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

I. Julian¹,*; E. Wallin²; M. Vendt²; L. Ventura¹; F. Galindo³; S. Ascaso¹; R. Fornell²; M. Gomez-Perez¹,*

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

20% Primary raw material intensity
15% Energy efficiency
25% Waste generation
Better understanding of relevant barriers
30% Total energy intensity
Effective dissemination of major innovation outcomes
40% CO₂ emissions
Demonstration of environmental gains and replication potential

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

- 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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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

Billerundkorsnäs
(Paper&Pulp company)

Linde energi
(Energy, heat and power provider)

Lindesberg
(Municipality, 12k inhabitants)

Paper mill

Local energy company

CO₂ upgrading

Greenhouse

Electricity

Cooled water

Flue gas

CO₂

Nutrients

Heat

Aqua Farm

Tomatoes

Organic waste

Shrimps

Heat

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

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<thead>
<tr>
<th>Option</th>
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<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
<tr>
<td>CO2 source</td>
<td>CCU (Carbon capture utilization)</td>
<td>Flue gas scrubbing</td>
<td>External supplier</td>
<td>Natural gas boiler</td>
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CO2 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.
Method for calculating the costs for positive and negative outputs

**POSITIVE OUTPUTS**
- Products – Intermediate

**NEGATIVE PRODUCTS**
- Avoidable
- Unavoidable
- Losses
Tecno-economic assessment of Industrial Symbiosis Actions

**MFCA Methodology**

- Quantity centers (QCn): CO₂ 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

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

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<td>Monetary efficiency</td>
<td>47 %</td>
<td>54 %</td>
<td>50 %</td>
<td>46 %</td>
</tr>
</tbody>
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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

Case-study #2
(technology-driven)

Quimica del Estroncio (QSr)
(Fertilizers company, Fertiberia Group)

Bioethanol refinery

(Mineral oils producer)
Tecno-economic assessment of Industrial Symbiosis Actions

DECISION TOOLS

Material Flow Cost Accounting (costs of losses-based)

*The relative circle size for each item qualitatively indicates the change of its required / produced amount per unit of KNO₃ produced in the pre- and post-IS scenarios*
Tecno-economic assessment of Industrial Symbiosis Actions

Case-study #2
(technology-driven)

MFCA methodology implementation

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
Case-study #2
(technology-driven)

Sankey diagram for KNO3 production

Energy and material flows

PRE-

Cost flows

POST-

Decision Tools

Material Flow Cost Accounting
(costs of losses-based)
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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