# CORALIS Project and Industrial Symbiosis in the Aluminium Industry

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CORALIS
Industrial Symbiosis
in Energy Intensive Industries

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

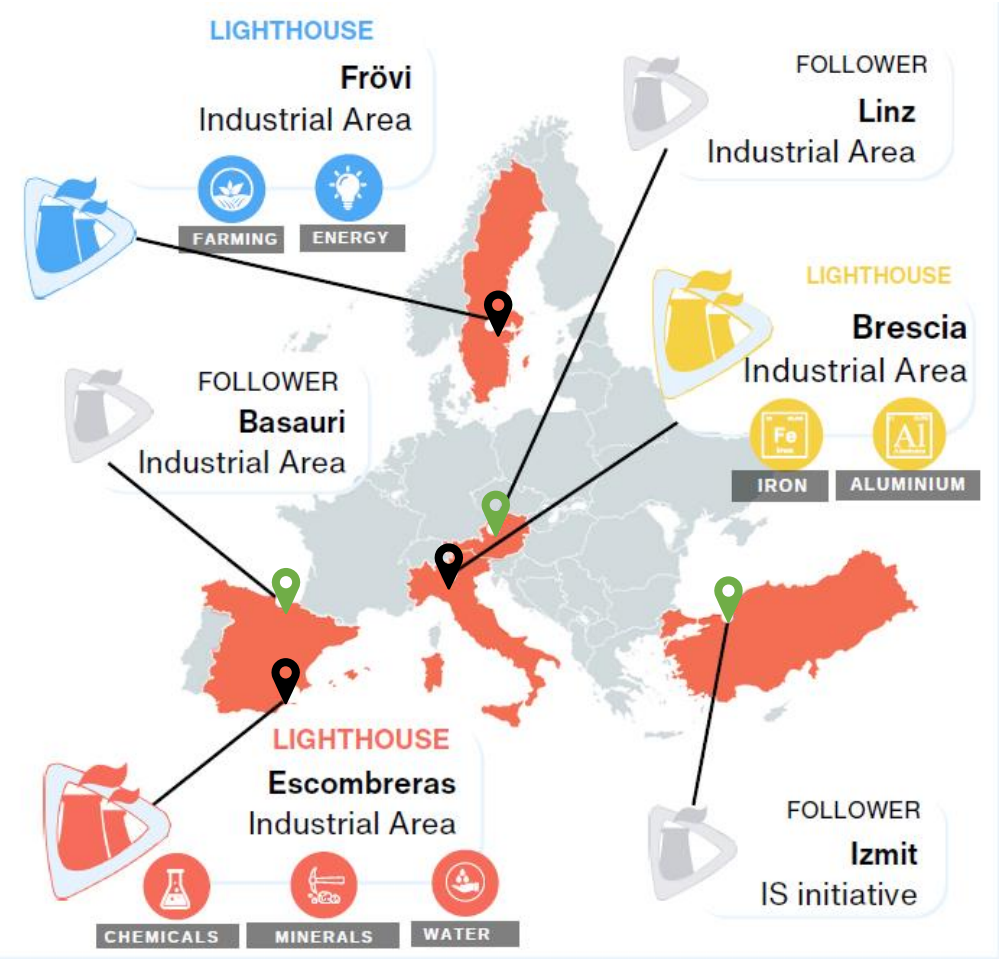
# CORALIS PROJECT

CORALIS has been designed as a demonstration project for the generation of real experiences on the deployment of Industrial Symbiosis (IS) solutions and the overcoming of the barriers faced by these initiatives.

- Total budget: 22.72 M €
- EU contribution: 17.99 M €
- Consortium: 28 (from 7 countries)
- Duration: 54 months (4 ½ years)
- Funding: European Union's Horizon 2020 research and innovation programme

## CONSORTIUM

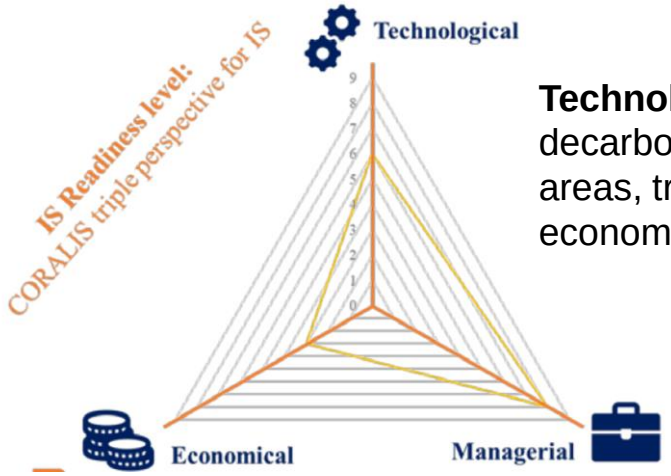
# CORALIS PROJECT




CORALIS aims at demonstrating **long-term synergy models** in a total of **3 industrial areas (lighthouses)**

Also, other **3 industrial areas acting as followers** will learn from the projects results to progress in there IS readiness level and implement new IS activities after the project's end.

The concept of **IS readiness level** is developed by addressing three factors:




**Technological factors (TRL)-** decarbonization of industrial areas, transition to circular economy

**Economic factors (ERL)-** business models

**Managerial factors (MRL)-** tools and procedures

# EXPECTED IMPACTS

- Step change towards closing *circular loops*
- Improvement of at least 15% in **energy efficiency** of the targeted industrial processes, compared to the non-symbiotic scenario
- Reduction of at least 30% in total **energy intensity**, on the basis of full life cycle considerations
- Overall reductions in **CO2 emissions** of 40%, compared to the non-symbiotic scenario
- Reduction in **primary raw material intensity** of up to 20%
- Reduction of **waste generation** by at least 25%
- Better **understanding of relevant barriers** (e.g. end of waste criteria)
- Effective **dissemination of major innovation outcomes**
- The **environmental gains** in absolute figures, and weighted against EU and global environmental footprints, should be demonstrated
- **Replication** potential

CORALIS

# Overview of the demonstrator cases: LIGHTHOUSES

# Lighthouse #1

## Escombreras

CHEMICALS MINERALS WATER

- **Core Ambition: Recovery of CaCl2 from wastewater, CO2 utilization for fertilizer production, study for integration of a shared CSP plant**

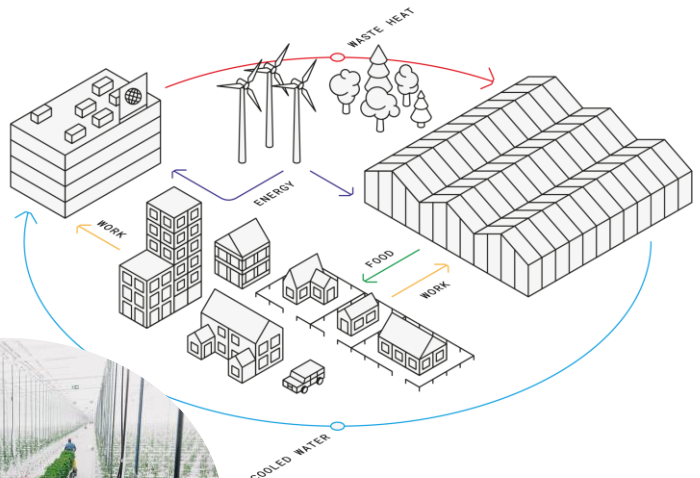
- To readapt the current fertilizer production process in one company (new fertilizer production process)
- Use of CO2 from surranding industries
- Reduce water consumption and wastewater discharge
- Recover raw materials (HCl and CaCO3)

# Lighthouse #2

## Frövi

PULP & PAPER FARMING ENERGY

- **Core Ambition: Reutilisation of CO2 and low-grade waste heat from a Pulp&Paper for supplying a nearby greenhouse**

