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ECOLE

ECOLE:

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

DRAFT: Benchmarking study on the circular economy approach in industrial parks

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ABBREVIATIONS USED

AS	Alpine Space
ECOLE	ECO industrial park network for the Alpine Regions Leveraging smart and Circular Economy
EMAS	Eco-management and audit scheme
EIP	Eco-industrial park
EU	European Union
HSE	Health, safety and environmental
KPI	Key Performance Indicators
LP	Lead partner
PP	Project Partner
UNIDO	United Nations Industrial Development Organisation

1. Objectives and summary

The overall aim of this document is to assist ECOLE project partners and their stakeholders with the practical implementation of the eco-industrial park (EIP) concept into existing industrial parks (brownfield investment) and new industrial parks (greenfield investment). This benchmarking exercise is meant to be informative for practitioners in the early stage of their efforts to understand the possible scope of actions, to conceive roadmaps for actions, and define the overall scope of interventions that may contribute to attracting necessary investments.

To this end, we start with a brief overview of core concepts, such as circular economy and its multi- dimensional implications especially for the manufacturing sector (section 2) and we continue with explaining what EIPs are (to help set boundaries for action), briefly highlighting performance requirements, and providing some general insights on core technologies and processes (section 3). More detail on both these general aspects will be provided in deliverable D.1.1.2 “Eco-Industrial Concept in the Alpine Regions”. For our assessments, we rely on the International Framework for Eco-Industrial Parks, other related UNIDO and World Bank reports, policy documents, and academic literature.

Beyond the succinct overview of the key concepts and performance requirements for EIPs, this document focuses specifically on systematically assessing relevant cases of EIPs in Europe and beyond (section 4). The general framework (discussed in section 3) therefore guides our case studies review and allows for a certain degree of benchmarking. As the profile of the industrial parks, as well as the way they are structured and operate differ significantly across cases, we will compare along some core dimensions and highlight any differentiating factors. Yet, because of the differentiating factors (size, industrial profile) and because of limited empirical evidence on performance indicators, a rigorous benchmarking outcome would require further research based on interviews and site-visits. We end with practical insights on pre-requisites for success derived from international best practice examples, which may inform action in the Alpine Space region (section 4).

Results from this assessment certainly suggest that practice does not yet match the ambition of strategies aimed at transforming industrial parks in EIPs. While the EIP concept points to extensive opportunities for harnessing co-benefits for the EIP tenants and the surrounding communities, few examples, if any, have gone to the extent of achieving even the full-fledged minimum requirements of the International Framework for EIPs. Our assessment also points to large challenges in terms of monitoring and evaluating performance due to limited empirical data on key performance indicators (KIP). This limitation also has implications on how we understand EIPs and where we ‘draw the line’ between well performing and less well performing EIPs. A key take-away is that to take full advantage of the wide opportunities offered by circular economy approaches in industrial parks, more systematic efforts are necessary to collect and analyse data on resource used and demanded and material flows within the industrial park and in the surrounding communities. As circular economy and sustainability-related regulations become mainstreamed across the EU and internationally, policymakers and practitioners need to set in place more effective mechanisms for monitoring and evaluation of EIP performance requirements. The effectiveness of such interventions will critically depend on close partnerships across stakeholders within and outside the industrial parks.

2. Circular economy and industrial symbiosis

A circular economy is an industrial system that is restorative or regenerative by intention and design. It is a systems solution framework that addresses global challenges like climate change, biodiversity loss, waste, and pollution by replacing the traditional “take-make-waste" system or “linear processes” with a circular system based on three principles: eliminate waste and pollution, keep products and materials in use, and regenerate natural systems (Ellen MacArthur Foundation 2013).

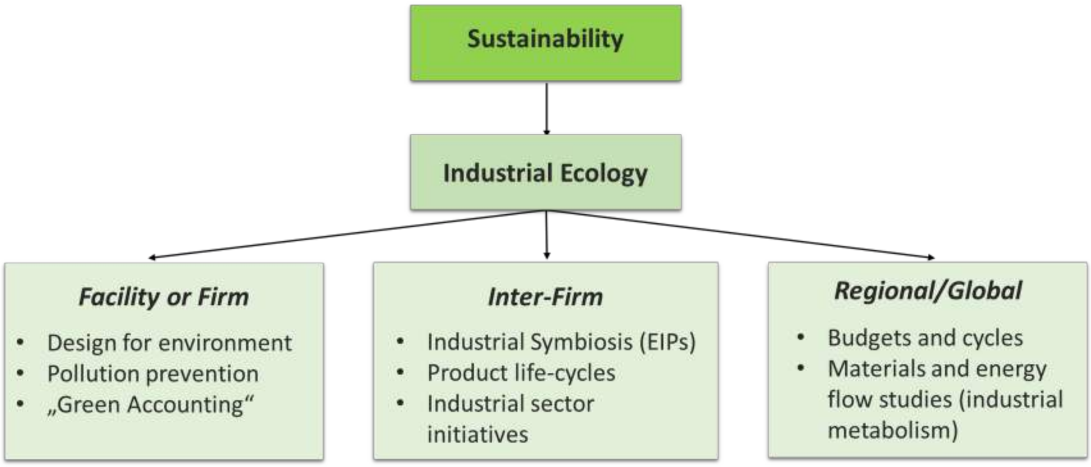
The practice of the circular economy is a transformative way to decouple economic growth from the loss of environmental value and from carbon-and resource-intensive industrial development. It includes practices such as eco-design of products to ensure durability, reusability, upgradability, and reparability, addressing hazardous chemicals and enhanced energy and resources efficiency in a systematic way. As such, 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).

Therefore, the circular economy concept is closely connected to industrial ecology and industrial symbiosis. Industrial ecology (the study of the flow of materials and energy through industrial systems) provides the analytical tools to optimize the use of materials and energy within and between firms. This is important, as the traditional linear organization of industrial productions fails to recover much post-production and post-consumption materials. In an ideal (sustainable) industrial ecosystem, the goal is to achieve “zero discharges” by a complete or nearly complete internal recycling of materials and energy.

This is where industrial symbiosis comes into play, as a sub-set of industrial ecology. Industrial symbiosis connects traditionally separate entities in a collective approach to achieve competitive advantage with physical exchange of materials, water, energy, and by-products. Industrial symbiosis occurs at the inter-firm level and focusses on the collaboration and synergistic possibilities offered by geographic proximity (Chertow 2000). To differentiate these two terms (i.e., industrial ecology and industrial symbiosis), it is important to highlight that industrial ecology (itself a subset of the general sustainability term) focuses on three levels: the facility level, the inter-firm level, and the regional or global level. Industrial symbiosis occurs at the inter-firm level (or inter- stakeholder level to also include municipalities in the surrounding territories, as we will discuss in D1.3.1), including exchange options between organizations (see Figure 1).

By working together, companies pursue a collective benefit that is greater than the sum of the individual benefits that could be achieved by acting separately. This collaboration can foster social relationships among participants, which can also be extended to surrounding neighborhoods, with no strict boundaries of an industrial area (Chertow 2000). Such relationships take the form of synergies of different types, such as supply and co-location of suppliers and clients (e.g., producers and suppliers of raw materials, fabricators, manufacturing, business clients), utility synergies (e.g., water recovery and energy co-generation), service synergies (e.g., joint training of staff and sharing of maintenance contractors), by-product synergies and waste exchanges (industrial symbiosis), and new innovative sectors and activities emerging from collaboration and exchange of ideas.[1]

Figure 1. Levels of industrial ecology



Source: Based on Chertow (2000)

According to Morales and Diemeer (2019), the analytical process of industrial symbiosis can be driven by two mechanisms that guide the sustainable transition of industry. First, the internal evaluation of the firms' production looking for the **economic viability** window at the intersection between costs reduction from efficiency and the valorization of by-products improving technical and economic productivity resulting from cooperative synergies. Any reduction in economic benefits may be sufficient to interrupt the symbiotic flow or to force the departure of a firm from the network. The second driver concerns the **broader social sphere**, with the objective of understanding and developing stakeholder coordination within the industrial symbiosis. These drivers then suggest that for industrial symbiosis to be effective, it does not only have to result on a positive environmental impact; it also has to lead to improving profitability. Both these outcomes are critically dependent on the governance framework between firms and other relevant stakeholders (e.g., communities) based on effective and systematic collaboration.

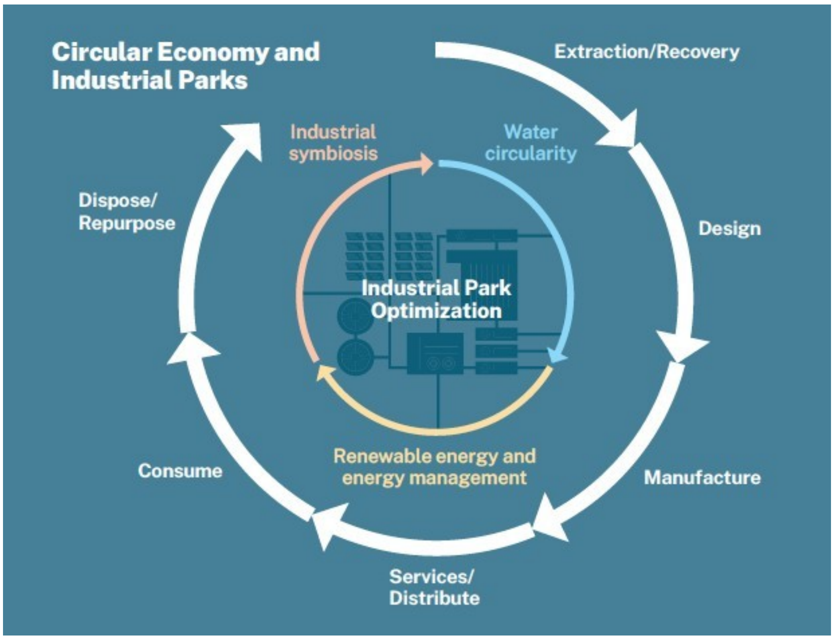
Circular economy approaches have, therefore, become a core part of industrial policy in Europe, especially more recently with the advance of the European Green Deal and the adoption of the Circular Economy Action Plan in 2020. The Circular Economy Action Plan focuses on legislative and non-legislative measures to encourage initiatives along the entire lifecycles of products, targets how products are designed, promotes circular economy processes, encourages sustainable consumptions, and aims to ensure that waste is prevented, and resources used are kept in the EU economy for as long as possible (European Commission 2020). The sectors that are in focus are those that are more resource intensive, for which circular solutions could add significant value, such

[1] Points suggested by colleagues from Grenoble-Alps Metropole (GAM).

as electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water, and nutrients.

Circular economy has, therefore, come to the forefront of the competitiveness agenda not only for individual forward-looking firms, but also across sectors. Industrial parks are particularly well suited to take advantage of the innovative technologies and business models related to circularity, due to the agglomeration effects of co-location, which facilitate the exchange of information and resources. As such, industrial parks can be "important building blocks for scaling up the circular economy approach" (World Bank 2021: 1). In turn, circular economy approaches contribute to industrial park optimization (see Figure 2).

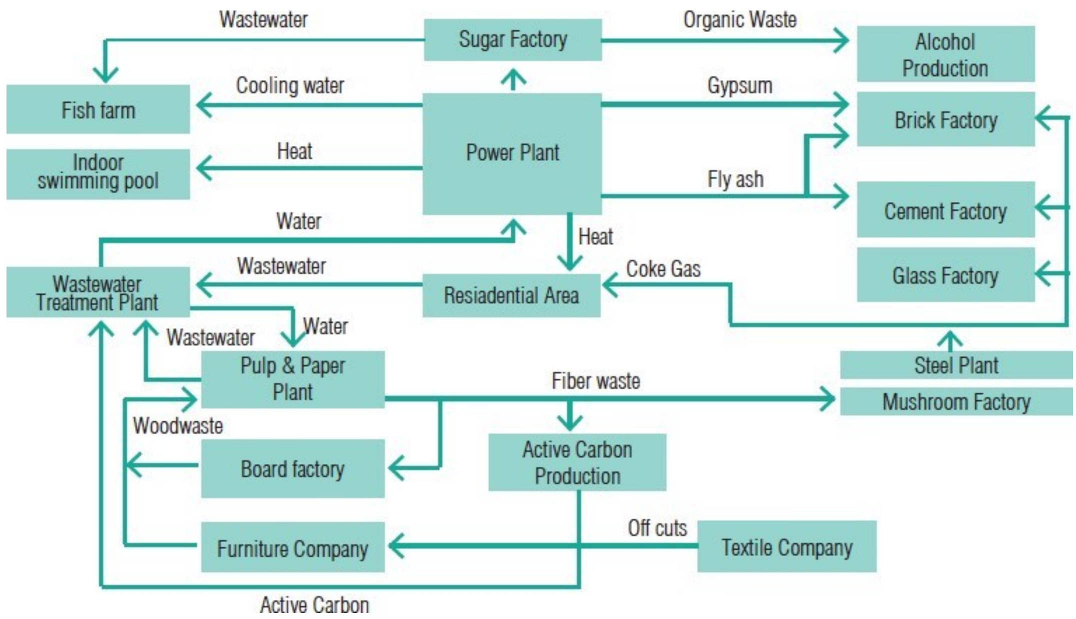
Figure 2: Circular economy principles applied to industrial parks



Source: World Bank (2021: 2)

Specifically, through integrating industrial symbiosis practices in the operations of EIP's tenant companies, the use of renewable energy and wide application of energy and environmental managing systems, as well as relying on water circularity, industrial parks can not only reduce costs, but also contribute positively to the environment, foster stronger community cohesion, and drive innovation, as we discuss below. Figure 3 illustrates how such symbiotic relationships could materialize between different industries, residential areas, energy, and service providers.

