Factsheet

WATER PROOF

# Industrial-Urban Symbiosis

## Unlocking Potential to Create Value from Waste

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Most modern economies still largely follow a take-make-waste logic: resources are extracted, turned into products, and finally discarded. The circular economy offers a different vision. Here, waste is minimized, and the value of products, materials, and resources is preserved for as long as possible.

Industrial Symbiosis – and its urban extension Industrial-Urban Symbiosis – is a powerful approach to transfer this vision into practice. By connecting industries and urban areas it enables the efficient exchanges of energy, water, and materials. By-products are repurposed as valuable inputs rather than being discarded as waste. This keeps resources in the loop, reduces costs, and strengthens local resilience.

The European Union highlights Industrial Symbiosis activities as a key element of its Circular Economy Action Plan (2020), promoting it as a way to drive resource efficiency and transform industrial consumption and production towards greater circularity.[1]

## What is Industrial-Urban Symbiosis?

Symbiosis, a term borrowed from biology, refers to two or more species benefiting from living closely together. In the economic context, Industrial Symbiosis (IS) describes the use of one company's underutilized resources by another. These resources could include waste, by-products, and residues, but also energy, water, or even capacities and expertise. The goal of Industrial Symbiosis is to keep resources in a productive loop for longer, therefore integrating sustainability in the industry sector.[2]

As soon as urban material streams, such as municipal solid waste or wastewater from households, are integrated as feedstock, one refers to this as Industrial-Urban Symbiosis (I-US). Therefore, I-US relies on collaboration between businesses and urban waste management companies to share and exchange their resources to save money and minimize waste.[3] At its heart, I-US relies on having a network of localized and trusted relationships, that are professionalized – a bit like asking your neighbor to borrow a screwdriver, except on an industrial scale. However, for this innovative and systemic approach to thrive, a collaborative culture needs to be established and fostered: Identifying potential synergies can be difficult, and it is even more challenging to transfer these synergies into a working relationship between companies. Many barriers can stand in the way: costs, logistics, and consistency, but also, perhaps most relevant, a lack of trust and innovative strategies.

I-US collaborations can be created by rather spontaneous cooperation by companies motivated to cut costs and improve efficiency (bottom-up model) or be initiated and facilitated in a top-down model by governmental or municipal actors. Empirical experiences confirm that both approaches can be successful. They also show that as more actors join a symbiotic exchange and the network becomes more complex, the role of a dedicated organization that facilitates cooperation between the companies becomes increasingly important.

Often, I-US collaborations are facilitated by local clusters, e.g., in eco-industrial parks, where the collaborating companies are from different sectors, but from the same geographical area. Because the use of synergies is especially practical and economically viable over short distances, proximity is an important factor to support I-US.[4]

## What are Advantages of I-US?

Industrial-Urban Symbiosis offers a wide range of advantages for many stakeholders, ranging from stronger business revenues to healthier cities and regions, creating benefits that extend across both economies and ecosystems. Businesses, industrial sites, local authorities, and municipal actors alike can draw value from the opportunities Industrial-Urban Symbiosis provides.[5]

### Economic

For the companies involved in symbiotic cooperation, economic value is created by turning by-products into tradable resources, lowering costs for raw materials and offering resilience against volatile resource prices, reducing waste management expenses and opening new market opportunities. It is also a central element of the circular economy, supporting the transition from unsustainable production models to long-term profitable and sustainable manufacturing practices.

### Environmental

Transfer and sharing of resources between industrial and urban stake-holders reduces the need for the extraction of raw materials, increases recycling and keeps resources in the loop, lowering waste generation. This has major environmental impacts limiting land use, preventing water shortages and reducing greenhouse gas emissions. As the industrial sector accounts for 30% of global greenhouse gas emissions, IS helps reduce this impact and contributes to a greener future.

### Social

Implementing circular industrial systems helps their surrounding regions and cities to benefit from healthier ecosystems, with less pressure on local resources. It strengthens regional economies and increases employment opportunities, setting an example for regionally anchored, sustainable production and value creation.

## Drivers and Barriers of I-US Potential

Overview of key drivers for the implementation of Industrial-Urban Symbiosis, barriers, and strategies to overcome these barriers:

### Drivers

- Concern for environmental issues and knowledge of I-US benefits
- Established cases of implemented I-US
- Existence of self-organised I-US networks
- Existence of facilitators
- Geographical proximity
- Diversity of industries

### Strategies to adress barriers

- Regulatory changes and political incentivization of waste use
- Implementation of facilitating entities
- Provision of training & information dissemination
- Kick-off funding opportunities
- Investments in research and development of technological innovations
- Use of digital tools and platforms for matching, communication and information sharing

