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Techno-economic assessment of Industrial Symbiosis interactions based on Material Flow Cost Accounting methodology coupled with cost/benefit analysis

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CORALIS
Industrial Symbiosis in Energy Intensive Industries

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CIRCE is energy

30 YEARS OF R&D&i SERVICE TO COMPANIES, THE SOCIETY AND THE ENVIRONMENT

MISSION

To improve the competitiveness of **companies** by generating and transferring **technology** through market-oriented R&D&I and training activities in the field of sustainability and resource efficiency, energy networks and renewable energies.

VISION

- International **reference** in energy.
- Investment **multiplier** in R&D&I.
- Focus on **talent**.
- Generator of ideas and **solutions**. Innovative and competitive.

VALUES

- **Quality** and agility
- **Commitment** and responsability
- Passion for challenge and **innovation**
- **Transparency**
- Enthusiasm for **collaborative** work
- **Vocation** for economic, social and environmental sustainability

We are a technology centre funded in 1993, seeking to provide innovative solutions for a **SUSTAINABLE DEVELOPMENT.**

Our research centre consists of a highly qualified and multidisciplinary team, composed **by more than 282 professionals.**

We work towards improving the competitiveness of enterprises through **generation of technology transfer** by means of R+D activities and market-oriented training within the field of resource sustainability and effectiveness, energy grids and renewable energies.

CIRCE's purpose is to anticipate and transfer technological solutions for their sustainability and competitiveness.

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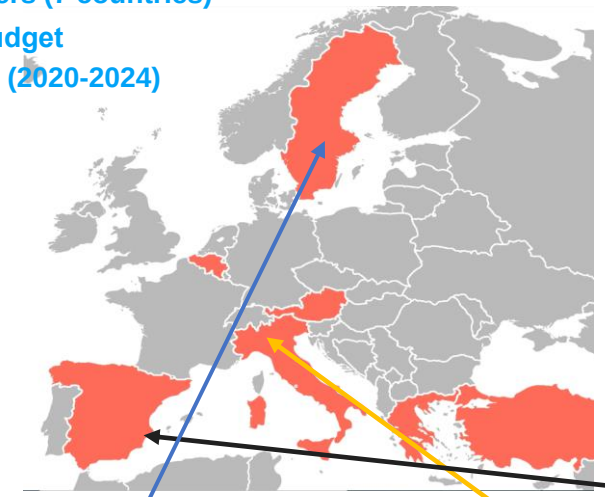
Industrial Symbiosis
in Energy Intensive Industries

28 Partners (7 countries)
20 M€ budget
4 Years (2020-2024)



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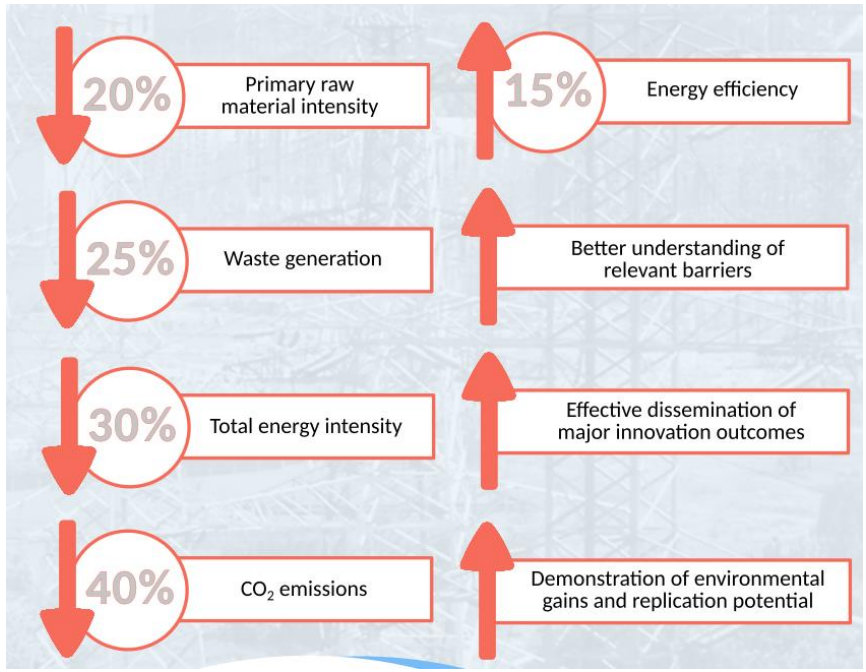
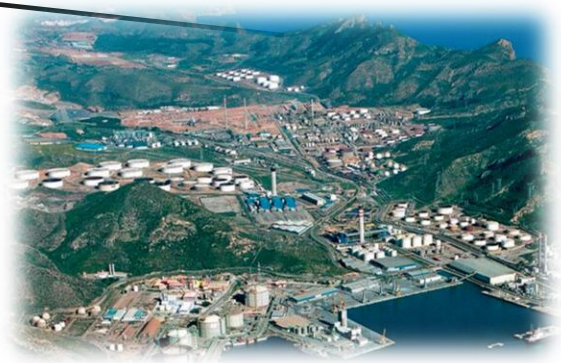


Frövi

Brescia



Escombreras

Basauri

Linz

Izmit

What is Industrial Symbiosis (IS)?

