Interreg Alpine Space

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ECOLE

ECOLE:

ECO industrial park network for the Alpine Regions Leveraging smart and Circular Economy

Systemic thinking community model and key principles for its activation in various contexts

Deliverable D1.3.2

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Review academic and non-academic literature on the governance of eco-industrial parks, and stakeholder engagement and activation. Develop the framework conditions (or principles) for an effective systemic thinking community model for eco-industrial parks.

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ABBREVIATIONS USED

AF	Application Form
AP	Associated Partner
AS	Alpine Space
EC	European Commission
ECOLE	ECO industrial park network for the Alpine Regions Leveraging smart and Circular Economy
ERDF	European Regional Development Fund
EU	European Union
ICT	Information and communication technologies
JS	Joint Secretary
KPI	Key Performance Indicators
LP	Lead partner
PP	Project Partner
WP	Work Package
WPL	Work Package Leader

1. Objectives and summary

Circular economy is a key lever to enable the transformation towards sustainability across sectors. The four main principles of circularity (reduce, reuse, recycle, recover)[1] guide and inspire stakeholders and especially companies and consumers on how to make circular choices and strategies (at the level of products, systems, value chains, and business models) that ultimately minimise waste and increase the efficiency of various inputs. At the basis of such transformations are complex and novel dynamics across stakeholders that require sharing of information, data, alignment of interest, and rethinking models of production and consumption of products and services.

A major contributor to circular economy generally, and in particular in the context of an industrial park, is industrial symbiosis. Such a process is grounded in cross-stakeholder cooperation in industrial networks and symbiotic relationships that result in economic gains (e.g., lower operation costs, lower taxes), social benefits (e.g., job creation, community cohesion), and environmental improvements (e.g., reduced waste and emissions) for those involved (de Jesus et al. 2018). Industrial symbiosis essentially ensures that underutilised assets/materials (e.g., machines, vehicles, infrastructures, personnel, expertise, storage space) are shared among diverse companies and the residual outputs from one industry (e.g., materials, by-products, energy, waste) become feedstock for the production processes of other industries (Chertow 2000) (see also D1.1.1 and D1.1.2 for more detail).

Such synergies can go beyond industrial stakeholders to also include local/regional communities, networks that are commonly described as urban-industrial (or recently also regional-industrial) symbiosis. Yet, in spite of demonstrated benefits, empirical evidence shows that beyond technical and economic barriers and low commitment to sustainability, a major constraint to implementing industrial symbiosis processes emerges from lack of cooperation and information sharing (Krom et al. 2022). For industrial symbiosis processes to operate effectively, cooperation among firms in unrelated industries and surrounding communities, as well as the geographical proximity offered by clusters or industrial parks are essential (Benedict et al. 2018). Especially when it comes to cooperation, these requirements are even more prominent when synergies are to be identified and maintained beyond the premises of an industrial park.

Therefore, considering the complex dynamics that industrial symbiosis relies on, the concept has been more recently expanded to also include more sophisticated forms of cross-stakeholder cooperation that may not be highly dependent on geographical proximity. As per more recent evidence and applications, industrial symbiosis networks go beyond purely material and energy transactions to also include exchange of knowledge, information, and expertise to enable eco- innovation and long-term cultural exchange (Krom et al. 2022; Yeo et al. 2019; Lombardi and Lybourn 2012).

[1] The four Rs have been extended to 10Rs, as explained in D1.1.2 based on Kirchherr et al. (2017): refuse,

rethink, reduce, re-use, repair, refurbish, remanufacture, repurpose, recycle, recover.

For these reasons, the governance of such symbiosis networks is essential and needs to be better understood, also laying the foundation for more broader processes related to enable circular economy processes and behaviour-related innovations in an industrial park (i.e., the focus of our ECOLE project). Given the focus of most industrial parks on resource intensive (often manufacturing) activities, we therefore focus on symbiosis processes specifically, extrapolating governance implications to other circular economy activities within an EIPs.

To set up and effectively manage a governance system, in the ECOLE project's deliverable D1.3.1 we describe the systemic thinking community model (STCM) as a tool that aims to leverage synergies for urban-industrial symbiosis and circular economy processes in industrial parks and to extend the EIP benefits beyond the park tenants to the surrounding communities. This model is meant to strategically identify key stakeholders in each stage of the transformation of traditional industrial parks into EIPs or each phase of implementation of symbiosis relationships, giving the local/regional community the same importance as the rest of the stakeholders and thus providing a more holistic approach for the governance of such EIP-related projects.

This paper adds deeper insights into why such a governance model is necessary and provides evidence-based guidance on how to go about sharing information and engaging the larger community to fully capitalize on the systemic benefits from EIPs. Therefore, within this context, as also explained in deliverable D1.3.1, by "community" we refer to the full range of stakeholders within but also outside the perimeter of the industrial park (for example, industrial park tenants but also local municipalities, local residents, education and training institutions in the region, or government institutions).

The analysis in this paper relies on a systematic and detailed literature review of academic studies and policy reports on the development of industrial symbiosis networks. It deepens the understanding of urban-industrial symbiosis approach and the enablers and barriers of these symbiosis relationships to highlight the importance of social/stakeholder interactions in the development of such relationships and suggest a new approach to engage and empower information and resources sharing across stakeholders.

We start in **section 2** by defining the concept of urban-industrial symbiosis within the context of circular economy, and identifying the factors acting as enablers and barriers to the implementation of these interactions. This section also points out some examples of channels for sharing information and ways in which EIPs can achieve a community engagement. **Section 3** then focuses on how urban-industrial symbiosis and circular economy actions can be put in practice to enable the type of systemic thinking processes across diverse stakeholders, necessary for effective EIPs. **Section 4** wraps-up the paper with so-called principles for a systemic thinking community model for EIPs, meant to offer practitioners guidance on setting-up such governance processes.