### Barriers

- **Economic barriers**
  e.g. high processing and logistic costs, lack of funding to promote I-US, market immaturity
- **Management related barriers**
  e.g. lack of management and intercompany support, lack of trust, personal barriers
- **Cognitive and technological barriers**
  e.g. lack of awareness of I-US concept, lack of technology and infrastructure readiness, economic and technological infeasibility
- **Environmental & policy barriers**
  e.g. lack of legal requirements and political incentives for I-US, low waste disposal costs

**Unlock I-US potentials**

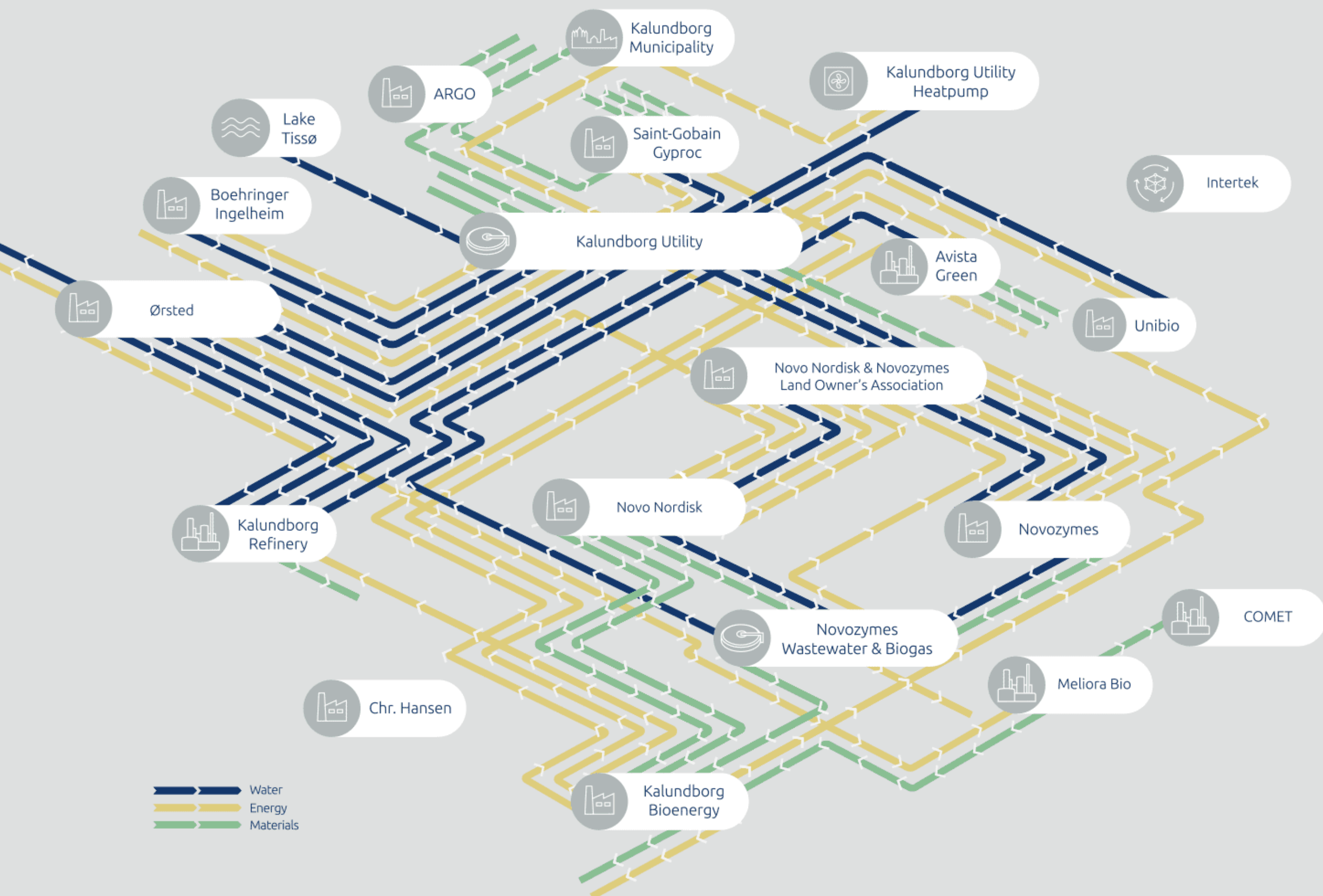
Own representation according to Hossain et al. (2024) and Neves et al. (2019).[6]

## Kalundborg Symbiosis as Flourishing I-US Example

Located in Denmark, Kalundborg Symbiosis is a vivid example of an Industrial-Urban Symbiosis network: What began in the 1970s as a collaborative agreement between a few local industrial companies to share water resources grew over time into a unique example of an organically-evolved and self-sustaining symbiosis network.