Figure 3: A schematic of symbiotic relationships



Source: Bandyopadhyay (2015) in World Bank (2016)

Symbiotic relations between the industrial park tenants and the surrounding communities are an essential element of an effective 'full-scale' EIP. Yet, such complex relations are yet to materialize in practice and, as we see in Section 4, evidence of such cases remains scattered. Figure 4 illustrates how such so-called industrial-urban symbiosis can be leveraged between individual firms, the industrial park operations, and the neighboring (urban) community. More evidence of such relations and their governance will be discussed in D.1.3.2 of the ECOLE project, the paper on the systemic thinking community model.

Figure 4 – A simple model of industrial-urban symbiosis

Source: UNIDO (2019)

3. Eco-industrial parks: A framework for action

This section delves deeper into how eco-industrial parks (EIPs) can become such building blocks by contouring a general framework for action, which will be further elaborated in later phases of the ECOLE project. Such a general framework (along with other project deliverables) is meant to serve as guidance for developing specific action plans in various locations across the Alpine Space.

To this end, for clarity, we start with a brief definition of what we mean by EIPs and the benefits that are generally associated with such industrial activity 'structures' (section 3.1). We then explain who the main stakeholders of EIPs are, as the effectiveness of EIPs is closely associated with tight collaboration across diverse entities (section 3.2). Further, we highlight the various dimensions along which performance of EIPs tends to be evaluated (section 3.3) and refer to various technologies /technology groups and analytical tools and processes that are commonly part of the EIP toolkit for practitioners, important for various stages of implementation.

3.1. EIP definition and derived benefits

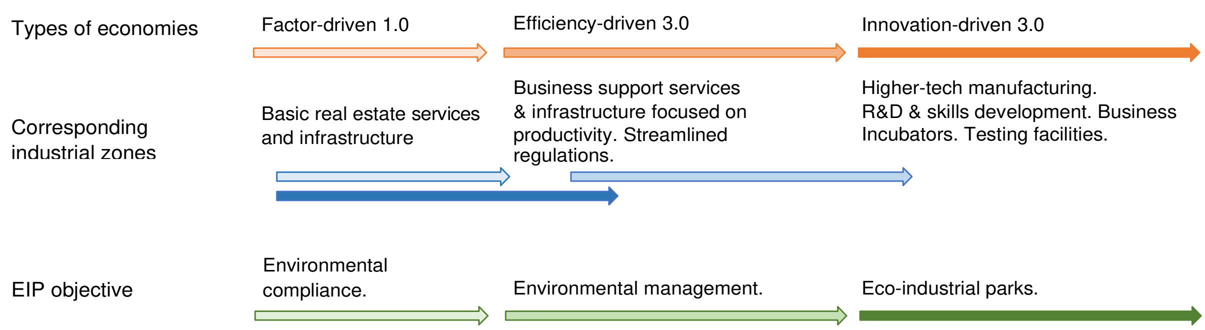
The EIP is not a new concept, but its implementation has increased significantly over the last decades. The basic idea was established already in the 1960s following the Earth Summit "as a local collaborative set of strategies that industrial facilities can follow to more efficiently utilize materials, and to both reduce and recycle waste" (Perrucci et al. 2022: 2). Already then, EIPs were closely aligned with the circular economy concept. Interest in the notion of EIPs (from a theorical and practical point of view) increased especially since the 2000s when empirical evidence showed the growing and disproportionate share of greenhouse gas (GHG) emissions emerging from the industrial sector. Regulatory action at national level, consumer pressures on firms, and global agreements to enable transformation of economies towards sustainability have led to technological innovation and raised awareness of firm level competitiveness advantages associated with adopting circularity in production processes.

Industrial parks are also known as industrial areas, industrial zones, industrial investment regions, special economic zones, or industrial corridors (World Bank, UNIDO and GIZ, 2021). Such structures or areas have played an important role in industrial development around the globe. Such industrial parks/economic zones, cluster different firms (often in the same sector, but not only), and offer tailored infrastructure and business services, contributing to job creation, transfer of skills and technologies, and export diversification, often lead by foreign direct investment (World Bank 2016). Over time, however, due to the resource-intense production processes, such parks/zones have come to be associated with environmental degradation and dysfunctional/controversial regional development model due to enclave nature of most of such industrial agglomerations.

At international level, an EIP is generally defined as a "dedicated area for industrial use at a suitable site that supports sustainability through the integration of social, economic, and environmental quality aspects into its siting, planning, management and operations" (World Bank, UNIDO and GIZ 2021: 14). Similarly, the European Environment Agency (n.d.) defined an EIP as a community of manufacturing and service businesses located together on a common property, who seek enhanced environmental, economic, and social performance through collaboration in managing environmental and resource issues. As per the definition, EIPs also integrate and drive benefits for neighboring communities to assure that the net impact of its development is positive.[2] By consequence, functional synergies need to be formed such that they benefit tenant firms and their communities around the EIPs (Perucci et al. 2022). Such synergies may be in the form of sharing materials, resources, infrastructure, information, or industrial ecology principles (i.e., one entity using the by-product of another entity as input, see section 2).

EIPs have evolved over time, due to increasingly stringent regulatory requirements, evolving technology innovation, as well as due to the gradual change in the economic model paradigm (i.e., decoupling of economic growth from resource extraction and consumption, and innovation driven development). As figure 5 illustrates, EIPs can be viewed as the “third generation” of sustainability oriented industrial parks, evolving from industrial parks that satisfy national (and international) environmental compliance to parks that follow a more coordinated and integrated approach, moving towards integrated economic and industrial communities approach, with circular and smart technologies at its core. In such an approach, deep linkages across firms, other stakeholders, and the communities surrounding the park that create synergies across activities and enhance efficiency, are key.

Figure 5. Progression of zone development and EIPs



Source: Based on World Bank (2016)

EIPs provide multi-staged and inter-linked benefits along all the three pillars of sustainability: environment, economy, and society. Table 1 provides a summary of such benefits that are, at the same drivers of performance for EIPs.

[2] Other definitions exist, but they converge along the core concept. For example, the U.S. Environmental Protection Agency defines EIPs as “a community of manufacturing and service businesses seeking enhanced environmental and economic performance through collaboration in managing environmental and resource issues including energy, water, and materials. By working together, the community of businesses seeks a collective benefit that is greater than the sum of the individual benefits each company would realize if it optimized its individual performance only” (Lowe at al. 1996:

2).

Table 1 Main benefits derived from EIPs

Environmental	Economic	Social
More efficient use of resources (e.g., energy, water, materials)	Lower operation costs	Creation of (non-relocatable) jobs
Lower waste generation	Lower production cost due to material and energy efficiency	Provision of vocational training
Lower emissions and land degradation	Higher productivity	Stronger community networks and trust building / community cohesion
Greening supply chains	Reduction in waste disposal costs	Larger tax base
Improve resource security /resilience to risks	Reduction in waste recycling needs	Occupational health and safety
Drive environmental policy change	Compliance with regulatory policies	Improved labor rights and relations / working conditions
Cost effective infrastructure that adapts to climate change	New sources of income for industries through sale of unwanted by-products	Improved gender equality within the park
Responding to environ. and social concerns of consumers and communities	Tech and knowledge transfer	Social infrastructure for workers and community
Contributing to industrial decarbonization &green innovation	Skills-upgrading of the labor force	Transition to sustainable land use

Source: Own design

The performance expectations associated with EIPs are the same regardless of whether they are brownfield (traditional industrial parks transformed in EIPs) or greenfield developments (new EIPs). The process, however, may be different, as some aspects may be more important. Generally, greenfield developments offer a great opportunity to integrate circular economy principles from the very early design stages. As such, a thorough planning and design process, including the selection of the most suitable site should be a key component for a greenfield EIP.

The way sustainability and circularity aspects will be implemented in an industrial park (greenfield or brownfield) will closely depend on the park characteristics, such as: type of industry sectors (e.g., light or heavy industry), park size, level of technology development, and park management. In addition, the type of sectors and their needs also define the **type of industrial synergies** that can be exploited within an EIP. Drawing on Van Beers et al. (2007), four different types of industrial synergies could be exploited within an EIP:

- **Supply synergies and co-location of suppliers and clients**: co-location and clustering of companies in the supply and value chains (e.g., producers and suppliers of raw materials, fabricators, manufacturing, business clients);
- **Utility synergies**: shared used of utility infrastructure, mainly revolving around water and energy (e.g., water recovery and energy cogeneration);

- **Service synergies**: sharing of services and activities between companies (e.g., joint training of staff and sharing of maintenance contractors);
- **By-product synergies and waste exchanges** (industrial symbiosis): the use of previously disposed waste (as solid, liquid, gas) from one facility to another facility to provide a valuable by-product.

As mentioned earlier, **EIP planners can consider choose between two possible types of EIP sites**: greenfield developments (on virgin land), and brownfield developments, which may be within currently operating industrial parks or (more challenging) on abandoned, idled, or under-used industrial and commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination (see Table 2). All these types of sites offer very different challenges and opportunities for creating EIPs.

Table 2 – Main characteristics associated with different EIP sites

Greenfield industrial park • In the design phase, greenfield projects offer the highest degree of freedom for applying and testing new approaches. • Points of control in the design process (i.e., cost/benefit analysis, regulation, planning, and zoning) are relatively well defined and commonly understood). • Greenfield design projects also often engender a high level of innovation in participants and the envisioned solutions.
Conversion of currently operating industrial parks to EIPs • Require working with established parks and their companies to fundamentally enhance environmental performance and, where necessary, clean up past pollution. • Existing parks have a relatively high degree of constraint in the basic mix of companies (with their plants and equipment) in place, established attitudes and environmental practices may hinder innovation, and existing pollution and liabilities may limit choices. • Points of control in the transformation process are less clearly defined than with greenfields. • Demonstrating EIP strategies in existing parks opens opportunities for widespread improvement in environmental performance.
Conversion of abandoned, idled, and often contaminated sites to EIPs • May include urban industrial parks located in industrial regions that have suffered from the decline of heavy industry such as steep and auto industries, or unused military bases. • The cost of cleaning up the environmental contamination often exceeds the market value of the property; once cleaned up, new owners may still face liabilities for past contamination. • May offer valuable resources including airstrips, housing, hospitals, and recreational areas and valuable infrastructure such as roads, sewers, and electric and phone lines. • The environmental, social, and economic benefits of redevelopment may be significant.

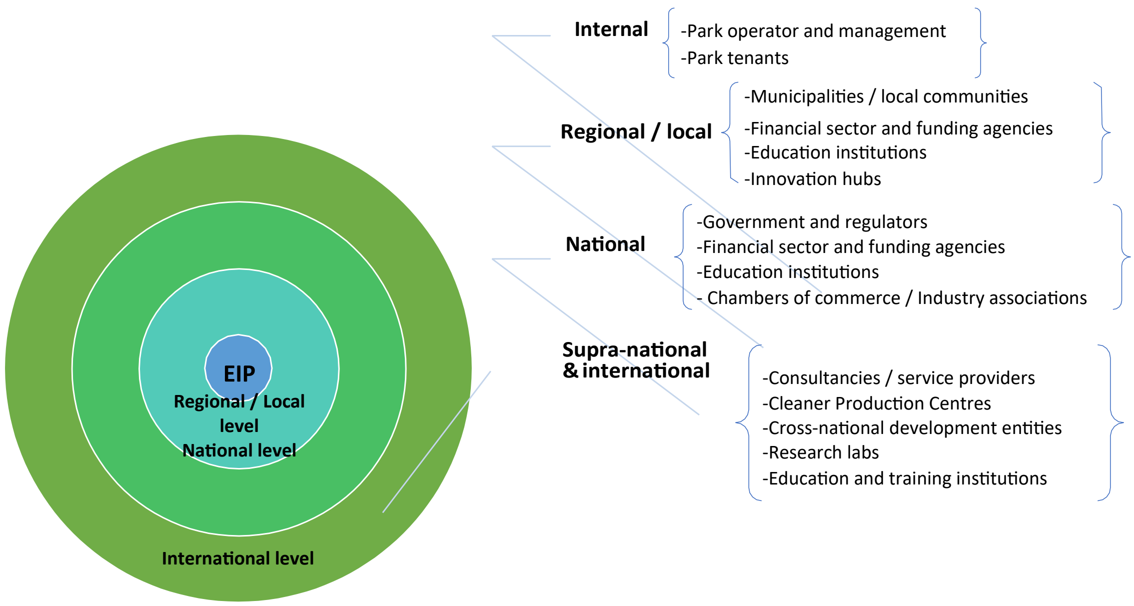
Source: Based on Lowe (1996)

3.2. Key stakeholders

Managing such complex synergies in an effective way within an EIP requires motivating and engaging a variety of stakeholders in a systematic manner (for more detail see the ECOLE deliverables D.1.3.1 and D.1.3.2). Relevant stakeholders can be roughly grouped as internal and external to the EIP. External stakeholders could be regional and/or national and supranational (e.g.,

Alpine Region authorities, European level policy makers, European or international investors). Figure 6 provides a summary with examples of key stakeholders in each of these groups.

