling*. However, mini-wastewater treatment plants give a higher value for the *environmental protection*. The reason for this is that a reduction of phosphorus is valued higher than a reduction of nitrogen to coastal areas.

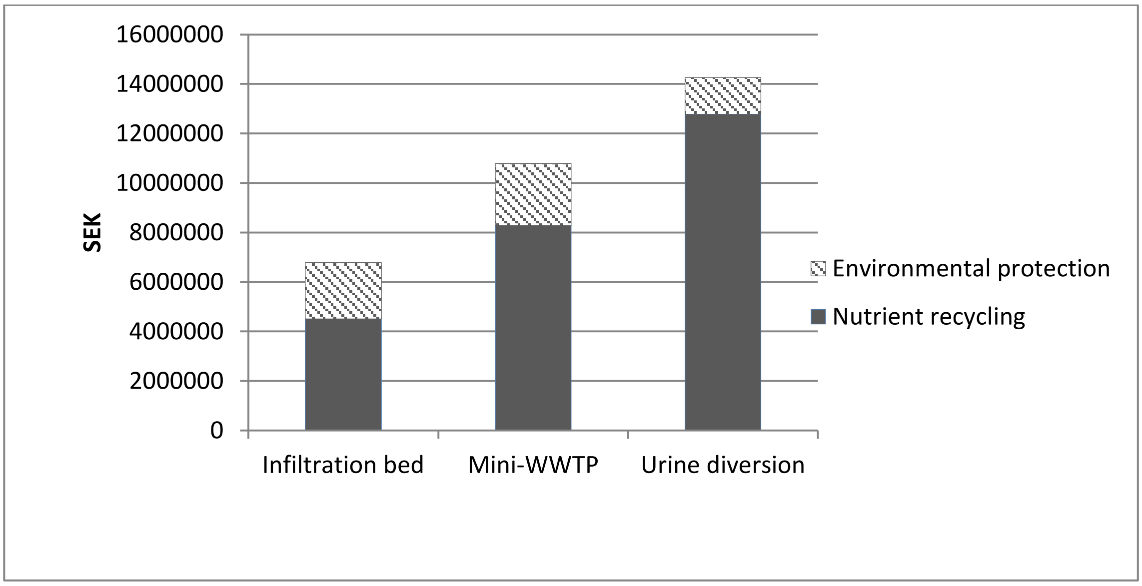

Figure 8 Calculated Benefits of the systems

Figure 9 shows the costs for the different systems over its lifetime. As can be seen, urine diversion has the highest *investment costs*. However, since the *maintenance* *costs* are lower, it is the least costly alternative. The mini-wastewater treatment plant is the most expensive system.

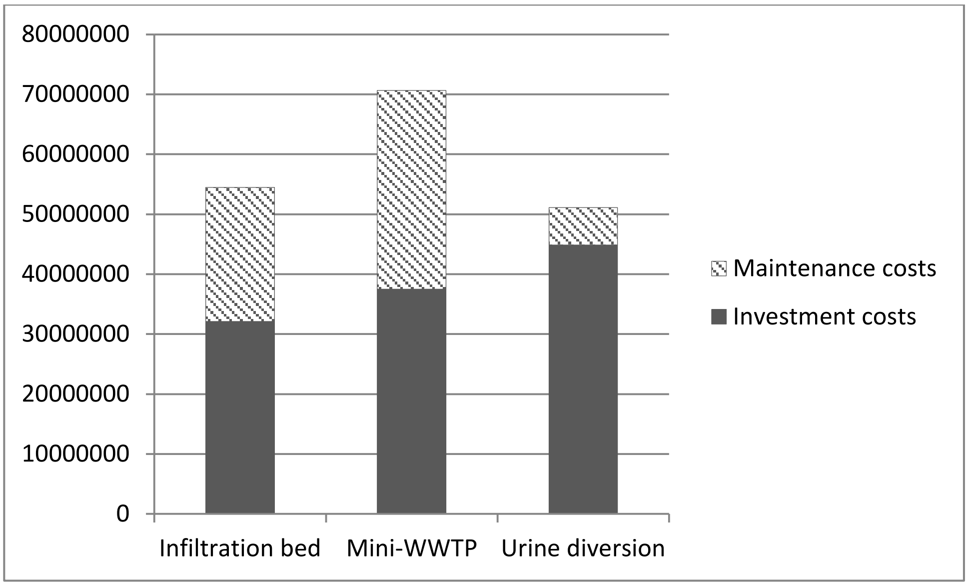

Figure 9 Investment costs and maintenance costs for the systems

The resulting net benefit cost ratio is shown in Figure 10. As can be seen, all systems give similar negative values. However, urine diversion gives a slightly higher value, which means that it is the most beneficial one.

