ecology eco economy

VERSATILITY - DRI

DRI – Future of the steel industry

ABSTRACT

The replacement of an integrated steel plant by a combination of a DRI reactor and an EAF where DRI is hot charged is environmentally viable but far away from net zero. An EAF with scrap and DRI preheating is both environmentally and economically better and can reach net zero targets. We show a way to make this work.

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DRI – Future of the steel industry?

Summary

How is the problem of zero CO_2, the Gordian knot of today, to be solved?
Hydrogen is often mentioned as an alias for the sword of Alexander the Great. In every area of the main producers of CO_2 there are solutions, as well as in the steel industry, but is the hydrogen-based future realistic or just fiction?
In the steel industry, the direct reduction of ore with hydrogen is seen as dawning, but if you take a closer look, there are some obstacles that need to be overcome.
One hurdle is the hydrogen itself. Its volatility makes the distribution system very vulnerable. Its production is electricity intensive. Its application in direct reduction produces a 0%C product, the 0%C DRI. Can the steel industry handle 0%C DRI?
This article shows a viable path that offers a solution for e-steel production that can be realized in the short term: The ECOFEEDER two-chamber scrap preheater with integrated DRI preheating and conveying of the DRI under suitable, safe transport conditions. Since scrap will also be used in connection with the future 0%C or the current DRI (the worldwide scrap volume is constantly increasing), the two-chamber scrap preheating is an investment for the future, even for demanding steel grades.

Conclusion: Yes, DRI can be the future of the steel industry, set the case that the scrap and the DRI are preheated sensibly, i.e., resource-saving, the preheating process is batch-neutral (no mixing), the preheated scrap can be 'stored hot' and the DRI is preheated in a quasi-inert atmosphere.
The two-chamber scrap preheating offers many advantages: high preheating temperatures (approx. 750°C), batch-independent preheating (no mixing), integrated combustion of pollutants and odors, constant residual gas temperature with low oxygen content, storage of preheated scrap, and others.
Talk to us.

'Are greenhouse gas emissions the Gordian knot of today? '

According to legend, the oracle prophesied that the one who would untie the Gordian knot would gain control of Asia. At that time, Asia was the world.

Is CO_2 the Gordian knot of today? Today we know that with constant greenhouse gas emissions, mainly CO_2, the associated rise in temperature, the ice masses of glaciers melt, and the coastal areas of the world are threatened and flooded by rising sea levels – so CO_2 is today's Gordian node. We know that this knot needs to be resolved, but not how it can be resolved.

The product of burning fossil fuels (coal, oil derivatives, etc.) is mainly CO_2. Energy generation, mobility (transport) and industrial processes are the main producers of CO_2 with over 69%. The steel industry is at the forefront of this.

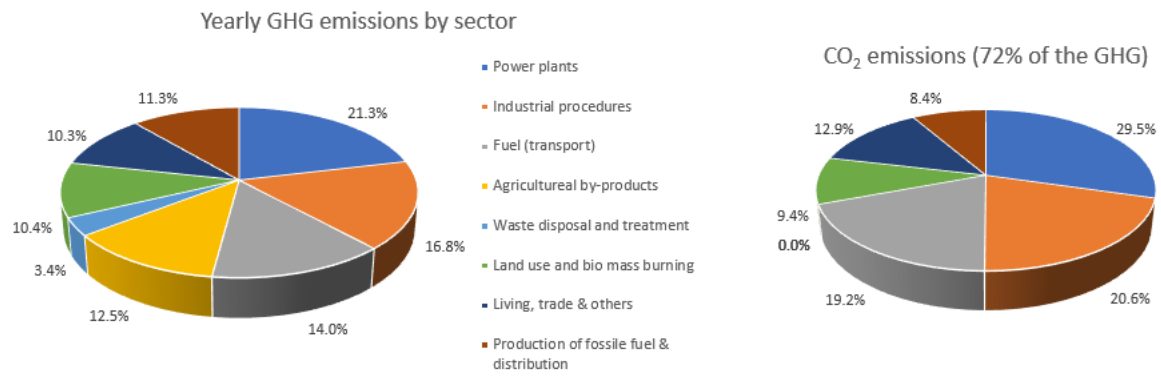

Figure 1 / Green house gas (GHG) and CO2 emissions by sectors

The main producer of CO_2 in steel production is the integrated steel mill around the blast furnace, which reduces oxygen from the ore by means of coal. The liquid iron is then further processed, where massive CO_2 is also released via the fresh process. This manufacturing process is now to be used by direct reduction (DR), i.e., instead of coal (C), e.g., hydrogen (H2) or natural gas (NG) as a reducing agent. The product is called DRI (Direct Reduced Iron), in the case of hydrogen H_2-DRI.