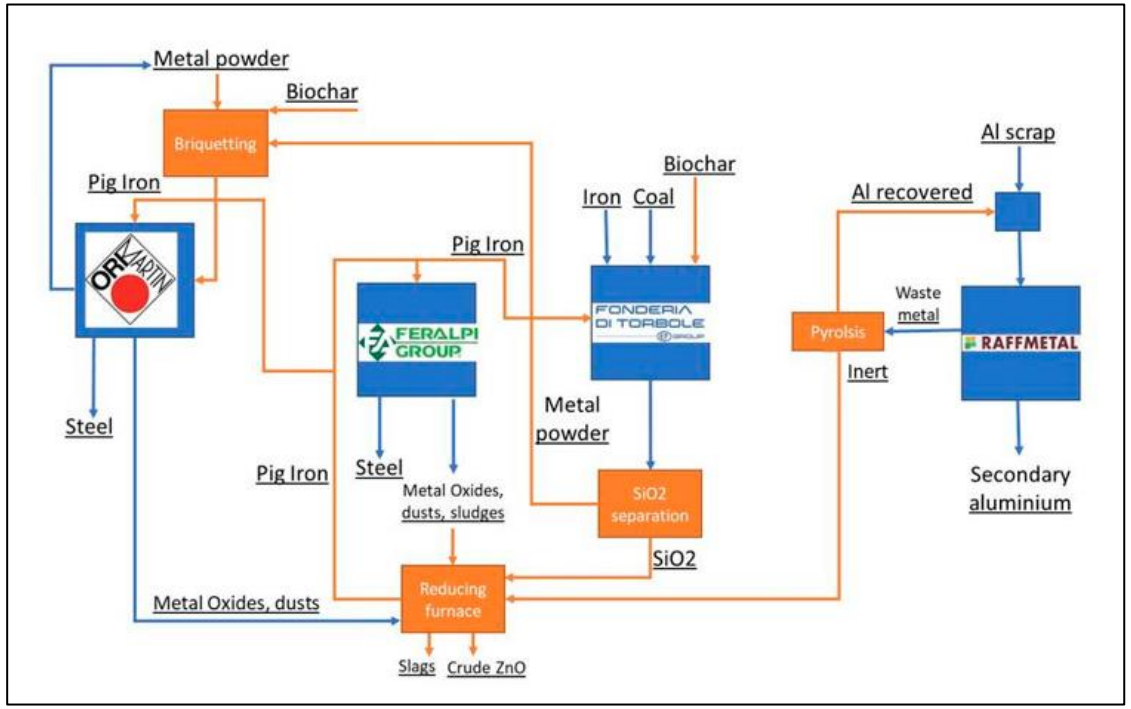



# Lighthouse #3

Brescia

IRON ALUMINIUM

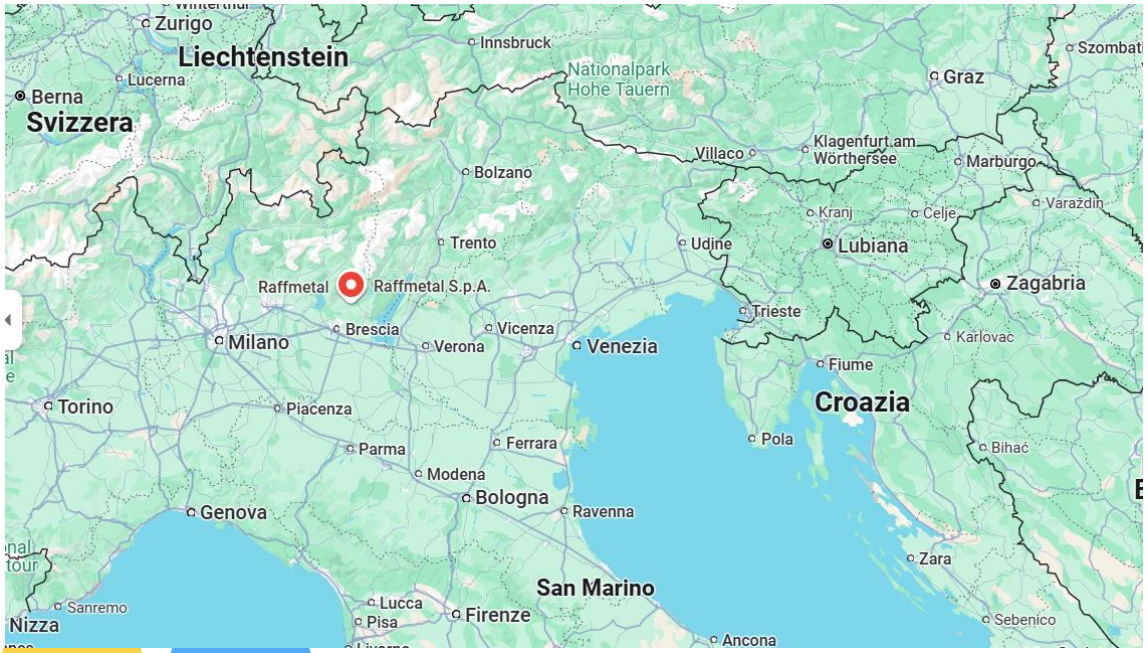
- **Core Ambition: Reduction of landfill disposal by replacing key raw materials like carbon sources for iron production with industrial waste and bioresources**

