Source separation: How Ready in the Swedish Wastewater Sector for Technology Transition?

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Abstract
Source-separation has been applied in small-scale and decentralized wastewater systems in Sweden for the past 25 years. The Swedish experience with source separating systems is relatively well documented; however, few reports have specifically studied the potential for up-scaling this innovation. The aim of this study is to fill this knowledge gap by assessing the status of source-separating technologies in Sweden based on a transition theory perspective. This study uses a multi-level perspective to determine how ready the Swedish wastewater sector is for transitioning to alternative systems. Barring an unforeseen crisis within the macro-landscape or existing wastewater regime it seems unlikely that changes within these levels will lead to a transition to source separation. Instead, the initiative must come from the niche itself, exploiting institutional cracks in the regime and opportunities from shifting trends in the landscape. If source-separation is to be mainstreamed in Sweden it will need to break into markets within the wastewater jurisdictions. In order to do so, further knowledge needs to be developed that will overcome glitches with immature technologies, investigate potential risks, and clearly define system advantages. This may require the use of new costing perspectives that focus on holistic sustainable use of resources, including other nutrients than phosphorous. There is also a strong need for improve knowledge dissemination regarding best-practices for implementing source-separation technologies and supporting organisational structures. Similarly, support for entrepreneurial activities within the niche needs to increase, not least through strengthening social networks and communication platforms.

Keywords
Innovation, Resource recovery, Source separation, Transition, Wastewater

INTRODUCTION

Given the global environmental crisis and resource crunch there is an increasing need to consider all waste products as potential resources. The paradigm shift to waste reuse has started with many experts calling for greater resource recovery (Guest et al., 2009; Larsen et al., 2009). At the same time, there are significant limitations to promoting reuse within conventional waste and wastewater systems at the global scale (e.g. existing infrastructure lock-in and difficulties to optimize recovery from systems designed with a different purpose, i.e. for reduction of water emissions of organic matter and nutrients from the wastewater). Source separation has been shown to be advantageous for contributing to food security and improving the capacity and efficiency of treatment plants (Borsuk et al., 2008; Cordell et al., 2011; Jönsson, 2001). However, it is often ignored or dismissed in urban planning processes and is not widely applied in urban settings today.

Source-separation has, however, been applied outside existing wastewater jurisdictions using on-site wastewater systems in Sweden for the past 25 years. The Swedish experience with source separating systems is relatively well documented, both from national synthesises (Johansson et al., 2009; Vinnerås and Jönsson, 2013) and reports from specific cases. However, few reports have studied the relative strength of this innovation and its potential for integration within the existing urban wastewater sector.

The aim of this study is thus, to fill this knowledge gap by assessing the status of source-separating technologies in Sweden based on a multi-level perspective to technology transition and identify where there may be "windows of opportunity" to scale-up implementation and potential transformation pathways for improving resource management on a larger scale in urban areas. The study is based on the assessment of niche cases where source-separation has been implemented within Swedish municipalities, a rapid assessment of the existing Swedish wastewater regime, and critical macro-environmental factors affecting both the niche and regime.

METHODS

This study uses a multi-level perspective (Geels, 2002) to transition theory to assess the status of source-separating technologies for wastewater treatment in Sweden. These systems must be understood as socio-technical systems in which technical infrastructure interact with users and organizations. Therefore, the assessment includes aspects which relate to both hardware (e.g. toilets, tanks, trucks) and software (e.g. organizational structure, user attitudes, regulations). Since one of the aims of these systems is to return nutrients to agriculture, the system boundaries are set to include the user interface, collection system, transportation, treatment, and reuse. The geographical boundaries of each system generally correspond with municipal boundaries.

The multi-level perspective highlights three layers, the micro-, meso- and macro-levels of technological systems. The meso-level is called the regime and is represented by the existing dominate system of water-borne sewers within existing wastewater jurisdictions. Analysis of the regime brings in institutional issues (Fuenfschilling and Truffer, 2014) and certain aspects from a Technology Innovation System (TIS) approach (Bergek et al., 2008). The micro-level or niches represent areas of new development and radical innovation, in this case source-separation systems. The niche is assessed through applying a TIS lens to case studies of 8 Swedish municipalities with source-separation systems outside existing wastewater jurisdictions. The macro-level is the background landscape and consists of slow-changing trends which influence the other level. It is analysed using a STEEPLED approach (McConville et al., 2014).