'Is hydrogen-based steel production realistic or just a fiction? ' (S. Hornby, AIST Vol. 19, No. 1) This is now the question to be solved as part of the Gordian knot.

Facts: The global steel industry needs 8% of the world's energy produced and produces 7% of all man-made CO_2. The main energy source (75% of the energy) is coal.

The integrated steel mills (IS) produce 72% of the steel production and are responsible for 93% of the CO_2, while the electric steel mills (ES) produce 28% of the steel and are responsible for 7% of the CO_2.

Figure 2 / Steel production and CO_2 emissions

With the DR, we could ideally reduce 93% of 7% of CO_2 emissions, i.e., 6.3%, if all ore is directly reduced with H_2! And what are all the others doing? Everyone is challenged, energy producers focus on renewable energy sources (and nuclear power plants), the transport sector is electrified (as long as resources (rare earths and H_2) last), biomass combustion is 'reduced' (but rising temperatures cause more forest wildfires), agriculture is 'veganized' (plants convert CO_2 to O_2). , and fewer animals produce less methane and nitrogen oxides) and the heaters are made greenhouse gas-free wherever possible (heat pumps). Set the case, everything would be so feasible, who pays for all this?

By means of electrolysis, oxygen and hydrogen are obtained from water. Depending on the power source, the hydrogen produced by electrolysis is divided into gray, blue or green hydrogen.

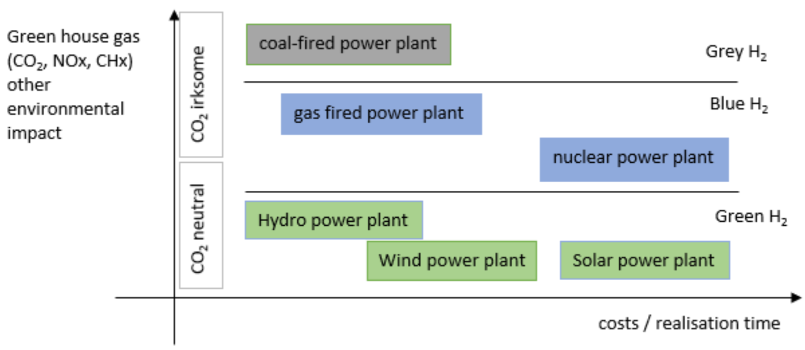

Figure 3 / H_2 production

If the hydrogen economy is to become a reality for the steel and other industries, sufficient green hydrogen must be available at economically reasonable prices, i.e., locations, construction times and costs of the energy production plants must be planned and provided. This also raises the question: is the mountain coming to the mouse or does the mouse go to the mountain? Or to put it another way: wouldn't it be better for the steel industry to settle in the area between desert (sun, ore) and sea (transport)?

By converting all blast furnaces to direct reduction plants (DR) with hydrogen (H_2) as a reducing agent, CO_2 emissions can be massively reduced. But it's not that simple. For the DR it needs large amounts of hydrogen, or energy for electrolysis and the H_2-DRI has 0% C, so carbon must be supplied, because iron without coal is not steel.

This raises the question of what is possible, more economical and more ecological to produce DRI with H_2 (→ 0%C) or with natural gas (CH_4→ 2.5-4%C) or with a mix (CH_4/H_2→ 0.5-1.5%C).

Conclusion: the integrated steel mills must be rebuilt, or newly built and steel production must become CO_2 poorer.

DRI in the steel industry

It is becoming increasingly clear that DRI will be increasingly represented in electric steel production in addition to scrap in the future. Depending on the furnace and benefit strategy, the mix of DRI and scrap can lead to different additional costs for energy and raw materials. The melting time is getting longer, the amount of slag is increasing, and CO_2 emissions are increasing.

Hot DRI (HDRI) comes out of the reduction system at a temperature of approx. 700°C and can be easily transported taking certain safety aspects into account. The use of HDIR is demonstrably beneficial, but there are not yet many steel mills where an electric arc furnace is downstream of a reduction plant.

