



## Research article

# Legitimacy of source-separating wastewater systems with Swedish water utilities

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## ABSTRACT

Nutrient management is one of the critical challenges for developing sustainable circular economies in cities. Nutrients such as nitrogen and phosphorus from our food end up in our wastewater and pose an environmental threat when they are released in waterways. Yet, these nutrients are essential for crop production and food security. Hence human excreta contains the bulk of nutrients going through the urban ecosystem. Source separation of excreta from the rest of urban wastewater flows can enable safe and efficient nutrient recovery. Yet, source-separating wastewater systems are not yet common in urban areas. The aim of this study is to assess the legitimacy of source-separating wastewater systems from the perspective of wastewater professionals in Sweden. The study uses interviews and a survey to explore the pragmatic, normative, cognitive and regulatory dimensions of legitimacy and how these aspects can vary between different municipalities. Finally, it looks into possible knowledge-based activities to increase legitimacy. The results from this study show variations in legitimacy levels in urban areas in Sweden. Overall opinion appears to be neutral to the concept rather than negative. Although many see multiple barriers to implementation. Normative legitimacy (moral motivation) was relatively high, while cognitive legitimacy (knowledge & experiences) was lowest. Respondents from organizations where source-separation is being implemented, or they believe that it will be implemented within 10 years, generally saw more drivers and fewer barriers. These innovators were also more interested in knowledge-based activities. Overall recommendations to increase cognitive knowledge regarding source-separating systems among multiple stakeholders seems the most promising path forward to increase legitimacy in the Swedish wastewater sector.

## 1. Introduction

Cities and urban areas are powerhouses for economic growth, and as of 2022, 55% of the world's population live in cities (UN-HABITAT, 2022). However, to be sustainable, cities have to minimize their resource use and develop circular models, including recovering local wastes (EEA, 2015). Safe and efficient circularity needs to consider all waste streams in an urban ecosystem as valuable materials (Mohan et al., 2020), including organic matter, heat, water, and nutrients. Urban wastewater contains not only water and energy, but also the bulk of nutrients going through the urban ecosystem. In Sweden, 84% of nitrogen (N) and 77% of phosphorus (P) entering cities ends up in municipal wastewater (Wivstad et al., 2009).

Source-separating wastewater systems are a possible solution to

improved nutrient management. These systems separate and treat different wastewater streams independent from each other, e.g., grey-water collected separately from excreta, feces, and urine. Source separation increases the potential for nutrient recycling and biogas production (Kjerstadius et al., 2015; Larsen et al., 2009), offers more efficient treatment/removal of micro-pollutants (Lienert et al., 2007), and reduces risk for eutrophication by five times compared to conventional wastewater treatment (Malila et al., 2019). In addition, it reduces emissions of pathogens to receiving waters (Nordzell and Soutukorva, 2018), reduces carbon footprints (Kjerstadius et al., 2017), saves water and lead to postponed reinvestments in existing infrastructure (Kvarnström et al., 2022).

While source-separating wastewater systems have been used for on-site sanitation in Sweden since the 1990s, implementation in urban

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areas has been slower (McConville et al., 2017). Yet recently, there is renewed interest in urban source-separating wastewater systems, and several larger-scale projects within urban wastewater jurisdictions have emerged. The city of Helsingborg, Sweden, has installed a system with three different wastewater pipes for greywater, blackwater and food waste which serves 450 apartments, an office building and a hotel in the urban renewal project of H+ (NSVA, 2021). In a similar project, driven by visions of a circular economy, a blackwater separation system with local treatment of black- and greywater has been built at Jenfelder Au in Hamburg, Germany, which serves 835 apartments (European Commission, 2021). Urban projects with local treatment and use of source-separated wastewater can also be found in San Francisco, USA (San Francisco Public Utilities Commission, 2021), France (Joveniaux et al., 2022), Belgium and Germany (Skambraks et al., 2017).

Given the renewed interest in new wastewater treatment systems it is important to understand current attitudes within the sector towards these systems. Legitimacy is the perception that the actions of an entity or technology are desirable or appropriate within the socially established worldviews, norms, beliefs, and definitions of roles of users, regulators, and engineers (Binz et al., 2016). It thus encompasses the acceptability of a solution and whether it is seen as a reasonable option in terms of compatibility with organizational structures, regulations, and technologies. Whether an option is reasonable or not also depends on how decision-makers perceive the drivers and barriers associated with the option (Hekkert et al., 2007). Legitimacy is both multi-dimensional and dynamic as it changes during the development process (Bergek et al., 2008a). In order to understand the potential for future up-take of source-separating wastewater systems, we need to better understand what makes it legitimate.

Previous studies of acceptance and legitimacy of source-separating wastewater systems have largely focused on on-site systems or the concept of recycling human excreta. A multi-country study on recycling human urine as fertilizer found that 68% of respondents were positive to the concept (Simha et al., 2021). Social acceptance for implementing on-site, source-separating wastewater systems in Sweden has generally been favorable, ranging between 70 and 83% acceptance (McConville et al., 2017). A review of urine source-separation projects in seven European countries showed that a majority of users found the systems acceptable (Lienert and Larsen, 2010). While all of these studies provide a picture of existing legitimacy for source-separating wastewater systems for on-site sanitation, there are few studies that have investigated legitimacy for these systems at a larger scale in urban areas.

The aim of this study is to assess the legitimacy of source-separating wastewater systems from the perspective of wastewater professionals in Sweden. By source-separating wastewater systems, we mean systems that separate either toilet water (blackwater) or urine from other wastewater fractions. The study has targeted employees and decision-makers at Swedish wastewater utilities in order to understand how and why decisions are made in relationship to the implementation of source-separating systems. The specific objectives of this study are to:

- Understand what aspect of source-separating wastewater systems are perceived as legitimate by Swedish utilities (*multi-dimensionality of legitimacy*)
- Explore how views on drivers and barriers for implementation of source-separating wastewater systems vary between different Swedish utilities (*dynamic aspects of legitimacy*)
- Identify knowledge and activities needed to increase the legitimacy of source-separating wastewater systems (*pathways*)

## 2. Theoretical frameworks

In order to explore the multi-dimensional and dynamic aspects of legitimacy, we use two main frameworks for this investigation: dimension of legitimacy and a synthesized list of common drivers/barriers for source-separation.

### 2.1. Dimensions of legitimacy

Legitimacy is a key concept in sociology and institutional studies. It is particularly important for socio-technical systems, such as wastewater management, where technology development is reliant not only on technology, but also on knowledge flows, cultural support, and connections to organizational structures (Suddaby et al., 2017). Studies of socio-technological innovations systems point at the need to establish belief in the system and cultivate a supportive network of actors before systems can be brought to scale (Bergek et al., 2008a). During the early development phases of an innovation, legitimacy plays a critical role in influencing the fulfillment of primary functions, such as knowledge development, diffusion, and entrepreneurial activity. Additionally, gaining legitimacy is imperative for emerging technologies in order to overcome resistance to change (Hekkert et al., 2007). Legitimacy is created by raising expectations about the technology's potential, often through assessment studies, and finding supportive actors (Bergek et al., 2008b). In later phases of growth, supportive actors may influence the institutional legitimacy through collective action and lobbying.

Organizational studies identify three primary forms of legitimacy: *pragmatic*, *normative* and *cognitive* (Suchman, 1995). Pragmatic legitimacy is founded on a calculated self-interest that weighs the capacity of the organization (e.g., time, knowledge, money) against the perceived risk. Openness to change and innovation will affect risk-taking strategies and the level of pragmatic legitimacy awarded to a system by certain actors (Binz et al., 2016). Normative legitimacy is founded on societal judgments about what is morally right or wrong, e.g., the standards of correct behavior. Within the sanitation sector, these norms may be felt as moral obligations for protection of health and environment. At the same time, norms are strongly linked to cultural hygiene habits and what may reasonably be demanded in terms of behavior change from users or within an organization. Cognitive legitimacy is formed by past experiences and knowledge of technology. Established systems have a high degree of technology lock-in, partly due to taken-for-granted assumptions about how systems should be designed. Lacking prior experience, people are likely to be skeptical of new technologies and demand a high level of proof before abandoning practices that are known to work.

An additional pillar of legitimacy that is critical for systems that must operate in accordance with legal rules is the *regulative* dimension (Binz et al., 2016). Systems that conform to existing laws, regulations, and policies will have a high degree of legitimacy, while systems that requires regulative changes will be less legitimate. Technological legitimacy can thus be categorized based on four key dimensions (Table 1). The introduction of innovations into existing structures may be confronted with legitimacy challenges in one or more of these dimensions (Binz et al., 2016).