RESULTS

Niche analysis

The performance of source-separation wastewater systems as a technical niche in Sweden was assessed using a TIS methodology in a parallel study based on 8 Swedish municipalities using these technologies. In general, it should be noted that the niche market for source-separation in Sweden is on-site systems which are outside the wastewater jurisdiction. There are a few cases of functional systems for urine diversion within wastewater jurisdictions, but these are mainly within schools or "eco-villages". The analysis assessed critical functions which affect how innovations develop (Bergek et al., 2008; Hekkert et al., 2007): knowledge development, entrepreneurial activities, legitimation, market formation, resource mobilization, and guidance of the search. Since previous sociotechnical studies of wastewater systems have highlighted the need for communication channels and participatory arenas between stakeholders (Fam and Mitchell, 2013), the function "development of social capital" was added to this analysis.

Considering that source-separation is still in a development phase, the study found that source separation works moderately well within the on-site niche and that blackwater systems in general perform better than urine diversion. Although Sweden has been the leading country in knowledge production related to urine diversion, and among the top 10 countries regarding nutrient recovery and source separation, knowledge development is still a major barrier for up-scaling these systems. This is because it has ripple effects in multiple other functions. For example, a major barrier for urine diversion has been technical problems with the toilets which have led to a decreased level of acceptance (legitimation) of the system. These technical problems are a result of immature technology and a function of weak knowledge development, but also inadequate entrepreneurial activity (e.g. a few small-size entrepreneurs) for ironing out uncertainties; these are of course influenced by resource mobilization and guidance of the search. Consequently, market formation and resource mobilization for source separating systems is weak, although not unreasonably so considering that these technologies have not reached a growth phase for development. There are few toilet models available, especially for urine diversion, and financing for infrastructure development has been limited.

Aside from technical challenges with immature technology, all of the studied cases have struggled with difficulties organizing the entire system from collection to reuse. These difficulties include establishing logistical systems for e.g. collection and transport, but also discrepancies in policy interpretation in the different municipalities and division of responsibility between stakeholders. Establishing an effective organisational structure is also made difficult as the recycling chain includes many actors, and several key actors (e.g. farmers, politicians) tend to be risk adverse, thus creating a barrier for both acceptance (legitimation) and development of social capital. There is some evidence that this may be changing as social capital, legitimation and guidance of the search are moderately strong functions in the more recent cases. Several correspondents in the study suggested that strengthening the currently weak advocacy coalitions could increase social capital, encourage entrepreneurs and also argue for the legitimacy of source separation beyond niche markets.

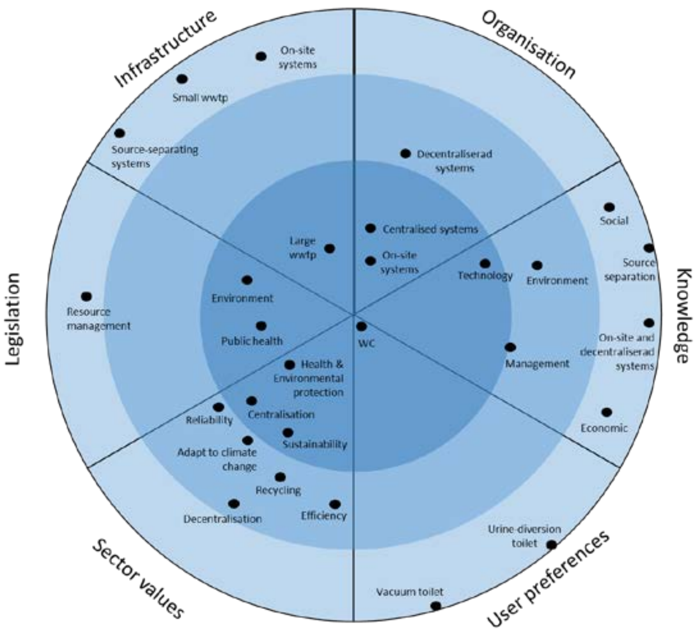

Figure 1. Structuration of the wastewater and sanitation regime in Sweden in 2016. Positions of the symbols represent the degree of institutionalization: the closer to the centre of the circle, the stronger its institutionalisation.

