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Investments in Innovative Urban Sanitation – Decision-Making Processes in Sweden

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ABSTRACT: This paper studies decision-making processes in relation to the implementation of innovative source-separating wastewater systems in the development area of Helsingborg called H+, and the non-implementation of the same in Stockholm Royal Seaport. Two analytical perspectives were used to identify critical organisational functions, drivers for change and the anchoring of these decisions within policy: (i) a sustainability transitions framework, and (ii) a policy trickle-down study assessing policy-concept uptake by stakeholders. Critical functions supporting implementation of source-separating systems in H+ were: common vision, leadership, cross-sectoral cooperation, and an innovative approach both within the utility and in the city administration in Helsingborg. In Stockholm, with regard to source-separating wastewater systems, there was a lack of common vision and of cross-sectoral cooperation and leadership. This was also evident in the lack of uptake by stakeholders of the policies for source separation. In Helsingborg, the main drivers for source-separating wastewater systems are increased biogas generation and improved potential for nutrient recycling. In Stockholm, these drivers have not been enough to create change, but the potential for increased heat recovery from greywater at source may be the additional driver necessary for future implementation of source-separating wastewater systems. Comparison of the stalled source-separation policy in Stockholm with a successfully implemented policy in a related field found a key criteria to be the presence of inspired individuals in positions where they had the mandate as well as the ability to create a common vision for change.

KEYWORDS: Wastewater, resource recovery, source separation, sustainable urban development, Sweden

INTRODUCTION

The link between eutrophication of water bodies and anthropogenic activities such as agriculture, industry and wastewater discharge was established in the 1960s and 1970s (Schindler, 1974). The Swedish wastewater sector took notice of this early on, and essentially all households in urban areas are connected to municipal wastewater treatment plants and over 95% of urban wastewater undergoes tertiary treatment. This shift started in the 1970s, and in 1995 nitrogen (N) removal was also introduced at a large scale (Naturvårdsverket, 2018). Sweden thus has a history of taking serious measures and making significant investments in its urban wastewater infrastructure in order to protect public health and prevent eutrophication of its waterways, something fundamental to the promotion of healthy aquatic ecosystems.

The world is now facing the challenge of adapting human activities' to the scarcity of resources such as phosphorus (P) and fossil fuels, and there is an increasing need to shift to a circular economy in which resources are used more efficiently. A circular economy is defined by the European Union as an economy where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste is minimised (European Union, 2015).

Applying a circular economy perspective to the wastewater sector means that it is not enough to protect waterways from eutrophication by removing phosphorus, nitrogen and organic matter from wastewater; it is also necessary to keep materials and resources in the economy for as long as possible and to minimise waste to a greater extent than is done today. Wastewater management has a critical role to play in achieving a circular economy. For example, the wastewater sector accounts for the second-highest internal flow of phosphorus in Sweden (Naturvårdsverket, 2013), and phosphorus is one of 27 critical raw materials listed by the European Commission for consideration within a circular economy perspective (European Commission, 2018). In addition, the necessity of transitioning to a circular economy for both phosphorus and nitrogen is supported by research on planetary boundaries which define the safe operating space for humanity. Nitrogen and phosphorus biogeochemical flows represent one such planetary boundary that humanity has already surpassed (Steffen et al., 2015).

A higher degree of circularity for resources in wastewater could be obtained through source control and source separation of different wastewater flow streams. Indeed, source control was recommended by Krebs and Larsen (1997) as the most robust strategy for increasing the sustainability of urban drainage systems. It has also been shown that source separation of wastewater flows, for example in the form of separate collection of blackwater or urine, facilitates nutrient recovery as well as pollutant removal (Larsen et al., 2004, Larsen et al., 2009). However, shifting from conventional wastewater systems to source-separating ones in urban areas represents a challenging sector transition. This study therefore applies a sustainability transition perspective in its examination of two different cities where this sector transition has been undertaken.

Two urban Swedish development areas with high sustainability profiles, Stockholm Royal Seaport (SRS) in Stockholm and H+ in Helsingborg, have considered the implementation of source-separating wastewater systems. Both projects have politically ratified sustainability policies which include goals on sustainable wastewater management. Even so, at the time of writing this article they differ in the realisation of their policy goals for wastewater management. Helsingborg is currently in the process of constructing a source-separating wastewater system in the H+ area, while no implementation decisions have been made in Stockholm. The aim of this paper is thus to study the decision-making processes in Helsingborg and Stockholm in relation to the implementation of source-separating wastewater systems in urban areas. The specific objective is to identify critical organisational functions and drivers that have affected the implementation outcomes in these two cities in their respective high-environmental-profile development areas.

The article begins by giving the background to this investigation, including the challenges for the wastewater sector and an elaboration of the sustainability transition perspective. It then outlines the

methodology by which the study is designed, and presents the scientific perspective. Results and analyses are then put forward, followed by a discussion of results within the larger context of societal benefits and sustainable development. Finally, conclusions are presented, findings summarised, and the wider applicability of the results is suggested.

BACKGROUND

Challenges for the European wastewater sector

Large parts of Europe face growing challenges regarding wastewater management. EurEau, the European Federation of National Associations of Water Services, has indicated that the dual challenge of ageing water service infrastructure and climate change will require far-reaching adjustment measures and long-term investments at all levels across Europe. In Sweden, ageing infrastructure is increasing the need for costly investments in sewer networks (Malm et al., 2013). Concerns about organic micropollutants, such as pharmaceutical residues, will also drive increased investment due to new, expensive tertiary treatment steps (Havs, 2018). Eutrophication related to wastewater discharge remains an issue of concern in Europe, particularly in countries where the EU wastewater directive has not been implemented but not excluding a country like Sweden where there is widespread tertiary treatment (Naturvårdsverket, 2018). An increased focus on nutrient management in connection with eutrophication and circular economy perspectives will likely demand more stringent effluent discharge regulations from wastewater treatment plants, as well as requiring increased recovery of phosphorus and nitrogen from wastewater.

Several of these challenges can be tackled with a higher level of resource recovery, recycling and reuse, which can be achieved through source control and source separation of different wastewater flow streams (Larsen et al., 2004; Larsen et al., 2009). Indeed, an analysis comparing a conventional wastewater system to two different blackwater systems in Stockholm showed that a blackwater system (i) increases the potential for biogas production by 70 to 80%, (ii) has the potential to reduce CO_2 emissions by 126 kg/capita/yr, and (iii) increases the agricultural reuse potential for N and P by more than 2000% (Lennartsson and Kvarnström, 2017). Separate collection and treatment of blackwater and greywater can generate other benefits for society as well. A recent cost-benefit analysis drawn up for a new development area in Stockholm showed that investment in a source-separating wastewater system (VA2) and investment in membrane filtration at the existing wastewater treatment plant (VA1) are both estimated to provide higher benefits to society than their respective costs (Table 1). The cost of the VA2 system is twice that of the conventional reference system which is referenced as a baseline (VA0), whereas an investment in a membrane filtration system (VA1) represents a cost increase of only 10% over the baseline (Nordzell and Soutukorva, 2018). However, the socio-economic net benefit of VA2 is ten times higher than that of VA1, even considering that six of the identified benefits of source separation cannot yet be monetised. It is also important to bear in mind that capital and investment costs (C2.1) associated with the novel installation of source separation (VA2) will likely fall considerably as the approach becomes more mainstream, after which the socio-economic net benefits will be even larger.

