ecology economy

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FUTURE VIEWS

DRI – food for future electric arc furnaces?

How can a steel plant strive towards net-zero targets and reduce costs at the same time?

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DRI – the food for future electric arc furnaces?

Summary

'Even if the will is there, the road can be stonier than expected.' as the conclusion of the analysis of the current situation and the possibilities that arise on the way to zero CO_2 emissions with the goal of 2050.

The current situation in Europe drastically illustrates the dilemma in which we find ourselves. On the one hand, there is war, a war that seems to be about borders, but is more about ideologies – about the choice between dictatorship and democracy. A war where we are shown the dependence and danger of globalization and where governments remain in a stalemate. Globalization, which is changing from a supposed blessing to a noose, forcing countries to take protective measures that were unimaginable just a short time ago. At the same time, the climate situation is worsening. Droughts follow floods, storm damage is getting bigger and bigger – we must finally act and drastically reduce CO_2 emissions! How does that work?

On the following pages, the current CO_2 emissions of the individual areas of the steel industry are shown and the emissions and energy demand when using a traditional energy mix (coal, gas, nuclear and hydroelectric power plants) are compared with an electricity mix from renewable energy sources.

The path of the integrated steel mills seems to be determined, the new primary steel production with DRI reactor, an electric arc furnace (SAF) and the proven converter significantly reduces CO_2 emissions but not sufficiently, but the energy requirement increases. The electric steel mill will have to reorient itself towards DRI as an additive, but it is precisely there that a new approach to energy-saving CO_2 emission reduction is available.

"Scrap preheating and DRI – don't exactly go together!" This sentence can confidently be deleted or rewritten, because the eco-e tech solution shows a feasible way even for special steel mills, which is cost-effective, environmentally friendly, and energetically optimal. In other words: "Scrap preheating and DRI – allow the steel mill and the environment to thrive".

Roland V. Müller, Consultant for Environmental and Energy Issues

Background

Not so long ago, I asked the question "Is DRI the future of the steel industry?"[i] and have come to the conclusion that the iron melted from DRI could replace the iron produced in blast furnaces and that the direct reduction of 0%C DRI can solve the problem of CO_2 in steel production, provided there is enough green hydrogen. But how far away is this future?

The facts:

2021: Global crude steel production reached 1952 million tons in 2021. Steel production from scrap reached 748 million tons in the same period, and DRI production reached 108 million tons, which is less than 10% of the production of steel from ore. Hydrogen production in 2020 was 90 million tons, almost exclusively for finishing and industrial applications and almost exclusively produced from fossil fuels. The global capacity of electrolysers needed to produce hydrogen has doubled in the last five years, reaching just over 300 MW by mid-2021.

The perspectives:

Steel: Global steel production in the net-zero scenario 2010-2030 foresees a slow increase towards 2030 million tonnes in 2030[ii].

Hydrogen: Around 350 projects currently under development could increase global capacity to 54GW by 2030. A further 40 projects with a capacity of more than 35 GW are at an early stage of development. If all these projects are realized, the global hydrogen supply by electrolysers could reach more than 8 million tonnes by 2030, which is about 1/10 of the hydrogen needed for 2030 on the way to net-zero CO_2 emissions by 2050[iii].

The outlook:

Due to the Environmental Act on Greenhouse Gas Reduction, most blast furnaces are replaced by DRI shaft reduction plants. This will be done from an economic point of view, i.e. after reaching the 'furnace journey' of the respective blast furnaces, which in most cases will be about 10 to 15 years. Some "young" blast furnaces will end their 'furnace journey' in 35 years at the latest. This would mean that the emission of about 2200 kg CO_2/ton of liquid steel will continue for a while. In this case, therefore, GHG emissions will not be significantly reduced for the next 5 years, as about 71% of the world's steel production is via the BF-BOF route. In a more pessimistic case, greenhouse gas emissions will remain at today's levels for the next 10 years.

The optimistic case requires swift and consistent action at both national and international level – because in order to protect the high investments of the steel industry, customs controls and tariffs must be installed (a political hurdle). As long as these security measures are not installed, no one will ever risk an investment in the tens of millions. On the other hand, if we are not able to make steel production CO_2 emission-free, then we will not be able to make the global economy CO_2-emission-free. Because steel is everywhere, which is what makes the decarbonization of steel so important. On the other hand, the continued existence of the integrated steel industry is socially important, as many jobs depend on it. The steel industry is also economically important.

