Governing industrial and urban symbiosis

Internal and external strategies for municipal development

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Research article

Governing industrial and urban symbiosis: Internal and external strategies for municipal development

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ABSTRACT

Industrial and urban symbiosis (IUS) is an emerging sustainability strategy in which organizations collaborate to optimize resource flows and minimize waste within urban environments. Rooted in circular economy principles, IUS has gained global attention as cities seek innovative solutions to enhance resource efficiency and resilience. However, local authorities play a critical yet underexplored role in governing IUS. While previous studies recognize their importance in initiating and expanding such initiatives, limited research has systematically examined how municipalities balance internal governance with external engagement strategies to manage IUS effectively. This study addresses this gap by analyzing the internal and external governing strategies employed by Swedish municipalities with emerging or established IUS initiatives. A survey of 22 municipalities revealed that while IUS is widely prioritized, the level of municipal engagement varies. Findings suggest that broader administrative involvement can strengthen capacity for circular solutions. Internally, self-governing strategies, particularly political anchoring, were key to successful implementation. Externally, municipalities adopted enabling, provision, and partnership strategies, emphasizing coordination and facilitation over legal enforcement. The results provide valuable insights for policymakers and urban planners in and beyond Sweden, offering governance strategies applicable to cities and regions seeking to integrate IUS into their sustainability agendas.

1. Introduction

Industrial symbiosis is a solution in which traditionally separate organizations come together and collaborate on resource flows (Chertow, 2000, 2008). Typically, it entails that one organization's residuals or wastes are utilized by another for its production processes, thereby preventing the use of virgin materials and enhancing resource efficiency (Fraccascia, 2019; Neves et al., 2020). Industrial and urban symbiosis (IUS) can be described as a sister concept to industrial symbiosis, in that it focuses specifically on waste and resource flows in urban environments (Van Berkel et al., 2009; Van Berkel, 2010; Dong et al., 2017). As cities grow and resource consumption increases, the need for sustainable urban-industrial collaboration becomes more pressing (reference). Around the world, municipalities are seeking ways to optimize resource flows, reduce waste, and promote circular economy solutions (Domenech et al., 2019; Palm et al., 2019; Prendeville et al., 2018). This can be seen as a positive trend not only because of the sustainability benefits linked to IUS implementation (Martin and Harris, 2018; Wadström et al., 2021), but also because of the important role local authorities in municipalities can play in IUS implementation and management.

Sweden has emerged as a relevant case study for IUS due to its ambitious environmental policies and strong municipal governance structures (Haller et al., 2022; Harfeldt-Berg, 2024). The country has a long-standing commitment to sustainability and circular economy principles, with municipalities playing a central role in implementing waste management, energy recovery, and resource efficiency initiatives (Andersson and Stage, 2018; Gustafsson et al., 2015; Saldert, 2017). However, Sweden still faces challenges related to urban sustainability, such as the need for improved waste-to-resource strategies and cross-sectoral collaboration in local governance (Avfall Sverige, 2021; Björklund and Gustafsson, 2015). With municipalities responsible for infrastructure planning, environmental oversight, and economic development, understanding how they govern IUS is crucial for enhancing circular economy implementation at the local level (Bolger and Doyon, 2019; Christensen, 2021; Södergren and Palm, 2021).

While Sweden has taken significant steps in integrating IUS into municipal governance, similar initiatives have been implemented in

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other countries, albeit with varying approaches. For instance, Denmark has developed extensive industrial symbiosis networks, exemplified by Kalundborg, where cross-industry collaboration has driven resource efficiency for decades (Jacobsen, 2006). China has actively promoted eco-industrial parks as a national strategy to facilitate industrial symbiosis, integrating regulatory incentives and centralized planning (Geng et al., 2012). In the Netherlands and Germany, decentralized governance structures have enabled municipalities to embed circular economy principles into urban planning and waste management strategies (Bocken et al., 2016). Understanding Sweden's approach in comparison to these international examples can offer valuable insights into the effectiveness of different governance models in fostering IUS.

Previous research on industrial and urban symbiosis has confirmed that local authorities are key players in initiating, developing, and expanding IUS (Van Berkel et al., 2009; Velenturf, 2016; Lander Svendsen et al., 2021). By adopting different roles and governing strategies they can, for example, facilitate, coordinate, and encourage action; provide different goods and services; implement enabling regulations; engage in favorable partnerships; and manage their own operations to support IUS (Södergren and Palm, 2021). In doing so, local authorities can also address important economic, technical, regulatory, social, and information-related barriers (ibid). While the preceding explanation provides a good starting point for understanding the role of local authorities in managing IUS, no study has systematically investigated external and internal municipal governing strategies—in other words, how municipalities handle external tasks and relations as opposed to how they address them internally. Previous research has mostly focused on the external dimension, neglecting aspects of internal organization and governance. It seems reasonable to assume, however, that internal and external roles and governing strategies differ depending on what is at stake (Filatotchev and Nakajima, 2010) and, importantly, that municipalities need to work both internally and externally to fully anchor the idea of establishing or supporting IUS (Den Exter et al., 2015).

This article intends to fill this gap by presenting a systematic analysis of existing internal and external governing strategies in Swedish municipalities. The aim is to determine which external and internal governing strategies are used in municipalities with emerging or established IUS initiatives and discuss how different strategies support IUS development. In order to support local authorities in managing and further developing IUS, it is important to include and understand existing municipal practices and perceptions. This is not only an important aspect for complementing and validating theory (Patten, 2016), but also gives a more nuanced understanding of the roles and strategies of local authorities and how these may differ depending on the divergent characteristics and sizes of the associated municipalities.

In the first part of the article, we explore the theoretical foundations of IUS and the role of local authorities therein. Second, the materials and methods underpinning our research are described. Next, the results are presented, followed by the analysis and discussion. Finally, the article concludes with some key takeaways and suggestions for future research on IUS.

2. Theory: governing industrial and urban symbiosis

Industrial symbiosis (IS) is a solution in which traditionally separate organizations come together around resource flows (Chertow, 2000, 2008). Typically, it entails the use of one organization's residuals or wastes by another for its production processes, thereby preventing the use of virgin materials and enhancing resource efficiency (Fraccascia, 2019; Neves et al., 2020). Industrial symbiosis has its theoretical roots in the field of industrial ecology and, in addition, has become a part of the circular economy agenda due to its potential for closing resource loops (Frosch and Gallopoulos, 1989; Bocken et al., 2016; Salomone et al., 2020). Industrial and urban symbiosis (IUS) is a similar concept that focuses specifically on waste and resource flows in urban environments (Van Berkel et al., 2009; Van Berkel, 2010; Dong et al., 2017). With increasing rates of urbanization and the acknowledgement that cities and municipalities play a key role in managing local resource use (Palm et al., 2019; Prendeville et al., 2018), the interest in and uptake of IUS has increased in recent years (Domenech et al., 2019). This can be seen as a positive trend not only because of the sustainability benefits linked to IUS implementation (Martin and Harris, 2018; Wadström et al., 2021), but also because of the important role local authorities can play in IUS development and expansion. As a result, more recent IS research has delved further into the roles of different actors, including public organizations, local governments, and municipalities (Boons and Spekkink, 2012; Gibbs and Deutz, 2007; Lenhart et al., 2015; Paquin and Howard-Grenville, 2012; Spekkink, 2015; Sun et al., 2017; Wolf et al., 2005).

Burström and Korhonen (2001) discussed how municipalities can play the role of anchor tenants in regional industrial ecosystems. They distinguished between a physical anchor tenant, "who is an influential driver of the main physical material and energy flows of the region" (ibid, p. 40), and an institutional anchor tenant, who "provide[s] the system with education, information, social and economic infrastructure, a decision-making forum, institutional and political support etc." (ibid, p. 41). While the first role has been mention in e.g. Van Berkel et al. (2009) and Van Berkel (2010), the latter has been investigated by researchers such as Wolf et al. (2005), Martin and Eklund (2011), Boons and Spekkink (2012), and Sun et al. (2017), suggesting that public organizations indeed have institutional capacities that can be developed to benefit local IUS implementation.