VA1 represents today's tertiary wastewater system with the addition of membrane filtration. VA2 represents a source-separated blackwater system where the blackwater and the greywater is collected and treated separately. VA0 is the system in place in Stockholm today (tertiary treatment with N and P removal), which constitutes the baseline to which the costs and benefits of other systems are compared. The cost of VA0 for 22,000 people is estimated to be 12.1 million Swedish kronor.

Table 1. Benefits and costs in million Swedish kronor (MSEK), identified for two different wastewater systems in Stockholm, for 22,000 people.

Benefits (B)	VA1 (MSEK/yr)	VA2 (MSEK/yr)
B1.1 and B1.2 Decreased release of N and P to receiving waters	0.49	1.36
B.12 Decreased release of pathogens, parasites and viruses/B2.1 Improved sanitisation	1.64	11.37
B1.3 Potential to remove pharmaceutical residues/ B2.8 Decreased release of pharmaceutical residues and hormones to receiving waters	x	3.68
B1.4 and B2.12 Increased knowledge	x	x
B1.5 and B2.14 Contribution to Swedish green tech export	x	x
B2.2 Reduced external effects from commercial fertiliser production		2.48
B2.3 Reduced water consumption		0.75
B2.4 Potential for heat recovery from greywater		x
B2.5 Biogas production		x
B2.6 Reduced release of greenhouse gases		3.61
B2.9 Reduced release of heavy metals to soil		0.13
B2.10 Acceptance of nutrient reuse in agriculture		x
B2.13 Potential contribution of the sustainability profiling of Stockholm Royal Seaport		x
Estimated minimum benefit compared to the baseline (VA0 – the existing conventional system)	2.1	23.4
Costs (C)	**VA1 (MSEK/yr)**	**VA2 (MSEK/yr)**
C0.1, C1.1 and C2.1 Capital and O&M costs	13.1	23.8-26.4
C2.2 Increased energy use in the treatment process		x
C1.3 Increased vulnerability at power outages		x
Estimated additional cost compared to VA0	1	11.7-14.3
Socio-economic net benefit	1.1	9.1-11.7

Source: Nordzell and Soutukorva, 2018.

Given the environmental and socio-economic net benefits, source separation of wastewater in urban areas makes sense from a circular economy perspective as a strategy to meet the wastewater sector challenges in the EU. Indeed, during the past decade there has been a renewed interest in urban source separation of wastewater, with several large pilot projects being constructed in Northern Europe. Skambraks et al. (2017) found strong environmental goals at national and local levels of government to be the main drivers for investment in new and integrated systems. However, they also note that implementation of source separation can be challenging since it requires the involvement of several municipal sectors. They thus suggest that a successful implementation of source separation requires

increased cooperation between the municipality and its utilities for water, waste and energy services if environmental gains from new systems are to be maximised.

Sustainability transitions perspective

There is growing recognition that due to the globalised and systemic nature of the environmental challenges we are facing, achieving sustainability goals will require fundamental changes to core societal systems. Such fundamental change has been termed a 'sustainability transition' and there is a growing field of research that aims to understand and guide these transformations. This study brings together three perspectives on sustainability transitions, from the field of governance, technology innovation and local/sector-specific institutional criteria for sustainability. These perspectives are used to build a framework of key functions for achieving sustainability transitions. This framework is then used to analyse the development paths of the two cities in this study. From a governance perspective, transition management has developed as a framework for creating space in society for co-production of sustainable solutions to societal needs (Loorbach, 2010). From the technology perspective, the framework of technological innovation systems (TIS) was selected. TIS studies aim to better understand the forces within sociotechnical systems that shape change towards higher sustainability (Hekkert et al., 2007). McConville et al. (2017) identified a number of functions, primarily based on Bergek et al. (2008), that were considered important for understanding how a source-separating wastewater system, as a technical innovation system, can develop in the Swedish sanitation sector. Finally, the framework includes local/sector-specific criteria from Storbjörk and Söderberg (2003), who studied the criteria necessary for transitioning the Swedish wastewater sector towards higher levels of sustainability. In Table 2 we have mapped and merged the functions/criteria suggested by the three perspectives into a simplified assessment framework.

The sustainability transitions framework applied in this study (see Table 2) is derived from three theoretical foundations. The functions listed on the left are a synthesised list of factors considered important for successfully shaping change in the Swedish sanitation sector.

METHODOLOGICAL APPROACH

Design of the comparative study

Two urban development areas in Sweden with high sustainability profiles, SRS in Stockholm and H+ in Helsingborg, were selected for study as both cities have considered the implementation of source-separating wastewater systems. Both projects being new developments, their city administrations and utilities are instrumental in implementing such infrastructure, the former planning and constructing the infrastructure and linking to developers in the area, the latter operating and maintaining the infrastructure.

In 2010, both cities adopted a policy for their respective sustainability profiled urban development areas with high ambitions to increase the circularity of technical supply systems, including source-separating wastewater systems. In the pre-feasibility studies following the adoption of the policies, Wittgren et al. (2011) in Stockholm and Engvall (2013) in Helsingborg independently arrived at similar results: that source separation of wastewater flow streams provides the best environmental benefits.

Table 2. Theoretical components of the sustainability transitions framework.