The timeframe runs counter to a sober and well-considered plan to replace the blast furnaces and reorganize the integrated steel mills – it is simply not possible to transform a grown and established industry in such a short time, and the time to act is short, very short.

The iron and steel industry, one of the sectors where it is notoriously difficult to rationalize operations, will suffer from the increase in production costs (> €120 per ton). The core problem of decarburization is not the lack of technical solutions, but that these solutions cause high implementation costs, which directly affects market share, trade and labor. Does it have to be? No, let's discuss this issue after we have laid out the facts.

In view of all this, the plan must include the following:

- Reduction of emissions, including those of existing electric steel mills
- Complete integration of the stock, as far as it makes sense
- Maintaining social attractiveness and protecting structures
- Maintaining market capabilities
- The support and protection of domestic industry

The Preview:

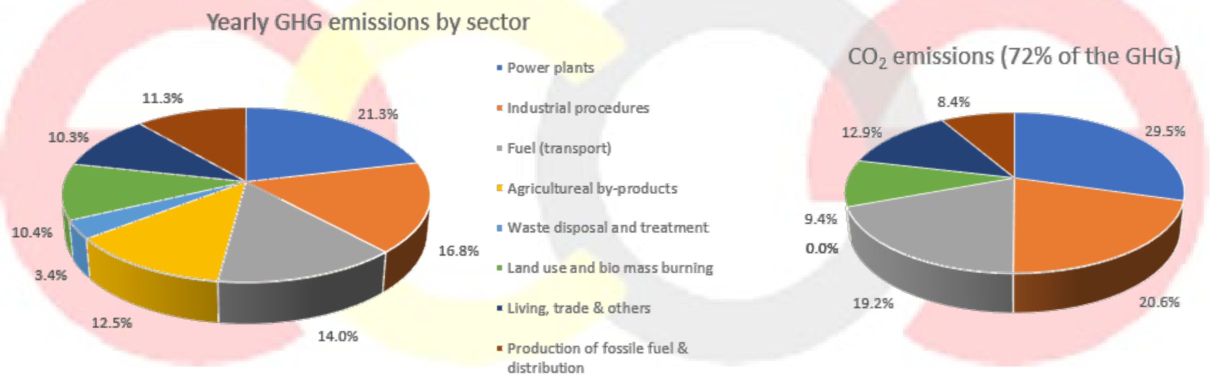

Figure 1 / GHG emission by sectors

'What can I achieve on my own?' half of humanity wondered.

Who will reduce their greenhouse gas emissions first? Is it the "power plants" sector, with its huge amount of coal and gas power plants, that emits the most greenhouse gases, especially CO_2? Or is it the "fuels (transport)" sector, with its myriad of old and polluting cars, in low-income countries? Or is it the "Landfill & Treatment" sector that takes care of all our waste? Or is it the "housing, trade and other sources" sector that also affects us directly? No, it is the industry that needs to take the first step, and here, as mentioned here above, it is the steel industry where a reduction in CO_2 emissions is possible that must take the lead. As I said, if we are not able to make steel production CO_2-free, then we will not be able to make the global economy CO_2-free.

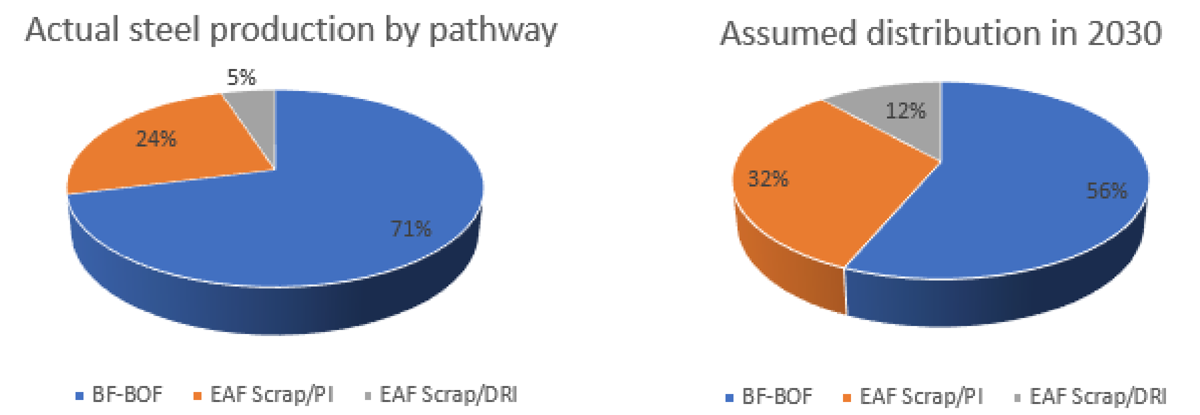

Figure 2 / Steel production by pathway

Here is a more realistic – or perhaps pessimistic – prediction of the reduction of CO_2 emissions on the basis of economically feasible facts. This scenario is based on a 3.3% increase in scrap raw material per year and a 13% increase in DRI production per year (excluding DRI production related to the conversion of blast furnaces, as this production is used for own consumption).