Figure 6: Key stakeholders, internal and external to the EIP



Source: Own design

Each of these stakeholders play a different role in the operation of an EIP and the outcomes it generates. Successful EIP design, construction, and management require that these groups agree on a vision for the EIP and work together to achieve it. As Lowe (1996: 3) mentioned, achieving the vision will be easier if “stakeholders understand the EIP and its local context, if they are aware of the potential benefit of the EIP, if they participate in setting performance objectives, and if the EIP is an integral part of a regional economic development plan.”

A short description of the role of each of these main stakeholders is provided in the table below (see table 3). For successful implementation and sustained performance, EIPs require a high degree of communication, trust, and cooperation across an extensive set of stakeholders.

Table 3: Key stakeholders and their main roles

Stakeholder	Main roles
Park operators and management	• Set up and maintain effective monitoring systems and support data collection and decision-making processes; • Use EIP performance monitoring to identify improvement opportunities in their industrial parks; • Use EIP performance monitoring to build market profile of industrial park; • Engage with the park stakeholders, including resident firms, communities, and regulatory authorities.

Park tenants (industries & business located in industrial parks)	• Collect and provide data for industrial park level management and monitoring systems;

	• Use EIP performance monitoring to identify economic, environmental, and social improvement opportunities; • Use EIP performance monitoring to increase company reputation among shareholders and consumers.
Industrial associations and chambers of commerce	• Liaison between the EIP and the larger set of firms within a particular sector; • Set performance targets and use EIP performance monitoring to ensure compliance; • Contribute to standards and regulation setting to raise compliance and performance in EIP and beyond the national level.
Private sector organizations in industrial land development	• Use EIP performance monitoring to access subsidies or funding for industrial parks, and market the industrial parks to potential investors.
Municipalities	• Design set of incentives at local level to attract investment and drive EIP performance; • Liaison between communities and the EIP management and tenants; • Provide infrastructure and services to the industrial parks.
Community organizations	• Communication, trust building, and awareness raising through organizing and participating in various EIP related events; • Collect data and information on community needs and impacts for performance monitoring.
Government / regulators	• Responsible for the development and operation of industrial parks; • Providers of infrastructure and utility services the industrial parks; • Issuing laws and regulations relevant for the EIPs; • Coordination of various initiatives.
Education and training institutions	• Develop and provide training and capacity building services; • Collaboratively piloting solutions in the EIPs; • Develop good practice case studies on performance monitoring and benchmarking.
Scientific research institutions	• Conducting applied research on topics relevant to EIPs; • Collaboratively piloting solutions in the EIPs.
Innovation hubs	• Pilot new ideas into actionable projects; • Organize hackathons on industry/community-based challenges; • Organize events to leverage funding for commercialization and scale-up; • Liaison between research, industry, and start-up platforms to develop impact-oriented solutions for EIPs.
Financial sector and funding agencies	• Support investment decisions in existing and new industrial parks (e.g., go/no go decision on park development); • Provide funding for investment decisions related to park transformation towards EIP.

National service providers & international support organizations	*(e.g., National Cleaner Production Centers, development agencies, technical and management consultancies)* • Support capacity building processes; • Develop practical EIP monitoring tools and processes;

	• Promote international good practices on EIP performance through demonstration projects; • Provide customized support on EIP performance monitoring processes, building on international experiences and learnings.

To understand how to best engage these stakeholders in the decision-making process, a detailed mapping of their level of interest and power in decision making related to the necessary actions related to the EIP is necessary (see D.1.3.1 and D.1.3.2).

3.3. Technology and processes

The technologies adopted in EIPs serve as building blocks for the transition to a circular economy and can be grouped in three areas: energy, water, and material and waste heat (see table 4). Within the EIP framework, waste and water management are the main drivers for circular economy at industrial level; utilizing water resources as efficiently as possible and turning large waste streams into material exchange lead to greening the industrial parks (World Bank 2016).

Table 4: EIP technologies

Energy	Water	Material and waste heat
Energy management -Energy management business models (energy performance contracting; energy supply contracting, integrated energy contracting) -Energy management system certification (ISO 50001, ISO 140001, EMAS)	**Sustainable water supply** -Rainwater harvesting -Desalination -Membrane technologies	**Industrial symbiosis**
Solar power **Wind power** **Biomass and waste-to-energy**	**Wastewater treatment** -Advanced biological wastewater treatment technology -Zero liquid discharge system -Heavy and valuable metal removal/recovery technologies	**Material and energy recovery** -High temperature pyrolysis -CO_2 recovery technologies -Organic rankine cycle

Source: Based on World Bank (2021) and World Bank, UNIDO and GIZ (2021)

Literature suggests that the adoption of waste treatment and renewable energy technologies is higher than resource efficiency, industrial symbiosis, and water efficiency technologies (World Bank 2021). Empirical evidence also shows that the types of park management model may influence the adoption of certain EIP technologies. Specifically, the presence of on-site management and its awareness of local conditions could help accelerate the decision-making process and contribute to choosing the “right” technology to match the needs and drive higher EIP performance (World Bank 2021).

Aside from specific technologies to be integrated in an industrial park, the transformation towards an EIP is facilitated by the application of various analytical tools that enable the collection and analysis of data cross stakeholders and streams of users and providers of energy and materials. Some of these tools are:

→ **agent-based modelling and analysis techniques**: can identify true costs and benefits and enable monitoring of EIPs during their operation;
→ **optimization techniques**: may be applied to overcome the complexity of multi-objective mathematical models aiming to balance the needs of multiple firms and multiple resources being allocated among them;
→ **non-competitive waste stream selection**: can alleviate various social concerns between firms in an EIP conglomerate, due to reduced competition and mutual benefit such a re- utilizing waste that is traditionally expensive to eliminate, reducing disposal costs, and raw material sourcing costs;
→ **ecological network analysis (ENA)**: methodology to support the success of EIP implementation by quantifying expected material flows to ensure producers can sustain consumers.
→ **social network analysis**: tool that assesses stakeholder engagement and communication across time and space.

3.4. Performance requirements for EIPs

The International Framework for EIPs guides performance assessments for EIPs on four different areas (see figure 7): park management, environment, social, and economic aspects. Performance in all these areas must ensure compliance with national and local regulations, as well as with fundamental international rights.

Figure 7: Performance areas for an EIP

Compliance with national and local regulations, and fundamental international rights

Park management
Environmental performance
Social performance
Economic performance

Source: Based on World Bank, UNIDO and GIZ (2021)

Within each category, **performance requirements are divided into prerequisites and performance indicators**. The International Framework stipulates that, *to be deemed an EIP, a park is expected to comply with all prerequisites and performance expectations (target values) as set by national governments in specific countries* (World Bank, UNIDO and GIZ 2021).

3.4.1. Compliance with national and local regulations

EIPs must comply with all applicable national and local laws, regulations, and standards, such as:

- National employment regulations
- Discharge limits
- National air emission limits
- Waste disposal techniques
- Waste transportation requirements
- Hazardous waste handling restrictions
- Noise limits during operations.

To this end, the **park management entity must have a monitoring system in place** (such as ISO 14001, ISO 5001, or EMAS) to report on the performance of firms, which provides guidance on establishing, developing, implementing, evaluating, maintaining, and improving a compliance management program. EIPs should also comply with international good practices when national regulations fall short of EIP expectations.

To ensure regulatory compliance, **the park management entity should compile an inventory of local and national regulations** to maintain compliance (see Table 5).

Table 5 – Type of national and local regulations to which compliance should be ensured

Park management compliance • National regulations on OH&S and emergency requirements (for example, protective clothing and equipment, safety features of machines and work posts, regular medical inspections, and preventative measures); • National regulations on anti-corruption (for example, access to information, accountability, bribery, and conflict of interest); • National regulations on violence and crime prevention (such as cybercrime, theft, violence against women, and protection of children and the elderly); • National regulations on land use planning, zoning, licensing and permits; • National regulations on intellectual property, trade and fiscal measures; • National regulations on emergency awareness and preparedness (including disaster risk management); • National regulations on environmental and social aspects (as listed below); • By-laws related to national regulations.
Environmental compliance • National regulations on air emission limits (for example, sulfur oxides (SOx), nitrogen oxides (NOx), heavy metals, particulate matter, GHGs and odors); • National regulations on water extraction, watershed management and water discharge limits; • National regulations on waste disposal (including contaminants, treatment requirements and recycling) and waste transportation (including labelling, maximum volumes, storage); • National regulations on hazardous waste handling restrictions (including labelling, containment, and use of qualified contractors); • National regulations on noise limits during operations (for example, maximum and ambient noise levels); • National regulations on energy and resource efficiency, as well as other regulations related to efficiency (for example, on circular economy practices);

• National regulations on soil and ground water contamination (including effluent/waste discharges); • National regulations on protection of the natural environment and biodiversity (for example, sensitive marine environments, inland water bodies, native forests, and protected flora and fauna); • National regulations related to climate change mitigation and adaptation; and • By-laws related to the national regulations listed above.
Social compliance • National regulations on human rights (for example, gender equality and women and children's rights); • National regulations for protection of indigenous people, and employment, vocational training and social security; • National regulations on addressing discrimination (for example, discrimination based on color, race, religion, gender, age, and disability); • National labor laws/regulations (including working hours, OH&S, prevention of child and forced labor, and maternity leave); • National laws on land acquisition and compensation of affected people; • National laws on protection of cultural heritage; • By-laws related to the national regulations listed above.
Economic compliance • National regulations on the reporting of financial performance and disclosure; • Regulations on the promotion of SMEs and local business development; • Regulations on technology transfer and protection of intellectual property; • Regulations on skills development and vocational training; and • Business regulations, including registration and licensing, financial, trade and fiscal regulations.

Source: World Bank, UNIDO, GIZ (2021: 34-35)

The assessment of which regulations are relevant for compliance can be made based on a regulatory mapping template, as the one provided in table 6.

Table 6 – Sample template for regulatory mapping

Socio-economic	Job creation /training /skill development	…
	FDI /export	…
	R&D /investment in or facilitation of technical development	…
	Tax laws	…
	Gender	…
	Community support / corporate social responsibility	…
Industrial competitiveness	Industrial growth	…
	SME	…
	Zone development (regulations related to developing SEZ, export processing zones, and industrial parks)	…

Financial	Investment and subsidies	…

Environmental	Climate change (mitigation & adaptation); sustainability; environmental impact assessment; disaster risk management	…
Energy and resource efficiency	Energy and resource efficiency	…
Land-use planning	Land use/zoning/urban and regional planning; infrastructure planning	…

Source: Based on World Bank, UNIDO, GIZ (2019)

3.4.2. Park management performance

The specific requirements for park management performance are listed in Table 7, for each of the main topics and related sub-topics. For each of these topics, **performance indicators are to be identified and target values** to be achieved. In addition to these indicators, a key performance aspect for which the park management authority is strongly responsible is that of orchestrating and ensuring effective cooperation patterns across stakeholders (i.e., the governance of the EIP). More on this aspect will be discussed in D.1.3.1 and D.1.3.2 where we present the systemic thinking community model and elaborate on why such a governance model is crucial for the long-term performance of the EIP.

Table 7 – EIP prerequisites for park management

Park management services	Park management entity	A park management entity (or alternative agency, where applicable) exists to handle park planning, operations and monitoring.
	Park property, common infrastructure, and services	The park management entity provides and facilitates common services and infrastructure to resident firms to ensure smooth operations.
Monitoring and risk management	Monitoring performance and risks	The park management entity has established and maintains a system for monitoring achievement of threshold EIP performance targets and management of critical risk factors within the park.
		The park management established measures to deal with climate change adaptation and disaster preparedness.
	Climate risk assessment	The park management entity collects, assesses, and reviews comprehensive risk information specific to the location of the park.
	Information on applicable regulations and standards	Park management has a good understanding of regulations and international standards applicable to industrial park compliance and enforces them in the park.

Planning and park design	Master plan development	A master plan for the EIP is developed by park developers and is applicable to both planning and operations by park managers.

Source: Based on World Bank, UNIDO, GIZ (2021)

3.4.3. Environmental performance

Beyond regulatory compliance, a range of environmental requirements must be satisfied for an EIP, in the area of management and monitoring, energy, water supply and wastewater, waste and material use, climate change and the natural environment. Table 8 summarizes the environmental performance requirements, based on which performance indicators will have to be identified.

