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Cross-fertilization of knowledge and technologies for fostering steelmaking decarbonization through industrial symbiosis

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Introduction and scope of the presentation

Exchange, use and valorisation of by-products between different industrial sectors (**symbiosis**) reduces the consumption of fossil fuels and non-renewable materials as well as the cost for treatments and waste disposals, contributing to the decarbonisation.

However this implies modifications (some times heavy and risky) of the conventional processes.

To be competitive and accepted, industrial symbiosis solutions must guarantee same (or improved) performance in terms of **productivity**, **quality** and **costs**.
This requires adaptation and developments of technologies.

This presentation – without entering in technical details –
shows examples of development of efficient symbiotic relations between steel and other industrial sectors,
realized **adapting and improving technologies**,
with a virtuous exchange of technical knowledge, in a **technology cross-fertilisation approach**.

Case 1. Symbiosis between electrical steelworks and territory

Italian steel industry is characterized by a large number of steelworks based on Electric Arc Furnace (EAF), distributed in areas at large density of population.

To implement symbiotic relation between wastes from the territory and clean energy from the steelwork has many positive impacts:

- Reduces of the energy cost and environmental impacts of industrial and territory wastes
- Facilitates the decarbonization of the steel sector
- Reduces the non renewable energy consumption, recovery and utilising thermal wastes from the steelworks,
- Favours the acceptance of the industrial activities

The following examples shows examples of exchange of materials and energy between steelworks and territory.

Use of residues from the territory in Electric Arc Furnace (EAF)

In EAF, steel scraps are melted to produce new liquid steel.
Although most of the energy is electrical, natural gas and coal are regularly used for improving productivity and reducing consumption.

The reduce CO_2 emissions, non recyclable plastic and biomass from agriculture residues could replace fossil fuels.

These alternative materials are largely available and today are essentially landfilled.
However to compensate the costs for collection and supply, and to promote the development of the necessary infrastructure, the use of these materials in EAF and the process performance must be competitive with natural gas and coal.

For this purpose, technological solutions for their production and preparation have been developed in order to guarantee easy handling and charging in EAF and positive impact on the process performance.

Use of residues from the territory in Electric Arc Furnace (EAF) – Example 1: plastics

Technologies for compacting, forming, modelling plastic materials are currently applied in the plastic industry. But not usually for wastes.

In the Polynspire project extrusion and granulation techniques have been studied to realise a materials with adequate properties for injection in EAF.

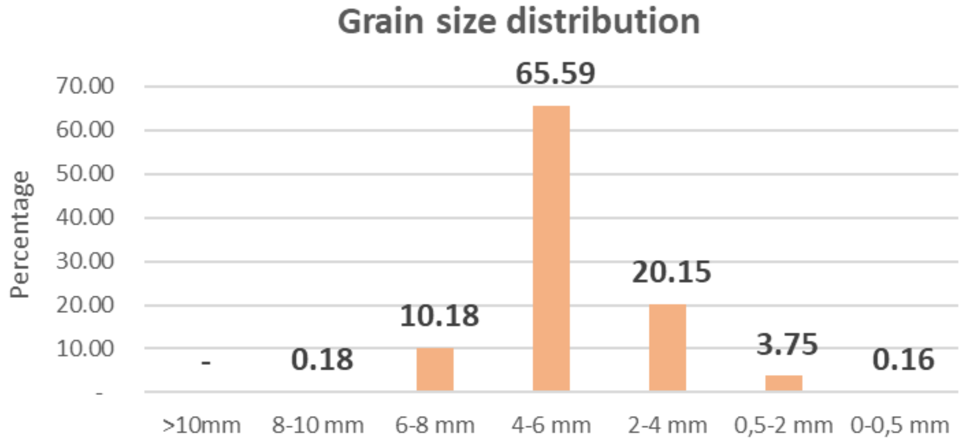
The aims of the pre-treatments were:

- Smooth injection of the quantities required by the process,
- Controlled heating behaviour to avoid rapid volatilisation favouring, on the contrary, carbon dissolution in the metal bath.

Polynspire - Demonstration of innovative technologies towards a more efficient and sustainable plastic recyclingHorizon 2020, grant agreement no. 820665
https://www.polynspire.eu/

Use of residues from the territory in Electric Arc Furnace (EAF) – Example 1: plastics

The material used is a mix of plastic as a final residue of the plastic packaging collection, sorting and recycling chain (Mixed Plastic Waste)