Regime analysis

Socio-technical regimes are characterized by inertia and self-stabilizing effects, thus representing significant barriers to the diffusion of alternative technologies (Binz and Truffer, 2009). The methodology used in this analysis is based on the premise that opportunities for innovation and change are greatest when the existing regime is destabilized (Geels and Schot, 2007) or weakly institutionalized (Fuenfschilling and Truffer, 2014). Assessment of each dimension thus attempts to determine how stable and institutionalised it is. For example, the existence of one dominant organizational form would indicate that this particular dimension is highly institutionalized and thus has a strong resistance to change. On the other hand, a diversity of sectoral values could indicate tension and the potential for changing interpretations. The analysis covers six dimensions of socio-technical regimes which have been identified by other researchers (Fuenfschilling and Truffer, 2014; Geels, 2005): technological infrastructure, organization and financing, techno-scientific knowledge, user preferences & norms, sector values and legislation (Figure 1). Information to evaluate these dimensions was collected from a variety of sources, including national statistics, national policy documents, literature and expert interviews.

Infrastructure. Approximately 91% of the Swedish population is connected to a municipal wastewater treatment plant and a majority of them (85%) are connected to large treatment plants serving more than 2000 person equivalents (SCB Statistics Sweden, 2014). Smaller treatment plants for between 25-2000 pe are estimated to treat 6% of wastewater (SCB Statistics Sweden, 2014). The remainder of the population is connected to on-site systems for single households or community systems for <5 households. Of these the most common systems are combinations of septic tanks and infiltration (approximately 5% of population), while around 2% of the population have permanent dwellings with on-site systems which source-separate urine and/or blackwater (Ek et al., 2011). Source-separation systems serving multiple households do exist, but are quite rare. Existing centralised and conventional waterborne infrastructure is thus highly institutionalized. Since wastewater infrastructure tends to have long service lifetimes, this creates a significant rigidity in the regime.

Organisation and financing. Organisational structures for wastewater management in Sweden are closely related to infrastructure and in general are highly regulated. The Public Water Services Act (LAV: *lag om allmänna vattentjänster* in Swedish) requires that municipalities provide communal water and wastewater service in areas where it is needed to protect public health and/or the environment. In these cases the municipal council defines the area as part of the wastewater jurisdiction and thus it falls under the responsibility of the wastewater utility. The utility is responsible by law for building, operating and maintaining the communal infrastructure. Utility operations are required by LAV to be self-financing through user fees. The large and small municipal wastewater treatment plants which serve over 90% of the population are all within defined wastewater jurisdictions and thus subject to LAV. Wastewater utilities in Sweden are normally operated by the municipality or a municipal-owned company. In either case, they are regulated by the same legislation regarding service provision. Residents within the jurisdiction are required to pay the service fees and follow the utility's requirements for water and wastewater installations.

Outside the wastewater jurisdiction, it is the responsibility of the individual household to assure that they meet the requirements set in legislation for the management of water and wastewater. All discharge of wastewater requires a permit, thus households are required to obtain a permit from the municipality and regularly control that their wastewater system meets code. Correspondingly, the environmental authority at the municipality is required to inspect and regulate wastewater systems outside the jurisdiction, as well as small plants within the jurisdiction. All costs for implementation and operation of on-site systems are considered the responsibility of the household. However, municipalities have sometimes been known to subsidize upgrading of on-site systems, including source-separation. This has generally been done when municipalities have received money from county or national level for such projects. Decentralised systems where several households together build and operate a wastewater treatment system is also fairly common. Legally, these community systems have the same obligations as individual households to meet legislative requirements and obtain a discharge permit. However, the management organisations of these community systems can differ depending on how the individuals involved decide to organise themselves; ranging from informal collaboration to formal association management.

