Global Energy Solutions e.V.

For Prosperity and Climate Neutrality

Climate-friendly steel

Factsheet

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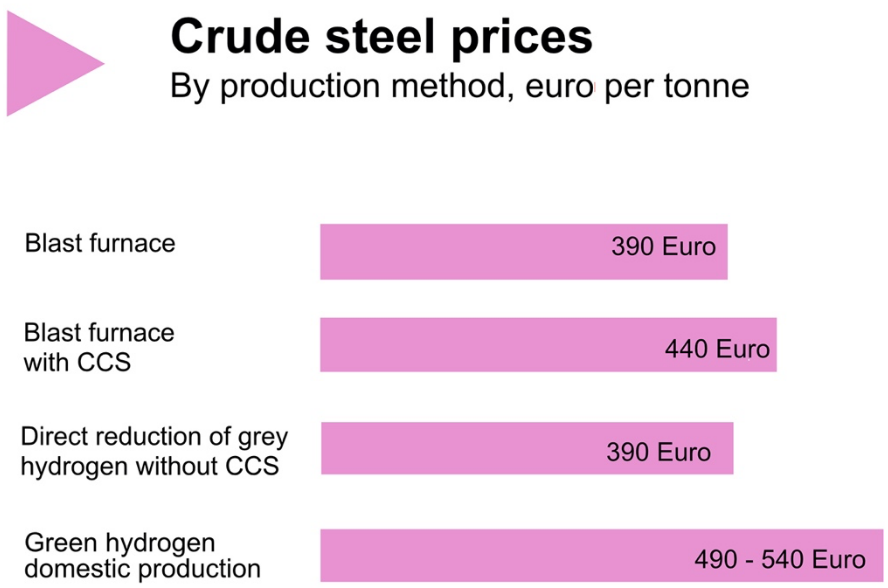

Source: own data, model calculation as of January 2021 Graph: GES

Why steel?

It is impossible to imagine the modern world without steel, for instance in mechanical engineering, in the transport sector or in construction. The strategic importance of this basic material extends even into military applications. It is important to be able to produce specific alloys (such as galvanised sheet metal for cars) in a way that is as customer oriented as possible. China is by far the largest steel producer. In Germany, about 40 million tonnes of steel are produced annually (about 2 per cent of global production). This amounts in CO_2-emissions of about 60 million tonnes in Germany, alone.

How is steel made today?

In Germany (and worldwide), 70 percent of crude steel is produced via the blast furnace route. It is not the heat that initially turns iron ore sinter into pig iron, but the carbon monoxide that is produced by heating the added coke. The reducing gas binds the oxygen contained in the iron ore and converts to CO_2 - amounting 1.7 tonnes per tonne of pig iron. The other approximately 30 per cent of the steel produced in Germany (about 24 per cent worldwide) are produced in the electric arc. In the so-called direct reduction process (about 6 per cent worldwide), natural gas is used (directly) instead of coke, which is split into carbon monoxide and hydrogen in a reformer and reduces the iron ore pellets to so-called sponge iron, which in turn is refined into steel in an electric furnace. This produces significantly less CO_2. (0.5 tonnes per tonne of steel)

Climate-friendly steel by blast furnace route with CCUS

One way to produce climate-friendly steel is to capture the CO_2 during the blast furnace route - and then dispose of it (CCS) or reuse it in the sense of a circular economy (CCU). Developments to use the CO_2 as methanol (ThyssenKrupp) or ethanol (Acelor Mittal) are underway. As the blast furnace route is very widespread worldwide, namely in China, this would be an option that would be suitable for production without major conversion costs. GES calculates steel at a price of 390 euros per tonne. Capturing CO_2 would cost about 50 euros per tonne of crude steel. This results in a total price of about 440 euros per tonne of steel produced.

Climate-friendly steel through direct reduction with grey hydrogen

Grey hydrogen is produced – through steam reforming - from natural gas. It is used in the direct reduction process common today, but without CCUS. In steel production, CO_2 emissions also occur here: 0.5 tonnes of CO_2 per tonne of steel, instead of 1.7 tonnes when using coke. In perspective, there are additional costs for the capture of CO_2. The price per tonne of steel for this process route is then (without CCUS) - depending on the price of natural gas - in the same order of magnitude as for the blast furnace route, i.e., around 390 euros per tonne of steel.

Climate-friendly steel through direct reduction with green hydrogen

If one uses green hydrogen instead of natural gas, CO_2 emissions approach zero. German politicians in particular are counting on this. Approximately 50 kilogrammes of hydrogen are needed to produce 1 tonne of steel. In favourable cases, grey hydrogen costs 1 euro per kilogram. Green hydrogen, on the other hand, costs at least 5 euros. That is between 50 and 250 euros per tonne of steel. Clearly, making only hydrogen produced at low cost a realistic option. If green hydrogen is produced in sun deserts (where the kilowatt hour of electricity already costs 2 cents or less), the price will be 1 euro per kilogramme. However, this does not yet include the transport costs to Europe. Moreover, the conversion of existing steel production plants to the direct reduction route is very expensive, up to 7 billion euros per steel plant.[1]

How much hydrogen does the German steel industry need?

If one wanted to produce Germany's entire steel production - currently about 40 million tonnes per year - with the help of hydrogen, it would need about 2 million tonnes of this gas. Germany is planning green electrolysis capacity in the order of 10 gigawatts by 2030. All domestic hydrogen production would then go into steel production. Since this is a low-probability scenario, significant amounts of green hydrogen will then have to be imported.

Conclusion

In Germany, direct reduction with domestically produced green hydrogen makes little sense. Even if the costs per kilogramme of hydrogen were to fall to 2 to 3 euros, steel production would become more expensive by 100 to 150 euros per tonne. This could lead to an exodus of the steel industry from Germany.

Instead, it seems advisable to either retrofit the existing plants of the blast furnace route step by step with CCUS or, in the case of new buildings, to also provide for CCUS for direct reduction. This way, these plants could also be operated long term with natural gas or - if available - with synthetic methane, which could, for instance, be procured subsidised via H2-Global. As shown, steel production is very sensitive to raw material costs. Green hydrogen will only become a viable option when it becomes available at prices of 1 to 1.5 euros per kilogram.

Especially on an international level, supplementing the existing blast furnace route with CCS or CCU seems to be a promising way forward. This is because the expensive conversion to direct reduction is not a realistic option in China and other countries.

The fixation on green hydrogen in steel production could get the German industry into serious trouble. When discussing a climate-friendly steel industry, GES recommends considering CO_2-elimination pathways other than direct reduction with hydrogen.

[1] https://scilogs.spektrum.de/gedankenwerkstatt/der-ueberteure-strom/