2. Urban – industrial symbiosis

The circular economy concept is closely connected to industrial ecology and industry symbiosis. Circular economy practices emphasize reuse of parts, components, and materials; repairs, refurbishments, and remanufacturing to keep products in use; recycling to extract materials for reuse; and recovering energy from nonrecyclables (World Bank 2021: 18). Circular economy, therefore, aims for a change in production and consumption

processes and novel business models that would decouple economic growth/activities from loss of environmental value and carbon- and

resource-intensive industrial development (see D1.1.1 and D1.1.2). At a more granular level, and with a specific focus on industrial sites/activities, industrial symbiosis connects traditionally separate entities in a collective approach to achieve competitive advantage with (mostly) physical exchange of materials, water, energy, by-products, and also (increasingly) information. Such exchanges of physical and non-physical resources are at the core of an industrial park, reason why we focus on such processes to distil the necessary stakeholder dynamics.

While industrial symbiosis processes have been traditionally focusing on industrial sites, it has become increasingly evident that expanding such synergistic relations to the surrounding communities (urban and/or rural) can scale up the benefits associated with a circular economy. On the one hand, a major drawback of industrial parks has been their relative isolation from the rest of the economy, aside from the environmental degradation effects of resource-intensive manufacturing zones. On the other hand, urban agglomerations have expanded significantly, especially around employment rich areas, placing higher pressures on (public or private) utilities companies to supply and efficiently manage resources such as energy, water, waste, and transportation.

It is in this context that urban-industrial symbiosis has received increasing interest both from an academic as well as operational point of view. The basic principles of circularity make it possible to promote and expand industrial symbiosis to the urban environment. Cities offer a variety of advantages for businesses, from a larger market to local suppliers, and to an environment conducive to technological inventions and knowledge. In addition, urban and/or rural communities offer an opportunity for scaling up and valorising resources that are currently thrown away and wasted. For clarity and generalizability across this paper, by “urban” in the term urban-industrial symbiosis we group together all surrounding residential and non-residential areas around a particular areal of an industrial park. These could be cities, towns, villages, and/or other economic areas.

In this section we explain the concept of urban-industrial symbiosis and we discuss the key enablers and barriers in the implementation of synergistic processes, with a particular focus on non- economic and non-technical factors and how these may differ across economic sectors.

2.1. The concept

Urban-industrial symbiosis was introduced in 2009 by Van Berkel et al. (2009) but the concept has not yet been widely implemented in practice. Nevertheless, it is gaining increasing attention across countries as sustainable development and circularity become more important in new policies and regulations regarding industrial processes. By now, for example, urban-industrial symbiosis is of particular importance in countries like Japan, where solid waste source separation systems are well established in municipalities (Ažman Momirski et al. 2021). Yet, despite the benefits it offers, urban- industrial symbiosis is grounded in inter-related physical, economic, social, and political processes and therefore does face various obstacles, including the challenge of managing the interests of all stakeholders involved.

Urban-industrial symbiosis can be generally defined as a network of community and industrial actors bridging local needs to improve resource utilization (Henriques et al. 2021). Different from industrial symbiosis where an exchange of waste resources and by-products

is established only between the enterprises within the park, urban-industrial symbiosis recognizes the use of solid

waste in cities as input sources for industries that do not normally accept these sources (Ažman Momirski et al. 2021). Vahidzadeh et al. (2021) also refer to regional industrial symbiosis stressing the importance of broader spatial approaches to achieve more effective and inclusive environmental and economic benefits.

In these approaches, it is normally the government that facilitates synergistic relations between companies and communities (Ažman Momirski et al. 2021). However, given our focus on EIPs, we understand urban-industrial symbiosis processes to take place between the industrial park and the surrounding community, coordinated mostly by a central authority within the EIP that designs and manages the stream of exchanges, in close cooperation with the municipal/government entity.

An effective park management requires dedicated responsibilities and functions such as infrastructure and services management, coordination with various stakeholders and attracting investment for financial sustainability. It ensures continuity over time and consistency with EIP goals for companies, end customers, authorities, and communities. The park management authority within the park assists tenant companies creating industrial synergies as well as collaborating with local community and natural environment (UNIDO 2017). Local authorities play an active role in such networks, beyond acting as legislators (Horvath and Harazin 2016 in Vladimirova 2018). This could happen through, for instance, integrating a region/city's waste with an industrial park for a more effective material recovery and resource utilization. When utility companies are publicly own, local authorities are essential in enabling such processes to take place. In the (common) situation in which utilities are privately owned, local/regional authorities are key in setting the "right" incentives and regulatory frameworks to ensure that circular economy processes are integrated in the operations. The participation of local authorities is also of importance for the development of common infrastructures.

The development of urban-industrial symbiosis critically depends on technical, economic, and socio-political factors. It can be said that part of the success of these systems is based on the presence of basic components of these three factors and their coordination (UNIDO 2017). For example, an EIP and an urban area may have the know-how, technologies, and infrastructure necessary to develop synergistic relations, but if investors or tenant companies cannot make the investment profitable, symbiotic exchanges will not take place. The same is true for socio-political factors.

UNIDO (2017) specifically identifies three success factors for EIPs' contribution to sustainable development in the surrounding urban areas:

1. ***Awareness among local authorities and communities:*** Local authorities are in the end, responsible for promoting the development of urban-industrial symbiosis aligned with citizens' interest. It is, therefore, important to involve the community in this process to ensure that they will use services offered by the EIP and contribute to the synergies created. The behaviour of the population can have a significant impact on the success of these systems, for example in waste classification. If the community develops a sense of belonging and importance in the system due to the constant involvement in various activities by the local authorities and the central authority of the EIP, the industries that will use the community's waste will (arguably) have a higher quality by-

product or will have to invest less effort in sorting it. Therefore, diverse activities (e.g., conferences, workshops,

