INSTITUTE OF COMMUNICATION, INFORMATION AND PERCEPTION TECHNOLOGIES

Scuola Superiore Sant'Anna

ICT COISP

Information and Communication Technologies for Complex Industrial Systems and Processes

IMPROVING THE BY-PRODUCTS REUSE IN INTEGRATED STEELMAKING FACILITIES: SCENARIO ANALYSES THROUGH THE COMBINATION OF PROCESS MODELLING, SIMULATION AND OPTIMIZATION TECHNIQUES

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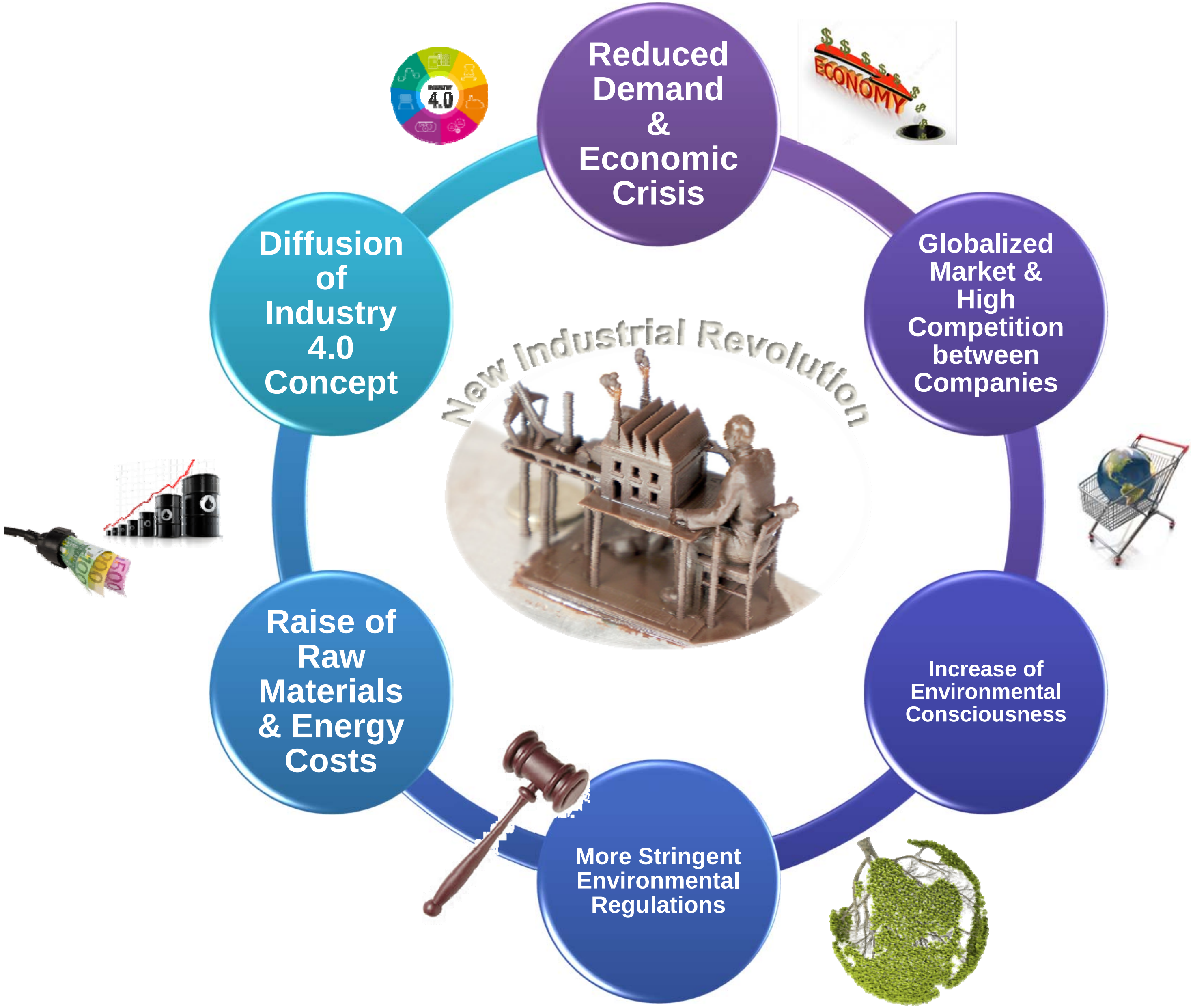
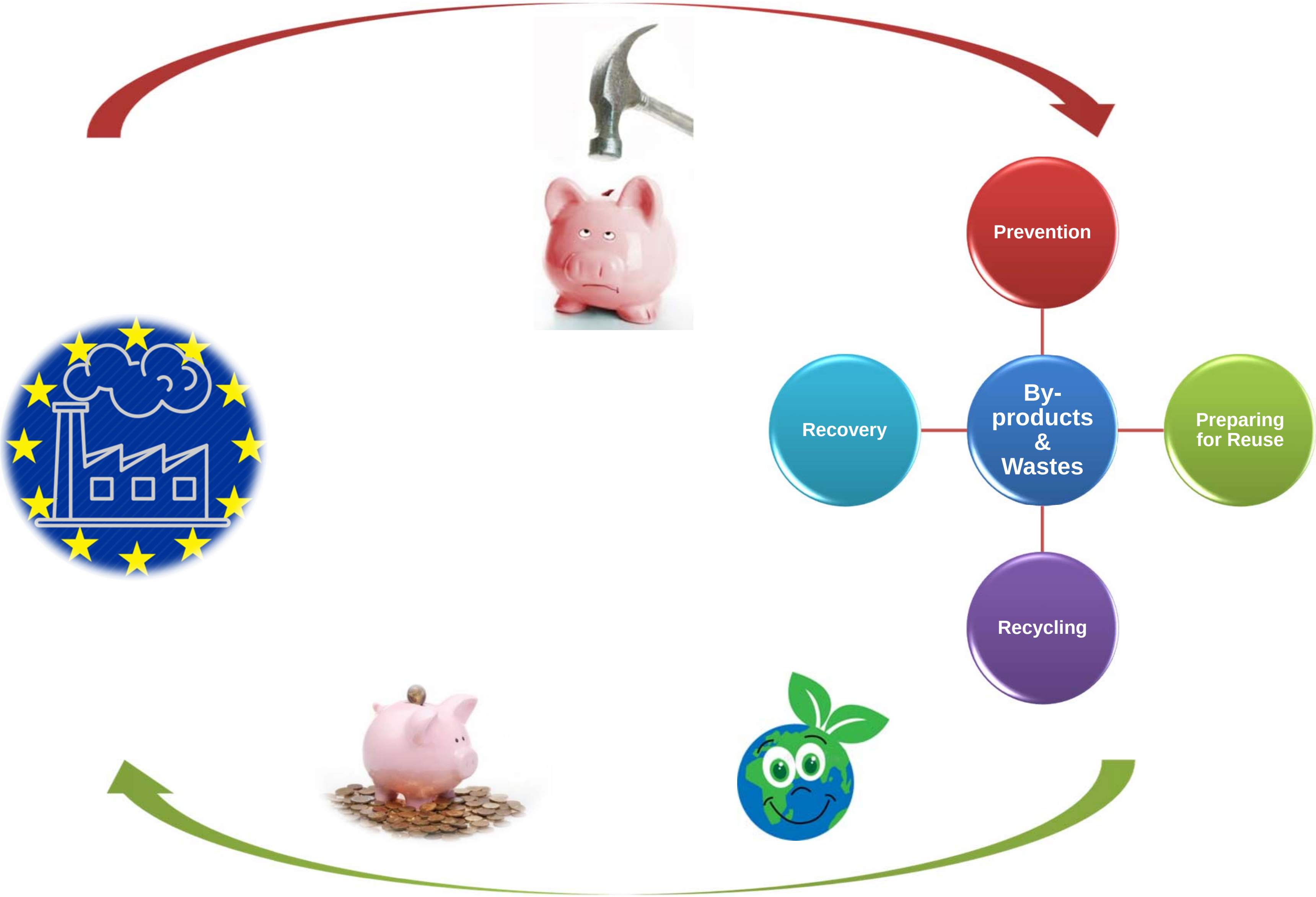
Content