Table 8 – Environmental performance requirements

Management and monitoring	Environmental and energy monitoring systems	Firms have functioning and fit-for-purpose EMS/EnMS systems. Summary information from these management systems is provided to park management, who aggregate and report on data at the park level.
		A summary of data from firms' EMS/EnMS systems to be provided to park management, for aggregation at the park level.
		10% of firms' energy consumption covered by an energy management system.
Energy	Energy efficiency	Energy efficiency opportunities should be identified at the park and firm levels to reduce energy use and associated greenhouse gas emissions. EIPS should identify and promote technological ad process-related interventions in their own and resident business operation. The equivalent of at least 10% of the total CO2 emissions (scope 1 and 2) is covered by the percentage of firms that have a qualified energy efficiency certification (LEED, Industry EDGE, German Sustainable Building Council (DGNB) or ISO 50001 or their national equivalent).
	Renewable and clean energy	The industrial park leverages available renewable energy with plans to increase its contribution for shared services (e.g., solar streetlamps). Total renewable energy use for electricity and heat production in the industrial park is equal to or greater than renewable energy share in the annual national electricity mix in the grid.
	Energy network and waste heat recovery	An industrial heat recovery strategy is in place to investigate opportunities for heat and energy recovery for the major thermal energy-consuming firms in the park. (Typically, these are firms that individually use at least 10-20% of total firm level energy consumption.)
		Park management provides the physical network for waste heat/energy exchange at park level, and assists firms to connect to the network. A commonly accepted rewards

		system for waste heat/energy provision/use is in place.
Water supply and wastewater	Water efficiency, reuse and recycling	Park management entity has operational plans to increase water reuse in next five years. This would be achieved by either reuse of industrial effluents, or by rainwater/storm water collection. 25% of total industrial wastewater from

		firms is reused responsibly within or outside the industrial parks.
		Park management entity provides the physical network for water reuse/cascading of water. 25% of nonhazardous, solid industrial waste generated by firms is reused/recycled by other firms, neighboring communities, or municipalities.
Waste and material use	Dangerous and toxic material	Obeying the principles of good practices for the management of hazardous materials and waste as part of legally binding agreements.
	Resource conservation	Obeying the principles of circular economy is part of the Park's Code of Conduct, and any legally binding agreement between tenant firms and the park authority. 20% of manufacturing firms adopt circular economy practices, including engagement in Industrial Symbiosis Networks in the park; or actively exchanging secondary raw materials, or waste, or other circular economy practices.
	Treatment of waste	A central park facility or other mechanism is in place to treat waste that cannot be processed by individual firms. 100% of industrial wastewater generated by industrial parks and resident firms is treated in accordance with appropriate environmental standards.
	Disposal of waste	A monitoring system is in place that controls and registers origin, type, mode and route of transport and final destination of waste/secondary raw material leaving the park.
Climate change and the natural environment	Air, GHG emissions and pollution prevention	A program is established with clear evidence of steps takes to monitor, mitigate and/or minimize GHG emissions such as CO2, methane, and nitrogen oxides.
		Reducing CO2 emissions is an integral part of the park's code of conduct, which urges firms to reduce their carbon footprint. The park acknowledges actions in this regard through an awards and incentive system. 50% of firms in park which have pollution prevention and emission reduction strategies to reduce the intensity and mass flow of pollution/ emission releases that exceed national regulations.
	Environmental assessment and ecosystem services	The park management entity has a plan in place to assess operational environmental impacts and aims to limit these impacts on prioritized local ecosystem services.
		The park management implements measures to protect biodiversity, and protects or creates natural/recreational areas in and surrounding the park.

Source: Based on World Bank, UNIDO, GIZ (2021)

3.4.4. Social performance

Good social performance is important for EIPs especially when it comes to social management practices, including decent work, social and community infrastructure, and relations with the local community. Performance should be aligned both with national regulations as well as with international frameworks. As such, social performance of an EIP should be an indicator of its inclusiveness, local employee and community welfare, and equal opportunities across social groups (World Bank, UNIDO, GIZ 2021).

Table 9 – Social performance requirements

Social management systems	Management team	Dedicated personnel exists (as part of the park management entity) to plan, manage and enforce social quality standards.
Social infrastructure	Primary social infrastructure	Essential primary social infrastructure has been adequately provided in the site master plan and is fully operational in the park. Gender perspectives are incorporated in the formulation, management and monitoring of plans and programs. A particular entity exists, which investigates and plans for future developments/challenges to the social environment due to the introduction of new technologies such as Industry 4.0 and AI controlled production processes.

Source: Based on World Bank, UNIDO, GIZ (2021)

3.4.5. Economic performance

As per the sustainability principle, economic performance of EIPs is equally important along with environmental and social performance. In essence, industrial parks are main policy instruments to boost manufacturing, export performance, and value added. They are also an (often) effective ways to generate employment.

Table 10 – Economic performance requirements

Local business and SME promotion	SME development	Park management entity allows and promotes the establishment of SMEs that provide services and add value to park residents.
Employment generation	Maximizing local benefits	Park management entity has a strategy in place to maximize local benefits.
Economic value creation	Market demand for EIP services and infrastructure	A market demand and feasibility study, supported by a business plan for specific “green” infrastructure and services has been undertaken to justify planning and implementation in the industrial park.
		Park management is financially solvent to operate/provide park infrastructure and services.
		Park management should be economically viable in terms of contributing to jobs, technology, and acting

		as a catalyst to development of local industry.

		Park management entity is responsible for marketing the park and park concepts (EIP concept) to potential national and international investors.
Park entity's financial viability	Service delivery pricing	Park management should render its services at realistic costs to cover operational expenditures.

Source: Based on World Bank, UNIDO, GIZ (2021)

4. Insights from best practices around the world

EIPs have been around for several decades, but the uptake of such practices in traditional industrial parks has increased significantly in the last decade (World Bank 2021). Reflecting on past experiences and drawing insights from good practices internationally is, therefore, likely to inform new efforts on how to best customize complex interventions. This is especially important as many EIP projects failed to be fully implemented or have fallen back on traditional industrial practices (Perrucci et al. 2022). Yet, several interlinked challenges are associated with efforts to benchmark EIPs.

First, the International Framework for EIPs developed jointly by the World Bank, UNIDO, and GIZ (2021) is relatively new and has only recently developed guidelines for practitioners interested to apply sustainability and circular economy principles in industrial parks. The **framework, as such, also sets minimum requirements that could be followed on a voluntary basis**, without offering a certification scheme (or standards) to label or define an EIP.

Second, and related to the above, our research on good practice examples points to **wide variation across industrial parks (self) labeled as EIPs, sustainable, or green**. This suggests that, in this early process of wide transformation pathway of the industry and society towards sustainability, **industrial parks often use such qualifications (i.e., eco, green, circular, sustainable) for deriving co-benefits (i.e., marketing purposes), without clear evidence of them adhering to a certain set of minimum requirements**. The World Bank and UNIDO have partnered with various industrial and policy decision makers internationally to widely apply the framework and guide businesses and implementing agencies. Yet, many of those initiatives are currently still ongoing. For these reasons, we have drawn as much as possible on examples featured in such reports, but such examples are few and mostly focused on developing and emerging economies.

Third, national regulations for EIPs are still evolving is most countries and there is wide variation not only in terms of degree of commitment towards achieving environmental and social performance, but also in terms of the enforcement capabilities. Instead of regulations, most countries have formulated sectoral or cross-sectoral strategies and commitments towards integrating sustainability principles in existing and planned industrial parks or zones.

Forth, and perhaps most important in the context of our benchmarking exercise, is the observed **severe lack of consistent data on EIP performance**. While the concept of EIP has been around for several decades and isolated cases of EIPs have been identified since the 60s, little research has been conducted on studying and comparing performance in a comparative way. Even of widely cited cases of best performance, available indicators of performance are not up to date. In addition, published data is often available for only some performance areas, mostly energy consumptions, waste or water management. As the KPIs for minimum requirements are more widely adopted by industrial parks in their efforts to transform towards EIPs or by investors in their efforts to build greenfield EIPs, and as policy-makers develop appropriate regulations, industrial park operators are likely to engage more systematically in performance-related data collection and analysis.

Lastly, as the cases below clearly suggest, each of the featured **industrial parks have a very different profile both in terms of their size, sectoral composition, engagement with the surrounding communities, and impact (to the extend it has been measured).** The sector composition ultimately defines what may be possible to be achieved in terms of circular solutions and industrial symbiosis. While measures related to renewable energy, energy efficiency, and some minimal requirements related to waste and water management can be applied almost across each and every industrial park, more complex processes related to material flows, waste, and water management are very much conditional on the needs and resources associated with specific firms within the industrial park and the economic structure of the neighboring communities.

For these reasons, the **interpretation of these cases should be made with care as generalizations to another national and industrial site context should be avoided**. These cases should rather inform the practitioner on examples of actions that could be taken and ways in which interventions were implemented in a particular context and constellation of stakeholders.

4.1. European Union cases

In the absence of EIP performance-based rankings and comprehensive empirical data, the cases from the European context were selected based on their relevance to the Alpine region and following their prominence in the literature.

4.1.1. Ecopark Hartberg, Austria[3]

Geography	Austria, Styria		
Type of park	Industrial		
Size of park	15 ha	30 companies	200 jobs
Sustainability criteria	Renewable energy Waste management Water management Material flow Social aspects		
Type of investment	Public private partnership		

[3] Most information on this case derives from FOEN and ECO-INNOVERA (2014) and the website www.oekopark.at.

Origin: Hartberg Municipality created the Ecopark Hartberg in 1997 to redevelop the industrial estate. The development of the park was supported also by the federal government of Austria and the European Union.

Profile: The Ecopark was developed in a strategic location close to main European markets, but also to active markets of Croatia, Slovenia, and Hungary. It is well connected to the main Austrian cities through a motorway and close to the airport of Vienna. The park is adapted to companies concerned with the production of a variety of good and environmental services or technologies. Research centers that investigate environmental solutions to improve energy efficiency are also found in the industrial park. The actors participating in the park work together to improve the environmental performance of the region through recycling of industrial waste (Valentino et al. 2015).

The main objectives of the park have been to underline and demonstrate the viability of environmental techniques in industrial parks and to promote those techniques at international level. Three approaches have been adopted to reach these goals: (i) the creation of park for eco- business; (ii) the creation of an applied research center; (iii) the creation of an exhibition and a leisure park. The last approach is implemented mainly through the dissemination of promotional material and the creation of exhibition attraction spaces such as an aquarium, paper making workshops, and the energy and nature trail (Valentino et al., 2015).

Park management: The Hartberg Ecopark is part of an ecological Styrian project based on the implementation of industrial ecology principles not only within an industrial park, but within the region. Consultancy and environmental services are offered to firms to identify the right area within the park, recruitment of human resources, and selection of potential partners (Valentino et al. 2015). The park operator carries out public events on environmental topics and social initiatives to promote and communicate its services and objectives as an industrial park.

Environmental performance: The Ecopark utilizes the organic fraction of municipal solid waste from the city to generate electricity through a biogas plant. The biogas plant is supplemented with a solar photovoltaic system and with turbines that supply energy for the electricity, heating and cooling systems for the entire Ecopark, making them carbon dioxide neutral. Ecological waste management, wastewater treatment, and rainwater collection are also part of the integrated approach to achieve sustainable resource utilization on both the city and the Ecopark. Wastepaper from urban consumption (i.e., from newspapers, restaurants, and cinemas in Hartberg city) is utilized as raw materials for the manufacturing of cellulose insulation products, thus creating a symbiotic relationship. The park has also been designated as an Eco-Innovation Park.

Internal studies estimate an ***average annual reduction of water consumption by 10%, energy consumption by 30%, and costs related to the disposal of industrial waste by 60%*** (Valentino et al., 2015).

Social performance: Ecopark provides facility services to its community as well as recreational spaces such as an Underwater and Aquarium World and a cinema. An organic supermarket, a private school and a kindergarten are also available on site (Valentino et al., 2015)

Economic performance: The Ecopark has attracted 30 small and medium-sized firms in the last years, generating around 200 new jobs.

4.1.2. Industrial Zone NÖ-Süd, Austria[4]

Geography	Austria, Lower Austria Province		
Type of park	Industrial and services		
Size of park	280 ha	370 companies	11,000 jobs
Sustainability criteria	Energy efficiency Waste management Biodiversity Mobility, transport Social aspects Environmental management system		
Type of investment	Private		

Origin: The industrial park was established in 1962 in the Lower Austria Province. The mandate of IZ NÖ Süd is to ensure added value for the region, create local jobs, and build sustainability for regional development.

Profile: The industrial park covers 280 hectares and comprises 370 companies. These companies are mostly small and medium enterprises and international companies that rent the facilities for office, storage and production space purposes. The sectors that are represented in the industrial park include: food and beverage, aluminum and steel converting, production of energy and technical components, environmental services and technologies, and logistics.

Park management: The park is managed by Ecoplus, a private business holding company with over 50 years of experience in managing 17 industrial parks. Ecoplus provides a one-stop service hub that connects institutions, public authorities and partners. It offers guidance from conceptualizing business ideas to their financing. Additionally, it supports tenant firms to obtain permits from local authorities.

Environmental performance: Ecoplus operates different central infrastructure services for the park such as a central wastewater treatment plant. It is also working on renewable energy projects to improve the energy efficiency of buildings in the park and plan the construction of charging stations for electric vehicles. Additionally, it maintains 100,000 square meters of green space, shrubs and trees within the park, with attractive landscapes and recreational areas. Collaborations with academia and dialogues with different businesses partners are being carried out to address industrial environmental and social sustainability issues.

Social performance: An extensive social infrastructure provision exists in and around IZ NÖ-Süd. It has grown into a small city that offers many services such as postal offices and customs services, restaurants, a business hotel, two small on-site shopping malls and Europe's biggest shopping mall (SCS), a private childcare center, and security system. Employees and local communities can enjoy many recreational facilities near the park, including tennis courts and golf courses.