The role of public actors was also addressed by Van Berkel et al. (2009) in their study of the symbiotic exchanges between industries and cities in Japan's eco-town program. Twenty-six eco-towns developed specific plans for IUS, with outcomes including productivity levels, environmental quality, community development, and quality of life. Local governments were primarily involved in the program as initiative facilitators and promotors. Lenhart et al. (2015), on the other hand, investigated how local authorities contributed to developing symbiotic connections in the city of Rotterdam. They found that the local authority was more prone to design, facilitate and coordinate urban symbiosis projects than to implement them. Lander Svendsen et al. (2021) also discussed the role of municipalities in initiating, developing, and expanding IUS in their study of nine cases in six European countries. They found that municipalities worked with IUS as initiators, facilitators, owners, authorities, or businesses, particularly in the areas of land use planning, waste and supply services, business development, and public procurement (ibid).

In recent years, researchers have begun to examine IUS through a governance perspective, highlighting the role of public authorities in shaping and facilitating symbiotic exchanges. Governance networks, multi-level governance, and municipal autonomy are critical for understanding how cities implement sustainability initiatives, including IUS (Hooghe and Marks, 2003; Joss, 2017; Williams, 2019). Different governance models—such as hierarchical (top-down), networked (collaborative), and adaptive governance—have been applied to analyze municipal involvement in sustainability transitions (Bai et al., 2010; Folke et al., 2005; Sørensen and Torfing, 2007). These perspectives highlight the complexity of governing across different scales and involving multiple stakeholders in collaborative environmental governance. However, these approaches do not provide a systematic typology of municipal governing strategies.

Velenturf (2016) explored governance strategies for industrial symbiosis, identifying four roles for government organizations: strategic regulator, strategic facilitator, operational regulator, and operational facilitator. Södergren and Palm (2021) expanded this work by drawing on a typology developed by Bulkeley and Kern (2006) and Bulkeley et al. (2009), identifying five governing strategies that municipalities use to support IS development: governing through enabling, governing through provision, governing by authority, governing through

partnership, and self-governing. These strategies are summarized in Table 1 below.

Although this framework provides a strong foundation for understanding municipal roles in IUS, existing research has primarily focused on external governance—how municipalities engage with businesses and other regional actors (Mortensen et al., 2024). Far less attention has been given to the internal governance of IUS within municipalities themselves. Burström and Korhonen (2001) briefly noted institutional resistance and resource constraints within municipal departments, while Wolf et al. (2005) highlighted issues of poor integration within local authorities. However, no study has systematically examined how municipalities balance internal and external governance strategies when implementing IUS. Despite this lack of attention, it seems reasonable to assume that internal and external roles and governing strategies differ depending upon what is at stake (Filatotchev and Nakajima, 2010) and, importantly, that municipalities need to work both internally and externally to fully anchor the idea of establishing or supporting IUS (Den Exter et al., 2015).

To address this gap, this study applies the Bulkeley and Kern (2006) and Bulkeley et al. (2009) framework to distinguish between **internal** and **external** governing strategies in IUS. Whereas enabling, provision, and partnership primarily involve external engagement, self-governing is internally focused. Authority spans both dimensions, as regulatory and strategic planning efforts can be directed either outward or inward. This distinction is illustrated in Fig. 1.

There is a notable lack of research on the internal roles and governance of local authorities. Furthermore, scant attention has been paid to understanding how different local authorities perceive their internal and external governing strategies. Despite this gap, no research has systematically compared and analyzed how different local authorities with emerging or established IUS initiatives perceive their roles in this context. To address this, we have investigated the governing strategies of Swedish municipalities working actively with IUS. Specifically, we have employed the division of external and internal governing strategies, as depicted in Fig. 1, to explore the roles that local authorities may assume in relation to IUS.

3. Materials and methods

The geographical scope of this article is focused on Sweden. Sweden is known to be a leader in the area of sustainability and has been ranked among the top European countries in terms of its progress toward achieving the Sustainable Development Goals (SDSN, 2022). In recent years, Sweden has also been working toward advancing a circular economy agenda (Regeringskansliet, 2023). As in other countries, municipalities in Sweden are taking the lead in these efforts (Harris et al., 2018), making it an interesting case for comparison. With 96 % of Sweden's materials coming from virgin sources, and only 3.4 % of resources cycled back into the economy after use, there is an important circular gap to be closed (Circle Economy, RE:SOURCE, & RISE, 2022). As part of a global trend, the Swedish case is also valuable for studying circular economy initiatives such as IUS implementation in other constituencies. As will be described below, 22 municipalities working with IUS development in Sweden in various capacities participated in this study, making it a comprehensive case for researching IUS agendas and governing strategies.

To ensure a thorough investigation of all known symbiosis networks in Sweden, municipalities were identified based on multiple sources, including research reports, expert consultations, and publicly available summaries of existing IUS initiatives. While there are no official policy documents listing municipalities actively engaged in IUS, a structured selection process was followed. The 28 municipalities initially contacted for participation were identified through (1) reviewing previously published texts and summaries of IUS initiatives in Sweden (Neves et al., 2020; SNIUS, 2023), (2) consulting experts in the IUS field, (3) contacting the RISE research institute, which is actively engaged in setting up a center for IUS in Sweden (RISE, 2023), and (4) engaging with municipal contacts to identify additional IUS-active municipalities. The methodology aligns well with the recently published report by RISE (2024) which provides further evidence of the widespread development of IUS initiatives across Swedish municipalities. While there is substantial overlap between the municipalities in our study and those listed in the RISE report, we have also been in contact with municipalities that the report does not mention. This suggests that our approach has captured a slightly different, but complementary, representation of IUS activity in Sweden, reinforcing the robustness of our sample selection.

In order to research IUS in Swedish municipalities, a questionnaire was constructed. Questionnaires are useful when seeking to gather larger quantities of information, as they constitute an effective method of comparing and structuring data. According to Boynton and Greenhalgh (2004: pp. 1312), they are particularly useful in offering "an objective means of collecting information about people's knowledge, beliefs, attitudes, and behaviour." In contrast with structured interviews, self-completion or self-administered questionnaires give the respondents an opportunity to answers questions on their own terms, including making decisions such as when to respond and how much detail to include (Bryman and Bell, 2015). They may also help avoid interviewer effects such as social desirability bias if sensitive information is shared, since the interviewer is eliminated in physical form (Krosnick and Presser, 2010). Together, these factors can help researchers reach and attract more respondents to participate in a given study (Bryman and Bell, 2015).

The self-administered questionnaire used for this study was created based on a review of previous literature focused on the role of municipalities in IUS and actor experiences of existing barriers to establishing an IUS initiative (Velenturf, 2016; Södergren and Palm, 2021; Lander Svendsen et al., 2021). The questionnaire was created in Google Forms and comprised 18 questions with both closed- and open-response options (Boynton and Greenhalgh, 2004; Bryman and Bell, 2015). Questions were designed to be "clear, simple, specific and relevant for the

Table 1
Five governing strategies for local authorities to overcome barriers in industrial symbiosis.

Governing strategy	Enabling	Provision	Partnership	Authority	Self-governing
Definition	Facilitating, coordinating, and encouraging action.	The provision of different goods, services, and resources.	State and non-state actors working together in an equal relationship.	Regulation, enforcement, and use of sanctions.	The capacity of the local government to control or manage its own activities and operations.
Activities	Argument, persuasion, and inducements (for example, when introducing campaigns or granting distribution to promote sustainability initiatives).	Material and infrastructural activities (for example, providing infrastructure, public transport services, and recycling schemes for residents and/or companies).	Knowledge building, information sharing, project implementation, and voluntary agreements in situations where the local government has no formal governing power over other actors.	Strategic planning and policymaking.	Developing internal procurement guidelines, energy standards, etc. for municipal organizations and buildings.