### 2.2. Drivers & barriers for source-separating wastewater systems

Drivers and barriers to change are linked to legitimacy and the ability of innovations to overcome resistance to change (Hekkert et al., 2007). In a case where barriers dominate people's mental models, the emerging technology will not be able to gain momentum and legitimacy to take off. How decision-makers perceive the drivers and barriers thus influence whether source-separation is a reasonable (legitimate) choice or not. Common drivers and barriers (risks) for source-separating wastewater systems have been summarized from the experience of the Swedish MACRO project that has documented processes for the development of source-separating systems in urban areas (Kvarnström et al., 2022).

## 3. Methods

The study uses semi-structured interviews and a questionnaire to gather information on the different dimensions of legitimacy, the

**Table 1**  
Dimensions of legitimacy adapted from Binz et al., (2016).

	Pragmatic	Normative	Cognitive	Regulative
Definition	The self-interested calculations of an organization, based on direct utility of the technology.	The role of social and moral obligations.	Pre-conscious, taken-for-granted understandings of organizations or technologies	In alignment with policies, rules, and legal obligations.
Characteristics	Capacity of organization, financing, risk-taking	Organizational culture, values, habits & norms	Technology, knowledge, assumptions & experiences	Policy guidance
Motivation	Self-interest	Social obligation	Taken-for-grantedness	Politically correct
Basis of legitimacy	Personal/organizational evaluation	Morally governed	Comprehensible	Legally sanctioned
Affect	Utility/Indifference	Pride/Shame	Certainty/Confusion	Innocence/Fear, Guilt

strength of specific drivers & barriers for source-separation, and possible pathways for strengthening the legitimacy of source-separating wastewater systems.

### 3.1. Expert interviews

Semi-structured interviews were performed with 10 experts in order to gain a deeper understanding of the multi-dimensionality of legitimacy. Interviewees were purposefully selected to represent key sector interest organizations at a national level and municipal wastewater utilities known to have varying experience of source-separating wastewater systems within the wastewater jurisdiction (Table S1 in SI). Representatives from nine utilities were interviewed, plus one representative for Svenskt Vatten, the sector association that represents all water and wastewater organizations in Sweden. Three of the interviewed utilities are either implementing source-separation (1) or planning for implementation (2). Two utilities have looked at source-separating wastewater systems in strategic planning in recent years and the remaining four have not considered source-separation within their jurisdiction. The interviewed utilities have connected person-equivalents (pe) that vary from around 70,000 to 1,500,000.

The interviewees were asked to respond from their organization’s perspective rather than their personal opinions. The interview guide included questions regarding organizational experience with source-separating wastewater systems and specific questions relevant to each of the four categories of legitimacy (see interview guide in SI). Interviews were transcribed close to verbatim, and were sent to each interviewee for review and approval.

Interviews were coded for content with regards to the four dimensions of legitimacy. The questions asked for each legitimacy type, and which questions were coded, are available in the SI (S1.2 in SI). Support for source-separation was coded on a scale from “high” (dark green) to “not at all” (red). The orange color was used for “I don’t know” answers. Missing answers are represented by white. Results are presented as the number of answers (green, red etc.) in relation to the total number of coded questions asked for the legitimacy category. Responses to questions that were not coded were used as qualitative data to support the findings. Suggestions for knowledge and activities needed to increase the legitimacy of source-separating wastewater systems were coded as they arose during the interviews.

### 3.2. Practitioner questionnaire

An online survey (Qualtrics survey software) was designed to capture practitioner attitudes towards the legitimacy of source-separating wastewater systems within the wastewater jurisdiction. Fifteen multiple-choice questions covered topics regarding demographics of the participants, level of interest from the municipality regarding source-separation, drivers and barriers, visions for future development and interest in knowledge-related activities (see S.4). Specifically, questions were asked about the state of implementation of source-separating wastewater systems in urban areas in the municipality today and where the respondent believes the municipality will be in 10-years.

Respondents were asked to respond from their organization’s perspective unless the question specifically asked for a personal opinion. The survey was distributed through the newsletter of Svenskt Vatten (national sector association for water organizations) and directly to 290 municipalities through their public contact email (asking them to forward the survey to the appropriate contact). The survey was started by 83 people, and completed in 66 cases (N = 66).

Analysis of the survey results focused on demographic variables and responses regarding barriers, drivers and interest in activities. First, responses to the survey were analyzed for effects of demographic variables using chi-square tests. Second, respondents were divided into groups based on the existing state of source-separating wastewater systems in their municipality and how they envisioned the future of source-separation in 10-years. In naming these groups we apply adopter categories from diffusion of innovation theory (Rogers, 2003). Accordingly, Innovators plan to have source-separating wastewater systems in operation in ten years, Early adopters will have made the decision to implement within the same timeframe, the Early majority has started investigating the issue, but do not expect a decision within ten years, while the Late majority are currently not discussing it but believe they will start investigating in the next 10 years. Finally, the Laggards do not believe that there will be any discussion of source-separating wastewater systems in their municipality. Dividing the analysis in this way allows us to analyze possible differences in attitudes and interest in activities between the groups. Differences between groups was checked for statistical difference with chi-square tests.

## 4. Results

Results from the interviews and questionnaire are presented below. The interview results are presented according to the four legitimacy categories, while the questionnaire results are presented according to drivers, barriers and knowledge needs linked to legitimacy within organizations.

### 4.1. Interviews

The interview results are summarized in Fig. 1 and further analyzed per legitimacy category. The figures are based on subsets of coded questions, but replies on non-coded questions are also included in the text below.

#### 4.1.1. Pragmatic legitimacy

Pragmatic legitimacy was based on eleven questions, plus follow-up questions, related to organizational capacity, financing, risk-taking and cooperation. For the pragmatic legitimacy assessment there is an even spread between issues ranked as “high” legitimacy and as “not-at-all”. Most “not-at-all” were found for the category *capacity* and *cooperation*, whereas the “high” assessments were more evenly spread out between *risk*, *financing* and *cooperation*.

For *capacity*, the utility implementing source-separating wastewater systems said that access to the right human resources is more challenging than access to funds. For the two utilities planning for source-

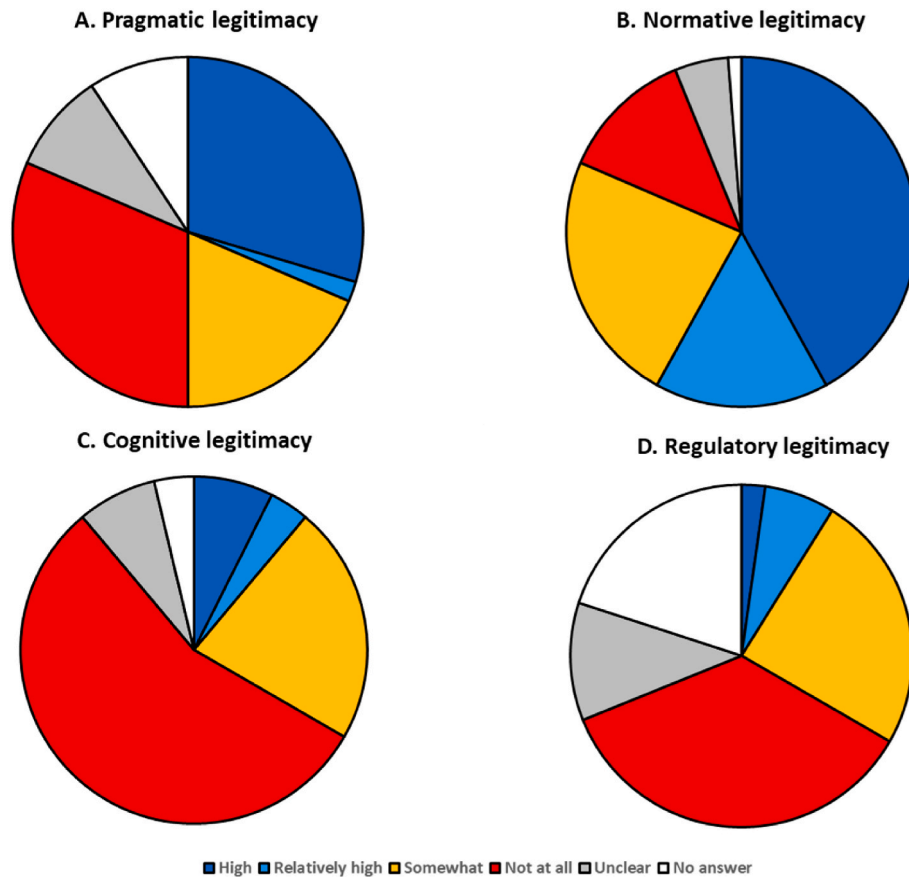


Fig. 1. Legitimacy of source-separating wastewater systems in nine Swedish utilities with respect to four dimensions. A) Pragmatic legitimacy (based on six coded questions and 54 data points), B) Normative legitimacy (based on nine coded questions and 72 data points), C) Cognitive legitimacy (based on three coded questions and 27 data points) and D) Regulatory legitimacy (based on five coded questions and 45 data points).

separating systems it was commented that one utility had just enough capacity to move forward, and the other utility said that it is more challenging to get the organization fully on board rather than the capacity per se. The remaining six interviewees all said they did not have capacity within their respective organization.