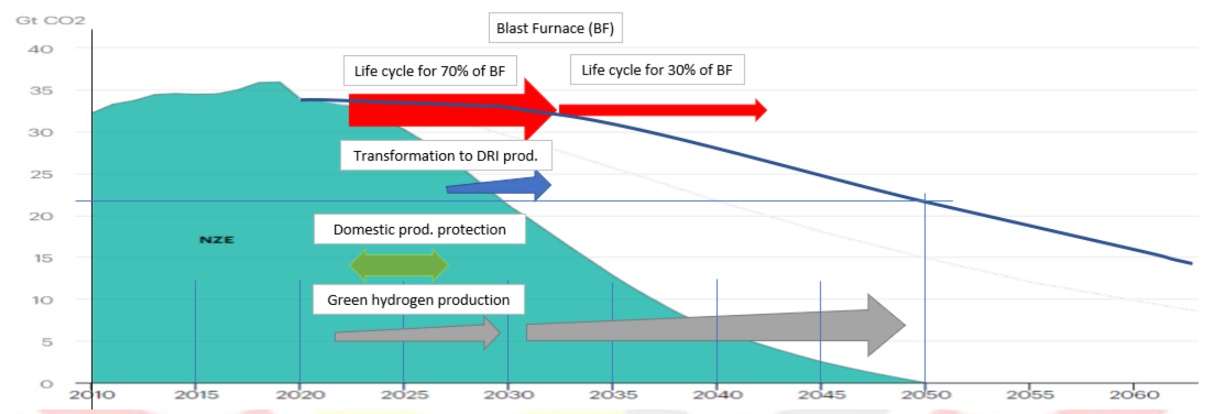

Figure 3 / CO2 emission evolution – pessimistic prediction

The assumed increase in scrap raw material and the increase in DRI production for non-integrated steel production will lead to an increase in the share of electric steel production to around 44% of global crude steel production by 2032.

The above assumption also provides for a continuation of 70% of the installed blast furnaces in the next 10 years for economic reasons and low international cooperation in customs and protection matters.

The routes:

The integrated route (primary steelmaking)

As the use of blast furnaces continues, we need to consider a new plan to reduce greenhouse gas emissions, at least for the next 8 to 10 years.

First, how much CO_2 does a blast furnace produce? Figure 4 shows the GHG gas production per tonne of steel (HM) and the energy used for it. The data is based on following assumptions:

- 460 kg-CO_2/MWh for electrical energy. This value is based on a mix of different energy sources, including coal- and gas-fired power plants, nuclear power plants and renewable energy (hydro-electric power plants). This value has fallen in 2020 but has risen to a new peak value in 2021. For comparison, electrical energy based on high carbon intensity has a GHG emission value of 711 kg-CO_2/MWh[iv].

- 0 kg-CO_2/MWh for renewable electrical energy. This value is based on a mix of renewable energy sources such as photovoltaic (solar), wind and hydro-electric power production.
- 392 kg-CO_2/t_{HM} for processing iron ore for the use in blast furnaces (production of pellets, sintering and coke production)
- 356 kWh/t_{HM} electrical energy for the entire process.
- 1476 kg-CO_2/t_{HM} to produce the liquid iron. This is produced by a coal-based reduction in the blast furnace
- 192 kg-CO_2/t_{HM} is the amount released in the converter, where mainly carbon from the liquid iron is burned.