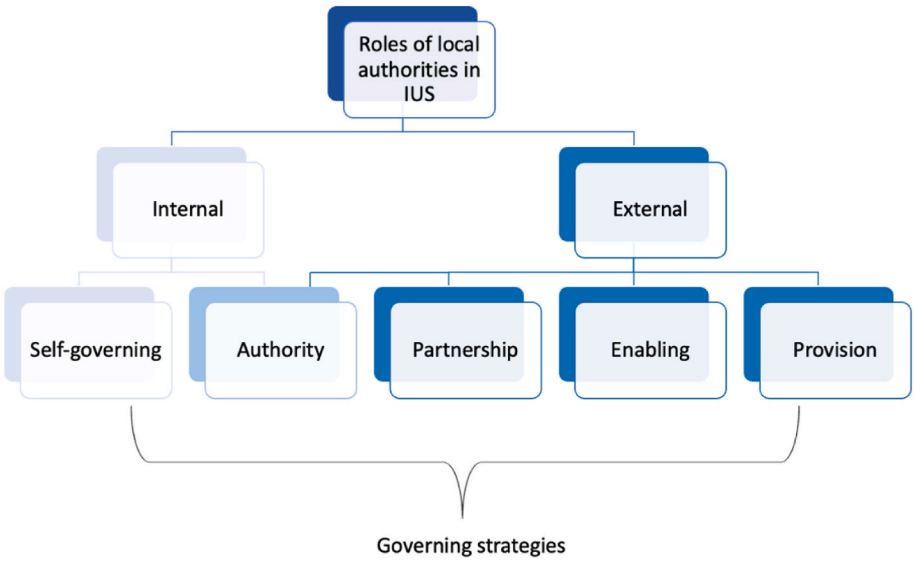

Fig. 1. Internal and external roles and governing strategies for local authorities in IUS.

study's research aims" (Lietz, 2010: pp. 265), and the structure of the questionnaire followed Krosnick and Presser's (2010) recommendations in terms of optimizing question order. Respondents were asked about their role in the IUS initiative; the duration of its operation; whether IUS is a priority in their municipality; what they consider the role of the municipality to be in the IUS initiative; whether there is something the municipality should *not* be doing in regard to IUS initiative; where the responsibility for IUS lies in the municipal organization; which administrations are involved in managing the IUS initiative; which municipal corporations are included in the IUS initiative; what municipal tools and processes are applied to the IUS initiative; whether citizens are involved in IUS development, and if so, how; and, finally, who is responsible for the IUS initiative, and what would happen if it were to fail or close. The questionnaire was tested on two Swedish sustainability experts for quality assurance (Krosnick and Presser, 2010). It was originally distributed in Swedish, but an English translation is available in Appendix 1.

The questionnaire was sent out to the 28 municipalities identified as actively working on IUS. Through email conversations, one key contact was identified in each municipality and was asked to answer the questionnaire online, except for one municipality in which two people wanted to answer the questionnaire together. While more than one respondent per municipality would have been welcomed, in many cases, only one person was formally working with IUS-related issues, often as a dedicated resource but sometimes in addition to other responsibilities. Respondents were encouraged to consult colleagues where relevant. Future research could consider expanding this approach to include multiple respondents per municipality where possible.

The questionnaire was available between 28 March and May 5, 2023. Out of the 28 municipalities, 22 submitted completed questionnaires (see Fig. 2 and Appendix 2). Three municipalities declined to participate due to a lack of time or resources, and three left the questionnaire unanswered.

While the sample size may appear limited, it is important to note that the number of municipalities with active or emerging IUS initiatives in Sweden is relatively small. Our study includes a substantial proportion of these municipalities, ensuring a representative overview of IUS development in the country. Given that IUS implementation is still evolving in Sweden, this study provides valuable insights into governance strategies at the municipal level. Future research could explore international comparisons to examine how different governance contexts influence IUS development.

The data from the questionnaire were analyzed qualitatively and

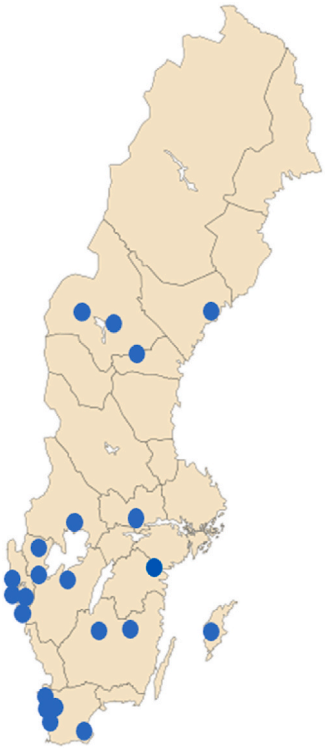

Fig. 2. Map of municipalities in Sweden with active industrial symbiosis networks that participated in the study.

processed using Microsoft Excel. Figures and graphs were created to visualize and illustrate the results. For quantifiable questions, such as closed-response and multiple-choice questions, data was coded in line with the predefined answers. Data from the qualitative questions, such as long- and short-answer questions, were coded thematically and presented in text form.

4. Results

Twenty-two municipalities working on IUS across Sweden participated in this study. Notably, the questionnaire showed that 9 out of the

22 IUS initiatives were being developed. Three IUS projects were started in the last year, meaning between 2022 and 2023. Two IUS initiatives had been operating for 1–5 years and another two for 5–10 years. Four IUS initiatives had been running for more than 20 years, and therefore have the most accumulated experience of the 22 participating projects (See Fig. 3 below.).

To obtain a better understanding of the internal organization of the IUS initiatives, we asked the respondents about their roles. Seven of the respondents worked in business development in various capacities and at various levels in their municipalities. Four respondents worked on environmental or sustainability issues. Two respondents worked specifically on IUS development, one as a project manager and one as an IUS developer. Two respondents worked on development-related matters in their municipalities. One respondent referred to themself as a "spider in the web"—a Swedish idiom meaning someone who orchestrates or is at the center of things. One respondent worked as a research and innovation coordinator, while another was part of their municipality's IUS steering committee. Finally, four respondents explained that they did not yet have either an active or specified role in the IUS initiative.

The possibilities for working strategically both internally and externally on IUS depend on the number of people engaged in the work in municipalities. This study found that the number of people working actively on IUS in the municipalities differed (see Fig. 4 below). Most municipalities had one to three people dedicated to working on IUS-related issues, while one municipality had as many as 10 people. Two municipalities did not have any dedicated IUS resources, and three municipalities struggled to identify how many people worked on the topic. Some respondents said that it was hard to answer the question because the workload was often split between different areas and tasks, meaning that IUS was not the only area they were responsible for and, hence, their activity and engagement might vary depending on which priorities were seen as being most urgent.

When asked about the job position or level of the people working actively on IUS in the municipality, 19 respondents replied "officials", indicating that many of the municipal IUS activities were handled by officeholders. Four of the respondents answered that middle managers were involved in IUS work, and two respondents said that project employees—for example, people hired on short-term contracts—were involved. One respondent answered that politicians were involved in their IUS work. No one indicated that employees working as administrative heads were involved.

The respondents were asked whether IUS was considered a priority or a prioritized issue in their municipality. Twenty respondents (91 %) answered "yes" or "yes, but through another topic", such as the circular economy, energy, water, etc. One respondent specified that IUS had not been an explicit political priority, but that officials in the municipality worked as though this were the case. Another respondent commented that the word "urban", as in industrial and *urban* symbiosis, did not accurately describe their constituency, which has more of a rural character. Only two respondents, representing 9 % of the 22, answered "no" to IUS being a prioritized issue. One of these added "not any longer" as a comment, indicating that priorities may have changed in the municipality over the years (See Fig. 5 below.).

Respondents were also asked about what they deemed to be the roles and activities of municipalities in IUS (see full text in Appendix 3). They were able select multiple answers, with suggestions inspired by Velenturf (2016), Södergren and Palm (2021), and Lander Svendsen et al. (2021). Their answers are ranked in Fig. 6 below and color coded according to the different "governing strategies": self-governing (yellow), enabling (green), provision (blue), partnership (purple), and authority (orange).