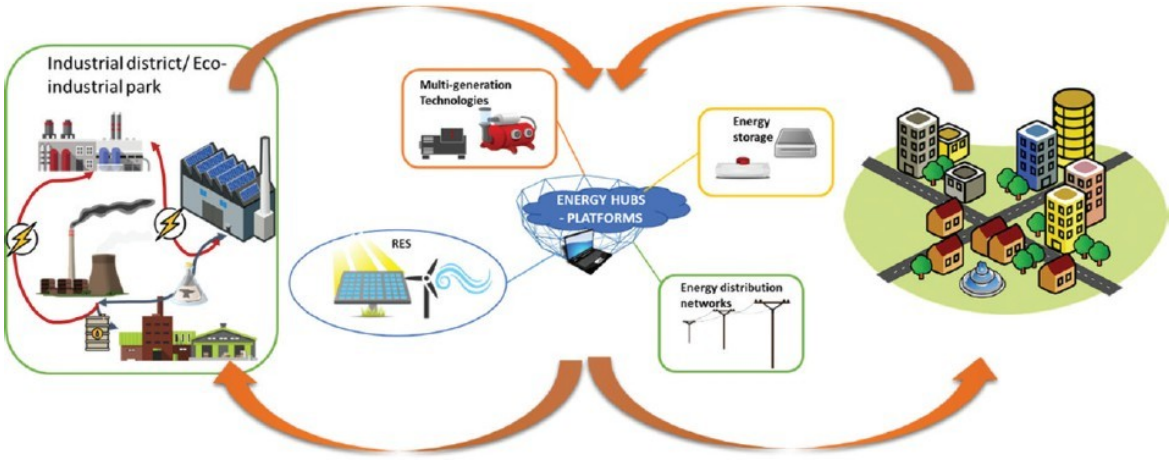
distribution of flyers) should be considered and promoted during the whole lifecycle of the project to ensure that all stakeholders support urban-industrial symbiosis. Taddeo (2012) points out that there may also be legal and procedural resistance if an EIP transformation project is perceived poorly by the public, which is likely to be the case when stakeholders do not engage with communities productively early on. One example can be the negatively affected public perception of an EIP project in Tianjin, China, after an unrelated industrial accident near the project site. The Tianjin Eco-City was planned to be a mix of industrial and residential development and has successfully attracted many international companies that have set up either regional headquarters or subsidiaries. Even though several strategic alliances have been established and companies work together to achieve circularity goals, the occupancy rate of the eco-city is relatively low (Mathews et al. 2018).

2. ***Relevant and adaptive urban infrastructure:*** Planning of common and urban infrastructure systems must be flexible enough to establish synergetic relations. For example, when already established waste processing facilities operate with large quantities of materials, there may be resistance to implement or accept the integration of innovative recycling solutions that will reduce the input quantity of these facilities, if, for example, the business models of those facilities depend on the processing increasing quantities of materials.

3. ***Efficient urban waste collection system and waste characterisation:*** An efficient collection system of wastes generated in a city is crucial to enable an effective urban-industrial symbiosis system. As mentioned above, the population has a strong influence on waste quality through source separation. The characterization of municipal waste streams is essential to allow revalorization in industrial parks (Dong et al. 2013 in UNIDO 2017).

To these three success factors existing literature also emphasizes the importance of sharing energy and transport infrastructure (for people and goods) (Ribeiro et al. 2018) and making use of heat waste streams. While energy production from urban wastes and the heat recovery from industrial processes and co-generation plants for district heating have been widely discussed in the literature, other type of energy-based urban-industry symbiosis are also important. In particular, renewable energy symbiosis networks between industrial and urban areas have been shown to be increasingly important for expanding renewable energy systems and advancing the energy transition (Butturi and Gamberini 2020). Such energy synergies form what Butturi and Gamberini (2020) call “energy hub platforms” driving such urban-industrial symbiosis processes (see Figure 1).

Figure 1: Energy hubs serving urban-industrial symbiosis



Source: Butturi and Gamberini (2020: 360)

A more recent interpretation made by Lombardi and Lybourn (2012) drawing on practical experience and discussions with contractors and policy makers, suggests that industrial symbiosis operates in a network with diverse eco-innovation organizations and long-term cultural change. Practices such as knowledge creation and sharing in the network drives mutually profitable transactions to recover necessary inputs, find value-added targets for non-productive products, and improve business and technical processes. Based on this interpretation, geographical proximity receives a lower emphasis for the success of such symbiotic relations, stressing the importance of dialogue and alignment across stakeholders.

2.2. Enablers and barriers

Urban-industrial symbiosis projects are characterised by a high level of complexity because they involve multiple stakeholders that often have different interests. Several studies have identified and categorized key symbiosis factors into two groups: (a) **factors that can unlock, facilitate, and support** the implementation of synergies (enablers, drivers, or triggers), and (b) **factors that can block or hinder** the concretization of an initiative (barriers, challenges). Henriques et at. (2021) suggest that these enablers and barriers can be presented in seven fundamental dimensions, namely social, economic, policy, management, technological, geographical and intermediaries. In addition, the economic, environmental, political, and social context of a country can be decisive in the way sustainability is addressed and consequently in how it can favour or condition the development of these projects (Neves et al. 2019).

Common enablers have been identified among European countries that have been most active in implementation of industrial symbiosis relationships (such as Italy, Sweden, and Finland), such as awareness of environmental issues and search for sustainable solutions, longer practical experience with industrial symbiosis, a considerable number of cases of self-organised symbiosis networks, the existence of facilitators through national agencies or local governments, and stringent environmental regulations (Neves et al. 2019). Existing legislation, plans and policies are also referred to as drivers of industrial symbiosis as companies are encouraged to set up synergy networks by imposing limits on emissions or

waste disposal through regulations and taxes. This

promotes the use of waste as by-products and the allocation of funds to innovative and sustainable technologies.

On the other hand, Neves et al. (2019) also points out that existing legislation may often limit the implementation of synergistic relationships, especially when it is too rigid, unclear, or inconsistent. In addition, the social and economic instability of a country can also represent a barrier to these practices, since other social issues (e.g., poverty, unemployment, violence) may be considered more important than sustainability issues.

Below, we discuss in more detail a few essential non-technical enablers and barriers that can be associated to the STCM for the implementation of urban-industrial symbiosis.