Introduction



Introduction

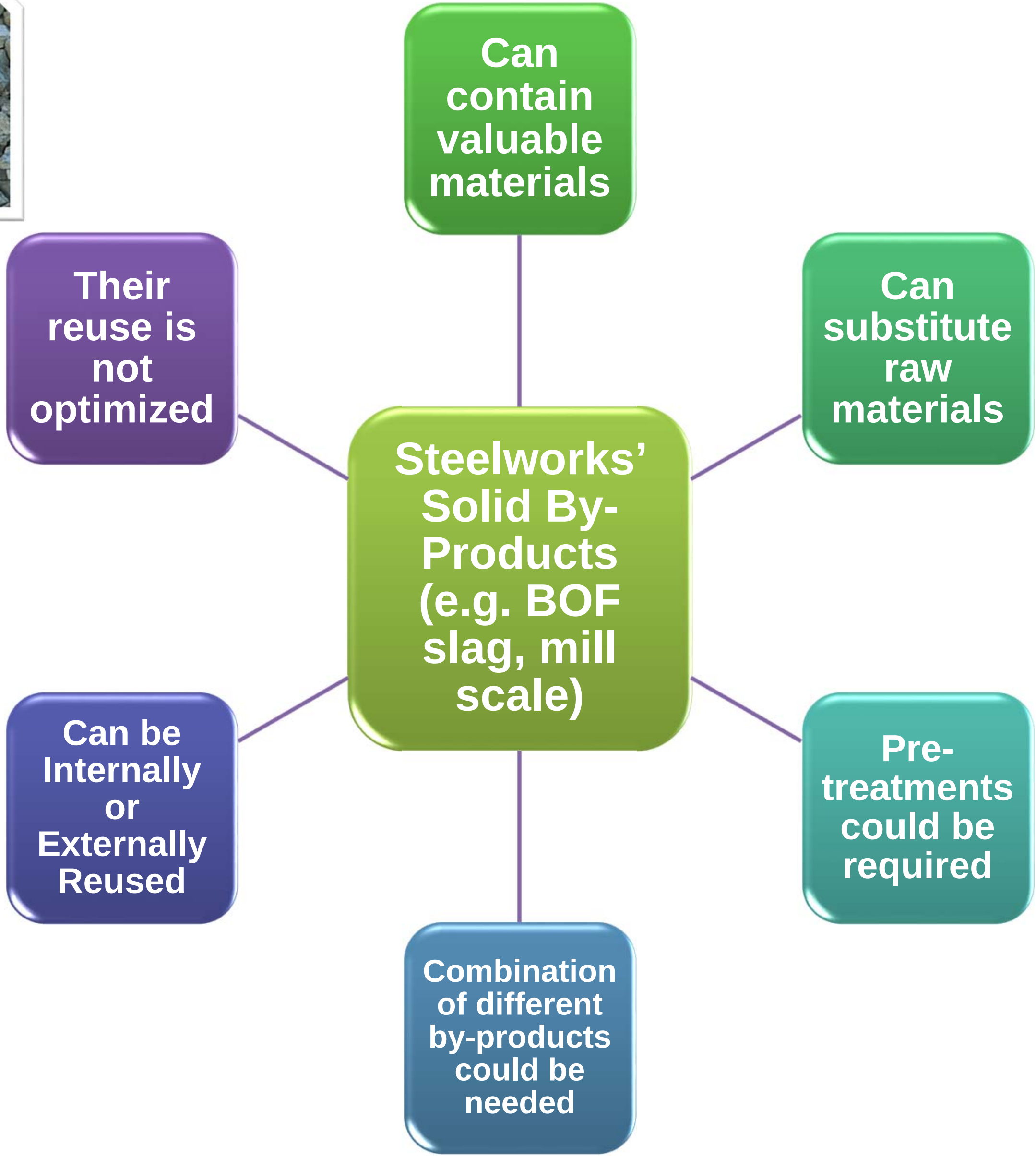


Introduction

Integrated Steelmaking Industries

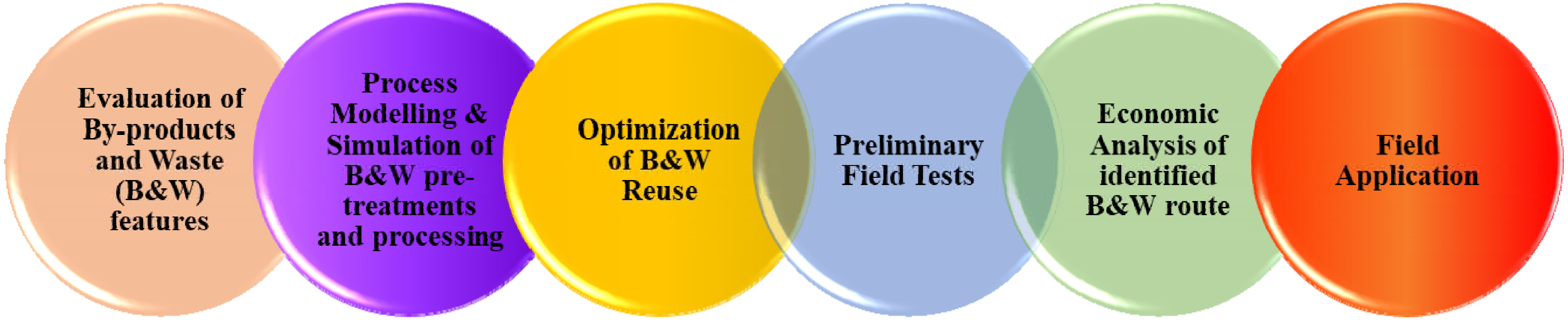
Solutions are researched to improve the industrial sustainability

Introduction



Introduction

Only few studies are based on holistic approach that investigate possible by-products reuse routes by taking into account the joint advantages and disadvantages of different pre-treatments and processing



Introduction

TINOS 2015
3rd International Conference on Sustainable Solid Waste Management
2nd - 4th July 2015
MUSEUM OF MARBLE CRAFTS
www.tinos2015.uest.gr
www.iswm-tinos.uest.gr

Matino, I., Branca, T.A., Alcamisi, E., Colla, V., Romaniello, L.: Evaluation of a BOF slag recovery treatment combining experimental and simulation studies. In: 3rd International Conference on Sustainable Solid Waste Management TINOS 2015

Matino, I., Colla, V., Branca, T.A., Romaniello, L.: Optimization of By-Products Reuse in the Steel Industry: Valorization of Secondary Resources with a Particular Attention on Their Pelletization. Waste and Biomass Valorization 8(8), 2569-2581 (2017).

