BioCoDe: BIOMASS FOR COKEMAKING DECARBONIZATION

Vincenzo PEPE – RINA Consulting – Centro Sviluppo Materiali, Roma, Italy

Angelo SORINO, Rosella ATTROTTO, Alessandro VECCHIO, Gabriele FIORENZA – Acciaierie d'Italia, Taranto, Italy

The European funded project "BioCoDe" (RFCS agreement n. 101112264) addresses the crucial challenge of decarbonizing the steel industry, one of the major sources of industrial CO_2 emissions. The project aims to partially replace the fossil coal currently used in the coke production process with up to 10% C-neutral biomass or biochar from the local agroforestry or wood sectors. BioCoDe aims to demonstrate the first industrial-scale replacement of fossil raw material with biomass/biochar (TRL 7) including activities at different scales from laboratory screenings to a large pilot experimental campaign and the validation with industrial tests at the cokemaking plant of Acciaierie d'Italia in Taranto. BioCoDe thus aims to establish biomass as a reliable, green, and convenient raw material for lower-emission coke production, promoting the principles of the circular economy and boosting local and European synergies between agriculture and industry. Started in July 2023, BioCoDe project paves the way for a more sustainable steel industry validating the benefits of such a circular approach to decarbonizing the steel production process considering also the main critical aspects of biomass availability at the local level and its influence on coke quality.

Keywords: BIOMASS, COKE, DECARBONIZATION, STEEL INDUSTRY, CIRCULAR ECONOMY

INTRODUCTION

The possibility of replacing part of the coking coal mixture with plant-based biomass is currently being studied within the BioCoDe project, started in July 2023 and funded by the European program "Research Fund for Coal and Steel" (RFCS). This project is carried out in collaboration between Acciaierie d'Italia (IT), ThyssenKrupp (DE), Paul Wurth (IT), and RINA-CSM (IT), and involves a multiscale study of biomass in the coking process, starting from the laboratory scale and progressing to the industrial scale (*fig. 1*).

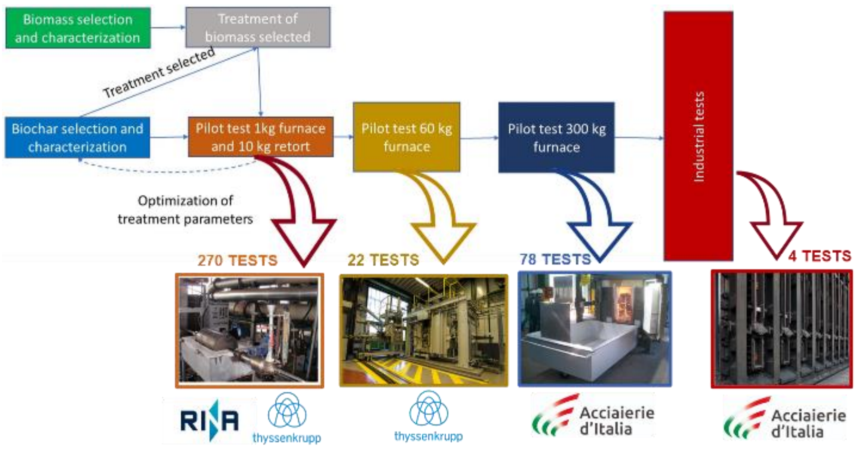
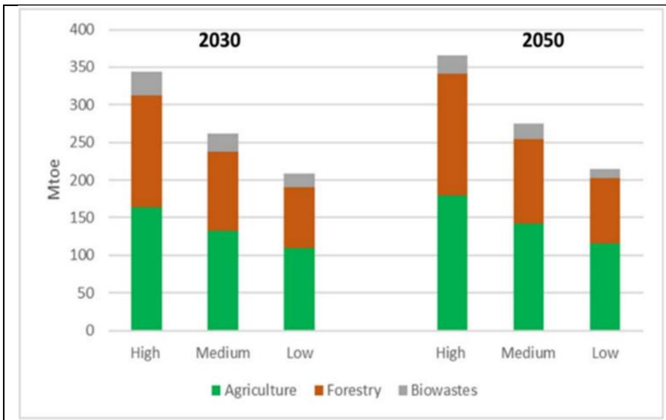