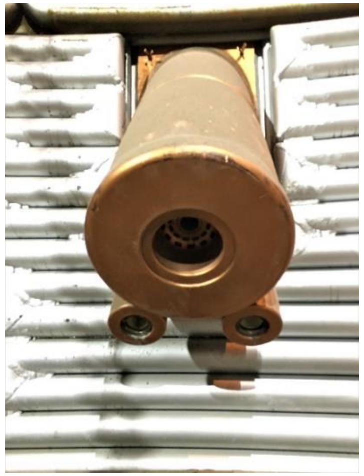


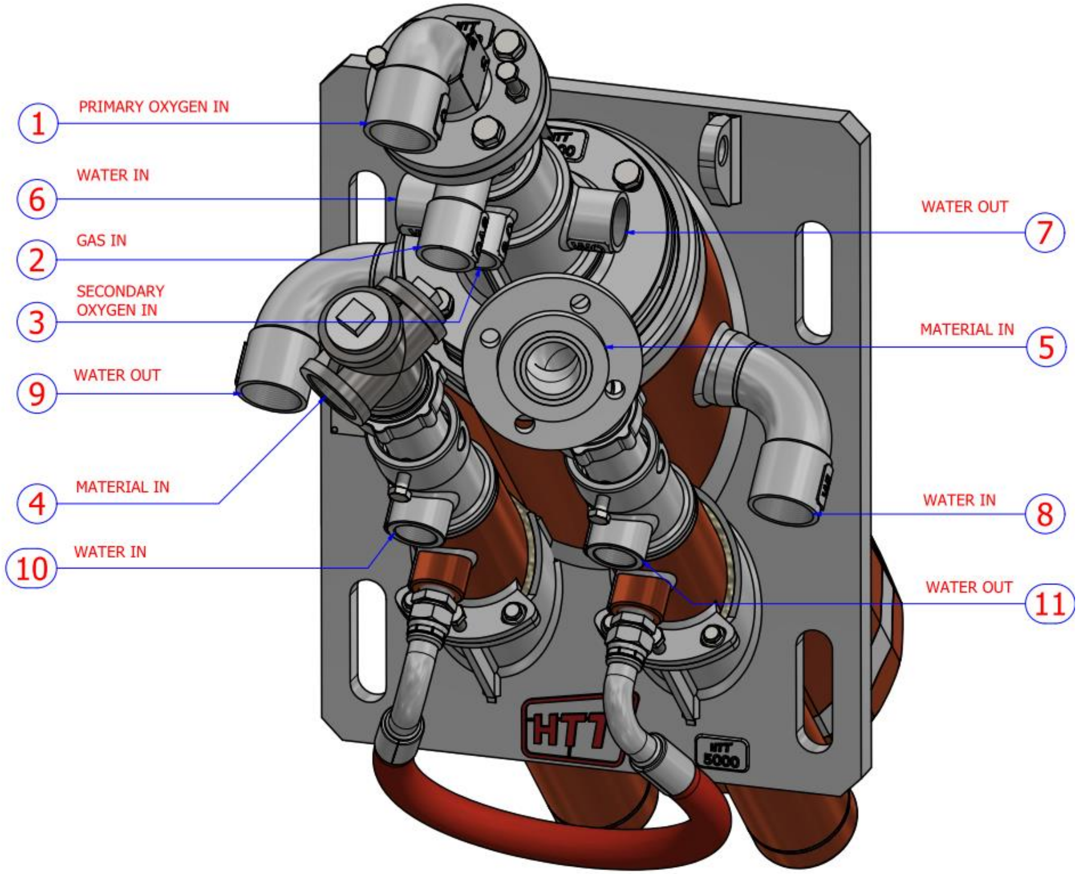
Transformed in new product at controlled grain size with mechanical and physical-chemical properties suitable for the utilization in the EAF process.

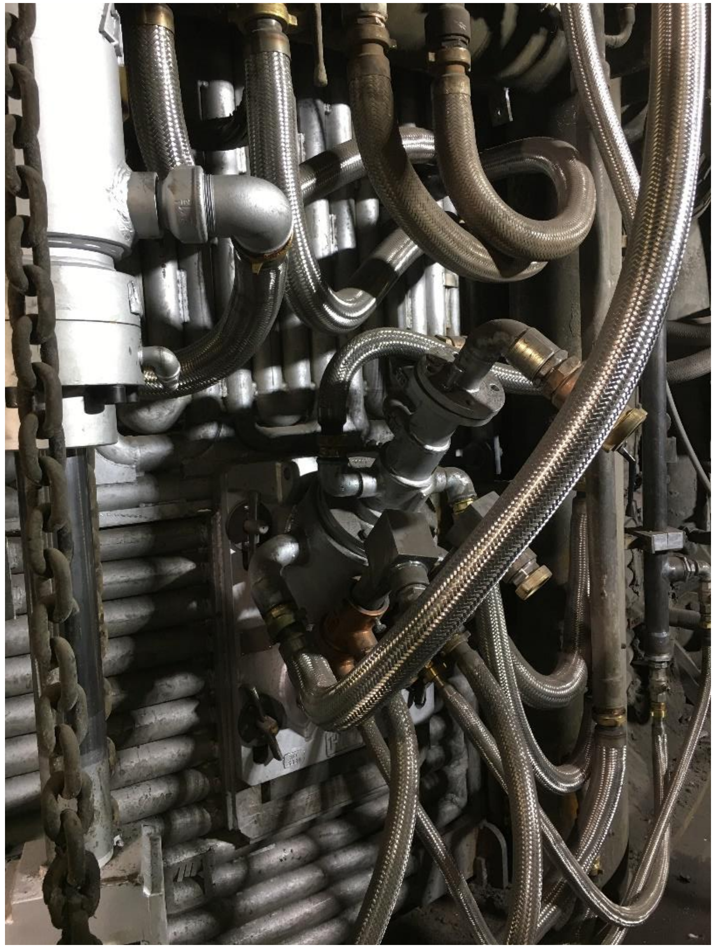
Polynspire - Demonstration of innovative technologies towards a more efficient and sustainable plastic recyclingHorizon 2020, grant agreement no. 820665
https://www.polynspire.eu/

Use of residues from the territory in Electric Arc Furnace (EAF) – Example 1: plastics

A dedicated system has been developed to inject the granulated plastic inside the slag bath.
The low molecular weight components volatilize, favouring the foaming of the slag (useful to the process).
High carbon components dissolve in the steel bath, supplying dissolved carbon (to control final steel quality)