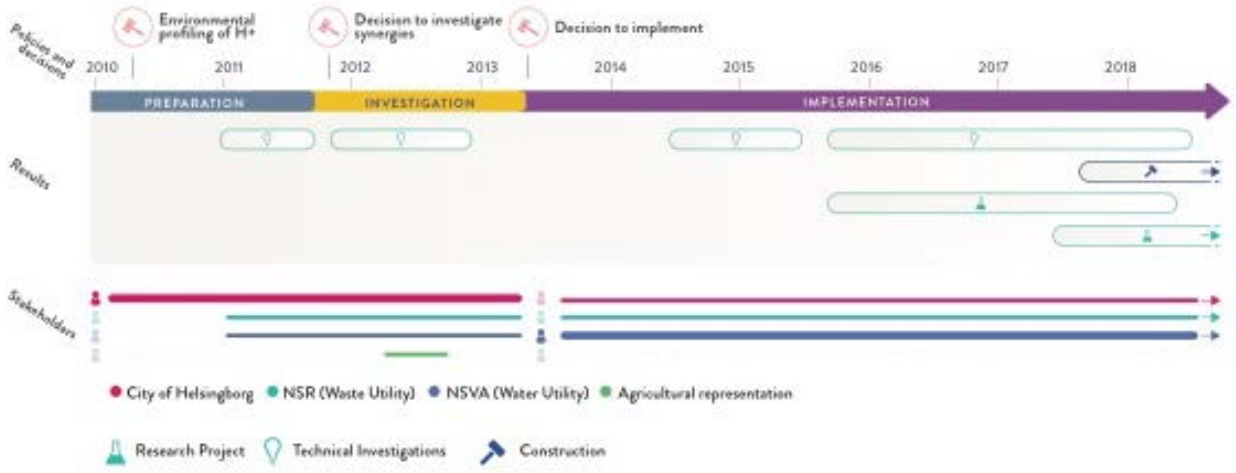
Sustainability transitions framework	Transition management perspective (Loorbach, 2010)	Technology innovation perspective (Bergek et al., 2008; McConville et al., 2017)	Swedish sanitation perspective (Storbjörk and Söderberg, 2003)
Enabling environment	A transition arena creating a safe 'space' for innovation	Legitimation: acceptance and proven technical advantages	Action space: legislative and political support
Common vision	A transition agenda builds a long-term collective vision	Guidance of the search: clear goals and visions	Value coalition between crucial actors: shared worldviews, problems and goals
Openness to experimentation	Executing transition experiments/innovations	Entrepreneurial activities: iterative and social learning to reduce uncertainty; market formation	
Resource availability	Transition experiments are costly and time-consuming: feasibility should be monitored	Resource mobilisation: human and financial; Knowledge development: sufficient quality and quantity of knowledge	Access to resources
Communication	Collective reflecting and learning in a process of social learning		Communication with users
Conflict management	The transition arena creates open societal networks leaving room for dialogue and dissent	Social capital: process of building social relationships	Arena for participation and conflict management
Clear roles and responsibilities	Identify responsible parties		Explicit division of responsibilities and risks
Leadership	Building on actions of 'frontrunners' promoting sustainable development in society		Driven and responsible actors

Over the past nine years, the planning and implementation processes in Stockholm and Helsingborg have been different in nature, content and result, despite similar starting points in both cities (Figure 1). As can be seen in Figure 1a, a decision to implement source-separating systems was taken in Helsingborg in 2013, whereas Stockholm is still in the investigation phase (Figure 1b). This study was designed to

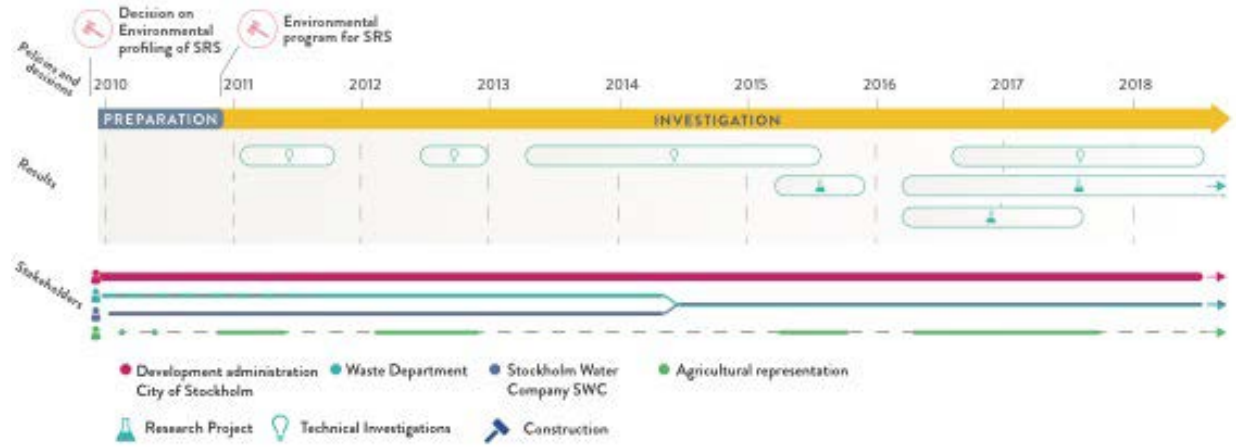
examine the reasons behind the different outcomes in the two cities. Two analytical perspectives were used: (i) the sustainability transitions framework adapted to the Swedish sanitation sector (Table 2), and (ii) a policy trickle-down study assessing where and how specific policy concepts were taken up/not taken up by various stakeholders.

Figure 1. Decision-making process for source-separating blackwater system in a) H+, Helsingborg, and b) SRS, Stockholm.

a)



b)



In addition, a second analysis was carried out solely for SRS in Stockholm with regard to another policy decision that was successfully implemented. The aim of this analysis was an internal comparison of why one policy initiative was successful while another was not. The Green Space Index (GSI) is a tool to measure the level of achievement of policy goals in relation to ecosystem services. An operational goal for GSI was defined in the 2010 policy for SRS (City of Stockholm, 2010), and responsibility for its implementation has been spearheaded by the city's Environmental Administration. Ecosystem services are defined as the direct and indirect contributions of ecosystems to human well-being (Biodiversity Information System for Europe, 2010). Urban nature is not only for decorative purposes; it serves a wide

range of critical functions, such as managing and purifying rainwater, enhancing well-being, providing food for insects, and reducing the city's noise. The GSI is a tool for calculating eco-efficiency, and adds a range of ecosystem services into the urban green space (City of Stockholm, 2011). The implementation of the GSI has been successful in SRS and has been made a prerequisite for all new developments on municipally owned land in Stockholm. The policy goal of the GSI is operational and thus appears in the policy document of 2010 on the same level as source-separating wastewater systems. It was therefore considered interesting to analyse GSI for the purpose of comparing the two. Similar to sanitation, implementation of the policy goal for GSI requires cooperation by two municipal entities: the Stockholm City Development Administration and Stockholm City Environmental Administration. Both analytical perspectives described above were therefore also applied to the GSI policy.

Sustainability transitions assessment

An assessment was performed on how well each of the cities fulfilled the factors considered to be important for successfully shaping change in the Swedish sanitation sector (Table 2). Case study methodology was applied as an appropriate method for gaining in-depth understanding of how stakeholder dynamics, decision-making frameworks and external factors can affect outcomes (Yin, 2003). In order to qualitatively assess the status of each function in the framework, data was collected through six in-depth, semi-structured interviews with key actors within each city's Development Administration and public water utility. The interviewees were senior managers from both city administrations and from the utilities that had been directly involved in the decision-making process by developing policies, managing investigations and, in Helsingborg's case, being involved in the implementation. In-depth interviews were also held with key actors connected to the GSI and urban ecosystem services policies in Stockholm.