"Industrial symbiosis is **the use by one company or sector of underutilised resources** broadly defined (including waste, by-products, residues, energy, water, logistics, capacity, expertise, equipment and materials) **from another**, with the result of keeping resources in productive use for longer". CEN, 2018 (European Committee for Standardisation and European Committee for Electrotechnical Standardisation)

Challenges for techno-economic analysis in Industrial Symbiosis

TARGET	DECISION TOOLS	INDICATORS
Evaluation of technological feasibility and economic opportunity for IS	**Cost-Benefit Analysis** (CAPEX / OPEX-based) **Material Flow Cost Accounting** (costs of losses-based)	CAPEX, OPEX, NPV, ROI, PBP

- Challenges include technological investments for waste upgrading, conflicting interests of companies, and site-specific regulations.
- Traditional cost-benefit analysis (CBA) alone is insufficient for assessing the viability of IS solutions.
- Material Flow Cost Accounting (MFCA) is a complementary tool that quantifies material flows and hidden costs, aiding in evaluating IS opportunities.
- A hybrid methodology combining CBA and MFCA can provide guidelines for techno-economic assessments of IS scenarios, considering both financial and material aspects

Material Flow Cost Accounting (MFCA) methodology

MFCA can be conducted in different ways and its implementation is dependent on the specific context of its use.

Fundamental elements includes by the methodology:

- Quantity centers
- Selection of allocation method
- From material/energy balance to cost balance
- From one organization to interlinked systems

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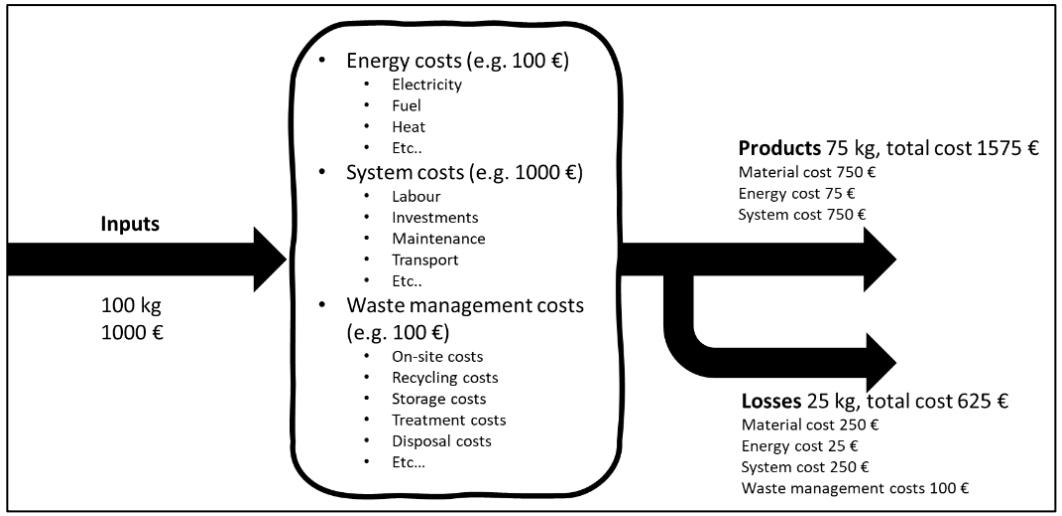

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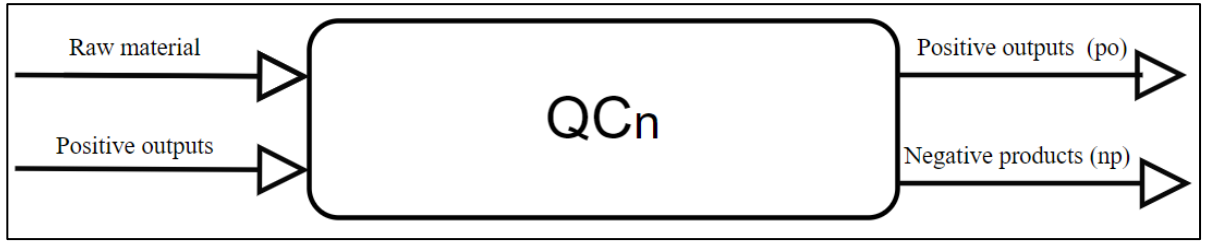

COST TYPES:

- ❑ material cost
- ❑ energy costs
- ❑ system related cost
- ❑ waste management cost

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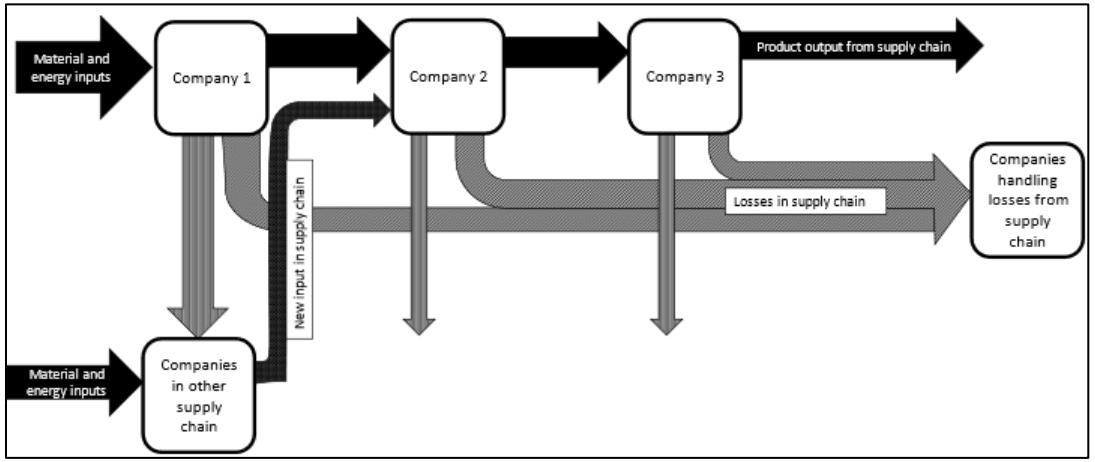

Material Flow Cost Accounting (MFCA) methodology

In this work, the aim is to **test the application of an MFCA** on **two different symbiosis systems** in order to understand when and how much value can be created in terms of economic assessments for the specific contexts of these different types of symbiosis networks.