NAXOS2018
13-16 June 2018
6th International Conference on Sustainable Solid Waste Management

Matino, I., Branca, T. A., Fornai, B., Colla, V., Romaniello, L.: Improving the by-products reuse in integrated steelmaking facilities: scenario analyses through the combination of process modelling, simulation and optimization techniques. In 6th International Conference on Sustainable Solid Waste Management NAXOS 2018

2015 — 2017 — 2018

Improvements have been done by starting from previous works in order to make more holistic investigations about by-products reuse in integrated steelworks

Materials and Methods

Conventional Industrial Process Investigation Techniques

- **Theoretical studies**
- **Experimental Campaign**

+

Industrial Process Simulation & Optimization through standard and advanced tools

- **Assessment of non-conventional scenarios** difficult to evaluate or test

→ **Detailed & Holistic Industrial Process & By-Products Route Analyses**

More agile, dynamic and flexible supervision of:

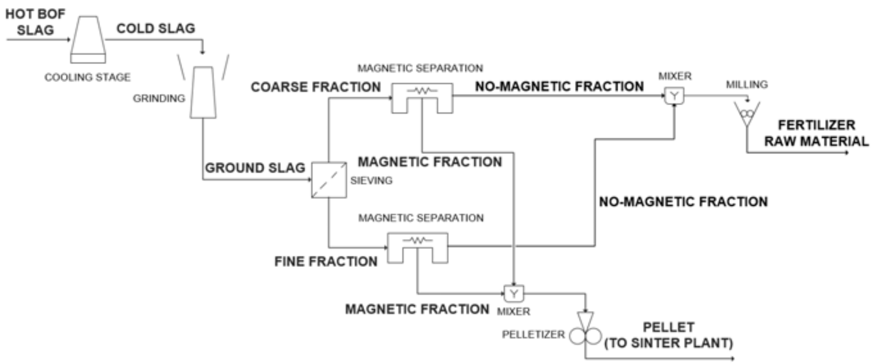
- **all the aspects of the considered processes or routes**
- **the interactions among different sub-processes or route**
- **processes and related parameters** that can be difficult to directly test due to not very known technologies or applications

Materials and Methods – BOF Pre-treatment model

Matino, I., Branca, T.A., Alcamisi, E., Colla, V., Romaniello, L.: Evaluation of a BOF slag recovery treatment combining experimental and simulation studies. In: 3rd International Conference on Sustainable Solid Waste Management TINOS 2015

Starting point

Preliminary Results about BOF slag Pre-treatment configurations to obtain a Fe-rich fraction and a Ca an P rich fraction



Improvements

Development of a **''digital twin'' by Aspen Plus of the suggested configuration** in order to:

- evaluate the **robustness** of the process **with different kind of BOF slag**
- evaluate the s**uitability of different types of magnetic separation steps**
- investigate possibilities of **changes in configuration and in operating conditions**

Materials and Methods – BOF Pre-treatment model

The developed **model** contains some duplicator blocks to **allow evaluating simultaneously**:

- **different treatment configurations**
- **different process units**

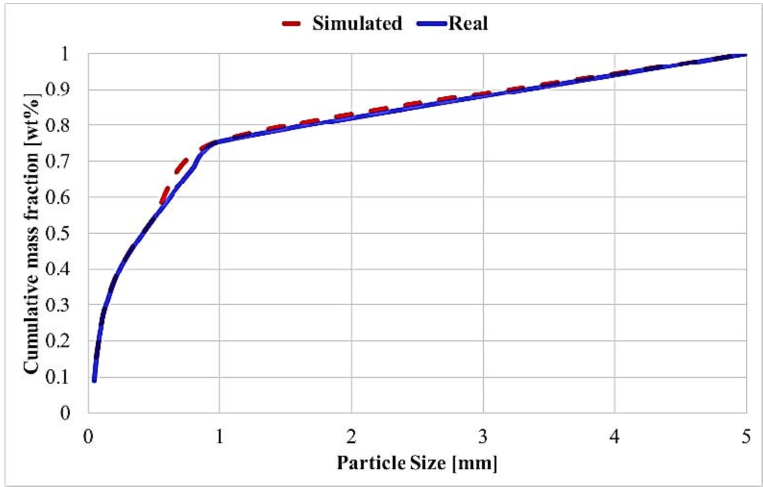
The following **parameters** can be **monitored:**

- **Distributions of chemical compounds** depending on cooling stage and on Particle Size Distribution (PSD) **after grinding;**
- **Composition of the main fractions** (e.g. ≤ 2mm and > 2mm) **after sieving;**
- **Compositions of magnetic and non-magnetic fractions after different kind of magnetic separations**
  - **Manual with neodymium magnet (M)**
  - **Wet High Intensity (WHI);**
  - **Wet Low Intensity (LWI);**
  - **Dry (D)**
- **Estimation of required energy in the grinding step based on Bond's Law.**