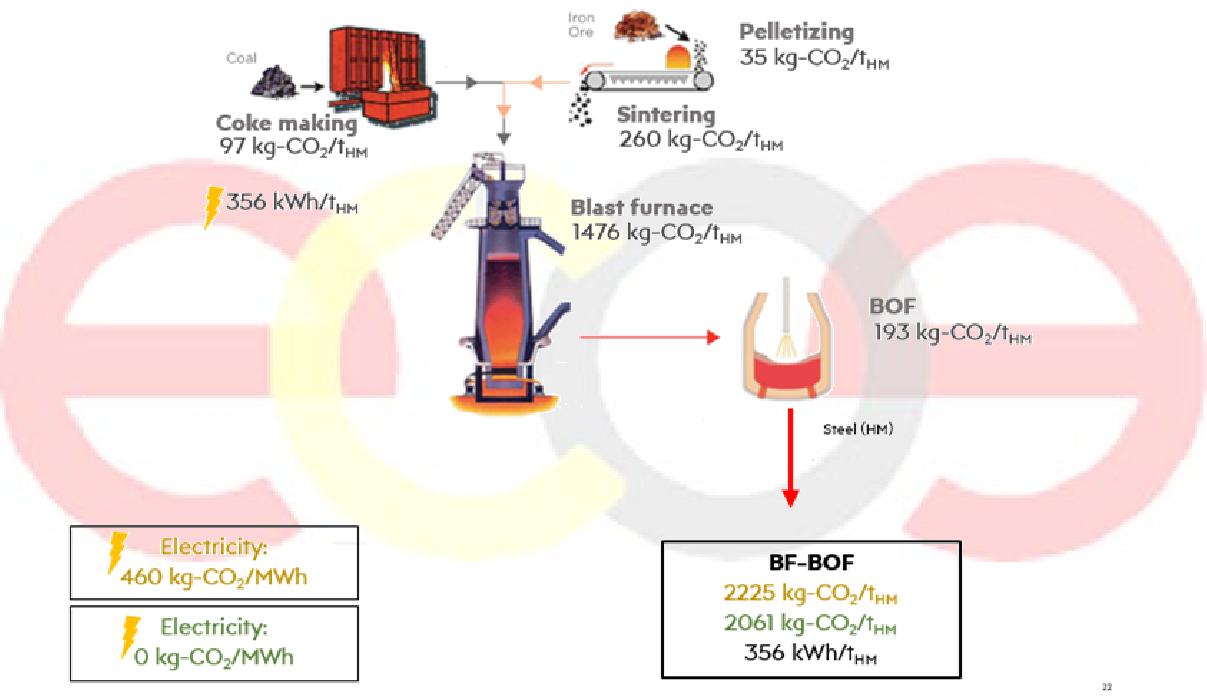

Figure 4 / CO_2 emissions and energy input integrated route [22]

In 2021, 71% of the world's steel production was produced by the integrated steel mills, the primary steel production. 29% of the world's steel production was produced by the secondary steel production, the electric steel mills. Secondary steel production is divided into 25% scrap and pig iron raw materials and 4% scrap and DRI raw materials (see figure 2).

Global steel production is expected to remain at the level of 2021 (see figure 2). However, the distribution is changing. The melting unit (blast furnace (BF)) shall be replaced by a direct reduction unit (DRI reactor) and an electric arc furnace (submerged arc furnace). The refining tool, the Basic Oxygen Furnace (BOF) must be preserved. The aim is to reduce the GHG emissions.

Table 1 / Integrated route

CO_2 emissions integrated route BF-BOF technology					
Process		Electricity		Emissions	Emissions
	[kWh]	[kg-CO_2/MWh]		[kg-CO_2/t_{HM}]	[kg-CO_2/t_{HM}]
Blast furnace				1476	1476
Coke Making				97	97
Pelletizing				35	35
Sintering				260	260
BOF steelmaking				193	193
El. Power	356	460*)	0**)	164	0
Total				2225	2061

*) Mix of different energy sources, mean value (coal, gas, nuclear, renewables)
**) renewable energy sources (wind, photovoltaic (solar), hydro-electric power)

Based on the above figures, for 2030 about 56% of the annual steel production, which is expected to be about 2030 million tons/year, is to be produced via the integrated route, which is about 1140 million tons. The GHG emissions (CO_2 only) amount to approx. 1140 million tons * 2.225 tons-CO_2/t_{HM} = 2530 million tons of CO_2 or 1140 million tons for 100% renewable energy * 2.061 tons-CO_2/t_{HM} = 2350 million tons of CO_2. The electric energy input for the BF-BOF route is 0.356 MWh/t * 1140 million tons = 405 TWh/year.

The integrated steel mills (more than 80% of the existing blast furnaces are in Asia) could save 190 Mio. Tons of CO_2, if the 405 TWh could be supplied from renewable sources. However, this amount will not be available until 2030.