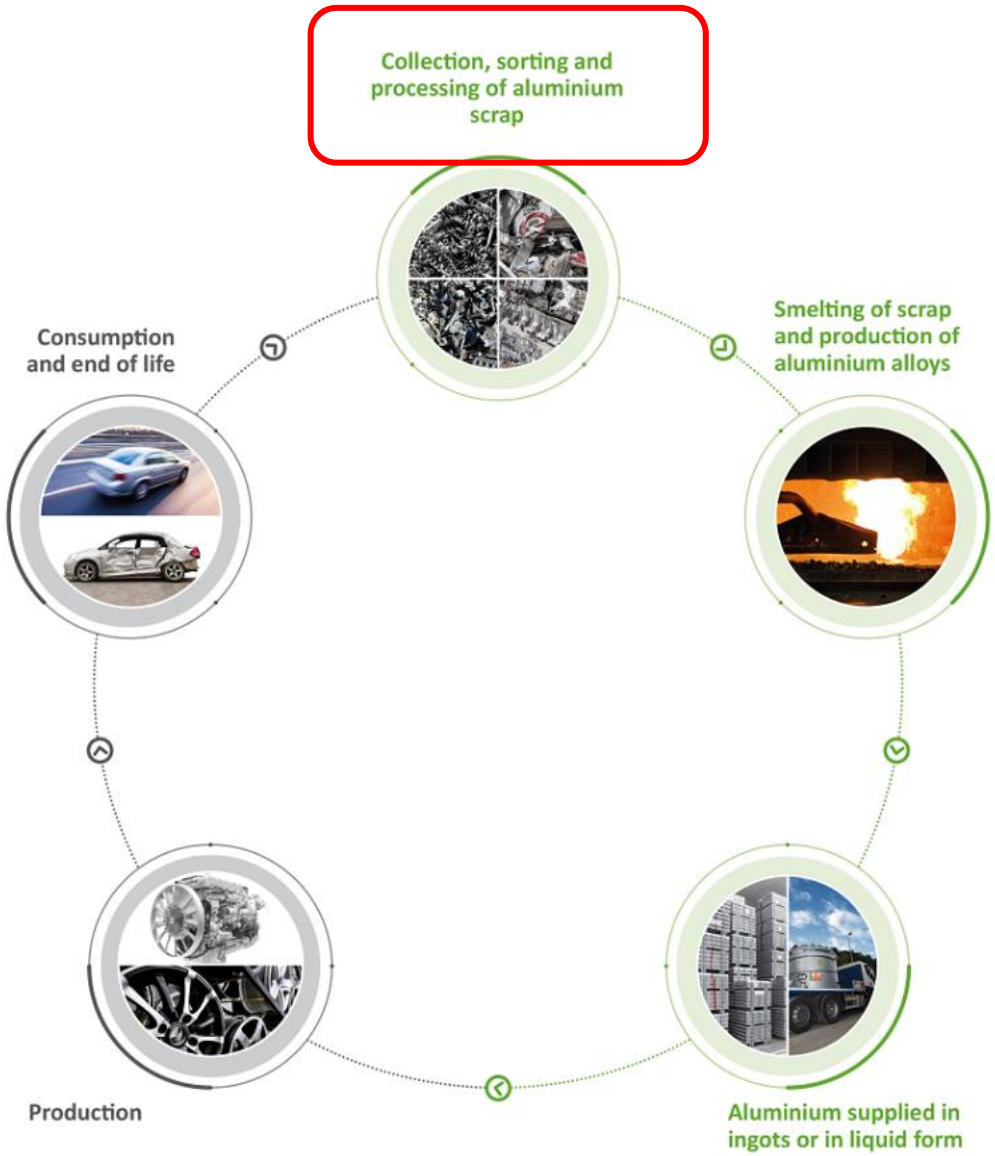




- **Ori Martin:** to produce and industrially test briquettes obtained with metallic residues
- **Feralpi**:) to run reducing trials for recovering metal oxides, b) Ferroalloy generation from white slag recovery and Al oxides
- **Torbole:** a) to install and test the complete treatment line to separate the silica sand from metal powders, b) to install a pulverized char injector and to carry out industrial trials
- **Raffmetal:** to design and install a pyrolysis plant for energy and Al recovery.

# RAFFMETAL ACTIVITIES

- Aluminium refiner located in Northern Italy;
- Raffmetal is part of the Brescia Province;
- It produces Alumium Alloys in ingots or liquid Aluminium;
- 100% recycling process from Aluminium scraps



# THE ALUMINIUM SCRAP RESIDUE

Mixed residue from Aluminium scrap pre-treatment (post-shredding and floating waste) – **«FLUFF»**

MEDIUM COMPOSITION

- Plastic and rubber 45-80%
- Metals 15-20% (also Aluminium)
- Glass and Wood 1-25%

# THE ALUMINIUM SCRAP RESIDUE

The management of the waste residues is quite critic:

- Negative impact on sustainability and Carbon Footprint;
- Loss of raw materials (metals);
- Loss of energy (organic fraction);
- High transport and incineration/disposal costs;
- Complicate legislation for transport and incineration/disposal.

# INTERNAL AND EXTERNAL VALORIZATION

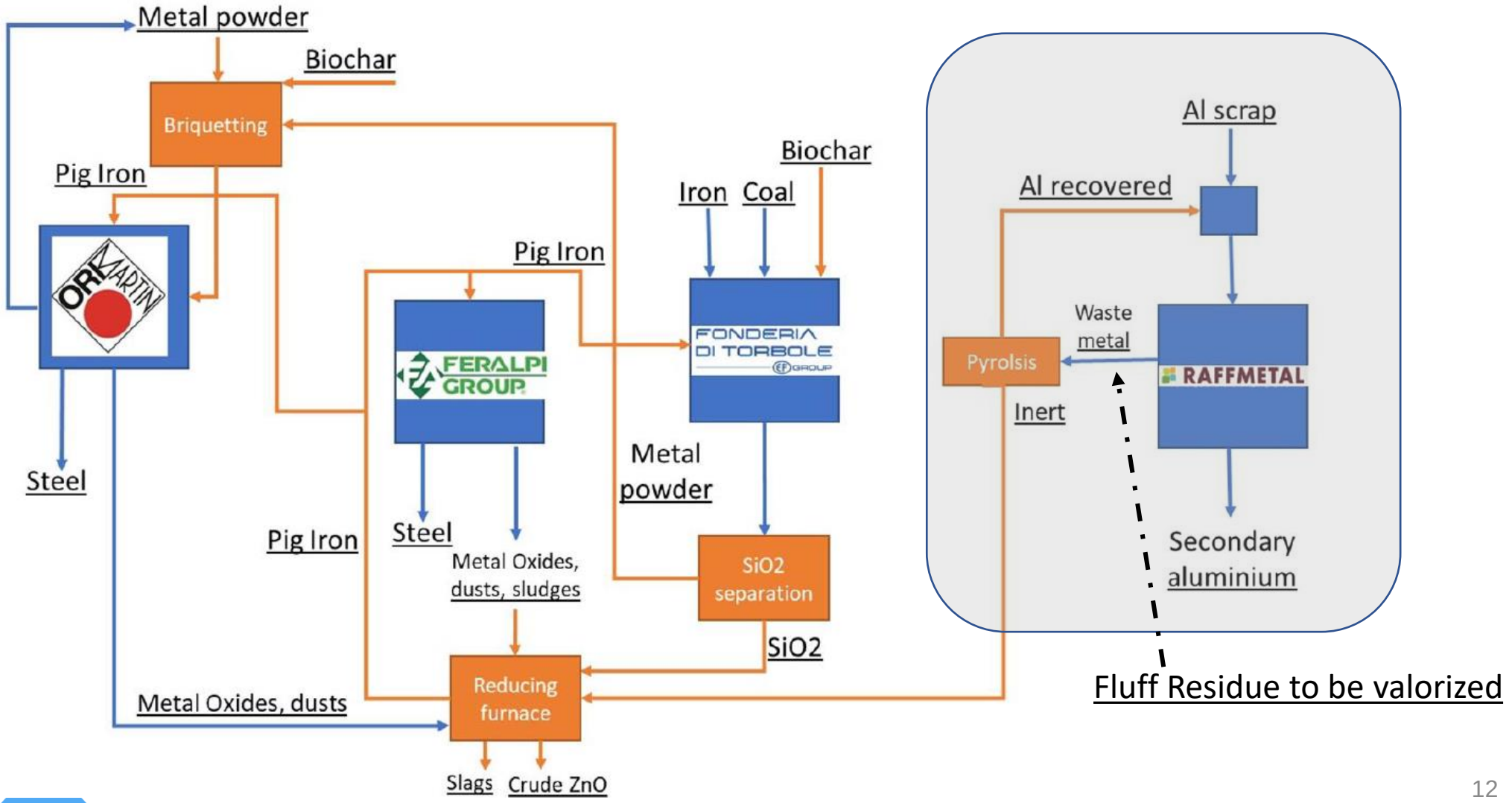
PROBLEM: FINDING A SOLUTION TO VALORIZE THE FLUFF RESIDUE IN ALL ITS FRACTIONS (PLASTIC,, METALS, ETC.)