The most common response was creating political anchoring, selected by 18 of 22 respondents (81.8 %). In fact, most activities categorized as "self-governing" (marked in yellow in Fig. 6) scored high on average. This includes bringing cross-sectoral thinking and a broad sustainability perspective into the symbiosis process; developing internal symbiosis and material flows in the municipal administration; incorporating symbiosis thinking into different municipal processes (governing documents, procurement, establishment, permit processes, etc.); being responsible for strategic leadership (for example, by creating pre-conditions for symbiosis through urban planning, impact through owner management of municipal corporations, etc.); and taking a lead in

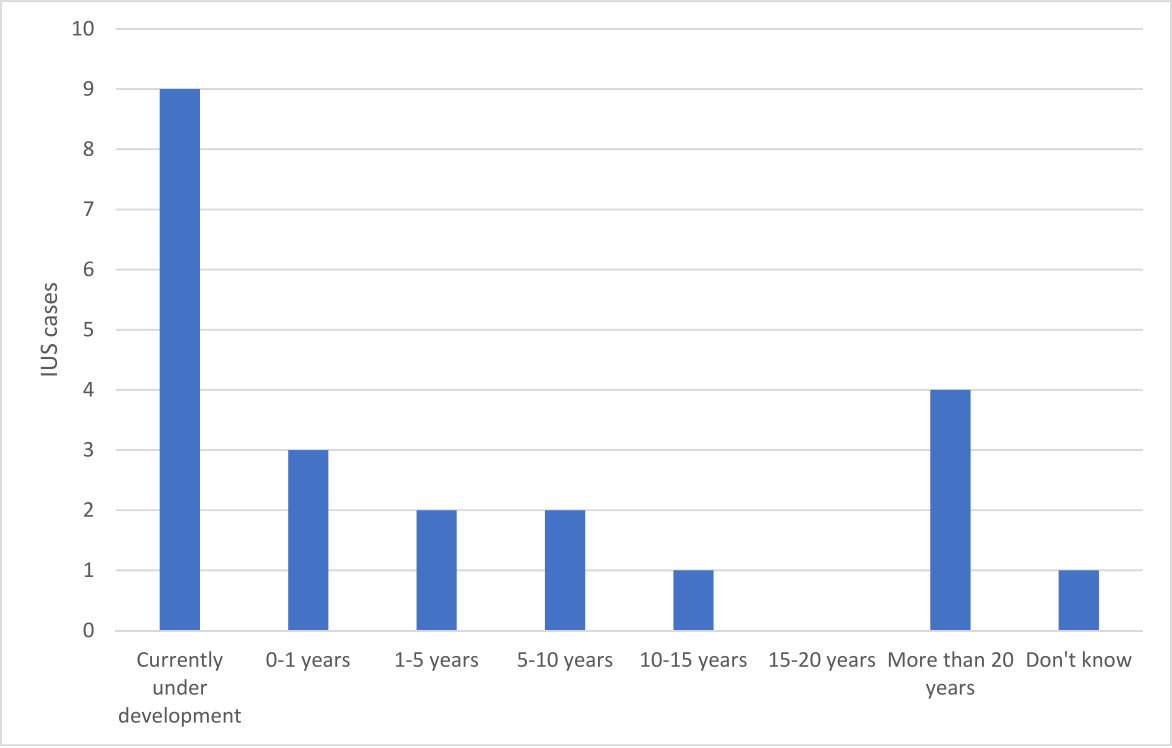

Fig. 3. Development in years for IUS networks participating in this study.

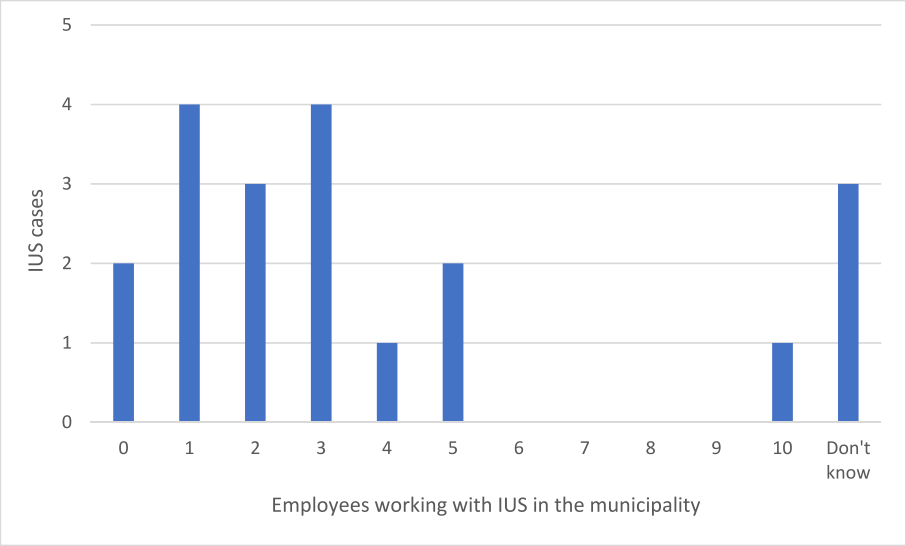

Fig. 4. Number of employees working actively on IUS in the municipality.

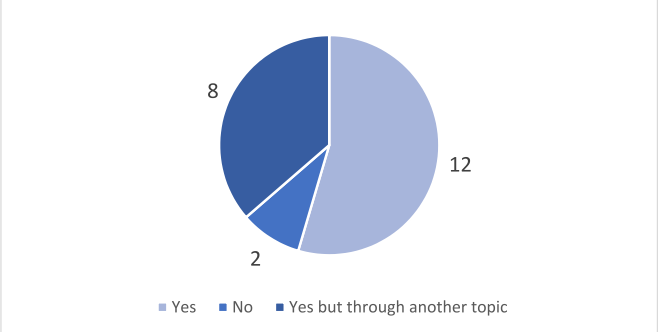

Fig. 5. Municipalities in which IUS is considered to be a priority.

the contact with municipal corporations.

Other popular activities were to "facilitate and coordinate between actors," and "support networking and relationship building (for example through corporate gatherings)," with 16 of 22 respondents (72.7 %) choosing these options. "Create a meeting point for different actors" and "promote symbiosis through communication and marketing (spread information)" were two other popular answers, with 15 and 14 respondents agreeing with these suggestions, respectively. Taken together, these and the remaining activities representing "enabling" as a governing strategy (marked in green in Fig. 6) also scored relatively high, including the following options: "inspire and motivate actors to participate in symbiosis-related work"; "build trust in participating actors"; "create common goals and visions for symbiosis development"; "drive, take the lead"; "contribute with knowledge and competence"; "innovate and experiment through, for example, providing a test bed for symbiosis"; and "offer counseling and education."

In the "provision" governing category (marked in blue in Fig. 6), "provide infrastructure, meeting venues, etc.," "assist with applying for projects and project funding," and "collect and share data about different material streams among actors" were the three activities most often selected. These options were chosen by 11, 10, and 9 respondents, respectively. "Provide financial support, grants, etc." seemed to be a less common activity, with only five respondents agreeing that this should be an activity for the municipality.

As for the "partnership" governing category (marked in purple in Fig. 6), one activity was included in the questionnaire: "participate in symbiosis as a consumer of residual flows (from external actors)." Ten respondents, or 45.5 % of the total, agreed with this suggestion.

In the "authority" governing category (marked in orange in Fig. 6), nine respondents agreed with the activity "work with impacting legislation or legal change nationally and internationally." The other activities in this category, however, ranked lowest overall. Four respondents agreed with the suggestion "create laws and legal framework that support local symbiosis development," while the activities "give legal support linked to symbiosis" and "have the overall responsibility if problems arise or if the symbiosis needs to be closed down" were each chosen by only one respondent.

Respondents were also asked if there was something that the municipality did not do, cannot do, or should not do in relation to IUS. Five respondents answered that municipalities should not give preference to and prioritize certain IUS initiative member companies over others. Giving contributions to a specific company or IUS initiative would contradict the Swedish Local Government Act (Government Offices of Sweden, 2023). The municipality should not work with corporate questions that only concern IUS member companies, and it should neither dictate the corporate contacts nor the terms of business. One respondent answered that the municipality should avoid competing with industry and make sure to avoid hindering business development. Another respondent answered that the municipality should not take on the role of the state or region; however, what this state/regional role entails was not further specified.

