440 kWh energy saving and emission reduction

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Integrated steelmaking sites on the basis of blast furnace technology still account for 58% of steel production within the European Union (28) and even 73% of the worldwide steel is provided via the blast furnace route [3]. About 26% of the worldwide steel is produced by scrap recycling via an electric arc furnace (EAF) [3]. In sum, the energy-intensive steel industry is a large emitter of CO2 emissions accounting to about 7% of total worldwide anthropogenic emissions [4]. Although steel is a material with a highly effective recycling loop, the predicted worldwide demand of steel until 2050 and beyond needs considerable input of iron ore, since the increasing demand cannot be filled by scrap recycling alone [4].

Integrated sites persist to incorporate iron ore into the production cycle of steel.

Integrated sites will continue to produce high purity steel qualities with superior surfaces, which set the standards in premium flat products.

The coal-based metallurgy of blast furnaces within the integrated sites causes an inacceptable high carbon footprint. Coal-based reduction of ore needs to be replaced by carbon reduced techniques.

DR technology and direct reduced iron (DRI) material can be included into the existing material streams of existing plants in different ways. Figure 1 shows possible outbound material streams of DR plants. Several possible paths are described: the first one, DRI or in form of hot briquetted iron (HBI) material can provide feedstock to an existing blast furnace (BF), see arrow 1. HBI would be the natural choice in this case as DRI usage bears the risk of re-oxidation in the upper parts of the BF. Although the required carbon input into the blast furnace can be reduced by HBI input, the energy for melting still originates from coal. Subsequently reduction in carbon dioxide emissions is not complete [6].

Possible Flow schemes for Direct reduced Iron/Hot briquetted Iron (DRI/HBI) at integrated sites

Path 2 in Fig. 1 uses DRI or HBI as a scrap substitute at the BOF. Reduction in CO2eq emissions are limited as is the scrap rate in BOF steelmaking. Path 3 overcomes the limitations of path 2 by pre-melting DRI or HBI in an electric melting unit. This melt replaces hot metal and therefore makes blast furnaces obsolete. The melting unit process will still require some metallurgical carbon, which needs additional attention to reach decarbonized steel production. Path 4 uses a classical electric arc furnace (EAF) to melt DRI/HBI and scrap. This straightforward concept replaces not only blast furnaces but also BOFs. Some metallurgical carbon might be required here as well to preserve advantages of a foaming slag within the EAF [7].

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In order to produce high quality steel grades lowest levels of nitrogen, phosphor, or carbon can be mandatory [8, 9]. Murphy discusses various aspects of nitrogen control in EAF steelmaking and concludes, "Technological solution is required to enable EAF to compete with BOF route on all grades" [8]. The problem to reach lowest nitrogen contents becomes even more difficult when lowest carbon content is simultaneously necessary [8, 9]. So far, no economically reasonable solution is available, while such steel grades are widely used in automotive applications, electro-mobility and deep drawing [9]. This can be a limitation for path 4 in Fig. 1 (EAF steelmaking).

In a direct comparison of converter vs. EAF steelmaking the following matters: The integrated steelmaking based on BOF process reaches nitrogen values between 20 and 40 ppm even in final products [9]. The BOF vessel shields the melt well against the surrounding atmosphere and it takes additional high-volume streams of carbon monoxide to keep nitrogen low throughout the blowing process. EAF modules do not present a similar air tightness and reach typical nitrogen values between 40 and 90 ppm [9].

Focus of this paper is the environmental evaluation of a DR plant combined with an electric melting unit (Fig. 1, path 3). The life cycle assessment (LCA) according to the international standards ISO 14040/44 [10, 11] is an established standardized methodology to determine the environmental influence of products. Within an LCA material and energy-related flows as well as environmental impacts are assessed in a holistic approach. LCAs for the current steel production are already widely applied in steel industry:

Norgate et al. [12], Burchart-Korol [13], Renzulli et al. [14], Chisalita et al. [15], and Backes et al. [16] presented LCAs for conventional steel production via the currently most common BF-BOF route. The presented product carbon footprints range from 1.6 kg CO2eq/kg steel up to 2.3 kg CO2eq/kg steel. Besides the product steel, some studies relate the environmental impact to the product hot-rolled coil. Different scrap rates, quality of raw materials, technical production sites, and methodological assumptions explain the differences.