Polynspire - Demonstration of innovative technologies towards a more efficient and sustainable plastic recyclingHorizon 2020, grant agreement no. 820665
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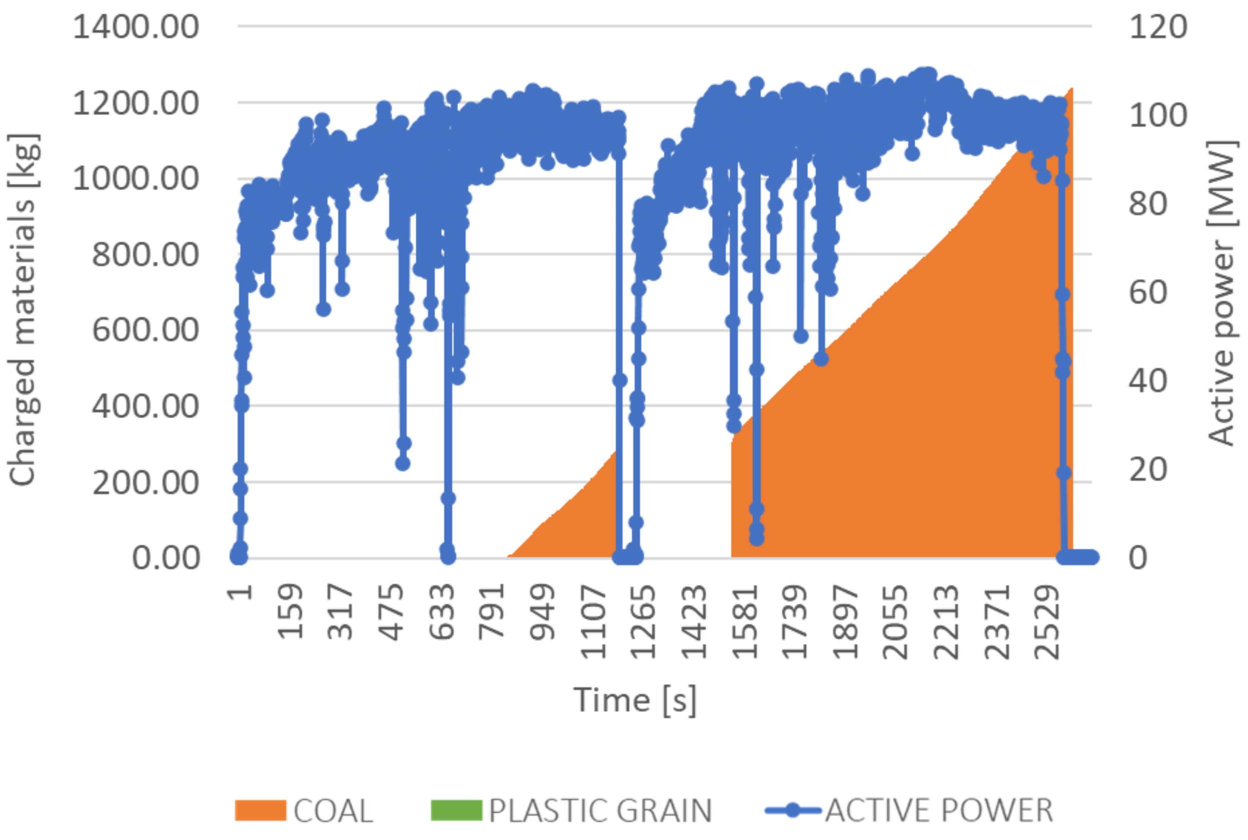
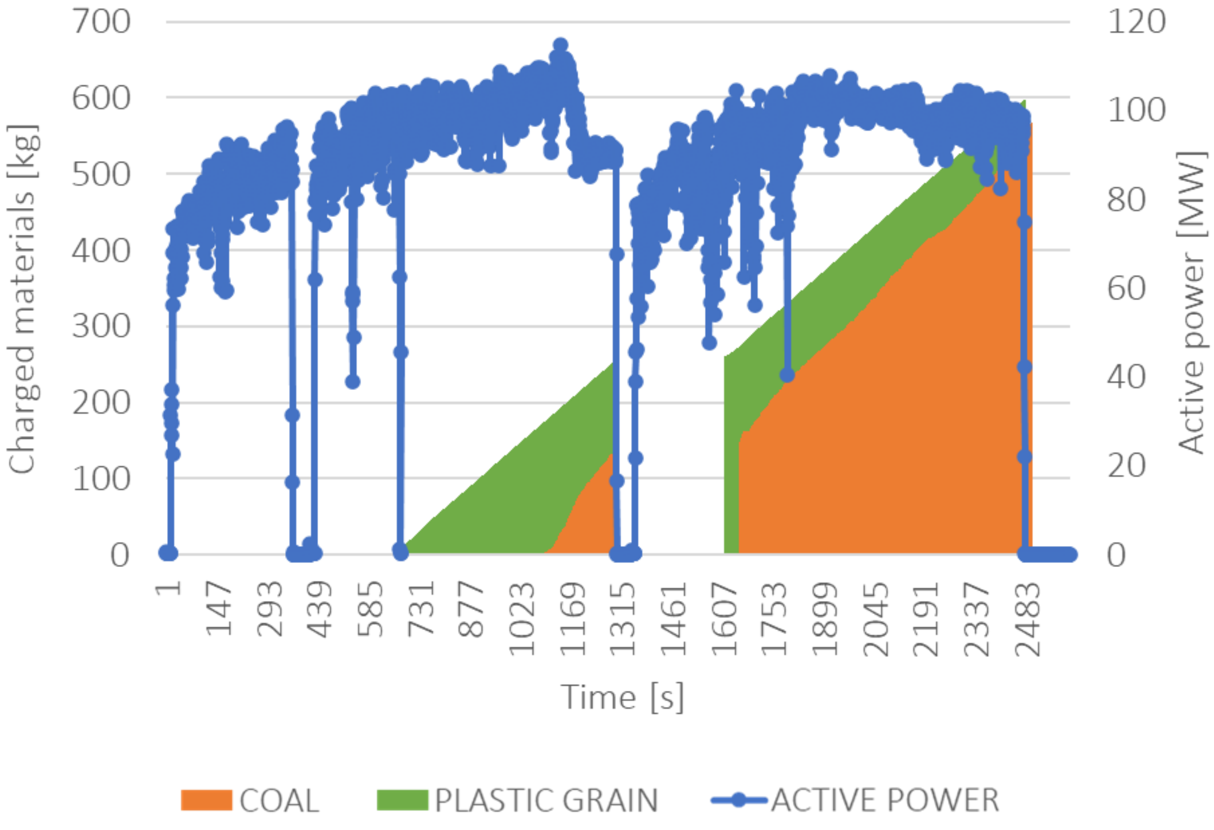
Use of residues from the territory in Electric Arc Furnace (EAF) – Example 1: plastics