2.2.1. Enablers of social/stakeholder interactions

Firms within an EIP form a network of strong social ties, which create high social embeddedness (Boons and Howard-Grenville 2009). This results in a trust climate across the industrial network that sustains and cultivates cooperative and stable exchanges to enable circular solutions. In urban- industrial symbiosis, ***trust between stakeholders***, particularly firms, is required for four main reasons.

First, in the transformation process of an EIP, private firms may be unwilling to invest in sustainability initiatives when immediate benefits are minor (or not entirely evident), and payback periods are long (Valentine 2016).

Second, interdependencies between companies develop and strengthen through exchange relationships (Ehrenfeld and Gertler 1997; Gibbs 2003). When the suppliers do not have the capacity to manage the flows or the quality of the exchanged by-products varies, the cost for downstream companies can be very high (Sterr and Ott 2004; Van Beers et al. 2009).

Third, contracts or agreements on which EIPs are based are often complex and not transparent (Park et al. 2016). Long-term contracts with specified material exchange details could be a problem if the goals and interests among stakeholders change in the first stages of the EIP development process until the project matures. Last, firms may be cautious of sharing confidential information that may benefit symbiotic relations within the park and other stakeholders such as communities (Ramsheva et al. 2019; Gibbs et al. 2005).

The central authority within the EIP and local authorities may help create trust by enabling communication between the different stakeholders. Ramsheva et al. (2019) points out that companies first develop calculation-based trust in the commercial viability of EIPs, then knowledge- based trust from participating in and/or observing successful cooperation, and then identification- based trust as firms' goals and decision-making becomes collectivized.

Education to ***increase awareness*** is a key enabling tool to implement these projects (Freitas and Magrini 2017) and promotes engagement between the stakeholders by highlighting the benefits and added value of circular solutions for industrial parks. The full potential of an EIP can only be developed if stakeholders are convinced by the usefulness of the concept and the associated benefits relevant to them (UNIDO 2017). Awareness raising is crucial across the whole lifecycle of the project, but especially in the initial phases. Topics such as environmental, economic, and social benefits of synergistic relations support and motivate the participation of different stakeholders in

industrial parks. At the same time, it is important to talk about possible challenges related to EIPs to avoid problems and setbacks due to misunderstanding of certain requirements.

Introducing environmental management education programs is an example of awareness raising initiatives (Ceglia et al. 2017) required both in greenfield and brownfield projects. Education is also relevant to engaging suppliers to improve their understanding of the needs of the buyers and encourage their communication, which will gradually lead to transforming linear to circular supply chains (see D1.1.2). A detailed stakeholder mapping and analysis is necessary to determine how to best implement awareness raising interventions (UNIDO 2017) (see deliverable D.1.3.1 on how to go about identifying, analysing, and mapping stakeholders).

Moreover, the adoption of synergistic practices also depends on **community engagement** (Freitas and Magrini 2017). ***Learning networks*** and ***forums*** support the development of trust-based relationships between stakeholders (Ceglia et al. 2017; Yedla and Park 2017) supporting innovative solutions for new products, novel circular business models, or synergies across firms in terms of use of inputs and outputs. To this end, close cooperation with education and training institutions is essential for designing customised education programs at different levels and for various circular economy-related topics.

In addition, ***information databases*** and ***effective communication channels*** are crucial to enable sharing of experiences, statistics, opportunities for circular solutions and symbiosis exchanges (Liu et al. 2018; Yedla and Park 2017; Desrochers 2001). Individual reports with information (e.g., performance indicators, process flow, waste streams) about a firm can be helpful for client firms to understand potential synergy opportunities and benefits. Yeo et al. (2019) indicate that databases need to inform potential participants of EIP about development opportunities and existing flows in regions; combining material flow data with a geographic information system (GIS) is a possible way to achieve this. However, databases for sharing information about ongoing EIP projects are usually restricted due to confidential information, hiding possible success cases.

Last, Ceglia et al. (2017) mention that ***developing networking knowledge amongst national/federal, state/regional and local governments*** is relevant for sustainable development and the transition to a circular economy. The government needs to play a strong role both in paving access to funds and creating a regulatory environment that rewards environmentally friendly production, nudging behavior of consumers and producers towards circularity, and creating the conditions for successful EIPs projects to develop (Massard et al. 2018).

2.2.2. Barriers of the social/stakeholder interactions

Given that the contexts are very different for each country and the policies and regulations in which an EIP can be developed vary according to many factors, a wide range of challenges have been identified in the literature. Factors described as enablers in the section above might operate as barriers depending on the context and how they are managed.

As we know, trust between stakeholders is a critical enabler for the implementation of EIPs, but it can also be problematic for many organizations where competition is the norm, or for firms with long histories and stable contexts that keep them away from changing existing

practices (Taddeo 2016). We refer to such a barrier as a ***lack of transparency*** in communication across different stakeholders. Some of the reasons we associate with this barrier are lack of internal resources and/or capabilities that allow the dissemination of information and communication (Zhu et al.

2015), an (often unjustified) emphasis of some firms on confidentiality (Fraccascia and Yazan 2018), lack of channels for coordination among firms within an EIP, and lack of external support from communities and government policies (Zhu et al. 2014). When these factors are present, firms are not able to see or identify the opportunities and benefits of EIP projects and therefore are not inclined to engage in creating synergistic relationships, which in turn does not promote a transparent operation relative to the rest of the stakeholders.

Economic and operational factors may also act as barriers, as for example the time taken for a return on initial investment (Taddeo 2016) compounded by a ***lack of understanding of the economic viability*** of circular economy solutions or of participating in industrial symbiosis networks. Circular economy and the development of industrial symbiosis networks is driven in part by economic benefits, i.e., cost savings, enhanced competitiveness, reduced infrastructure costs and improved revenue generation. If these benefits are not clear to firms, no engagement in EIPs will take place as firms might not necessarily be interested in optimizing the benefits for the entire system when they cannot understand their own benefits. At the same time, the self-interest or competitive nature of certain industries can lead to ***conflicts of interest*** (Henriques 2021), which can be associated with ***power or status asymmetries*** (Ashton et al. 2017).