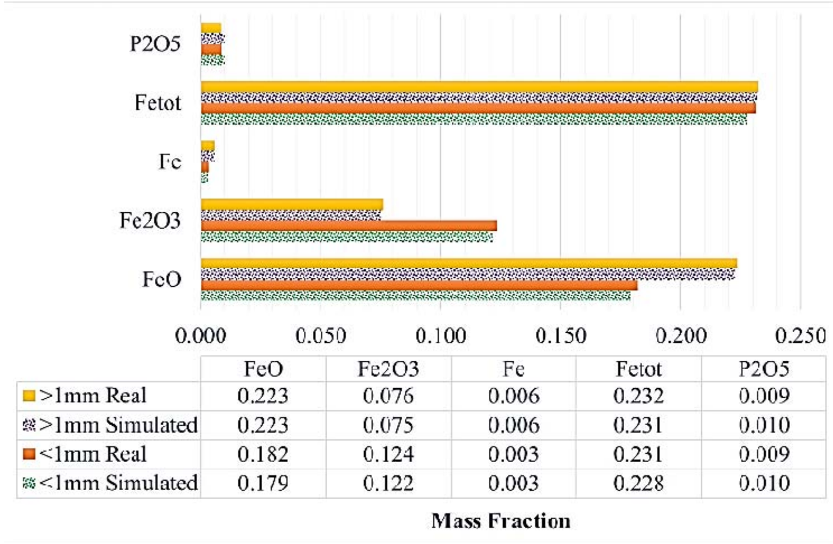
Materials and Methods – BOF Pre-treatment model

The **model** has been **tuned and validated** by comparing results of experimentation carried out on one type of BOF slag

Examples



Real and simulated cumulative PSDs after grinding



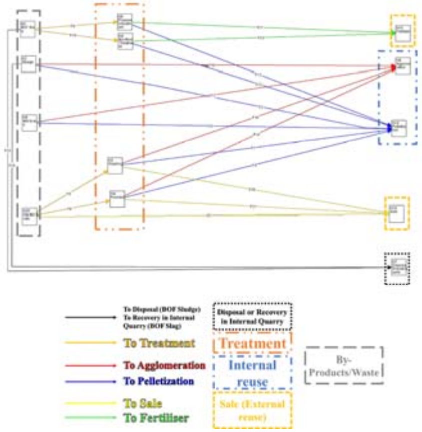
	FeO	Fe2O3	Fe	Fetot	P2O5
>1mm Real	0.223	0.076	0.006	0.232	0.009
>1mm Simulated	0.223	0.075	0.006	0.231	0.010
<1mm Real	0.182	0.124	0.003	0.231	0.009
<1mm Simulated	0.179	0.122	0.003	0.228	0.010

Real and simulated composition of slag fractions after sieving

Materials and Methods – reMIND improved superstructure for by-product reuse optimization

Matino, I., Colla, V., Branca, T.A., Romaniello, L.: Optimization of By-Products Reuse in the Steel Industry: Valorization of Secondary Resources with a Particular Attention on Their Pelletization. Waste and Biomass Valorization 8(8), 2569-2581 (2017).

Starting point



A **first reMIND superstructure to allow the optimization of by-products routes in integrateed steelworks** has been developed