The transport of cold DRI is more demanding; cold DRI is pyrophoric, i.e. self-igniting, and can form hydrogen when it comes into contact with water. Cold DRI decomposes under pressure thanks to its high porosity to dust, which is also pyrophoric again. However, spontaneous combustion requires that sufficient oxygen is available. This poses a problem with direct preheating by means of burners (patent of Air Products Inc. PA, USA).

In one of our articles, we described the ECOFEEDER two-chamber system with its fairly constant residual gas emissions after scrap preheating ('The energy(pr)icebreaker'). This residual gas is ideal for DRI preheating. The residual gas is low in oxygen and therefore prevents possible spontaneous combustion of DRI.

With a rotary kiln, DRI throughputs of 0.3 – 1.4t/min can be achieved and the DRI can be heated to a temperature of approx. 300-600°C. This corresponds to an increase in enthalpy of 65-120kWh/t_{DRI}

Here again the residual gas emission of the ECOFEEDER compared to the traditional furnace without scrap preheating and to the single-chamber system (all kinds of shaft furnaces or extensions)

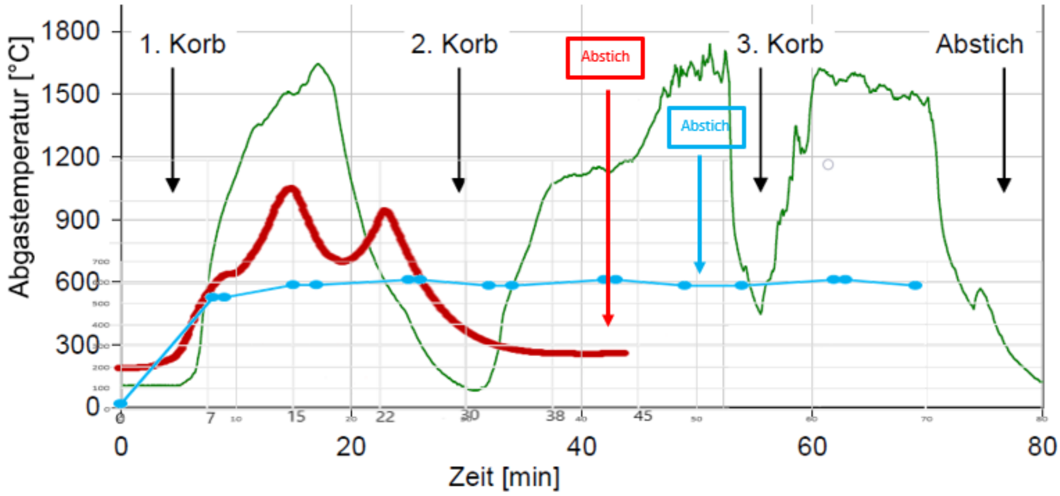

Figure 1 / Residual gas emissions in comparison (green EAF without scrap preheating, red single-chamber system, blue two-chamber system)

From these considerations, the following values can be concluded:

Table 1 / energy input for various procedures [kWh/t$_{LS}$]

Raw material / Energy	Hot metal / scrap	Scrap (100%) preheated *)	Scrap / DRI (x%/y%) preheated *)	Scrap preheated *) / cold DRI	Scrap (100%)	Pig iron / scrap	DRI _ HBI / scrap
Electrical energy	180 -300	240-300	250-310	300-370	320 -520	325 - 400	470 -600
Chemical energy**)	200 - 320	230-300	230-300	230-300	280 – 480	350 - 420	200 - 330
Preload ***)	300	-	-	-	-	-	-
Total energy input	750	540	570	600	680	720	750

*) Tow chamber scrap preheating

**) Fossil energy carrier (gas (LPG, NG), carbon)

***) imported enthalpy

In the table above (Table 1), we assumed that 100% scrap use will achieve the best values. But if we use the numbers from Nucor Steel, Arkansas (S. Hornby, AIST Vol. 19 No. 1), which DRI used together with scrap, a different picture emerges.

