SESSION 3: 10:30–10:45

ESTEP workshop

SecCarb4Steel

Preparation and use of biogenic and non-biogenic secondary carbon carriers (SCC) in processes for iron and steelmaking

BioCoDe

Biomass for cokemaking decarbonization. Objectives and first project results

Alessandro Vecchio[1]

[1] Acciaierie d'Italia

Research Fund for Coal & Steel

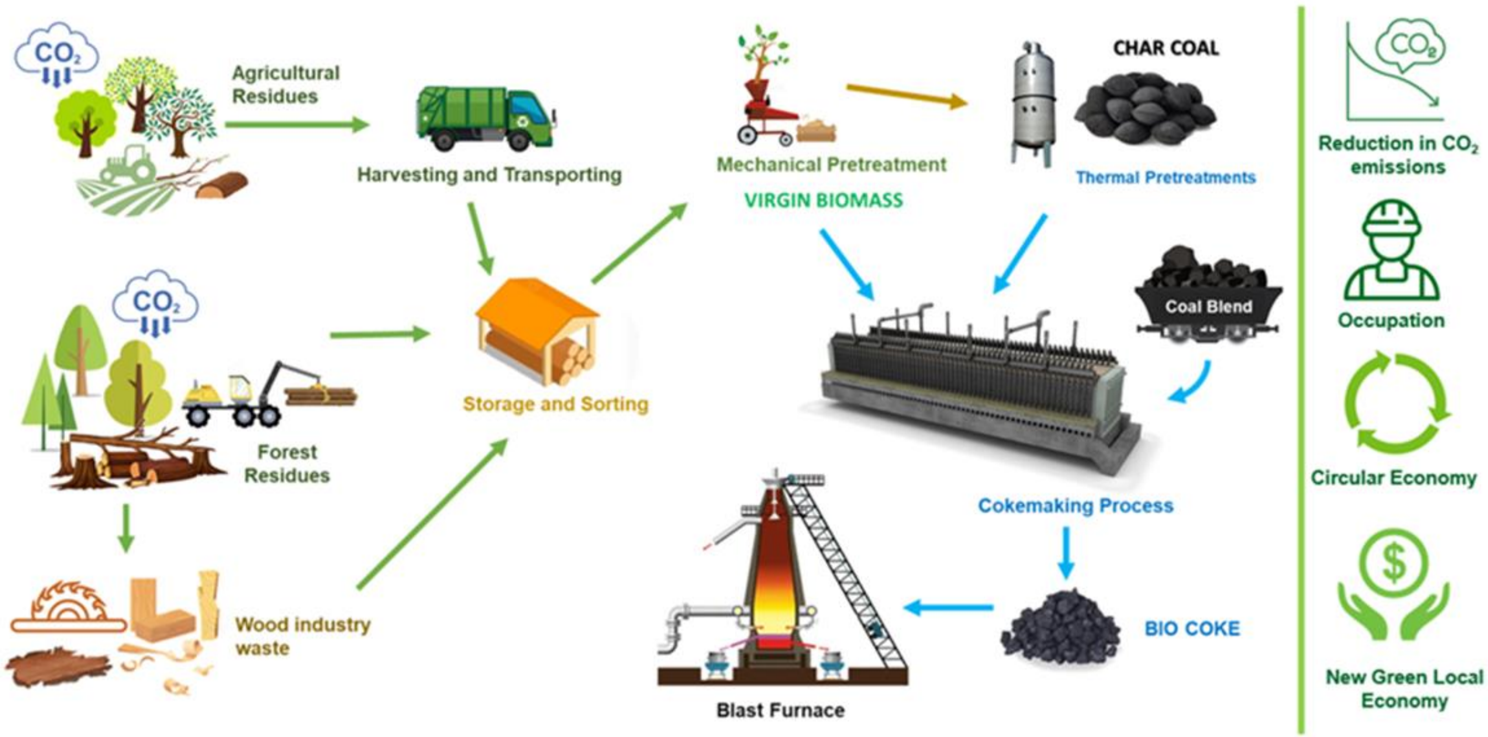
Acciaierie d'Italia

Introduction to «BioCoDe» project

The steel industry belongs to the '**hard to abate**' industrial sector. Its high CO_2 emissions and limited technological options for decarbonization represent a significant challenge in the transition to a low-carbon economy.

The **BioCoDe project**, funded by the **RFCS**, aims **to reduce CO_2 emissions** from integrated steel production.