In general, organisational forms regarding centralised systems within the wastewater jurisdiction and individual on-site systems are highly institutionalized with legislation governing roles and responsibility of the actors involved. Decentralized systems with multiple households outside the jurisdiction are still subject to the same legislation, but there appears to be a greater flexibility for structuring the management organisation. In addition, decentralised systems often fall into a grey zone regarding the applicability of LAV and hence the municipality’s role within these systems is more adaptable. Several municipalities are currently exploring alternative management structures for areas with on-site and decentralized systems.

Knowledge. Knowledge trends in the Swedish wastewater and sanitation sector were mapped based on an evaluation of publications produced in Sweden during the period 1995-2015 (source Scopus). Of course, a large amount of knowledge is found in grey literature and in Swedish reports which are not reflected in this study. Themes related to centralized vs decentralized treatment, source separation, and different sustainability factors were chosen to try to capture the diversity of knowledge that may be produced in the sector. These key word searches were then compared to the total number of publications in the sector. The majority of publications were related to technologies (77%). However, management (66%) and environment (60%) were also dominant trends in Swedish publications. Publications related to decentralized and on-site systems represented 3% and 5% respectively for total knowledge produced. Economic and social issues were relatively common at 20%, respectively 15% of the publications. However, publications related to source separation and urine-diversion represented just 2% and 3% of publications, respectively (blackwater had even less). The small amount of knowledge being produced for alternative systems indicates that the majority of knowledge production is still related to conventional wastewater treatment processes and plants. However, since 2012 there has been a trend in Sweden, as well as globally, with an increasing number of publications related to resource and nutrient recovery. If this trend continues it may contribute to a destabilization this dimension of the regime.

User preferences & norms. Positive user attitudes and acceptance is a prerequisite for widespread diffusion of technologies(Rogers, 2003). However, a major challenge for source separation systems is offering a competitive alternative to the regime standard of a WC. In Sweden, there is a clear preference for flush toilets, with approximately 99% of the population connected to a WC (SCB Statistics Sweden, 2014; Wallin et al., 2013). Many consider that an alternative toilet may be acceptable in a vacation house, but at home people want the convenience of a flush toilet (Swedish EPA, 1997; Wallin et al., 2013).

Management of human excreta is an issue that evokes strong emotions and avoidance reactions in all cultures. Conventional flush-and-forget technologies have achieved widespread acceptance because they allow for the physical and mental avoidance of this subject (Lienert, 2013). Alternatives to the standard WC system will need to provide an equivalent level of comfort, convenience and cleanliness if they are to gain widespread acceptance. This is predominantly an engineering and design challenge; however, it will need to be coupled with good arguments and motivators for changing user habits and preferences. Sociological research on source separation technologies indicates that users are surprisingly open to these new technologies, especially if they are well-informed of the benefits (Lienert and Larsen, 2010). Understanding the reasons for the success of the WC and including users in the design process is likely the key to developing successful alternatives. This is exemplified in the most enduring urine diversion systems in Sweden which have been collectively designed, implemented and organised by the users (Fam and Mitchell, 2013).

Sector values. Assessment of dominant values in the Swedish wastewater sector was done based on analysis of policy documents from a selected number of municipalities. Municipal water and wastewater policies in Sweden are non-binding documents which clarify strategic choices, priority issues and set guidelines; thus representative documents for assessing the values driving decisions. A sample of 35 municipalities was chosen, representing 29% of the total Swedish population, 12% of total municipalities, and including municipalities from 20 of the 21 counties. The documents were coded in an iterative process in which stated values were streamlined and aggregated into common themes. Protection of health and environment are the most dominant values with all policies referring to one or both of these goals (83% refer to both). Sustainability (71% of policies), adaptation to climate change (66%), and closed-loop systems for water and nutrients (63%) are also popular values coming from an environmental good logic.