SOME FRACTIONS (EX. FERROUS) CANNOT BE INTERNALLY RECYCLED IN RAFFMETAL

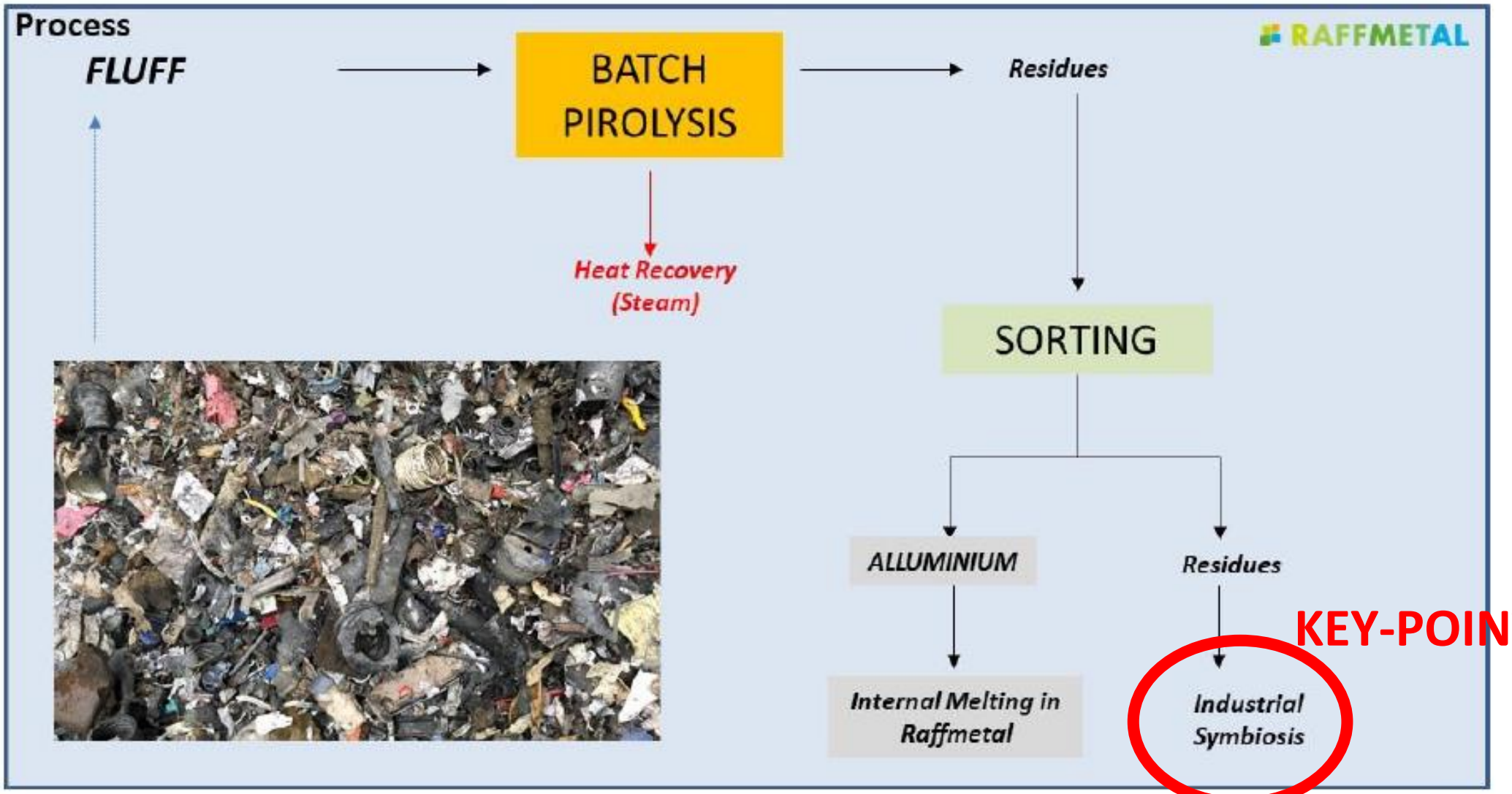
INDUSTRIAL SIMBIOSYS WITH STEEL MAKERS IN BRESCIA DISTRICT

CORALIS PROJECT FOR EVALUATION OF IS

# PROJECT FOR IS IN BRESCIA DISTRICT



# PYRIOLISIS OF THE FLUFF RESIDUE FOR ALUMINIUM RECOVERY



# PROJECT FOR IS IN BRESCIA DISTRICT

RAFFMETAL CORALIS PROJECT GOALS:

- Improve the sustainability of the scrap recycling process;
- Reduction of the Carbon Footprint;
- Exploit the energy of the plastic/rubber fraction residue in the scraps post-shredded fraction («FLUFF»);
- Valorization of the fluff waste as a new raw material in all its fractions;
- Reduction of burocracy and environemantal impact for transport and incineration of the fluff waste;
- Internal recovery of the Aluminous fraction still present in the «FLUFF»;
- Development of INDUSTRIAL SYMBIOSIS in Brescia District by collaboration with local steel makers.

A deep feasibility study is required to evaluate the INDUSTRIAL SYMBIOSIS

# THE EXPERIMENTAL RESULTS IN RAFFMETAL

Q. What type of experimental trials were conducted?

A. LAB TRIALS

- Full physio-chemical characterization of the input raw material (Fluff).
- Measure of the Enthalpy;
- Thermogravimetric tests (DTA – DTG)
- Qualitative and quantitative determination of the released syngas and synoil
- HSE evaluation (Atex report, CO-release, etc.)
- Determination of the heat recovery data as steam;

A. SEMI-INDUSTRIAL TRIALS

- Batch process industrial trials
- Continous process industrial triala

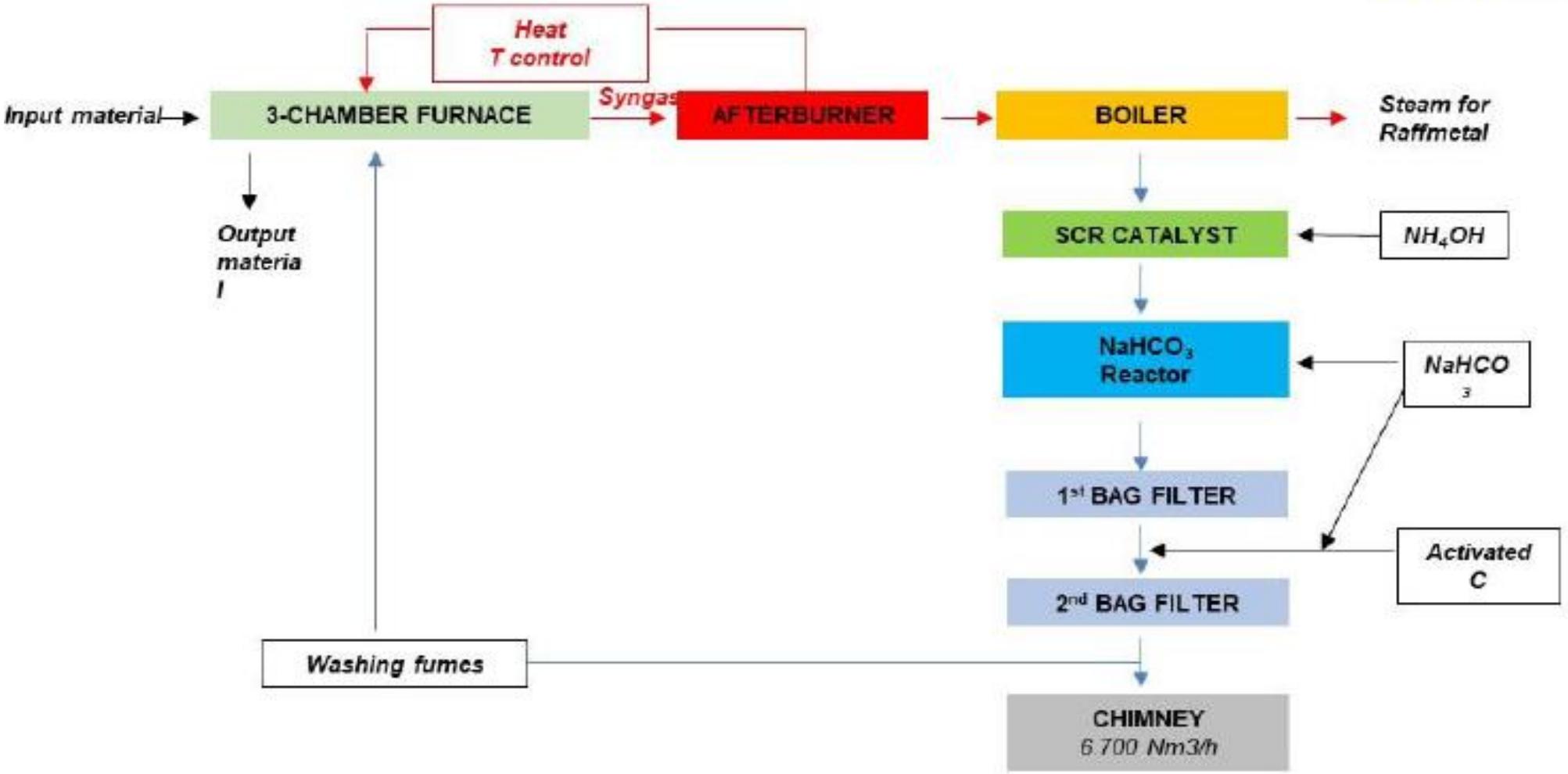
# THE EXPERIMENTAL RESULTS IN RAFFMETAL

Q. Which deliverables were obtained?

1. SUSTAINABILITY DATA ABOUT THE PIROLYTIC PROCESS
2. ESECUTIVE ENGINNERING FOR A BATCH-PROCEESS PILOT PLANT;
3. FRACTION OF RECOVERABLE ALLUMINIUM
4. OUTPUTS PHYSIO-CHEMICAL CHARACTERIZATION AND QUANTIFICATION (BOTTOM ASHES, EMISSIONS, ETC.)
5. ENERGETIC FINAL REPORT;
6. SAFETY FINAL REPORT;
7. **CHARACTERIZATION DATA OF THE FERROUS FRACTION FOR THE INDUSTRIAL SYMBIOSIS WITH LOCAL STEEL MAKERS**

