Comparative life cycle assessment of primary low alloy steel with hydrogen direct reduced iron and optimized blast furnace processes

Koroma Michael Samsu[1,2]; Brown Nils[2]; Maarten Messagie[1]; Thierry Coosemans[1]; Giuseppe Cardellini[1]

1. MOBI Research Group, Vrije Universiteit Brussel (Belgium)
2. KTH Royal Institute of Technology (Sweden)

Globally, steel production contributes significantly to climate change. To reduce climate impact according to Paris agreement targets, significant changes are needed along its entire value chain. One technology currently being considered to reduce the sector's climate impact is the use of hydrogen for the direct reduction of iron ore.

This study aims to compare the environmental impacts on a life-cycle basis to produce low alloy steel using three alternative processes for iron production: Firstly, an optimized blast furnace method, secondly hydrogen direct reduced iron (H-DRI) and finally a reference blast furnace process. These alternatives are compared based on 1 kg low alloy steel.

Foreground data for iron production in the optimized blast furnace process are taken from the NEEDS optimistic-realistic scenario (NEEDS, 2009). Foreground data for the H-DRI process is based on a recent Swedish pilot study (HYBRIT, 2018). It is assumed that hydrogen in this process is produced with an electricity mix with 90% renewables. Foreground data for the reference process are taken from the relevant ecoinvent v3.1 process. Background data for all alternatives are based on the relevant ecoinvent v3.1 process. It is further assumed that process energy requirements reduce by 20% and 35% compared to the reference for the optimized blast furnace and the hydrogen direct reduced iron processes respectively, based on recent assessments of future efficiency potential (IPCC, 2014).

Global warming potential (GWP) is 6 % and 45 % lower than the reference for the optimized blast furnace and the H-DRI processes respectively. Other impacts are also lower for H-DRI compared to the reference - fine particulate matter formation by 18%; terrestrial acidification by 11%; fossil resource scarcity by 32% and freshwater eutrophication by almost 7%. However, impacts such as terrestrial ecotoxicity and freshwater ecotoxicity increase for the H-DRI process compared to the reference. Analysis shows that all these changes are due to the substitution of coal in reference iron production with hydrogen based on largely renewable electricity in the H-DRI process.

Analysis also shows that the potential for H-DRI based low alloy steel to reduce GWP compared to a reference, is limited by the GWP due to alloying elements in low alloy steel such as nickel, chromium and molybdenum. On the other hand, the proportional GWP reduction for unalloyed carbon steel produced with H-DRI (without alloying metals) is potentially much greater than for low alloy steel considered here.
Novel processes for e.g. nickel production are also necessary to achieve GWP reductions for low alloy steel production in line with fulfilling the Paris agreement. This presents challenges in process and supply chain innovation but also business opportunities for innovators.

Keywords: Life cycle assessment; Steel; Direct reduced iron; Hydrogen; Climate change