For *financing* we asked whether source-separating wastewater systems could be financed within their normal financing mechanisms. Four answered “yes”, one “yes, probably”. While no one said “no”; the remaining five made reference to the need for additional financing for such projects, and/or to uncertainty of whether source-separating wastewater systems can be considered “necessary costs” and therefore be included in the tariff.

To assess *risk* we asked whether there is any opposition against source-separating systems within their organizations. Four interviewees said there is no opposition within their organizations, two somewhat and three that there is opposition. Two interviewees mentioned that there is more interest in source-separating systems in younger staff. One interviewee mentioned that there are differences in acceptance for the systems between the utility and the municipality. Another interviewee explained that opposition was not against the technology per se, but related to the lack of knowledge for implementation. One interviewee mentioned that there is not really opposition, but rather healthy skepticism with their operational staff, which has diminished with increased experience and reduced operational problems.

In the final category, *cooperation*, we asked how important cooperation is for source-separating wastewater system projects and eight out of nine answered “very important” and one “somewhat”. Five of the organizations have been involved in cooperation projects to advance knowledge about source-separating systems. On the question whether

existing cooperation networks are sufficient to advance source-separating wastewater systems one out of nine answered that implementation without the existing networks would be difficult, one that the networks need to be expanded, five answered “no”, and three that they do not know. It was commented that networks bringing utilities together with their respective city planning departments are needed.

#### 4.2. Svenskt Vatten’s perspective: pragmatic legitimacy

The interviewee thought that Svenskt Vatten currently has enough capacity related to source-separating wastewater systems, although it had not worked actively to obtain it. However, this capacity needs to increase over time in order to be able to support its members. They were of the opinion that a shift is needed in the sector regarding responsibilities: “... it can be compared with stormwater, which can be said not to be the water utility’s responsibility, or the utility can assume that responsibility and put itself in the driving seat because the utility will benefit from stormwater management. We can compare that with source-separating wastewater systems. We can say it is not our responsibility, or we can see that source-separating can allow for resource-efficiency and decrease the pressure on existing infrastructure and that is excellent. Maybe we have a cultural shift that is slowly happening.” When asked about resistance within the organization towards source-separating wastewater systems the interviewee answered no, but that there is a sound discussion around challenges with the systems.

##### 4.2.1. Normative legitimacy

Normative legitimacy was based on eight questions, plus follow-up questions, related to organizational values and culture, as well as



attitudes. The normative legitimacy was assessed as relatively high, since more than half the answers were coded as either “high” or “relatively high” (Fig. 1B).

For *organizational values* it was found that seven out of nine interviewees thought that their internal goals support implementation of source-separation systems to a high degree; one thought the goals support to a relatively high degree and one said that the goals neither support nor hinders source-separating wastewater systems. All respondents in this study said that there are challenges with the current system. Fast growing cities coupled with aging infrastructure is putting pressure on the utilities to upgrade, improve or expand on existing wastewater treatment plants. Many utilities face a lack of capacity in the wastewater networks and/or treatment plants. At the same time, pipe networks need replacement. Utilities also worry about increasing demands for nitrogen removal and potentially removal of pharmaceutical residues and other micro-pollutants. Finding competent staff can also be difficult. On top of this, climate change is increasing risks for flooding and combined sewer overflows. Four out of nine respondents thought that source-separation can be one solution to these challenges and thus in-line with organizational mandates, two thought that they might, one said no, one did not know and one did not answer.

For *organizational culture* we asked about research and innovation and the expected level of implementation of source-separation in ten years' time. All respondents answered that they work with research, innovation and/or development to some degree. However, only about half of the respondents have an internal structure for this work. Three mentioned that they think that implementation of source-separation would be harder than other innovations, making reference to the infrastructure changes and demands for cooperation. One respondent thought it is not more difficult with source-separation than the other innovations. In the responses to the question whether the municipality will have implemented source-separation within ten years, five out of nine respondents leaned towards “yes, definitely” or “yes, probably”. Only one respondent answered that they definitely would not be implementing source separation in the next ten years.

Questions about *attitudes* were asked in the introductory questions. Five out of nine respondents were positive or very positive to source-separating wastewater systems, two moderately positive, one skeptical (due to lock-ins in the existing system) and one did not know. For the utilities implementing, planning or investigating source-separating wastewater systems there was a larger degree of interest both in the organization and with the interviewees for source-separating wastewater systems compared to in the four remaining utilities. According to all respondents, their respective organization has views similar to their own, but they generally rated the organizational view a notch down from their own acceptance (e.g. a respondent who answered very positively has an organization with a positive view, etc.).

#### 4.3. Svenskt Vatten's perspective: normative legitimacy

In the Svenskt Vatten interview it was stated that the organization is positive to source-separating wastewater systems in new developments, but that it is harder to implement in existing cities. Traditionally, Svenskt Vatten's focus has been on conventional and centralised systems, yet they recognize the need to provide for support source-separating wastewater systems, e.g. publications and advice. Source-separating wastewater systems fits within Svenskt Vatten's overarching goals (creating the best conditions for its members to assume their responsibility in terms of sustainability, cost effectiveness, delivery of water-related services and contributing to societal development), even if Svenskt Vatten has not yet included the concept in its core activities. Svenskt Vatten has, however, been participating in research and development projects focusing on source-separating wastewater systems. “Circular systems” is a prioritized area in their development platform, yet they see that responsibility for circular systems lies not only on the wastewater sector: “... *The question cannot only be pushed*

*from the water utility perspective. It has to be a part of the urban planning, the urban development perspective needs to be there for it to work.”. The respondent felt that there would be standards available for source-separating wastewater systems in ten years' time.*

##### 4.3.1. Cognitive legitimacy

Cognitive legitimacy was based on six questions related to knowledge & experience with source separation. More than half of the questions for cognitive legitimacy were assessed with a low level of legitimacy (as “not at all”), Fig. 1C.

Only one of the interviewed utilities has practical *experience* of implementation of source-separating wastewater systems. They pointed out that their knowledge has been acquired through learning-by-doing throughout planning, implementation and now during operation and maintenance of the system. Another interviewee stated that they have knowledge, but it sits with few individuals, making the organization vulnerable.

Lack of *knowledge and information* range from technical implementation (e.g. treatment methods for source-separated fractions and requirements for operation & maintenance), to strategic decision-making support (e.g. broad systems analyses, investments and operation costs, cost/benefit studies, etc.). There is also a lack of information regarding aspects on the building side of the connection point (e.g. responsibilities of building owners, installation codes, odor, blockages, etc.), and consequences on the utility side of the connection point, such as decreased flows. The implementing water utility mentioned that there is generally very low knowledge of how to implement a source-separating wastewater system, from installations in the building to treatment of separate flows, including authorities responsible for issuing permits and their general understanding of the system. This low level of knowledge generates obstacles and challenges throughout the planning and implementation, which has been their biggest hurdle to overcome. At the same time, they see their role as part of creating this knowledge: “*There is a lack of knowledge regarding what is needed for the systems to work well, and that knowledge one cannot get without implementing*”.

#### 4.4. Svenskt Vatten's perspective: cognitive legitimacy

The interviewee pointed out that Svenskt Vatten has basic knowledge about source-separating wastewater systems through some of its employees. However, the knowledge level on source-separating wastewater systems is low in society at large, including in the water sector in Sweden. The interviewee thought that this low knowledge level is connected to a generally low level of understanding of the resources there are in wastewater, which in turn connects to acceptance issues. The sector needs to think about how we communicate around the resources in wastewater. The knowledge that needs to be gathered and disseminated should include technical aspects, but also organizational forms since source-separating wastewater systems demand more cooperation. It should be noted that several of the other interviewees saw Svenskt Vatten as an important vehicle for spreading knowledge by providing, e.g. technical handbooks and courses.

##### 4.4.1. Regulatory legitimacy

Regulatory legitimacy was based on six questions, plus follow-up questions, related to policy guidance and legal processes. The regulatory legitimacy was assessed as low (more than half of the answers were assessed as “not at all” or “somewhat”); and about 30% of the answers were “unclear” or “no answer” (Fig. 1D).

Regarding *policy support/guidance* seven of the nine interviewees answered that there is a definite need for national policy support. Many interviewees had suggestions for policy support that should be developed, including national goals of nutrient recycling, support for implementation, legal advice, and national incentives to make the municipal actors utilities, city planning and development work together.

