ESTEP
European Steel Technology Platform

ESTEP Focus Groups
Smart Factory and
Circular Economy & Sustainability

FERALPI GROUP

SMS group

Digital-4-Environment

ESTEP Workshop

Overview, recent developments and future trends

Methodology for emission and waste accounting in an industrial symbiosis system

Daphne Mirabile, Loredana Di Sante, Filippo Cirilli - *RINA-CSM (IT)*

Sonia Ascaso Malo, Manuel Gomez Perez – *CIRCE (ES)*

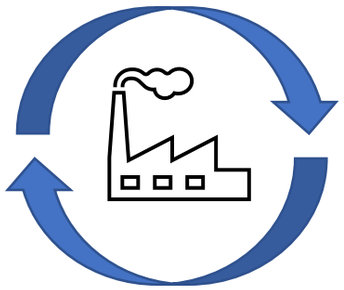
Annika Lowgren, Katarina Lorentzon, *RI.SE (SE)*

20th – 22nd February 2024

Industrial symbiosis

Industrial symbiosis engages separate industries in a **collective approach to achieve competitive advantages** and increase resource efficiencies, involving physical exchanges of materials, energy, and services.

HOW TO QUANTIFY THE ENVIRONMENTAL IMPACTS AND WHAT KIND OF METHODS CAN BE USED TO DEFINE THE INDUSTRIAL SYMBIOSIS BENEFITS

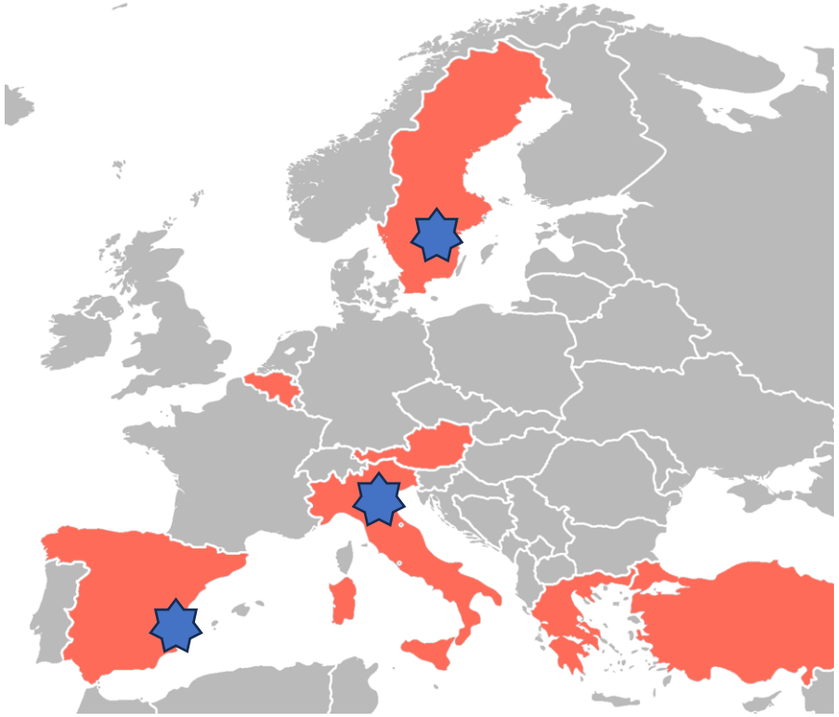


CORALIS project

Creation Of new value chain Relations through novel Approaches facilitating Long-term Industrial Symbiosis

CORALIS

The main objective of CORALIS is **to create pathways for the decarbonisation** of resource in energy intensive sector value chains through the implementation of viable **industrial symbiosis** approaches combining new business and management strategies with innovative technology-based enablers.
This whole approach will be **demonstrated in three real industrial areas** covering different sectors, geographical dimensions and resources, improving the knowledge basis and laying the foundations for exploiting the potential of Industrial Symbiosis in EU process industry.



29 partners from 7 countries

https://www.coralis-h2020.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958337.

State-of-art on IS effects

Studies concerning **quantification of economic, environmental, social benefits** for companies involved in an industrial symbiosis network **are rare**.