[4] Most information on this case derives from World Bank, UNIDO and GIZ (2021).

Economic performance: The park employs around 11,000 people and collaborates with local vocational schools in four neighboring municipalities, ensuring the recruitment and retention of highly skilled labor. Other economic features offered by Ecoplus include the creation of business networks, the operation of conference and event facilities, and coordinating joint media efforts for companies and the industrial park.

4.1.3. Höchst Industrial Park, Germany[5]

Geography	Germany, Frankfurt am Main		
Type of park	Industrial		
Size of park	460 ha (50 ha available for new construction)	90 companies	22,000 jobs
Sustainability criteria	Renewable energy Energy efficiency Waste management Water management Transportation services		
Type of investment	Private		

Origin: The industrial park was created in 1863, as the former main site of Hoechst AG, a modest factory for coal tar dyes. It has operated as an EIP for over 22 years and continues to attract investors. It is currently one of Europe's largest, most successful industrial estates.

Profile: The park hosts companies across a range of sectors: pharmaceuticals, biotechnology, basic and specialty chemicals, crop protection, food additives and services. The park provides an on-site trimodal port and ecofriendly infrastructure (i.e., modern waste management facilities and efficient energy generation plants). The park serves as testbed for biotechnology, automated logistics, sustainable energy production and resource conservation, and modern research methods and production processes.

Park management: The park is operated by Infraserv Höchst since 1997, which beyond the operative activities is also responsible for maintaining links to and engaging with external stakeholders (i.e., communities, investors, policy makers). When it comes to waste management the role of the operator has been background operational activities, such as collection of waste material from source, testing waste for digestibility before acceptance, managing waste treatment process and distribution of power, steam, and biomethane to tenant firms.

Environmental performance: The efficient energy generating plants have made the park energy independent. The waste management system resulted in ***310,000 tons per year of sewage sludge that has been recovered***. Water is recycled in sophisticated processes and then reused up to 50 times (once it served its purpose, the water is extensively purified and discharged back into river Main). It has a ***capacity to purify up to 15,000 cubic meter river water per hour***. In 2023 a power-

[5] Most information for this case derives from World Bank (2021), www.infraserv.com, and www.chemietechnik.de

to-liquid pioneer plant, INERATEC, will start producing synthetic fuels at the park. In 2022 the regional public transit operator will begin replacing its diesel locomotives with 27 fuel cell trains. Intraserv Höchst will be supplying the hydrogen and building the necessary fueling infrastructure and the industrial park.

Social performance: Regular donations are collected, yearly ca. 75,000 Euro, which are then spend on the neighboring communities' kindergartens, schools, and associations.

Economic performance: Since 2000 $9 million in investment has been made by tenant firms and nearly 22,000 jobs have been created across the 90 companies.

4.1.4. Value Park, Germany[6]

Geography	Germany, Schkopau		
Type of park	Industrial		
Size of park	150 ha	26 companies	1,600 jobs
Sustainability criteria	Waste management Water management Material flow Mobility and transport Social aspects		
Type of investment	Private		

Origin: The industrial park was established in 1998 by Dow Olefinverbund GmbH, a large-scale chemical and plastics multinational enterprise, and its subsidiary Bsl. Value Park is located in the small town of Shkopau, in the center of Germany. The main aim of the park is to offer a potential location to companies related to Dow and Bsl, such as rubber manufacturers and suppliers, to create long-term relationships and improve the productivity and attractiveness of the region. The idea is to set up a value-added network where firms can share infrastructure and services, supply raw materials, and buy and manufacture their products.

Profile: The network between the companies is characterized by the presence of Dow, which is the first producer in the park and plays the role of the anchor company.

Park management: Since its foundation, Dow has led the management of the park. It plays an executive and hierarchical role in the selection of firms that can integrate into the system. Some of the services offered by Dow include counseling for planning and obtaining permits, a wastewater treatment plant, waste incineration, intercompany transport and logistics, chemical analysis, and emergency services. Dow is also in charge of organizing events, conferences, and workshops not only with firms and entrepreneurs, but also with students and researchers (Valentino et al. 2015).

The symbiotic relationship between the companies can be explained by their role as first or secondary producers and consumers. Dow, as the first producer, supplies the raw materials

[6] Most information on this case derives from www.de.dow.com.

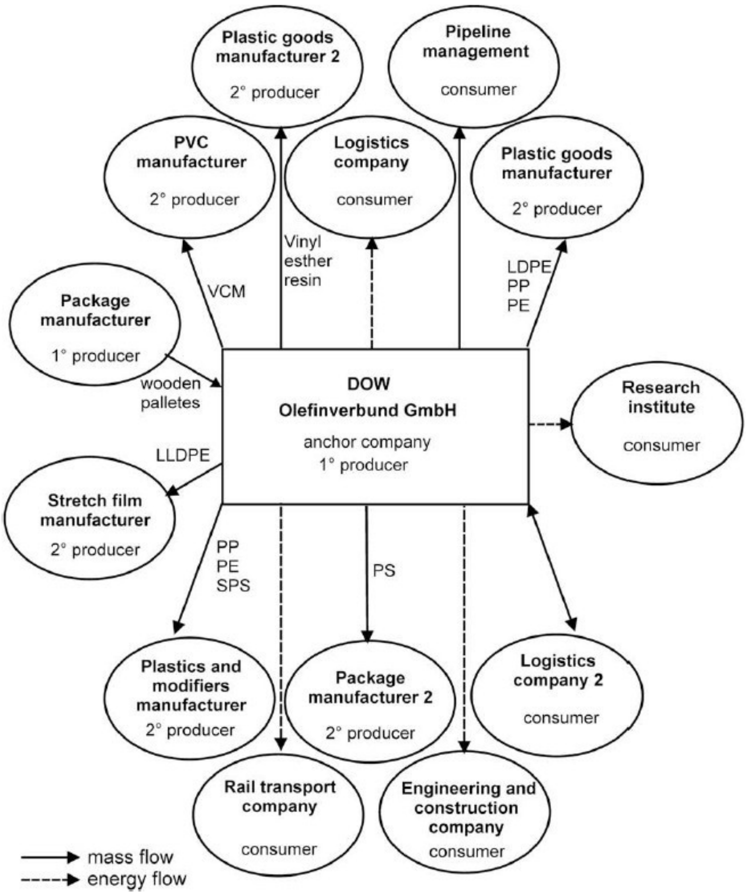
(different polymers) to the secondary producers, which then manufacture the polyolefins and other chemicals into stretch films, modifiers, PVC windows, and many other plastic goods (Valentino et al. 2015). Figure 8 shows is a representation of the material flow when 13 companies were present in the park. Today, 26 companies are part of the network.

Environmental performance: “Vision Zero”: zero accidents and zero damage to the environment is one of the fundamental concepts in the park. Dow joined the Responsible Care initiative in 1989, which aims to favor continuous improvement in health, safety and environmental (HSE) performance with open and transparent communication with stakeholders in the chemical industry (FOEN and ECO-INNOVERA, 2014). Value Park offers the following environmental services to firms located within the park: treatment of sewage; teat treatment of productive waste; monitoring of industrial waste, pollution, and temperature; storage of products; routine maintenance; laboratory tests.

Social performance: Dow aims every day to build a culture that embraces innovation, responsibility, and diversity. It supports 16 nonprofit organizations as part of the “Wir für Hier” donation program. In Value Park, Dow has been promoting the voluntary commitment of non-profit associations and organizations around other plants in Germany, to develop educational projects, sport clubs and environmental initiatives.

Economic performance: Currently, around 1,600 employees work for the 26 companies established in the park.

Figure 8 – Symbiotic network in Value Park



Source: Liwarska-Bizukojc et al. 2009

4.1.5. Kalundborg Industrial Area, Denmark[7]

Geography	Denmark, Sjaelland, Kalundborg		
Type of park	Industrial and urban		
Size of park	N/A ha	14 companies	4,500 jobs
Sustainability criteria	Renewable energy Energy efficiency Waste management Water management Material flow Transportation services Social aspects		
Type of investment	Private		

[7] Most information for this case derives from www.symbiosis.dk and www.sustainablecities.dk

Origin: Created in 1961, Kalundborg industrial area and municipality is the world's most well- known example of a competitive model of industrial symbiosis. The project started out of the necessity to address scarcity of water in the region. Interestingly, the industrial symbiosis model of Kalundborg was not the result of government planning. It was rather the result of a gradual development of cooperation between neighboring industries and the municipality of Kalundborg (Desrochers 2002). The impetus to develop the recycling system and structures of Kalundborg was purely economic; on one hand to reduce the costs associated with waste disposal and on the other hand, to have an extra income-producing service for other companies located nearby (Baldwin 2004). Today, Kalundborg Symbiosis' vision is to be the world's leading industrial symbiosis with a circular approach to production, creating a local partnership where resources are sourced, shared, and recycled for mutual and increased value generation.

Profile: The Kalundborg EIP is essentially an industrial symbiosis network in which companies in the region collaborate to use each other's by-products and otherwise share resources. Presently, Kalundborg symbiosis network includes 14 public and private enterprises, among which the world's largest producer of insulin, the world's largest enzyme producer, the largest sewage treatment plant in Northern Europe, the largest oil refinery in the Baltic region, as well as firms in economic sectors such as gypsum, recycling and recovery of waste and contaminated soil, waste treatment. At the center of the exchange network is the Asnaes Power Station, a 1500 MW coal-fired power plant, which maintains material and energy links with the community and other companies.

Park management: The Kalundborg Symbiosis Institute was created in 1996 to encourage, facilitate and manage the value driven business relationships. The basis of the industrial symbiosis cooperation in Kalundborg is open communication and mutual trust between the partners. The synergies are implemented in a voluntary basis. The Kalundborg Symbiosis systematically identifies potential and initiate new projects to ensure resource optimization, disseminate knowledge, document value creation, and facilitates new symbiosis collaborations.

Environmental performance: More than 20 different streams of excess resources flow between the companies, creating a symbiosis or resource exchange, as well as adding more resilience and profits to the companies (see Figure 9). For example, Novozymes, one of the world's largest producers in biological solutions and supplier of enzymes and microbial technology, produces enzymes to boost detergency of washing powders and reduce the amounts of chemicals used in the process. The enzymes are produced via fermentation of agricultural raw materials and the residual biomass of the process becomes afterwards the raw materials for Kalundborg Bioenergy. At the biogas plant, biomethane is produced and upgraded to natural gas quality through a refining process. Hydrogen sulphide is removed from biomethane and used to collect sulphur, which is then reused in fertilizer products together with the biomass residual. The biogas is sent to other companies in Kalundborg Symbiosis.

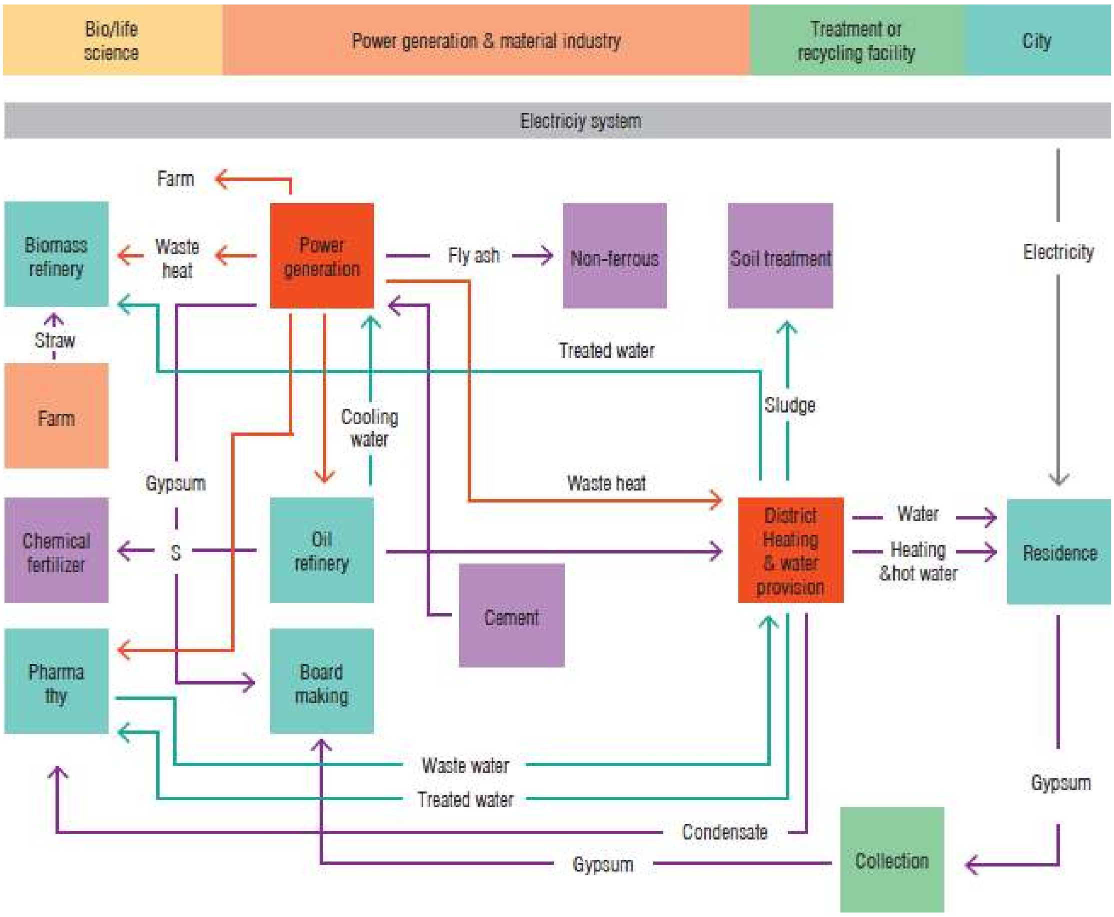
Every year, the impact of the symbiosis in Kalundborg is reflected in ***savings of 4 million m^3 of groundwater by using surface water instead; 586,000 tones of CO_2 are saved; 100 GWh in energy savings; 87,000 tons of savings in solid waste; and 62,000 tones of***

residual materials are recycled. Overall, 80% of CO_2 emissions have been reduced since 2015. The local energy supply is also by now CO_2 neutral. The EIP also aims for zero waste performance in the coming decade.