One respondent mentioned that the municipality cannot work as a lobbyist or create legal frameworks. Another respondent stated that the municipality lacked direct influence over permit processes, and a further respondent mentioned that the municipality did not have the proper technical competency to lead IUS development. One respondent answered that the municipality could facilitate and support IUS, but that industry must be the ultimate driving force if the effort is to succeed over the long term. Taken together, these points are interesting, considering that they conflict somewhat with what a number of other respondents stated to be the role of the municipality in IUS in Fig. 6 above (e.g., "promote symbiosis through communication and marketing (spread information)"; "create laws and legal framework that support local symbiosis development"; "work with impacting legislation or legal change nationally and internationally"; "get symbiosis thinking into different municipal processes (governing documents, procurement, establishment, permit processes, etc.)"; "contribute with knowledge and competence"; "bring cross-sectoral thinking and a broad sustainability perspective into the symbiosis process"). Another constraint in what the municipality could or could not do in IUS was linked to whether or not

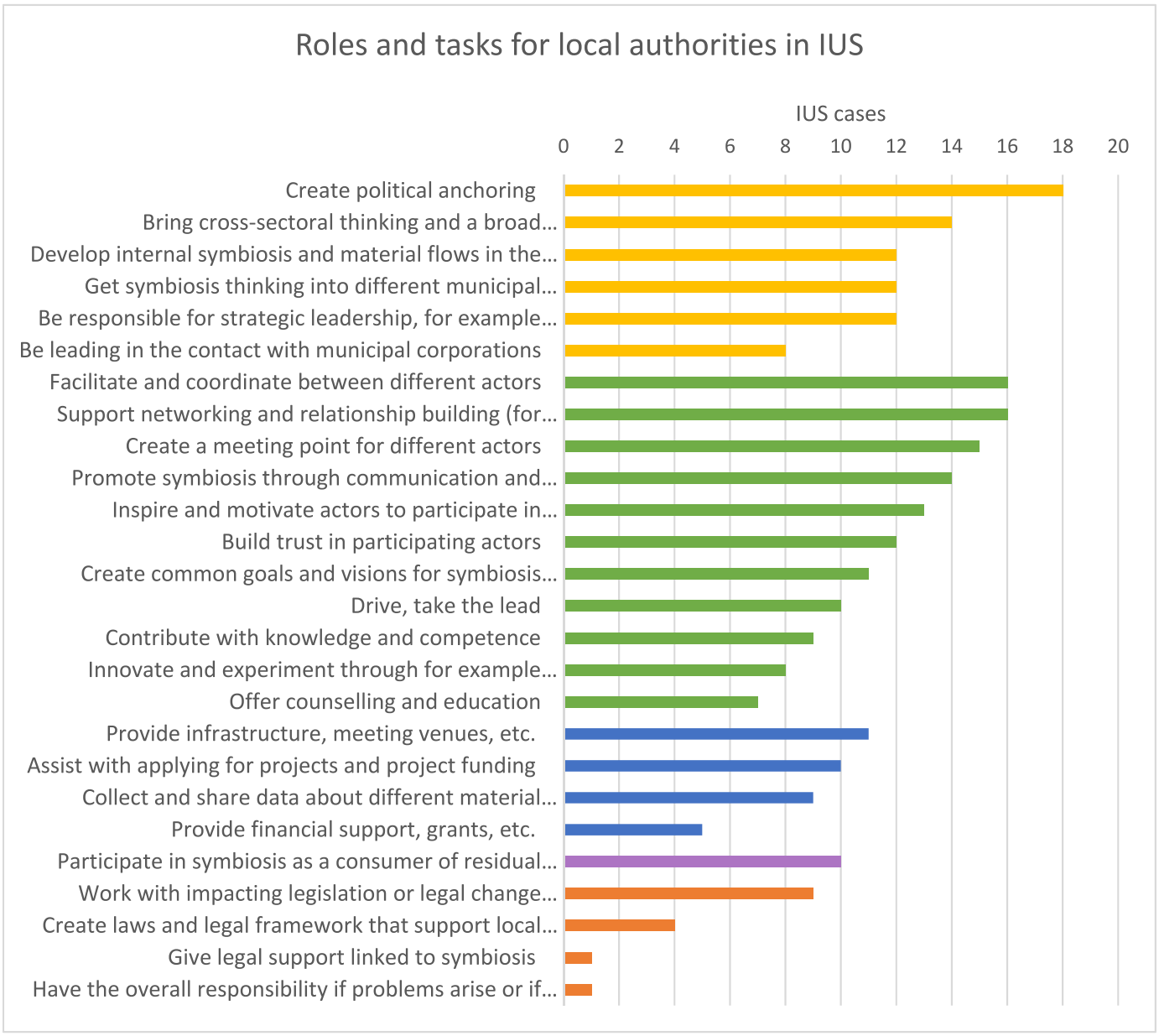

Fig. 6. Roles and activities for local authorities in IUS. Note: Bars are color coded as follows: self-governing (yellow), enabling (green), provision (blue), partnership (purple), and authority (orange). Numbers refer to IUS cases agreeing to each answer option.

the municipality owned the land: if the land where the IUS initiative was located was owned by private actors, the municipality had less of a say in how things were done. Finally, one respondent mentioned that it was difficult for the municipality to take even the smallest risks (which may be necessary in the early phases of IUS development), since its operations were financed by money from taxes.

In another question, respondents were asked how many different municipal administrations were involved in their work on IUS (see Fig. 7 below). In most municipalities, one to four administrations were active in the IUS work. Three municipalities had as many as 9 to11 administrations involved. Three other municipalities had zero administrations involved, although in these situations, the IUS initiatives were very recently developed or were under construction.

Respondents were also asked which municipal administrations were involved in their work on IUS. Business administrations was the most common answer, chosen by 17 of the 22 IUS initiatives included in this study. This was followed by technical administrations and urban planning and infrastructure administrations, both of which were selected by

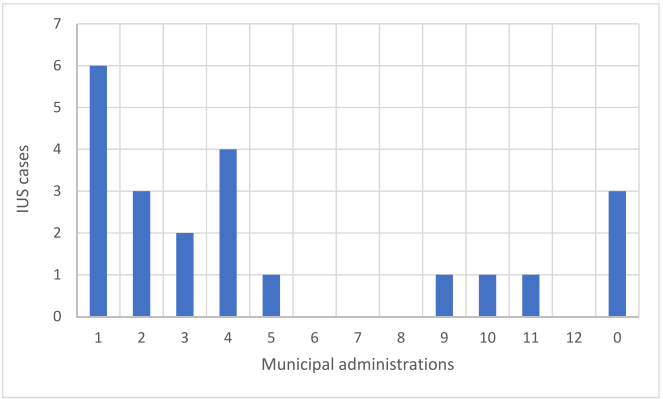

Fig. 7. Number of municipal administrations involved in IUS.

nine respondents. Environmental administrations and city (or municipal board) administrations were each chosen as being involved in six cases. Finally, labor market and social administrations, service and property administrations, health care and social care administrations, cultural administrations, school administrations, and leisure administrations were active in two to three of the cases. One respondent said that the "development section" of their municipality was responsible for IUS, but did not specify the administrative area (See Fig. 8.).

The respondents were asked what roles the different municipal administrations played in IUS. Business administrations were commonly responsible for contact, network building and communication with industry. They investigated challenges and opportunities for corporate members of the IUS initiative linked to innovation support systems and potential funding schemes. In some cases, they also played a part in establishment-related issues, such as where in the IUS to place a given type of company/organization. Urban planning and infrastructure administrations were responsible for issues regarding land ownership, planning, exploitation, building permits, infrastructure, and construction. In some cases, they were responsible for aligning work with the municipality's broader vision and ensuring that this corresponded to their social obligations. In other cases, the latter fell under the purview of city administrations (or municipal board administrations). City administrations could also take on strategic questions such as transformation and digitalization. Environmental administrations were responsible for issues around supervision and permits, and could also collect data about resource and material streams relevant to IUS through mandatory environmental reports. One respondent mentioned that their environmental administration worked as a facilitator and knowledge bearer. As for technical administrations, only one respondent answered that they were in charge of providing necessary technical infrastructure and supplies.

When it comes to different municipal corporations (fully or partly owned by the municipality), energy companies and water and sewage companies were most involved in IUS, while waste companies were also frequently mentioned. Real estate companies, housing companies, and biogas companies were each involved in one IUS case. Eight respondents stated that no municipal corporations had yet been involved in their IUS initiative. In most of these cases, however, the IUS project had just been developed or was under development (See Fig. 9.).

When respondents were given a list of municipal tools and processes and asked to indicate those used in their work on IUS (see Fig. 10), the development and implementation of strategic goals and processes was the most popular selection. This category could refer to visionary goals or development plans, such as "becoming carbon neutral." Establishment processes were also frequently used by municipalities, allowing them to create rules or recommendations for companies wanting to settle in areas where IUS solutions were implemented or envisioned. With the use of planning processes, local authorities can set out their aspirations and lay the foundations for creating IUS initiatives. Advance planning of IUS initiatives can lead to better physical and technical solutions. This is also true for exploitation processes, where future plans and aspirations can be determined before exploiting the land. If the municipality decides to develop the land itself, it has more of a say in the kind of activities pursued there than if the land is sold to a private developer. Even in this latter case of "external" exploitation, however, there could be room for local regulation to be implemented. The municipality could, for example, include stipulations regarding IUS and other sustainability and resource-saving practices in the contract. As for inspection and permit processes, these were only used in a couple of IUS projects. Here, the municipality could use inspections as a tool for mapping what types of resources are available at companies operating in their local constituency. Procurement is another municipal tool that could be used for enhancing IUS practices, primarily within the internal organization when local authorities are required to procure materials and services. The development of procurement guidelines so that more sustainable materials and services (e.g. through IUS) are promoted in the bidding process is under discussion. Three respondents answered that it was too early in the stages of the IUS development process to comment on which municipal tools and processes could be useful. Some respondents also stated that they did not use any of the above-mentioned practices.

