Image caption: Credit: Pelle Berglund Znapshot

Blast furnaces ain't going nowhere!

There seems to be a consensus today that renewable energy and hydrogen are the means by which the steel industry shall be decarbonized. Billions are put into research projects for new processes and yet very little so far has happened. European integrated plants struggle with reinvestment plans in technology that they know will never be profitable or just give up and convert to scrap-based production. In the meantime, new blast furnace plants are being built around the world and nothing indicates that the process will lose its dominant position in the period until 2050 or even this century. To paraphrase the American writer Samuel Langhorne Clemens, better known as Mark Twain: 'The reports of the death [of the blast furnace] are greatly exaggerated.' By **Rutger Gyllenram***

IN principle there are three energy sources for low-emission ironmaking:
1) fossil reductants coal and natural gas combined with CCS.
2) low emission electricity from wind, solar, and nuclear power.
3) biomass.

The products are either a liquid hot metal with or without carbon or a solid sponge iron also with or without carbon. Without pretence of being exhaustive, some of the possible process alternatives are shown in **figure 1**. Low-emission hydrogen can be made from natural gas with CCS (blue H2), electrolysis of water using low-emission electricity or from biomass (both considered green H2). Future process development will tell whether it is preferable to have a mix of carbon monoxide and hydrogen as reductants or if pure hydrogen is more efficient. Reduction mechanisms are complex, and it is doubtful whether one can draw far-reaching conclusions from calculations, simple lab experiments, or even pilot plant tests.

Fossil reductants and CCS

To the left in **Fig 1** we have the processes that use fossil coal and natural gas which all face the challenge of abating the upstream emissions of methane from coal mining and gas extraction that can be as important as capturing and storing the inherent carbon dioxide emissions. The blast furnace (BF) whether it is using a blast of oxygen enriched air, or as in the oxygen blast furnace with top gas recycling (O2BF TGR), pure oxygen, needs a minimum amount of coke to ensure a permeable bed, often said to be around 280-300 kg/ton hot metal. When that is satisfied, alternative non-fossil reductants or sponge iron with a

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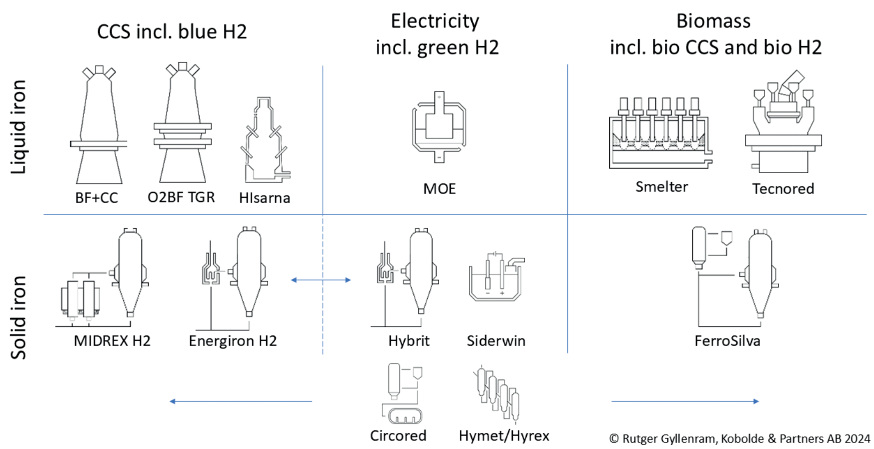

Figure 1. Emerging technologies for iron ore reduction with low emissions of carbon dioxide.

low-carbon footprint can be used to reduce the emissions and avoid another 200 kg of coke. HIsarna has the advantage of not needing agglomerated raw materials but is dependent upon carbon capture and storage to decrease emissions if fossil coal is used. All alternatives have been tried in pilot plant tests but have not yet had a commercial breakthrough.

MIDREX, which is the dominant sponge iron process patented by the eponymous company, has announced a variant where the ironmaker starts with natural gas and then increases the hydrogen level when hydrogen is available. Until then, the carbon dioxide has to be captured from a diluted flue gas. Energiron, a process jointly developed by Tenova and Danieli, uses natural gas as a reductant but the companies claim that they can increase the hydrogen level to close to 100%. On the other hand, the process today uses carbon capture as an inherent part of the process in order to recycle carbon monoxide into the shaft and, therefore, a process enhancement capturing most of the carbon dioxide would be possible with only minor adjustments to the layout.