<u>The new integrated route</u>

Let us now consider the different DRI processes, coal-based, gas-based and hydrogen-based reduction in combination with a 'Smelter' (Submerged electric Arc Furnace (SAF)). The data is based on the following assumptions:

- The preparation and pre-treatment required for the direct reduction process yields 307 kg-CO_2/t_{HM}.
- There are three different DRI processes that need to be distinguished
    - The coal-based DRI with about 4% C, which produces approx. 1048 kg-CO_2/t_{HM}. The energy required for this reduction is approx. 380 kWh/t_{HM} at a rotary kiln and approx. 100 kWh/t_{HM} at a shaft reactor
    - The gas-based DRI with about 2 to 3.5%C (NG-H_2 mixture), which gives about 522 kg-CO_2/t_{HM}. Here, the energy requirement for a shaft reactor is approx. 73 kWh/t_{HM}
    - The hydrogen-based DRI with 0% C, which produces 0 kg-CO_2/t_{HM}. The required energy is approx. 60 kWh/t_{HM}
    - The DRI produced by the above process is usually hot charged into the melting unit. This unit is a large scale, slow melting electric arc furnace (mainly a submerged arc furnace) designed for continuous melting.
    - The last unit is the refining tool – the converter (BOF).

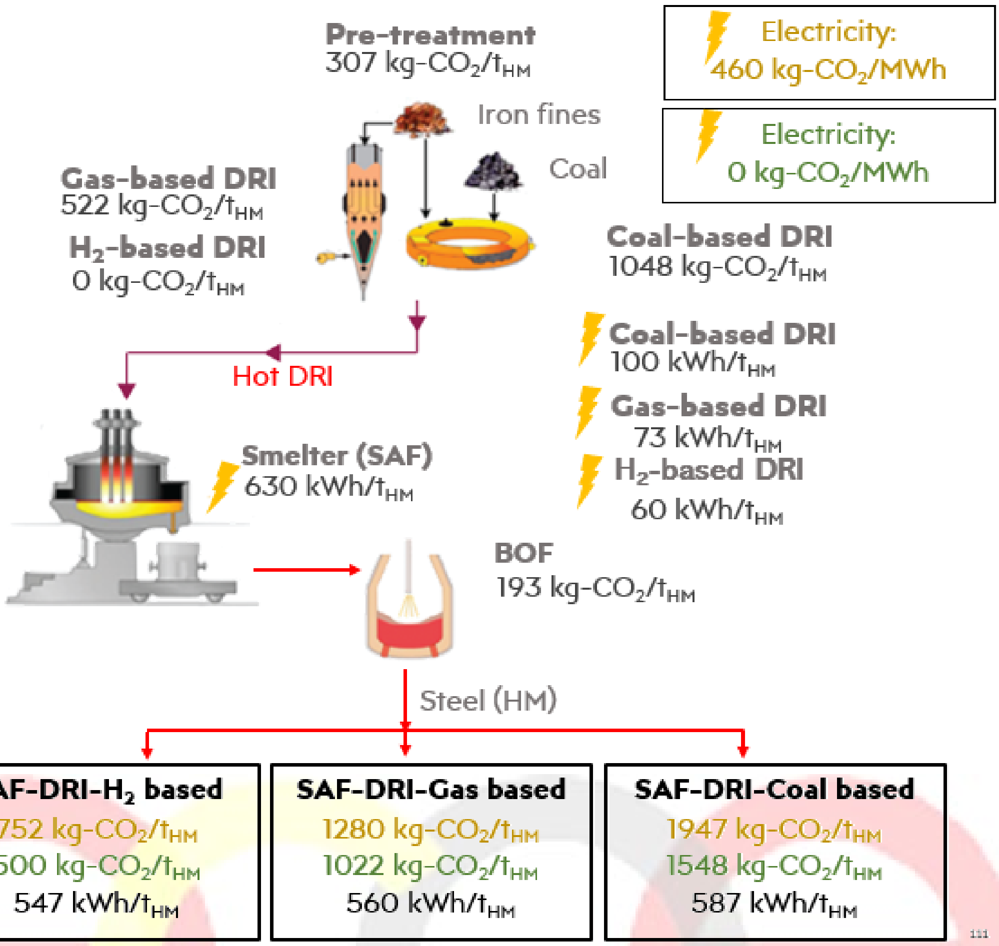

Figure 5 / CO_2 emission and energy input of the primary route of the future (DRI and SAF) [111]

Figure 5 shows the replacement of the BF-BOF production line, modern primary steel making, a combination of direct reduction and a submerged electric arc furnace (SAF).