The interview questions were open, such as "What does your enabling environment look like?", "How was the source-separating wastewater system identified as an issue to address in your process?", or "Was there consensus around the decision? If yes: how did you reach consensus; if no: why not"? The questions were developed based on the eight critical functions of the sustainability transitions framework (Table 2), and were aimed at capturing each organisation's perspective on the process and outcome of considering source-separating sanitation systems. If a certain function was found to be missing within their process, they were asked to elaborate on why. Interviews were coded for content and compared against the sustainability transitions framework in order to qualitatively assess the achievement of the functions (i.e. red indicates lack of functionality, yellow indicates that a process of establishing functionality is ongoing, and green indicates that functionality is in place).

Policy trickle-down analysis

The policy trickle-down analysis aimed to identify to what degree specific policy concepts were taken up by various stakeholders. This analysis thus illustrates how well-anchored the concept of source separation (and GSI in the case of Stockholm) was within different city organisations. In order to understand how and if policy goals have been operationalised, we reviewed annual reports and budgets from actors within each city: Stockholm City and Helsingborg City, the urban planning administrations (Exploateringskontoret, Stadsbyggnadsnämnden), and the public water and waste utilities (Stockholm Vatten och Avfall, SVOA; Nordvästra Skånes vatten och avlopp. AB, NSVA; and their R&D branch, Swedish Water Research). For the GSI study, documents from Stockholm City's Development Administration (city budget and annual report) and its Environmental Administration were reviewed. The starting year of the analysis was 2011 for Stockholm and 2014 for Helsingborg, reflecting when the policy decisions on source-separating wastewater systems were taken in each city. NVivo qualitative data analysis software (QSR International Pty Ltd) was used for document coding and analysis. The policy formulations and text search queries that were used (including how goals were formulated in the guiding policy document) are shown in Table 3. The results of these queries were coded for content in order to see if they matched the

guiding policy documents. The results show which documents, and thus which organisations, have operationalised the policy goals in their annual activities.

The policy trickle-down analysis for the GSI was performed in a similar manner. The guiding policy formulation for GSI is shown in Table 3, as well as the terms used for text search queries. Note that for the GSI document study, references to percentages of projects that practice greenspace compensation were not included in the coding, since the practice of compensation was in place prior to setting the SRS goals and did not include qualitative aspects that would provide specific ecosystems services. However, references to strategies for greenspace compensation were included in the GSI coding because the GSI reflects a more strategic approach to greenspace compensation, and these strategies are therefore relevant to observing the process of change.

Table 3. Overview of policies, formulations and search terms for the policy trickle-down analysis.

	Stockholm source-separating wastewater system	Helsingborg source-separating wastewater system	Stockholm Green Space Index
Guiding policy document	Overall Program for Environment and Sustainable Urban Development in the Stockholm Royal Seaport (City of Stockholm, 2010) and Program for Sustainable Urban Development (City of Stockholm, 2018)	H+ Environmental Profile (City of Helsingborg, 2010)	Overall Program for Environment and Sustainable Urban Development in the Stockholm Royal Seaport (City of Stockholm, 2010) and Sustainable Urban Development in the Stockholm Royal Seaport (City of Stockholm, 2010)
Formulation and goals of policy	(i) The nutrient content of wastewater will be returned to the productive soil. Source-separated wastewater fractions should be utilized to provide an effective return of nitrogen and potassium to the soil. (City of Stockholm, 2010, Operational goal 8.2.3). (ii) The water and wastewater system shall have an optimal recycling of energy (biogas and waste heat), contribute to a climate-positive development in the Stockholm Royal Seaport, and it shall be based on energy efficient technology (City of Stockholm, 2010, Operational goal 8.2.4). (iii) Develop knowledge among all stakeholders on the benefits of source-separating wastewater	(i) Use of natural resources that is economised and streamlined with a lifecycle approach (ii) Waste recycling is efficient and resource-saving (iii) Energy neutrality, to which H+ will contribute by adding more energy to the city than it uses	(i) Stockholm Royal Seaport is a neighbourhood with a green structure that support and develop the ecosystem and biodiversity as well as the maintenance of valuable ecosystem services. (ii) Each property and all public areas shall achieve the Green Space Index specified by the city for each development stage, taking into consideration the quality of the greenery. (City of Stockholm,

	systems (City of Stockholm, 2017, Operational goal 3.2.1). (iv) Plan for collected waste products from wastewater to be of such quality that they can be recycled to a greater extent, specifically optimising energy and resource use (City of Stockholm, 2017, Operational goal 3.2.2).	2010, Operational goal 5.2.3).
Search terms used	• wastewater (avlopp*/spillvatten*/toalett*) • source separation (källsort*/sorter*) • resource recovery (kretslopp*/återvinn*/återanvänd*/hushållning*/återför*/återför*/tillvara*/resursbesparande) • energy (energi*) • nutrients (näring*/kväve/fosfor*/kalium/gödsel*)	• ecosystem services (ekosystem*) • Green Space Index (grönyt*/GYF)

ANALYSIS AND RESULTS

The analysis and results of both the sustainability transitions assessment and the policy trickle-down analysis show key differences between the three studied cases.

Critical functions from the sustainably transitions assessment

Figure 2 illustrates how SRS and H+ score on critical factors affecting sustainable transitions within sociotechnical systems (as shown in Table 2). The top triangle represents an assessment of the responsible department at the municipal level, and the bottom triangle that of the water utility in question. The colour gradients show the degree to which the function is fulfilled: red indicates a lack of functionality, yellow indicates that a process of establishing functionality is ongoing, and green indicates that functionality is in place.

In Helsingborg, where the public water utility NSVA manages the planning and implementation of the source-separating wastewater systems, steady progress has been made from the initial investigations in 2012 to implementation, with construction of the first phase of source-separating wastewater systems in H+ starting in 2017 (Figure 1a). In Stockholm, where the Stockholm City Development Administration manages the process, the demand from the water utility for more substantial investigations of technical feasibility, responsibilities and legal aspects as well as cost-benefit analyses have delayed implementation, and a decision to implement had still not been taken as of the end of 2018 (Figure 1b).

The reasons for these differences in results were investigated during the spring of 2017, using the sustainability transitions framework that was adapted in this study for the Swedish sanitation sector (Table 2), as well as in-depth interviews. The processes in the two projects were analysed, comparing similarities and differences between the cities. The sustainability transitions assessment showed that the H+ project scored green for all the key functions considered by the framework for both the city and the utility, indicating that each of the functions was in place (Table 4 and Figure 2). The interviews pointed out that the success of the H+ project is particularly due to having established a common vision through a cross-sectoral collaboration within the municipality. Instrumental to the process has been the involvement of key stakeholders and support from top management, as well as a team that was able to think out of the box.

