PROVIDING FLEXIBILITY IN EUROPEAN POWER SYSTEMS BY DECARBONISING THE IRON AND STEEL INDUSTRY

Annika Boldrini, Joint Research Centre – European Commission / Utrecht University, +31655540472, annika.boldrini@ec.europa.eu
Derck Koolen, Joint Research Centre – European Commission
Wina Crijns-Graus, Utrecht University
Machteld van den Broek, University of Groningen

Overview

The decarbonization of the European iron and steel industry (ISI) will play an important role in the EU's ambitions to become climate neutral by 2050, with the sector contributing to 6% of European CO_2 emissions. To meet the challenging CO_2 emission reduction targets, new technologies and production processes will transform the industry. These processes, at different development stage, often entail a higher degree of electrification. Furthermore, where hydrogen may be used as fuel and feedstock, electrolysis may contribute to an even larger demand for (clean) electricity.

At the same time, the share of variable renewable energy sources in the European power sector is expected to continue to grow. The intermittent nature of of wind and solar may cause uncertainty in power markets and power prices to fluctuatue heavily. Since demand and supply must match to provide grid stability, , there is an increasing need for flexibility at both the demand and supply side in European power systems. Demand Side Response (DSR) may offer flexibility at the demand side, entailing that a flexible power consumer increases or decreases its load in response to a price signal. The advantages are twofold: ensuring grid stability while lowring the electricity bill for end-consumers.

If iron and steel processes undergo electrification, electric consumption can be shifted in time while maintaining steel production – i.e., load shifting. If (green) hydrogen feeds the industrial processes, the operations of the electrolysers can be regulated to better accommodate renewable energy sources, particularly if hydrogen storage is in place. The objective of this study is to assess the evolution of the technical potential for electricity load shifting, taking into account various decarbonisation pathways for the iron and steel industry (ISI).

Methods

To fulfil the objective of the study, first, some exemplary steel plants are defined for the most relevant iron and steel manufacturing technologies; secondly, we assess the flexibility potential per technology; and third, the overall demand response potential is assessed and compared through a cost optimisation linear program.

We select the relevant technologies based on three criteria: (1) in line with EU decarbonisation targets; (2) at a stage of development that its deployment is realistic in the time-frame of 2050; (3) relevant in the context of flexible electricity consumption or generation. Then, we assess the theoretical potential of DSR for each process by retrieving time series of electricity power demand per process and their share of flexible capacity. We characterise the identified production routes by type and size of manufacturing plants, material and energy storages, material and energy flows from each stage of the production processes. Then, we apply to these systems a cost optimisation linear program to define the potential for minimising electricity operating costs taking into account technical limitations that constraint the flexible load.

The DR strategy under study is *load shifting*, thus if the operation of one or multiple manufacturing plants is decreased or increased at a certain point, this should be compensated for at another point in time. That entails that steel production should be maintained within a pre-defined time-frame. The study assesses DR potential while ensuring either daily, weekly or monthly steel production. The optimisation under different time-frames allows a better understanding of the potential flexibility that can be exploited by these industries in relation to the power system requirements on different time-scales. A factor that thereby influences the load shifting potential is *capacity utilisation*, indicating the extent to which the production capacity of a plant is used.

Results

The technologies identified that fulfil the above-mentioned criteria are (i) the integrated route composed by blast furnace and basic oxygen furnace with a carbon capture plant (BF-BOF-CCS) and (ii) green hydrogen production and the direct reduction of iron coupled with an electric arc furnace (DRI-EAF). As in the system (ii) the EAF can also be fed purely by scrap steel, the flexibility potential of EAF only (secondary route) can also be derived.

The BF-BOF-CCS route includes the integrated processes that are minor electricity consumers, as these processes are mainly fossil fuel-based. Furthermore, it incudes a power plant that is fed by the waste arising gases from the blast furnace, the coke plant and the basic oxygen furnace plant. These are gases high in carbon content, thus CO2 is capture by the flue gases through a post-combustion amine based carbon capture technology and compressed. The sources of flexibility in this route are the the power plant – which can provide supply-side flexibility – and the CO2 compression, which contribute to the highest share of electricity consumption in the carbon capture process. Additional flexibility can be exploited in this route by decoupling the power plant flue gases flow and the flow of CO2 that must be compressed by increasing the size of the tank that stores the solvent rich in CO2 in the capture system. In such manner, compression can be delayed at times of high power prices, so that the power plant can sell additional electricity to the grid.

For the DRI-EAF route a number of sub-cases are identified. The shaft furnace used for DRI making can be fuelled either by hydrogen, natural gas or a mixture of the two. Similarly, the EAF used for the steel making process can be fed either by DRI, scrap steel (recycled steel) or a mixture of the two. In reality, the shares of fuels and materials feeding these plants is defined by external factors such as scrap availability and cost, possibility of cheaply producing hydrogen locally, hydrogen and natural gas market prices, or chemical requirements to produce a certain steel quality. However, these factors fall out of the scope of this research and, thus, a number of sub-cases are defined that include a variety of conditions the plants can operate with, and energy demand and flexibility are identified for each sub-case. Load shifting potential arises from the flexible operations of the electrolyser that produces green hydrogen, that is also the largest electricity consumer of the production route, and by flexible operations of the EAF. The EAF operates in batches that can be shifted in time and/or melted at various power rates – e.g., decreasing the melting power rate from nominal power increases the batch melting time. Furthermore, the supply chain from electrolysis to steel production can be delay so that electrolyser and EAF can operate independently. The extent to which this can be done depends on storage capacities and specific sub-case considered.

The technology DRI-EAF offers significant potential thanks to large variety of condition it can operate. We expect a sub-case with DRI produced by a mixture of hydrogen and natural gas and the EAF fed by scrap and DRI to offer the highest potential.

Conclusions

This study analyses the flexibility potential for European power systems by decarbonising the iron and steel industry. We study the main low-carbon technologies for steel manufacturing that will be deployed in Europe. With the direct electrification of processes, the utilisation of green hydrogen as fuel, and, to a lower extent, carbon capture of CO2 emitting processes, the iron and steel sector is believed to be able to provide a significant flexibility potential to European power systems. The flexibility that can be achieved, thus the potential economic savings, can be further enhanced at times when steel demand is low.