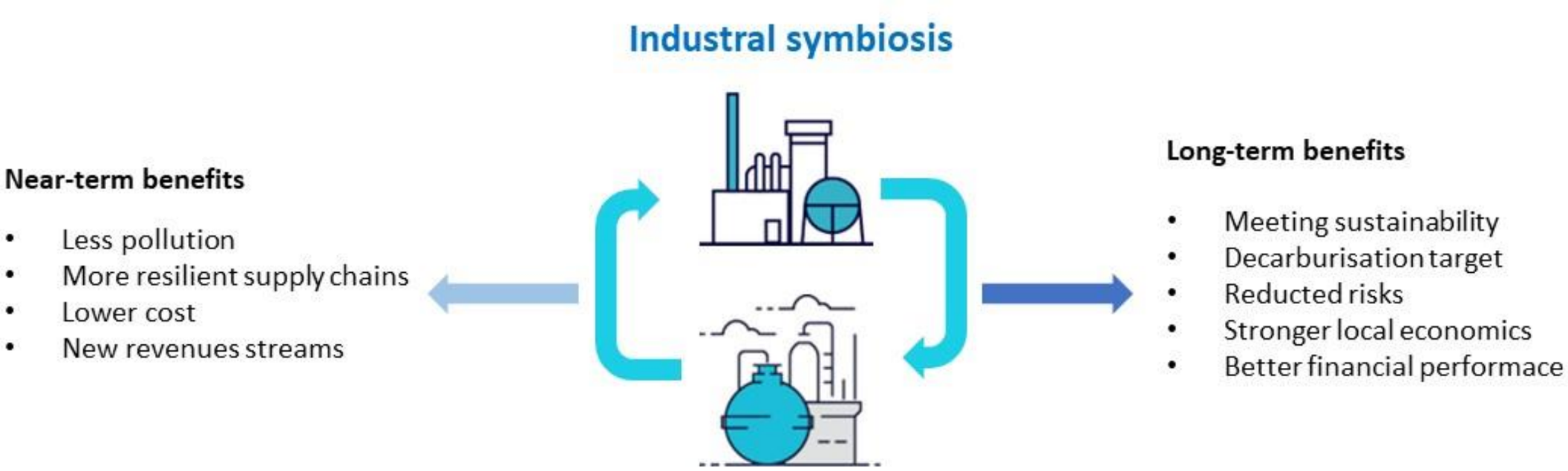
The available studies analyse the impacts of the industrial symbiosis network for a specific exchange or analyse the overall IS network respect a previous situation.

Since the main IS objective is to create advatages situations for all the involved companies, it is important to furnish suitable instruments to quantity the benefits. Rarely environmental evaluation (such as the life cycle assessment) are used.

Standard or guidelines related to the quantification of benefits or impact on industrial symbiosis network are **not available**.

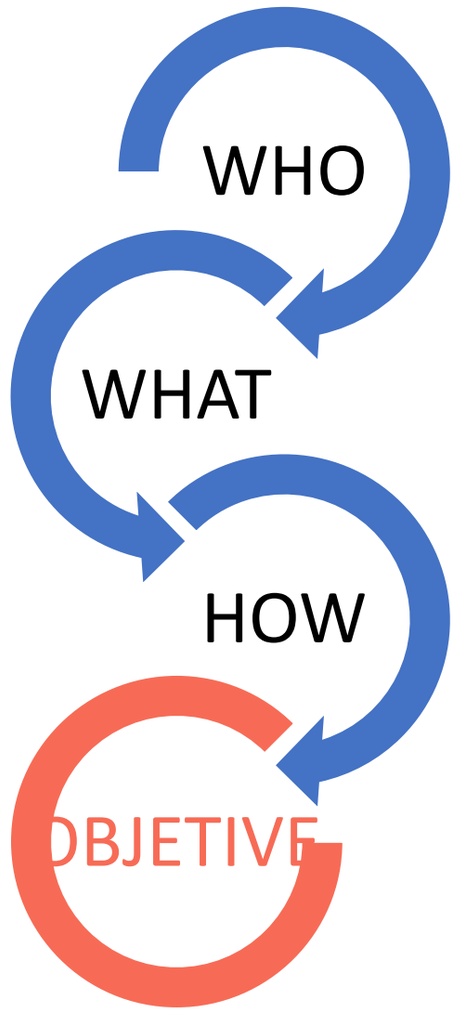
State-of-art on IS effects

Since the objective of the IS is to cooperate, to create together competitive advantages and to augment the overall efficiency of the resources (in such a manner that would not be reached by a single company), **how allocate between the IS companies the environmental profit is a theme often debated**. The environmental advantages are connected to the wastes and the emission reduction.