Social performance: The diversity of businesses, the relative geographical isolation of the companies and the awareness of the economic value added of the synergies facilitate the emergence of the network across firms. Local authorities benefit from a reduction in environmental pollution and in harmful industrial substances. The park increases the quality of life, employment rate, and makes the area attractive to regional and international markets (Valentino et al. 2015).

Economic performance: Key economic benefits derived from this model are the achieved cost reductions, estimated at the level of 24 million Euro annually (Engie, n.d.). The EIP also currently employed 4,500 people and over the years has developed extensive international cooperations with private and public institutions.

Figure 9 – Industrial symbiosis relationship in Kalundborg



Source: World Bank (2016)

4.1.6. Macrolotto di Prato, Italy[8]

Geography	Italy, Toscana, Prato		
Type of park	Industrial		
Size of park	150 ha	ca. 700 companies	4,000 jobs
Sustainability criteria	Energy efficiency Water management Material flow Social aspects Mobility, transport Air pollution prevention Environmental management system		
Type of investment	Private		

Origin: Macrolotto di Prato is located in Tuscany, one of the most important productive districts of Italy. Established in 1975, it represents one of the principal Italian EIPs and it is the most advanced in eco-innovation technologies and services. The starting point towards a more sustainable production was the first environmental assessment carried out in 1999 through a top-down intervention. Even though the transition into an EIP happened in 2015, it shaped the industrial development processes by creating awareness among the actors of the problems of industrial production to the environment.

Profile: Macrolotto di Prato specializes in wool production and its main characteristics are related to the centralized environmental services, its wastewater recycling plant, and its performance of management. Its network involves actors from the government like the Regional Government of Tuscany, Prato Municipality, the Ministry of Environment, the Ministry of Productive Activities, and other; intermediary organizations like CONSER (the first management body), Confindustria Toscana Nord (current management body), the Management of Prato District, the Industrial Association of Prato, and the Chamber of Commerce of Prato; private companies such as the water management company GIDA and located companies; non-profit organizations; research centers; and investment banks (Susur et al. 2019).

Park management: CONSER, as the first management body, has been a crucial facilitator of interactions in the network and envisioned the link to the environmental sustainability benefits. It has played an important role in the management of water, energy, security, and dissemination. The current management body, Confindustria Toscana Nord, was created in 2015 as an attempt to reinforce the territorial industrial representation and increased industrial efficiency. It has facilitated the interaction between regional, national and international actors (Susur et al. 2019).

The fact that Macrolotto di Prato has been a concentrated and homogeneous area composed of mainly textile companies has allowed the park to develop a series of EIP practices. Moreover, the

[8] Most information for this case derives from FOEN and ECO-INNOVERA (2014).

good communication strategies regarding the associated economic gains of the EIP practices have resulted in a high number of private companies in the EIP network.

Environmental performance: Confindustria Toscana Nord is in charge of the environmental management of the park. Among the 350 companies settled, 52% have industrial activities and around 10% are characterized by high water consumption related to dyeing, printing, and carbonizing activities (FOEN and ECO-INNOVERA 2014). CONSER promoted the adhesion of the whole industrial area to the Eco-Management and Audit Scheme (EMAS) as well as energy efficiency, broadening of recycling water use and water and air quality monitoring. A non-profit organization manages the recycling plant and the filtration system of the Bisenzio River to provide water for processes, firing, cooling and sanitation. This plant is able to produce around 5,000,000 m^3 per year (CONSER 2009) and allows a saving of groundwater equivalent to the consumption of 100,000 inhabitants/year. The park also counts with two photovoltaic plants to provide energy to the kindergarten and reduce the energy costs related to the recycling water system (Puig 2019).

The most significant initiative in the energy sector that CONSER promoted was a convention with a local bank to allow firms to implement photovoltaic systems, entirely funded by the bank. In 2012, more than 20 ha of photovoltaic systems were built on the firms' roofs resulting in a ***reduction of CO_2 emissions of 16,000 tonnes per year*** (Mazzoni 2020).

Social performance: CONSER introduced innovative measures to secure the entire area of the park, among which:

- Firefighting aqueduct fueled by recycled water, planned to operate as a centralized firefighting system in the entire area. The main objectives were to ensure safety measures and eliminate the costs associated with the previously existing 380 firefighting systems present in single firms.
- Centralized parking lots in the busiest areas to reduce potential road accidents.

Other measures that have been implemented to improve the quality of life of the employees are:

- An inter-company kindergarten, available for employees of all firms within the park at reduced tuition fees.
- Centralized laundry, pharmacy, post and grocery services, directly delivering the products
  and services to workers' houses with reduced prices.
- Free car-pooling and car sharing services are available for all firms operating in the cluster to reduce pollution due to transportation of people and goods and reduce traffic in busiest areas.

Economic performance: Macrolotto di Prato has now the participation of around 700 small and micro firms and employs about 4,000 workers. In 2009, some of the economic benefits that firms have due to the ***water recycling system*** and ***photovoltaic systems for energy production*** were estimated around ***300,000 euros per year*** and ***4.5 million euros per year*** respectively (CONSER 2009).

4.1.7. Plaine de l'Ain Industrial Park, France[9]

Geography	France, Communaute de communes de la Plaine de l'Ain, Rhone- Alpes		
Type of park	Industrial		
Size of park	1000 ha	188 companies	8,265 jobs
Sustainability criteria	Energy efficiency Waste management Water management Biodiversity Mobility and transport Social aspects Environmental management systems		
Type of investment	Public		

Origin: Built in 1975 in a previously rural and agricultural area, Plaine de l'Ain is one of the largest industrial parks in France. Its key objective has been to drive economic/industrial development in the region for job creation to contribute to the revitalization of the rural area. The park's planning policy mentions three main strategic goals: control over development, diversity of activities, and environmental protection.

Profile: The park hosts companies from a variety of sectors, including manufacturing, logistics, R&D, food processing and chemicals. It has offered a range of high-quality facilities and infrastructures since its development. The park's geographical location and geological features are ideal for industrial activities, attracting local and international investors that promotes a dynamic environment in France's most heavily industrialized department. It is also served by a first-rate motorway network and is just a few hours' drive from some of Europe's major conurbations. Moreover, Lyon Saint-Exupéry International Airport is just 25 minutes away from the park (Syndicat Mixte de la Plaine de l'Ain, 2011).

Park management: The Syndicat Mixte de la Plaine de l'Ain (SMPA) manages the park. It controls the sitting of new activities to respect the sustainability objectives of the part and adopts a participatory approach towards and neighboring communities, which are systematically consulted regarding new developments in the area (services or infrastructures). Diversity is promoted by the SMPA as an asset for the park's resilience and local employment.

Regarding new business ideas, the Plaine Multi-Benefit Incubator (PAMPA) is a service also provided by the management body to provide set-up solutions for start-ups, including communal services charged on a shared-cost basis. It offers personalized growth support services and post-incubator support to promote long-term partnerships (Syndicat Mixte de la Plaine de l'Ain, 2011).

Environmental performance: The park was Europe's first to be certified ***ISO 14001*** and ***EMAS.*** Companies in the park do not have to obtain the certification individually, but the SMPA encourages

[9] Most information for this case comes from FOEN and ECO-INNOVERA (2014) and www.plainedelain.fr

sound environmental management practices around them. For biodiversity, SMPA established a partnership with the French Bird Protection League (LPO) to minimize the impact of industrial urbanization on the park's wildlife (FOEN and ECO-INNOVERA, 2014). A toral of ***96 bird species*** that can be found withing 122 ha of land earmarked as "refuges" by the LPO. The SMPA also promotes landscape architecture, and it has incorporated ***220 ha*** of green spaces and ***450,000 trees have been planted***. Moreover, the park manager has developed shared services and infrastructures for ***wastewater treatment, ordinary and hazardous industrial waste management*** and ***fire protection*** (Syndicat Mixte de la Plaine de l'Ain, 2011). The innovative indicators used to protect the park's environment and quality of life are:

- the water table is monitored and analyzed using on-site piezometers;
- rainwater contaminated with hydrocarbons is treated via biophotodigestion;
- industrial wastewater is biologically treated;
- biodiversity is monitored and protected: the park has "zero tolerance" policy towards agrochemical products;
- air quality is monitored through lichen analysis

Regarding transport and mobility, a railway connects the park with the nearest train station and 25% of the employees use carpooling (national average is 3%).

Social performance: The SMPA was awarded LUCIE accreditation for its commitment to Corporate Social Responsibility in 2012. The park provides and exceptional quality of life based on three key assets:

- ***Leisure and relaxation areas and day-to-day services*** including restaurants, cinema, grocery stores, car hire and car wash service, petrol station, tennis courts, aquatic centre and fitness gym, 3-star hotel and a day nursery.
- ***Social and cultural events at the park*** such as park festivals and concerts.
- ***A variety of businesses that provide a multitude of professional services***.

The park also counts with a Business Club to encourage cooperation between companies. More than 70 member businesses are part of this club where networking and socializing opportunities are possible (Syndicat Mixte de la Plaine de l'Ain, 2011).

Economic performance: In 2022, 8,265 employees were reported.

4.1.8. Industrial Park Kleefse Waard, Netherlands[10]

Geography	Netherlands, Arnhem		
Type of park	Industrial		
Size of park	90 ha	80 companies	N/A jobs
Sustainability criteria	Renewable energy Energy efficiency Waste management		

[10] Most information for this case derives from Valladolid Calderon (2021).

	Material flow Transportation systems Environmental management systems
Type of investment	Private

Origin: The industrial park Kleefse Waard resulted from the transformation of a chemical manufacturing site between 2003-2011 into a sustainable industry park, in close collaboration with the City of Arnhem. The park specifically focuses on providing the best climate for innovative companies in energy and environmental technology. In 2019 the park has won the Circular Economy Award for being the most sustainable park in the Netherlands. The goal of the owner is to become entirely circular and most sustainable industrial park in the country by 2025.

Profile: The 90 ha park hosts 80 companies engaged in sustainable innovations, mainly in the energy sector, in the areas of power generation, hydrogen, mobility, and wood preservation. With its focus on innovation and entrepreneurship, the park has developed an ecosystem that blends economic and social activities with production processes, energy and waste flows. The park engages stakeholders such as research institutions (e.g., HAN University of Applied Sciences, Mobility Innovation Center, Power and Hydrogen Lab), environmental and natural organizations (e.g., Natura 2000) to ensure that its impact go beyond the premises of the park. The Park also has an innovation incubator on side.

Park management: The park, purchased in 2003 by developer and real estate developer Schipper Bosche is privately managed. The park manager assesses which companies can join the park, communicated with the relevant stakeholders, and ensures that companies achieve the set objectives in terms of sustainability performance.

Environmental performance: The environmental services company, Veolia, is responsible for ensuring that the park's utility supply is sustainable. The park is self-sufficient as it has its own water treatment plant and power plant for heat, electricity, and gas. Aside from the energy side, the park also operated exchanges of waste such as plastic and wood between some companies. The park has also installed a medium-sized wood-fired biomass boiler in 2018 to reduce gas consumption, using residual wood collected from a radius of 100 km around the park. With the biomass boiler, Veolia has managed to ***reduce gas intake by 84% and to reduce 60,000 tons of CO2 emissions since 2014***. Aside from wood, plastic is also processed and transformed in new products by Save Plastics, a company located at the park. Wood waste is also reprocessed into new furniture used on site or sold.

The heat from biomass' plant generated steam is also collected and goes into the network. The park also has almost 25,000 solar panels installed on roofs, is installing solar fields with a total of 50,000 solar panels and has four wind turbines. Electricity is also generated with running water by the watermill developed by the Park's incubator. The goal is that over the next year 2/3 of the energy consumption will be generated by renewables. The energy, stored into batteries, is used for electric car charging plaza of more than 70 charging points (for e-vehicles and e-bikes). A joint project with the city council and a number of companies pilots and tests hydrogen technologies.

All buildings have also been renovated with climate control and new designs for higher energy efficiency standards (i.e., energy label A).

Social performance: The focus of the park on clean tech companies enabled the emergence of a community, also enhanced by various communal facilities and activities, and conference areas. Various social and sports events are also organized at the park, such as the Green Industry Events. Also, low-emission commuting solutions are provided to people living further away from the park. Shared bikes and shared e-autos are also offered.

