STEEL PRODUCTION WITH HYDROGEN

COMPARISON OF STEELMAKING PROCESSES

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Introduction

About 22% of greenhouse gas emissions in Germany are caused by the industrial sector. In 2018 this amounted to 124 million t CO_2 eq from plants subject to the European Emissions Trading System. Of these, the steel industry accounts for the largest share of CO_2 emissions at 35.6 million t CO_2 eq. This corresponds to around 30% of total emissions from industrial plants. Traditional steel production relies on blast furnaces which are coke-fired.[1,2] Steel manufacturers are looking for alternatives and developed a direct reduction process with hydrogen. In this process, hydrogen is used instead of coke for the reduction to iron. The sponge iron produced can then be further processed into steel in the electric arc furnace. The process chain can basically be completely electrified, when hydrogen from water electrolysis is used. The aim of this study was to examine the emissions generated by the alternative steel production methods. In particular, it could be shown how environmentally compatible steel production with hydrogen is. In addition, the contribution of electricity generation to the environmental impact was examined. We used the Umberto© life cycle assessment software.

System boundaries

- Geographical: Germany
- Time: 2018 and 2050
- System: cradle-to-gate (non-casted or rolled steel)
- LCIA: ReCiPe (2016)
- Transport routes for hydrogen were not considered in the models for the hydrogen route. It is assumed that it can be produced on site or in the near vicinity.
- The energy-intensive storage of hydrogen is thus not included in the model.
- The construction of the DRI plants for the hydrogen routes was not taken into account due to the lack of data.

Steel production

Blast furnace
In this process, pig iron is first produced from iron ore and coke. After that, steel is produced from pig iron by further processes. For the blast furnace route, process from Ecoinvent 3.3 was used for simplification reasons.

Hydrogen route
Two variants of the hydrogen route are presented in the material flow models. These differ not in the process, but in the type of electricity used to produce the hydrogen. One type uses exclusively wind energy and the other type uses the German electricity mix 2018 as its power source.[3, 4, 5]

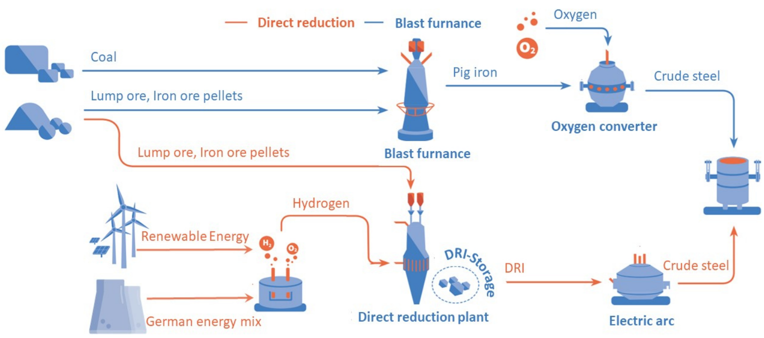

Figure 1: steel manufacturing methods. The upper part of the figure shows production via the blast furnace route. The lower part shows the two variants of the hydrogen route.[6]

Results

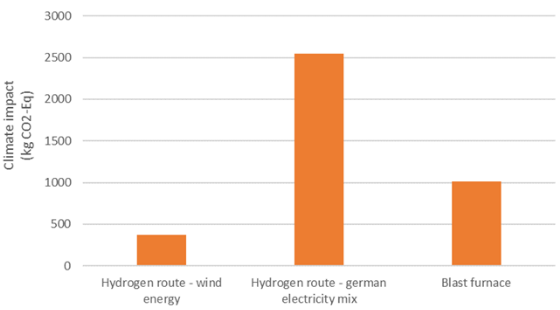

Figure 2: Global Warming Potential. The focus of the comparison was to show the GWP, expressed in kilograms of CO_2 equivalents. The results showed that the hydrogen route with wind power is the most favorable production method. From these results, it can be derived that with a 79% share of renewable (wind) energies in the German electricity mix, the climatic impact of the hydrogen route would be equal to the load of the blast furnace route. A linear reduction of the climatic load with the increase of the share of renewable energies is assumed.