WHO-WHAT-HOW

To establish mechanisms to measure the impacts of the industrial symbiosis, it is important to define:



Participating entities
Symbiotic schemes

Exchange of wastes/by-product/energy
Sharing of the infrastructure and
Supply of services

Methodology to represent
+boundary conditions
+allocation of the CO2

WHO-Classification

The schemes of the industrial symbiosis have been classified considering both spatial and organisation factors.

The definition of the limits used for the evaluation of a IS project will influence the classification.
A single project can belong to more that one category.

Micro

- Individual firm level, where resources are exchanged within a facility, firm or organization and material exchanges can extend along the supply chain of a product under single ownership.

Meso

- Inter-firm level, which is associated with the exchange among firms collocated in a defined eco-industrial park with geographic proximity but can also be extended to other local partners.

Macro

- Regional or national level, when the symbiotic schemes can be implemented among local firms that are not collocated and bring the industries together to benefit based on input–output matching.

WHO-Classification

Micro Industrial Symbiosis

The industrial symbiosis that **occurs inside the boundaries of an individual firm level**, where resources are exchanged within a facility, firm or organization and material exchanges can extend along the supply chain of a product under single ownership. Some kinds of material exchange can occur primarily inside the boundaries of one organization rather than with a collection of outside parties.

Significant gains can be made within one organization by considering the entire life cycle of products, processes, and services, including upstream operations such as purchasing and product design. Rather than being an exchange between different companies, some material exchange can occur inside the boundaries of one organization (**large organisation**).

WHO-Classification

Meso Industrial Symbiosis

Inter-firm level, which is associated with the exchange among firms collocated at an industrial site but can also be extended to other local partners. In this approach, businesses and other organizations located in the equivalent of an **industrial park** can exchange energy, water, and materials and can go further to share information and services such as permits, logistics, and marketing. These exchanges primarily occur within the defined area of the industrial park, but it is possible to involve other partners “over the fence.” The areas can be new developments or retrofits of existing ones.

Macro Industrial Symbiosis

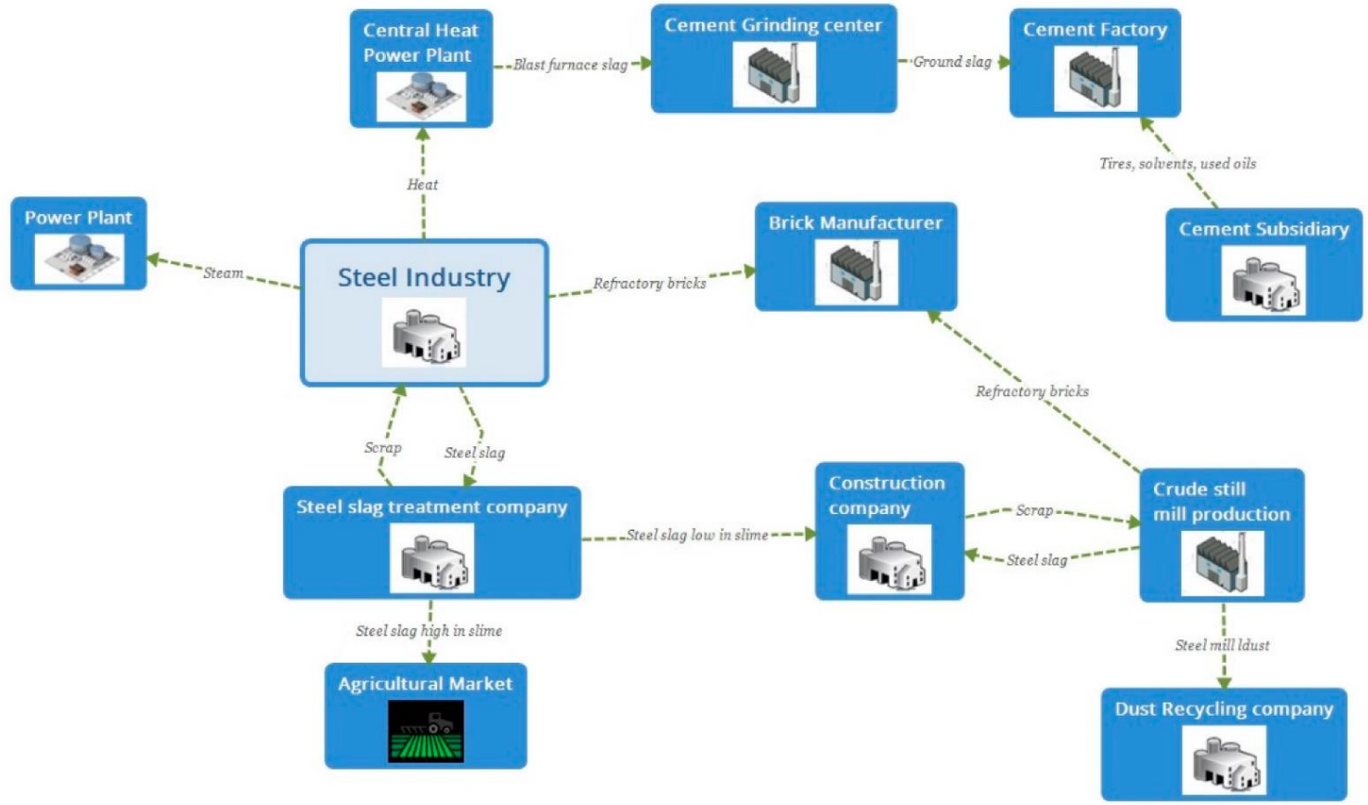
Regional level, when the symbiotic schemes can be implemented among local firms that are not collocated yet bring the industries together to collectively benefit based on input–output matching. This type of exchange takes as a starting point what is already in place within an area, linking together existing businesses, with the opportunity to also create new ones.