Aside from environmental values and recycling, there are also strong values which are more representative of public and economic good logics which can be in conflict with environmental good, e.g. system reliability (66%) and resource efficiency (60%). A potential conflict also exists between valuing expansion of the centralized wastewater system (71%) and support for decentralized solutions (51%). This analysis indicates strong environmental values within the regime and a willingness within half of the municipalities to explore alternative options to centralization. However, there are also strong values driving decisions based on economic efficiency, risk reduction, and maintenance of existing infrastructure (60%). There appears to be significant tension and room for debate within regime value structures.

Legislation. Swedish legislation related to wastewater management covers three generations of regulatory development with different focuses: health protection, environmental protection, and resource management (Christensen, 2015). Regulations regarding wastewater management from a health perspective have existed in Sweden since the 1860s with the primary aim to protect public health. The first environmental regulations related to wastewater came in 1942 and were strengthen in in environmental protection laws in 1969 which were coupled to national support for construction of municipal wastewater treatment plants. The current Swedish Environmental Code (EC: Miljöbalken in Swedish) from 1999 is a compilation of fifteen previous health and environmental acts, thus building on previous legislation and layering new laws in concord with the previous ones (Christensen, 2015). The EC also contains the first Swedish regulations requiring resource management, emphasizing recycling and efficient use of natural resources (EC chapter 2 §5). Since 2006, the Swedish Environmental Protection Agency's EC guidelines for on-site sanitation are based on the best-available technology (BAT) principle, instead of prescribing specific technologies. In parallel to the EC, sixteen National Environmental Quality Objectives were established in 1999. Recirculation of natural resources (including plant nutrients) was part of these objectives and one of the targets stated that by 2015 at least 60% of phosphorus compounds present in wastewater would be recovered for use on productive land (this target was removed in 2012 when the objectives were revised). In addition, as a member of the European Union, Sweden follows European Water and Wastewater Directives and the non-binding policy goals of the EU 7th Environment Action programme (2013) which also specifies resource management as a goal for 2020.

The requirements for resource management set in the EC are worded to be on-par with the goals set for environmental and health protection with no difference in their degree of applicability. However, the regulations related for resource management are rarely applied today and there has been surprisingly little precedent related to this regulation after 17 years. The few precedents that exist highlight the difficulty of applying this legislation. For example, strictly speaking, recycling of nutrients from wastewater is not a function of the collection and treatment system, but rather of the fact that a farmer uses them in agriculture to replace other fertilizers. However, there is a Catch-22 moment in the regulation where on one hand the courts have ruled that a municipality cannot make demands for, e.g. source-separating systems, if there is no recipient for the collected nutrients, while on the other hand a farmer cannot legally be forced to use a product (e.g. source-separated urine) that is not available on the market. Municipalities are thus in the difficult position where they must manage a waste, but control neither the production stage (household toilet) nor the recycling stage (farmer). An additional complication is that source-separated wastewater fractions are classified as household solid waste and thus the responsibility of the municipal waste management department (often separate from the municipal wastewater department). This separation of legal responsibilities makes organisation of the service chain difficult. On the other hand, the Planning and Building Act (2010) gives municipalities the ability to single-handedly decide on the spatial planning and infrastructure development in the local situation, but this is hardly ever used to enable closed-loop approaches for wastewater systems.

In general, Swedish wastewater legislation can be seen as highly institutionalized, particularly with regards to health and environmental standards. However, the legislative system has been built up over more than 150 years in different legislatives based on the needs of society at the time. As a result, there is a certain lack of coordination between laws, resulting in gaps, overlaps and sometimes contradictions. In particular, legislation related to resource management is relatively new and untested in the courts. While there are significant challenges to ironing out gaps, precedent and contradiction in this third generation of legislation, there are also still, after 17 years, opportunities for new interpretations.

Table 1. STEEPLED factors with the potential to impact on technology transitions in the Swedish wastewater sector. Factors in bold are judged to be most likely opportunities (green) or threats (red).