The modified new plastic material, replacing 50% coal, allowed to perform the process with same performance, as proved by the same trends of the active power



<u>Reference</u>: 1200 kg coal injected during a heat



<u>50% substitution</u> - 570 kg coal and 600 kg plastic during a heat

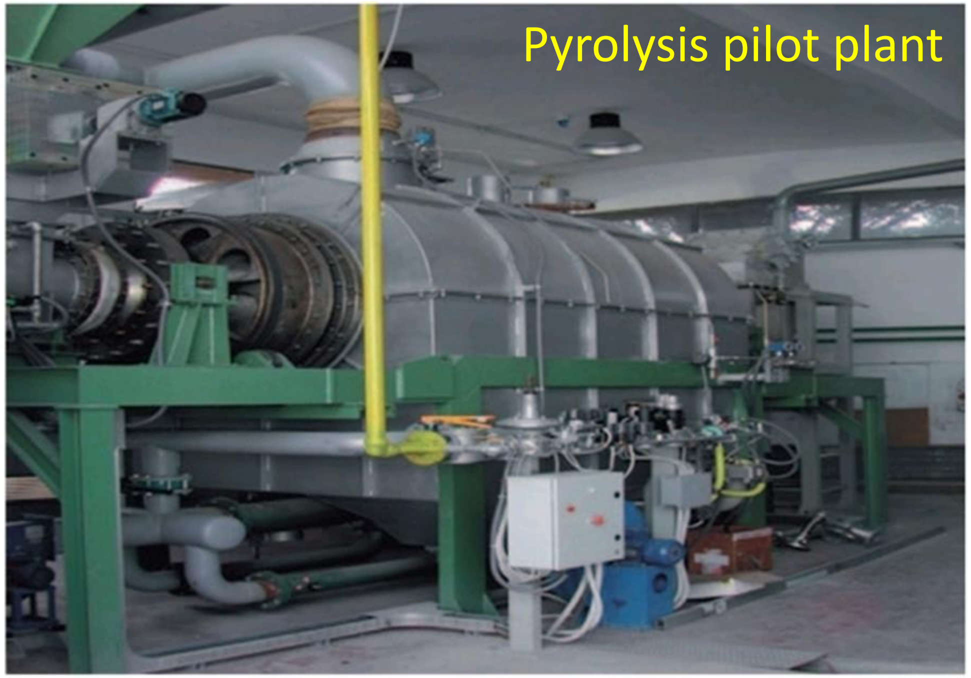
Polynspire - Demonstration of innovative technologies towards a more efficient and sustainable plastic recyclingHorizon 2020, grant agreement no. 820665
https://www.polynspire.eu/

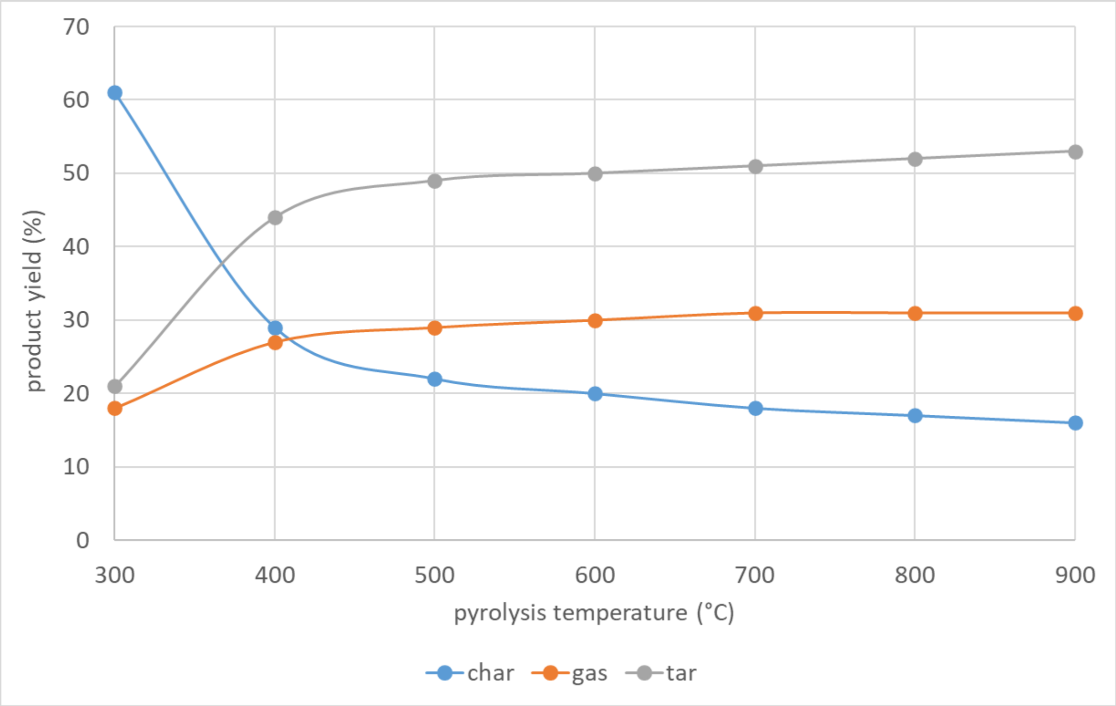
Use of residues from the territory in Electric Arc Furnace (EAF) – Example 2: biomass