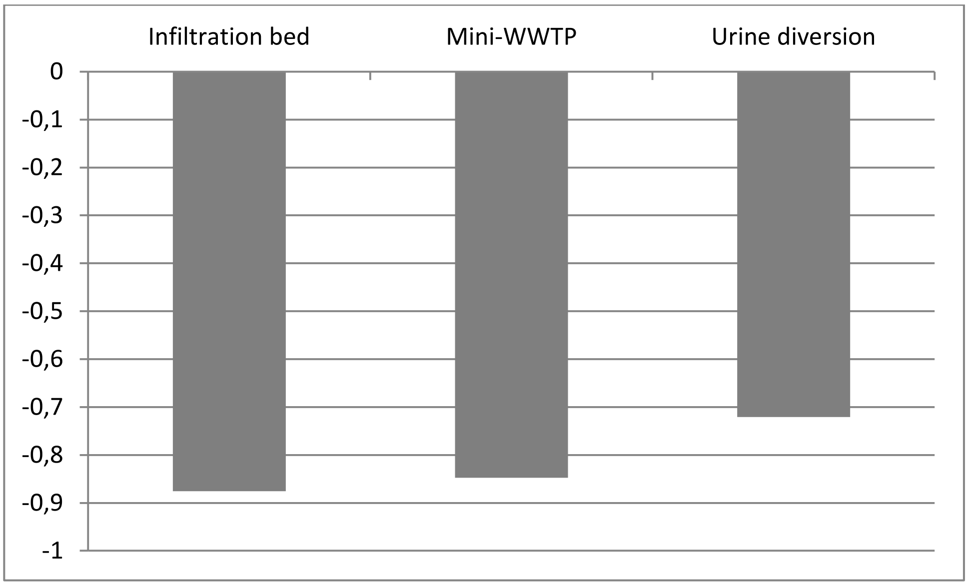

Figure 10 Net benefit cost ratio

5 Discussion

The main focus of this study has been the values and barriers of the studied urine diversion systems. This will also be the center of this discussion. But first sources of errors will be evaluated.

5.1 Sources of error

This study contains some sources of errors and uncertainties. Many of the sources of errors are related to the interviews performed during the case study. For example, only six household users were interviewed in Linköping which gives a weak material for drawing any conclusions. It does however give a hint to some of the values and barriers that are experienced by the users. The results from the interviews are compared to the household-questionnaire in Norrköping and other reports, which increases the possibility to draw valid conclusions.

Both the household user-interviews in Linköping and the household-questionnaire in Norrköping have an uncertainty connected to who chose to answer the questions. The users had the opportunity to decline to do the interview or to not fill in the questionnaire. It is possible that persons with strong opinions chose to participate to a higher extent or that persons who strongly disliked the system did not want to be bothered with an evaluation.

The fact that only one farmer was interviewed is another uncertainty. Even though LRF was interviewed, their insight to the specific systems was limited. However, it still gives some guidance to the opinions of farmers concerning these systems. The farmer in Linköping is nevertheless a very important actor in the system since he/she is the only receiver of urine, and is the one that is supposed to make sure that it is used in a meaningful way. Also here comparisons are made with literature to strengthen the conclusions.

A commonly mentioned barrier that was not encounter in the interviews performed in this study, is the fact that men has to urinate sitting down. Half of the interviewed users were men but even though they got the question "Have you needed to change the use or cleaning of the toilet compared to a regular one?" they did not mention this issue. However, in the report from Ekoporten (Norberg, 2002) it was noticed that the interviewees did not mention this by themselves but had to be asked specifically about this to comment it, even though they found it to be a problem. To evaluate this problem for the users in Linköping, the question would have had to be more specific. This also highlights a more general problem with this study; that it is limited by the types of questions asked. There may have been other barriers or values in the systems that were not mentioned during the interviews because of which questions were asked and how they were worded.

There are also uncertainties related to the assumptions made in VeVa for the cost-benefit analysis. The assumptions are based on different projects (both the case study systems and other) as well as literature. Often a number within a wide range has been chosen. This adds uncertainty to the analysis. However, many of the assumptions are made for all three types of systems, which should make the comparison relatively accurate. For this reason, not so much weight should be put on the resulting numbers but rather the relation between the three systems.

5.2 Comparison between the analysis groups

In this report, four different analysis groups have been interviewed. By comparing the results from the different groups some interesting observations can be made.

The systems of Linköping and Norrköping are quite similar. One difference is that the economic incentive for urine diversion is slightly bigger in Norrköping: besides the free collection of urine, a discount is given on the emptying of the regular septic tank. Three of the actors in Norrköping noticed this as they saw the value "*economically advantageous"*. As can be seen in Chapter 4.3.2.1 the investment cost is the largest cost and it is paid by the household users. It is therefore interesting that about 35 % of these users found the system to be economically advantageous and that not one of them said that it was expensive in the household questionnaire. In Linköping on the other hand, some of the users did mention that the emptying of the urine tank was free, but four of six users also said that it was an expensive system. This implies that, in the eyes of the users, free collection of the urine is not enough to compensate for the higher investment cost.

When looking at the tables in Chapter 4.3.1 it appears that there was more agreement between the actors in Norrköping. This is however for the most part explained by which actors were interviewed. In Norrköping both municipal employees and a former municipal employee was interviewed, which counts as two actors. It is of course quite expected that they would experience the same values and barriers to a larger extent than actors that have different roles in the system.

It is interesting to compare the results from the current system to that of the pilot projects because it gives an idea of which problems have been overcome, which still remain, and if there are any new ones compared to the early days of modern urine diversion. The main problem for Stångåstaden was the transport of the urine. Today the municipality of Linköping has a system for collecting the urine, which is done by their regular sludge emptying sub-contractor. Ekoporten in Norrköping had problems finding a farmer willing to receive the urine. This does not seem to have been a problem in either of the municipal systems. Another difference is that there seems to have been a bigger ideological value when the pilot projects were started because questions related to urine diversion were more intensely debated. One thing that has not changed is the technical problems related to the toilets: all technical problems mentioned by the project leader of Stångåstaden were found in the current systems too.

The political input provided by politicians and LRF-representatives mostly mentions values and barriers found in the other analysis groups as well. One exception is that most of the actors in this group talked about the advantages of urine compared to sewage sludge. This implies that urine is more socially accepted as a fertilizer than sewage sludge.

5.3 Actual values

The results from the cost-benefit analysis showed that urine diversion was the most beneficial system of the ones that were compared. This despite the fact that the investment cost were the highest for urine diversion. This was compensated by the maintenance costs, which were significantly lower than for the other systems. It can be noted that the cost-benefit analysis shows the overall cost of the system and not for the different actors. The household users pays all the costs for infiltration bed and mini-wastewater treatment plants, but for urine diversion the municipality pays almost all of the maintenance costs. This makes the urine diversion even more beneficial for the users in the long term.