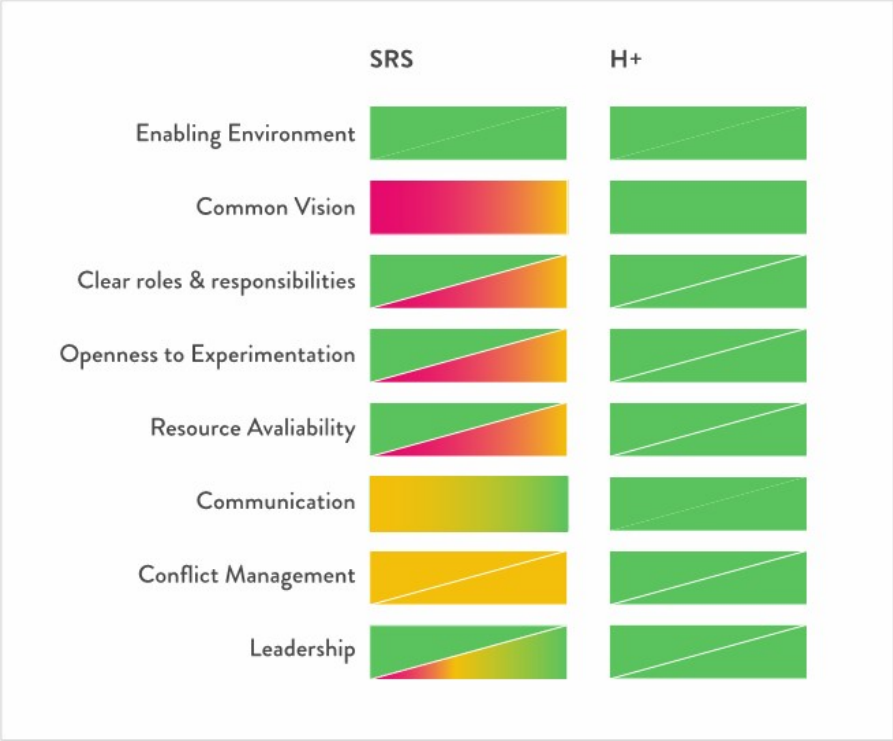
In Stockholm, on the other hand, the transition assessment showed a lack of common vision between the city and the utility in the establishment of a source-separating wastewater system, which probably has hampered the establishment of roles and responsibilities and resource allocation, or lack thereof, within the utility (Table 4 and Figure 2).

Table 4. Summary of results from the in-depth interviews related to the sustainability transitions framework (Table 2), based on responses from interviewees.

Sustainability transitions framework	Helsingborg	Stockholm
Enabling environment	The general policy on increased resource efficiency was taken up in 2009 and translated into a detailed policy in 2013.	The policy was adopted in 2010 and is very explicit on implementation of source separation for resource efficiency.
Common vision	The policy on source-separating wastewater systems involved the energy, waste and water utilities. In the course of an investigation phase, a common vision was created which was anchored in the top management of each utility. Land allocations to developers included requirements on source-separating wastewater systems.	During the first six years it was difficult to establish a platform to talk about a vision, possibly due to an earlier reorganisation of SVOA which considerably reduced their strategic unit. Since 2016, the process has been more open and positive, but the common vision on implementation of source-separating wastewater systems in SRS is still a work in progress.
Openness to experimentation	There is a genuine interest in sustainable development and what it requires in terms of experimentation.	The Development Administration is open to experimentation and has several times included requirements on source-separating wastewater systems in land allocation agreements with developers. The importance of the water utility's cooperation in such an endeavour is clear, but they have not been open to experimentation within this particular field.
Resource availability	Resources have been set aside, primarily to apply for external funding.	Resources have been and are made available by the Development Administration for applying for external funding, and for carrying out investigations and research activities to establish a common vision. Since 2016, the water utility has also made resources available for these activities.
Communication	The city has a culture of cooperation and networking between municipal entities. This has also been the case for the H+ project.	Communication between the city's administration and the water utility has been ongoing through studies and research projects. Since 2016, communication has been more open and constructive.

Conflict management	Differences of opinion have been resolved in working groups. The policy, the vision and the clear mandate of the water utility have been the backbone of all discussions.	Differences of opinion regarding the assignment are being discussed and resolved in a working group. Some strategic issues are passed upwards to the steering group which, since 2017, includes representation from the water utility.
Clear roles and responsibilities	Roles and responsibilities were defined early in the process. Assignments were delegated by the city director and accepted by the management of each utility.	The assignment of coordinating the environmental profiling was given to the city's Development Administration. Over the past several years, roles and responsibilities have been discussed with the water utility.
Leadership	Management at all levels and in each participating entity have been, and continue to be, very interested, supportive and proud of the process.	Management personnel in the Development Administration are interested and supportive. The water utility has started an anchoring process at the management level.

Figure 2. SRS and H+ score on critical factors in the transition management framework.



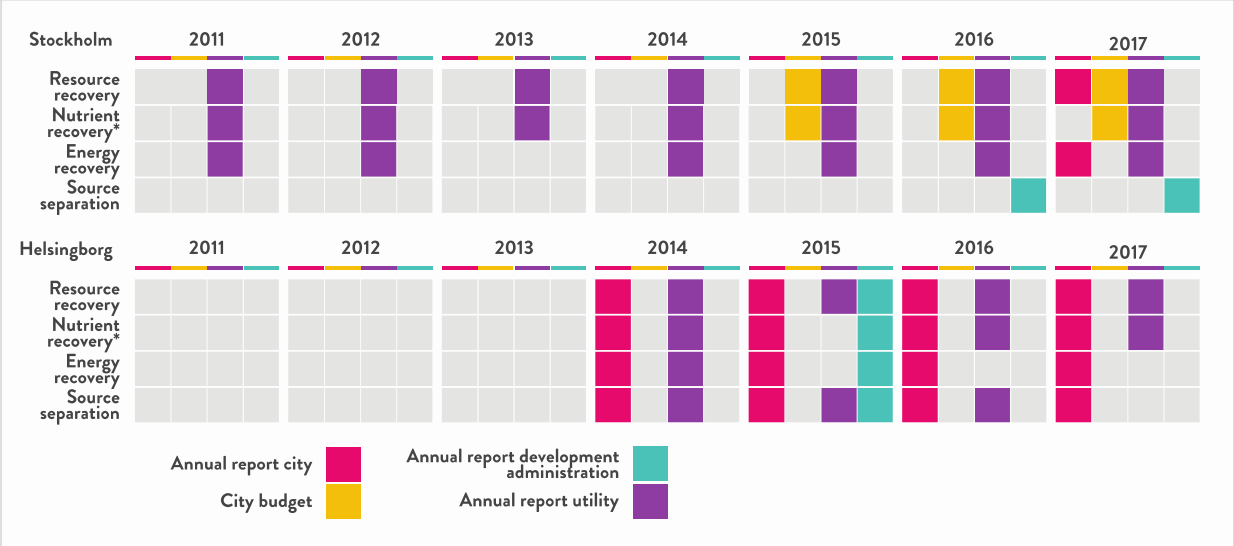
The overall coordination of the environmental profiling of SRS was assigned to the Development Administration (City of Stockholm, 2010) and has been carried out through a steering group consisting of the directors from the technical administrations. Through the steering group, administrations have taken on the assignments they have considered to be within their scope and allocated resources for their implementation. In terms of the goal of establishing a source-separating wastewater system, the

responsibility for implementation was unclear as the water utility had not been represented in the SRS steering group from the beginning, nor did they have an assignment in relation to goal implementation. The Development Administration has therefore been the driving force behind ensuring that the process continues. Since 2017, the water utility has been represented in the SRS steering group by the umbrella public company for all municipal utilities (Stadshus AB). It can also be noted that meetings and agreements between the water utility and the City of Stockholm during the last two years seem to have brought the two entities closer to a common vision of source separation in SRS, and hence may provide a potential foundation for an implementation decision for the last development phase of SRS.