Regarding *legal processes*, it was mentioned that the existing

regulations do not prohibit source-separating wastewater systems in urban areas, however it is not promoting it either. Two utilities mentioned that the existing regulation and legislation are supporting source-separating wastewater systems as they see it, but the support has not yet been tried in court. In particular, four interviewees underlined the need to get court rulings (legal praxis) on what is meant with “necessary costs” in the water legislation (a water utility can only transfer “necessary costs” to the water tariff according to the Swedish water legislation). While praxis is lacking, the permit process related to source-separating wastewater systems with county boards was mentioned as problematic due to low levels of knowledge. In contrast, three interviewees pointed out that utilities have decisive power over their technical systems beyond the connection point via the utility-specific local regulation (ABVA), which could thus provide legislative legitimacy. However, as one interviewee mentioned, utilities tend to play it safe and stay with the conventional approaches to avoid appeals and hence avoid testing new interpretations of the legislation. To overcome this, one utility saw that the whole water legislation should be seen as outdated and revised from the current focus on emission concentrations to recovering resources. This sentiment was reflected by another interviewee who pointed out the importance of taking care of resources, irrespective of where the legal responsibility for the resource lies: *“To provide a recycled water for non-potable use is not a standard solution in Sweden today; it is important to think about forms for this. I think that if we challenge the legislation a bit and provide a recycled water for non-potable use; as long as the solution gets installed it will be difficult to take it away, even if it might be that the responsibility will have to be moved to another actor. It is important to take care of the resources even if the responsibility does not fall under the water utility in the long-term”.*

4.5. Svenskt Vatten’s perspective: regulatory legitimacy

The interviewee thought that there are no direct regulatory barriers against implementation of source-separating wastewater systems, but also no support to stimulate their implementation. The utility-specific local regulation (ABVA) was mentioned as a tool that can be used to indirectly set requirements on technology choice for developers in new, urban developments.

4.6. Practitioner questionnaire

All respondents to the survey were employed at either a municipality (13 respondents), a water utility (36 respondents) or both (17

respondents). Municipally-owned utilities are common in Sweden which may explain that respondents checked multiple answers. The majority of respondents had worked less than 5 years at their organization (29 respondents). Others had worked between 5 and 10 years (17 respondents), 10–20 years (14 respondents) and over 20 years (6) respondents. There were 39 women, 25 men and 2 people preferred not to state a gender. No statistically significant relationship was found between any of the demographic variables and the respondents’ opinions about source-separating systems.

The majority of respondents felt that they had a moderate (30 respondents) or low (25 respondents) level of knowledge about source-separating systems. Only seven had a large amount of knowledge and four had no knowledge. Approximately half knew of a source-separating wastewater system implemented in an urban environment (34 respondents), with the majority mentioning Helsingborg, Sweden (26 respondents).

Respondents were asked about the current situation in their municipality with regards to source-separating wastewater systems and what they thought the situation would be in ten years (Fig. 2). Respondents to the survey can be divided into five groups based on how they envision the development of source-separating systems. The majority of the organizations currently have no discussion about source-separation (78%). Respondents in approximately half of these organizations do not expect the situation to change in the next ten years (Laggards: 34%). In 40% of the cases, respondents thought that the issue would start to be investigated (Late majority). Of those currently investing the idea, 9% felt that it would still be under investigation in ten years’ time (Early majority). Six respondents predicted that there would be a decision to build source-separating wastewater systems taken in the next ten years (Early adopters: 9%). All five respondents with current decisions or plans to implement (Innovators: 8%) felt that they would have a system in operation in ten years. Note that this distribution of adoption groups does not follow a normal bell curve, but is skewed towards the later adoption groups (Fig. 2). A positive correlation was found between the amount of knowledge that individuals have on source-separating wastewater systems and their belief in how far the municipality will have come in implementing source-separation in the next ten years.

There does not appear to be a dominant driver for source-separating wastewater systems (Fig. 3). A majority of respondents found that all factors were at least moderate drivers for implementation. Not surprisingly, the strongest drivers are those that are connected to the core activities of the utilities, i.e. water and nutrient management as well as public health. Drivers that are relatively weak are related to climate

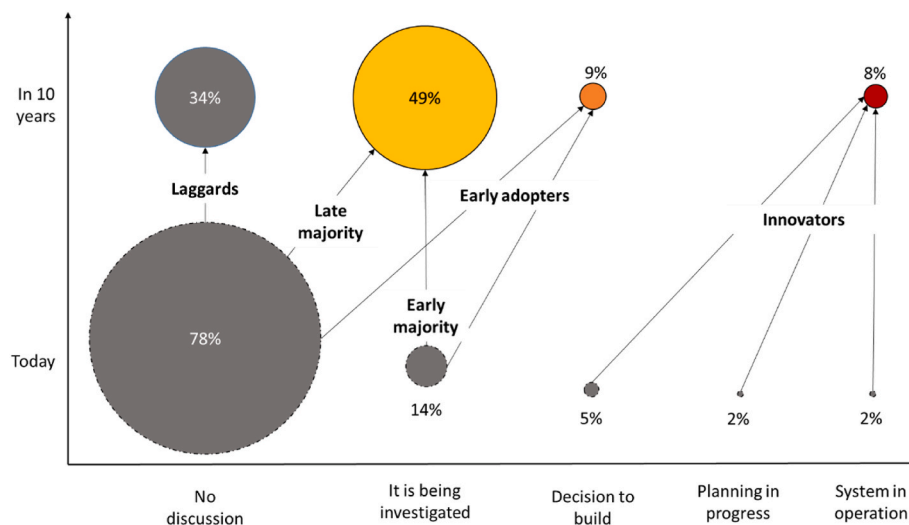


Fig. 2. Adoption groups used in the analysis based on belief in future development of source-separating wastewater systems. Arrows show how respondents answers shifted from today to the situation in ten years’ time. Note: only 65 respondents answered these two questions.

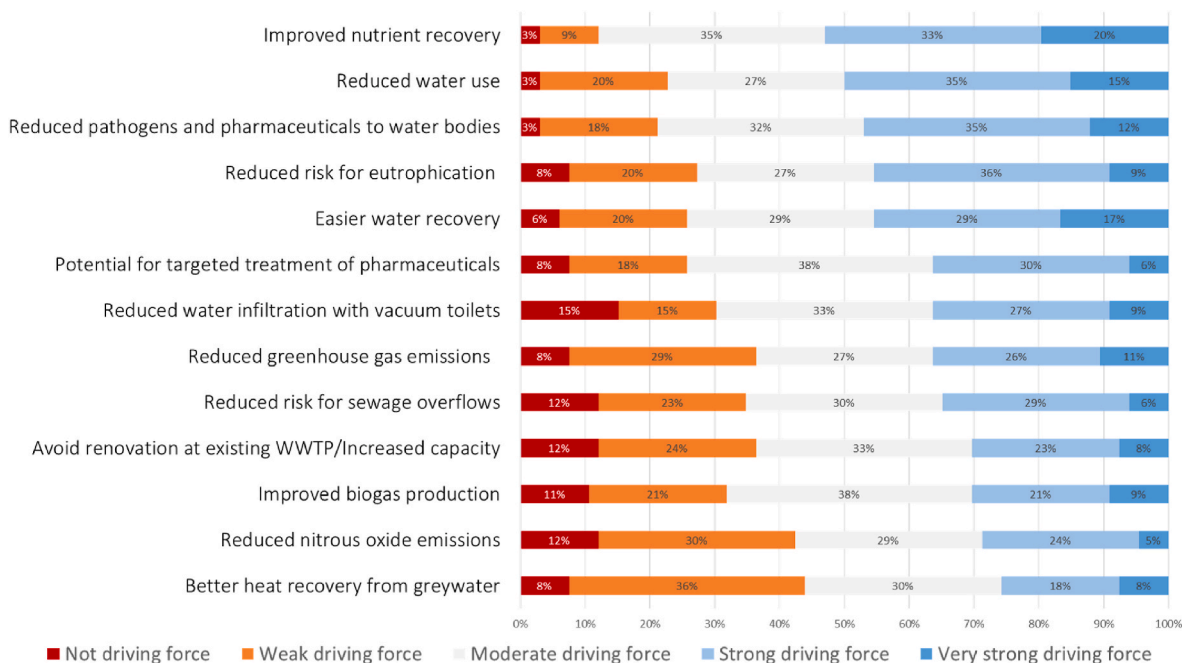


Fig. 3. Strength of the drivers for implementing source-separating wastewater systems within Swedish water utility jurisdictions, based on 66 responses.

impacts and energy. Additional drivers written in the comments included reduced chemical and energy usage at the wastewater treatment plant. Drivers vary between the different adoption groups (S2.1 in the SI). In general, earlier adopter groups saw the drivers as stronger. The innovators saw avoided renewal costs at the existing treatment plant as the strongest drivers, followed by reduced water use, water recovery, and nutrient recovery. The strongest drivers for the early adopters were nutrient recovery, reduction of pathogens and pharmaceuticals to water bodies, as well as potential for targeted treatment of pharmaceuticals.