# PYRIOLISIS OF THE FLUFF RESIDUE FOR ALUMINIUM RECOVERY

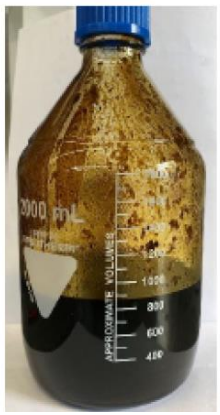
RAFFMETAL

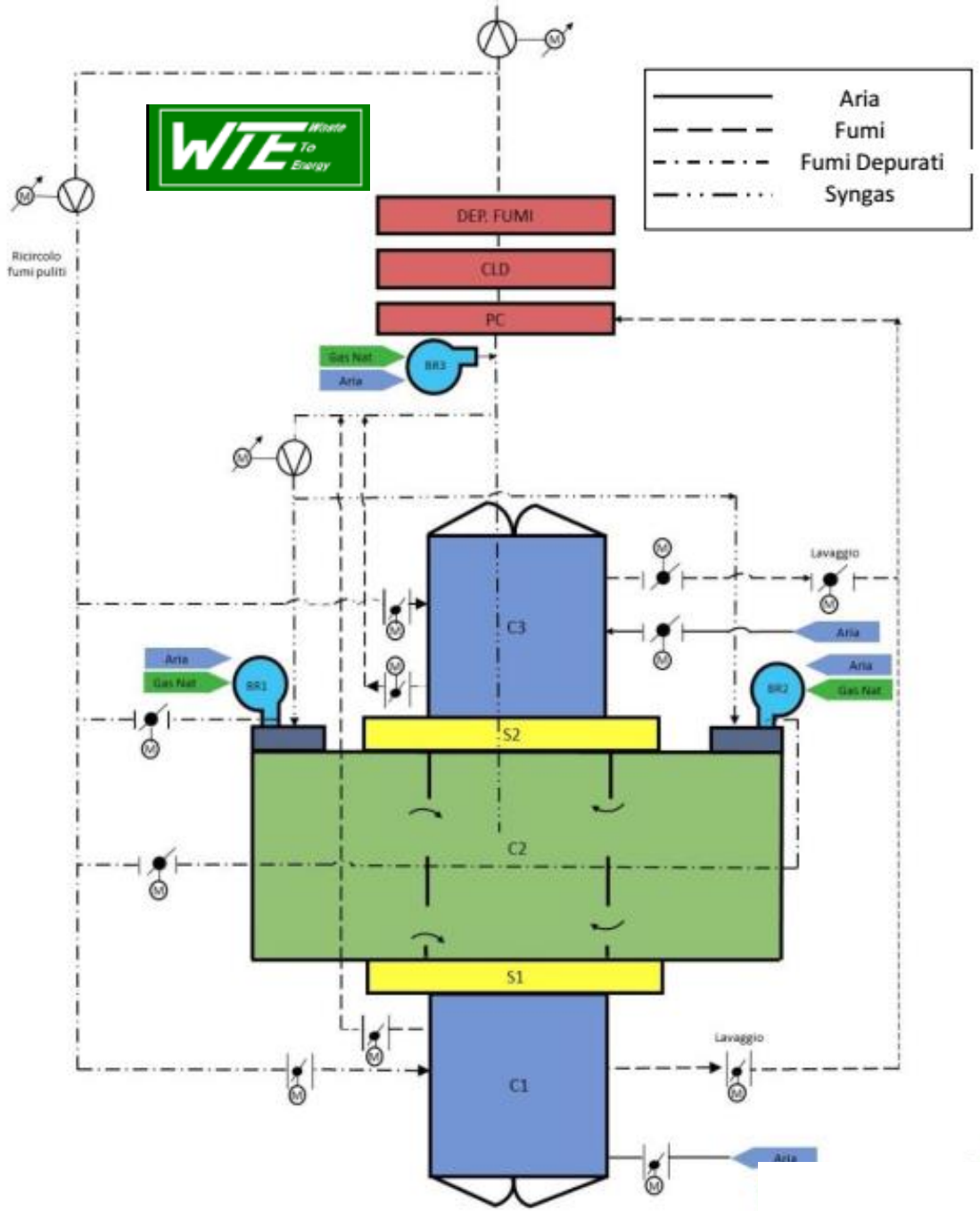


# THE ENGINEERING

Technical requirements for pilot pyrolisis plant

- Capacity: 5 tons/day
- Batch Process
- 3-chamber furnace
- Furnace Temperature: 500 °C
- Oxigen in the furnace < 3% v/v
- Heat Recovery to produce Steam for Raffmetal
- Energetic costs close to zero;
- No Pre-Treatment of the Input Material (no shredding)
- Syngas treatment by afterburner
- No condensation of the synoil





# EVALUATION FOR IS IN BRESCIA

VALORIZATION OF THE PYROLITIC RESIDUE BY INDUSTRIAL SYMBIOSIS

Bottom ashes from Pyrolitic process at 500 °C → Magnetic sorting → Eddy Current Sorting → RESIDUE

Magnetic sorting → **Higher rich-Ferrous fraction (Fe +)**

Magnetic sorting → **Lower rich- Ferrous fraction (Fe -)**

Eddy Current Sorting → **Alluminium for internal recovery in Raffmetal (Al)**

*INDUSTRIAL SYMBIOSIS WITH STEEL MAKERS IN CORALIS??*

# EVALUATION FOR IS IN BRESCIA

CHARACTERIZATION OF FERROUS FRACTION IN RINA-CSM TO EXPLORE THE INDUSTRIAL SYMBIOSIS

| | Fe content (%) | Cr content (%) | Ni content (%) |
|---|---|---|---|
| Higher Ferrous Fraction (Fe+) | 44% | 0,3% | 0,2% |
| Lower Ferrous Fraction (Fe-) | 9% | 0,1% | < 0,01% |

**The concentrations of Fe, Cr and Ni are too low for a valorization as raw material in steel production**

# ISSUES FOR INDUSTRIAL SYMBIOSIS IN BRESCIA DISTRICT

## 1. TECHNICAL ISSUES

- Chemical composition of the outputs: the Iron content was too low and not aligned with the Steel Makers requirements;
- Not homogenous input raw materials («Fluff») and outputs. Difficulities for a complete robust physio-chemical characterization;
- Difficulties to find industrial plant for the trials;
- Safety issues with the flue stack treatment of the pyrolitic process.

## 2. LEGISLATIVE ISSUES

- Classification of the outputs (Ferrous fractions) as hazardous wastes because of the content of heavies;
- The steel makers must authorize new hazardous wastes as input material;
- Need of local permits from CA to install new hazardous plant as the pyrolytic furnace.