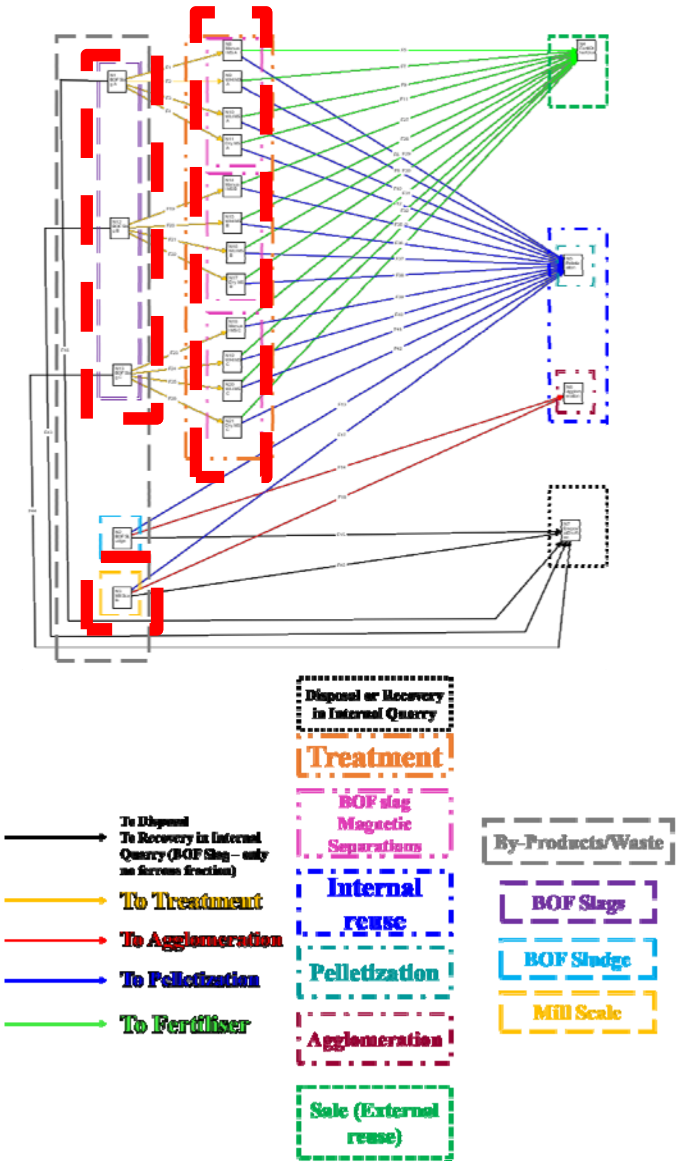
Improvements

Superstructure improvement:

- **inclusion of** the **different BOF slag magnetic separations** as in the BOF slag pre-treatment model
- **inclusion of three main BOF slag qualities**
- **removal of the** choice of **the oily mill scale treatment**

The same **indicators** of the previous superstructure have been considered and are related to: c**apital and operating costs, revenues, environmental impact, quality of the output products, efficiency of treatment processes**. These are the **objective functions**.

Materials and Methods – reMIND improved superstructure for by-product reuse optimization



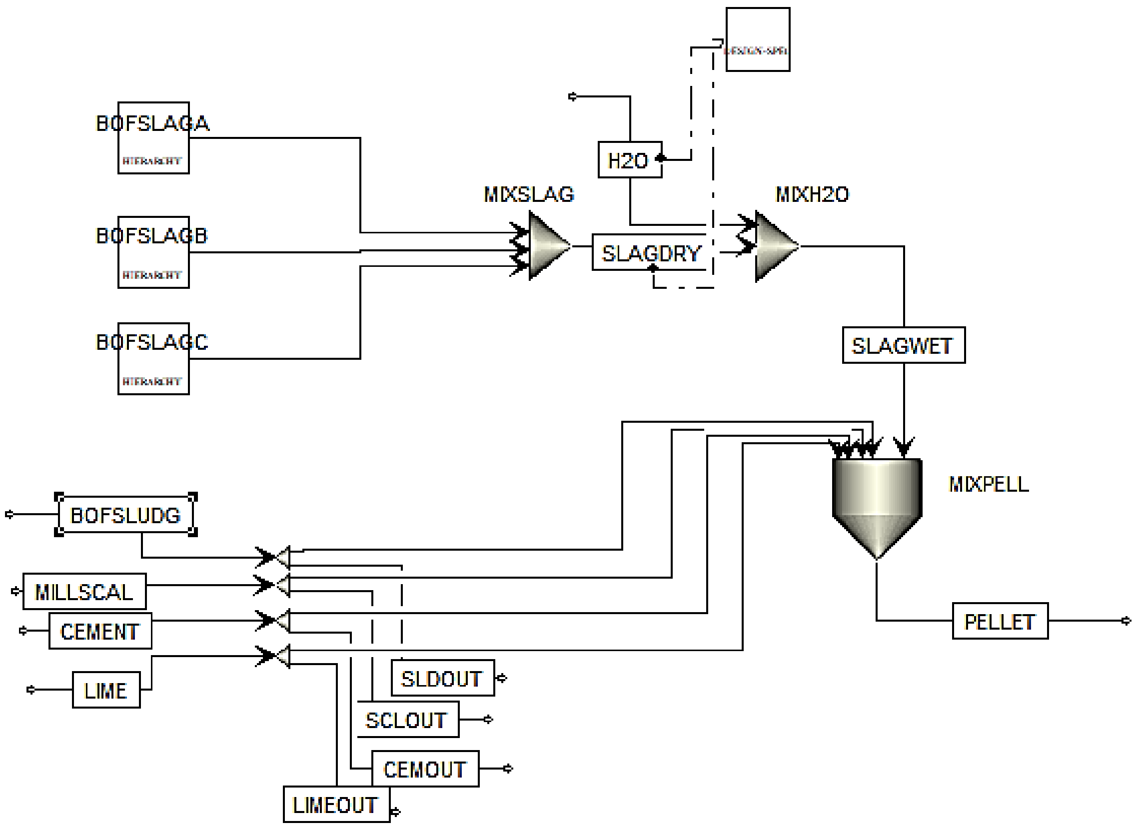
main improvements

The reMIND improved superstructure allows:

- identifying the best route for by-products reuse
- obtaining indications about the best BOF slag quality to be reused
- suggesting the best BOF magnetic separation dipending on the different slag qualities

Materials and Methods – Pellet mixture composition model

An Aspen Plus model has been developed in order to compute the composition of pellet mixture (a possibility to reuse internally by-products) that exploits the indications and by-product combinations obtained by the other two models



Materials and Methods – Connections between the three models

The three models can be used stand-alone or in cascade

BOF Slag Pre-treatment model

- It exploits also real data (e.g. by plant or by experimental trials)