Urine diversion was also the system that gave the highest environmental value. However, the calculation showed that urine diversion did not fulfil *high protection level* for phosphorus according to the guidelines from the Swedish Environmental protection Agency (NFS 2006:7).

The actual value will be incorporated in the discussion of the values and barriers below.

5.4 Values and barriers

In Chapter 4.3 experienced values as well as actual values were analyzed. The most interesting results from this analysis are discussed below.

5.4.1 Resource mobilization

As shown in Chapter 4.3.2.1, urine diversion is comparatively cheaper than both the systems infiltration bed with phosphorus trap and mini-wastewater treatment plant with phosphorus trap. As already mentioned, the cost for urine diversion is even less for household users than what is shown in the cost-benefit analysis, since the municipality pays most of the maintenance costs. Despite this, the high implementation cost for the users is mentioned as a barrier by many actors. A reason for this can be that it is meant in comparison with other "regular" systems that do not fulfil the demands of nutrient recycling. Another reason can be, as a municipal employee pointed out, that it is harder to communicate to users that even though the investment costs are higher than for other systems it pays off in the long term because of very low maintenance costs. Norrköping Municipality was planning to develop information material to show the investment costs and maintenance costs of different solutions for on-site wastewater systems. This could be a good way to promote urine diversion.

5.4.2 Legitimation

In all analysis groups, most barriers were found in the functional criterion Legitimation. This is natural, since this criterion is about social acceptance and people are likely to voice opinions about this. Other criteria may be harder to examine from an outsider's perspective since the actors may not want to admit if there are problems.

It could have been suitable for Legitimation to be divided into several different categories for a more structured analysis. A way to do this would be to use the categories Technical Legitimation, Environmental Legitimation and Political Legitimation. This categorization is done below.

5.4.2.1 Technical Legitimation

It is noteworthy that none of the Legitimation barriers found in Linköping are user-related. However, many of the technical barriers were pointed out by the users. They think that the problems are related to the system itself, but it is also possible that they are caused by improper use. This is a valuation that has been difficult to make throughout the analysis and it is most probable that the problems are in fact a combination of technical and user-related factors.

All technical problems related to the toilets that were found in this study have been mentioned in other earlier reports, some which are 20 years old. For most problems solutions has already been found. For example, leakages are believed to be caused by poor installation and inserts for children are available to enable proper separation. Jönsson (2009) points out that the small market for urine diverting toilets affects the product development negatively. If better market conditions existed, it seems likely further improvements of the toilet design would be possible. The author of this report believes that a design to ease the clearing of stoppages is an example of a possible product development.

This study did not examine which different toilet models that have been used. An investigation of the different models would have been interesting to see if and how the manufacturers have managed these problems.

However, it is likely that the urine diversion toilets will always demand different use and maintenance compared to a conventional WC. For example, other cleaning routines will be necessary, as well as, the occasional clearance of stoppages. A couple of the interviewed users had major problems that they did not seem to see any solution to, for example a leaking toilet or separation-problems for children. Some also expressed a feeling of hopelessness since they did not think that the system worked but felt it had been forced on them.

As mentioned above solutions have already been found to many of the problems with the toilets. However it seems like some users are not aware of these solutions. This was also found by Andersson (2008) from interviews with household-users with urine diversion in Tanum, where the users were not aware of the recommendations on how to clear stoppages. The author of this report believes that if the users are motivated and well-informed, there will be less technical problems related to the toilets.

In the report about Ekoporten it was suspected that not all urine was separated correctly. If too much urine is separated in the wrong way it could mean that the releases of nutrients to the recipient increases since the system that treats the greywater and feces may not be dimensioned for the extra nutrient loading. According to Johansson et al. (2000) the percentage of separated urine is dependent on the motivation of the users. This implies that unmotivated users could pose an environmental risk to the system. This is also shown in the report about Ekoporten (Norberg, 2002) when it comes to cleaning routines. A user that did not think the urine was recycled anymore started using chemicals that could make the urine unusable. Depending on how much monitoring is done of the collected urine, it is possible that these chemicals would not be detected and thereby end up on cropland.

This shows that it is crucial to keep the household users motivated and well-informed, both because the toilets will cause less problems to the users themselves, as well as, pose a smaller risk to the environment. A way to do this could be to regularly send out information to the users with up-to-date recommendations on possible solutions to problems with the toilets, for example with information on which producers that sells inserts for children and how to prevent/clear stoppages most efficiently. This information could also contain a short report from the farmer on how the urine has been used.

A problem that could be important to solve is that the collected urine is very diluted. This both affects the value of the urine as a fertilizer and it increases the need for storage and transportation. Andersson et al (2012) suggests that the urine could be concentrated through reverse osmosis. Another possibility would be to use urine diverting vacuum toilets. Both of these solutions would mean increased costs but since it would probably decrease other costs (transports and storage demand) as well as increase the value of the urine, it could be justified to use either of the methods.

5.4.2.2 Environmental legitimation

Some actors found it to be a barrier that human urine is not allowed on KRAV-cropland. As Norberg (2002) pointed out, human urine would be suitable for ecological farming since it is done in small scale and is only allowed to use organic fertilizers. This is a possible barrier for the municipalities to find farmers willing to accept the urine since farmers that are KRAV-certified are excluded. However, it does not seem to have been a problem to find farmers in neither Norrköping nor Linköping. When looking at the systems from a wider perspective, it can also be pointed out that one of the main motivations for developing modern urine diversion was the realization that excessive use of mineral fertilizers is unsustainable. If human urine is used on ecological crops, where mineral fertilizers are not allowed anyway, the amount of mineral fertilizers used will not change. This means that it would be the most meaningful to use it on non-ecological crops. However, it is unlikely that the urine would actually decrease the amount of mineral fertilizers used, because of the small amounts collected today. But if the system was implemented at a bigger scale this is a possibility.