- **A new IS opportunity:** a new IS process design in Frövi (Sweden) for the inter-sectorial re-use of CO2 and energy flows between a pulp-and-paper industry and a newly constructed greenhouse
- **IS-promoted process upgrade**: a new innovative production process in a fertilizers plant within the chemical pole of Escombreras in Spain using waste streams from neighbouring companies

Industrial Symbiosis activities @ Frövi

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Billerundkorsnäs

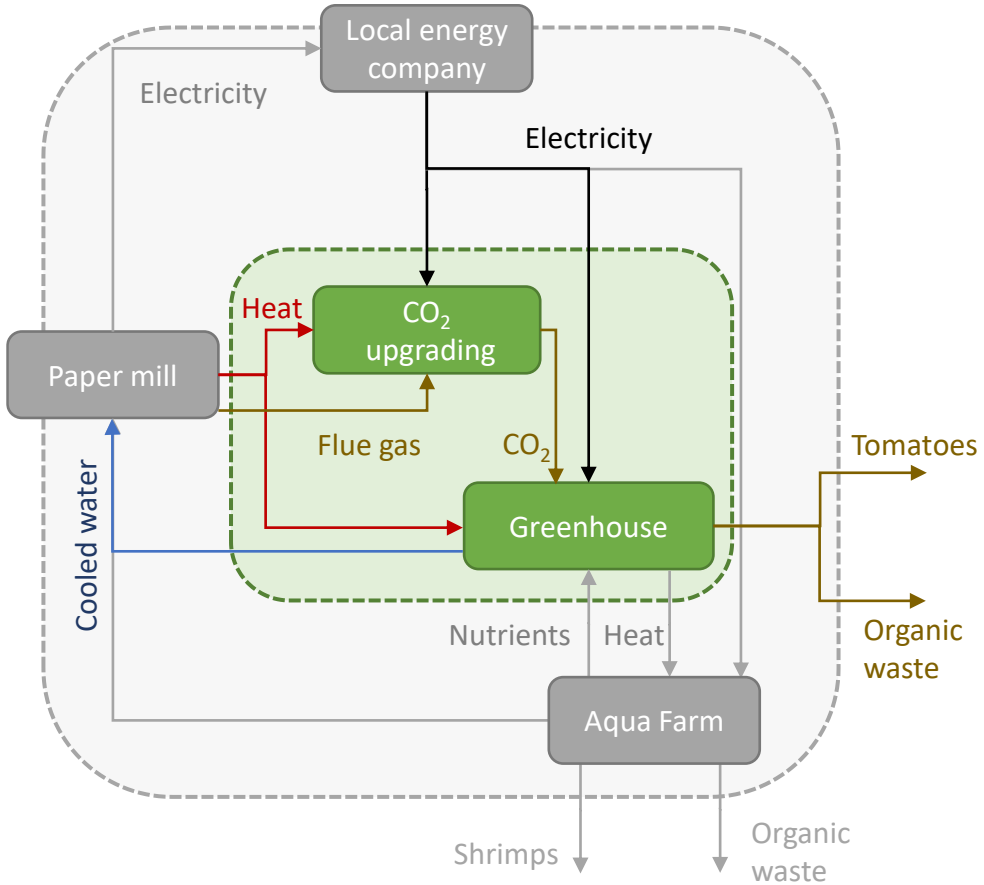
(Paper&Pulp company)

Linde energi

(Energy, heat and power provider)

Lindesberg

(Municipality, 12k inhabitants)

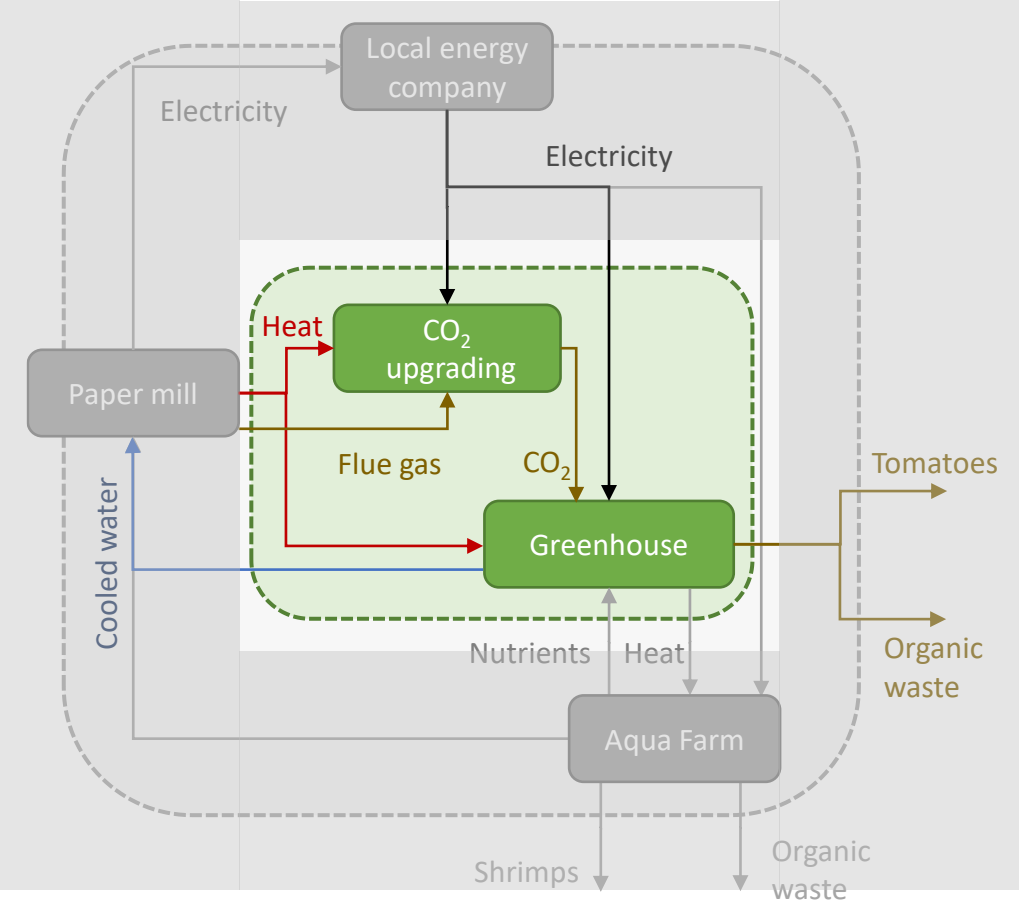


Tomatoes greenhouse

(To be implemented)