The project **seeks to validate,** for the first time on **an industrial scale (TRL** 7), the introduction of up to **10 % biomass (or biochar) into the fossil mix** in metallurgical coke ovens. This approach not only contributes to the environmental sustainability of coke making process but also promotes local economic and social development.



Project number: 101112264
Call: RFCS-2022

Project starting date: 1 July 2023
Project duration: 42 months

BioCoDe

Research Fund for Coal & Steel

Acciaierie d'Italia

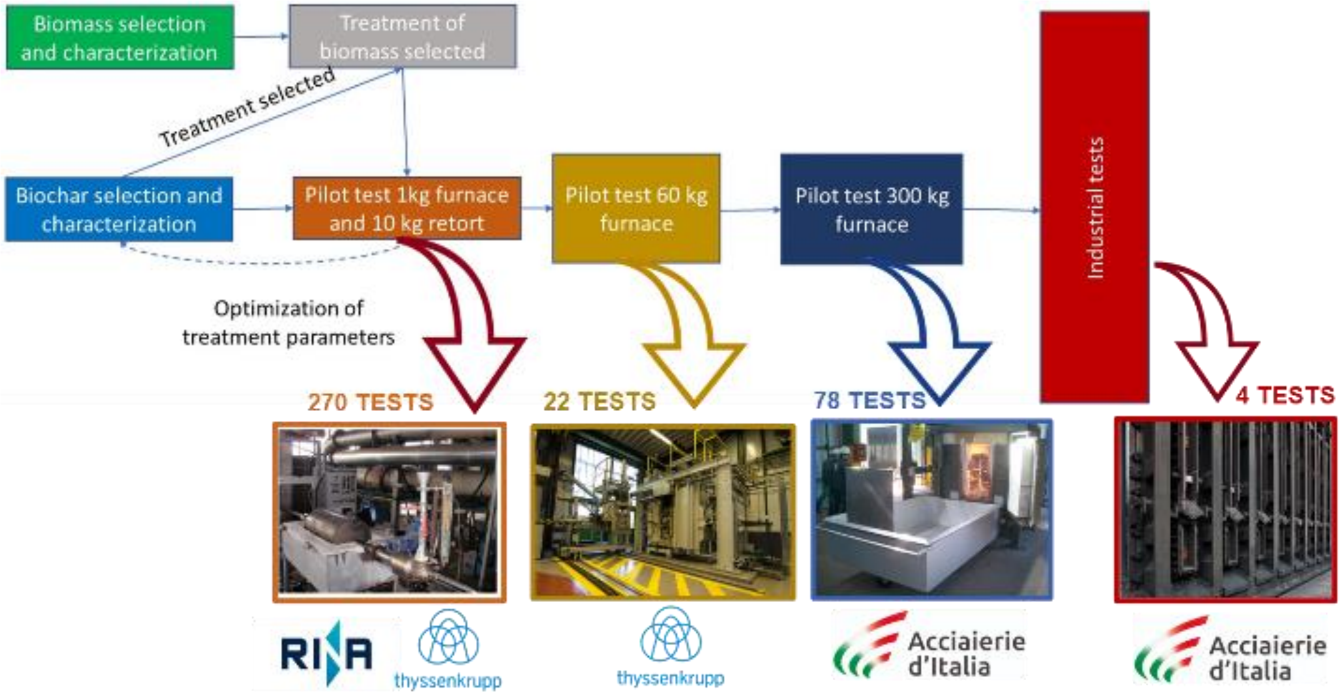
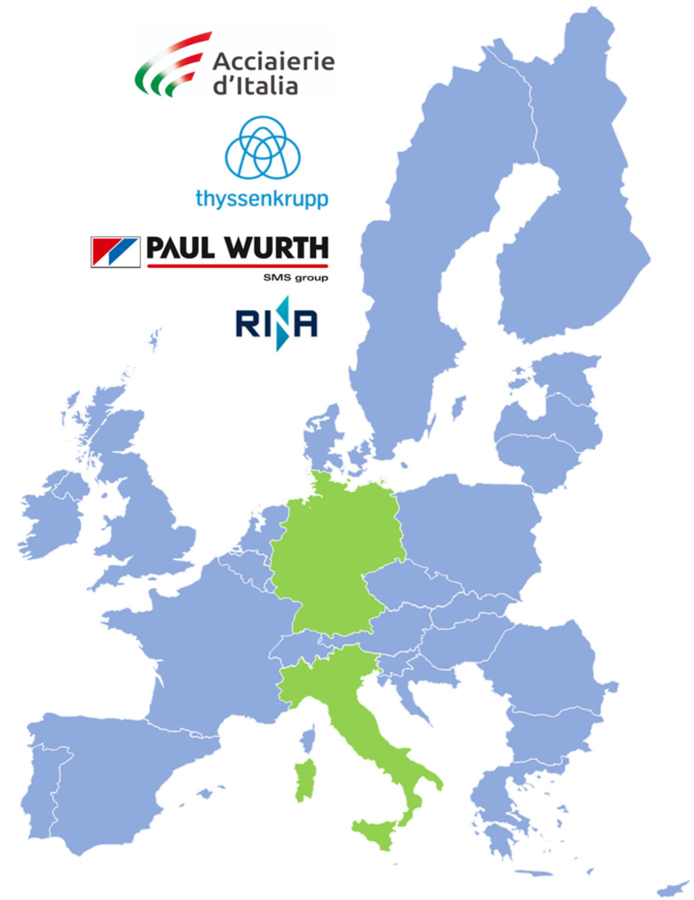