Interestingly, respondents from the late majority rated more drivers as ‘very strong’ than other groups. There was no dominate driver within this group, rather they saw most of the drivers as applicable. Not surprisingly, the laggards saw fewer drivers and rated more of them as weak to moderate. One respondent commented that water utilities are steered by their environmental emission standards and legally they are not allowed to incur additional costs beyond fulfilling their mandate to meet these standards: “All the factors listed are in themselves positive, but they are not individually justifiable for the financial investment required to introduce a

Table 2  
Common drivers and barriers for source-separating wastewater systems in municipalities (adapted from Kvarnström et al., 2022).

	Pragmatic	Normative	Cognitive	Regulatory
<b>Drivers</b>	<ul style="list-style-type: none"> <li>Avoid renovating and/or increase capacity in existing infrastructure</li> <li>Wastewater network</li> <li>Reduced risk for sewage overflows</li> <li>Source-separating wastewater systems with vacuum have no water leakage into the pipes</li> <li>Treatment plant</li> <li>Source-separation of wastewater fractions enable demand-adapted treatment of e.g. pharmaceuticals</li> </ul>	<p>Possibly:</p> <ul style="list-style-type: none"> <li>Moral obligations for resource efficiency</li> <li>Moral obligations to protect the environment &amp; health</li> </ul>	<p>Resource use</p> <ul style="list-style-type: none"> <li>Improved biogas production<sup>a</sup></li> <li>Improved nutrient recovery</li> <li>Better heat recovery from greywater</li> <li>Easier water recovery</li> </ul> <p>Environment &amp; health</p> <ul style="list-style-type: none"> <li>Less risk of eutrophication because less nutrients are released from the treatment plant to the recipient</li> <li>Reduced water use</li> <li>Reduced greenhouse gas emissions (due to heat recovery &amp; increased biogas to replace fossil fuels)</li> <li>Reduce nitrous oxide emission from WWTP</li> <li>Reduced emissions of pathogens &amp; pharmaceuticals to water bodies</li> </ul>	<p>With stricter treatment standards (currently not required):</p> <ul style="list-style-type: none"> <li>Source-separation of wastewater fractions enable demand-adapted treatment of e.g. pharmaceuticals</li> <li>Easier to meet treatment standards if less nutrients enter the treatment plant</li> </ul>
<b>Barriers</b>	<ul style="list-style-type: none"> <li>High costs</li> <li>Lack of resources for project development</li> <li>Immature technology</li> <li>Few companies who can provide technologies</li> <li>Time-consuming partnerships are needed</li> <li>Greater commitment required by the organization</li> <li>Requires new routines and working methods</li> </ul>	<ul style="list-style-type: none"> <li>Greater commitment required by the organization</li> <li>Requires new routines and working methods</li> <li>Low acceptance of the technique</li> <li>Today’s system works good enough</li> </ul>	<ul style="list-style-type: none"> <li>Lack of knowledge regarding source-separating technologies within the organization</li> <li>Consultants lack knowledge</li> </ul>	<ul style="list-style-type: none"> <li>Legal uncertainty/lack of clarity in regulations</li> </ul>

<sup>+</sup> (Lennartsson and Kvarnström, 2017).

<sup>a</sup> (Kjerstadius et al., 2015).

source separation system.”. Thus, without economic returns on investment or changes in their mandate, these municipalities see it as difficult to prioritize source-separating wastewater systems.

It should be noted here that the drivers used in this survey are primarily cognitive drivers (Table 2). The strongest drivers are all cognitive ones and the pragmatic drivers for avoiding sewage overflows or renovations at the existing treatment plant are weaker. While none of the drivers are directly related to regulatory legitimacy (given existing legal frameworks), there is the possibility of stricter emission requirements from wastewater treatment plants with regards to nutrients, pathogens and pharmaceuticals. Three of the top four drivers are related to these issues and can potentially be seen as both cognitive and regulatory drivers. Respondents were allowed to add additional drivers in their response, but no additional drivers were added. As noted in Table 2, the normative drivers for source-separating wastewater systems are related to moral drivers for sustainable lifestyles. These were not captured in the survey.

In addition to the drivers, survey respondents ranked the strength of the barriers that are commonly associated with source-separating wastewater systems (Fig. 4). All twelve barriers in the questionnaire were seen as at least moderate barriers, confirming that these barriers are real issues for implementing source-separating wastewater systems. Indeed, only two additional barriers were mentioned in the survey – uncertainty regarding future regulations and lack of space for new infrastructure. The barriers can be linked to different dimensions of legitimacy. The majority of barriers are related to pragmatic legitimacy, followed by normative issues. Higher costs and lack of resources for development projects appear to be the largest barriers. Followed by immature technology and low acceptance of the available technology.

Perspectives on barriers also vary between the adoption groups. The innovators saw low acceptance of available technologies and lack of resources as the largest barriers (S2.2 in the SI). The early adopters also saw that few technology suppliers and the good performance of the existing system as significant barriers. Interestingly, the innovators saw the cognitive and regulatory barriers as bigger than the early adopters, while pragmatic barriers of costs and lack of resources were less strong for innovators compared to early adopters. Overall, the early adopters ranked more barriers as small compared to the innovator group. Similar to results from drivers, the early majority was less positive and ranked all barriers as at least moderate. Perhaps this is due to the fact that they appear to be stuck in the investigation phase. All of the barriers are seen

as very big by at least a few members of late majority and laggards. There is no significant difference between these groups, with a majority of the barriers viewed as at least moderate by over 78% of the respondents. Additional barriers mentioned in the comments included pragmatic aspects of lack of space for additional pipes and treatment units (early majority) and the proximity of well-functioning conventional treatment plants that reduces the motivation to put in something new (late majority). Another comment mentioned uncertainty regarding future regulations as a barrier in the sense that it reduces the drivers (late majority).

Several barriers are related to both pragmatic and normative legitimacy. These barriers are related to organizational changes that require greater commitments and new routines within the organization. Such changes require time and effort to implement and are thus a pragmatic challenge. However, they are also related to organizational culture and values – thus closely connected to the normative legitimacy for change. These barriers are moderately strong barriers with a majority of respondents rating them as moderate.

In addition to normative barriers, the survey also explored individual and organizational attitudes towards source-separating wastewater systems. Individuals’ attitudes towards source-separating wastewater systems are generally more positive than those of their organizations. The majority (68%) of respondents believe that source-separating wastewater systems are a solution to sanitation-related challenges (question 5). Individual opinions about source-separation in new urban developments is positive (44%) or neutral (50%), with only 6% responding negatively (question 8). A majority of organizations have not expressed opinions (77%), and there is generally a weak interest (40%) for source-separation at the organizational level with only 9% expressing a strong interest and 19% a moderate interest (question 15). Nearly a third of the respondents (30%) concluded that there is no interest at all in their organization.

4.7. Knowledge and activities needed to increase the legitimacy

Both the interviews and the questionnaire asked respondents about knowledge and activities related to source-separating wastewater systems that they felt were needed. Suggestions from the interviews pointed to a general cognitive knowledge gap on the part of multiple stakeholders (Table 3). This result is perhaps logical, given that answers in the interview had pointed at cognitive legitimacy as having the highest

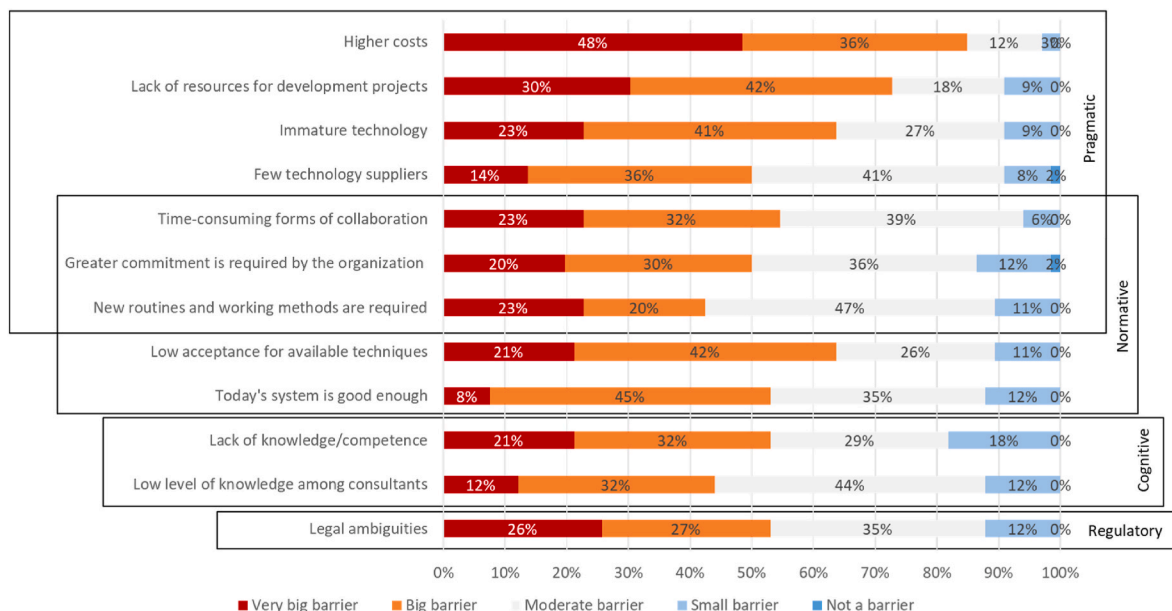


Fig. 4. Level of barriers for implementing source-separating wastewater systems within Swedish water utility jurisdictions, based on 66 responses.