Trickle-down of policy in implementation

A comparison between Helsingborg and Stockholm regarding the uptake of source-separation policy into city documents is shown in Figure 3. The mapping also includes the functions that source separation should achieve, i.e. resource recovery, nutrient recovery and energy recovery. It is clear from this study that the guiding policy document's formulations in Helsingborg (Table 3) are well reflected in both the city's and the water utility's annual reports, even though it can be noted that the policy did not include technology specifications in relation to wastewater systems. Instead, technical investigations showed source separation to be the most efficient system for achieving the environmental ambition outlined in the policy, which was then implemented.

Figure 3. Uptake of source-separating wastewater systems in city documents: A comparison between Stockholm and Helsingborg.



Stockholm

Although Stockholm's guiding policy goals on source separation as a technical solution to implement in SRS are explicit (City of Stockholm, 2010, 2017), there is no mention of source separation in any budget or annual report, with the exception of the Development Administration's annual reports from 2016 and 2017. They include a budget line for testing source separation which was noted to be moved to the following year.

SVOA, the Stockholm water utility, consistently refers to resource recovery in their annual reports. The introduction of each report states that the public utility is responsible for waste products and that they reuse the residues efficiently in a circular economy. Every year (with the exception of 2013) the

utility mentions their current production of biogas from wastewater and states that they recycle phosphorus in the form of certified sludge. In 2012 and 2014-2017, SVOA also refers to recycling of heat energy in the central heating system. On average, annual reports from the SVOA refer to resource recovery from wastewater three times per document, though none of these references relate to source-separating wastewater systems. Other documents from Stockholm only contain one reference to resource recovery per document.

The Stockholm City budget includes ownership directives to the municipal companies, including SVOA. Since 2015, the ownership directive for SVOA has stated that the utility should actively work to increase recycling of nutrients from wastewater, however there are no specific budget lines for doing so. Stockholm City's 2017 annual report includes references to the production of biogas from food waste and fat as part of its wastewater system, and to the Plus-Energy buildings in SRS that recycle wastewater. However, recycling of wastewater was never implemented in the Plus-Energy housing project, though recycling of heat from wastewater has been implemented (City of Stockholm 2018).

In interviews with key stakeholders in Stockholm, it was explained that the guiding policies and goals that have been ratified by the city council should be listed in the steering documents of the city's budget. If they are not listed there, they should not be prioritised. One possible reason for the lack of a common vision between the public utility and the city's Development Administration regarding implementation of source separation could therefore be the fact that the SRS policy documents related to the environmental profiling were, for unknown reasons, never included as steering documents in the city's budget. The inclusion of the SRS environmental policy in the 2011 (and later) budgets as a budget steering document would have provided an 'officiality' to the policy and would have allowed for more leverage for the Development Authority in its work to install source-separating wastewater systems.

Helsingborg

In Helsingborg, the annual reports from the city clearly follow the H+ environmental profile. The reports state that H+ is considered to be a role model for the future of Helsingborg, where innovative, source-separating solutions will yield a more effective capture of energy and cleaner nutrient products for recycling. The collaboration between the municipal utilities for water and waste management is mentioned, as is the city's involvement in research projects, such as the Vinnova-financed test bed, Urban Magma, and an innovation competition. In 2015, the Development Administration in Helsingborg mentions source-separating and resource-recovery (biogas and agricultural products) systems for wastewater in H+ only when they also mention the activities that they held that were connected to the innovation challenge "Food Waste and Blackwater Challenge". In all city budgets reviewed, there are specific budget lines related to the development of H+, but nothing specifically related to the wastewater system being developed. Every budget includes mention of and/or budget lines for building a cover over the existing wastewater treatment plant in order to make the development of H+ possible, however budgets mention nothing related to source separation or resource recovery. In relation to the term 'resource recovery', the water utility is explicitly mentioned, together with at least one other utility, in 7 of 16 references, which demonstrates the visibility in the documents studied of the multisector approach to resource recovery in H+.

Sweden Water Research, which is the R&D branch of the water utility NSVA, has also followed the vision laid out for H+. They have been involved in the innovation challenge and development of the test bed for treating source-separated food and wastewater flow streams. They have also been involved in a number of workshops/seminars with politicians, wastewater practitioners and farmers, which address source separation and resource recovery. It is interesting to note that annual reports from Sweden Water Research always mention resource recovery, but do not always specify whether it is energy or nutrients that will be recovered. For example, in 2015 the utility mentions involvement in the innovation challenge and test bed – which both aim at recycling source-separated wastewater – but mention no specific

purpose for which resources are recovered. Resource recovery and source separation are each mentioned an average of two times per annual report. In 2017, neither source separation nor energy recovery were mentioned in the utility reports.

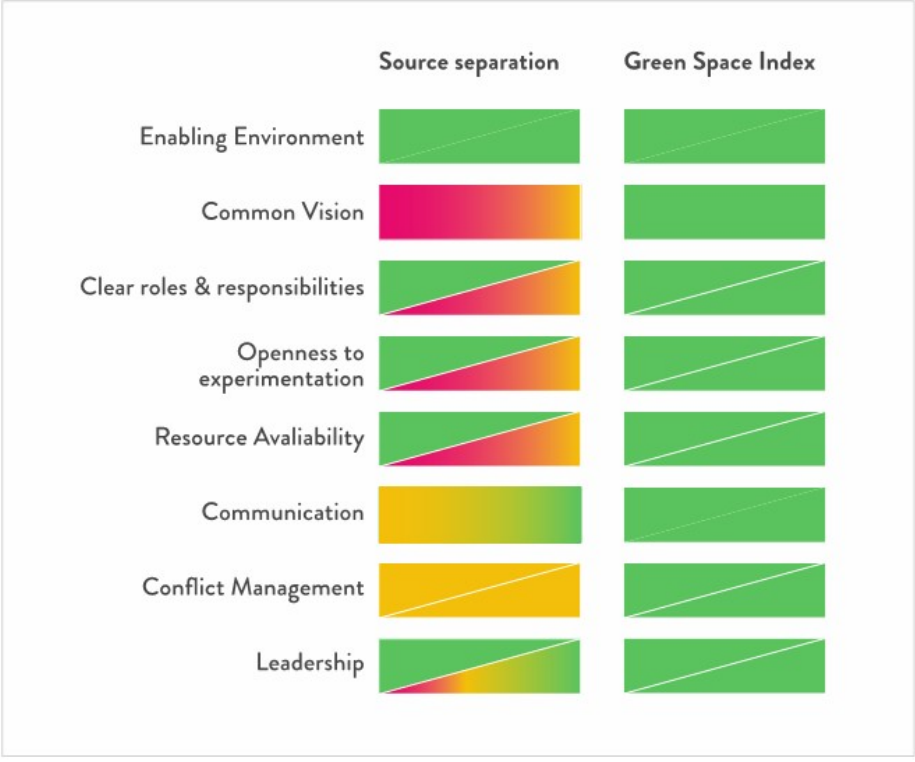
Internal comparison study – Green Space Index in Stockholm