Char from wood and wood industry residues is currently produced for civil applications (e.g. pellets for fires). But not usual for making char to be injected in EAF.

In the projects GreenEAF and GreenEAF2 pyrolysis technologies have been adapted to produce char and syngas from **agriculture residues** to be used instead of coal and natural gas in EAF.

Different ratios syngas/char and char with different properties (volatile matters, porosity) can be produced by regulating the pyrolysis conditions (temperature and atmosphere), allowing to supply the most adequate materials for different EAF processes requirements.



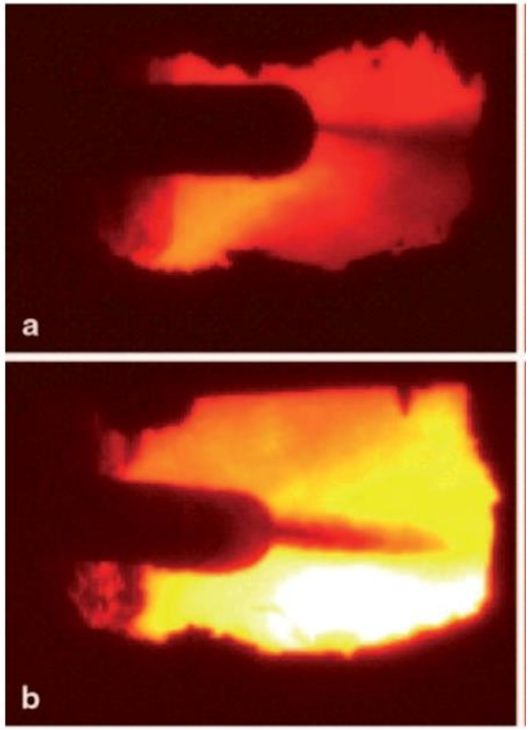


Yield of the products of pyrolysis as a function of temperature

GreenEAF- Sustainable EAF steel production, RFSR-CT-2009-00004, Final Report
GreenEAF2 - Biochar for a sustainable EAF steel production, Final Report, EUR29517

Use of residues from the territory in Electric Arc Furnace (EAF) – Example 2: biomass

Adjusting pyrolysis conditions and with appropriate post-treatments, char in different formats and different characteristics (density, volatile matters) have been realized to be charged in different modalities according to the process needs and plants characteristics



Powder char (at higher volatile matters) injected into slag (producing foam)

Char (at low volatile matters and low porosity) in pellets and briquettes for charging with basket

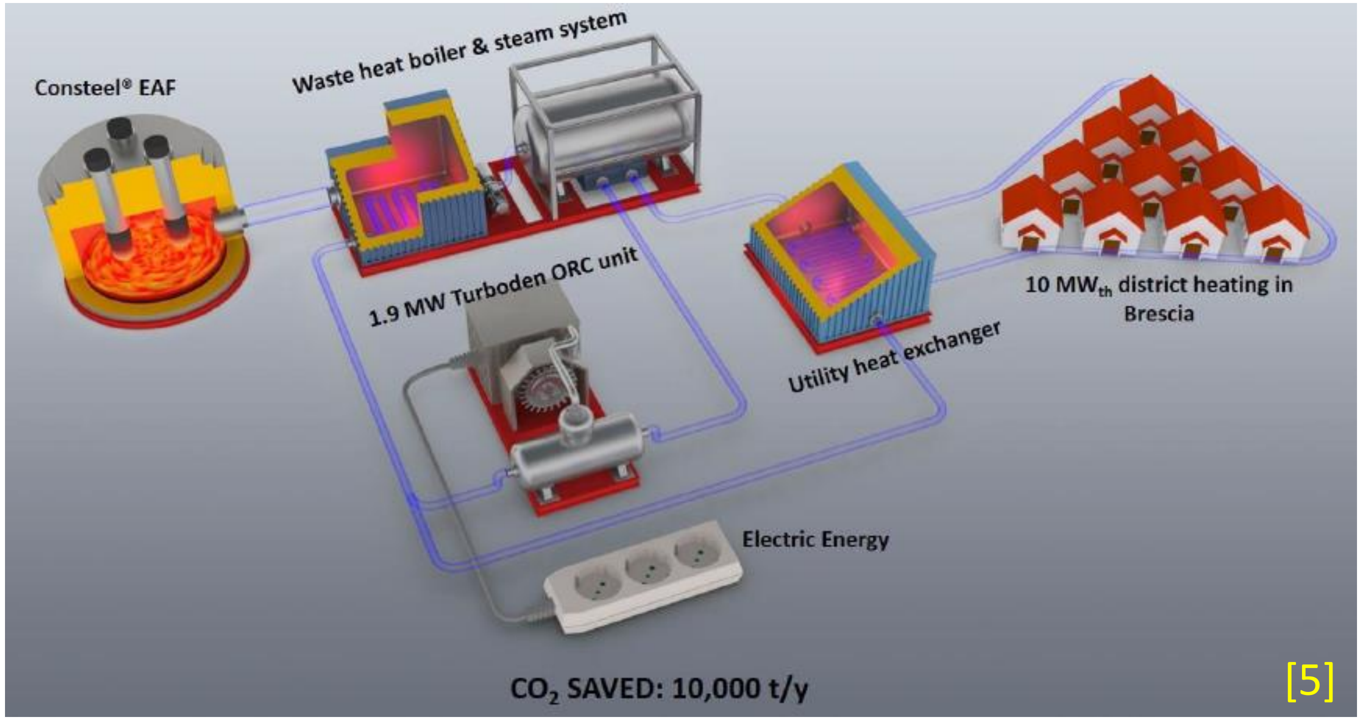
The use of char from biomass residues is now a consolidated technology linking in stable symbiosis steelworks and territory