One of the most frequently mentioned values is *environmental protection.* This refers to the reduced releases of nitrogen and phosphorus to the environment. The guidelines about *high* and *normal protection levels* are related to this. Norrköping states that most nutrient recycling systems achieve *high protection level* according to (NFS 2006:7). However, as can be seen in Chapter 4.3.2.1 this is not true for urine diverting systems when combined with an infiltration bed. A brochure about available technologies confirms that extra phosphorus treatment is needed in order to fulfil *high protection level* (Avloppsguiden, 2011). This means that if the on-site wastewater system is situated in an area where *high protection level* is needed, further treatment steps may be necessary.

The other main ideological value is *nutrient recycling.* Both Linköping and Norrköping demand systems that enable nutrient recycle for all newly built on-site wastewater systems. Along with urine diversion they consider for example mini-wastewater treatment plants to fulfil these demands. However, as can be seen in Chapter 4.3.2.1 urine diversion has a much bigger potential for recycling nutrients than mini-wastewater treatment plants. This implies that from a nutrient recycling perspective, these two kinds of systems should not be considered equal. In a policy-document from Norrköping it is stated that the environmental office should promote urine diversion as the primary choice as a nutrient recycling system for on-site wastewater systems (Norrköping Municipality, 2011). This does however not seem to be done. If the municipality really thought this is the best alternative they should put more effort into promoting it. One step in the right direction is that they are planning to develop information material to compare the costs for different systems, see Chapter 5.4.1.

The project leader of Stångåstaden thought that much of the motivation to build urine diversion systems had disappeared since there is not a lot of debate about it anymore. It is true that subjects like peak phosphorus seems to have been discussed more intensely twenty years ago. However, these kinds of topics are still relevant. This is for example emphasized by the new proposal for a phosphorus-goal given by the Swedish Environmental Protection Agency, see Chapter 2.2.2.2. The Swedish Agency for Marine and Water Management has also newly published guidelines for municipal planning for drinking water and wastewater (Havs- och vattenmyndigheten, 2014). In these guidelines it is suggested that nutrient recycling should be considered in the planning process. The production of mineral fertilizers is also an energy-consuming process which releases greenhouse gases. These kinds of questions are widely debated today which stresses the relevance of urine diversion.

5.4.2.3 Political legitimation

In both municipalities there had been support for the development of urine diverting systems. The municipal employees also found that there was legal support for these kinds of systems, where particularly the guidelines for on-site wastewater system from the Swedish Environmental Protection Agency were mentioned. Employees from Norrköping did however point out the fact that these are just guidelines and not legally binding. Some actors also said that it was an unequal system compared to other municipalities that do not have demands on nutrient recycling solutions. The new phosphorus-goal and new guidelines for municipal water and drinking water mentioned above are incentives that could lead to the implementation of similar demands in other municipalities.

5.4.3 Stakeholder arena

The organization of Stångåstaden showed that it is difficult for one actor to manage the entire system. This is a problem that does not exist in the current systems since there are several actors involved. All actors also said that the collaboration worked well and only minor problems were found in this category.

Municipal employees from both Linköping and Norrköping emphasized that if the users were not happy with the systems they could apply for another solution. They said that the users could always say their opinion on the system but it did not seem like they had any way to influence the system. Some users also seemed to have serious problems with their urine diverting toilets. Since these problems had not been corrected, it is likely that they did not know who to turn to. Storbjörk & Söderberg (2003) stressed the importance of a clear division of responsibilities. It is important that the users know who to contact if they have problems with their system.

This responsibility could be divided in different ways. The household-owners could still be responsible for the system but be given clearer instructions on who to contact if there is a technical problem. Another option is for the municipality to be responsible also for the systems on private property.

An example of the latter is currently developed in Norrköping. Instead of connecting an area of houses to the conventional wastewater system the municipality chose to install blackwater separation with a collective facility for greywater treatment (Christensen, 2013). The municipal water company will own the blackwater tanks even though they are located at the property of the household users.

5.4.4 Breadth and depth of support network

As mentioned before the farmer did not see a particularly large value in the system. Some other actors said that they do not have the full picture of the system and can therefore not determine if it is a good system or not. Both of these things imply that not all actors are very motivated. Storbjörk & Söderberg (2003) has identified enthusiastic actors as an important criterion for new technological systems. However, no problems related to the fact that these actors are not motivated have been found. Nevertheless, the fact that the system is quite small and that very few household-users install urine diversion today may be related to the lack of enthusiastic actors.

For some time, urine diversion was the only option when property owners wanted to install water closets. Since other options were allowed, the number of installations seems to have decreased. The author of this report believes that the reason for this is that there are two big barriers for this system from a user's perspective: the investment costs and the need to change user habits. To be willing to overcome these barriers, the users need to see the values of the system. This can be achieved by either increasing the economic value, for example by subsidizing the investment costs, and/or by increasing the ideological value, for example by providing more information on the environmental benefits of the system.