Municipalities play a significant role in fostering and upholding

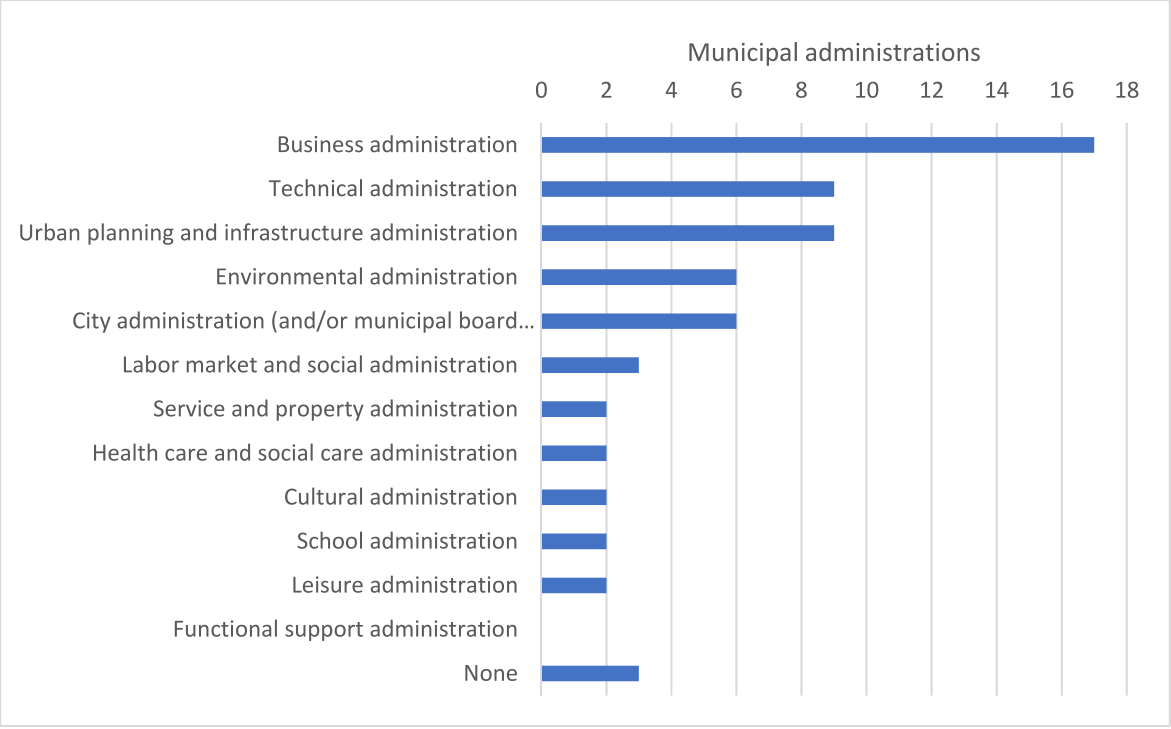

Fig. 8. Municipal administrations actively involved in the IUS cases.

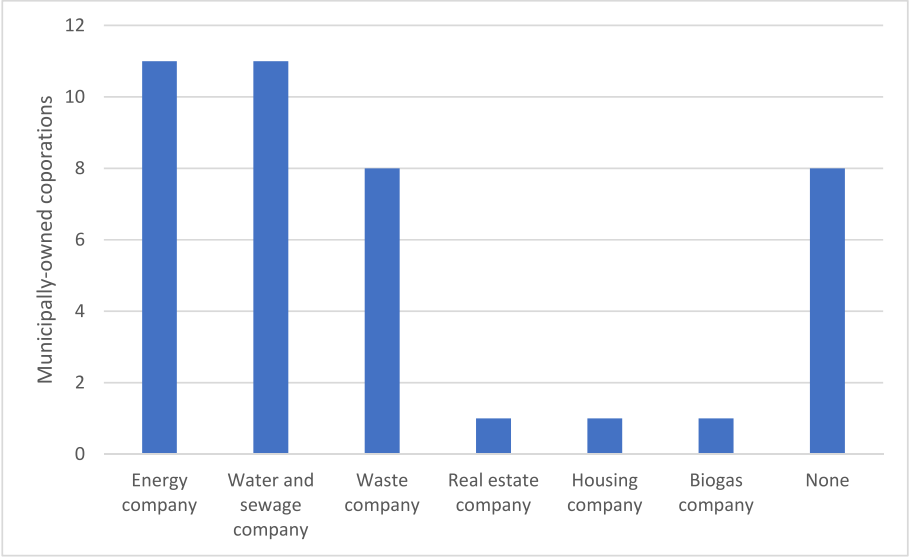

Fig. 9. Municipally-owned corporations involved in the IUS cases.

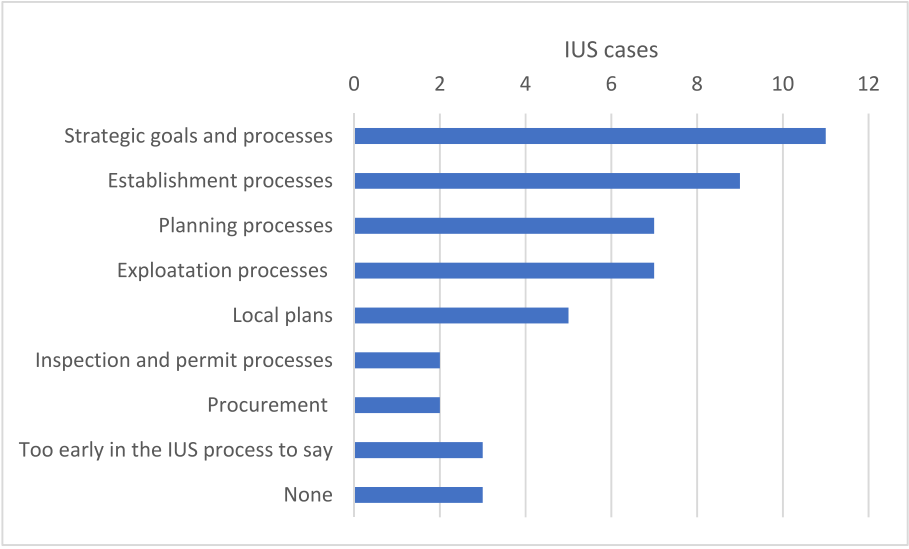

Fig. 10. Use of municipal tools and processes for promoting IUS.

democracy at the local level and in encouraging citizen participation in local governance. When asked whether citizens had been involved in developing the IUS cases, 15 respondents (68.2 %) answered "no" or "I don't know." Only seven respondents (31.8 %) answered "yes" (see Fig. 11 below). When this latter group was asked to specify how or in what capacity citizens had been involved, several different responses were offered. One respondent explained that they had started "collecting the social and societal effects" of their symbiosis in order to expand their general way of working. Another respondent replied that they "involved champions" that could contribute to their IUS, adding "But we can become better than we are today. Not just in finding them but in understanding HOW they can be involved." Yet another respondent referred to citizen involvement in the collection of food waste that goes to the biogas company that is central to their IUS initiative. Three respondents mentioned different types of informational campaigns and events, including exhibitions, seminars, study visits, and training sessions. One of them referred to citizen dialogues, such as consultation processes for local development plans.

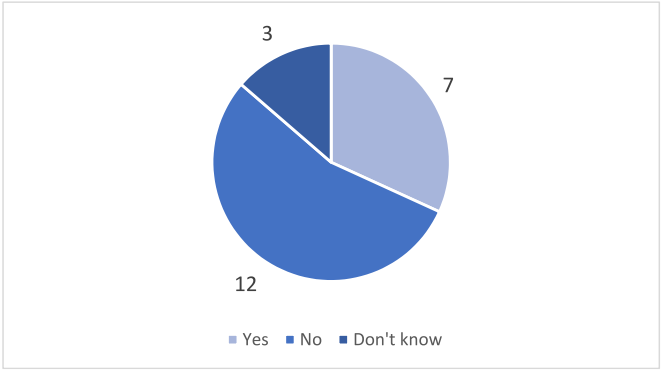

Fig. 11. Citizen involvement in IUS initiatives.