# HOW TO MANAGE AN IS PROJECT

Q. What have we learned about INDUSTRIAL SYMBIOSIS by CORALIS?

- Mutual knowledge of stakeholders production processes and their specification *is essential.*
- The role of the coordinator in the IS project *is fundamental.*
- Legislative issues for authorization of new plant and new waste streams between the stakeholders *is a strict bottle-neck.*
- Legislative semplification of plant authorization and materials classification (wastes, EoW, etc.) *is urgent*.
- *Need of specific rules* to allow easy expeditions of wastes for industrial trials in external sites.
- Full large analytical characterization of input raw materials and outputs *is mandatory*, mainly for not-homogeneous materials.
- An increment of local industrial symbiosis between different industrial sectors should *be promoted.*

# CORALIS OUTPUTS

6 demonstrator cases (lighthouses + followers)

- Participation of industries, academic and public administrations
- Different sectors involved
- Different regions and regulatory framework
- Different mature level of IS solutions

**GUIDELINES – TOOLS – LEARNINGS**

| | |
|---|---|
| Phase of implementation | Initiation – Implementation -Evaluation |
| Type of stakeholder | Industry – Facilitator – Public administration |

**Facilitator**

Individuals or teams capable of **coordinating and mobilizing resources** (public, private, or both) to support ecosystems in achieving large-scale industrial symbiosis, industrial-urban symbiosis, and circular economy initiatives in various ways. These facilitators are recognized by their ecosystem as key references in defining collaborative initiatives that benefit all the members they oversee, coordinate, or guide.

# GUIDELINES DEVELEOPED BY CORALIS

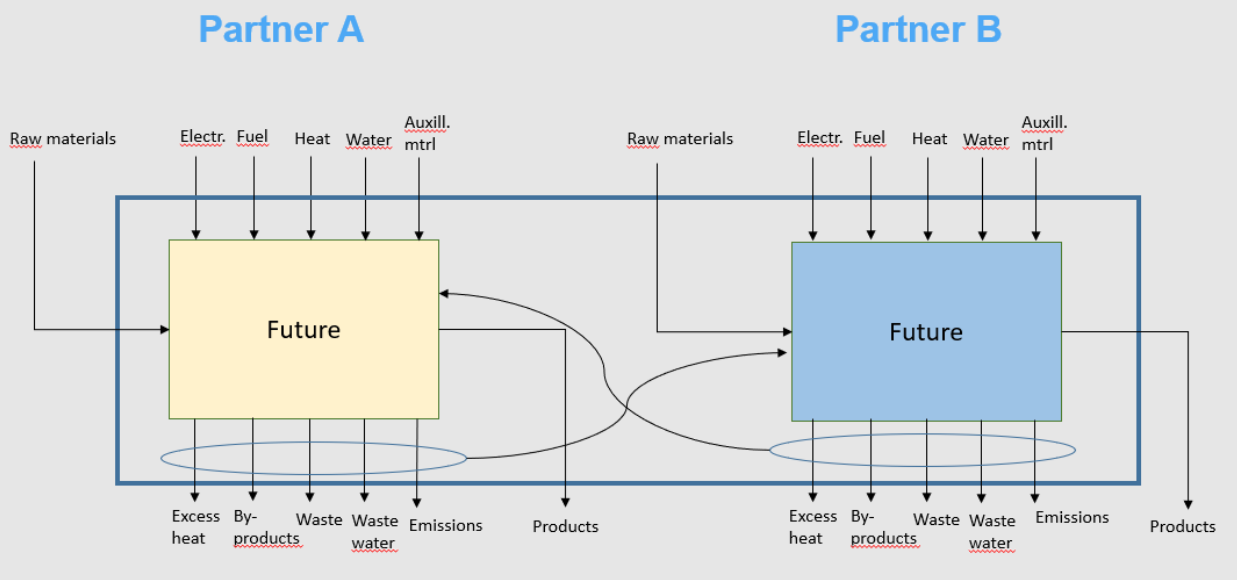
| | INITIATION | IMPLEMENTATION | EVALUATION |
|---|---|---|---|
| **Market analysis**: to identify opportunities and risks for the market uptake of an Industrial Symbiosis (IS) project solution | ✓ | | |

The relationship of Industrial Symbiosis in the case of X solution

| The relationship of Industrial Symbiosis in the case of XXX | |
|---|---|
| Geographic location of partners participating in the IS solution | Please describe where the partners are located (e.g., Are they all at the national level or not? Same region? Same industrial area?) |
| Nature of the subjects participating in the industrial symbiosis | e.g., private companies, public bodies |
| Size of companies participating in the IS solution | Small companies (11-49 employees), Medium companies (50-250 employees), large companies (+250 employees). |
| Business sector of the companies participating in the IS solution | e.g., chemical sector, metallurgical sector, etc. |
| Nature of the "object of exchange" of industrial symbiosis | Explain what they exchange specifying the typology of what they exchange (e.g., chemical waste, specifically sulfuric acid). |

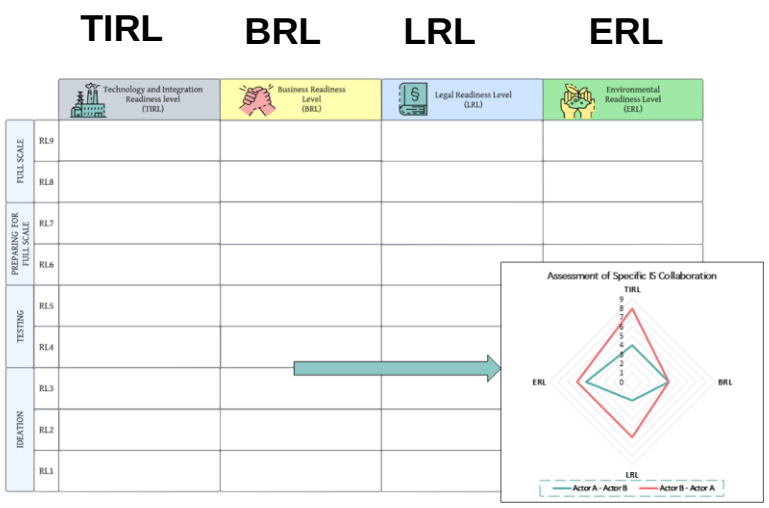
# GUIDELINES DEVELEOPED BY CORALIS

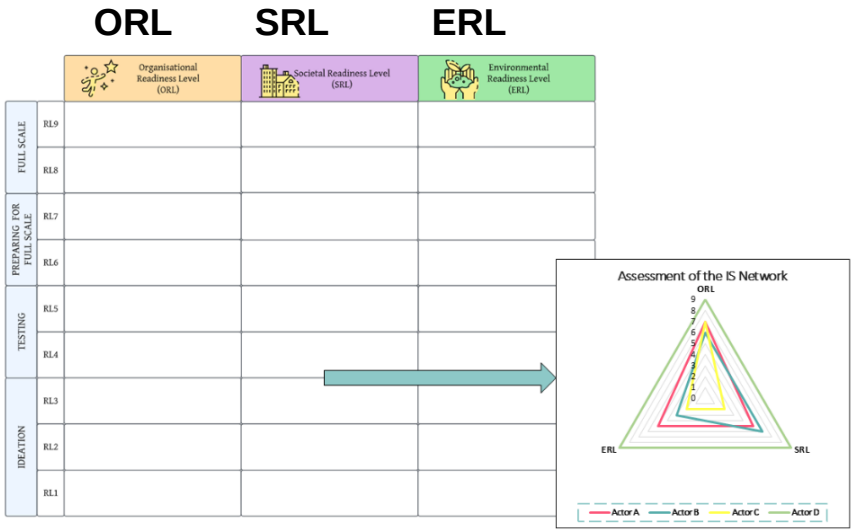
| | INITIATION | IMPLEMENTATION | EVALUATION |
|---|---|---|---|
| **Selection of reference and IS scenarios**: to establish a reference scenario that serves as a baseline for comparison with the Industrial Symbiosis (IS) scenario. | ✓ | | |



# GUIDELINES DEVELEOPED BY CORALIS

| | INITIATION | IMPLEMENTATION | EVALUATION |
|---|---|---|---|
| ▷ **IS readiness level matrix:** The purpose of the ISRL Matrix is to evaluate and support the progress of the IS network | ✓ | ✓ | ✓ |



# GUIDELINES DEVELEOPED BY CORALIS

| | INITIATION | IMPLEMENTATION | EVALUATION |
|---|---|---|---|
| **Risk managment tool:** To Identify potential risks that may occur in the context of symbiosis activities, as well as establish common mitigating actions in addition to fostering and strengthening collaboration and communication among symbiosis participants | ✓ | ✓ | ✓ |