5.4.5 Access to knowledge

The uncertainties surrounding pharmaceuticals in the urine is a barrier in this category. There is a lack of research concerning how they affect the crops when used as fertilizer. This barrier is mentioned by one actor in all analysis groups except pilot projects. However, none of the actors that mention it empathize it particularly strongly, which implies that they are not overly concerned about potential negative effects. In the system today, the human urine makes up a very small fraction of what the farmers spread on their fields and the author of this report finds it probable that the pharmaceutical residues that are being spread are negligible. However, if the systems were to be implemented in a larger scale research on this subject would be necessary to gain a broader social acceptance. Research should be done about if the pharmaceutical residues are harmful and in that case which kinds of pharmaceuticals. With this information available, it would be possible to evaluate if removal of pharmaceuticals is necessary and in that case if it is needed everywhere or only in buildings such as hospitals and retirement homes, where the use of pharmaceuticals is expected to be higher than the average. As mentioned in Chapter 2.2.4 there are methods available for removal of pharmaceuticals and pharmaceutical residues.

5.4.6 Uncategorized values and barriers

Some values and barriers did not fit into any of the functional criteria. They will be discussed here.

As mentioned above, it seems likely that the technical problems related to urine diverting toilets could be solved or at least decreased. However, it is likely that the motivation for companies to do so is minimal, since the demand for urine diverting toilets is quite small. This was also pointed out by Jönsson (2009). The small demand leads to few actors on the market which leads to minimal competition which in turn leads to high prices. This creates a vicious circle because urine diverting toilets may not be chosen because of the technical problems and the high price, which reduces demand. Many of the barriers that were not categorized are related to this issue. For example, that the prices are very high, it is hard to obtain toilets, and that mini-wastewater treatment plants outcompete urine diversion.

This implies that a functional criterion related to the market size would be appropriate. Bergek et al (2008) does in fact suggest "market formation" as one of their criteria for technological innovation systems.

Several actors pointed at factors that suggest that the value of the system would increase if the system was implemented at a larger scale. The value the farmer sees in the system, or rather that he does not see, is one such factor. Since the volume of urine is so small compared to what the farmer gets from his/her own animals it is barely noticeable. However, he/she admitted that if it would have been larger quantities it would have become more interesting for him/her, thus the value would have increased. The project leader of Stångåstaden also indicated that a larger scale would make the system easier because of the transports.

However, a representative from LRF believed that these types of systems are more suitable for smaller scale. He/she thought that in a bigger system the anonymity would be a problem since it could possibly make the users not follow the instructions about what is allowed to pour down the toilet. He/she believed that the sense of responsibility would be stronger in a small system and that the quality of the urine would thereby be higher.

Both views have valid points. It is probably true that larger systems means a higher risk of unwanted substances in the urine than a smaller system where the users perhaps know which farmer collects the urine and for what he/she uses it. But this comes back to the challenge of keeping the users motivated and well-informed. Maybe a more extensive testing of the urine is needed in large systems to make sure no unwanted substances end up on cropland. However, the author of this reports believes that the two arguments for a large-scale solution are more significant; the possibility to make the transports easier and to increase the value of the end-product. However, this does not mean that small-scale systems should be phased out. The village outside of Linköping, which is mentioned in 4.1, has a urine diverting system that has worked for twenty years and is a good example of that small scale systems can also work. But in order for a municipality to create a system with substantial values, a larger scale is believed to be preferable.

6 Conclusions and recommendations

To conclude this study, the research questions found under Aims and goals will be answered. The conclusions are mainly based on results from the current systems, since these are the main focus of the report.

What values did the different actors of the systems experience? Were these economic or ideological values?

Both economic and ideological values were found in the systems. The main ideological values were the reduction and recycling of nutrients. The main economic values were reduced maintenance costs for users and a well-working collaboration between actors. A well-working collaboration is seen as an economic value since it is expected to make the organization run more smoothly, which in turn will decrease working times and consequently the cost of the system.

What are the actual values produced by the system?

The actual value of the systems, as calculated through a Cost-Benefit Analysis, shows that urine diversion with an infiltration bed for greywater was more beneficial than an infiltration bed with phosphorus trap for blackwater and mini-wastewater treatment plant with phosphorus trap. This was mainly due to the low maintenance costs. The environmental values were also higher for urine diversion.

What barriers were encountered? Why do these barriers exist?

Most of the barriers were related to the functional criterion Legitimation. This was expected since this criterion is about social acceptance and people are likely to voice opinions about this. Other criteria may be harder to examine from an outsider's perspective since the actors may not want to admit if there are problems.

Many of the barriers were related to technical difficulties with the toilets. These were believed to be related to how the user maintains the toilets and it is therefore considered important to motivate and inform household users. Design improvements are also believed to be possible.

The urine was found to be diluted, which is expected to be an important barrier because it affects the value of the urine as a fertilizer. Reverse osmosis or urine diverting vacuum toilets are possible solutions to this problem. Another barrier related to the value of urine is the uncertainties concerning medical residues in the urine. This is expected to be a minor barrier in small scale systems like the ones investigated, but more important if an up-scaling of the system is considered.

Another important barrier is that few household users install the system today. This is believed to be because of high investment costs as well as the need to change user habits. To overcome this barrier, increased economic and/or ideological value is needed. This could for example be done by giving a subsidy for the installation of a urine diverting system and/or by informing the households about the environmental benefits of urine diversion.

The interviews with household users showed that some of them had severe problems with their toilets. Since these problems had not been corrected, it implies that they do not know where to turn to for help. A clearer division of responsibilities is needed to overcome this barrier.

Lack of enthusiastic actors does not seem to be a barrier in the current systems. However, despite that there are values found in the system by all actors, there does not seem to be any actor that is pushing for an expansion of the systems. As already mentioned very few installations are made today. This implies that the experienced values are not strong enough to outweigh the barriers. However, the author of this report thinks that the barriers are manageable in comparison to the values. A way to increase the willingness to expand the system would be to make all actors aware of the economic and environmental advantages of urine diversion compared to for example mini-wastewater treatment plants.