Given the lack of uptake of the guiding policies on source-separating wastewater systems in Stockholm, it was decided to further investigate how the Green Space Index – another concept that was new to the city at the time of SRS's environmental profiling – has been reflected in Stockholm's annual reports and budgets. For triangulation purposes, analysis of the GSI followed the same sustainability transitions framework and policy trickle-down analysis that were used in the Stockholm-Helsingborg comparison.

Figure 4 shows the comparison of results from the sustainability transition assessment for GSI and source separation in Stockholm. The top triangle represents the assessment of the Development Administration and the bottom one that of the Environmental Administration, the two agencies that are jointly responsible for the implementation of the GSI. For the source-separation case study, the Development Administration is also assessed in the top-left triangle whereas the utility is in the bottom-right triangle. Colour gradients show the degree to which the function is fulfilled: red indicates a lack of functionality, yellow indicates that a process of establishing functionality is ongoing, and green indicates that functionality is in place.

Results from the transition assessment for GSI (Figure 4) show that, similar to the H+ case, the GSI policy has successfully met all the function criteria for transition. In particular, coordination between the responsible sector organisations has been successful for GSI and there has been a common vision between the two administrations from the start, which probably has positively influenced the implementation of the GSI in SRS and elsewhere in Stockholm.

Figure 4. Stockholm's score on critical factors in the transitions management framework, a comparison of source separation and GSI.



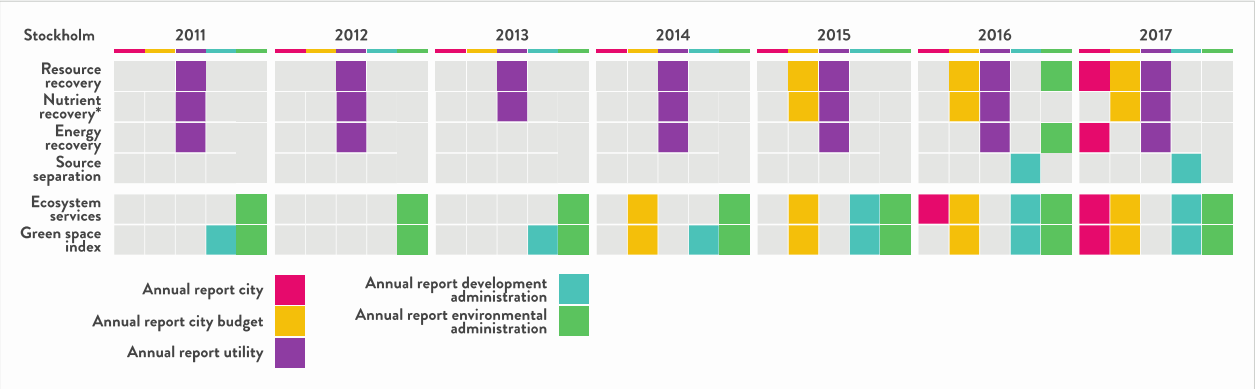
The policy trickle-down analysis (Figure 5) shows that GSI has been reflected both in the city's Development Administration and in its Environmental Administrations from the start of the environmental profiling. During 2011-2014, the GSI is referred to by the Development Administration as a tool for the environmental profiling of SRS. Since 2015, references to ecosystem services and the GSI in the annual report of the Development Administration have increased and are often linked to strategic initiatives in collaboration with other city administrations such as the Environmental, Traffic and Building Administrations. In these reports, ecosystem services or GSI are mentioned an average of four times per report.

The environmental department has had a clear focus on developing strategies and activities for ecosystem services and the GSI since 2011. Already in 2012, they were working to apply experience from using the GSI in SRS to other areas of the city. Environmental work relating to ecosystem services or the GSI are on average mentioned 10.5 times, or 3.6 times per report. Starting in 2011, the reports also mention external research funding for the development of tools for quantifying ecosystem services. This can be compared to Stockholm documents, which lack any mention of research funding for source separation studies despite the fact that the city has been involved in government-funded projects (for example, from the Ministry of Environment and Vinnova) for source-separation systems since 2011.

The GSI first appears in the city´s budget in 2014. Since then, the city budget refers to ecosystem services and the GSI on average 13 times, or 6.5 times per document. Stockholm City's annual reports start referring to ecosystem services in 2016, including a focus on strategic investment in green space. In 2017, the city's annual report includes the implementation of a new requirement for use of the GSI on all city land allocations.

Even though neither the Development nor the Environmental Administrations were officially assigned in the city budget to work on GSI, they have both used their own financial and external resources to develop strategies for ecosystem services. They have even proposed to the city council that they be given the assignment of developing the GSI tool as a means to expand the urban ecosystems services in all of Stockholm. Over time, both the concept and the tool have become integrated into the city's urban development plans. Since 2014, the concepts of ecosystems services and the GSI have taken a clear place in the city budget. Ecosystem services are included in guidelines for city planning and development, management of parks and stormwater, as well as in specific organisational goals for the Property Administration, Development Administration, Environmental Health Administration and municipal-owned real estate and housing companies. Starting in 2014, the city budget specifically states that the GSI should be developed for broader use within the city.

Figure 5. Uptake of source-separating wastewater systems and the Green Space Index in city documents: a comparison for Stockholm.



DISCUSSION

What drives a transition – Policy or people?

The guiding policy document for H+ Helsingborg is relatively vague in its formulation of goals, but even so the progress on source-separating wastewater systems has been steady. It is not possible to pinpoint the exact way in which the policy document has been steering towards the implementation decision, but through the interviews it can be concluded that commitment and leadership have been strong, giving a clear direction on how to proceed towards implementation. According to the interviews, the city director was instrumental in the decision and in the division of responsibilities between entities. The leadership within each entity has also appointed responsible people where necessary. Furthermore, the leadership has also been instrumental in overcoming internal resistance to change.