Risk management methodology template

**Risk Management Methodology for Industrial Collaborative Ecosystems**

| | | | |
|---|---|---|---|
| Project name: | | Template number: | |
| Stakeholders: | | Total page: | |
| Prepared by: | | Date: | |

| General risk | ID nº | Risk event | *Current risk evaluation* | | | | | | | *Results* | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Impact | I | Likelihood | L | Detection effectiveness | D | RPN (1) | Correction actions | Responsible | I | L | D | RPN (2) |
| **Category:** Operational & technical | | | | | | | | | | | | | | | |
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| | | | | | | | | | | | | | | | |
| **Category:** Organisational & Governance | | | | | | | | | | | | | | | |
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| **Category:** Economic & Financial | | | | | | | | | | | | | | | |
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| **Category:** Legal | | | | | | | | | | | | | | | |
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| **Category:** Environmental | | | | | | | | | | | | | | | |
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| **Category:** Social | | | | | | | | | | | | | | | |
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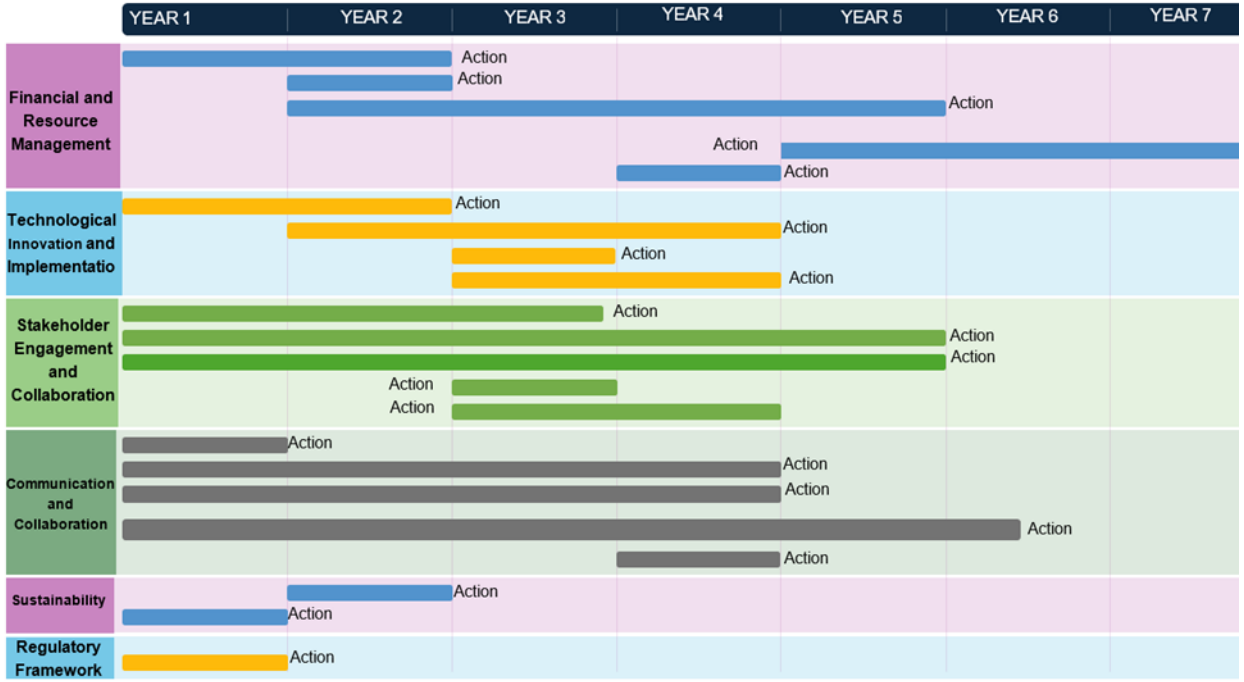
# GUIDELINES DEVELEOPED BY CORALIS

| | INITIATION | IMPLEMENTATION | EVALUATION |
|---|---|---|---|
| **Roadmap planning**: to create a structured roadmap to facilitate and optimize industrial symbiosis initiatives. | ✓ | ✓ | ✓ |

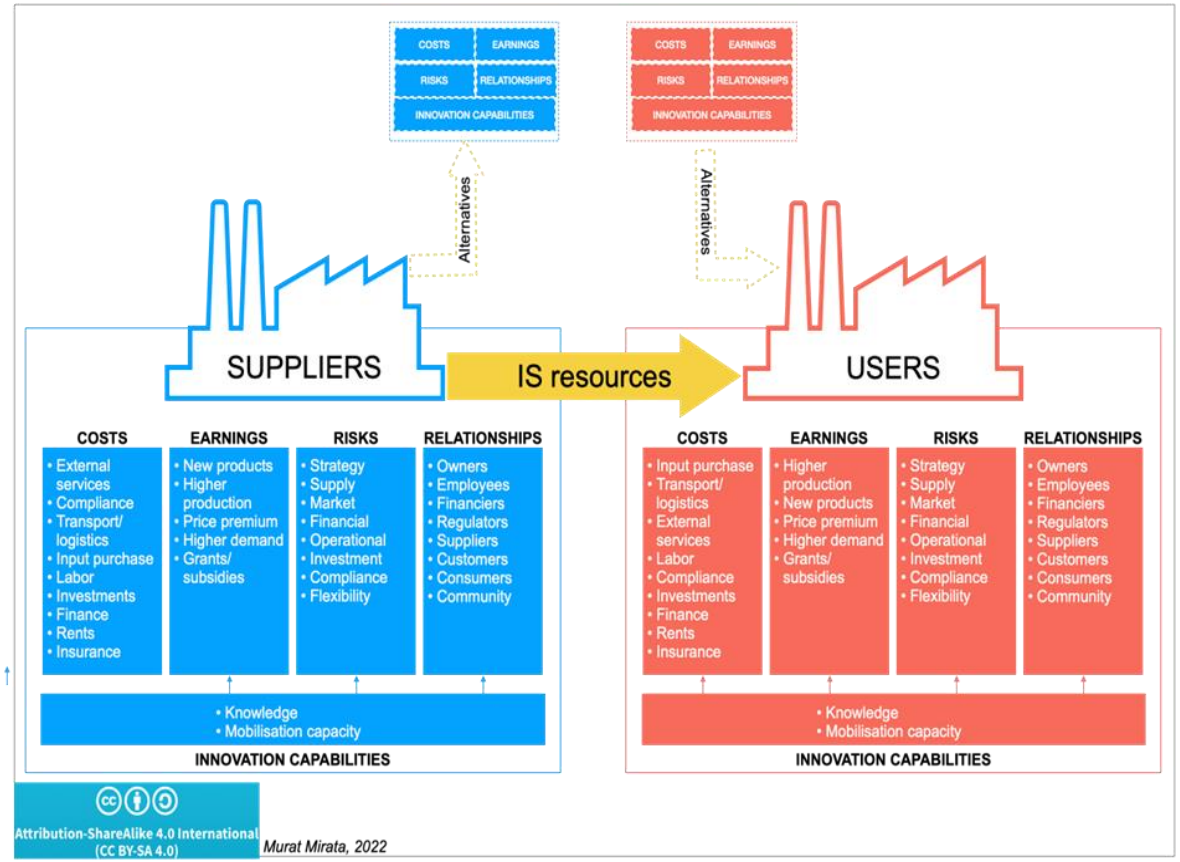
Example of a roadmap



# GUIDELINES DEVELEOPED BY CORALIS

| | INITIATION | IMPLEMENTATION | EVALUATION |
|---|---|---|---|
| **Pricing**: to identify and assess business values that IS can offer to individual actors and the partnerships as a whole. | ✓ | ✓ | |

Business value framework for comprehensive and transparent value assessment in IS relationships (Mirata, 2022)