Studies on EIPs highlight the importance of a centralized management model to ensure the smooth operation of a park. An EIP with ***no institutional support or poor management*** may have problems with integration, coordination, and communication (Vladimirova et al. 2018) between companies within the park and the local authorities and communities. Problems such as a resistance to collaboration may derive from unengaged leaders. Bacudio et al. (2016) suggest that an industrial symbiosis approach needs to be incorporated in standard industrial parks management practices as part of their policy.

Other barriers to the creation of industrial symbiosis found in the literature are the general ***lack of knowledge of the industrial symbiosis mechanisms*** both at the level of firms, as well as the urban communities and regional policy makers, as well as the ***lack of knowledge of companies and municipalities***, for example, on the potential to receive or provide waste (Neves et al. 2019). The fact that companies are being encouraged to implement measures to reduce waste generation has also been identified as a barrier, as there is a concern that the stream of waste involved cannot be guaranteed.

3. Community-industry synergies in practice

Effectively integrating circular solutions and implementing urban-industrial symbiosis processes requires continuously capitalising on those drivers and minimising those barriers discussed in section 2, across the entire policy cycle and EIP project lifetime. Empirical evidence from implementation experiences points to several tools that support the needed system-level processes, offering a solid base for interests' alignment, data and information sharing, awareness building, engagement, coordination, and ultimately trust building across the range of relevant stakeholders. Below we shed light on two categories of such tools: (a) platforms for sharing data and information; and (b) modalities for community engagement.

3.1. Platforms for sharing data and information

As the concept of (urban-)industrial symbiosis implies, sharing of information across previously disconnected entities, is essential. Information and communication technologies (ICT) play an increasingly important role to support data collection, facilitate (real-time) exchange of excess resources in symbiosis networks, and matchmaking that facilitates the identification and exploitation of synergistic opportunities (Krom et al. 2022; Benedict et al. 2018).

Industrial symbiosis tools include online marketplaces, databases, social networks applications and knowledge repositories (van Capelleveen et al. 2018). Information sharing can also be achieved through workshops, working group discussions, and conferences (Neves et al. 2019).

Digital platforms allow firms to easily share information among themselves and with other stakeholders (e.g., municipalities) about their geographic location, characteristics of their products, type and amount of required resources, as well as their availability to start new industrial symbiosis relationships. These platforms and the willingness of companies and municipalities to share information with each other can play a critical role in the initial phase of an EIP. Although information sharing might increase the trust between companies, it can also be interpreted as revealing sensitive data about the companies' products (Fraccascia and Yazan 2018). According to Otto et al. (2020), one major reason that companies do not engage in data-sharing models is the perceived lack of control when data leaves their premises.

For instance, in the Korean EIP program, the development of a resource database was relevant and part of the strategy to identify industrial symbiosis projects. These central databases were designed not only for material resources but also for the organizational, human, and infrastructure resources available in the region by conducting surveys and compiling environmental statistics from governmental and research institutions (Park et al. 2015).

To facilitate information sharing related to symbiotic relationships, the adoption of closed-loop models (e.g., platforms for resource sharing, recovery, and recycling) should be considered, as the market for such tools have significantly evolved (World Bank 2021). SHAREBOX is an example of a digital platform that works as a management tool for industrial symbiosis and a marketplace for trading industrial waste and by-products. Companies are able to record their excess resources or those needed, and the platform facilitates matching supply and demand by using AI-powered algorithms. Specialised modules allow users to evaluate transaction opportunities, have technical discussions, bilaterally negotiate deals, and follow up, mange, and report on the synergies created (Krom et al. 2022). Other examples of digital platforms found in the literature include:

- Waste-to-Resource Matching platform (Low et al. 2018)
- Waste Electrical and Electronic Equipment (WEEE) platform (Marconi et al. 2018)
- By-Product Exchange Network (BEN) (Raabe et al. 2017)
- Networking platforms for waste exchanges information (Ceglia et al. 2017)
- SymbioSyS Tool (Álvarez and Ruiz-Puente 2017 in Vladimirova 2018)

Other examples of digital tools are those offered by the SIA Working Group for Sustainable Industrial Areas.[2] One such tool is the *Industrial Area Information Management System (IAIMS)*, specifically focused on collecting and managing technical data from across the industrial park, especially related to raw materials, consumption, outputs, waste production and environmental performance. The collection and management of such data requires close cooperation between the relevant stakeholders. Another SIA platform is the *Baseline Analysis Tool*, which allows identifying hotspots for action, monitoring of indicators, and provide information for action to relevant stakeholders, including municipalities, tenants, suppliers. Customized digital platforms for the EIP community can also be designed to ensure a continuous flow of information and regular exchange between relevant stakeholders.

These digital platforms and information sharing mechanisms can be driven by intermediaries/knowledge brokers/coordinating bodies. As "neutral players" they help facilitate communication, build partnerships and collaboration across stakeholders (Vladimirova et al. 2018). They can assist the EIP park management on what specialist knowledge is required and where it could be sourced from, enabling collaborations between universities, research organisations, and park tenants to develop the right digital platforms or information sharing technologies to facilitate industrial symbiosis.

Moreover, local/regional authorities should allocate sufficient funds to build capacity through academic training and workshops and disseminate through multi-media channels including TV programs information such as on the advantages of circular economy, current global and local environmental situation, benefits of current EIPs projects.

3.2. Modalities for community engagement

Community engagement is the process of working collaboratively with and through groups of people linked by geographic proximity, common interest, or similar framework conditions to address issues affecting well-being and enhance co-benefits. It is perceived as a powerful vehicle for bringing about environmental and behavioural changes that will improve the health of the community and its members. Community engagement often involves partnerships and coalitions that help mobilize resources and influence systems, change relationships among partners, and serve as catalysts for changing policies, programs, and practices (CDC, 1997). Given our approach to EIPs, the term "community" refers to the different stakeholders (e.g., park management, park tenants, municipalities, local communities, education institutions, government and regulators, financiers, cross-national development entities, etc.) involved in the whole lifecycle of a park.