Currently, seventeen partners, consisting of public and private companies, are physically connected with more than 20 different streams. Their symbiotic network saves 4 million $m^3$ of groundwater by using surface water and allows for 62,000 tons of residual materials to be recycled each year.

Additionally, saving $CO_2$ emissions each year and reducing $CO_2$ emissions by 80% since 2015, the symbiosis has benefited the partners, nature, and the region for over a decade.[7]




Graphical representation of water, energy and resource flows in the Kalundborg Symbiosis network (source: https://www.symbiosis.dk/en/presse/)

# WaterProof Technology and its I-US Potentials for Captured $CO_2$ and Formate-derived Chemicals

**Captured and electrochemically converted $CO_2$ serves as an alternative carbon feedstock for chemical applications**

The utilisation of captured $CO_2$ is a striking example of Industrial-Urban Symbiosis, where emissions from waste (water) become a valuable feedstock for new products:

In the WaterProof project, an electrochemical process converts $CO_2$ from waste incineration and wastewater treatment into formic acid. To increase sustainability and support the transformation to industrial electrification, the process can be powered by renewable energy.

The $CO_2$ derived formic acid can be directly used for sustainable tanning of fish leather and serves as an active ingredient for consumer cleaning goods. Furthermore, it can be chemically transformed into Acidic Deep Eutectic Solvents (ADES), which can be applied for the recovery of precious metals from waste incineration ash and wastewater sludge. Peroxides, which emerge as the by-products of electrochemical conversion, can additionally be used to purify the wastewater from pesticides, antibiotics, and pharmaceuticals, further closing the loop.

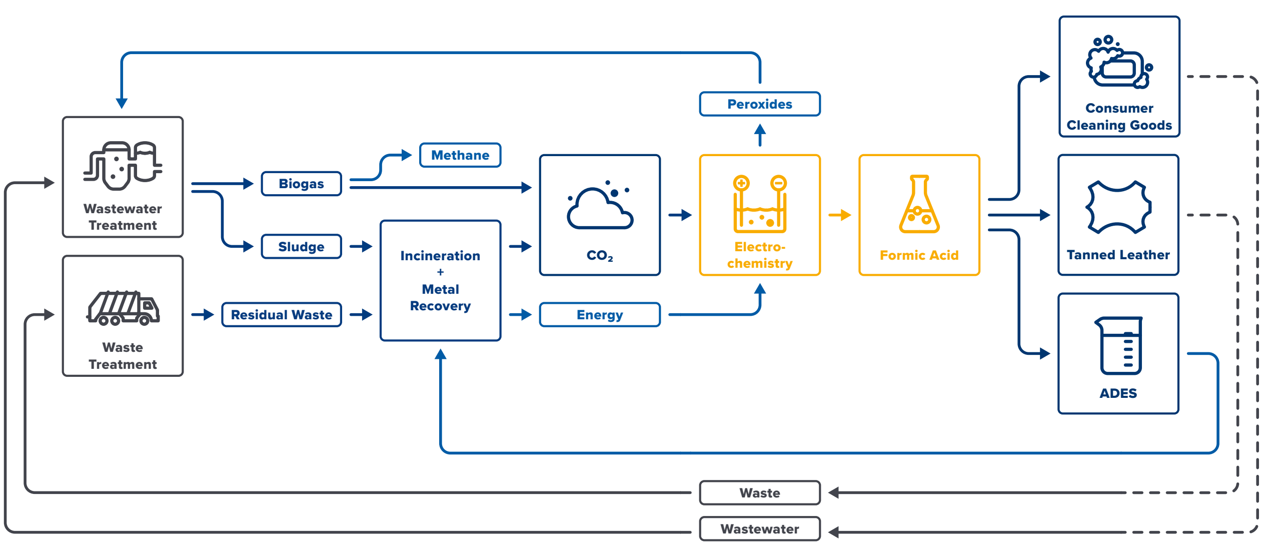
The WaterProof approach demonstrates impressively how technology transforms the urban waste (water) stream into valuable, alternative carbon-based industrial applications, fostering circular economy goals in the waste (water) and chemical industry sector.

**Supplying Sectors:**
- Urban waste (water) companies

**Receiving Sectors:**
- Chemical sector (cleaning product and tanning sector)
- Metal recovery/Urban mining sector
- Urban waste (water) companies

**Technologies:**
- $CO_2$-capture from waste and wastewater treatment
- WaterProof technology: Electrochemical conversion from $CO_2$ into formic acid
- Recovery of critical metals from waste ash from residual waste and seawage sludge with ADES

**Impacts:**
- Lowering $CO_2$ emissions from waste (water) treatment plants
- Moving away from fossil to renewable carbon feedstock
- Production of by-products (e.g., peroxides) and derivates (e.g., ADES)



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