Social	***Technological***	***Economic***	***Environmental***
Changing environmental awareness	**Innovation at WWTPs**	**Economic recession**	**Environmental disasters**
Dietary trends (e.g. meat consumption)	**Innovation in source separation technologies**	**Fertilizer shortage**	Deteriorated agricultural conditions
Waste handling practice, e.g. separation	Parallel innovations in other sectors	**Tax/subsidy policies**	Impacts of nutrient emissions
Media influence		Purchasing power	Water shortage
Political	***Legal***	***Ethical***	***Demographic***
Internal conflicts	**Fertilizer regulations**	**Precautionary principle**	**Urbanisation**
Knowledge bias of decision-makers	**Stricter pollution legislation**	Sustainability ethic	Local population growth
International agreements	Green procurement		Increasing immigration
Time frame of politicians			

Landscape analysis

The landscape level is defined by a diverse set of macro-environmental factors such as, energy prices, economic growth, conflicts, demographic trends, politics, cultural and normative values, environmental conditions, etc. In this framework, mapping of this macro-level will be aided by use of a STEEPLED analysis (originally known as PEST analysis). It covers Social, Technological, Economic, Environmental, Political, Legal, Ethical and Demographic factors that can influence the socio-technical regimes and niches. The list is derived from previous studies (Larsen et al., 2010; McConville et al., 2014) and adapted to the Swedish context based on the combined experiences of the authors.

A number landscape factors represent potential opportunities for source separation to grow. Environmental awareness is already quite high in Sweden which does not seem to have created more space for the niche. A recent survey found that 100% of Swedes feel that protecting the environment is personally important for them (European Commission, 2014). However, changes in how individuals understand environmental impacts and their own role as consumers can change and potentially drive alternative system choices. For example, mainstreaming of the circular economy movement might have this affect. Knowledge dissemination channels such as formal media and other ITC actors will play a crucial role here. In addition, innovations in source-separation technologies, e.g. vacuum systems, methods for concentrating fertilizers, would support the niche. Similar to environmental awareness, fertilizer shortages and the phosphorous crisis of 2008-2009 did not provide the expected boast to source separation. Again, however, this could change if the shortage is of longer duration or in relationship to other nutrients that are less easily extracted from mixed wastewater, such as nitrogen (N) or potassium (K). Stricter pollution and climate legislation, including reduced emissions of pharmaceuticals and pathogens, and perhaps coupled with tax/subsidy incentives could also support the niche. For example, taxes on high-energy processes like N-fixation or increased N-removal requirements could make source-separation economically competitive. The strong urbanisation trend and accompanying housing shortage in Sweden also creates opportunities for innovation in new building stock; and several cities are currently experimenting with urban source separation (Stockholm, Helsingborg).

Several landscape factors also represent threats to the expansion of source separation. For example, competing innovations which efficiently recover nutrients from WWTPs would reduce the need for source separation (this is already the case for P-recovery). Economic recessions or environmental disasters can lead to lack of funding for environmental projects or funds redirected to other needs. For example, flooding will likely distract resources away from sanitation in order to assure e.g. drinking water quality and protect existing infrastructure. Existing fertilizer regulations also pose barriers to up-scaling source separation, e.g. current EU regulations forbid the use of human excreta in organic farming which limits markets for reuse products. Similarly, ethical precautionary principles and risk aversion from key actors in closing the loop impede the spread of such technologies. For example, in spite of quality assurance large parts of the food industry in Sweden refuses to acceptance reuse from certified products, such as treated blackwater.

DISCUSSION

While source separation works moderately well within on-site niche markets outside of wastewater jurisdictions in Sweden, there may be significant challenges mainstreaming these technologies for use within wastewater jurisdictions. It is estimated that there are 700,000 on-site wastewater systems in Sweden and that 30% of these are vacation homes (Ek et al., 2011). Although this is not an insignificant market, especially considering the export potential to billions of on-site sanitation users around the world, it is a limited market compared to centralized systems. If source-separation is to be mainstreamed in Sweden it will need to break into markets within the wastewater jurisdictions. In order to do so, further knowledge needs to be developed that will overcome glitches with immature technologies, investigate potential risks, and clearly define system advantages. This may require the use of new costing perspectives that focus on holistic sustainable use of resources, including water and other nutrients than phosphorous, and taking into account global issues such as planetary boundaries (Steffen et al., 2015). Increased water scarcity due to climate change may well support such costing models. This knowledge can then be used to establish guidelines, norms and standards, as well as clarify the legislative structures that can support such a transition. There is also a strong need for improve knowledge dissemination regarding best-practices for implementing source-separation technologies and supporting organisational structures, both outside and within wastewater jurisdictions. Source separation can offer more flexibility in the extension of communal wastewater services, something that many municipalities are now looking for in high-density rural areas where LAV requires municipal service provision; but this requires clarifying new organisational models. Similarly, support for entrepreneurial activities within the niche needs to increase, not least through strengthening social networks and communication platforms.