Engagement is not generally driven by a 'model' so much as by the specific needs and the framework of guiding principles, strategies, and approaches that may be specific to the cultural and socio-economic and political context. This framework is based on principles that respect the right of all community members to be informed, consulted, involved, and empowered. Community

[2] See more detail here: https://www.sia-toolbox.net

engagement emphasizes building and enhancing trust as a key element for long-term sustainable engagement and effective governance (PennState, n.d.).

How community engagement can be implemented in practice can be best illustrated through an example. We refer here to the Korean EIP program, as it has been one of the most comprehensive and systematically designed globally. Five regional EIP centres administer the overall process of project development: from devising strategies based on local contexts to facilitating the development of project ideas. To mobilize the participation of various stakeholders in addition to business actors, the regional EIP centres organized 27 forums for 969 stakeholders from businesses, universities, research institutes, and local governments as a strategy to promote **communication, information sharing, and cooperation** among them. Local experts such as business retirees and professors were also invited as coordinators to help take advantage of local tacit knowledge in project development and implementation (Park et al., 2015). Drawing on European experiences Neves et al. (2019) also stress that facilitators could play a very important role to enable communication, information sharing, and cooperation, and therefore coordinate and identify possible symbiosis relationships. The role of facilitators could be played by public entities such as local governments, by the park management entity, or by business associations.

The Korean EIP program identified the importance of social factors in the development and implementation of industrial symbiosis projects, even if the participation of local governments and communities was not envisioned in the initial strategy. Social dynamics at both inter-organizational and organizational levels may be determining factors in these projects. Therefore, community engagement strategies and practices are necessary to encourage and sustain the cooperation among the partners. For example, the development of a by-product reuse project can weaken or even remove the role of the waste department, discouraging the assistance of waste department personnel. To address this, the regional EIP centres help participating firms provide fair project benefits and recognize the personnel and department in charge of the project for their work. If necessary, a new unit for resource recovery and circulation could be evaluated so the role of the unit aligns with the goal of the EIP project without net loss of jobs, if possible.

Urban symbiosis projects in Japanese eco-towns also showed that working with local governments and communities provides more opportunities and increases effectiveness for developing resource- sharing networks in a region (Van Berkel et al., 2009). Therefore, local governments were encouraged to provide financial support in the form of matching funds to attract their active participation during the first phase (Park et al. 2015).

Community engagement can generally be achieved through different channels, such as industry- academia forums, policy and technical roundtables, newsletters, create and maintain social media groups, innovative digital tools or platforms, hackathons for circular product design or circular business models, youth educational programs, competitions and performance driven awards, collaborative demonstration and pilot projects, or various events that facilitate the emergence of communities of practice. At higher levels, international bilateral engagement efforts may also be useful to facilitate technology transfer and establish R&D facilities to develop symbiosis solutions suited to local conditions and requirements (World Bank 2021).

4. Principles for an EIP systemic thinking community model

Developing EIPs requires actions at different levels that ultimately transforms the way we produce and consume products and services on the premises of an industrial park, in the larger regional context, and also along the supply chain that may span national borders. Within the regional context of an industrial park, urban/regional-industrial symbiosis offers the opportunity to fully take advantage of the benefits emerging from integrating circularity in industrial parks design and operations. Yet, as discussed in the previous sections, the effort is not trivial, being underpinned by complex dynamics across very diverse stakeholders with different (and often conflicting) interests, various roles and responsibilities, knowledge, resources, and capabilities. In this paper, we took a narrower view on such synergies considered key for industrial parks, to dive deeper into the governance processes that may underpin such processes also relevant for circular economy more generally.

We conclude that a systemic approach is needed to align, coordinate, engage, and build awareness and drive action. **Systemic thinking is, in this process, essential**. By systemic thinking[3] we refer to *the approach of making sense of complexity by focusing on the whole of the process (e.g., the end goal) and relationships (e.g., the synergies across stakeholders) rather than by splitting it down into parts (e.g., bilateral relations).* Systemic thinking is what **enables systems change, which is what is necessary to achieve effective urban-industrial symbiosis** outcomes and develop circular actions.

From this perspective, the transformation of a traditional industrial park into an EIP or the design of a greenfield EIP necessitates a comprehensive governance model able to set in motion and manage such complex dynamics along various levels, aligning also economic, social, technical, and political framework conditions across the entire policy cycle. We call such a governance model a **systemic thinking community model (STCM)**. The main objective of such a model is to **deeply understand stakeholders, assess their level of engagement, and plan engagement at different stages of the EIP project**. Deliverable D.1.3.1 provided the detailed methodology for carrying out these activities, including guidance on how to identify stakeholders, detailed analysis of their role and interests, multi-dimensional mapping to allow prioritization in line with different goals, and a thorough assessment of the baseline in terms of the existing level of engagement between stakeholders to identify potential gaps or strong links.

In this section we aim to synthesize the insights from the literature into a few so-called principles for effectively governing the EIP in this more comprehensive form of an urban-industrial symbiosis process, going beyond the immediate premises of the industrial park. **These principles** should be understood as **stepping-stones or key requirements to enable the kind of system-level changes** that make an EIP possible.

[3] Gallon (2019) defines systemic thinking as “the theoretical and practical ability to observe, think, model, simulate, analyse, design, and synthesize components, functions, connections, structures, interrelationships, and dynamics across disciplines, functions, organizations, people, trends, and

cultures in ways that lead to insightful problem interventions for attaining solutions aligned with sustainable development."

PRINCIPLE 1: The implementation of the methodology for the STCM model.

Implementing the activities highlighted in the STCM methodology are crucial at the start of the project or in the planning phase for greenfield EIPs and they should be conducted continuously across the duration of the project. Only then can barriers be minimized or eliminated. Moreover, EIPs are 'living organisms', meaning that they continuously evolve, i.e., the mix of stakeholders changes as do their capabilities, interests, and knowledge, the industrial mix within the park of the region, and therefore the type of resources and materials available for circular and symbiosis processes.

PRINCIPLE 2: Detailed monitoring and evaluation of outcomes and stakeholder dynamics.