***Fig. 2** – Schematic representation of the experimentation plan for biomass use in coking blend*



The project includes 4 principal phases:

- **selection and characterization of the biomass/biochar** to be tested
- **lab scale test** campaign;
- **pilot-scale test** campaign in a **10 kg, 60 kg,** and **300 kg coke oven**.
- industrial-scale phase in which the best solutions will be tested.

The project involves several international partners from the sector.

BioCoDe

Research Fund for Coal & Steel

Acciaierie d'Italia

First step: biomass characterization

With its porous structure and high mechanical strength, Coke is essential in integrated steelmaking as a reducing agent and fuel in blast furnaces. It is produced by pyrolyzing coking coal in ovens at 1000 – 1200 °C, without oxygen.

To reduce the coke production process's carbon footprint, in BioCooDe, **the most available biomass in the Taranto steel plant area (ADI)** was selected and characterized. These include 9 types of biomass, 3 of which derive from wood waste (pallets, fruit boxes), 5 from agro-forestry residues, and 1 (pomace olives) from transformation processes.

- The biomass, except olive pomace, was chipped and then finely ground for analysis.
- **A coal blend was used as a reference for the characterization.**

Fig. 3 *– (a) Pallet; (b) Pine; (c) Olive branches; (d) Olive trunks; (e) Boxes with plywood bottom; (f) Boxes with chipboard bottom; (g) Olive pomace; (h) Vine; (i) Straw*

BioCoDe

Research Fund for Coal & Steel

Acciaierie d'Italia

First step: biomass characterization

		Reference Standard
Elemental analysis	Sulfur	ASTM D4239 -18e1
	Carbon	ASTM D5373 -21
	Hydrogen	UNI EN ISO 21663:2021
	Oxygen	Calculated
	Nitrogen	UNI EN ISO 21663:2021
	Chlorine	UNI EN 15408:2011 + UNI EN ISO 10304-1:2009
Immediate Analysis	Moisture, Ash, Volatile Matter, Fixed Carbon	ASTM D7582-15
Bulk Analysis	Bulk Determination of Ash Content	Internal method derived from ISO 1171:2010
	Bulk Determination of Moisture	Internal method derived from ISO 589:2008
Ash chemistry	Ash Chemistry	ASTM D4326-13
	Sulfur Oxide	ASTM D5016-16
Calorific Value		ASTM D5865/D5865M -19
Technological tests	Plasticity - Gieseler Plastometer	ASTM D2639/D2639M -22
	Dilation - Audibert Amu Dilatometer	ISO 349:2020