Fig. 1 - Schematic representation of the experimentation plan for biomass use in coking blend

Specifically, the core of the experimentation will focus on pilot-scale coking tests of 60 and 300 kg, during which the selected biomasses will be substituted into the fossil mixture in various proportions to produce coke of quality compatible with industrial requirements. To this end, the study will also explore the effects of mechanical and thermal pre-treatments of biomass, including grinding to various particle sizes, pelletization, briquetting, and pyrolysis at different temperatures (such as torrefaction and carbonization) before the application in cokemaking. The intensive experimentation planned is well justified by the importance that coke holds within the blast furnace process. For this reason, the chemical and physical characteristics of the coke must be carefully monitored, starting from the selection of raw materials for the coal mixture. The same considerations are applied for the biomass used as a partial substitute for coals. The parameters defining the quality of coking coal and mixtures become essential to classify and select the types of biomass most suitable for the process. The initial phase of the BioCoDe project concerned the selection and characterisation of biomass, leading to actual coking tests. The results of this first phase of testing thus constitute an experimental basis for the continuation of the project and the subject of this dissemination.

BIOMASS AVAILABILITY

In the latest EUROFER report, it was stated that in 2023, almost 70 Mt of steel was produced via the BF-BOF cycle, equivalent to 73 Mt of hot metal, which required about 24 Mt of coke, or rated 32 Mt of fossil coal blend. Based on the recent data, replacing 5% of coking blend with biochar would result in a reduction of fossil consumption by 1.6 Mt (considering an equal coke yield for fossil coal and biochar), leading to a consequent reduction in direct CO_2 emissions of 4.8 Mt/year (considering an emission factor for fossil coal of 2,963 tCO2/t coal). The production of this amount of biochar would necessitate between 12 and 20 Mt of virgin biomass, depending on the conversion yields of various processes and the characteristics of the biomass itself. These quantities are well within the available biomass resources for energy purposes in the European border. In this regard, an estimate made by the Imperial College of London of the potential availability of sustainable biomass in the European Union and the United Kingdom by 2030 and 2050 is reported in *fig. 2*. The study considered only domestic raw materials (EU27 and UK) of agricultural, forestry, and waste origin, analysing three different availability scenarios: low) low biomass mobilization, medium) improved mobilization in selected countries through improvements in agricultural and forestry practices, and high) greater availability through research and innovation (R&I) measures, as well as better mobilization through improvements in agricultural and forestry practices.



Agricultural feedstocks	-Secondary agricultural residues from agro-industries -Cereal straw, maize stover -Solid and liquid manure from poultry, pigs, cattle -Oilseed crop residues -Agricultural pruning
Forest feedstocks	-Primary forest residues -Secondary forest -Residues -Stemwood (fuelwood) -Post-consumer wood
Biowastes	-Paper cardboard, Wood waste, Animal & mixed food waste, Vegetal waste, Municipal solid waste (MSW) - Sewage sludge - Used Cooking oil

Fig. 2 - Sustainable biomass availability for bioenergy in 2030 and 2050 (in Mtoe) in Europe and UK borders [1]

Considering the socio-economic characteristics of Italy, and in particular, the Apulia region where the integrated steel plant of Taranto is located, the selection of biomass investigated in the project focused on those produced by the wine, olive oil, and cereal sectors. As evidence of the importance these sectors hold within the region's economy, *fig. 3* shows the areas cultivated with cereals, grapes, and olives [2], from which an estimated potential availability of biomass in the form of straw and prunings is respectively 1200 kt and 800 kt per year, sufficient to cover the quantities necessary for the implementation of the project's approach at the plant (considering a hot metal production of 4 Mt/year, with a consequent consumption of 1.6 Mt/year of coking coal, and a substitution rate of 5% with biochar, an estimated 500 kt/year of virgin biomass would be required). Regarding the olive oil sector, the production of olive pomace, a by-product of olive pressing, is also significant, with an estimated availability of over 250 kt per year. Straw, olive trunks and branches, vine prunings, and olive pomace were therefore the initial biomasses selected within the research project. Subsequently, wood derived from the disposal of pallets and fruit crates, both easily obtainable in areas where agricultural products are collected, processed, and distributed, was added. Finally, pine wood was selected as it is one of the most readily available biomasses as a residue from urban green space maintenance and coastal forest management operations.