Tecno-economic assessment of Industrial Symbiosis Actions

Case-study #1
(business-driven)



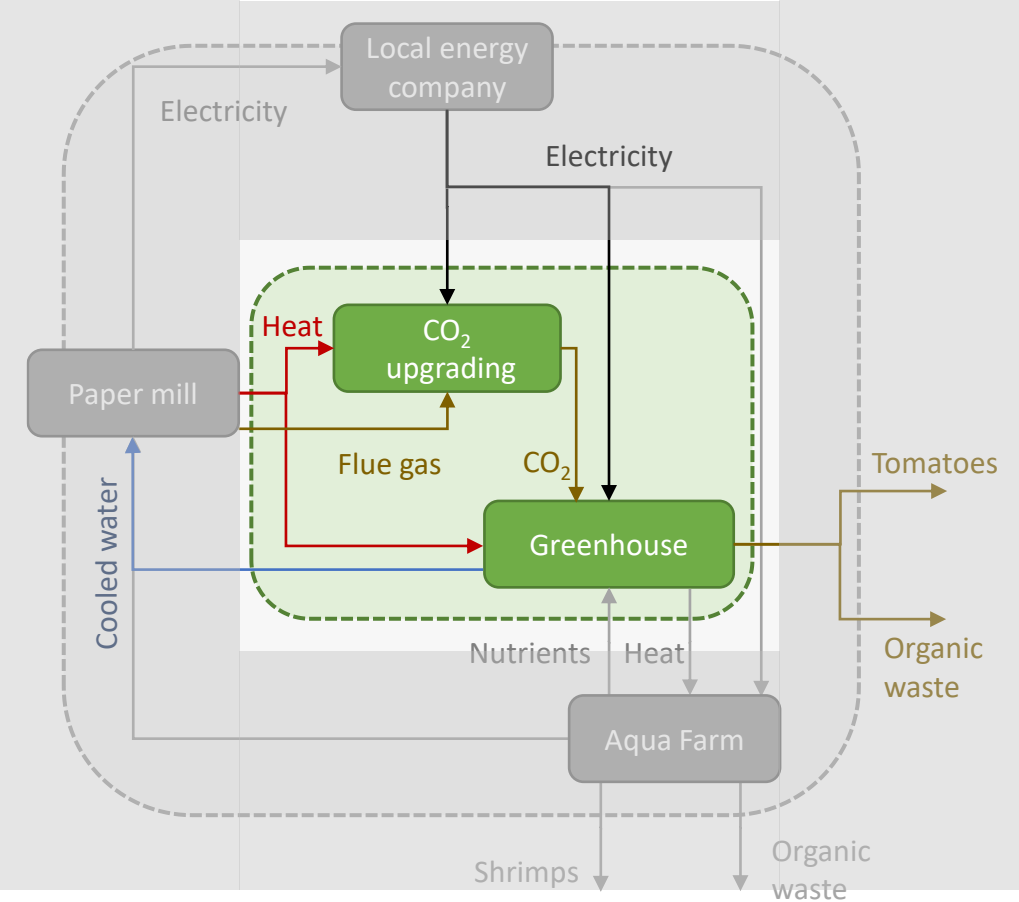
- The Swedish case study is mainly prospective since the site is under construction
- MFCA could be used as a **structured approach** to assess both **economic variables and resource efficiency** in an integrated analysis

Option	A	B	C	D
CO2 source	CCU (Carbon capture utilization)	Flue gas scrubbing	External supplier	Natural gas boiler

CO_2 from the neighboring paper mill in an IS collaboration

Tecno-economic assessment of Industrial Symbiosis Actions

Case-study #1
(business-driven)



- Inputs used in the assessment
  - Historical data on temperature and flow of the residual heat
  - Composition of the flue gases
  - Local climate data
  - An algorithm to capture the growers general CO2 supply philosophy
- Economic inputs
  - Markets prices, except for flue gases and residual heat which were estimated using the cost-plus price setting method.

Tecno-economic assessment of Industrial Symbiosis Actions

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Method for calculating the costs for positive and negative outputs

Case-study #1
(business-driven)