It is striking that there is a big difference between H_2-based DRI and coal-based DRI steel production in CO_2 production and in the required energy input.

Table 2 / New primary route

CO_2 emissions scrap and DRI technology										
Process		Power mis Trad/Renewable		Emissions	DRI-coal	DRI-gas	DRI-H2	DRI-coal	DRI-gas	DRI-H2
	[kWh/t$_{HM}$]	[kg-CO$_2$/MWh]			[kg-CO$_2$/t$_{HM}$]					
Pre treatment				307	307	307	307	307	307	307
DRI coal based	100	460	0	1048	1094	-	-	1048	-	-
DRI gas based	73	460	0	522	-	556	-	-	522	-
DRI H_2 based	60	460	0	0	-	-	28	-	-	0
Hot DRI	-143	460	0	0	-66	-66	-66	0	0	0
Smelter	630	460	0	0	290	290	290	0	0	0
BOF		460	0	193	193	193	193	193	193	193
		CO_2	[kg-CO$_2$/MWh]		1818	1280	752	1548	1022	500
		Energy	[kWh/t$_{HM}$]		587	560	547	587	560	547

Note: the green columns are calculated with renewable energy, while the brown columns are calculated with the traditional energy mix.

From an energy point of view, the new primary steel production is very interesting, not as low as the old primary steel production, but still in a good range. However, CO_2 emissions are still quite high, with the exception of DRI production with hydrogen. The disadvantage of this process is its absence of carbon, so a mixture of natural gas with hydrogen is an optimal way for DRI reduction (see below). Traditionally, the distances in integrated steel mills are quite short, so that the associated transport costs and the associated CO_2 emissions are not taken into account.

The recycling route, the electric steelmaking (secondary route)

Electric steel production is the most common way to recycle steel scrap and produce high-quality steels. But even if steel is endlessly recyclable, there are limits to foreign metals that come into the melt with the scrap. To improve purity, cold pig iron or HBI can be added to the scrap basket. Liquid iron from DRI, HBI, or pig iron can also be added directly to the melt. Hot iron from DRI, HBI or pig iron can be melted in a smelter (see above) or, if available, obtained from the blast furnace. Pig iron is rich in carbon, which is burned with oxygen during refining.

Another way to increase steel quality (fewer foreign metals and unwanted additives) is to continuously supply the furnace with cold DRI through a fifth hole aligned so, that the DRI enters directly into the plasma around the electrodes. DRI should not be added to the scrap basket or only in small quantities, as this would lead to the formation of icebergs in the furnace. These icebergs remain and melt only by massive overheating of the melt. The indication when adding DRI is that the SOP (standard operation practice) and ViU (Values in Use) must be adapted to this situation since the melting of scrap with the addition of carbon in form of HBI is not the same as melting scrap with the addition of pig iron and specially not the same as melting scrap in combination with DRI.

The melting energy of DRI as a function of the carbon content:

DRI requires more energy to melt than steel. It is obvious that DRI with a high percentage of carbon requires less electrical energy input than DRI with a low carbon content. The graph below shows this trend. This is very important in the production of electric steel as the oxygen activity actively supports melting.

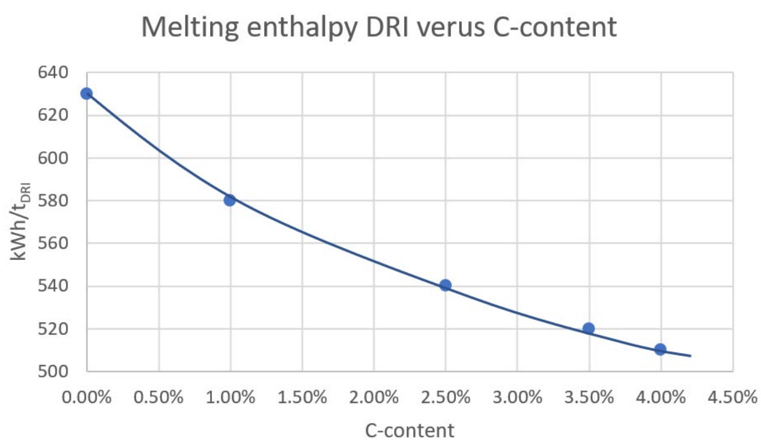

Figure 6 / The melting enthalpy of DRI

The transport of DRI:

Hot DRI can be transported over limited distances, with covered conveyor belts or in closed containers (trucks). If DRI must be transported over longer distances, then only in the cold state. This is also not without danger, so that certain conditions must be met, e.g., sea transport only in covered containments and under inert atmosphere (any contact with seawater must be avoided).[v]

In contrast to the integrated steel mills, where the transport of the DRI is not taken into account, the transport of DRI must be taken in account in the emission calculation of the electric steel mills at least for the CO_2 emissions.