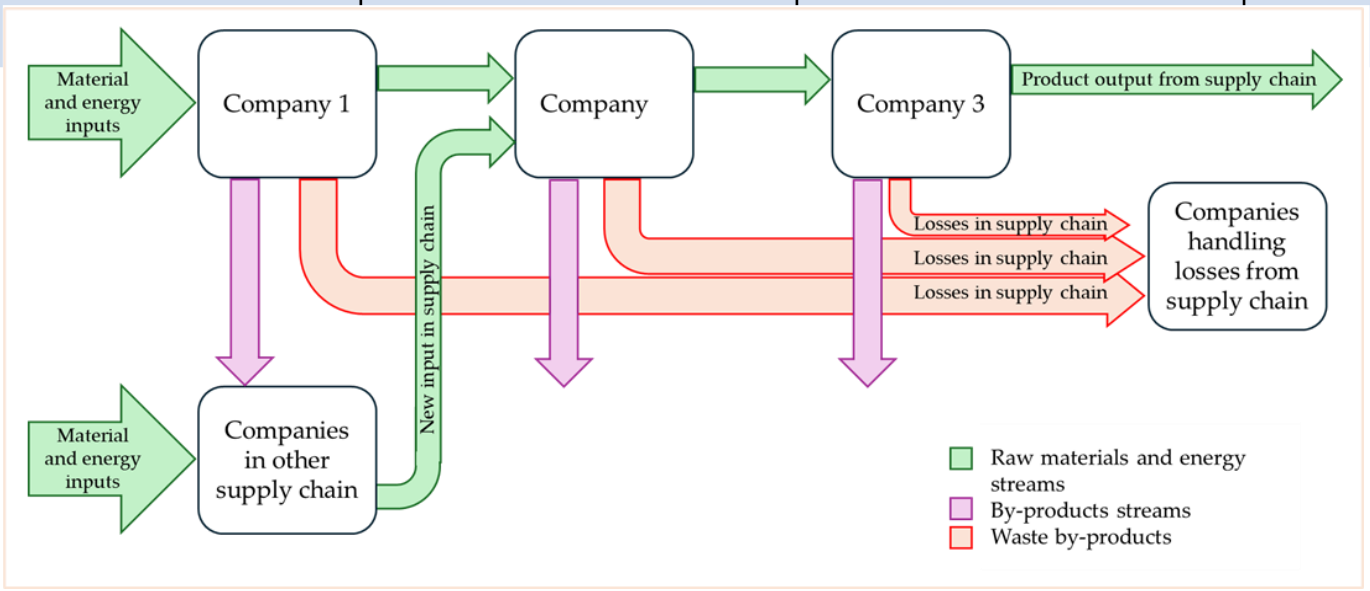
# GUIDELINES DEVELEOPED BY CORALIS

| | INITIATION | IMPLEMENTATION | EVALUATION |
|---|---|---|---|
| **Secure funding:** to identify potential sources of funding for IS and implement activities to obtain funding needed for its development | ✓ | ✓ | |
| **Develop a Business Plan – business agreements:** to develop and implement business agreements that support successful emergence and stable operation of IS partnerships. | ✓ | ✓ | |
| **Business model canvas:** to integrate industrial symbiosis into the core operations of a business. The business model ensures the fair distribution of costs, risks, as well as economic and environmental benefits among the partners involved | ✓ | ✓ | |

# GUIDELINES DEVELEOPED BY CORALIS

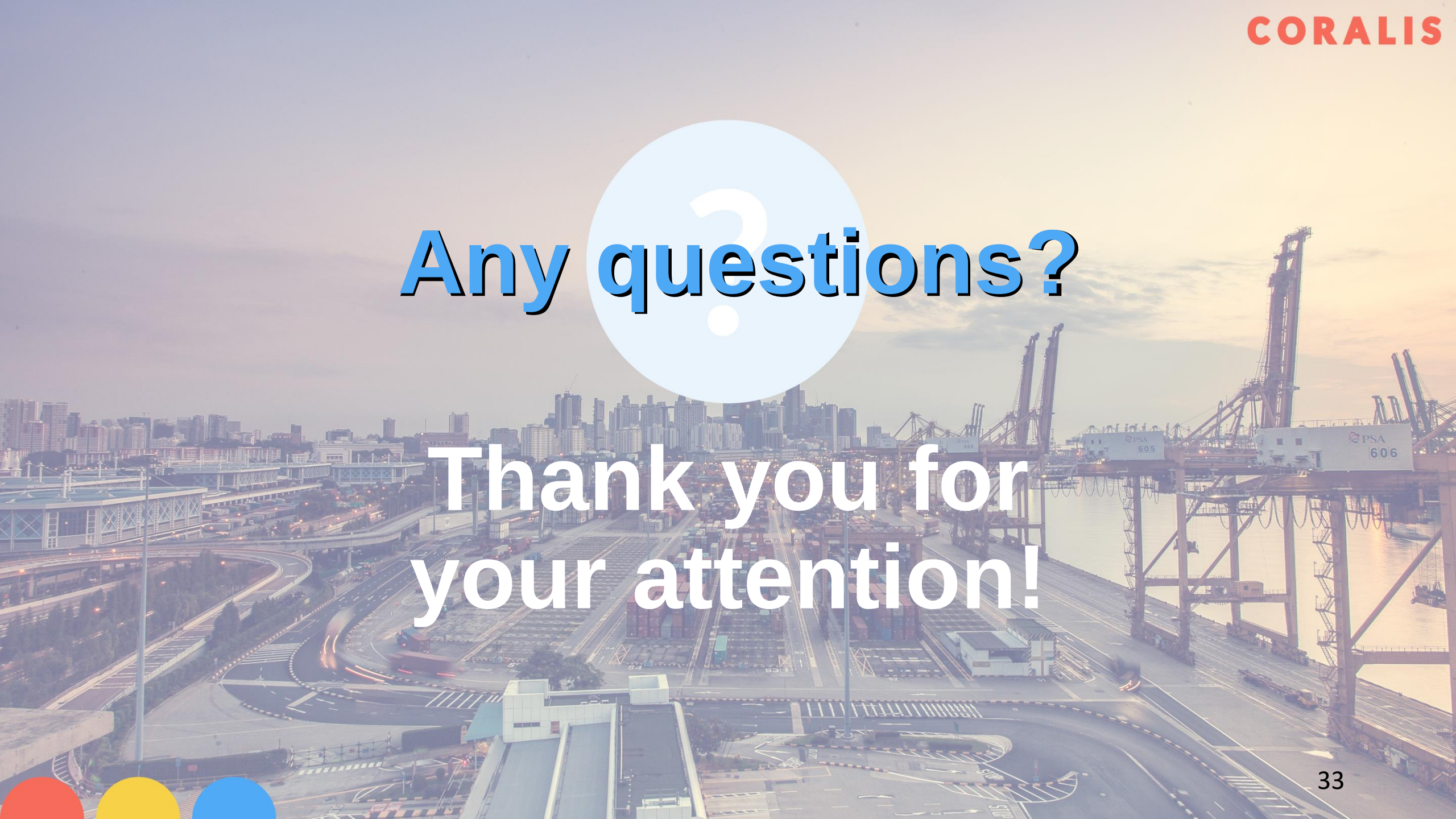
| | INITIATION | IMPLEMENTATION | EVALUATION |
|---|---|---|---|
| **Techno-economic feasibility tools:** typically involves analyzing capital and operating costs, along with potential revenues, to determine the economic feasibility of industrial processes<br>▷ Mass Flow analysis (MFA)<br>▷ Material Flow Cost Accounting (MFCA)<br>▷ Cost benefit analysis (CBA)<br>▷ Pinch Analysis (PA)<br>▷ Thermo-Economic Analysis<br>▷ Life Cycle Cost Analysis (LCCA) | | | |

Integration of **MFCA** assessments between companies within a supply chain and between supply chains.



# CORALIS LEARNINGS

- IS is highly site-specific and usually requires extensive technical trials at low TRL to ensure their effectiveness.
- It is necessary to combine both legal and technical disciplines to expedite the implementation of industrial symbiosis



# Any questions?

# Thank you for your attention!

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