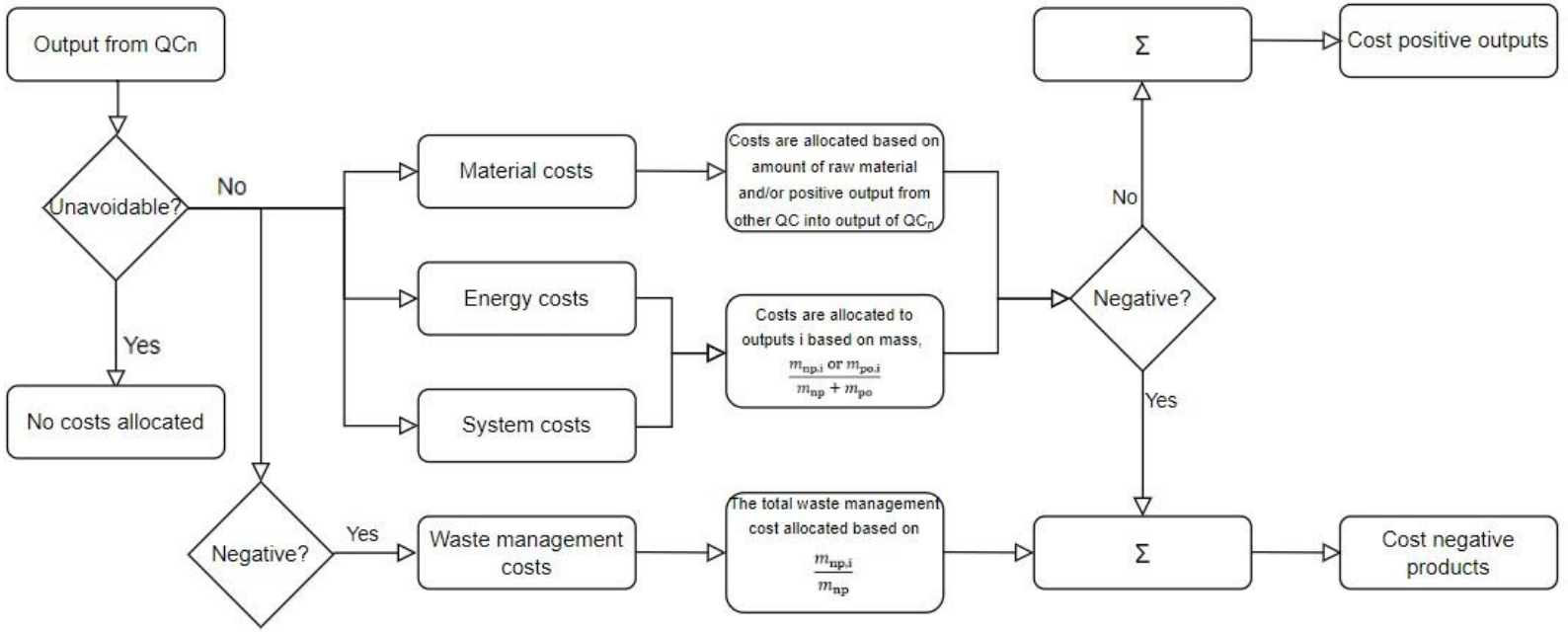
POSITIVE OUTPUTS

Products – Intermediate

NEGATIVE PRODUCTS

- Avoidable
- Unavoidable

Losses



Tecno-economic assessment of Industrial Symbiosis Actions

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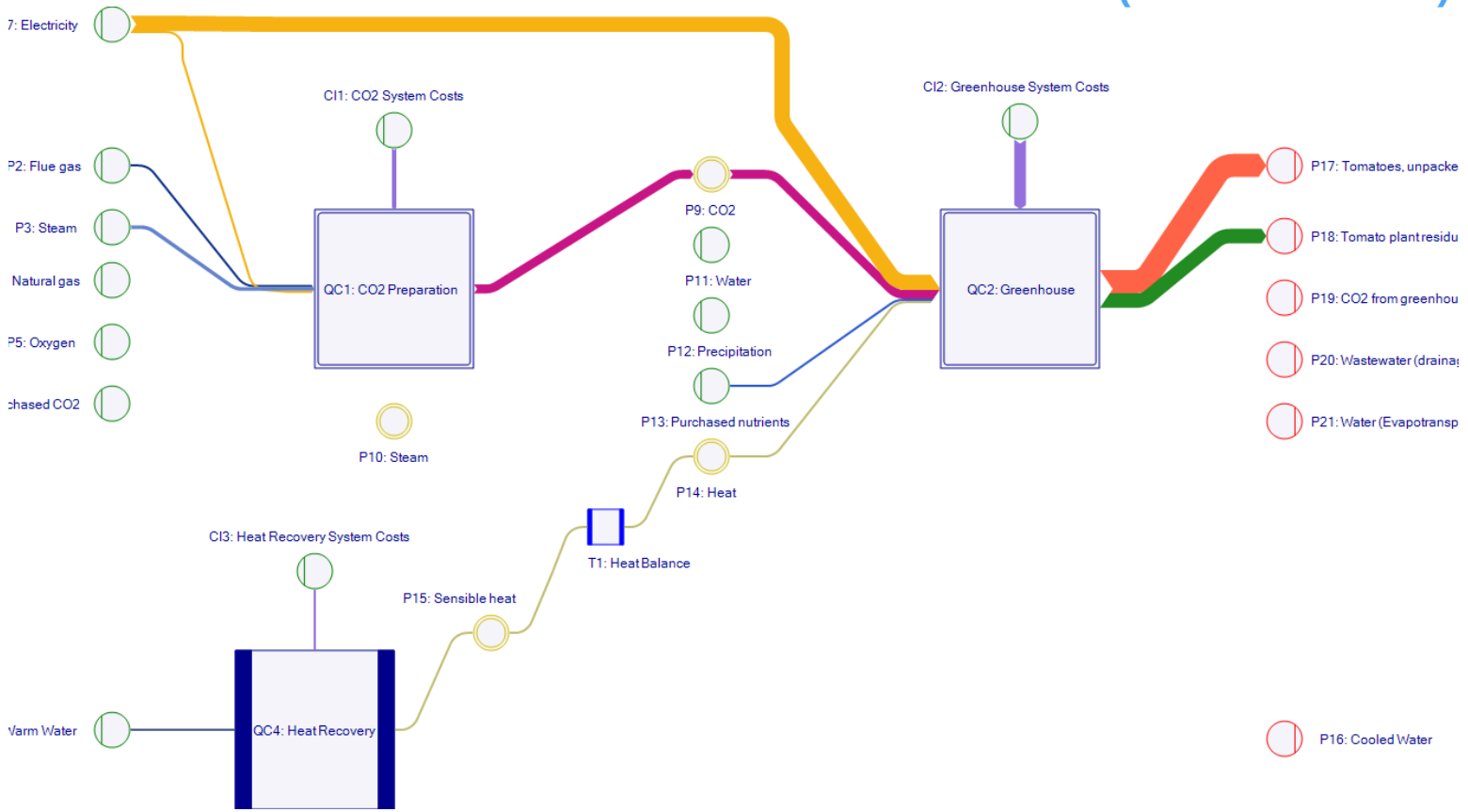
MFCA Methodology