WHAT – Type of Exchange

Dunkirk is in an area highly industrialised that includes steelwork, chemical, petrochemical, energetic, food and logistic activities.

In 2001, the fundation **Écopal** has been created with the objective to promote circular economy projects in this area.

Dunkirk - Meso Industrial Symbiosis



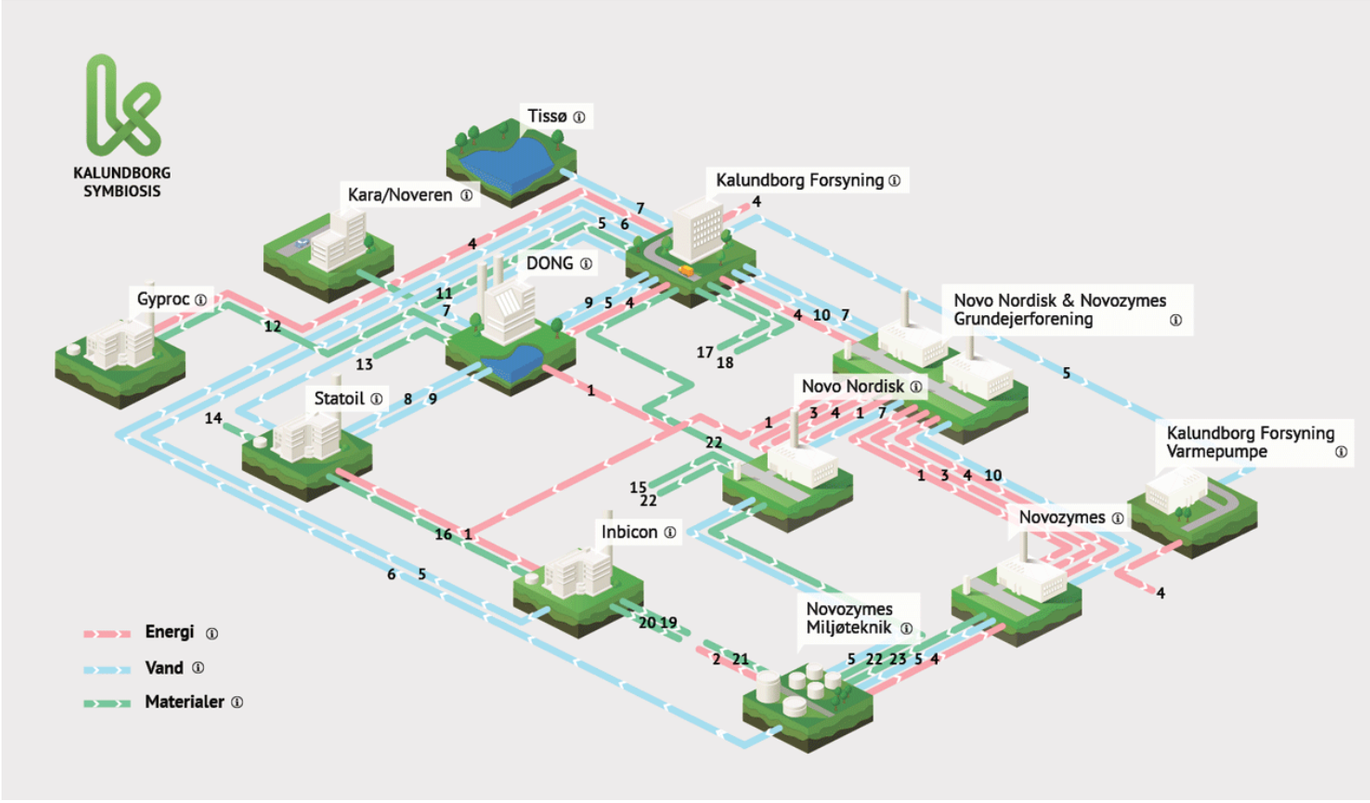
Main motivations, for the realisation of IS projects, are:

- the difficulties of the companies to efficiently manage wastes according to the law,
- the high landfilling costs
- the lack of suitable information for a fair management of the business

WHAT – Type of Exchange

Kalundborg *(Denmark)*: since 1972, Kalundborg Symbiosis is a *partnership between eighteen public and private companies*. The symbiosis saves 4 million m^3 of groundwater by using surface water. 80% of CO_2 emissions has been reduced since 2015 and the local energy supply is CO_2 neutral. 62,000 tonnes of residual materials are recycled.

Macro Industrial Symbiosis



Asnaes, a *thermoelecric central,* feeded with carbon (rated powder = 1.5 M Watts).

- An *oil refinery*, belonging to **Statoil**, where each year more that 5 milion tonnes of crude oil are transformed
- **Novo Nordisk**, danish company, world leader in the *production of enzymes*
- **Gyproc**, *gypsum producer*
- **Forsyning**, *heat and water supplier* for the city of Kalundborg.

HOW-Methodology

Three methodologies:

- ❖ **Material Flow Analysis**,
- ❖ Substance Flow Analysis,
- ❖ Enterprise Input-Output approach.

Material Flow Analysis (MFA) is an analytical **method to quantify flows and stocks of materials in a well-defined system**.

MFA is an important tool to study the bio-physical aspects of human activity on different spatial and temporal scales and doesn't require specific mathematical calculation. MFA is used :

1. to study material, substance, or product flows across different industrial sectors or within ecosystems
2. to **measure environmental (and economic) benefits derived from an IS network** in terms of reduction of not used raw materials, wastes and GHG emission,
3. to study the circular economy
4. to map energetic fluxes between companies or processes.

HOW-Methodology

Three methodologies:

- ❖ Material Flow Analysis,
- ❖ **Substance Flow Analysis**,
- ❖ Enterprise Input-Output approach.

Substance Flow Analysis (SFA) permits **to monitor fluxes of single substance**, such as chemical elements (atoms) or chemical compounds (molecules) in a specific system. This methodology is useful for analysing substances that are associated to **specific risks**, both environmetal and healty.

In the IS system, SFA is normally used to map the **carbon fluxes** between companies and the production processes in order to evaluate reduction of CO2 emissions.

HOW-Methodology

Three methodologies:

- ❖ Material Flow Analysis,
- ❖ Substance Flow Analysis,
- ❖ **Enterprise Input-Output approach**.

The **Enterprise Input-Output** (EIO) models can be used as accountability tools, with the objective **to map physical fluxes (materials, energy and water) or monetary** in the productive processes of a single company or between different companies. The EOI models can **analyse logistic fluxes** between different companies or can **support the coordination policy**.

The system represents different production processes that absorb input (materials and energy), transforms them in output and produces wastes. The generated output can be intermediate goods, that became input for other processes, or final products, that are sold in external markets. *Respect to the MFA approach, this method permits to model the input needs and the waste production in function of the output of each productive processes*.

HOW-Methodology

Three methodologies:

- ❖ Material Flow Analysis,
- ❖ Substance Flow Analysis,
- ❖ **Enterprise Input-Output approach**.