At the regime level the dominance of centralized wastewater treatment plants is support by the strong institutionalization of infrastructure, organizational structures, legislation, and user preferences. The strong degree of institutionalization in this system makes it resistant to change. These findings are in line with previous research (Wallin et al., 2013) and perhaps unsurprising considering that the WC has been the dominant technology in urban Sweden for nearly a hundred years. An exception here is on-site and decentralized systems where the regime is less rigid. There is also more variance in sectoral values and types of knowledge produced. These dimensions indicate potential tension within the sector about primary aim of the sector (e.g. public vs. environmental good) and a diversity of problem-solving approaches. In addition, the issue of resource management, both as a value and a legal obligation, is very weakly institutionalized and subject to interpretation. This analysis would therefore suggest that key opportunities for mainstreaming the niche lay in exploiting these weak points in the regime – that is alternative organisational structures (e.g. decentralization) and changing values regarding resource management, efficiency and recycling. However, this will need to be done using technology that provides equivalent user convenience to the standard WC. Given good arguments for change people are willing to be environmentally friendly if it is not too complicated, too time-consuming, or too expensive (Lienert and Larsen, 2010).

The landscape level does not appear to be applying strong pressure to the regime; however, there are a number of factors that may, if current trends continue, create pressure for change, e.g. increasing public environmental awareness; fertilizers shortages; stricter environmental regulations and incentives, especially regarding medical residues, other micro-pollutants and pathogens; and urbanisation. Many growing municipalities want to build in attractive areas near sensitive waterways, but water and wastewater services must first be improved. Thus economic growth and expanding urban areas can push municipalities to try innovative solutions. However, based on the strength of the current regime, it is deemed unlikely that any of these factors alone will push regime actors to quickly adopt source-separation. However, they are issues that niche actors could use to craft messages that would support expansion of the niche.

Barring an unforeseen crisis within the landscape or existing wastewater regime it seems unlikely that changes within these levels will lead to a transition to source separation. Instead, the initiative must come from the niche itself, exploiting institutional cracks in the regime and opportunities from shifting trends in the landscape. This paper has highlighted opportunities to strengthen the niche from within and advocacy arenas (trigger points) for potential expansion of source-separation within the regime.

REFERENCES

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008. Analyzing the functional dynamics of technological innovation systems : A scheme of analysis. *Res. Policy* **37**, 407–429.

Binz, C., Truffer, B., 2009. Leapfrogging in Infrastructure Identifying transition trajectories towards decentralized Urban Water Management Systems in China, in: DRUID Conference. Copenhagen.