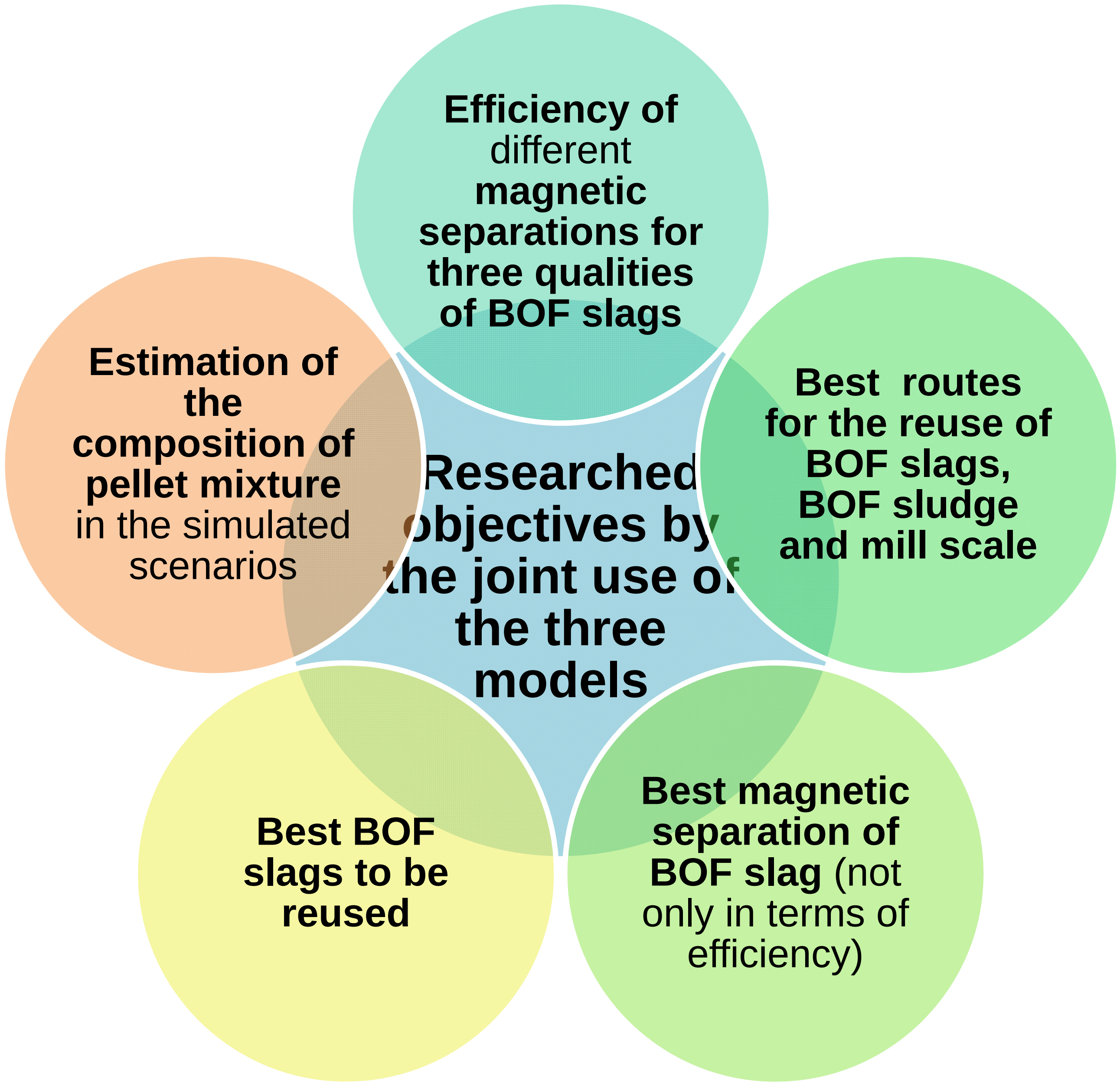
reMIND improved supestructure

- Data from real experimentations or from other simulations can be added

Pellet mixture composition model

- The obtained composition can be exploited to guide pellet production for internal use

Results and Discussion



Results and Discussion

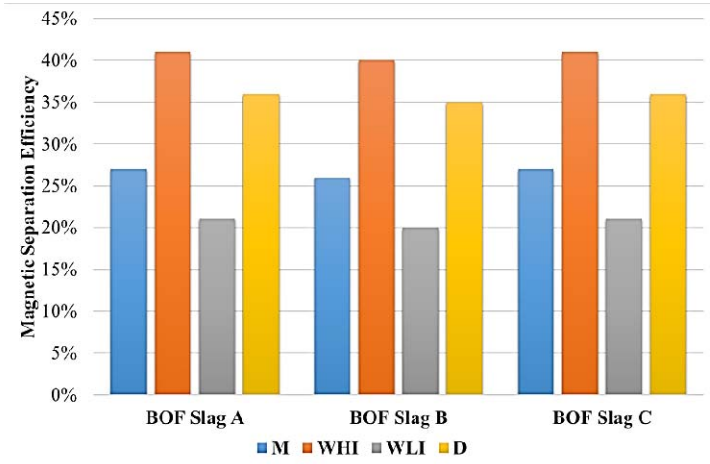
BOF Slag Pre-treatment Model has been exploited to evaluate the treatment of 3 qualities of BOF slags in the following configuration suggested by previous work:

1. cooling
2. grinding and sieving
3. two different magnetic separation steps
   - for coarse fraction
   - for fine fraction

A **simultaneous evaluation of different magnetic separation techniques** have been carried out

	Mass Percentage	BOF Slag A	BOF Slag B	BOF Slag C
CaO	wt %	41.8	47.3	40.3
SiO_2	wt %	12.3	12.6	13.4
Fe_{tot}	wt %	22.3	16.7	21.7
P_2O_5	wt %	1.0	1.6	1.1
Others	wt %	22.6	21.8	23.5

Treatment



Wet High Intensity Magnetic Separation appears the best tecnique in terms of efficiency to be used for the separation of the magnetic matter from all the three tested BOF slags

Results and Discussion

After that the results of the last simulations have been included in the superstructure as well as the others already included in the not improved superstructure, the new **reMIND superstructure** has been **exploited for** the following **two optimization studies**.

1. **O1 – multi-objective optimization that considers each indicators, except the quality index, in the objective function**

2. **O2 – global multi-objective optimization**

	External Reuse		Pelletization		Agglomeration		Disposal or Environmental Recovery	
	O1	O2	O1	O2	O1	O2	O1	O2
BOF Slag A	0 %	0 %	0 %	0 %	N.A.	N.A.	100 %	100 %
BOF Slag B	80 % (WLI)	60 % (WHI)	20 % (WLI)	40 % (WHI)	0 %	N.A.	0 %	0 %
BOF Slag C	21 %	0.6 % (WHI)	6%	0.4 % (WHI)	0 %	N.A.	73 %	99 %
BOF Sludge	N.A.	N.A.	100 %	100 %	0 %	0 %	0 %	0 %
Mill Scale	N.A.	N.A.	100%	0 %	0 %	100%	0 %	0 %

Results and Discussion

Mass percentage of by-products in pellet mixtures obtained after the optimization studies carried out through the reMIND supestructure

	O1	O2
BOF Slag A	0 %	0 %
BOF Slag B	30.2 %	60.7 %
BOF Slag C	9.0 %	0.6 %
BOF Sludge	38.5 %	38.7 %
Mill Scale	22.2 %	0 %

Results and Discussion

The obtained **pellet mixtures** have been included in the pellet mixture composition model in order to know their **chemical composition**

		Fe_{tot}	SiO_2	CaO	C	P_2O_5	Others
O1	wt %	46.4	5.2	19.5	2.8	0.4	25.7
O2	wt %	33.9	7.6	28.1	3.0	0.7	26.7
Winning formula of previous real trials	wt %	30.9	8.5	29.5	2.1	0.6	28.4

- **The mixture O1 has a higher amount of iron →** mill scale is included in the mixture but it is important to take into account results from previous works: **mill scale decreases the quality of pellet**
- **The composition of O2 is perfectly in line with the one tested in a previous work →** only small differences in terms of iron content

Conclusions

Previous research works on steelworks by-product pre-treatment and reuse **have been continued and improved in order to make more holistic analyses**

A **combination of modelling, simulation and optimization approaches** has been exploited

A **suite of tools** have been provided in order to:

- make scenario analyses on **BOF-slags pre-treatments**
- find the **best destiny of some by-products and wastes** coming from steelworks
- calculate the **composition of by-products mixture to be used in pellet production** for an internal reuse

The tool suite can be easily used by industrial staff in order to make preliminary investigations devoted to extend the borders of experiments and to pave the way to most suitable field tests for the optimization of by-products/waste management

Conclusions

Scenario analyses have been carried out by using the deleloped tools

- The **Wet High Intensity magnetic separation** has shown to be the **most suitable** separation method **for iron contained into the BOF slag**;
- **By-products reuse is often preferred** to disposal or environmental recovery;
- **Only some BOF slags appear suitable for pellet production**;
- **BOF sludge is a good component of pellet mixture**;
- **Mill scale is preferred to be used directly in sintering process** because, although it increases the iron amount in pellets, it affects negatively the quality of pellets (as proved in previous trials)
- The “global optimized” pellet composition obtained combining the three developed tools is very similar to the composition of “winning pellet formula” real tested in previous experimentations.

Future Works

The suggestions provided by the ''tool package'' can lead to more targeted field trials for practices showing a relevant potential for saving natural resources with consequent significant environmental and economic advantages

Further pre-treatment models for other by-products can be added to the suite

Optimization superstructure can be increased according to the needs

Similar approaches and tools can be transferred to other industrial fields

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