This methodology is useful to analyse **dynamic scenarios** characterised by market dynamics and abnormal events.

Different types of **indicators have been proposed**. At first, the **direct and indirect benefits** derived by the adoption of IS **can be** easily **recorded**. The direct benefits are created by the companies involved in the IS, whereas the indirect benefits are created by companies of the supplier chain or that exchange residues/wastes. As *environmental benefits*, the reduction of discarged wastes and the reduction of input quantities, used in the productive processes, are considered. As *economic benefits*, reduction of production costs and increase of revenues are considered.

HOW- CORALIS project

Accounting emissions

Most of the methodologies are based on:

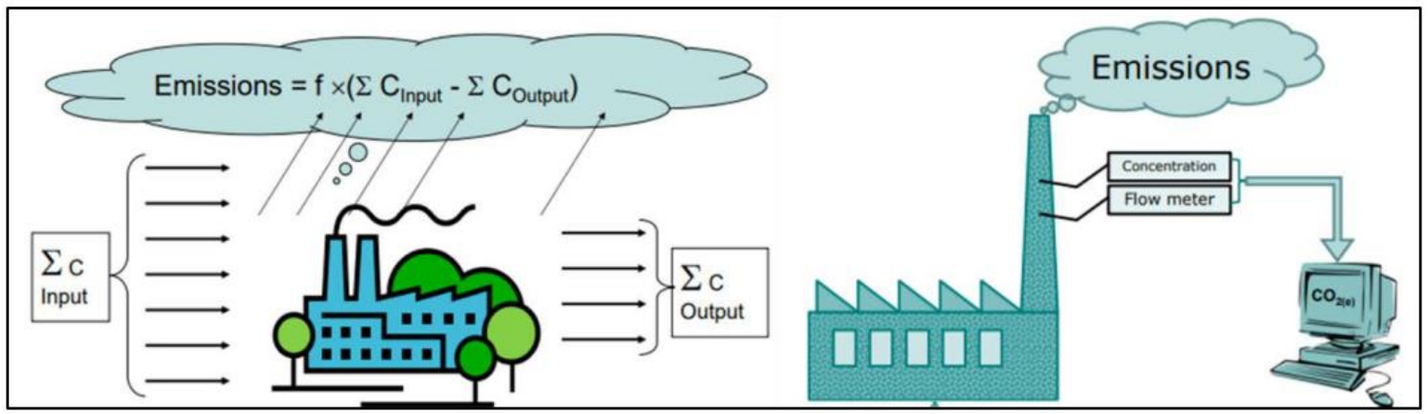
- Green House Gas (GHG) protocol
- System for the exchange of the EU Emissions Trading System (ETS), the principal instrument to contrast climate changes and reduce in an efficent economic way the GHG emissions

Impact allocation

The impact distributional symbiotic level is based on:

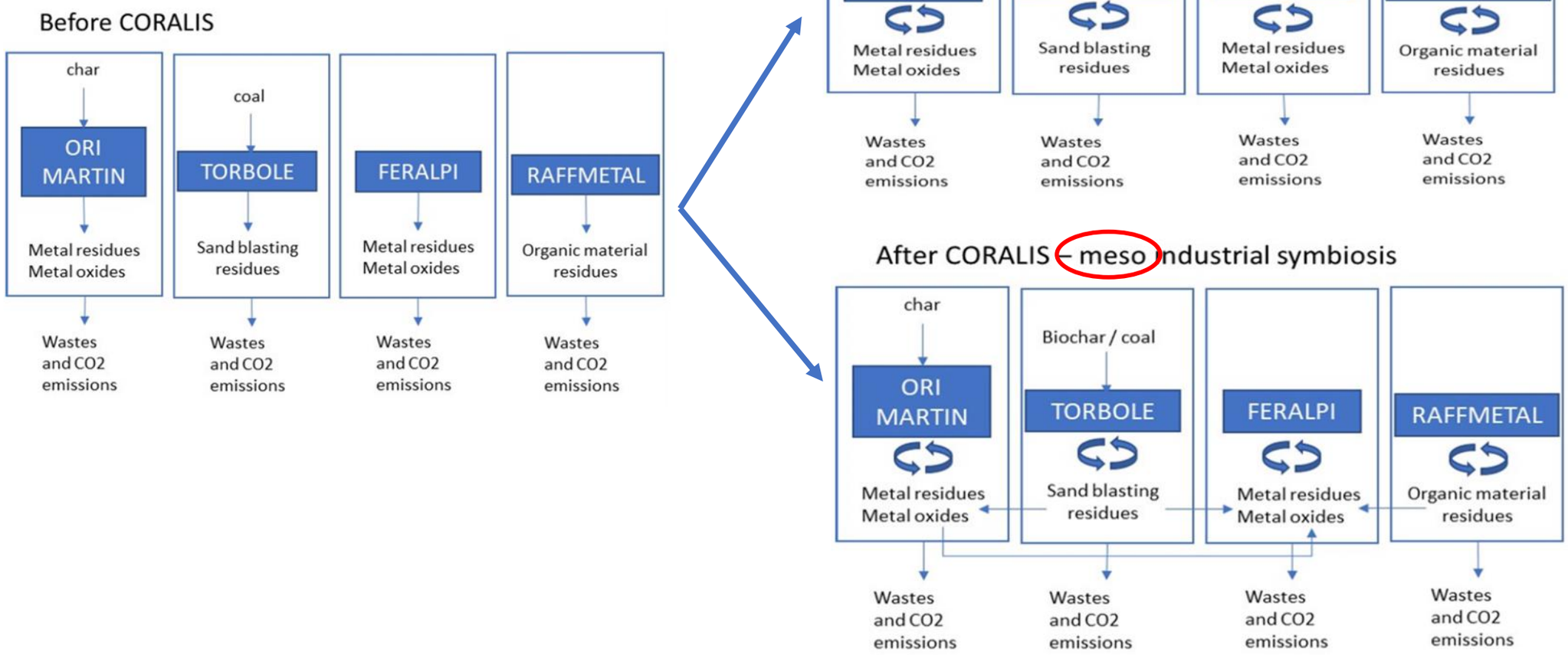
- Distributed credit system (50/50 method)
- Cut-off allocation method
- Avoidance of impact

All methods are based on LCA



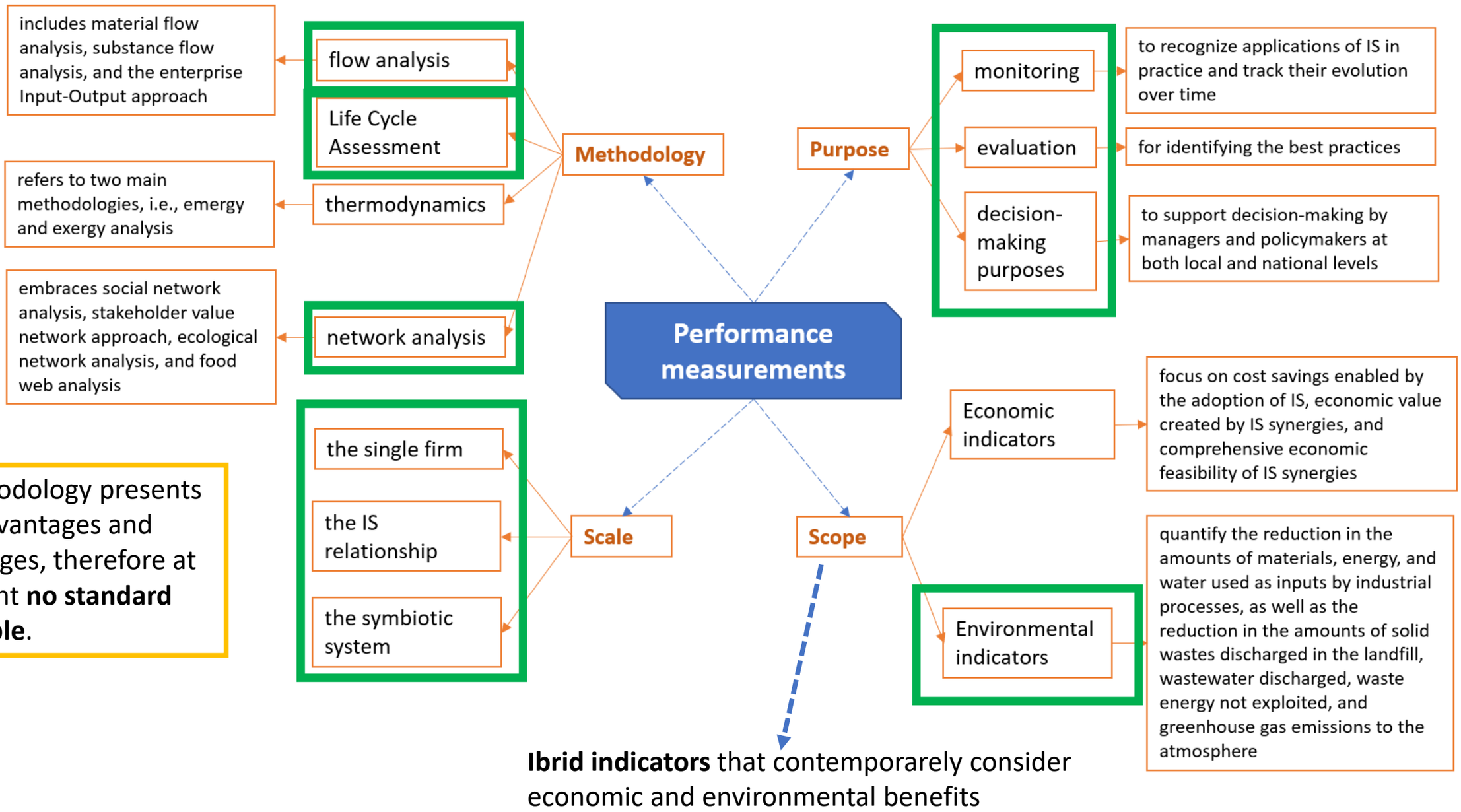
EU ETS accepted ways of measuring emissions left: calculation based, right: measured based