The main barriers in the pilot projects are overcome today – the municipality has developed a system for collection and there are farmers willing to receive the urine. The barriers that remain are mainly high investment costs and technical problems with the toilets. These are problems that exist in the current municipal systems for urine diverting on-site wastewater treatment as well, which implies that no additional barriers exist for implementing the systems in urban areas. However, if urine diversion was to dominate urban areas the transport of urine with trucks might not be possible or feasible anymore. The need to install an extra set of pipes in the regular wastewater network (a separate pipe for urine) would mean big changes in the system and high investment cost. This means that additional barriers do exist for implementing urine diversion on a bigger scale in urban areas.

Based on the findings in this report, the following recommendations can be made for future implementation and expansion of urine diversion systems:

- A larger scale system is expected to increase the values of the system.
- A clear division of responsibilities is needed.
- Household users should be well-informed.
- Economic or ideological values for household users are needed to increase the willingness to install the system.
- Research on the consequences of medical residues on cropland is needed for a broader social acceptance of urine as fertilizer.

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Appendices

Appendix 1: Question guide

Table 11 Question guide: M= Municipal employees, St=Project leader from Stångåstaden, S=Sub-contractor, F=Farmer, U= Household-users, P=Politicians, L=LRF

Functional criteria	Indicators	Source	Sub-research questions	Interviewees
Resource Mobilization	Financial resources used	Interviews, calculations	Was there an experienced economic value? Was there an actual economic value? Were there economic barriers?	M, St, S, F, U, P, L
Legitimation	Visions	Interviews, reports	What was the motivation for implementing the system?	M, St, S, F, U, P
	Perceived legitimacy (among actors)	Interviews	Did the different actors experience any economic value? Did they find any ideological value?	M, St, S, F, U, P, L
	Actual environmental value	Calculations	What is the environmental value?	
	Beliefs in growth potential	Interviews	Do the actors believe that an expansion of the system is possible/suitable?	M, F, U, P, L
	Technical legitimation	Interviews	Are there any technical problems?	M, St, F, U, L
	Alignment with current legislation	Interviews, reports	Are there any legal incentives? Are there any legal barriers?	M, St, F, U, P, L.
	Political support	Interviews	Is there political support for the system?	M, St, P
Stakeholder Arena	Division of responsibilities/risks	Reports, interviews	Is there a clear division of responsibilities?	M, St, S, F, P
	Arena for participation and conflict resolution	Interviews	Are there any organizational or user-related values or barriers related to conflict resolution?	M, St, S, F, U, P
	Collaboration between actors (learning & feedback)	Interviews	Are there any barriers related to the collaboration between actors?	M, St, S, F, P
	Communication with potential users	Interviews	How well does the communication with the users and farmers work?	M, St, S, F, U, L
Breadth and Depth of Support Network	Enthusiams of actors	Observation, interviews	What are the actors attitudes towards the project?	M, St, S, F,U, P, L
	Capacity of implementing the system	Interviews, reports	How was the initial support for the system?	M, St, S
Access to Knowledge	Existing human capital	Interviews	Are there any barriers related to the lack of experience?	M, St, S, F

Appendix 2a: Interview questions for municipal employees and project leader of Stångåstaden

Table 12 Sub-research questions and linked interview questions for municipal employees and project leader of Stångåstaden

Sub-research questions	Interview questions English	Interview questions Swedish
Was there an experienced economic value? Was there an actual economic value? Were there economic barriers?	What is the cost of the system compared to conventional systems?	Vad är kostnaden jämfört med konventionella system?
What was the motivation for implementing the system?	Why did you choose to invest in urine diversion?	Varför valde ni att satsa på urinsortering?
Did the different actors experience any economic value? Did they find any ideological value?	What positive effects have you seen of the system? Is it possible to measure these effects?	Vilka positiva effekter har ni sett av projektet? Kan man mäta dessa effekter?
Do the actors believe that an expansion of the system is possible/suitable?	Are there/has there been any plans for expanding the system? Has there been any plans to implement it in urban areas?*	Finns det planer på att utveckla systemet? Finns det/har det funnits planer på att införa systemet i tätort?
Are there any technical problems?	Does the urine diversion work?	Fungerar urinsepareringen?
Are there any legal incentives? Are there any legal barriers?	Is there support for this system in legal documents etc.?	Finns det stöd för detta system I lagstiftning etc.?
Is there political support for the system?	Have you had political support for the implementation of urine diversion?	Har ni haft politiskt stöd för införandet av urinsortering?
Is there a clear division of responsibilities?	How is the responsibility divided between actors of the system?	Hur är ansvaret uppdelat mellan olika aktörer I systemet?
Are there any organizational or user-related values or barriers related to conflict resolution?	How do you deal with conflicts? Is there any possibility for household-users to for the household-users to give criticism?	Hur hanterar ni uppkomna konflikter? Finns det möjlighet för fastighetsägarna att komma med kritik?
Are there any barriers related to the collaboration between actors?	How does the collaboration between different actors work?	Hur fungerar samarbetet mellan olika aktörer?
How well does the communication with the users and farmers work?	What information do the household-user/farmers receive when they install a urine diverting toilet/become a part of the system?	Vilken information får fastighetsägarna/lantbrukarna när de installerar urinsorterande toalett/ansluter sig till systemet?
What are the actor's attitudes towards the project?	What is your attitude towards the system? Why? Has it changed since the system was implemented?	Hur är din inställning till systemet? Varför? Har den förändrats under tiden systemet har varit igång?
How was the initial support for the system?	Was it hard to achieve support of the new system from for example household users or politicians? How does it work to use this system together with the existing wastewater system?	Var det svårt att få stöd för detta nya system av olika aktörer, t.ex. brukare eller politiker? Hur fungerar det att använda detta system tillsammans med befintligt VA-system?
Are there any barriers related to the lack of experience?	What is your role in the organization of urine diversion? Have you worked with similar systems before?	Vad är din roll i organiseringen av urinsortering? Har du jobbat med liknande system förut?