***Table 1** – Biomass characterization*

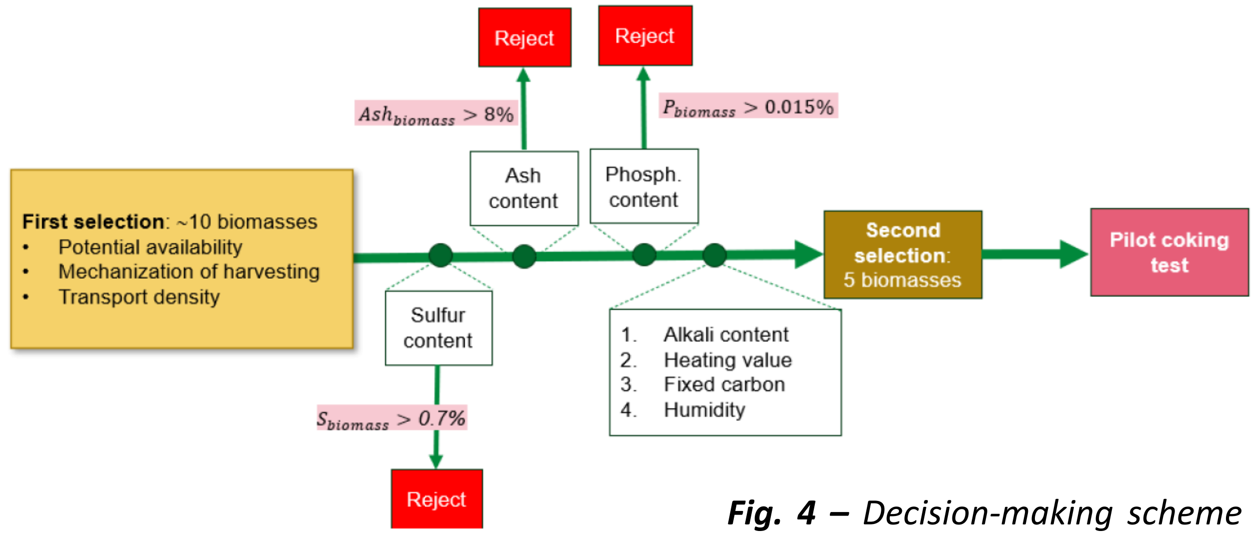


***Fig. 4** – Decision-making scheme for biomasses selection*

	Limits	Pallet	Pine logs	Olive twigs	Olive tree trunks	Wooden crates	Particle board crates	Olive pomace	Vine shoots	Straw	Coal blend
Ash (wt%)	<8%	0.3	0.8	3.7	3	1.2	4.8	3.1	2.7	9.1	8.7
S (wt%)	<0.7%	0.04	0.03	0.07	0.14	0.07	0.04	0.06	0.08	0.13	0.66
P (wt%)	<0.015%	0.003	0.008	0.072	0.011	0.010	0.023	0.097	0.157	0.085	0.0012
Alkali (wt%)	-	0.019	0.056	0.424	0.223	0.082	0.358	0.963	0.233	1.457	0.0015
HHV (MJ/kg)	-	18.8	19.7	20.5	19.7	19.3	19.3	19.7	18.8	17.6	32.3
Fixed Carbon (wt%)	-	18.7	33.4	18.4	24.8	20.8	21.2	15.3	20	18.8	63.8
Moisture (wt%)	-	9.9	28	33.6	15.5	12.2	11.8	56.1	41.3	12.2	7.1

***Table 2 –** Biomass comparison based on the identified selection scheme*

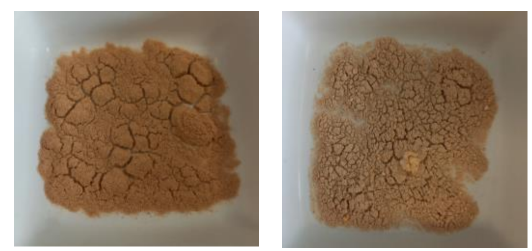


***Fig. 5** – Biomass ashes*

BioCoDe

First step: biomass characterization

1. **Biomass can replace fossil coals in coke production** but reduces the yield due to its **higher moisture** content and **lower fixed carbon**
2. High **O/C and H/C ratios** imply **lower** biomass **reactivity** and lower **calorific value**
3. Biomass has a **lower ash content** than fossil blends, but a **higher volatile matter** content
4. Biomasses contain **significant amounts of alkalis** (Na_2O and K_2O), **low sulfur** content, and, in some cases, **higher levels of phosphorus** than fossil mixtures, which are undesirable in cast iron
5. According to the selected decision framework, **only four of the nine biomasses** (pallets, pine, olive logs, wooden boxes) **are suitable for use**
6. In general, the use of raw biomass leads to a reduction in process yield. Therefore, **thermal pre-treatments on biomass**, such as **torrefaction or carbonization, are necessary**

Second step: biochar characterization

Three types of biochar were selected from three different suppliers, all derived from the same biomass, namely virgin wood of forest origin