Economic performance: N/A.

4.1.9. Relvão Eco-Industrial Park, Portugal

Geography	Portugal, Santarém, Chamusca		
Type of park	Industrial		
Size of park	1,400 ha	26 companies	N/A jobs
Sustainability criteria	Water management Material flow Land use optimization		
Type of investment	Public-private partnership		

Origin: The Relvão Eco-Industrial Park (REIP) in Portugal was created in 2005 by the Chamusca Municipality as a result of jointed efforts of several different stakeholders, including the Portuguese Government, the Chamusca Municipality, the Technical University of Lisbon and industrial companies and entrepreneurs. At the time the Relvão project began, the Chamusca region was already starting to develop a large integrated recovery, treatment, and elimination center for hazardous waste. The national government chose the Chamusca Municipality to carry out the project due to this early initiative and to slow down the erosion of its social and economic base (Costa and Ferrão 2010).

Profile: REIP is the largest and most organized network of industrial symbiosis in Portugal. Currently the park includes companies whose activities go around the recycling and recovering of different types of materials, such as plastics, biomass, sanitary waste, and textiles. Pulp and paper companies, agro industries, several chemical companies (mainly fertilizer producers), and waste treatment facilities are the main sectors represented in the park. Since its foundation, it took around 4 years to attract more than 20 companies in the park (FOEN and ECO-INNOVERA, 2014). Its main objective is to improve local sustainability by stimulating the integration of life-cycle thinking into urban and industrial planning, as well develop and expand knowledge of the characteristics and quantities of waste materials between companies in the region in order to detect potential IS to implement and create innovative uses for waste materials (Costa and Ferrão 2010).

Park management: The part is mainly managed by the Chamusca Municipality; however, it works together with the Portuguese Government and the Technical University of Lisbon. The project was part of the European Network of Living Labs that promoted great cooperation relationships between local stakeholders and academic researchers (FOEN and ECO-INNOVERA, 2014). The main barrier faced by the consortium was the Portuguese waste management regulation. Portugal implements waste management regulations at national level rather than at regional level, which results in longer times for introducing any change in the regulatory framework to facilitate Industrial Symbiosis development (Costa and Ferrão 2010). Moreover, special permissions are needed to directly manage a resource classified as waste meaning that waste management companies have to take part in the symbiotic exchanges in the park.

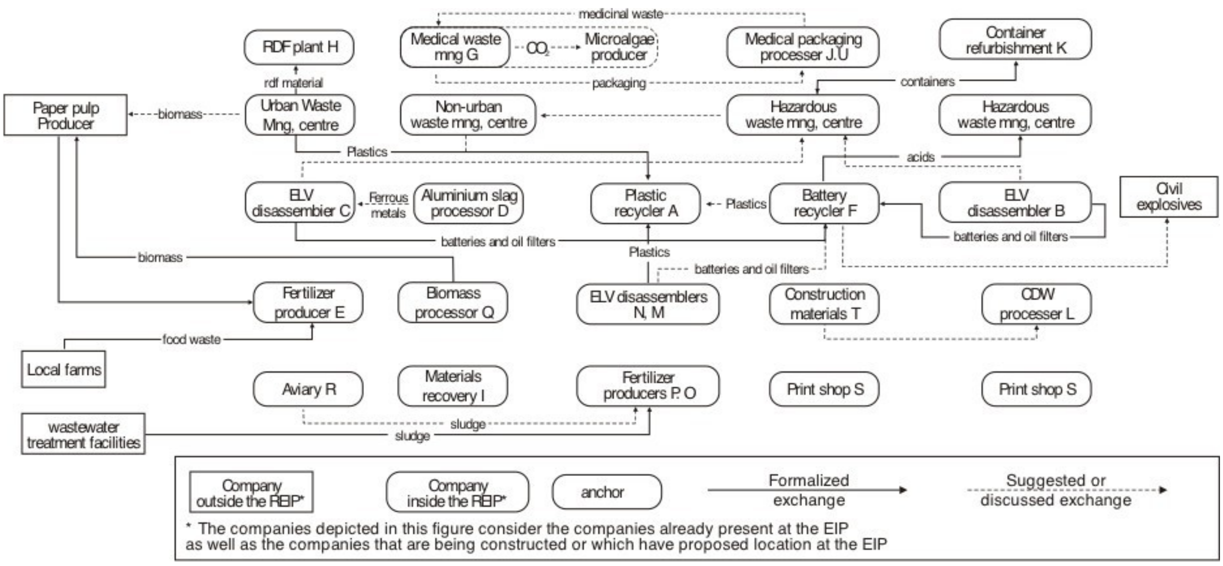
To overcome these barriers, the municipality directly involved waste management operators and companies already licensed to enable symbiotic exchanges emergence. The positive attitude of the local authorities towards Industrial Ecology and the openness to dialogue of the government allowed a successful symbiotic exchange in the park.

Environmental performance: A reduction in waste reduction and CO2 emissions are expected from symbiotic waste exchanges, recycling of materials and waste management activities in the park; however, no quantitative information is available. Figure 10 is a representation of the industrial symbiosis developed in Relvão. An environmental impact assessment was carried out in 2010 to analyze the impact of the subdivision on building lots of an area of 25 ha (FOEN and ECO- INNOVERA, 2014).

Social performance: The local community and companies were also considered during the development of the park. The involvement of the local community contributed the absence of “not- in-my-backyard" effects, which are common in other industrial areas in Portugal (Costa and Ferrão 2010).

Economic performance: N/A.

Figure 10: Industrial Symbiosis in Relvão EIP



Source: Costa and Ferrão (2010)

4.2. Non-EU cases

For the non-EU cases we relied on the good practice examples widely featured in the World Bank and UNIDO reports, as these have been more extensively researched and emerged from a stronger national and sector-level commitment towards transforming industrial parks in EIPs. Limited empirical data, however, poses challenges also when it comes to benchmarking these examples.

4.2.1. Ulsan Mipo and Onsan Industrial Park, South Korea

Geography	South Korea, Ulsan City		
Type of park	Industrial		
Size of park	6,540 ha	1,052 companies	N/A jobs
Sustainability criteria	Renewable energy Energy efficiency Waste management Water management Material flows		
Type of investment	Public		

Origin: The Korean National Cleaner Production Center (KNCPC) launched the National EIP program in 2003, to promote innovative industrial development which simultaneously achieves environmental sustainability. The Ulsan metropolitan city is known for its transformation from a small fishing and agricultural town with rich and natural resources to the nation's number one industrial city with a population of 1.2 million.

Profile: The EIP comprises mostly large companies in heavy industry sectors, such as s vehicle manufacturing, shipbuilding, oil refineries, machineries, non-ferrous metals, pulp and paper, and fertilizer and petro-chemical industries.

Objectives: The main objective of the Ulsan Mipo and Onsan EIP initiative was to transform the Mipo-Onsan conventional national industrial complex into sustainable EIPs based on the national EIP development master plan.

Park management: The execution of the national EIP initiative is carried out by the Korea Industrial Complex Corporation (KICOX), a semi-governmental body that manages national industrial complexes. It handles overall planning, budget accounting, approval of project proposals, and connection with governmental bodies and concerned organizations. The Ulsan ***regional EIP center*** also plays an important role, led by an advisory board composed of representatives from local government, academia and industry, highly interested in enhancing local industrial symbiosis. The EIP regional center plays an important role in identifying industrial symbiosis projects (Park et al. 2016) by: (a) developing a resource database (not only for material resources, but also for organizational, human, and infrastructure resources); (b) organization of forums; (c) appointment of coordinators. Over the years, extensive efforts have been made ***to build up stakeholder relationships and communication channels***.

Environmental performance: The Ulsan EIP program saved 279,761 tons of oil equivalent in energy use during 2005-2016, which resulted in a ***reduction of 665,712 tons of CO2 emissions and 4,052 tons of toxic gases***, such as SOx and NOx. Additionally, ***79,357 tons of water and 40,044 tons of by- products and water were reused*** (World Bank, UNIDO, GIZ 2021). In addition, the *organic waste-to- energy network* developed in cooperation with the Ulsan Municipality from synergies with the surrounding farms and food industries ***delivers 9,000 m³/day to the chemical industries and 91.2 ton/day steam to the paper industries*** (Park 2013). The successful steam sharing network between the city waste-to-energy incinerator and a chemical company become pilot project that got replicated in other regions in Korea (Park et al. 2016).

Social performance: A total private investment for the construction of industrial symbiosis networking facilities amounted to US$ 245.8 million (as of 2016) ***creating 195 new jobs*** (World Bank, UNIDO, GIZ 2021). The industrial symbiosis processes and overall increased environmental performance enhanced relations with local communities and improved the negative image of regional industrial complexes as polluters (World Bank 2018).

Economic performance: Firms in Ulsan Mipo and Onsan have invested some $520 million in energy efficiency, industrial symbiosis, waste management, and other eco-friendly improvements, which has ***yielded $554 million in savings***, while ***firms in the EIP generated $91.5 billion in revenues*** (World Bank 2018). Government investments have totaled $14.8 million for project research and development, including center operations. From this government research fund, further ***income of***

$65 million/year has been generated from selling by-products and waste for recycling purposes (World Bank, UNIDO, GIZ 2021). An additional ***$78.1 million/year was generated from energy and material savings*** in 2016 (ibid).

4.2.2. Hoa Khanh Industrial Zone, Vietnam[11]

Geography	Da Nang City, Lien Chieu District, Vietnam		
Type of park	Industrial		
Size of park	396 ha	168 companies	73,215 jobs
Sustainability criteria	Energy efficiency Waste management Water management Material flows		
Type of investment	Public		

Origin: The industrial park was stablished in 1996 by the Da Nang Administrative Committee and located in the Lien Chieu District of Da Nang City. Between 2014 and 2019, the Ministry of Planning and Investment with support from UNIDO and the World Bank, has been involved in developing a national strategy on EIPs in Vietnam. The Hoa Khanh Industrial Zone would then become one of five industrial areas to be transformed into an EIP. Still, the policy framework for the transition to the EIP model is both insufficient and inconsistent.

Profile: Industries based in this park include food and seafood processing, mechanics, assembly, forest products processing, construction materials, and electronics.

Park management: The park is managed by the Da Nang Industrial Zones and Export Processing Authority, an administrative authority belonging to the Da Nang People's Committee, which monitors planning, investment, labor, security, and environmental issues within industrial zones in Da Nang. Improvements have been to be needed when it comes to expertise and coordination within the management board. UNIDO has supported the scaling-up of park management capacity through different and dedicated training sessions, expert group meetings and study tours. The

[13] The information for this case derives from World Bank, UNIDO and GIZ (2021).

objective of these activities has been to exchange experiences and international good practices in industrial parks. The park has a functioning monitoring system in place but does not yet have centralized management services. Every firm located in the industrial zone must sign a contract with the Central Branch of Hanoi Urban Environment Company (URENCO) for waste collection and treatment services. In addition, insufficient attention has been paid to date for the creation of connections between the industrial park and the local community.

Environmental performance: The Vietnam National Cleaner Production Center (VNCPC) has performed resource efficient and cleaner production (RECP) assessments with 20 firms. The implementation of RECP has achieved annual savings of $500,000 and saved 2,571 tons of solid waste, 1,034,300 kWh of electricity, and 6,000 kiloliters of water per year over the course of the projects. A centralized wastewater treatment plant, managed by the Central Branch of Hanoi Urban Environment Company, has been operating since 2007 with a capacity of 5,000 m^3/day. It applies chemical-biological technology which results in reduced chemical consumption rates and chemical sludge generation. It was assessed as relatively efficient; however, the problem is that the volume of wastewater exceeds the capacity of the plant by an average of 40%.[12]

Social performance: Essential social infrastructure is available in the immediate vicinity of the Hoa Khanh industrial zone and includes local shops and banking facilities. Lack of public or park transportation and low national standards for occupational health and safety are aspects that can be further improved.

Economic performance: In 2015 73,215 employees were reportedly working within the industrial park, of which 99% were domestic SME workers. More recently, international companies are much more involved in career development programs than domestic SMEs.

4.2.3. Izmir Ataturk Organized Industrial Zone, Turkey[13]

Geography	Ciğli County, Izmir Province, Turkey		
Type of park	Industrial		
Size of park	634 ha	556 companies	37,000 jobs
Sustainability criteria	Energy efficiency Environmental management Waste management Water management Mobility and transport Material flows		
Type of investment	Private		

[12] The total volume of waste amounts to 3,600 tones/month (94% is industrial waste), of which 55% is

[13] The information for this case derives from World Bank, UNIDO and GIZ (2021).

landfilled (World Bank, UNIDO, GIZ 2021).

[13] The information for this case derives from World Bank, UNIDO and GIZ (2021).

Origin: The Industrial Zone was established in 1990 and is currently in the process of transforming towards an EIP.

Profile: The park has a mix of sectors, the largest of which are (in terms of the number of firms) machinery-metal casting, plastics, food and beverages, textiles and ready-made clothing, and chemicals. The zone offers 50 km of internal roads connected to airport, bus terminal, and port and city centres. The zone authority owns a natural gas-fuelled combined cycle power plant with a capacity of 120 MW. The Zone is responsible for distributing municipal water and it has a 75 km rainwater drainage system with 11 pumping stations and a firefighting station.