**Table 3**  
General cognitive knowledge gaps attributed to different stakeholder groups, according to the interviewees in this study.

Politicians	<ul style="list-style-type: none"> <li>• Lack of knowledge about source-separating systems</li> </ul>
Municipalities	<ul style="list-style-type: none"> <li>• Lack of knowledge about source-separating systems</li> <li>• Lack of knowledge about the decision process, utility/planning and other stakeholders needed for source-separating systems</li> </ul>
County boards	<ul style="list-style-type: none"> <li>• Lack of knowledge about permit processes for source-separating systems</li> </ul>
The Swedish Association of Local Authorities and Regions (SKR)	<ul style="list-style-type: none"> <li>• Lack of knowledge about water in general</li> </ul>
Technology providers	<ul style="list-style-type: none"> <li>• Technology development needed</li> </ul>
Fertilizer producers	<ul style="list-style-type: none"> <li>• Need more energy efficient processes for recovering N and P</li> <li>• How to integrate recovered nutrients into fertilizer production</li> </ul>
Agricultural sector	<ul style="list-style-type: none"> <li>• Lack of knowledge about alternative products</li> </ul>

fraction of answers was categorized as “not-at-all” legitimate (Fig. 1C). The interviewees also saw a lack of cognitive knowledge among municipal stakeholders for (Fig. 5). They deemed that a certain level of cognitive knowledge is needed to embark on planning and implementation of these systems. Yet, it was also voiced in the interviews that some knowledge can only be created by implementation.

National organizations such as the Swedish Association of Local Authorities and Regions and the Swedish National Board of Housing, Building and Planning have roles to play. The fact that multiple stakeholders lack knowledge, illustrate the need for cross-sectoral involvement and cooperation for the implementation of these systems (Table 3). The existence of these knowledge gaps makes it difficult for individual municipalities wanting to implement source-separating wastewater systems. As an implementing water utility put it: “... the low level of knowledge is the largest problem with source-separating wastewater systems because they involve so many sectors (buildings, pipes, pumps, treatment plants, permitting authorities) ... it becomes very difficult when so many sectors and people are involved and when the general knowledge is so low”.

Conversely, the closing of these knowledge gaps would facilitate implementation.

The knowledge needs for implementation can be linked to different phases of the implementation chain (Fig. 5). Most knowledge needs were expressed for the “preparation” step in the implementation chain, which is again not surprising, given that there were only three interviewees with experience from more steps along the chain than “preparation”. The knowledge needed in the preparation and planning steps for city planning and the water utility should be done in such close cooperation that we have not divided the studies per actor for these steps.

Based on the results of the questionnaire, the strongest interest was for study visits and cost-benefit analyses (Figure S14 in SI). Otherwise, there was overall weak interest for most of the knowledge-based activities. The innovators and earlier adopters saw more need for knowledge-based activities (S2.3 in the SI). Innovators were interested in all activities, although lobbying was less interesting than other activities. Early adopters were most interested in study visits, technical manuals, networking and guidance for implementation (in that order). Interest from the other groups was increasingly less, with very little interest in any activity from the laggards (possibility with the exception of study visits). One respondent commented that they were too small of an organization to participate in such an early phase of technology development.

### 5. Discussion - pathways towards source-separating systems

The nuanced investigation presented here allows us to pinpoint areas for intervention. Specifically, we can answer the following three research questions.

What aspects of source-separating wastewater systems are perceived as legitimate?

Based on the interviews, source-separating wastewater systems have the highest legitimacy from the normative and pragmatic perspectives. A majority of respondents felt that source-separating systems were in-line with the organizations’ goals and could help to overcome some of the challenges currently facing wastewater systems in Sweden. The survey also showed that nutrient recovery and water savings were major drivers for source-separation. There is also a positive culture towards

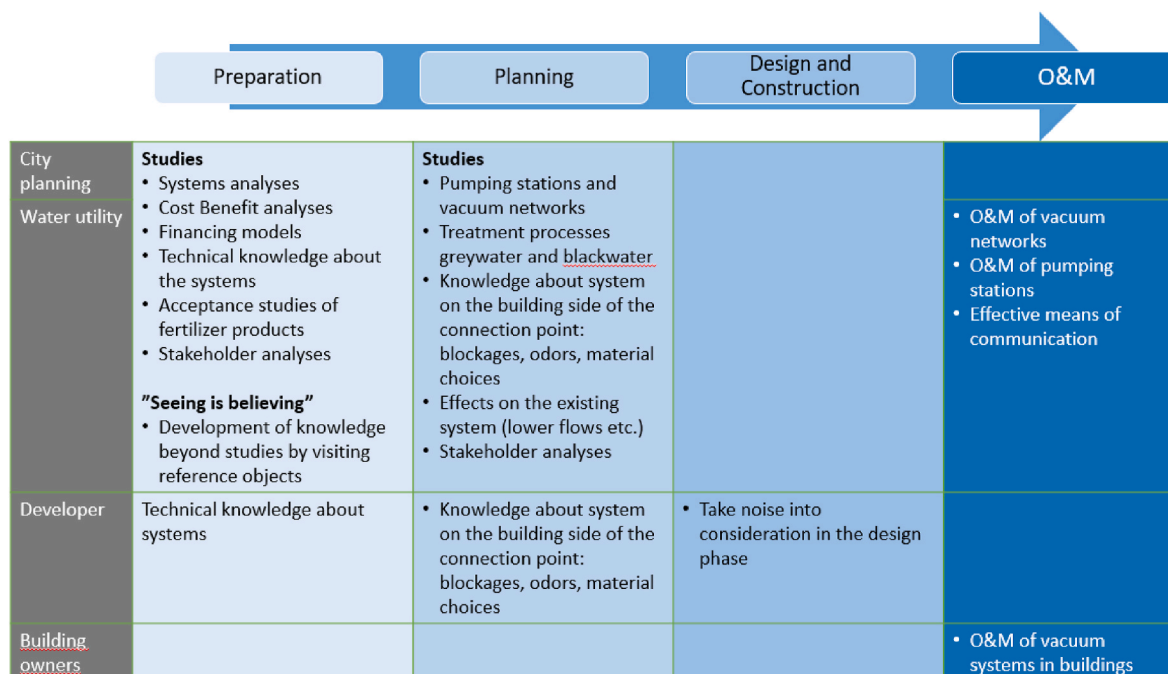


Fig. 5. Knowledge needs along the implementation chain in an urban source-separating wastewater project, according to nine Swedish water utilities.

innovation and development, which is an important starting point for the implementation of new systems. From the pragmatic perspective, legitimacy of source-separating systems is primarily related to cooperation, financing and risk. Most respondents felt that source-separating systems could be financed with existing mechanisms and two-thirds felt that there was no resistance within the organization to working with source-separation. Half of the interviewees had participated in cooperation projects (5/9) related to source-separation, indicating that they have interest and some experience with the topic.

While certain aspects of normative and pragmatic legitimacy appear to be relatively high, according to the survey the highest barriers for implementation of source-separating systems are also related to these two categories. Specifically, the highest barriers are pragmatic aspects of higher costs, lack of resources, and immature technology, as well as normative aspects of low acceptance of the techniques. There appears to be a dichotomy of rhetoric that theoretically supports the idea that source-separating wastewater system can be an innovative way of solving current challenges, but that uncertainty related to source-separating is stopping action. Specifically, results from the survey show that respondents see low acceptance and lack of capacity as barriers. Thus, while certain aspects of source-separating systems are pragmatically acceptable, there are still other pragmatic aspects that limit legitimacy.

### 5.1. What factors appear to affect legitimacy?

In the case of Sweden, cognitive and regulative legitimacy appear to be lagging behind normative and pragmatic aspects of legitimacy. This was also shown in a previous study of source-separation systems in Sweden, which highlighted risk aversion (pragmatic) and weak national advocacy coalitions to establish regulative guidance (McConville et al., 2017). Establishment of legitimacy is a process and it can be expected that not all dimensions of legitimacy emerge at the same time. In a study of potable water reuse in California, researchers found that initial efforts to establish legitimacy focused on normative aspects by influencing norms within a network of experts, valorizing reuse through prestigious prizes and public outreach campaigns (Binz et al., 2016). It was during later phases of general validation of water reuse that California applied strategies to address pragmatic (resource mobilization), cognitive (education) and regulatory (advocacy, political work) legitimacy aspects (ibid). Interestingly, the Innovators in this study share a similar story. They have established a local normative network and are convinced of the pragmatic self-interest of implementing source-separation. However, as they have come further in implementation they have rated cognitive and regulatory barriers as higher than other respondents and had to develop strategies to deal with them.