*this question was not asked to the projectleader of Stångåsstaden

Appendix 2b: Interview questions for Subcontractors

Table 13 Sub-research questions and linked interview questions for Subcontractors

Sub-research questions	Interview questions English	Interview questions Swedish
Was there an experienced economic value? Was there an actual economic value? Were there economic barriers?	What is the cost of the system compared to conventional systems?	Vad är kostnaden jämfört med konventionella system?
Did the different actors experience any economic value? Did they find any ideological value?	What positive effects have you seen of the system? Is it possible to measure these effects?	Vilka positiva effekter har ni sett av projektet? Kan man mäta dessa effekter?
Is there a clear division of responsibilities?	How is the responsibility divided between actors of the system?	Hur är ansvaret uppdelat mellan olika aktörer I systemet?
Are there any organizational or user-related values or barriers related to conflict resolution?	How do you deal with conflicts? Is there any possibility for household-users to for the household-users to give criticism?	Hur hanterar ni uppkommna konflikter? Finns det möjlighet för fastighetsägarna att komma med kritik?
Are there any barriers related to the collaboration between actors?	How does the collaboration between different actors work?	Hur fungerar samarbetet mellan olika aktörer?
How well does the communication with the users and farmers work?	What information does the household-user/farmers receive when they install a urine diverting toilet/become a part of the system?	Vilken information får fastighetsägarna/lantbrukarna när de installerar urinsorterande toalett/ansluter sig till systemet?
What are the actors attitudes towards the project?	What is your attitude towards the system? Why? Has it changed since the system was implemented?	Hur är din inställning till systemet? Varför? Har den förändrats under tiden systemet har varit igång?
How was the initial support for the system?	Was it hard to achieve support of the new system from for example household users or politicians? How does it work to use this system together with the existing wastewater system?	Var det svårt att få stöd för detta nya system av olika aktörer, t.ex. brukare eller politiker? Hur fungerar det att använda detta system tillsammans med befintligt VA-system?
Are there any barriers related to the lack of experience?	What is your role in the organization of urine diversion? Have you worked with similar systems before?	Vad är din roll i organiseringen av urinsortering? Har du jobbat med liknande system förut?

Appendix 2c: Interview questions for farmer

Table 14 Sub-research questions and linked interview questions for farmer

Sub-research questions	Interview questions English	Interview questions Swedish
Was there an experienced economic value? Was there an actual economic value? Were there economic barriers?	Do you notice any reduction of other fertilizers because of the use of human urine?	Märker du av någon minskad användning av gödsel på grund av användandet av humanurin?
What was the motivation for implementing the system?	Why did you choose to become a part of the system?	Varför valde du att ansluta dig till systemet?
Did the different actors experience any economic value? Did they find any ideological value?	What positive effects have you seen of the system? Is it possible to measure these effects?	Vilka positiva effekter har ni sett av projektet? Kan man mäta dessa effekter?
Do the actors believe that an expansion of the system is possible/suitable?	Are you interested in a continued/extended collaboration with this system?	Är du intresserad av ett fortsatt/utökat samarbete med detta system?
Are there any technical problems?	Is the stored urine of sufficient quality?	Är den lagrade urinen av tillräckligt god kvalitet?
Are there any legal incentives? Are there any legal barriers?	How does it affect you that KRAV-certification does not allow human urine as fertilizer? Have you experienced any similar problem?	Hur påverkar det sig att KRAV-märkning inte tillåter gödsling med humanurin? Har du stött på andra liknande problem?
Is there a clear division of responsibilities?	How is the responsibility divided between actors of the system?	Hur är ansvaret uppdelat mellan olika aktörer I systemet?
Are there any organizational or user-related values or barriers related to conflict resolution?	Have you been involved in any discussions concerning the system? Do your opinions get heard?	Har du varit delaktig i diskussioner kring systemet? Får du gehör för dina åsikter?
Are there any barriers related to the collaboration between actors?	How does the collaboration between different actors work?	Hur fungerar samarbetet mellan olika aktörer?
How well does the communication with the users and farmers work?	What information did you receive when you became a part of the system? Was this information satisfactory? If not, what more information would you have wanted?	Vilken information fick du när du blev delaktig i projektet? Var denna information tillfredställande? Om inte, vad hade du velat få mer information om?
What are the actors attitudes towards the project?	What is your attitude towards the system? Why? Has it changed since the system was implemented?	Hur är din inställning till systemet? Varför? Har den förändrats under tiden systemet har varit igång?
Are there any barriers related to the lack of experience?	What is your role in the organization of urine diversion? Have you worked with similar systems before?	Vad är din roll i organiseringen av urinsortering? Har du jobbat med liknande system förut?

