16th International Conference on Greenhouse Gas Control Technologies **GHGT-16**

23-27th October 2022, Lyon, France

Assessing the role of negative emission technologies in the low carbon transition of the iron and steel sector

Carlos Andrade[c], Lucas Desport[a,b], Gondia Sokhna Seck[c], Sandrine Selosse[a]

[a]MINES Paris, PSL University, CMA - Centre for Applied Mathematics, Rue C. Daunesse, 06904 Sophia Antipolis, France
[b]TotalEnergies, Gas, Renewables & Power Division, TR&D Group, 2 place Jean Millier, 92078 Paris la Défense, France
[c]IFP Energies Nouvelles, 1-4 Avenue de Bois-Préau, 92852 Rueil-Malmaison Cedex, France

Abstract

According to the latest IPCC Assessment Report (Masson-Delmotte et al., 2021), achieving the objective of limiting temperature increase to 2 °C or even 1.5 °C will require the massive roll-out of solutions to reduce CO_2 emissions as soon as possible. For the industry sector, which represented around 25% of global CO_2 emissions in 2018 (IEA, 2020), the decarbonization pathway is particularly complex. Indeed, part of the CO_2 emissions from industrial activities coming from production processes are inevitable, as it cannot be avoided by simply replacing fossil fuels use with other renewable energies (Suopajärvi et al., 2017). Moreover, industrial activities are expected to grow steadily in the coming years as their products are essential for the development of the human society. The improvement in energy efficiency might be overcompensated by the increase in production and emissions would further increase. This is especially the case for the iron and steel industry (ISI) (responsible for 6% of global emissions). Steel is notably a very important product, and in the energy transition it is essential because most green technologies, e.g. low carbon transport, wind energy, etc, depend on it (GMK Center, 2021).

Currently, 70% of the world's steel production is based on the blast furnace-blast oxygen furnace technology that relies heavily on the use of coke for the iron reduction (World Steel Association, 2020). Coke is vital for this because, having the most suitable characteristics for the production of high quality iron, it is cumbersome to replace it with other materials (Yang et al., 2021). Subsequently, to reduce CO_2 emissions in this sector, some of the most studied options are the integration of carbon capture and storage (CCS) and/or utilization (CCU) technologies, as well as the replacement of part of the coke use by charcoal (a biomass pyrolysis product) (Mousa et al., 2016). Complete replacement of coke is not possible as charcoal does not present the same physical properties as coke. Figure 1 shows the possible options, found in the litterature, to replace part of the consumption of coke and other fossil fuels by biomass products at different stages and in different iron making technologies. There is also an option for the use of slag with CO_2 for the production of carbonates that can capture CO_2 for several decades, reducing consequently its concentration in the atmosphere. Thus, options appear very promising for decarbonizing ISI, however, the study of these options combined together, and on a global scale, has received little attention. This is all the more surprising since the use of bioenergy with CCS/CCU (BECCS/BECCU) may yield negative emissions. Indeed, biomass being consider as carbon neutral, by capturing and storing $CO_{2,}$ the latter can be subtract from the atmosphere (they are thus commonly referred to as Negative Emission Technologies (NETs)).

In this sense, the objective of this work is to analyse role of NETs in decarbonizing the ISI. How could they contribute to global climate objectives? How do NETs interact with other decarbonization options for this sector such as the use of hydrogen for iron reduction? Which regions are the most favorable to adopt NETs depending on biomass potentials and their specific characteristics? In this sense, will NETs foster biomass trade among different regions? and what would be the incurred economic costs that would allow further development of these technologies?

*Carlos Andrade. Tel.: +33 6 27 94 79 48, *E-mail address:* carlos.andrade@ifp.fr

This analysis is developed through TIAM-FR, he French version of the TIMES Integrated Assesment Model (TIAM). TIAM is the global version of the TIMES family models developed under the Energy technology System Analysis Program (ETSAP). TIAM-FR allows to evaluate and discuss the different perspectives of energy systems evolution with respect to the envisioned objectives and pathways. TIAM-FR is a partial-equilibrium model following a linear optimization paradigm. Its objective is to satisfy the exogenous energy demand (projected according to a set of assumptions on the drivers and on elasticities of the demands to the drivers and, optionnaly, to their own prices. These drivers are based to one of the 5 Shared Socioeconomic Pathways described by (Riahi et al.). The model minimizes the total discounted cost of the system while satisfying the different constraints that have been implemented (e.g. maximum amount of emissions). TIAM-FR represents the world energy system divided into 15 regions. For each of them, the energy system consists on a relationship between the flow of commodities from the different transforming and transporting technologies until how they can cover final energy demand. It is detailed as well, the different energy potentials for each region, and the possible technologies that can be developed with their respective technico-economic characteristics. The total discounted cost of the system is obtained as a result of the modelling, its new structure, emissions, and other elements that will allow to identify and analyze the effect of different decisions and the role of different decarbonization options in the low carbon transition. TIAM-FR includes a climate module that identifies the effect of the resulting emissions on the concentration of CO_2 in the atmosphere, the total change in anthropogenic atmospheric radiative forcing, and the resulting temperature changes. It also embodies the different ISI decarbonization options previously mentioned. An accurate identification of emissions at each of the producing and consuming stages provides different roadmaps of the low carbon innovation options. The TIAM-FR model is under calibration in order to express these possible future, and the analyses will rely on different contrasted scenarios related to the rise of temperature to 2 °C and 1.5 °C, maximum use of biomass in ISI, and the carbon-free steel production scenario.