GreenEAF- Sustainable EAF steel production, Final Report EUR 26208
GreenEAF2 - Sustainable EAF steel production, Final Report, EUR26208

Transfer of energy from the steelworks to the territory

The EAF employs 650-750kWh/t of steel of chemical electrical energy. In a conventional process, about 25-30% of this energy is dissipated in the process gas. New heat recovery systems allow significant recovery of the process gas energy producing thermal or electrical energy or both to be distributed in the territory.
In a case in Brescia, a steelworks (ORI Martin [1]) inside the city has installed since 2016 a recovery system (Irecovery® [2]) able to produce thermal energy in winter (for tele-heating) and electrical energy in summer [3] (EU project Piatagoras [4])

WHRU	• Average flue gases (dry) 120.000Nm³/h • Average inlet/ outlet T : 440°C/200°C • Nominal thermal capacity: 16MW$_{th}$ • Average generation: 92.800MWh$_{th}$/year
STEAM ACCUMULATOR	• Operating P and T: 10 - 24 barg /185 – 224°C • Storage capacity: 3MWh$_{th}$
ORC (2018)	• Average efficiency: 17 % • Nominal output power: 1.800kWe • **Electricity gen. (6-7/2018): 1.253 MWh**
DH SYSTEM (2018)	• Supply /return T to DH: 95-120°C/ 60-85°C • **Thermal energy gen. (10/2017-6/2018): 15.800 MWh$_{th}$/yr**



[1] N.Monti et al., ORI Martin: the new environmentally friendly and energy efficient scenario. operative results of the new consteel® evolution and irecovery® system; La Metallurgia Italiana - n. 2 2017
[2] https://tenova.com/technologies/irecovery-system
[3] https://www.turboden.com/case-histories/1162/ori-martin
[4] PITAGORAS, Sustainable urban Planning with Innovative and low energy Thermal And power Generation frOm Residual And renewable Sources; ENER/FP7EN/314596/"PITAGORAS, Final report 2017
[5] Waste Heat Recovery in Industry: Technologies and Applications. RFCS LowCarbonFuture. INDustrial TECHnologies 2018. Vienna, October (2018).

Case 2. Valorisation of steelmaking by-products

Steelmaking processes produce large amount of by-products (slag, scale, refractories dust, sludges) rich in iron and other valuable metals (Zn, Ni, Cr).

The recycling of these materials directly in conventional steelmaking processes, or in dedicated reactors have been proposed and experimented.

The drawbacks of these solutions are:

- The energy cost
- The large amount of produced slags (comparable with the amount of the original by-products)

Both these problems can be solved transforming the slag in high added-value materials.

The slag produced from the recycling of appropriate mixes of steel making residues can be vitrified in a rapid quenching process and transformed in valuable materials for producing added values products.

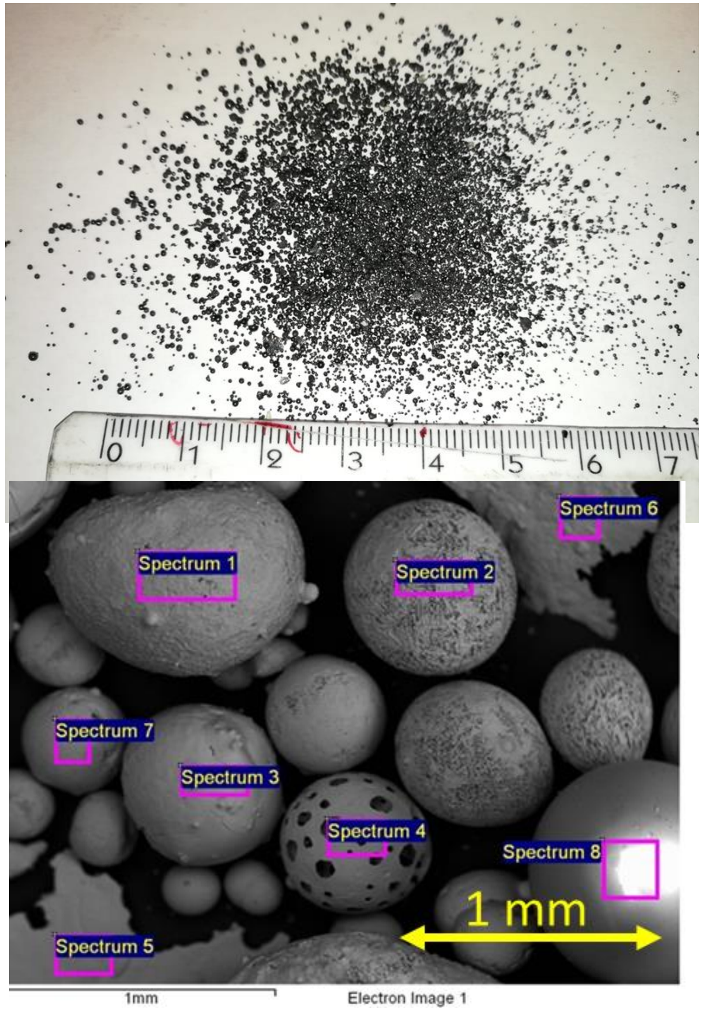
Vitrification techniques are currently used for producing mineral wood for insulating panels (from basalt) and more recently for dry granulation of ironmaking and steelmak8ng slags. But not usual for slags from wastes.