Case-study #1
(business-driven)

- Quantity centers (QCn): CO_2 preparation, Greenhouse and Heat recovery
- Waste management costs for each QC were allocated between negative products.
- Sankey diagram with the result of the assessment



Tecno-economic assessment of Industrial Symbiosis Actions

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MFCA Methodology

- It was challenging to visually represent the differences between the resulting Sankey diagrams for the alternative system designs in a clear manner.
- Monetary efficiency: costs allocated to positive products/total costs

Option	A	B	C	D
CO2 source	CCU (Carbon capture utilization)	Flue gas scrubbing	External supplier	Natural gas boiler
Monetary efficiency	47 %	54 %	50 %	46 %

Case-study #1
(business-driven)

1.Motivating Improvement: Increasing motivation to reduce the gap between business management and industrial ecology.
2.MFCA Limitations: Static nature of MFCA method and the need for further study in alignment with technoeconomic assessment of IS solutions.
3.Clear Overview: How MFCA provides a comprehensive overview of waste generation and assigns costs to each flow.
4.Investment and Utilization: Recognizing the need for investment in upgrading waste flows and the constraints of external utilization.

Industrial Symbiosis activities @ Escombreras

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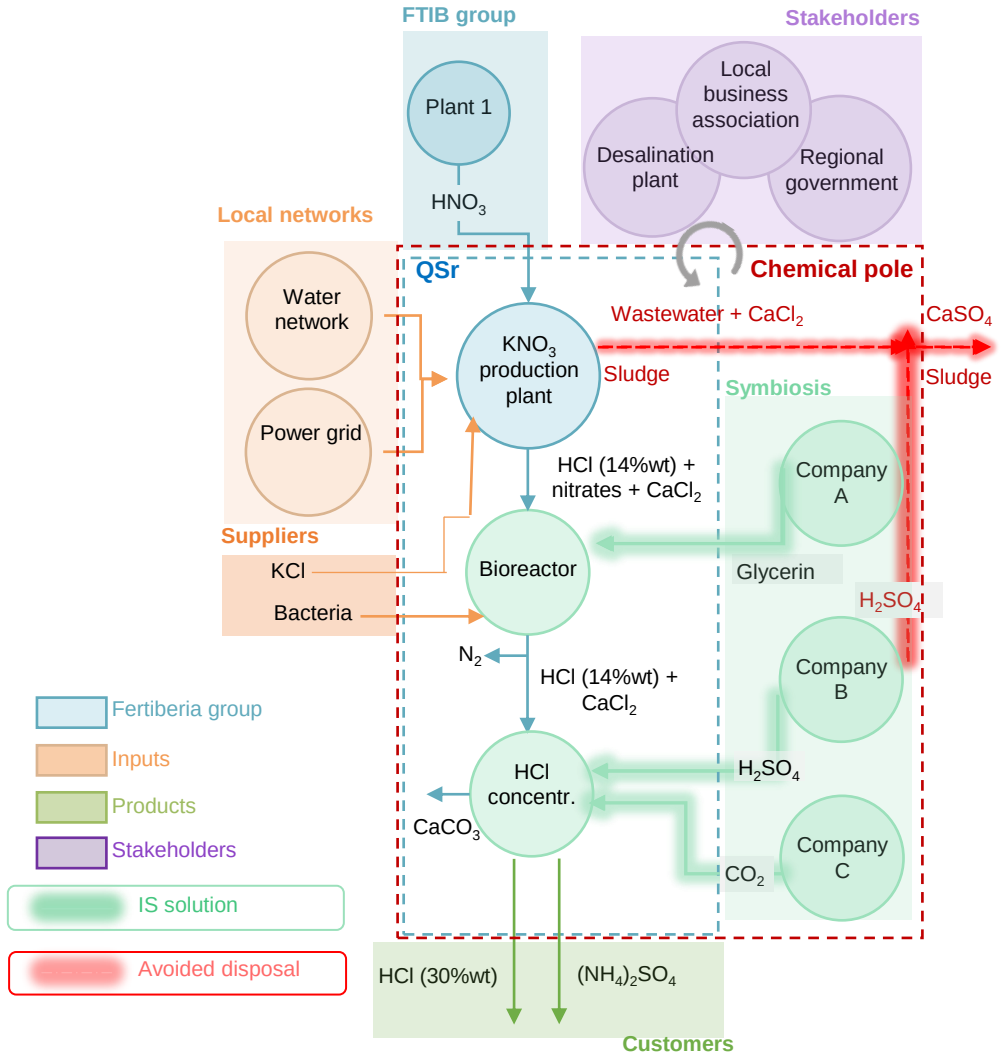
Case-study #2
(technology-driven)

Química del Estroncio (QSr)