Park management: The industrial zone is privately owned and operated by the Izmir Ataturk Organized Zone Authority. The zone authority is also responsible for awareness raising, monitoring, verification, and evaluation of various projects, including industrial symbiosis.

Environmental performance: The industrial park is ***ISO 14001 certified and has environmental and energy management units*** within its organisational structure. It also owns and operates and ***two wastewater treatment plants with capacities of 12,000 m3 per day and 9,000 m3 per day***, which operate beyond the national discharge standard and applied more stringent discharge parameters compared with other industrial parks in Turkey. In addition, water from drying the sludge is cycled back to the wastewater treatment plant. Rainwater and wastewater are collected separately through a 75 km-long storm water drainage system and a 45 km-long wastewater line. The zone also owns and operates a ***natural gas-fuelled 120 MW combined cycle power plant and a 500 kW solar photovoltaic plant generating 780,000 KWh annually***. Further, together with the World Bank, the park authority has worked on the waste data of 45 firms and matched 83 different types of waste with 31 different sectors, which led to the identification of ***10 industrial symbiosis opportunities***. Additional opportunities have been identified to reduce municipal waste use through ***wastewaste recycling,*** creating possibilities for ***cost, energy and carbon savings estimated at $1-2 million per year.***

Social performance: The management authority owns and operates a Private Technical College, a vocational training centre, a sports centre, a dispensary, and a kindergarten. It also organises sectoral workshops, R&D competitions, and seminars, and engaged in cooperation with universities.

Economic performance: The zone supports 37,500 employees. About 75% of the firms export their products mostly to the EU. The annual turnover of the first is $7.8 billion, annual exports are valued at $2.5 billion, and annual imports amount to $1 billion. The potential for cost reductions (due to energy and water efficiency upgrades) in the future is, however, considered to be large; for example: 2,200 MWh/year due to upgrading of electricity motors, 16,100 m3 of water and 644,000 KWh of electricity annually, 5,655 MWh annual energy efficiency savings by installing additional automated metering and monitoring of electricity, fossil fuel and/or thermal energy consumption.

5. Preconditions for success

The implementation of the EIP concept has not yet happened at large scale and in a systematic manner. Existing initiatives are rather scattered, and many projects are in pilot phase (or under development) even in more advanced economies. Moreover, as mentioned earlier, it remains difficult to identify which industrial parks comprehensively fulfil the performance requirements of an EIP, at least as specified in the International Framework for EIPs. Nevertheless, the cases sketched in Section 4 and existing literature do reveal several preconditions for effective implementation of EIP principles. More research, however, is clearly needed to delve deeper into these aspects across various industrial sectors, geographical contexts, and industrial park types and profiles. Such data collection efforts would need to be conducted on site with park managers and operators, tenants, policy makers, and surrounding communities. Lack of even recent data on sustainability performance emerges to be a major limitation for detailed benchmarking assessments.

Below we briefly highlight the most relevant preconditions for success we identified following desk research on various cases. These preconditions aim to offer guidance to practitioners on which areas to focus most while designing future interventions, regardless of whether the planned projects relate to transforming existing industrial parts towards EIPs or if they relate to greenfield investments.

Policy support

A supportive regulatory environment and specific government incentives to enable investment have been considered important for all of these cases, if not initially, then certainly later on in order to scale up EIP related initiatives. In addition, national level strategies to transform industries and industrial parks towards sustainability (such as in the case of Germany or South Korea) have also proved to be essential in achieving a high degree of spill over effects across sectors and to also create demand for industrial symbiosis processes. Overall, lack of awareness at the level of policymakers, lack of supporting regulations and their enforcement have contributed to slowing down the development and implementation of EIPs. Specifically, as Perucci et al. (2022) argue, while government support is crucial especially in the early stages of EIP implementation, continuous policy support during operation can lead to varying impacts on the success of an EIP depending on geographic location and the associated culture of the EIP (e.g., trust and communication).

Data availability and quality

Accessibility of reliable data at firm level and from the local/regional communities (e.g., on waste streams and the material/water/energy requirements of local industries and residential areas) is key for setting in motion the type of processes necessary for an EIP. Willingness to share such information in a transparent manner is often a challenge, even if the necessary platforms for data collection are in place. In addition, monitoring and record keeping of environmental and social compliance issues are also critical. In some of the above examples, such data collection processes, and the subsequent analyses have been performed either by the park management entities or by applied research institutes associated with the industrial parks. Generally, the quality of the information provided and shared across stakeholders is a highly important factor/precondition for success. For instance, a (digital) platform for data collection and sharing can only work if the firms are willing provide up to date data on a regular basis.

Cooperation and trust

Developing industrial synergies within the park (and with its communities) requires a high-level of cooperation and trust building based on effective communication. Efforts to build up stakeholder relations and to implement effective communication channels for sharing information in a transparent and trustworthy way are therefore essential given the high level of interconnectivity required for EIPs. Park management entities (as in most cases in European examples) or EIP regional centres (as in the case of South Korea) can play an important role for driving local coordination for formal and informal information collection, awareness raising, and stakeholder engagement. Lack of cooperation (and low mutual trust) between the industrial park tenants (and the surrounding communities) hamper not only industrial symbiosis processes (due to limited material and asset sharing) but also innovation (Krom et al. 2022).

Synergies with local communities

Many industrial parks are located close to populated urban or rural areas or to neighbouring businesses not part of the industrial park (e.g., farms, service providers). This makes it is especially critical to address environmental concerns, such as land, air and water pollution, waste collection and management across the large region. In addition, understanding the concerns and needs of the surrounding communities can open opportunities for value creation and industrial-urban/rural symbiotic relations. From this perspective, effective EIPs are conditional on effective stakeholder relations and community involvement (Morales and Diemer 2019).

Park operators and management

A dedicated park management entity needs to be in place and highly involved throughout the EIP development.[14] The park manager entity plays a key role not only in designing the master plan and coordinating actions; the entity is also key in driving awareness, sharing of data and information across tenants and with the community, and liaising with policy makers, investors, and other stakeholders. The park operator and manager should also be responsible for setting in place a process of monitoring and evaluation oriented towards continuous improvement based on evidence-based processes, essential to deriving extensive co-benefits for the industrial park stakeholders. Designing customised and efficient awareness raising activities also falls in the area of responsibility of the management entity, especially in the initial stages of an EIP but also throughout its operational phase. Channels for raising awareness could be meetings, workshops, interviews, website and newsletters, social networks, information materials, etc. Cases of EIP explored for this study revealed that most EIPs do not, for example, communicate relevant information on their EIP performance via their websites, offering therefore limited transparency to potential investors and relevant stakeholders. Park operators and managers also play a core leadership role in designing and monitoring KPIs for the park and coordinating service provision to tenant companies favouring industrial synergies.

Knowledge/capacity building

[14] Several EIP management models are discussed in relevant reports: associative management model, government management model, mixed public-private management model, or private company or individual management model (see UNIDO 2017).

Given the novelty involved in many of the processes leading to an EIP, upskilling and reskilling is important to support the type of innovations necessary and the various inter-linked processes that have to be implemented. Therefore, building up expertise and know-how for the park employees but also for the larger community, is important. This can be done in cooperation with research, education, and training institutes onsite or offsite. Close cooperation among these institutions, park managers, and park tenants can result in new on-site training programs and even new curricula at universities and at vocational training institutions.

Risk management

Although not explicitly mentioned in the above case studies, conducting risk assessments on the region, industrial park, and specific sectors, is key to avoid future disruptions given the high degree of interdependencies in supply and demand of resources required by an EIP. In addition, as supply disruptions from one firm may disrupt the entire process (Perrucci et al. 2022) having in place elaborated risk management processes can contribute to trust building across stakeholders, as well as to attracting investment for the EIP.

6. References

Baldwin, J. (2004). Modelling industrial ecosystems and the “problem” of evolution. *Progress in Industrial Ecology*, 1 (1/2/3), pp. 39-60. ISSN 1476-8917

Bandyopadhyay, A. (2015). *Developing low-carbon zones – concepts, tools, methodologies. EY India*. Presented at the Eco-Industrial Park 2015 Conference.

Chertow, M.R. (2000). Industrial Symbiosis: Literature and taxonomy. *Annual Review of Energy and the Environment*. Vol. 35: 313-337.

CONSER (2009). Rapporto ambientale e sociale anno 2009. http://www.arpat.toscana.it/notizie/arpatnews/2010/allegati/086-Conser-rapp-ambsoc.pdf

Costa, I. and Ferrão, P. (2010). A case study of industrial symbiosis development using a middle-out approach. *Journal of Cleaner Production*, 18: 984-992.

Desrochers, P. (2002). Regional development and inter-industry recycling linkages: some historical perspectives. *Entrepreneurship & Regional Development*, 14(1):49-65. DOI:10.1080/08985620110096627

Ellen MacArthur Foundation (2013). *Towards the circular economy: Economic and business rationale for an accelerated transition*. Volume 1.

Engie (n.d.). Kalundborg’s eco-industrial park transformed waste into savings. Case study. https://www.engieimpact.com/insights/eco-industrial-park-case-study-kalundborg

European Commission (2020). *A new circular economy action plan for a cleaner and more competitive Europe.* Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels: European Commission.

European Environment Agency (n.d.). *EEA Glossary: eco-industrial park*. Available at: https://www.eea.europa.eu/help/glossary/eea-glossary/eco-industrial-park (accessed on 2.2.23).

FOEN and ECO-INNOVERA (2014*). International survey on eco-innovation parks: Learning from experiences on the spatial dimension of eco-innovation*. Swiss Federal Office for the Environment (FOEN) and ERA-NET ECO-INNOVERA. Bern: Switzerland.

GGGI (2017). *Greening industrial parks – A case study on South Korea’s Eco-industrial Park Program*. Seoul: Global Green Growth Institute (GGGI).

Krom, P., Piscicelli, L., and K. Frenken (2022). Digital platforms for industrial symbiosis. *Journal of Innovation Economics & Management*, 3(39): 215-240.

Lowe, E.A., Mora, S.R., and Holmes, D.B. (1996). *Fieldbook for the development of eco-industrial parks. Final report*. Prepared for the US EPA. Oakland, CA: Indigo Development.

Mazzoni, F. (2020). Circular economy and eco-innovation in Italian industrial clusters. Best practices from Prato textile cluster. *Insights into Regional Development,* 2 (3), pg. 661-676.

Morrales, M. E. and Diemer, A. (2019). Industrial symbiosis dynamics, a strategy to accomplish complex analysis: The Dunkirk case study. *Sustainability*, 11(1971). DOI:10.3390/su11071971.

Park, H-S. (2013). *Eco-industrial Park Initiative in Korea.* Technician session Eco Industrial Park. Green Industry Conference 2013.

Park, J.M., Park, J.Y, and Park, H-S. (2016). A review of the National Eco-Industrial Park Development Program in Korea: Progress and achievements in the first phase, 2005-2010. *Journal of Cleaner Production*, 1(14): 33-44.

Perrucci, D.V., Aktas, C.B, Sorentino, J., Akanbi, H., and Curabba, J. (2022). A review of international eco-industrial parks for implementation success in the United States. *City and Environment Interactions*, Volume 16, December, 100086.

Puig. (2019). Comparative study of industrial symbiosis in Italy and Spain. Universitat Politecnica de Catalunya Bacelona Tech.

Syndicat Mixte de la Plaine de l'Ain (2011). Plaine Parc Industriel de l'Ain: Natural ambition. Accessible at: https://www.plainedelain.fr/decouvrir/

Susur, E., Martin-Carrillo, D., Hidalgo, A., Chiaroni, D. (2019). Unfolding eco-industrial parks through niche experimentation: Insights from three Italian cases. *Journal of Cleaner Production.* Volume 239, 118069.

Valladolid Calderon, C.E. (2021). *Creating synergies in eco-industrial parks in the Netherlands: A refined framework through a cross-case analysis*. Master Thesis. Delft University of Technology.

Valentino, A., Caroli, M., Cavallo, M. (2015). Eco-industrial parks: A green and place marketing approach. Luiss University Press, Roma, Italy.

Van Beers, D., Corder, G., Bossilkov, A., and van Berkel, R. (2007). Industrial symbiosis in the Australian minerals industry: The case of Kwinana and Gladstone. *Journal of Industrial Ecology*. Vol. 11.

UNIDO (2017). *Implementation handbook for eco-industrial parks*. Vienna: United Nations Organisation for Industrial Development (UNIDO).

UNIDO (2019). *Eco-industrial parks: Achievements and key insights from the global RECP programme 2021-2018*. Vienna: United Nations Organization for Industrial Development (UNIDO).

World Bank (2018). *Eco-industrial parks emerge as an effective approach to sustainable growth*. Washington DC: World Bank. Accessible at: https://www.worldbank.org/en/news/feature/2018/01/23/eco-industrial-parks-emerge-as-an-effective-approach-to-sustainable-growth

World Bank (2021). *Circular economy in industrial parks: Technologies for competitiveness*. Washington DC: World Bank.

World Bank, UNIDO, and GIZ (2021). *An international framework for eco-industrial parks*. Version

2.0. Washington DC: World Bank.