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Smart management of process off-gases paving the way to the decarbonization of the steel production route

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An optimal exploitation of energetic streams is of utmost importance for the sustainability of steel production not only in their current configuration but also in the perspective of the transition to new C-lean steel production routes. Process off-gases are among these energetic streams that are normally used for electrical and thermal energy production. The possibility of maximizing their usage by avoiding flaring shows a direct impact on the reduction of CO2 emissions, but this is not an easy task, as their production is often discontinuous in terms e.g. of calorific value and volume flows.

This issue will remain important even in future, when some processes are foreseen to gradually disappear being replaced by new ones, but possible fluctuations in the provision/production of relevant energy-carriers will need to be faced. Moreover, the transition toward fully C-lean steel production will not be sharp. During the transition, the problem of optimal handling, managing and exploiting gaseous energy carriers and their distribution networks will play a key role in ensuring economic and environmental sustainability of the transition itself. Furthermore, future steelworks will most probably be increasingly integrated within larger industrial parks by implementing industrial symbiosis solutions involving exchange and/or sharing of energy carriers to maximize energy efficiency.

Optimal exploitation of valuable energy streams can only be achieved by synchronizing their production and consumption and considering the boundary conditions related to availability and costs of external energy sources that will be needed by the new production processes. Therefore, the present work analyses different scenarios to assess the environmental, energetic, and economic impacts of transition from the traditional Blast Furnace-based route to a route based on Direct Reduction and Electric Arc Furnace from the perspective of the management of process off-gases. In particular, the present investigation explores how various system configurations and operational strategies affect the overall energetic performance of the steelworks. Among the developed models, Machine Learning-based solutions are adopted to accurately forecast off-gases generation and demand patterns, to enable the implementation of strategies to optimize their usage while minimizing energy waste and costs. Mixed-integer linear optimization techniques are incorporated to solve the energy distribution problem, considering constraints such as gas storage limits, calorific values, and process synchronization. Among the considered dynamic scenarios, this study considers the possibility to produce methane and methanol through novel synthesis processes that exploit process off-gases and hydrogen, an interesting industrial symbiosis solution, as these by-products could be sold or reintegrated into the steelmaking process, by contributing to increase revenues and reduce the company's dependence on external energy sources.

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