Finally, respondents were asked what would happen in the event of important changes to or even closure of the IUS. What would be the role of the municipality and who would be responsible? Four major strands could be identified among the replies. In the first strand, the role of the

industry was emphasized. Six respondents answered that industry would need to take on a leading role, especially larger business members of the IUS network. One respondent said, "the goal is for the concerned companies to drive this forward on their own." Another stated, "the symbiosis is based on a large number of companies with clear connections to and dependences on each other. Should any of the major players disappear, there is a risk that the entire symbiosis will fall apart in its current form." Yet another stated, "companies and organizations that participate have a joint responsibility for a functioning collaboration, but of course the larger slice of the pie falls on the bigger company if there is one such present [in the IUS]."

In a second strand, respondents referred to business contracts as a solution for handling uncertainty: "The actors who have established a business settlement based on symbiosis should have regulated this in their respective contracts." One respondent explained, "Companies have a plan B for all their resource streams.… They are aware of the risks and therefore have contracts with each other." Another respondent stated, "On behalf of the municipality, a key question for us to be able to specify our responsibility [in the IUS] is whether we will remain as landowners or whether we will sell the land. This has not yet been determined."

A third strand looked at IUS as not only a solution or a one-off mechanism, but as a way of thinking and working more broadly. One respondent explained that their work with IUS was merged with, or built into, their regular job, and another referred to symbiosis as a "permanent way of working." One commented, "Our work is no longer connected to just a specific IUS [initiative] but it is a holistic approach.… The municipality's continued work is secured through strategic steering documents. If they cease to work, we have secured our commitment through a well-established working method throughout the organization." One respondent working on a recently launched IUS explained that "finding an organization form and a continued work process" was part of the initial project. Having come a little further in their work, another respondent said that their IUS engagement was set up to take the role of a facilitator and this created conditions for great flexibility in their future work.

Finally, a fourth strand referred to the municipality itself as being responsible in the event of important changes to or closure of the IUS initiative. However, none of the respondents gave especially detailed descriptions of what this might look like. After mentioning companies and stakeholders, one respondent then added, "In some capacity, the municipality." Another respondent replied, "potentially the business administration, since work with IUS ideally helps to retain companies in the region."

5. Analysis and discussion

The results showed that of the 22 participating municipalities with active industrial symbiosis initiatives, a significant share (eight in number) was under development. This could be seen as a good indication of how industrial symbiosis has increased in popularity over recent years, thereby carving out a space on the political agenda. Indeed, when asked whether IUS was a prioritized issue, respondents in 20 out of 22 municipalities replied "yes" or "yes, but through another topic."

The results indicate that the number of people in the municipal organizations working on industrial symbiosis varied. While the most frequent number was from one to three people, some municipalities did not have any employees dedicated to working on IUS and others could not specify a number. Even if IUS is considered a prioritized issue, dedicated people and time are needed to fully anchor it within the municipal organization (Burström and Korhonen, 2001). The questionnaire responses also showed that the most common profession, or job position, of people within the municipal organization working on industrial symbiosis was "officials." Only a few middle managers, politicians, and dedicated IUS project employees were involved, and no heads of administration. Coming back to the question of anchoring, it could be questioned to what extent it is possible to fully embed an IUS project when not all areas and levels of the organization are involved (Den Exter et al., 2015). It has also been emphasized that it is important to ensure that those employees responsible for working on IUS in municipal organizations have the proper mandate and support (Mortensen et al., 2024; Roberts, 2004).

The questionnaire responses showed that in most municipalities, one to four different administrations were involved in working on IUS initiatives. Business administrations, technical administrations, and urban planning and infrastructure administrations were the most common types of administrations involved. Considering that industrial symbiosis seeks to be a systems-oriented solution (Salomone et al., 2020), one might ask whether its effectiveness and reach would not be enhanced if a wider strand of administrations were involved in the work by default (Mortensen et al., 2024). With business administrations oftentimes leading the work, it is also natural that primarily businesses are involved in the resource exchanges. However, if school administrations were involved, for example, a whole new segment of resource flows could become part of the IUS network. Involving schools would also be a way to build capacity for the development of future IUS projects by creating interest in and diffusing knowledge about circular solutions. Similarly, one imagines that valuable competencies for IUS purposes could be found via the labor market and social administrations. In other words, involving more and different administrative functions could create a more holistic IUS system that would have the added advantage of improving the institutional and physical anchoring of IUS in the municipal organization (Burström and Korhonen, 2001). It is important to note, however, that small municipalities have fewer administrations in place and often divide work between administrations with broader responsibilities, which gives them a more systematic approach to issues in general (Sveriges Kommuner och Regioner, 2022).

The results also showed that citizens were largely excluded from IUS processes. This is interesting, considering that the broader purpose of municipalities is—typically—to provide for their citizens. As much as industrial symbiosis can be seen as a business-driven or organizationally focused solution, if the municipality is to take part as an active participant, it should at least be asked to what extent citizens can—or should—be involved and informed. The role of citizens in IUS has not been widely researched to the best of our knowledge, making it an interesting issue to pursue in future studies. This observation is particularly relevant beyond Sweden, as municipal-citizen engagement varies significantly across countries, depending on governance traditions, regulatory frameworks, and public awareness of circular economy principles. Countries with more participatory governance structures may find it easier to integrate citizen engagement into IUS efforts, offering an area for comparative research.

As regards roles and responsibilities for local authorities in IUS, the self-governing strategy "create political anchoring" was the most popular response. This, along with the other response options in the self-governing category, scored highest on average, followed by the enabling, provision, partnership, and authority categories. This is particularly interesting considering the results from a previous, secondary-data-driven study, which indicated that governing through enabling was the most commonly referred-to strategy in literature, followed by authority, provision, partnership, and, lastly, self-governing (Södergren and Palm, 2021). This study suggests that the "internal" governing strategy implied by self-governing is in fact of utmost importance for ensuring that industrial symbiosis networks and projects are successfully implemented within municipalities.

In addition to anchoring IUS projects among colleagues in-house, developing internal symbiosis functions and flows thus becomes key. This can be compared to what has been described as both institutional and physical anchoring in previous literature (Burström and Korhonen, 2001; Martin and Eklund, 2011; Sun et al., 2017; Wolf et al., 2005). The organizational vision, ambition, and even its raison d'être become relevant for this internal dimension. Indeed, respondents agreed that local authorities can work to bring cross-sectoral thinking into IUS

processes, and that they can play a part in creating fruitful preconditions for IUS by means of forward-thinking strategic planning. Earlier studies have discussed the importance of policy instruments in developing industrial symbiosis (e.g. Alhola et al., 2019; Lehtoranta et al., 2011; Södergren and Palm, 2021) but studies in which municipalities have been asked more systematically about how they perceive the possibilities for using these policy tools are lacking. The results of this study show that there is an internal governing potential for municipalities in enabling IUS implementation by integrating symbiosis thinking into municipal processes, such as governing documents, procurement, establishment, and permit processes. Inspection and permit processes could help ensure the environmental performance of IUS systems, and procurement could be used as an enabler for incorporating more circular thinking (and acting) into the organization as a whole (Alhola et al., 2019; Xu et al., 2022).

From an international perspective, these findings highlight a contrast between Swedish municipalities and other governance models worldwide. In countries where central governments exert greater influence over local policymaking, such as China or France, self-governing strategies may play a more limited role, whereas top-down regulatory enforcement may be a stronger driver of IUS adoption (Sun et al., 2017). In contrast, in countries with decentralized governance structures, such as Germany or the Netherlands, municipalities may have greater autonomy to embed IUS into their strategies, potentially making self-governing approaches more impactful (Domenech and Davies, 2011; Geng et al., 2012; Laybourn and Morrissey, 2009). Thus, the Swedish case offers insights for regions seeking to balance local autonomy with national policy support in promoting industrial symbiosis.