Appendix 2d: Interview questions for household-users

Table 15 Sub-research questions and linked interview questions for farmer

Sub-research questions	Interview questions English	Interview questions Swedish
Was there an experienced economic value? Was there an actual economic value? Were there economic barriers?	Have you noticed any change concerning water consumption, fees or other costs compared to the system you had before?	Har du märkt av någon förändring av vattenförbrukning, taxor eller andra kostnader jämfört med det system du hade innan?
What was the motivation for implementing the system?	Why did you choose to become a part of the system?	Varför valde du att installera urinsorterande toalett/er i ditt hem?
Did the different actors experience any economic value? Did they find any ideological value?	What positive effects have you seen of the system? Is it possible to measure these effects?	Vilka positiva effekter har ni sett av projektet? Kan man mäta dessa effekter?
Do the actors believe that an expansion of the system is possible/suitable?	Would you recommend others to install urine diverting toilets at home?	Skulle du rekommendera andra att installera en urinseparerande toalett hemma?
Are there any technical problems?	How does the system work according to you?	Hur fungerar systemet enligt dig? Har du haft några problem? Hur har du behövt ändra användandet och rengöringen av toaletten jämfört med en vanlig toalett? Har detta fungerat tillfredsställande?
Are there any organizational or user-related values or barriers related to conflict resolution?	Have you been involved in any discussions concerning the system? Are your opinions heard?	Har du varit delaktig i diskussioner kring systemet? Får du gehör för dina åsikter?
How well does the communication with the users and farmers work?	What information did you receive when you installed the system? Was this information satisfactory? If not, what more information would you have wanted?	Vilken information fick du när du fick systemet installerat? Var denna information tillfredställande? Om inte, vad hade du velat få mer information om?
What are the actor's attitudes towards the project?	What is your attitude towards the system? Why? Has it changed since the system was implemented?	Hur är din inställning till systemet? Varför? Har den förändrats under tiden systemet har varit igång?

Appendix 2e: Interview questions for politicians

Table 16 Sub-research questions and linked interview questions for politicians

Sub-research questions	Interview questions English	Interview questions Swedish
What was the motivation for implementing the system?	Why did you choose to invest in urine diversion?	Varför valde ni att satsa på urinsortering?
Did the different actors experience any economic value? Did they find any ideological value?	What positive effects have you seen of the system? Is it possible to measure these effects?	Vilka positiva effekter har ni sett av systemet? Är det möjligt att mäta dessa effekter?
Are there any legal incentives? Are there any legal barriers?	Is there support for this system in legal documents etc.?	Finns det stöd för detta system i lagar och riktlinjer?
Is there political support for the system?	Have you had political support for the implementation of urine diversion?	Hur har den politiska opinionen sett ut kring urinsortering? Vilka för- och motargument används?
What are the actors attitudes towards the project?	What is your attitude towards the system? Why? Has it changed since the system was implemented?	Hur är din inställning till systemet? Varför? Har den förändrats under tiden systemet har varit igång?

Appendix 2f: Interview questions for LRF

Table 17 Sub-research questions and linked interview questions for LRF

Sub-research questions	Interview questions English	Interview questions Swedish
Was there an experienced economic value? Was there an actual economic value? Were there economic barriers?	How much money does the farmer make by being a part of these systems? Do you know if anyone receives such amounts of urine that they notice a reduction of other fertilizers?	Hur mycket tjänar lantbrukarna på att vara delaktiga i dessa system? Vet ni om det är någon som mottar sådana mängder urin att det märks en minskning i övrigt förbrukat gödsel?
Did the different actors experience any economic value? Did they find any ideological value?	What positive effects have you seen of the system? Is it possible to measure these effects?	Vilka positiva effekter har ni sett av projektet? Kan man mäta dessa effekter?
Do the actors believe that an expansion of the system is possible/suitable?	Do you think it is possible/suitable to expand these kinds of systems? What do you think about also implementing it in urban areas?	Tror ni det är möjligt/lämpligt att utöka denna typ av system? Hur ser ni på att även införa det i tätort?
Are there any technical problems?	How is the urine as a fertilizer?	Hur bra är urin ur gödslingssynpunkt?
Are there any legal incentives? Are there any legal barriers?	What is your opinion on that KRAV-certification does not allow human urine as fertilizer? Are there other similar problems that complicate the use of human urine?	Hur ser ni på att KRAV-märkning inte tillåter gödsling med humanurin? Finns det andra liknande problem som försvårar användandet?
How well does the communication with the users and farmers work?	What information do the farmers receive when they become a part of the system?	Vilken information får lantbrukarna när de ansluter sig till systemet?
What are the actors attitudes towards the project?	What is your attitude towards the system? Why? Has it changed since the system was implemented? Do you know what the involved farmers' attitudes are?	Hur är din inställning till systemet? Varför? Har den förändrats under tiden systemet har varit igång? Har ni någon uppfattning om vad de medverkande böndernas inställning är?

Appendix 3: Assumptions in VeVa

Table 18 Important assumptions for the calculations in VeVa. Other parameters were unchanged from those values that are found in VeVa[10].

Parameter	Value	Comment
Number of households in the area	300 persons	Total number of households with urine diversion in Norrköping, approximated from Carlsson (2011) and Andersson (2008)
Percentage sludge from WWTP reused in agriculture	52 %	Average from Linköping for 2011-2013 (Tekniska Verken, 2012) (Tekniska Verken, 2013b) (Tekniska Verken, 2014)
Investment cost urine diversion system (excluding infiltration bed etc.)	32 500 SEK	Average from Andersson (2008)
Storage, spreading and testing of the urine	150 000 SEK/year	Approximate value given by Tekniska Verken (2013)
Emptying of urine tank[11]	1143 SEK/year	Fee for emptying sludge-tank in Norrköping (Norrköping Municipality, 2013c)
Emptying of sludge tank	1143 SEK/year	Fee for emptying sludge-tank in Norrköping (Norrköping Municipality, 2013c)
Environmental value for reduction of phosphorus to coastal areas	1023 SEK/kg P	From Kinell et al. (2009)
Environmental value for reduction of nitrogen to coastal areas	31 SEK/kg N	From Kinell et al. (2009)
Prize for phosphorus mineral fertilizer	16,42 SEK/kg P	From Jönsson et al (2013)
Prize for nitrogen mineral fertilizer	11,11 SEK/kg N	From Jönsson et al (2013)

[10] VeVa is available at http://www.urbanwater.se/en/services-working-methods-and-tools/sustainability-assessment-transition-areas

[11] The emptying of the urine tank is free of charge for the users but the actual cost is expected to be the same as the emptying of a regular sludge tank