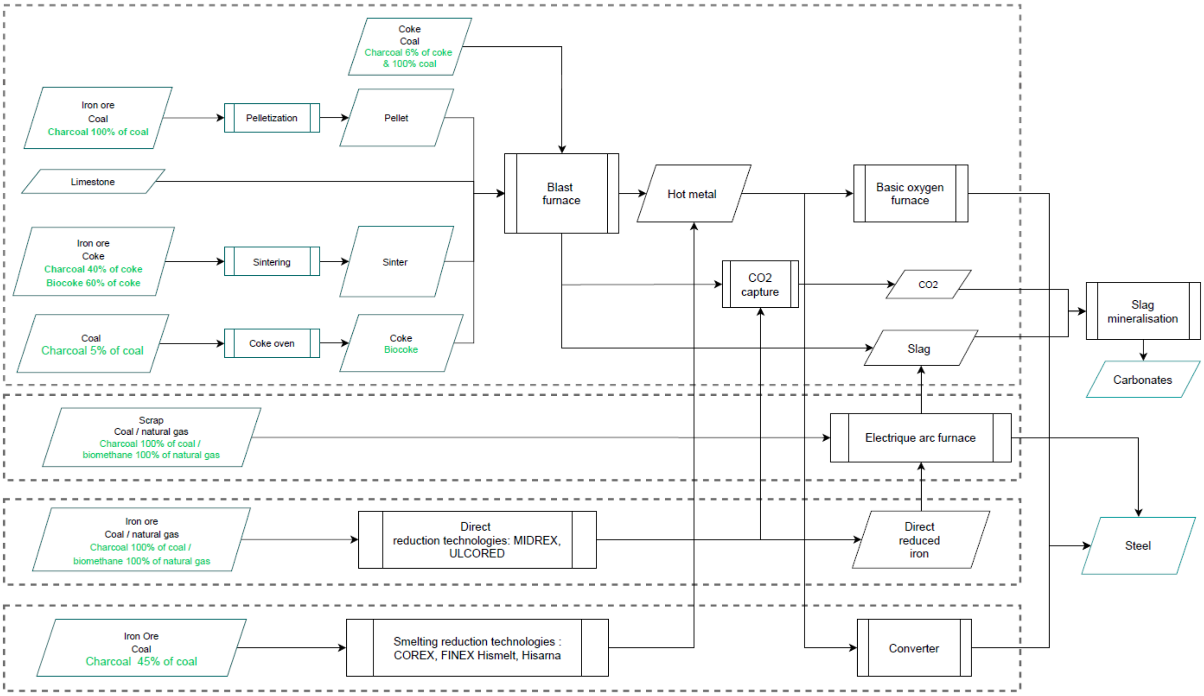

Figure 1: Possible replacement options of coal and charcoal with biomass for steel production

Keywords: Biomass, Negative emission technologies, Bioenergy with carbon capture and storage, Iron and steel industry, Decarbonization, Long-term energy modelling, TIMES

References

GMK Center. (2021). *Role of steel industry in Green Energy transition*.

IEA. (2020). *Tracking Industry 2020, IEA, Paris https://www.iea.org/reports/tracking-industry-2020*.

Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Péan, C., Berger, S., Caud, N., Chen, Y., Goldfarb, L., Gomis, M. I., Huang, M., Leitzell, K., Lonnoy, E., Matthews, J. B. R., K., T. M., Waterfield, T., Yelekçi, O., Yu, R., & B. Zhou (eds.). (2021). IPCC, 2021: Summary for Policymakers. In: Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. In *Cambridge University Press. In Press.* https://www.ipcc.ch/report/ar6/wg1/

Mousa, E., Wang, C., Riesbeck, J., & Larsson, M. (2016). Biomass applications in iron and steel industry: An overview of challenges and opportunities. *Renewable and Sustainable Energy Reviews*, *65*, 1247–1266. https://doi.org/10.1016/j.rser.2016.07.061

Suopajärvi, H., Kemppainen, A., Haapakangas, J., & Fabritius, T. (2017). Extensive review of the opportunities to use biomass-based fuels in iron and steelmaking processes. In *Journal of Cleaner Production* (Vol. 148, pp. 709–734). Elsevier Ltd. https://doi.org/10.1016/j.jclepro.2017.02.029

World Steel Association. (2020). *Steel statistical yearbook 2020 Extended Version*. 46.

Yang, F., Meerman, J. C., & Faaij, A. P. C. (2021). Carbon capture and biomass in industry: A techno-economic analysis and comparison of negative emission options. In *Renewable and Sustainable Energy Reviews* (Vol. 144). Elsevier Ltd. https://doi.org/10.1016/j.rser.2021.111028