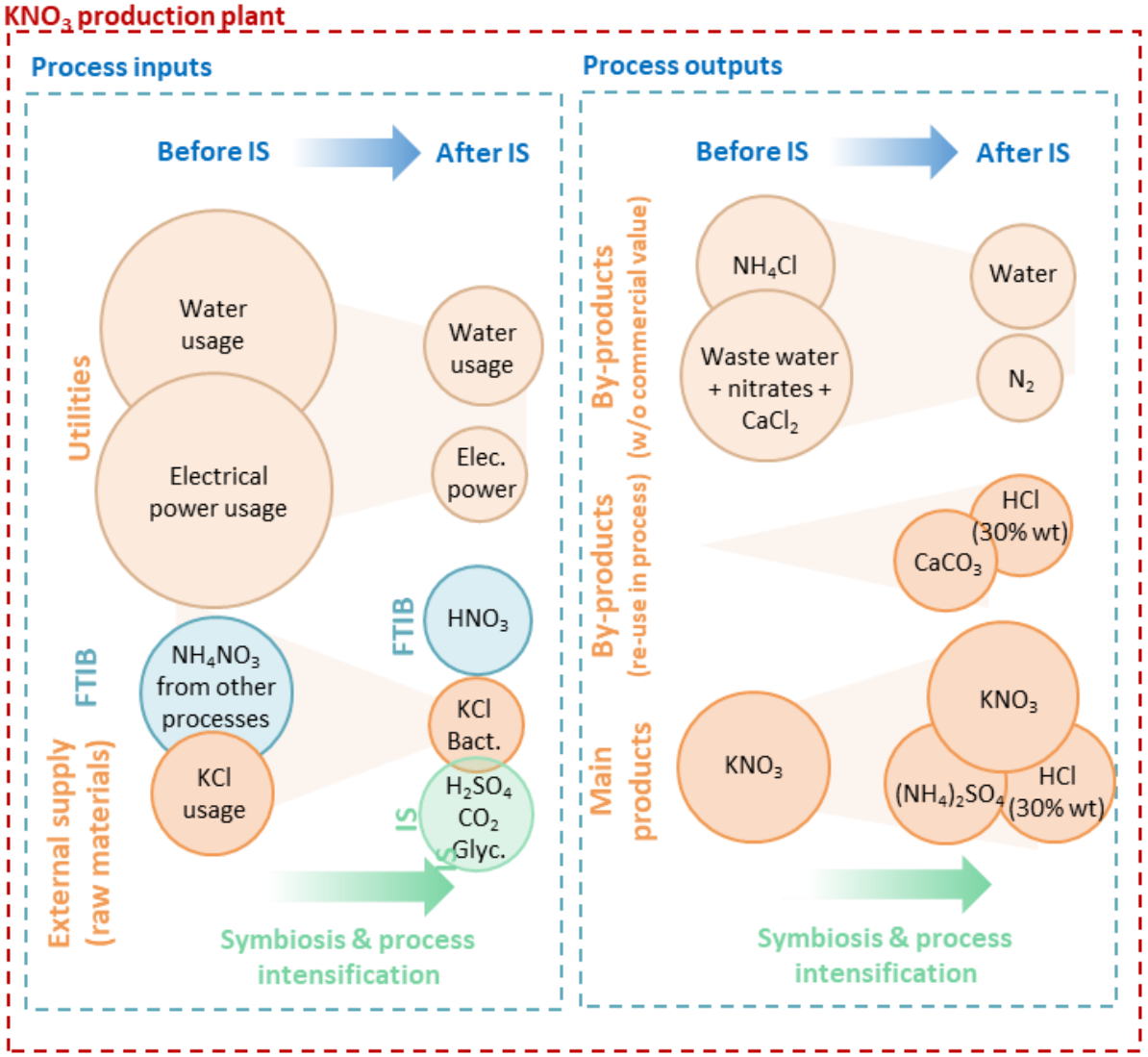
(Fertilizers company, Fertiberia Group)

QSr Química del Estroncio GrupoFertiberia

(Mineral oils producer)



Tecno-economic assessment of Industrial Symbiosis Actions



*The relative circle size for each item qualitatively indicates the change of its required / produced amount per unit of KNO_3 produced in the pre- and post-IS scenarios

DECISION TOOLS

Material Flow Cost Accounting

(costs of losses-based)

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Case-study #2
(technology-driven)

MFCA methodology implementation

DECISION TOOLS
Material Flow Cost Accounting
(costs of losses-based)

1. Definition of the baseline configurations
2. Establishment a block diagram
3. Definition of quantity canters (QC).
4. Matching of flows and units and streams characterization
5. Identification of waste flows
6. Transformation of material loss and energy inputs into monetary units
7. Characterization of the IS solution
8. MFCA results reporting
9. Calculation of CAPEX and OPEX of the involved processes in both current and IS solutions.
10. Establishment of guidelines for waste materials and energy exchange pricing

Tecno-economic assessment of Industrial Symbiosis Actions

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DECISION TOOLS

Material Flow Cost Accounting

(costs of losses-based)

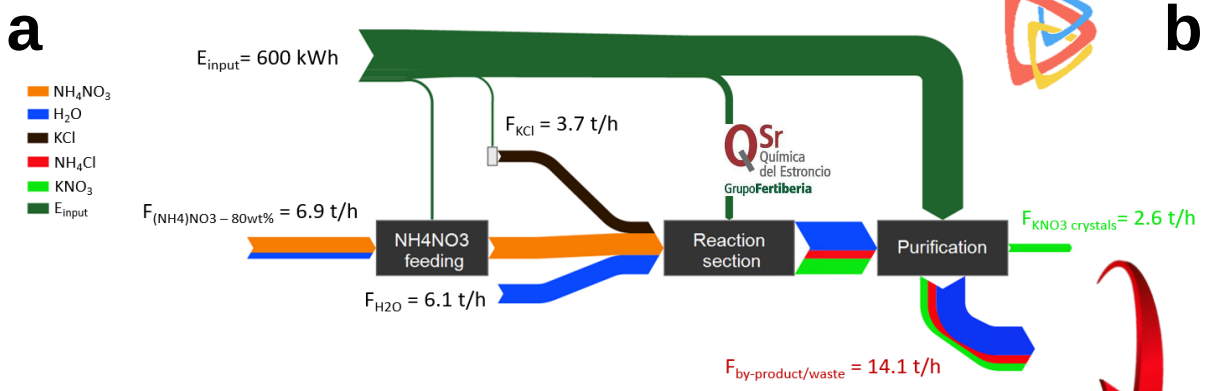
Case-study #2
(technology-driven)