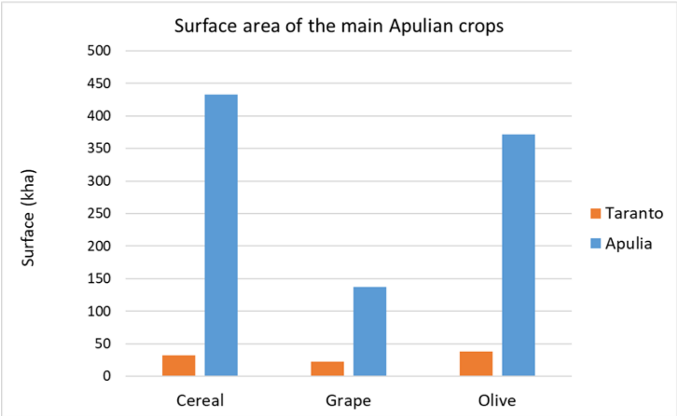


Fig. 3 - Surfaces cultivated with cereals, vines, and olive trees in Puglia and in the province of Taranto

MATERIALS

Half of the biomass samples analysed originate from farms in the province of Taranto. The straw comes from wheat threshing during the season before the testing period, then baled and stored under cover until sampling. Olive wood and twigs were collected directly from the field, during a pruning done in the autumn about six months before the tests. Vine prunings were also collected from the field, originating from winter pruning during the plant's dormant period. Olive pomace was provided in a wet form by an oil mill equipped with a cold-pressing line for olive paste. Fruit crates and pallets were recovered via the separate collection service of wooden waste within the Taranto steel plant. To assess the influence of clues or other non-wood components, a distinction was made between the crates entirely made of wood and those with particleboard elements. Pine wood was also recovered within the plant, resulting from green space maintenance operations carried out few months before sampling. Images of the raw samples are shown in *fig. 4*. Except for the olive pomace, all samples were chipped in a cutting mill to a size of approximately 40 mm. A portion of the chipped biomass was then further ground using a cup mill to meet the requirements of the subsequent analytical methodologies. As a reference for the characterization results, a two-component blend consisting of 40% medium volatile coal and 60% high volatile coal was used.

Fig. 4 - Biomass samples: a) pallets, b) pine logs, c) olive twigs, d) olive trunks, e) wooden crates, f) crates with particleboard elements, g) olive pomace, h) vine shoots, i) wheat straw

RESULTS AND DISCUSSION

Fig. 5 illustrates the decision-making scheme conceived within the project to select biomass from the identified ones. Besides setting limits on sulphur, phosphorus, and ash contents, certain parameters have been ranked by order of importance to evaluate the quality of the identified biomasses. These include, in order, the content of alkalis, calorific value, fixed carbon, and moisture content of the raw biomass.