So what factors have influenced legitimacy in the early stages of development of urban source-separating wastewater systems in Sweden? According to the three interviewees that are planning and/or implementing systems, important factors that influenced decision-making were: (i) study visits (seeing others overcome barriers), (ii) cross-sectoral cooperation within the municipality and wider cooperation projects (normative networks & knowledge exchange) and (iii) changes in political directives for the utility's operation (regulatory guidance).

Normative legitimacy appears to be necessary early in the process of establishing legitimacy, linking action to moral obligations and social values. In our case, normative motivation appears linked to achieving organizational goals for environmental protection and service efficiency. Yet, there are still worries about acceptance of these systems. Our results show that individuals' attitudes towards source-separation are generally more positive than those of their organizations (both in interviews & survey). This is similar to other acceptance studies that have found that respondents are generally more positive themselves to reuse of human excreta than what they believe their colleagues to be (Simha et al., 2021). Other studies link normative legitimacy to

perceptions of human waste. Hacker and Binz (2021), associated low legitimacy with the "yuck factor" associated with human excreta. Indeed, studies have found that reuse of human excreta is most acceptable when not associated with human consumption (McConville et al., 2022; Segrè Cohen et al., 2020). At the same time, user acceptance studies of existing source-separating systems have generally found that between 70 and 80% of users are satisfied (McConville et al., 2017). This level of acceptance is in-line with other studies of source-separating system that found relatively high acceptance from users (Lienert and Larsen, 2010). Yet, as this study shows, the worry of potentially low acceptance persists, creating barriers for legitimacy.

### 5.2. What can be done to increase the legitimacy of source-separating wastewater systems?

In order to establish legitimacy, the drivers for an innovative system also need to be greater than perceived barriers (Hekkert et al., 2007). A majority of the barriers commonly associated with source-separating wastewater systems are pragmatic, perhaps due to the newness and complexity of these systems. This was also shown in a study of alternative water systems, where the number and type of barriers increased for wastewater reuse compared to stormwater or greywater reuse, especially if agricultural reuse was intended (Hacker and Binz, 2021). Pilot projects as demonstrations of how to overcome pragmatic barriers and for establishing regulatory praxis have been recommended as an important step for up-scaling systems for recycling source-separated urine (Aliahmad et al., 2023). Additional, actions to strengthen drivers will be needed. Institutional studies have pointed at a number of tools for legitimizing technology, including advocacy, changing normative associations, theorizing, educating, valorizing and imagery to invoke emotions associations (Binz et al., 2016). A study of desalination in the Australian urban water sector found successful use of theorizing (e.g. use of scientific models to build a cognitive understanding), educating and advocacy to legitimize the technology (Fuenfschilling and Truffer, 2016). A study of potable water reuse in California found that Orange County's successful introduction of potable water reuse employed a diverse portfolio of legitimation strategies that targeted pragmatic (building trust & community outreach), normative (quality monitoring & personal involvement) and cognitive legitimacy (framing messages & providing experiences) (Harris-Lovett et al., 2015). Organizations working with urine diversion have worked to develop narratives connected to popular cultural concepts like sustainability and establishment of regulatory pathways for the use of urine fertilizers in agriculture (Larsen et al., 2021).

Below, we provide context specific suggestions drawn from the results of this study on how to increase legitimacy. At the *local level*, source-separating systems require cooperation between city planning, the utility and developers. A comparative study of planning processes for source-separating urban wastewater systems in Sweden found the establishment of a common vision was critical for success (Lennartsson et al., 2019). This is particularly important when shifting the vision of wastewater treatment from pollution reduction to energy efficiency, resource recovery and control of greenhouse gases, as these visions transcend traditional boundaries between energy, waste and water sectors (Skambraks et al., 2017). Interviewees in this study pointed to the need for internal and external communication to get everyone on board. More communication on the topic can increase normative legitimacy through changing social norms, possibly leading to changes in directive to utilities or local building standards that can increase regulatory legitimacy. Underlying the development of a common vision is the need for more studies to support cognitive legitimacy. Respondents in this study would like to see cost-benefit analyses, financing models, and system impact studies to support visioning and decision-making. However, there is also the need for pragmatic knowledge such as technical studies and manuals on operation, maintenance and design. In part this type of pragmatic-cognitive knowledge must be developed through

implementation. Yet, much can be gained at the local level through study visits to reference objects and collaboration projects. Finally, innovators in this study recommend bolder interpretation of existing water legislation by water utilities as a way to strengthen regulatory legitimacy.

At the *regional level*, there is also a need for communication and collaboration networks that can strengthen normative legitimacy, as well as practical knowledge for pragmatic legitimacy. Similar to the local level, studies that increase cognitive knowledge about the systems is needed. In particular, permitting agencies within county boards need more knowledge to facilitate permitting of source-separating systems. Low knowledge about source-separating systems in general compared to conventional wastewater systems has been shown to be a major cognitive barrier, locking development into conventional pathways (Aliahmad et al., 2022). In addition, regional courts have the power to provide regulatory guidance, such as what costs can be justified by the Swedish water legislation.

At the *national level*, there are opportunities to build on existing networks as a way to exchange knowledge and facilitate cooperation between stakeholders. Today, Svenskt Vatten plays a key role in the development of technical handbooks, courses, legislative interpretations, and guidance for innovation. Svenskt Vatten has historical acted to strengthen legitimacy of technologies within the sector. During the infrastructure roll-out of conventional wastewater treatment plants in the 1970s and 80s, Svenskt Vatten developed construction manuals and courses on pumping stations and sewer installations (Söderholm et al., 2023). In order to prepare its members for implementation of source-separating wastewater systems, a similar approach could be adopted by Svenskt Vatten. In addition, national goals for nutrient recycling and quality certification of source-separating systems and/or their products, by the national certification boards (e.g. Svenskt Sill) would support regulatory legitimacy. Lobbying may be needed to establish such policy guidance and create incentives for cooperation between utilities and city planners.

Finally, at the international level there are also opportunities for collaboration and knowledge exchange that would support legitimacy. For example, harmonization of water and wastewater directives within the European Union to support nutrient recycling from wastewater would also go far to support regulatory legitimacy.

## 6. Conclusions

The results from this study show variations in legitimacy levels of source-separating wastewater systems in urban areas in Sweden. Overall opinion appears to be neutral to the concept rather than negative. Normative legitimacy was relatively high as these systems can be in-line with organizational goals, however cognitive legitimacy (knowledge & experiences) was low. In this study, only the survey respondents from Innovator and Early adopter groups rated more drivers as strong compare to barriers, indicating a general need to increase drivers and lower barriers. Efforts to strengthen the legitimacy of urban source-separating wastewater systems in Sweden should focus on strengthening cognitive knowledge and regulatory drivers, while also lowering pragmatic barriers such as costs and immature technology.

## CRedit authorship contribution statement

**Jennifer R. McConville:** Conceptualization, Methodology, Survey, Investigation, Formal analysis, Writing – original draft. **Elisabeth Kvarnström:** Conceptualization, Methodology, Interview, Investigation, Formal analysis, Writing – original draft. **Abdulhamid Aliahmad:** Survey, Investigation, Formal analysis, Data curation, Writing – review & editing. **Maria Lennartsson:** Conceptualization, Methodology, Interview, Investigation, Formal analysis, Writing – original draft.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Data availability

Data will be made available on request.

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## Appendix A. Supplementary data

Supplementary data related to this article can be found at <https://doi.org/10.1016/j.jenvman.2023.119108>.