The first version of the Stockholm SRS policy document, on the other hand, was very specific in its goals. Even though it was ratified by the city council, it never became part of the city budget. This has resulted in a situation where its implementation has been left to specific municipal administrations – or even up to individuals – to carry the process forward. This becomes particularly clear when implementation of source separation is compared to the implementation of the GSI. An important aspect that contributed to the successful implementation of the GSI is that in the two responsible administrations there were inspired individuals in positions where they had the mandate, as well as the ability, to create a common vision. In addition, the administrations have both collaborated and contributed with their respective competences: the Environmental Administration through its ecologists, with their strategic perspective, and the Development Administration through the implementation perspective of its landscape architects. They were also in positions where they could explain the tool and the benefits of using it to their peers and their managers, thereby anchoring the tool and the process all the way up to their respective top managements.

In the case of source-separating wastewater systems in Stockholm, the Development Administration (which ensures that technical systems are included in the planning and construction process) and the water utility (as the future infrastructure owner), would have needed to cooperate to ensure that the goals were fulfilled. SVOA, the water utility, pointed out from the very beginning that without a formal assignment through their ownership directive they could not fully participate in the process. If SVOA had had a source-separation champion within its organisation in 2010, it is possible that we would have seen progress towards a common vision on how to fulfil the goals in relation to source-separating wastewater systems in SRS, in spite of the lack of specific ownership directives.

However, sustainability transition processes cannot be dependent only on champions, especially not in a larger municipality. Interviews with key stakeholders in Stockholm have also emphasised the importance of having stringent implementation processes and procedures in place in a municipality of Stockholm's size. (Stockholm's population in 2018 is 935,000, as compared to 145,000 in Helsingborg). All prioritised activities must be reflected in the budget and the implementation monitored through existing reporting systems. The larger the municipality the more important it is to have routines and processes in place that support transitions. However, even in a municipality the size of Stockholm, champions have kept the vision of source-separating wastewater systems going, guided by the SRS sustainability programme.

The Stockholm case shows that establishing a common vision can be very difficult, even if resources are dedicated to investigations and research activities whose purpose is to establish common ground. There must be a certain level of openness within the organisation that will receive, acknowledge and administer the results of these investigations. In order to anchor the vision, the findings then must be translated into messages that resonate with the organisations' overall assignment. This cannot be carried out only by policy, it requires people that understand and believe in the transition.

This study supports the earlier findings by Skambraks et al. (2017) that a successful implementation of source separation, and thus the maximisation of environmental gains, requires increased cooperation between the municipality and its utilities for water, waste and energy services.

Key drivers for source separation

The recovery of resources is a key driver of source-separating wastewater systems. Initially, the drivers for implementation of source-separating wastewater systems in both Helsingborg and Stockholm were to increase nutrient recovery and improve biogas generation. For Helsingborg, those drivers have been sufficient to carry the process forward towards implementation. In Stockholm, however, those drivers have not been convincing enough either for the Environmental Administration or for the water utility. As can be seen in Figure 1b, the investigatory phase has continued in Stockholm, under which more knowledge has been generated. With the help of new knowledge, new drivers have also surfaced, which have strengthened the support from both the Development and Environmental Administrations. Investigations into energy recovery from source-separated greywater have concluded that the heat that can be recovered from greywater at source can make a significant contribution to fulfilling another goal: a fossil-fuel-free energy system. It is possible that this additional driver will be what is needed to gain full political support for source-separating wastewater systems in Stockholm.

Qualitative cost and revenue/savings overview for source-separating wastewater systems

Implementation of source-separating wastewater systems will, as seen in Table 1, generate costs and benefits that, in turn, will translate into costs, revenues and savings outside the jurisdiction of the water utility. Figure 6 illustrates the qualitative assessment of how these costs and revenues/savings for implementation of source-separating systems are distributed between stakeholders. Red indicates net costs, green indicates net benefits, and yellow indicates no change in cost or benefits.

Figure 6. A qualitative costs and revenues/savings assessment.

The qualitative assessment indicates increased costs both on the developer and the utility level, but also the possibility of increased revenues/savings for both types of actors. Moreover, Figure 6 shows that the source-separation systems provide societal gains (see Table 1 for these societal benefits), which are not accounted for in a business model for a utility or a developer. From a sustainable development perspective where optimisation of societal benefits is desired, it is difficult to see how 'simple' business models for each stakeholder can be used. Figure 6 hence underlines the absolute necessity of cross-sectoral cooperation and decision-making on high levels (i.e. above the utility level). In this way, it is possible to avoid sub-optimisation within the wastewater sector in relation to its contribution towards overall sustainable development and maximised societal benefits. Introducing source-separated wastewater systems represents a paradigm shift that requires initial societal support, as do most large changes in infrastructure. This is not new to the Swedish wastewater sector. For example, the tertiary wastewater treatment that took off in 1970 is a result of national funding that was made available for the reduction of phosphorus emissions to receiving waters. National guidance and incentives need to be developed to support decisions and investments in source-separating wastewater systems on the municipal level.

Continued process

As of the end of 2018, Stockholm has not yet taken a decision to implement source-separating wastewater systems. Over the past few years, feasibility studies for source-separated systems in Stockholm have been performed, especially through the MACRO project (2016-2018), where the water utility SVOA together with the city authorities have cooperated with Helsingborg (among others) in investigating legal, organisational, technical feasibility and optimisation potentials, as well as economic aspects. This process has shifted the positions of key stakeholders in Stockholm in terms of working towards a common vision, and has resulted in an application for external funding to develop necessary documentation to implement source-separating wastewater systems in the last development phase of SRS.

CONCLUSIONS

The Helsingborg case reveals several factors that have made implementation of source-separating wastewater systems possible: 1) a common vision between the city administrations and the water and waste utilities, 2) cross-sectoral cooperation, 3) strong leadership, and 4) a focus in both the utilities and the city administrations on innovation. However, the interviewees point out that the common vision between the city and the utilities is the function that was most critical to the other supporting functions falling into place.

Transition can happen when the identified and communicated benefits resonate with the organisational assignment, leading them to accept a vision for change. Increased biogas generation and improved nutrient recycling are the main drivers for the source-separating wastewater system in Helsingborg. In Stockholm, it is possible that the improved heat recovery from greywater at source is the additional driver needed to gain full political support for source-separating wastewater systems.

At this stage, the costs for source-separating wastewater systems are higher than for conventional systems, but the associated benefits are also considerably larger. Since the benefits generated are mainly societal, implementation decisions cannot be based on traditional business models that are generally only focused at the utility level. New business models need to include other actors that have a stake in both the costs and benefits. Decisions that are so intimately connected to sustainable urban development thus need to be made and coordinated at the highest municipal levels, not on a utility level.

If Sweden is to continue to be a leading example of first-class wastewater treatment, it will need to transition more thoroughly to a circular economy – a transition that requires a common vision and coordinated policy action. Additional funding must be made available for the extra investment costs, as

it was for previous improvements in the wastewater sector in Sweden. Moreover, national guidance and incentives need to be developed to support decisions and investments at the municipal level.

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