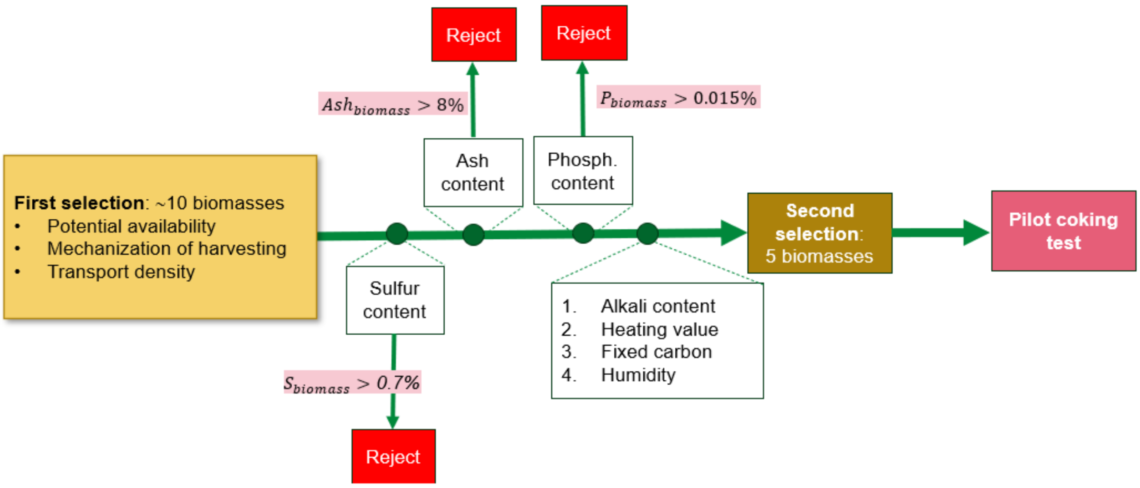


Fig. 5 – Decision-making scheme for biomasses selection

The first factor to consider in biomass selection is its local availability. Biomass derived from agroforestry waste is heavily influenced by the territory, climate, agricultural traditions, seasonality and the development of agro-industrial sectors in the region. Therefore, they are characterized by a wide variety of types and different availability across both Italian and European territories. Additionally, given their low energy density and the lack of large localized production centres, it is extremely important that their source is as close as possible to the final usage site to minimize transportation costs and related carbon emissions. At the same time, the quantities of available biomass must be sufficient to sustain the high industrial production process needs.

The first analysis on the selected biomasses involved the determination of the moisture content. This analysis was performed on bulk samples to account for the inherent high heterogeneity of biomass. The analysis was carried out directly on the chipped material to avoid weight loss due to finer grinding processes. All the biomass samples were characterised in terms of proximate (sulphur, carbon, oxygen, hydrogen, chlorine, nitrogen) and (moisture, ashes, volatile matter, fixed carbon) ultimate analyses, ashes chemical composition, phosphorous, alkali, calorific value (HHV). *Tab. 1* provides only the characterization values necessary to compare biomasses according to the selection criteria indicated in *fig. 5*. Among the nine identified biomasses, only pallets, pine, olive trunks, and wooden crates meet the established limits for ash and phosphorus content.

Tab. 1 – Biomass comparison based on the identified selection scheme of fig.5

	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

CONCLUSIONS

The use of these biomasses to replace fossil coals could therefore lead to a decrease in the cokemaking process yield, partly due to their high moisture content. Consequently, thermal pre-treatments such as torrefaction or carbonization are recommended and will be the focus of the upcoming studies in the BioCoDe project. All tested biomasses, except for straw, have lower ash content compared to the fossil mixture. However, the ash content of the two types of materials is comparable when considered in relation to the fixed carbon content. Regarding ash composition, there is a notable presence of alkalis (Na_2O and K_2O). A positive aspect of the biomasses is their low sulphur content, although phosphorus levels are higher in many cases compared to the fossil mixture, particularly in olive twigs, pomace, vine shoots, and straw. According to the decision framework outlined in *fig. 4,* only four of the nine identified biomasses, pallets, pine, olive trunks, and wooden crates are deemed suitable for further experimentation. Among these, pallets have the lowest alkali content, which is a key parameter affecting coke reactivity. However, based on the data obtained from the identified biomasses, it is believed that at this stage the selection of a limited number of them is not fully explanatory of their behaviour within the coking process. This could lead to the exclusion of some types of biomasses whose availability in the vicinity of the Taranto steel plant is higher. Therefore, the next step of the BioCoDe project will focus on the evaluation of the effect of biomass pretreatments on the coking capabilities of the mixture, regarding technological parameters such as fluidity and expansion.

ACKNOWLEDGMENTS

The BioCoDe project (Contract No. 101112264) is funded by the European Union's Research Fund for Coal and Steel (RFCS) program. The information and opinions expressed in this document are those of the author or authors and do not necessarily reflect the official opinion of the European Union. Neither the European Union institutions and bodies nor any person acting on their behalf can be held responsible for any use that may be made of the information contained herein.

Reference

[1] C. Panoutsou e K. Maniatis, «Sustainable biomass availability in the EU, to 2050,» London, 2020

[2] V. Mottola, N. Colonna, V. Alfano, M. Gaeta, S. Sasso, V. De Luca, C. De Angelis, A. Soda e G. Braccio, «Censimento potenziale energetico biomasse, metodo indagine, atlante Biomasse su WEB-GIS,» ENEA, 2009.