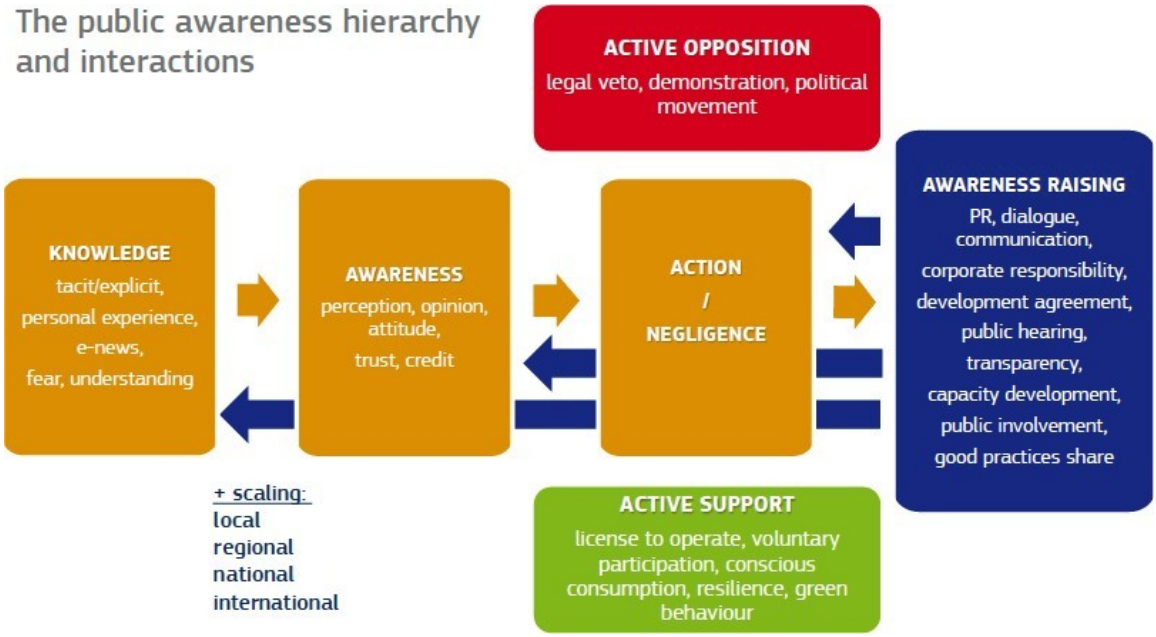
As explained earlier (in previous sections and in deliverables D1.1.1 and D1.1.2), urban-industrial symbiosis calls for defining clear goals, KPIs, and requires extensive exchange of data and information across diverse stakeholders. Aside from aligning interests, keeping track of performance through close monitoring of commitments and actions related to synergistic relationships, and evaluating the achievement of targets and the policy/regulatory context is crucial. Scoreboards on material exchanges, reports, and regular meetings should therefore be integrated in the design and management of the EIP. To this end, the park management entity plays a steering and main driver role. The management team, in its monitoring and evaluation efforts, may also target in the process initial (and additional) firms/players who may fit to the evolving nature of the EIP and can enhance the synergistic relations within the resource exchange network in the park and with the community.

PRINCIPLE 3: Awareness raising both in terms of objectives for EIPs and the associated benefits.

Promoting stakeholder cooperation is key to developing innovative, locally tailored, and economically and technically workable circular economy solutions (World Bank 2021). Within awareness, however, cooperation may not be feasible or even desirable. Awareness of potential benefits related to circular economy is important for several reasons: it promotes dialogue, it builds trust, it advances knowledge, and strengthens commitment, all critical factors for long-term collaboration. Park operators, for example, can improve awareness of good business cases among tenant firms through testing facilities or demonstration projects, as in Japan's Kitakyushu Eco- Town (ibid).

As Figure 2 illustrates, various concepts are related to awareness, and they are closely interrelated. For instance, increasing knowledge (through media, training, education) can impact perceptions, attitudes, opinions, which then influence the type of actions one decides to take. Awareness raising initiatives through different channels and practices, can impact on all these aspects. The stakeholder analysis mentioned in the first principle, above, can assist practitioners to identify who requires more interventions and how.

Figure 2: Relationships between public awareness concepts



Source: EC (2018: 62)

PRINCIPLE 4: Establish and maintain networks of materials and by-product exchange

As discussed in section 3, actively collecting, and sharing data and information related to material and resource flows across firms and the larger community is important not only for the efficiency of industrial symbiosis processes. Such exchange networks are also an important ingredient for building trust and aligning interest across stakeholders, and therefore a critical governance tool for the EIP. Setting the right conditions for enhancing such an exchange process is likely to determine the success of inter-stakeholder input-output matching, shared usage of waste water and energy management infrastructures, and other potential synergies across the larger region. Shortage of knowledge about potential resources that might be recovered and reused is a key technical barrier to the progress of urban-industrial symbiosis initiatives. At the same time, lack of transparency and low trust levels between relevant stakeholders hinder information sharing. Lastly, data and information sharing on the web of trades of materials, energy, and water, is also key for enabling innovation, which is crucial for the evolving nature of EIPs.

From an operational point of view, several steps may be relevant for practitioners to consider in establishing these networks (Lowe 1997: 60), the effectiveness of which depends closely on communication, alignment, and collaboration:

- Analyse material and energy inputs and outputs of major industries in the area, i.e., composition and nature of flows of materials and energy, amounts, distribution of flows in time (steady, periodic, episodic, irregular), material and energy quality (consistency over time and purity);
- Assess the potential for collecting and pooling small quantities of some materials to create flows sufficient to market (which may become a possible new local business

development opportunity with positive effects on employment);

- Disseminate information locally and as part of investment (or tenant) attraction efforts to verify matches with existing businesses and new local communities;
- Determine material and energy processing required to achieve quality requirements;
- Identify potential customer industries to utilize existing material and energy flows;
- Define volume requirements of potential customer industries or communities;
- Establish relative importance of by-product exchange in the overall investment and business attraction strategies;
- Monitor and evaluate results and adjust strategy as a result (see Principle 2).