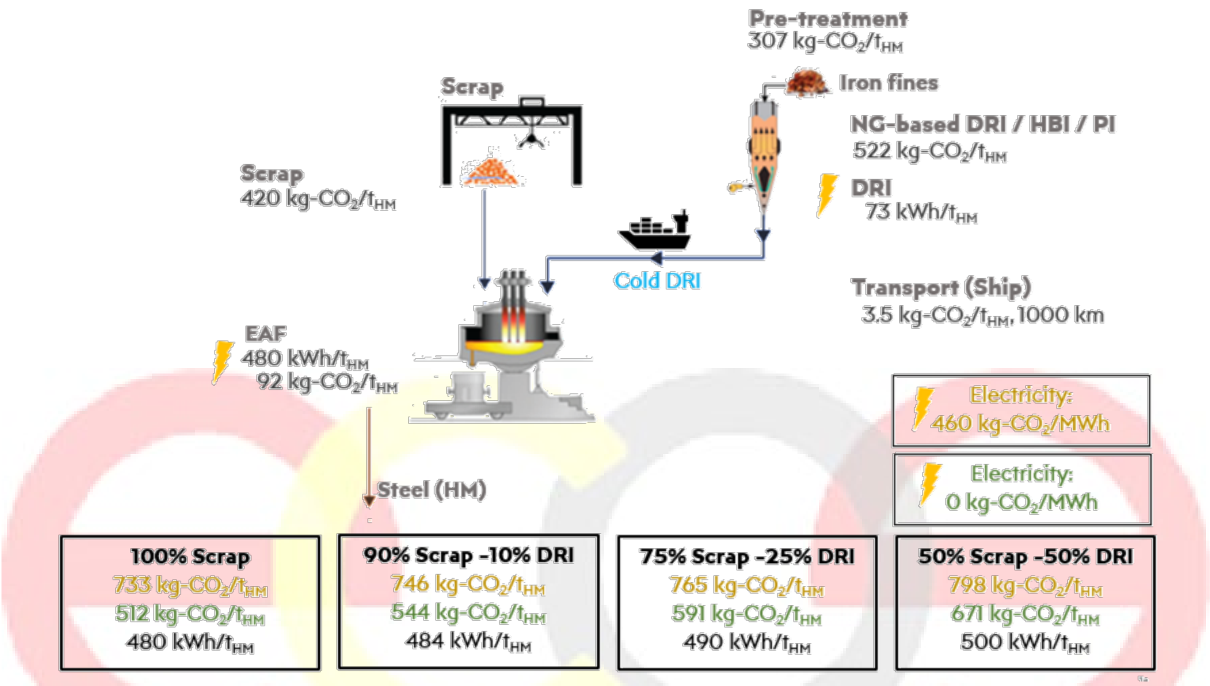

Figure 7 / CO_2 emission and energy input of the actual secondary route (EAF with or without DR/HBI/PI) [1a]

The picture above shows the traditional electric steel production using HBI, pig iron, or DRI. The energy consumption shown includes the total consumption for the production of steel: this includes the pre-treatment of iron ore, the energy consumption of a DRI shaft reactor and the energy consumption of the arc furnace. The same considerations apply to CO_2 emissions. When the DRI is purchased, the upstream processes can be neglected for the energy consumption analysis, not so for the CO_2 consideration. Depending on the melting energy of DRI, which is between 520 and 630 kWh/t_{DRI} depending on the C-content, DRI directly influences the energy consumption. The figures given (the last row, e.g., 480 kWh/t, 484 kWh/t, 490 kWh/t and 500 kWh/t) show the energy consumption without the energy required for DRI production.