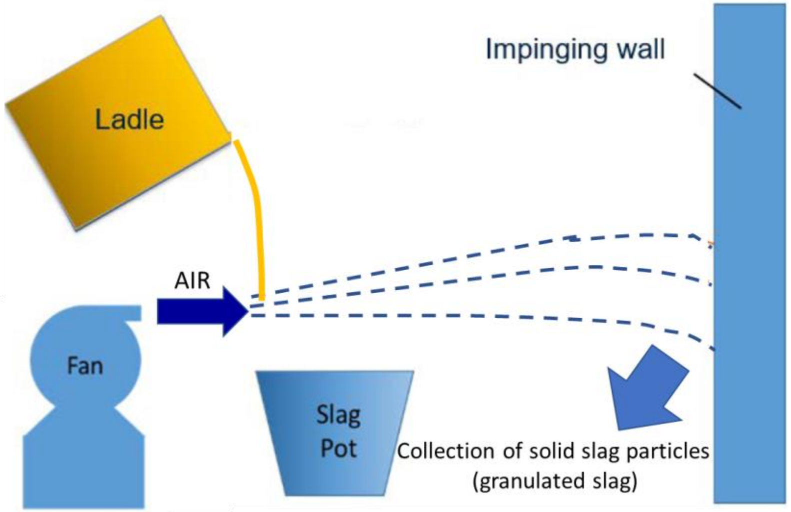
In the projects 3Dslag and Ecoslag innovative techniques of slag granulation have been developed to produce vitreous slags suitable for further applications, at high added value.

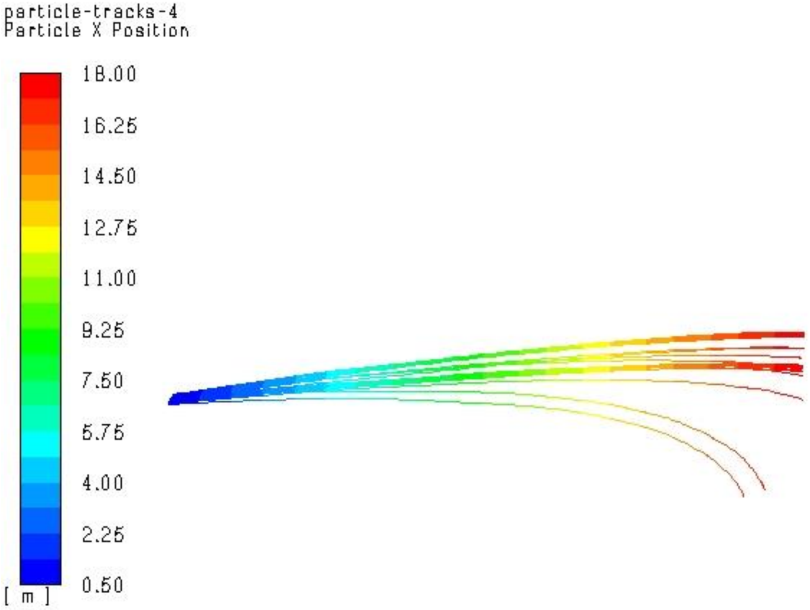
3Dslag project, https://www.3dslagproject.it/