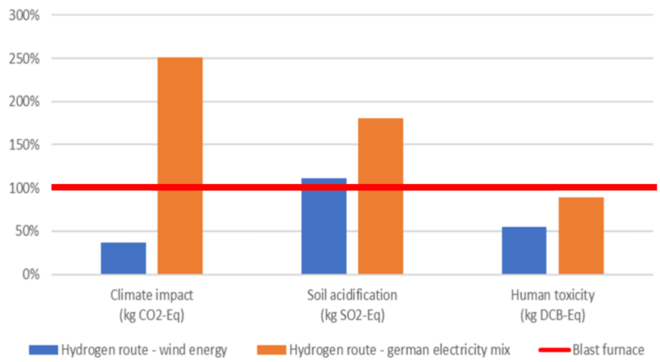

Figure 3: Comparison environmental impact. Figure 3 compares three different LCIA factors. These are GWP, soil acidification and human toxicity. It can be stated that the German electricity mix performs worst in terms of climatic impact as well as soil acidification. This is due in particular to the high shares of electricity generation by lignite and hard coal in the German electricity mix. However, wind power also achieves higher values in the area of soil acidification than the conventional blast furnace route. In particular, pollution occurs during the manufacture and construction of the wind power plants. The blast furnace route performs worst in terms of human toxicity.

Conclusions

The aim of the study was to compare two steelmaking process chains in terms of their environmental compatibility. A further objective of the work was to determine the contribution of electricity generation to the resulting environmental impact. For this purpose, the electricity production in the hydrogen route model was modeled as German electricity mix (2018) and 100% renewable (wind, 2050).
The evaluation of the LCIA factors showed, that steelmaking with hydrogen performs best for the majority of the LCIA factors investigated. In addition, it was found that steel production with hydrogen using the up-to-date German electricity mix does not make any environmental sense. In order to future use the German electricity mix for steel production, the share of renewable energies would have to be increased to at least 80%. The German government has set a target of 65% for the share of renewable energies in the German electricity mix for 2030.
Conclusion: For electricity network attached installations the steel production with hydrogen by direct reduction does not make environmentally sense until well after 2030. In the meantime, the full range process development should be completed or installations need to build up the necessary renewable energy capacities by themselves.

References

[1] Umweltbundesamt (2020a): Emissionsquellen, https://www.umweltbundesamt.de/themen/klima-energie/treibhausgas-emissionen/emissionsquellen#energie-stationar
[2] Deutsche Emissionshandelsstelle im Umweltbundesamt (2019): Treibhausgasemissionen 2018 Emissionshandelspflichtige stationäre Anlagen und Luftverkehr in Deutschland (VET-Bericht 2018), https://www.dehst.de/SharedDocs/downloads/DE/publikationen/VET-Bericht-2018.pdf?__blob=publicationFile&v=5
[3] Umweltbundesamt (2020b): Systemvergleich speicherbarer Energieträger aus erneuerbaren Energien. Abschlussbericht, Texte 68/2020, https://www.umweltbundesamt.de/publikationen/systemvergleich-speicherbarer-energietraeger-aus
[4] Weigel, M. (2014): Ganzheitliche Bewertung zukünftig verfügbarer primärer Stahlherstellungsverfahren. Einschätzung der möglichen Rolle von Wasserstoff als Reduktionsmittel, Diss., Wuppertal 2014.
[5) BDEW Bundesverband der Energie- und Wasserwirtschaft e.V. (2020b): Stromerzeugung nach Energieträgern 1990 - 2020 (Stand Dezember 2020), https://www.ag-energiebilanzen.de/
[6] Figure adapted from: Deutsche Energie-Agentur GmbH (2018). Stahlproduktion, https://www.dena.de/fileadmin/dena/Publikationen/PDFs/2019/Factsheet_PowerFuels_Stahlproduktion_Industrielle_Prozesswaerme.pdf

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