Product	Treatment	Temperature	Time
A	Pyrolysis	480°C	50 minutes
B	1st stage: pyrolysis	380°C	30 minutes
	2nd stage: gasification	1000°C	Few minutes
C	Pyrolysis	600°C	60 minutes

Table 3 *– Biochar production characteristics*

Research Fund for Coal & Steel

Acciaierie d'Italia

Second step: biochar characterization

Parameters	Values	Unit of measurement
Density	0.58	g/cm^3 DM
Moisture	40.72	%
Ash	13.66	%
Cl	0.02	% DM
S	0.056	% DM
Higher heating value	13.39	MJ/kg DM
Lower heating value	12.23	MJ/kg DM
H	0.79	%
N	0.36	%
C	45.52	%
Volatile matters	55.9	%
Fixed carbon	20.86	% DM
O	<5	% DM
Cd	<0.06	mg/kg DM
Hg	<0.1	mg/kg DM
Pb	92	mg/kg DM

***Table 4** - Analysis of product A*

Parameters	Values	Unit of measurement
Density	0.36	g/cm^3 DM
Moisture	15.05	%
Ash	9.46	%
Cl	0.018	% DM
S	0.051	% DM
Higher heating value	21.66	MJ/kg DM
Lower heating value	21.02	MJ/kg DM
H	1.30	%
N	0.54	%
C	64.29	%
Volatile matters	30.9	%
Fixed carbon	34.77	% DM
O	10.97	% DM
Cd	<0.06	mg/kg DM
Hg	<0.1	mg/kg DM
Pb	1.2	mg/kg DM

***Table 5** - Analysis of product B*

Parameters	Values	Unit of measurement
Density	0.51	g/cm^3 DM
Moisture	35.33	%
Ash	3.34	%
Cl	0.017	% DM
S	0.133	% DM
Higher heating value	19.43	MJ/kg DM
Lower heating value	18.28	MJ/kg DM
H	1.41	%
N	0.32	%
C	52.98	%
Volatile matters	44.6	%
Fixed carbon	33.33	% DM
O	10.10	% DM
Cd	<0.06	mg/kg DM
Hg	<0.1	mg/kg DM
Pb	2.9	mg/kg DM

***Table 6** - Analysis of product C*

BioCoDe

Second step: biochar characterization

1. **Biochar B** stands out due to its **high higher heating value (21.66 MJ/kg)** and lower heating value (21.02 MJ/kg), making it the **most energy-efficient among the three**
2. **Biochar B** has also **the lowest volatile matter content** that is preferred in coke production to achieve more stable and predictable combustion
3. In terms of chemical composition, **Biochar B has the highest fixed carbon content (34.77%)** that is **desirable in coke production** for producing high-quality coke
4. **Biochar C has significantly lower ash content (3.34%)** that indicates cleaner combustion and fewer solid residues
5. From an environmental sustainability perspective, **Biochar B has the lowest lead levels (1.2 mg/kg).** The presence of heavy metals such as lead is a **critical factor for the environmental impact and safety of the final product**

Second step: biochar characterization

Biochar	$T_{i,loss}$ [°C]	$T_{f,loss}$ [°C]	Initial weight [g]	Final weight [g]	Weight loss [g]	Percentage loss [%]
A	65	958	2.308	1.102	1.206	47.75
B	65	877	2.99	1.020	1.97	34.12
C	61	977	2.042	1.160	0.882	56.8

***Table 7** – Thermogravimetric analysis*

Thermogravimetric analyses indicate the **thermal stability and degradation behavior of each biochar**

Biochar B, with its dual-stage treatment (pyrolysis followed by gasification), **shows greater resistance to thermal decomposition**, making it **particularly suitable** for high-temperature applications typical in coke production

Research Fund for Coal & Steel

Acciaierie d'Italia

Conclusions

- **Using untreated biomass** instead of hard coal **can reduce the efficiency of coking, so thermal pre-treatment such as torrefaction or carbonization is required.**

- **The situation greatly improves with biochar**, which has proven to be much more suitable for the goal of the project

Next steps…

Obtaining and **characterization of biochar from selected biomass**

Pilot test campaign on an increasing scale before final use in the coke-making cells at the Taranto steel plan

BioCoDe

Thanks for the attention!

BioCoDe

Research Fund for Coal & Steel

Acciaierie d'Italia