Low emission electricity as energy source

Molten Oxide Electrolysis (MOE) is a process that is currently developed for the reduction of both iron and ferroalloys. An MOE plant is designed to run multiple cells in parallel with oxygen as an off gas and the production of a carbon-free liquid metal with a high temperature. Siderwin is another electrolysis process that produces iron cathodes at a low temperature. MOE and Siderwin are both at an early stage of development and the outline with many small cells makes the competitiveness with shaft furnaces something of a challenge for a low-cost material like iron, despite an expected low energy use.

Hybrit can serve as the first example of producing an initially carbon-free sponge iron with hydrogen made from the electrolysis of water. Pilot plant tests have concluded and a demonstration project is planned with a production rate of 1.3 Mt/yr, with construction due to begin in 2025. A challenge identified by the Hybrit team is the efficiency and stability of electrolysers for production of the large volumes of hydrogen needed in a commercial plant. Circored, Hymet and Hyrex are fluidised bed processes intended to produce coal-free sponge from fines. They all have a background in reduction with reformed natural gas or gasified coal but have now been redesigned for hydrogen.

Reductants of biogenic origin

Carbon dioxide emissions from biogenic sources are considered to be non-existent in most carbon accounting systems, except when captured and stored (or used to replace fossil carbon), when they are then given a negative value as a carbon sink. A smelter process is suggested as a way to do the smelting, final reduction, and carburisation of sponge iron before a converter step. Today most smelters use electrodes from fossil carbon which in the future must be produced from biogenic carbon to produce low emission iron. In the Tecnored process, charcoal is used to reduce iron ore in the form of cold-bound briquettes producing a hot metal similar to that from a blast furnace. Tecnored can be considered an alternative to charcoal blast furnaces. By gasifying biomass like forest residuals, as well as other biogenic materials, a syngas can be produced with the same composition as the reformed natural gas used in the MIDREX process. The FerroSilva process uses biogenic syngas to produce sponge iron with a normal carbon content while capturing the biogenic carbon dioxide for offtake. The project is in the early stages of development, with the first production of 50kt/yr planned for 2028.

MIDREX and Energiron can of course use green hydrogen, and Hybrit in the same

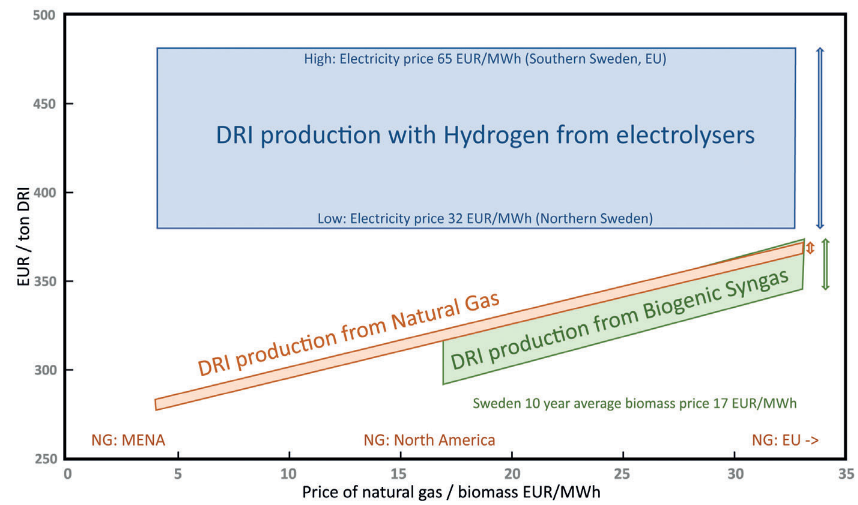

Figure 2. Indicative cost to produce sponge iron (DRI) using natural gas, biogenic syngas and hydrogen from electrolysers as reductants. Thickness of bars indicate the cost difference of electricity from €32-65/MWh.

way uses blue hydrogen, and to conclude, the fluidised beds may use any reducing gas. However, the way they are developed and marketed today indicates the most likely alternative.

Producing low-emission iron and steel

Paramount to low-emission iron and steelmaking are the availabilities of coal and natural gas with low upstream emissions, CCS capacity, low-emission electricity, and biomass. These will vary with location, time and available means of transportation. Technology readiness is an issue, although it does not seem to be recognised today. In my mind: new process ideas are nothing more than ideas until proven in full-scale and only then can they be put into any trustworthy pathway and the improvement of existing and functioning processes may be put aside to give room for new inventions.