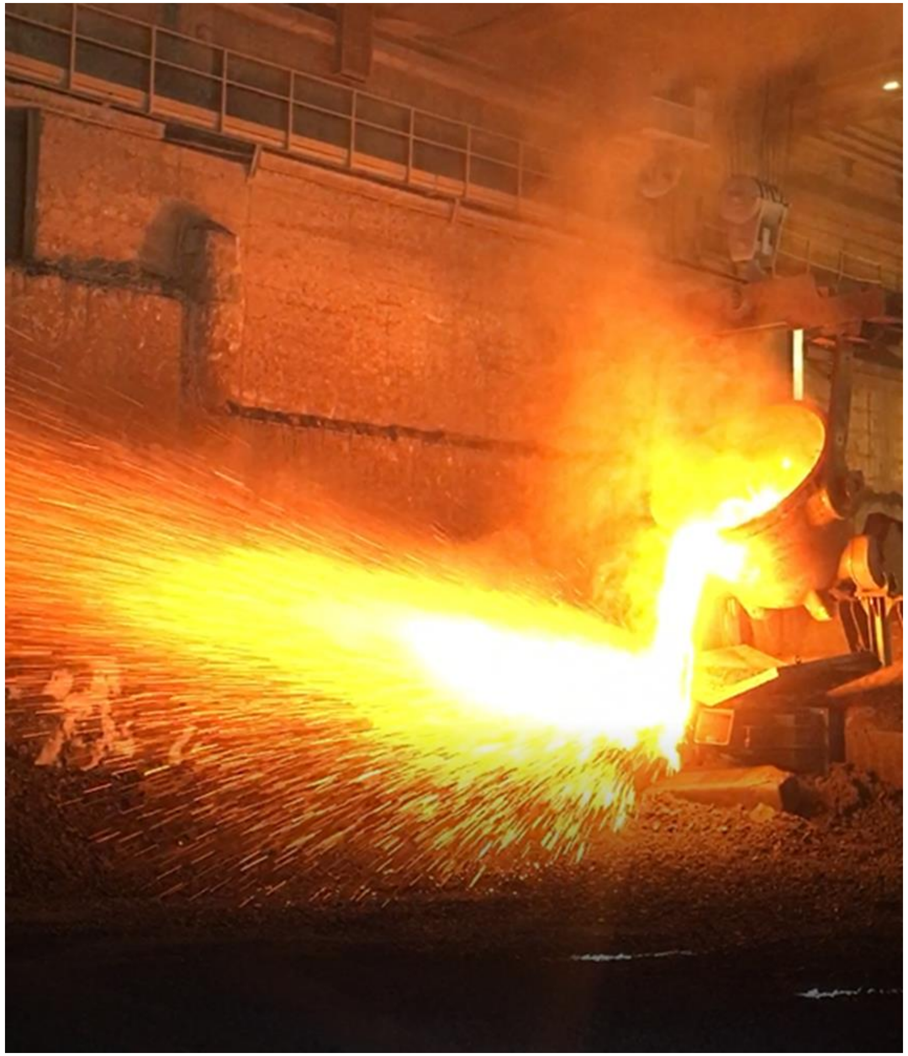
Case 2. Valorisation of steelmaking by-products

Scheme, CFD modelling and industrial test of dry-slag granulation for vitrification of steelmaking slags (pictures below)









3Dslag project, https://www.3dslagproject.it/

Case 2. Valorisation of steelmaking by-products

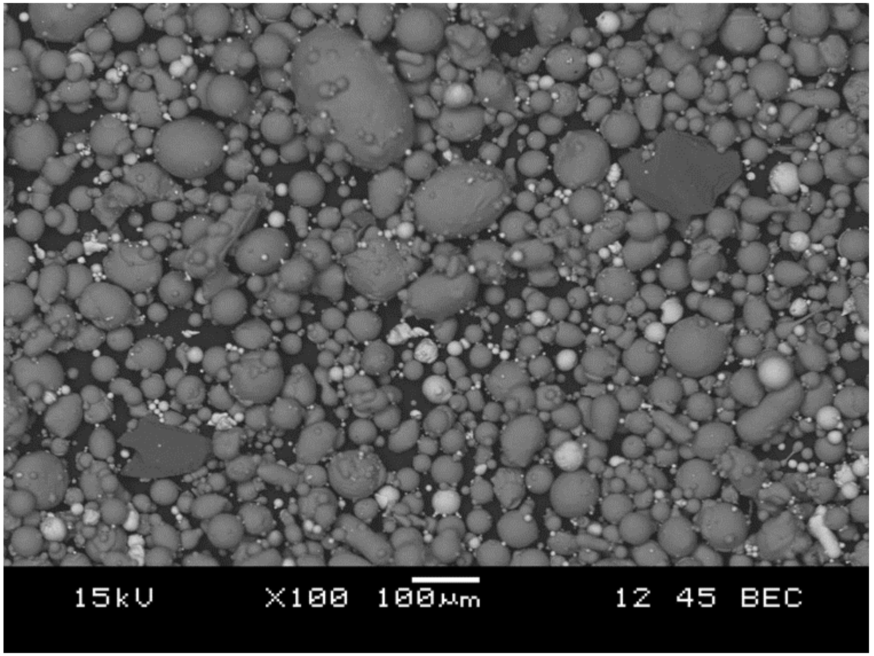
A more futuristic objective is the transformation of the slag in very small vitreous particles to be used for 3D printing of ceramic components.

The process is carried out by modifying and adapting the technology for producing metallic powder by Vacuum Induction Gas Atomisation (VIGA).

The solution has been tested at pilot plant.

Example 2. Valorisation of industrial residues

Vacuum Induction Gas Atomizer (VIGA) plant, currently used to produce metallic powders, have been modified and applied to produce atomized amorphous slag to be used for 3D printing of ceramic components



Amorphous slag particles to be used as “ink” for 3D printer

VIGA plant

Slag atomization

3Dslag project, https://www.3dslagproject.it/

Example 2. Development of components from granulated slags for steelworks and territory

3D printing of particle from slag can be used to produce:

- Special refractory components at higher properties for steel processes, reducing energy cost and long time for standard refractory manufacturing.
- Special flexible industrial constructions (for storing, handling, protection of raw materials and products) at lower energy cost.
- Constructions and special components for the territory

Establishing in this way a complex industrial symbiosis including:

- Steel industry
- Firms for slag treatments (atomisation)
- 3D printer developers
- Companies for components and construction printing

The realization of this future vision, strongly depends on the development of new technologies integrating knowledge and solutions from the various sectors.

(*) https://d-shape.com/

Concluding remark

The presented examples show applications of solutions derived by already existing technologies, with modifications making them fruitfully applicable in different sectors,
with benefits for the general final goal of the decarbonisation of the industry.

The lesson learned from these examples is that the developments of symbiotic industrial relations between different sectors, besides the exchange of materials, also implies (may be requires) exchange of knowledge and cross-fertilisation of technology.

To stimulate, create, use and recombine new and existing knowledge, the interaction and connectivity of multiple actors is required, establishing industrial and technological symbiosis.

The end

Thank you