Borsuk, M.E., Maurer, M., Lienert, J., Larsen, T.A., 2008. Charting a Path for Innovative Toilet Technology Using Multicriteria Decision Analysis. *Environ. Sci. Technol.* **42**, 1855–1862.
Christensen, J., 2015. Juridiken kring vatten och avlopp. Havs- och vattenmyndighetens rapport 2015:15, Göteborg, Sweden.
Cordell, D., Rosemarin, A., Schröder, J.J.J., Smit, A.L.L., 2011. Towards global phosphorus security: a systems framework for phosphorus recovery and reuse options. *Chemosphere* **84**, 747–758.
Ek, M., Junestedt, C., Larsson, C., Olshammar, M., Ericsson, M., 2011. Teknikenkät - enskilda avlopp 2009. Sveriges Meteorologiska och Hydrologiska Institut, Norrköping, Sweden.
European Commission, 2014. Attitudes of Europen citizens towards the enviroment, Special Eurobarometer 416.
Fam, D.M., Mitchell, C.A., 2013. Sustainable innovation in wastewater management: lessons for nutrient recovery and reuse. *Local Environ.* **18**, 769–780.
Fuenfschilling, L., Truffer, B., 2014. The structuration of socio-technical regimes—Conceptual foundations from institutional theory. *Res. Policy* **43**, 772–791.
Geels, F.W., 2005. Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. *Technol. Forecast. Soc. Change* **72**, 681–696.
Geels, F.W., 2002. Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Res. Policy* **31**, 1257–1274.
Geels, F.W., Schot, J., 2007. Typology of sociotechnical transition pathways. *Res. Policy* **36**, 399–417.
Guest, J.S., Skerlos, S.J., Barnard, J.L., Beck, M.B., Daigger, G.T., Hilger, H., Jackson, S.J., Karvazy, K., Kelly, L., Macpherson, L., Mihelcic, J.R., Pramanik, A., Raskin, L., Lossdrecht, M.C.M. Van, Yeh, D., Love, N.G., 2009. A New Planning and Design Paradigm to Achieve Sustainable Resource Recovery from Wastewater. *Environ. Sci. Technol.* **43**, 6126–6130.
Hekkert, M.P., Suurs, R.A.A., Negro, S.O., Kuhlmann, S., Smits, R.E.H.M., 2007. Functions of innovation systems: A new approach for analysing technological change. *Technol. Forecast. Soc. Change* **74**, 413–432.
Johansson, M., Kvarnström, E., Stintzing, A.R., 2009. Going to Scale with Urine Diversion in Sweden – From Individual Households to Municipal Systems in 15 Years, in: 1st IWA Development Congress. Mexico.
Jönsson, H., 2001. Urine separating sewage systems – environmental effects and resource usage. *Water Sci. Technol.* **46**, 333–340.
Larsen, T.A., Alder, A.C., Eggen, R.I.L., Maurer, M., Lienert, J., 2009. Source Separation: Will We See a Paradigm Shift in Wastewater Handling? *Environ. Sci. Technol.* **43**, 6121–6125.
Larsen, T.A., Maurer, M., Eggen, R.I.L., Pronk, W., Lienert, J., 2010. Decision support in urban water management based on generic scenarios: The example of NoMix technology. *J. Environ. Manage.* **91**, 2676–2687.
Lienert, J., 2013. High acceptance of source-separating technologies – but ..., in: Larsen, T.A., Udert, K.M., Lienert, J. (Eds.), Source Separation and Decentralization for Wastewater Management. IWA Publishing, London, UK, pp. 193–208.
Lienert, J., Larsen, T.A., 2010. High acceptance of urine source separation in seven European countries: a review. *Environ. Sci. Technol.* **44**, 556–66.
McConville, J.R., Künzle, R., Messmer, U., Udert, K.M., Larsen, T.A., 2014. Decision support for redesigning wastewater treatment technologies. *Environ. Sci. Technol.* **48**, 12238–12246.
SCB Statistics Sweden, 2014. Discharges to water and sewage sludge production in 2012 Municipal wastewater treatment plants, pulp and paper industry and other industry. Stockholm, Sweden.
Steffen, W., Richardson, K., Rockström, J., Cornell, et al. 2015. Planetary boundaries: Guiding human development on a changing planet. *Science* (80-.). 347.
Swedish EPA, 1997. Kretsloppsanpassade avloppssystem i befintlig bebyggelse (in Swedish) (No. Report No 4847). Swedish Environmental Protection Agency, Stockholm, Sweden.
Wallin, A., Zannakis, M., Molander, S., 2013. On-Site sewage systems from good to bad to...? Swedish experiences with institutional change and technological dependencies 1900 to 2010. *Sustain.* **5**, 4706–4727.
Vinnerås, B., Jönsson, H., 2013. The Swedish experience with source separation, in: Larsen, T.A., Udert, K.M., Lienert, J. (Eds.), Source Separation and Decentralization for Wastewater Management. IWA Publishing, pp. 415–422.