The role of low-emission sponge iron

When more and more blast furnaces close and switch to electric arc furnaces, the need for sponge iron increases to ensure a high steel quality. If the admixture is in the order of 20%, the gangue content is of less importance, even if a low content is preferable. Replacing blast furnace production with sponge iron melted in an electric arc furnace is only possible to a certain degree since it demands sponge from iron ore with a low gangue content and that constitutes a limited resource. However, the process that is available today to take care of ore or sponge iron with a high gangue content is the blast furnace. A maximum mixing of sponge iron in blast furnaces globally is, therefore, both a way to reduce carbon dioxide emissions and to use this type of ore economically.

Where to produce low-emission sponge iron

The cost to reduce iron ore to sponge iron, also called DRI, Direct Reduced Iron, with low emissions is shown in **Fig 2**. In the figure, the carbon dioxide from natural gas is captured and stored and the carbon dioxide from biogenic syngas is captured for offtake giving a premium. Of course, a calculation like this is only indicative and shows the reductant cost *ceteris paribus* which means that the ore cost and distance to the market is the same.

One conclusion that we can draw from **Fig 2** is that if we are looking for a place where we can reduce iron ore to low emission sponge iron as a means to reduce the emissions from the global steel industry, we must, for the foreseeable future, look for countries with low-cost natural gas. Another conclusion is that in order to produce sponge iron with hydrogen, you must have advantages such as closeness to iron ore. Merely being close to a steelmaking site may, as I see it, not be enough.

Meeting climate challenges with limited resources

Meeting the goals of the Paris agreement is a task for the entirety of society, and not just the steel industry, although it seems that exactly that is the narrative today. Having available low-emission electricity is key to decarbonizing all sectors, and the first question must be how to optimise the global impact. Is the use of renewable electricity to produce hydrogen optimal if the rest of the grid is powered with coal? Is replacing functioning blast furnaces with electric arc furnaces with a scrap burden reasonable when it results in new blast furnaces being built elsewhere when competition for scrap intensifies?

To anyone following the development in ironmaking it is obvious that the main ironmaking process still is the blast furnace in countries without natural gas and will stay so until we have a breakthrough in fossil-free energy production drastically decreasing the electricity cost. In the long run, we will have fossil-free new processes like in **Fig 1**, but it will take time before they are ready and can play a major role in the world market.

The availability of low-emission electricity and biomass will set limits and decide competitiveness and what markets in which they will thrive.

In the meantime, we must do what we can with what we have – and the easiest and most economical way to decrease the emissions in the global steel industry is to produce low-emission sponge iron with natural gas, using CCS to use in both electric arc furnaces and blast furnaces. ■

Let us end with another classic Mark Twain quote:

“The secret of getting ahead is getting started. The secret of getting started is breaking your complex overwhelming tasks into small manageable tasks, and starting on the first one.”

Hydrogen steelmaking – more questions than answers...

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Editor

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There's nothing like being offered the chance to moderate a discussion panel on hydrogen steelmaking to exercise the mind. And just as soon as I close our October edition (after completing this leader) I'll be taking a closer look at a subject that is relatively new in the greater scheme of things, even if it seems to have been around for some time.

Over the past few weeks, and prior to my invitation to moderate, I have been collecting notes on the subject of hydrogen steelmaking and there are, of course, many aspects to the process that will need to be looked at in Linz, Austria, at the end of this month; and I must say I'm looking forward to it, especially considering the cutting edge panel of experts involved.

When people talk about decarbonizing the steelmaking process, a lot of the experts in the field of steel production technologies claim that to successfully decarbonize the steel industry will only become a reality if multiple technologies are employed. In other words, it's not all about hydrogen; and of course we all know that. There are many different technologies under development designed to help steelmakers reduce their emissions and we all know that while there seems to be a perception that, one day soon, the industry will press a button and everybody will be making steel using hydrogen and EAFs, the reality is completely different. For a start, to make zero carbon steel requires renewable energy, and it is argued that there simply isn't enough of it 'to support the aspirational demand for green hydrogen'.

Steel made from hydrogen is widely regarded as the 'gold standard' and it will be produced – initially at any rate – by a select few, including SSAB, with its pioneering HYBRIT initiative and, of course, H2 Green Steel (recently renamed Stegra). There are others, like BLASTR Green Steel (see exclusive interview with CEO Mark Bula on page 20) and there will be more, but as Rutger Gyllenram of Kobolde & Partners says in this issue, 'new process ideas are nothing more than ideas until proven in full-scale'. In the meantime, he says, 'we must do what we can with what we have – and produce low-emission sponge iron with natural gas using CCS in both EAFs and BFs.' So don't think you've heard the last of the traditional blast furnace...you haven't.