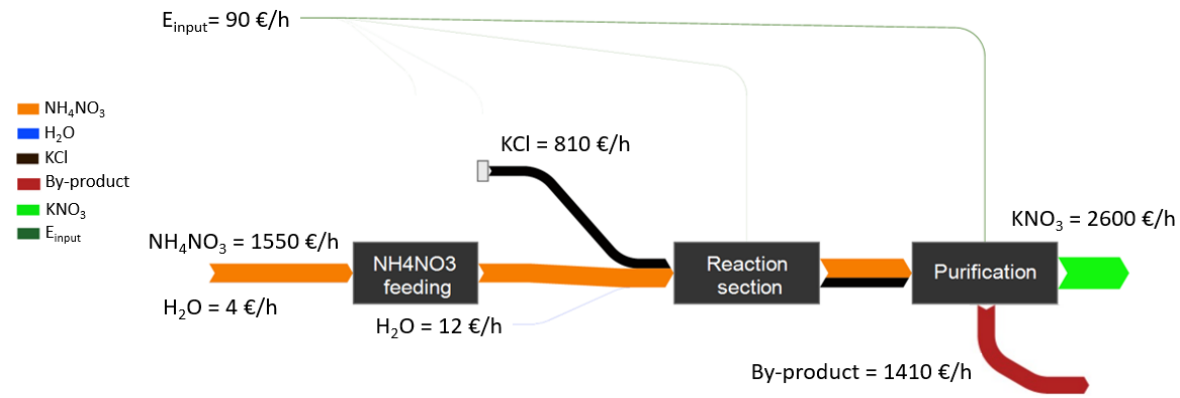
Sankey diagram for KNO3 production

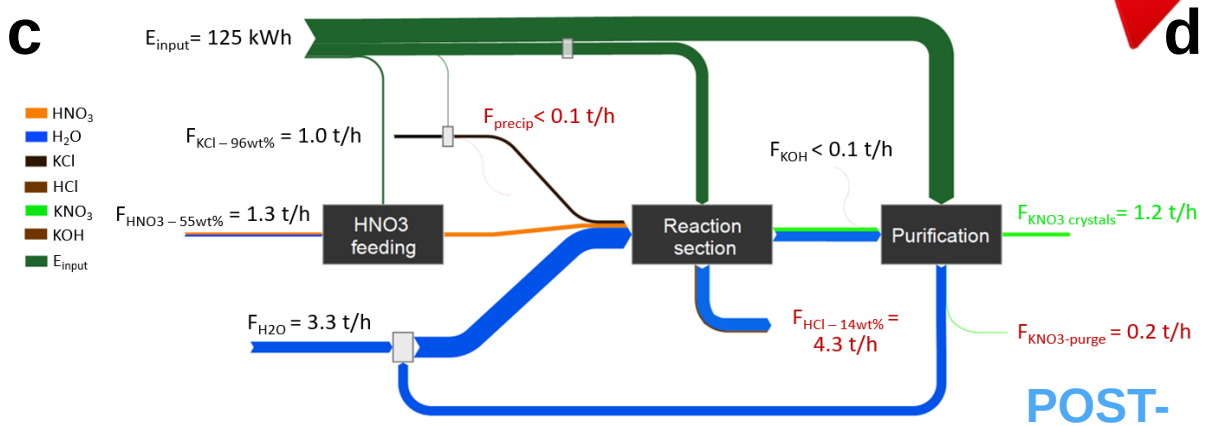
Energy and material flows

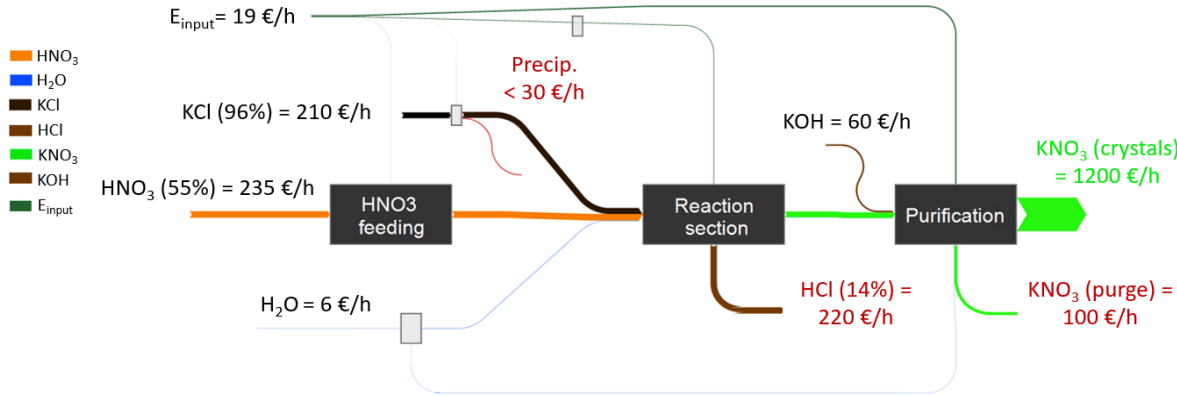
Cost flows

PRE-









POST-

Final remarks

- The complexity of IS alternatives and solutions requires the adaption and adequacy of traditional Techno-Economic Assessment (TEA) methodologies to assess each individual scenario
- MFCA is a valuable tool for assessing the true cost of **waste generation** and aiding decision-making in industrial symbiosis processes.
- MFCA primarily evaluates system performance and **helps identify opportunities** for financial and environmental benefits.
- The application of **MFCA with CBA allows for effective techno-economic assessment** in specific industrial symbiosis scenarios.
- Additional considerations, such as **CAPEX, OPEX, and market prices, are necessary** to establish comprehensive guidelines for **waste flow pricing** in industrial symbiosis.

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Thank you for your attention!

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