HOW-CORALIS project



HOW - Industrial symbiosis indicators

The **need to quantify and assess the performance of IS** has strongly emerged. Thus, a **high number of performance measurements** has been developed in the literature, differing in **scope, purpose, methodology and scale**.



Each methodology presents specific advantages and disadvantages, therefore at the moment **no standard are available**.

HOW - Industrial symbiosis indicators

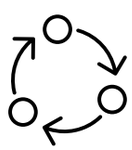
There are three principal **limits**:

1. **Indicators**, that **refer contemporarely to more than a scale, are barely diffused**. In fact, the indicators adopted at single company level do not furnish information at network level and vice versa.
2. The indicators **do not include a reference point** that would allow to understand if the IS network takes advantages from all the symbiotic exchanges.
3. The main part of the indicators furnish a **static view of the IS network** performances, with insufficient attention to the measurement of the functioning of the network during the time. This prospective is fundamental for the managers of the IS network and the policy-makers in the driving of the IS evolution, both from the strategic and operative points of view.

IS network can be considered **industrial ecosystems**, namely natural ecosystems in industrial context. A natural ecosystem consists of an *environment and living organisms* that interect by means of very complex relations and food chain. In the industrial ecosystems, the different companies are the «living organisms» and the environment refers to the area in which the companies are located and work.

HOW - Industrial symbiosis indicators

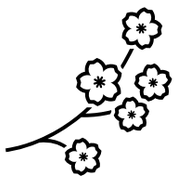
There are *four principles* of the natural ecosystems that can be applied to a IS network:



- **circularity** (roundput): lied to *the recycle of materials and energy* inside the system, so as to increase, as much as possible, the efficiency of the resources and to reduce the waste landfilling outside the system.

- **diversity**: the IS companies come from *different industrial sectors*: therefore, different types of input are needed and different types of wastes are produced. These companies collaborate between them due to waste management reasons.

- **localisation**: the *exploitation of local resources* inside the system, so as to reduce quantities of the input required from the outside.



- **gradual changement**: the system can change during the time, in terms of structure and models. *The IS networks are not static but evolve according to multiple logics*. Being the commercial environment a dynamic system, type and quantities of materials, energy and management costs can fluctuate during the time. As a consequence, news symbiotic opportunities can appear or the already existing can became more convenient.

Conclusions

The development of a **methodology for emission and wastes accounting** in an IS system is the preliminary phase of a complex circular pathway oriented to greatly reduce environmental impact of a production process connected directly or indirectly to other industrial processes.

The definition of a methodology, and consequently references, will allow IS industrial partners to have a **certification, valid at European level** at least, that will confirm all the effort made to have a production “greener”.

One of the possibility is to consider the industrial symbiosis as an «**industrial ecosystem**».