Table 2 / Energy input with various DRI mix [kWh/t$_{LS}$]

% scrap / % DRI / Energy / TTT	100 / 0	75 / 25	70 / 30	65 / 35	60 / 40	55 / 45	50 / 50
El. energy [kWh/t]	421	375	377	380	393	399	408
TTT [min]	61	52	53	54	55	57	59
Δ energy [kWh/t]	-	-46	-44	-41	-28	-22	-13

Based on the assumption that Nucor Steel, Arkansas would use an efficient two-chamber scrap preheater and that the furnace would operate according to the same values in use (VIU), the following picture would emerge:

Prerequisite: Preheating enthalpy 131kWh/t scrap (750°C)

Table 3 / Energy input preheated scrap and DRI mix [kWh/t_{LS}]

% Scrap / % DRI — Energy / TTT	100 / 0	75 / 25	70 / 30	65 / 35	60 / 40	55 / 45	50 / 50
El. energy [kWh/t]	290	244	246	249	262	268	277
TTT [min]	54	45	46	47	48	50	59
Δ energy [kWh/t]	-	-46	-44	-41	-28	-22	-13

These values seem very reasonable to us, especially since they also correspond to our calculations for the two-chamber scrap preheating system. In addition, the DRI preheating is included and does not incur any further costs.

However, if the furnace were operated with optimized values in use (VIU) for operation with a scrap preheater, its base values would come down by about 40kWh/t_{LS}, i.e., the following values would result:

Table 4 / Energy input preheated scrap (optimized VIU) and DRI mix [kWh/t_{LS}]

% Scrap / % DRI — Energy / TTT	100 / 0	75 / 25	70 / 30	65 / 35	60 / 40	55 / 45	50 / 50
El. energy [kWh/t]	250	204	206	209	222	228	237
TTT [min]	42	33	34	35	36	38	47

Despite the enormous economic benefits, the continuous addition of DRI has the following other advantages reported by operators of plants without scrap preheating:

- \+ Clean steel: Thanks to the increased CO production (DRI), there is an increased bath movement (flushing effect). This reduces nitrogen, hydrogen uptake and the formation of inclusions

  Together with preheated scrap, fewer icebergs are produced
- \+ Better use: service life of the lining is improved, the output increases
- \+ Foam slag: Faster and earlier formation of the foam slag causes better arc stability, better energy transfer, less thermal losses and less noise

- \- Energy consumption: The total energy expenditure when using DRI increases compared to the use of 100% scrap
- \- CO_2 emissions: CO_2 emissions increase compared to the use of 100% scrap.

However, the operation of the furnace must be adapted to the specific conditions that the use of DRI entails, depending on the C and gangue content.

The goal of reducing greenhouse gases can therefore only be achieved with DRI to the extent that CO_2 production at the blast furnace is reduced, but on the other hand increased in steel production. However, the associated disadvantages are so massive that a conversion is difficult to pay off, unless the prices for CO_2 certificates are massively increased (political control). It remains to be seen whether the states with the main production of iron will also adhere to this.

However, the preheating of scrap and DRI in the same step shows a viable way to reduce CO_2 production in a commercially profitable way.

0%C DRI or H_2 DRI

The reduction of iron ore by means of H_2 results in a C-free DRI. However, this confuses the process specifications at the EAF, because C-free DRI means less to no bath movement through CO production, and thus no foaming slag.

In addition, the associated investments (CAPEX and OPEX, energy and material costs) are so high that only a massive increase in CO_2 levies can justify the investments.

In the end, it all boils down to whether enough hydrogen can reach the end consumer at a reasonable price. On the one hand, the required amount of hydrogen, the problems with distribution (hydrogen is very volatile and escapes through the slightest leak), the costs for electrolysis and the still unknown conversion in the steel production process speak against this. A new value in use analysis that includes the environmental aspects must be the basis for the new development.

As environmentally conscious and caring entrepreneurs, we must assess such investments critically and forward-thinking. A first step towards a CO_2-free steel future is to optimize the resources used, i.e., through efficient scrap preheating (ECOFEEDER two-chamber system) and a DRI preheating system integrated in the preheating system for the continuous DRI feeding of the EAF. Even a future conversion of the work instructions to the 0%C DRI will not diminish the advantages of scrap preheating, because scrap will always remain part of the melt and an efficient preheating brings the energy back into the system.

Conclusion: Yes, DRI can be the future of the steel industry, set the case that the scrap and the DRI are preheated sensibly, i.e., resource-saving, the preheating process is batch-neutral (no mixing), the preheated scrap can be 'stored hot' and the DRI is preheated in a quasi-inert atmosphere.

March 2022, Roland V. Müller, eco-e AG (www.eco-eag.com)