Governing through enabling, provision, and partnership all represent external governing strategies in which relationships, activities, and actions outside the municipal organization are the focus (see Fig. 1). Among these external governing strategies, "facilitate and coordinate" and "support networking and relationship building" were the most commonly mentioned activities among the local authorities. This aligns with findings in earlier research (e.g. (Mortensen and Kørnøv, 2019; Södergren and Palm, 2021; Taddeo et al., 2017). Notably, the emphasis on facilitation and coordination resonates with global best practices in industrial symbiosis, particularly in countries like Denmark and South Korea, where public-private collaboration has been a key enabler of success (Behera et al., 2012; Jacobsen, 2006; Park et al., 2008). These findings indicate that municipalities in different governance settings may benefit from adapting external engagement strategies based on local institutional capacities and stakeholder dynamics.

In Fig. 1 above, the governing by authority strategy is placed between the internal and external dimensions. This is because legal aspects can impact both the internal organization and the external IUS network—separately and simultaneously. In our questionnaire, the authority category scored lowest on average among respondents (see also Fig. 6 above). The activity "work with impacting legislation or legal change nationally and internationally" was selected by nine of the 22 respondents. The other three activities, however, scored lower. For the activity "create laws and legal frameworks that support local symbiosis development," the reason is most likely linked to the use of the word "create." As Parliament is responsible for creating laws in Sweden, the responding municipalities may have interpreted this as a task beyond their authority. Interesting to note is that the municipalities did not agree with the activity "give legal support linked to symbiosis (resources, contracts, ownership, etc.)." Most municipalities in Sweden have one or several legal advisors that are available to residents, companies and organizations operating on their municipal grounds. However, their responsibilities are often connected to questions such as building permits, consumer advice, budgets and debts, etc. (Lagrummet, 2023). It is thus possible that respondents believed legal support linked to IUS fell outside their scope. The municipalities also did not agree with the activity "have the overall responsibility if problems arise or if the symbiosis needs to be closed down." Instead, most respondents suggested this activity should be governed by business and, preferably, issues should be regulated in corporate contracts.

6. Conclusion

This study aimed to investigate both the external and internal governing strategies employed by municipalities with emerging or established IUS initiatives and to explore how these strategies support the management of IUS. The study was based on an analysis of 22 municipalities actively involved in IUS initiatives in Sweden, covering a substantial proportion of the country's known IUS networks.

The findings highlight that IUS is a prioritized issue in most municipalities, yet dedicated resources remain limited. This limitation is particularly evident in terms of staff availability, the number of administrative functions involved, the application of strategic tools and processes for IUS initiatives, and efforts directed toward citizen engagement. This disconnect between political ambitions and resource constraints presents a potential risk to the successful institutionalization and long-term sustainability of IUS projects.

Municipalities employ different governing strategies to support both internal and external activities fostering IUS development. **Internally**, self-governing strategies were found to be crucial, particularly in integrating symbiosis thinking into governing documents, procurement processes, establishment policies, and permitting. Other important internal governance aspects include securing political support, incorporating cross-sectoral thinking, optimizing internal material flows, and assuming a strategic leadership role.

Externally, municipalities primarily rely on enabling and provision strategies to facilitate IUS, including coordinating interactions between actors, supporting networking and relationship-building, motivating participation, fostering trust, and providing necessary infrastructure. Governing by authority was perceived as a strategy that spans both internal and external roles, though respondents generally saw regulatory responsibilities as a state-level issue, with businesses taking the lead on operational matters.

6.1. Limitations and future research directions

While this study provides important insights, some limitations should be acknowledged. First, the study is based on data from 22 municipalities, covering a significant proportion of Sweden's IUS networks, but findings are specific to the Swedish context and may not be directly generalizable to other countries with different governance models. Future research could explore international comparisons to examine how governance strategies differ across policy and institutional settings.

Second, while the study aimed to capture the perspectives of key municipal actors, the questionnaire responses were primarily collected from one representative per municipality. Given that IUS-related responsibilities are often concentrated in a single individual within municipal organizations, this approach ensured that responses came from the most relevant personnel. However, in future studies, collecting input from multiple representatives per municipality could provide a broader perspective on the internal dynamics of IUS governance.

Third, this study did not examine how internal and external municipal strategies interact over time. A longitudinal study could provide deeper insights into whether and how internal municipal structures influence external collaboration efforts, and vice versa.

As the role of municipalities in fostering industrial and urban symbiosis continues to evolve, further research is needed to assess interdependencies between internal and external governance strategies. Additionally, future studies could explore how the inclusion or exclusion of different actors—such as citizens, businesses, and regional authorities—affects IUS development and long-term viability. Strengthening knowledge in these areas will be critical to supporting municipalities in advancing circular economy transitions through effective governance structures.

CRediT authorship contribution statement

Karolina Södergren: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jenny Palm:** Writing – review & editing, Writing – original draft, Supervision, Funding acquisition.

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.

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Appendix 1

Questionnaire about industrial and urban symbiosis implementation and political anchoring in municipal organizations.

1. In which municipality is the symbiosis you work with located, and what is the symbiosis called?
2. How developed is the symbiosis that you are working with?
3. What is your role in the symbiosis?
4. Is industrial and urban symbiosis a priority/prioritized issue in your municipality?
5. In your opinion, what role does the municipality have in the symbiosis?
6. Is there anything that the municipality does not do, cannot do, or should not do in relation to symbiosis?
7. How many people in the municipality are actively working with symbiosis?
8. Based on the previous question, are these people mainly: Officials; Middle managers; Administrative managers; Municipal manager; Politician; Other? Please select.
9. Where, within the municipal organization, would you say the responsibility lies for the symbiosis? (For example, under a certain administration.)
10. Which municipal administrations are actively involved in the symbiosis?
11. What are the roles of the participating administrations in the symbiosis? Please describe.
12. Would you like/need to reach other administrations that are not yet involved in the symbiosis? If so, which ones?
13. Which municipally owned companies (partly or fully owned) are included in the symbiosis?
14. Does your municipality use any of the following tools/processes to strengthen your symbiosis?
15. Were citizens involved in the development of symbiosis in your municipality?
16. If you answered yes to the previous question, how did your municipality involve citizens in the development of symbiosis?
17. What happens if the symbiosis changes or even ends? Who will then be responsible? Please explain your thoughts on this.
18. Does your municipality cooperate with other municipalities in (or in matters related to) industrial and urban symbiosis? If yes, please specify with which ones.

Appendix 2

Alphabetical list municipalities in Sweden that work actively with IUS and participated in the questionnaire.

1. Bengtsfors
2. Bjuv
3. Gotland
4. Göteborg
5. Helsingborg
6. Höganäs
7. Karlstad
8. Lidköping
9. Lindeberg
10. Lysekil
11. Malmö
12. Norrköping
13. Simrishamn
14. Sotenäs
15. Stenungsund
16. Sävsjö
17. Vänersborg
18. Vimmerby
19. Ånge
20. Åre
21. Örnsköldsvik

22. Östersund

Appendix 3

Governing strategies: roles and activities for local authorities in IUS.

Self-governing	Authority	Partnership	Enabling	Providing
Create political anchoring	Work with impacting legislation or legal change nationally and internationally	Participate in symbiosis as a consumer of residual flows (from external actors)	Facilitate and coordinate between different actors	Provide infrastructure, meeting venues, etc.
Bring cross-sectoral thinking into the symbiosis process	Create laws and legal framework that support local symbiosis development		Support networking and relationship building (for example through corporate gatherings)	Assist with applying for projects and project funding
Develop the internal symbiosis and material flows in the municipal administration	Give legal support linked to symbiosis (resources, contracts, ownership, etc.)		Create a meeting point for different actors	Collect and share data about different material streams among actors
Get symbiosis thinking into different municipal processes (governing documents, procurement, establishment, permit processes, etc.)	Have the overall responsibility if problems arise or if the symbiosis needs to be closed down		Promote symbiosis through communication and marketing (spread information)	Provide financial support, grants, etc.
Be responsible for strategic leadership, for example by creating pre-conditions for symbiosis through urban planning, impact through owner control of municipal corporations, etc.			Inspire and motivate actors to participate in symbiosis-related work	
Be leading in the contact with municipal corporations			Build trust in participating actors Create common goals and visions for symbiosis development Drive, take the lead Contribute with knowledge and competence Innovate and experiment through for example providing a testbed for symbiosis Offer counseling and education	

Data availability

Data will be made available on request.

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