Such networks can be facilitated by closed-looped models (e.g., platforms for sharing, recovery, and recycling), for which various examples exist (see section 3).

PRINCIPLE 5: Continuous community outreach and dialogue

Lastly, it should be evident by now that the governance model and overall implementation of symbiosis processes withing the circularity paradigm closely depends on continuous community engagement and dialogue across stakeholder groups. This is important because stakeholders cannot be conceived in a static way since the network of interactions changes permanently and therefore is defined by dynamic change (Morales and Dietmer 2019). Therefore, when the system is handled strategically, stakeholders are able to trade off imbalances (misalignment of interest and resources) (ibid). Therefore, and in line also with Principles 1 and 4, a systematic dialogue and analysis must be embedded from the early stages of design, diagnosis, and monitoring and evaluation (Principle 2) to build trust, achieve cost reduction, improve productivity and efficiency, reduce natural resources consumption and general impact on the environment related to symbiotic relations and circularity.

International experience shows that the engagement of firms in community activities can lead to positive outcomes such as strengthening trust and relationships between industries and local communities. Such channels for community outreach and dialogue could take the form of, for example, workshops, roundtables, joint committees (for example for types of resource streams), innovation competitions for start-ups, education, and training programs. The forms of outreach and dialogue will inevitably differ at various stages of implementation (or maturity) of an EIP, as well as the types of stakeholder interactions. The Annex synthesizes various stakeholder interactions starting from the early stages in the EIP transformation when focus is stronger on trust building between the firms and local communities, to increasing awareness, connecting across the ecosystems, organising synergistic relations, adjusting actions and strategies (following close monitoring and evaluation). For instance, early on it may be necessary to focus more on awareness building initiatives to build up know-how, for increase trust and align interest, and to ensure commitment for a shared vision around the EIP. Once the first actions have been implemented, dialogue and outreach may be focused on expanding synergies, scaling-up and enhancing capacity through targeted training and education programs, avoiding, and managing any existing conflict between firms, residents, and other organisations.

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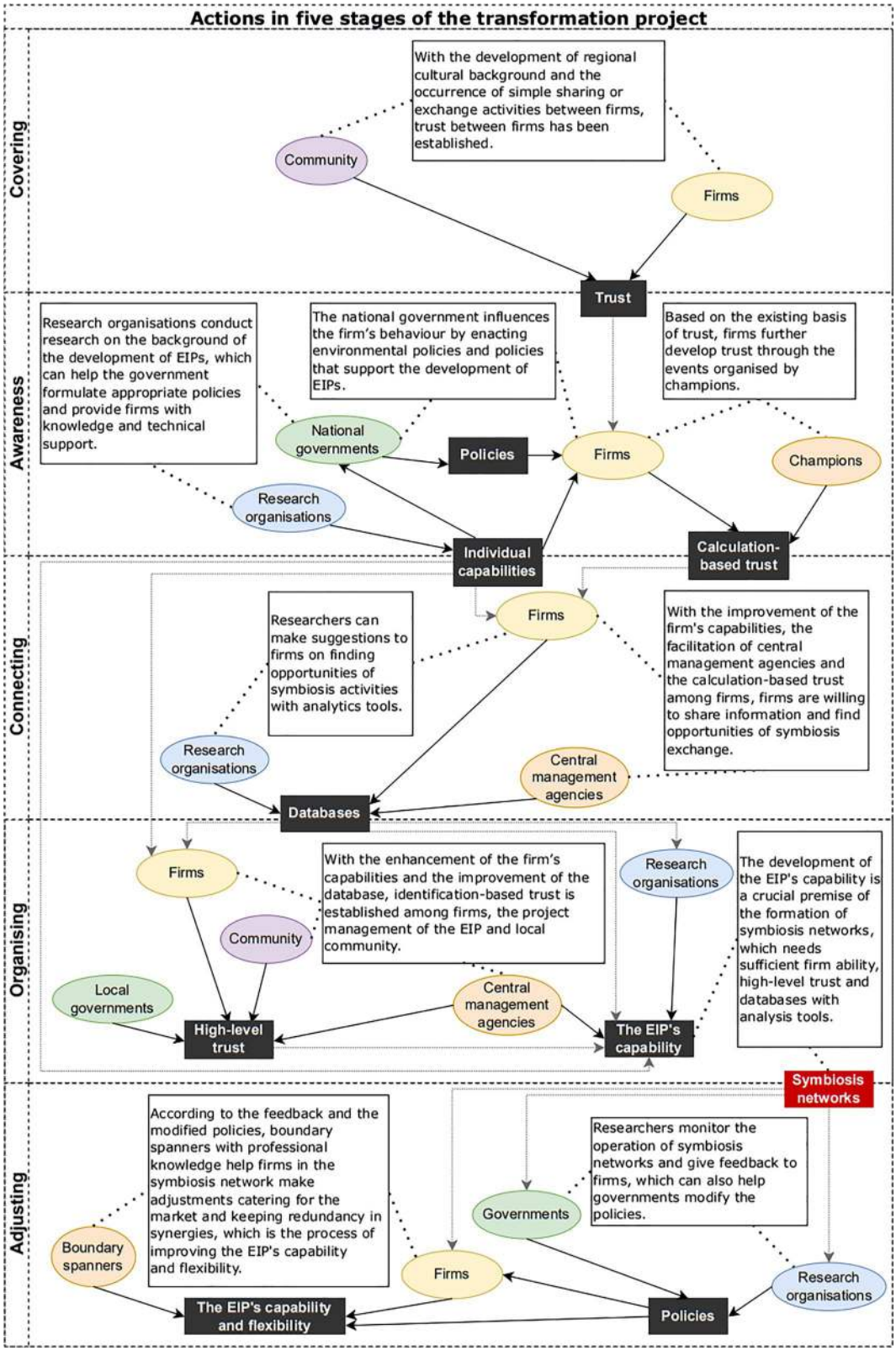
6. Annex

Synthesis of stakeholder engagement and relevant factors for different stages of EIP transformation



Source: Dai et al. (2022)