## References

- Aliahmad, A., Harder, R., Simha, P., Vinnerås, B., McConville, J., 2022. Knowledge evolution within human urine recycling technological innovation system (TIS): focus on technologies for recovering plant-essential nutrients. *J. Clean. Prod.* 379, 134786.
- Aliahmad, A., Kanda, W., McConville, J., 2023. Urine recycling-Diffusion barriers and upscaling potential; case studies from Sweden and Switzerland. *J. Clean. Prod.* 414, 137583.
- Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., Rickne, A., 2008a. Analyzing the functional dynamics of technological innovation systems: a scheme of analysis. *Res. Pol.* 37 (3), 407–429. <https://doi.org/10.1016/j.respol.2007.12.003>.
- Bergek, A., Jacobsson, S., Sandén, B.A., 2008b. 'Legitimation' and 'development of positive externalities': two key processes in the formation phase of technological innovation systems. *Technol. Anal. Strat. Manag.* 20 (5), 575–592. <https://doi.org/10.1080/09537320802292768>.
- Binz, C., Harris-Lovett, S., Kiparsky, M., Sedlak, D.L., Truffer, B., 2016. The thorny road to technology legitimation - institutional work for potable water reuse in California. *Technol. Forecast. Soc. Change* 103, 249–263. <https://doi.org/10.1016/j.techfore.2015.10.005>.
- EEA, 2015. Urban sustainability issues - what is a resource-efficient city? (EEA Technical report, Issue. E. E. A. (EEA)). <https://www.eea.europa.eu/publications/resource-efficient-cities>.
- European Commission, 2021. Hamburg Water Cycle - Jenfelder Au. Retrieved 2023-07-26 from. [https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n\\_proj\\_id=3987](https://webgate.ec.europa.eu/life/publicWebsite/index.cfm?fuseaction=search.dspPage&n_proj_id=3987).
- Fuensschilling, L., Truffer, B., 2016. The interplay of institutions, actors and technologies in socio-technical systems - an analysis of transformations in the Australian urban water sector. *Technol. Forecast. Soc. Change* 103, 298–312. <https://doi.org/10.1016/j.techfore.2015.11.023>.
- Hacker, M.E., Binz, C., 2021. Institutional barriers to on-site alternative water systems: a conceptual framework and systematic analysis of the literature. *Environ. Sci. Technol.* 55 (12), 8267–8277. <https://doi.org/10.1021/acs.est.0c07947>.
- Harris-Lovett, S.R., Binz, C., Sedlak, D.L., Kiparsky, M., Truffer, B., 2015. Beyond user acceptance: a legitimacy framework for potable water reuse in California. *Environ. Sci. Technol.* 49 (13), 7552–7561.
- 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 (4), 413–432. <https://doi.org/10.1016/j.techfore.2006.03.002>.
- Joveniaux, A., Legrand, M., Esculier, F., De Gouvello, B., 2022. Towards the development of source separation and valorization of human excreta? Emerging dynamics and prospects in France. *Front. Environ. Sci.* 10, 2388.
- Kjerstadius, H., Haghhighatafshar, S., Davidsson, Å., 2015. Potential for nutrient recovery and biogas production from blackwater, food waste and greywater in urban source control systems. *Environ. Technol.* 36 (13), 1707–1720. <https://doi.org/10.1080/09593330.2015.1007089>.
- Kjerstadius, H., Saraiva, A.B., Spångberg, J., Davidsson, Å., 2017. Carbon footprint of urban source separation for nutrient recovery. *J. Environ. Manag.* 197, 250–257.
- Kvarnström, E., Lennartsson, M., Widén, A., 2022. Planeringshandbok För Källsorterande Avloppssystem I Urbana Områden. <https://www.macrosystem.se/wp-content/uploads/2022/10/Planeringshandbok-for-kallsorterande-avloppssystem-i-urbana-omraden-2022-06-15.pdf>.
- 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 (16), 6121–6125. <https://doi.org/10.1021/es9010515>.
- Larsen, T.A., Gruendl, H., Binz, C., 2021. The potential contribution of urine source separation to the SDG agenda – a review of the progress so far and future

- development options. *Environ. Sci. J. Integr. Environ. Res.: Water Research and Technology* 7, 1161–1176. Royal Society of Chemistry.
- Lennartsson, M., Kvarnström, E., 2017. Food and Energy in a Circular Economy. [https://vaxer.stockholm/globalassets/omraden/-stadsutvecklingsomraden/ostermalm-norra-djurgardsstaden/hallbar-stadsutveckling/forskning-och-utveckling/food-and-energy-in-the-circular-economy\\_2017-06-30.pdf](https://vaxer.stockholm/globalassets/omraden/-stadsutvecklingsomraden/ostermalm-norra-djurgardsstaden/hallbar-stadsutveckling/forskning-och-utveckling/food-and-energy-in-the-circular-economy_2017-06-30.pdf).
- Lennartsson, M., McConville, J., Kvarnström, E., Hagman, M., Kjerstadius, H., 2019. Investments in innovative urban sanitation – decision-making processes in Sweden. *Water Altern. (WaA)* 12 (2), 588–608.
- Lienert, J., Bürki, T., Escher, B.I., 2007. Reducing micropollutants with source control: substance flow analysis of 212 pharmaceuticals in faeces and urine. *Water Sci. Technol.* 56 (5), 87–96.
- Lienert, J., Larsen, T.A., 2010. High acceptance of urine source separation in seven European countries: a review. *Environ. Sci. Technol.* 44 (2), 556–566. <https://doi.org/10.1021/es9028765>.
- Malila, R., Lehtoranta, S., Viskari, E.L., 2019. The role of source separation in nutrient recovery - comparison of alternative wastewater treatment systems [Article]. *J. Clean. Prod.* 219, 350–358. <https://doi.org/10.1016/j.jclepro.2019.02.024>.
- McConville, J.R., Kvarnström, E., Jönsson, H., Kärrman, E., Johansson, M., 2017. Source separation: challenges & opportunities for transition in the Swedish wastewater sector. *Resour. Conserv. Recycl.* 120, 144–156. <https://doi.org/10.1016/j.resconrec.2016.12.004>.
- McConville, J.R., Metson, G.S., Persson, H., 2022. Acceptance of Human Excreta Derived Fertilizers in Swedish Grocery Stores. *City and Environment Interactions*, 100096.
- Mohan, S.V., Amulya, K., Modestra, J.A., 2020. Urban biocycles—Closing metabolic loops for resilient and regenerative ecosystem: a perspective. *Bioresour. Technol.* 306, 123098.
- Nordzell, H., Soutukorva, Å., 2018. Samhällsekonomisk analys av VA-system i Norra Djurgårdsstaden. In: *Rapport Framtagen Inom MACRO Projektet*.
- NSVA, 2021. Three pipes out. In: *Nordvästra Skånes Vatten Och Avlopp (NSVA)*. Retrieved 2023-07-26 from. <https://projekt.nsva.se/kommuner/helsingborg/tre-ror-ut/three-pipes-out/>.
- Rogers, E.M., 2003. *Diffusion of Innovations*. Free Press. <http://www.amazon.com/Diffusion-Innovations-5th-Everett-Rogers/dp/0743222091>.
- San Francisco Public Utilities Commission, 2021. Onsite Water Reuse. Retrieved 2023-07-26 from. <https://sfpub.org/construction-contracts/design-guidelines-standards/onsite-water-reuse>.
- Segrè Cohen, A., Love, N.G., Nace, K.K., Árvai, J., 2020. Consumers' acceptance of agricultural fertilizers derived from diverted and recycled human urine. *Environ. Sci. Technol.* 54 (8), 5297–5305. <https://doi.org/10.1021/acs.est.0c00576>.
- Simha, P., Barton, M.A., Perez-Mercado, L.F., McConville, J.R., Lalander, C., Magri, M.E., Dutta, S., Kabir, H., Selvakumar, A., Zhou, X.Q., Martin, T., Kizos, T., Kataki, R., Gerchman, Y., Herscu-Kluska, R., Alrousan, D., Goh, E.G., Elenciuc, D., Glowacka, A., Vinneras, B., 2021. Willingness among food consumers to recycle human urine as crop fertiliser: evidence from a multinational survey [Article]. *Sci. Total Environ.* 765, 14443810.1016/j.scitotenv.2020.144438.
- Skambraks, A.-K., Kjerstadius, H., Meier, M., Davidsson, Å., Wuttke, M., Giese, T., 2017. Source separation sewage systems as a trend in urban wastewater management: drivers for the implementation of pilot areas in Northern Europe. *Sustain. Cities Soc.* 28, 287–296. <https://doi.org/10.1016/J.SCS.2016.09.013>.
- Söderholm, K., Vidal, B., Hedström, A., Herrmann, I., 2023. Flexible and resource-recovery sanitation solutions: What hindered their implementation? A 40-year Swedish perspective. *Journal of Urban Technology* 30 (1), 23–45.
- Suchman, M.C., 1995. Managing legitimacy: strategic and institutional approaches. *Acad. Manag. Rev.* 20 (3), 571–610. <https://doi.org/10.5465/amr.1995.9508080331>.
- Suddaby, R., Bitektine, A., Haack, P., 2017. Legitimacy. *Acad. Manag. Ann.* 11 (1), 451–478. <https://doi.org/10.5465/annals.2015.0101>.
- UN-HABITAT, 2022. World cities report 2022: envisaging the future of cities. In: S. P. (UN-habitat). U. N. H., [https://unhabitat.org/sites/default/files/2022/06/wcr\\_2022.pdf](https://unhabitat.org/sites/default/files/2022/06/wcr_2022.pdf)
- Wivstad, M., Salomon, E., Spångberg, J., Jönsson, H., 2009. *Ekologisk Produktion: Möjligheter Att Minska Övergödning*. <https://www.slu.se/globalassets/ew/org/centrb/epok/aldre-bilder-och-dokument/publikationer/eko-prod-overgodning-syntes-web.pdf>.