Table 3 / CO_2 emission and energy consumption

CO_2 emissions / combined supply scrap-DRI																		
Process (3.5%C)		Emissions	Power mix Trad/Renewable		DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	Scrap	Scrap
100% NG	[kWh/t_{HM}]	[$kg\text{-}CO_2/t_{HM}$]	[$kg\text{-}CO_2/MWh$]		10%	90%	10%	90%	25%	75%	25%	75%	50%	50%	50%	50%	100%	100%
Scrap		420				378		378		315		315		210		210	420	420
Pre-treatment		307			31		31		77		77		154		154			
DRI	73	522	460	0	56		52		139		131		278		261			
EAF	480	92	460	0		282		83		235		69		156		46	313	92
Cold DRI	520	CO_2	[$kg\text{-}CO_2/t_{HM}$]			746		544		765		591		798		671	733	512
		Spec. energy	[kWh/t_{HM}]			**484**		491		**490**		508		**500**		537		**480**

Looking at the production chain in Table 3, the brown figures are based on a traditional energy mix while the green numbers are based on renewable energy sources.

The comparison between the use of hot and cold DRI

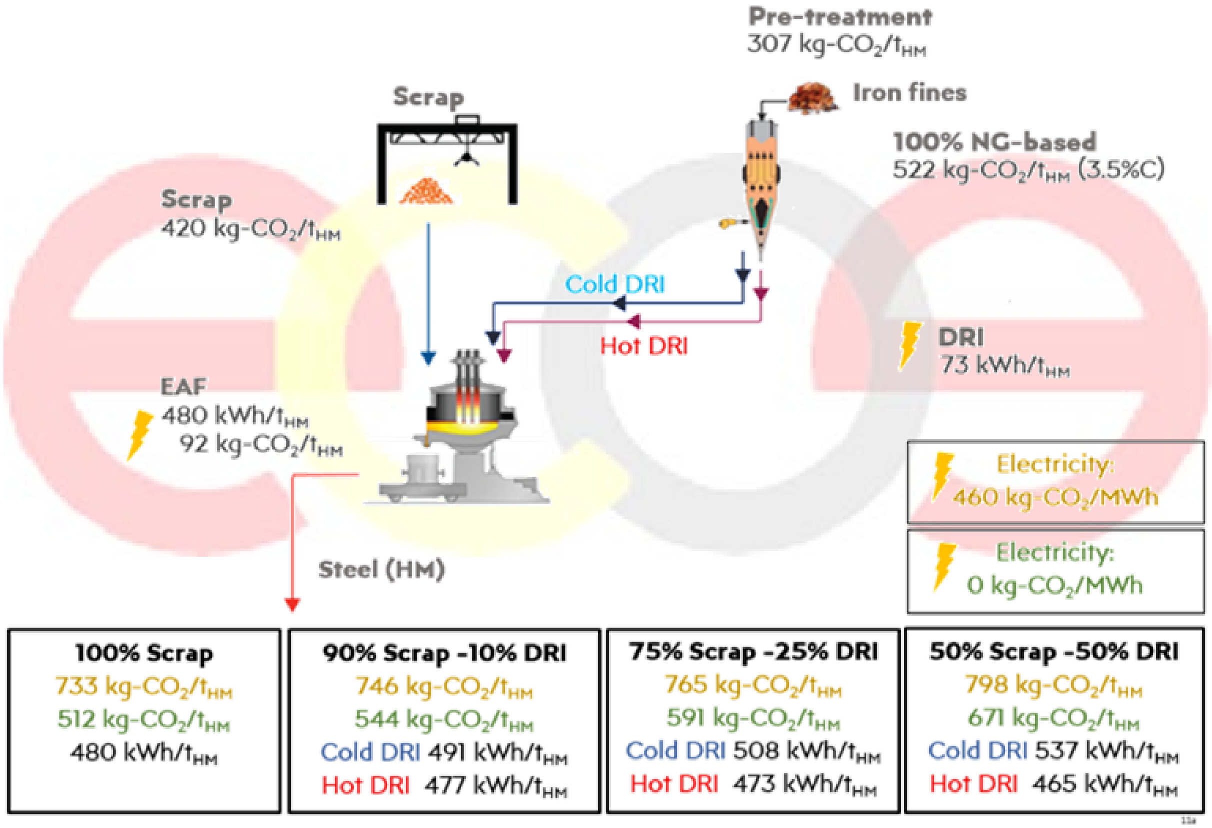

Figure 8 / Comparison of energy consumption of Hot DRI and Cold DRI (11a)

The picture above shows the same situation as Figure 7 with the difference that this time the production energy for DRI is also taken into account. Note that the energy consumption to make steel increases when using cold DRI, while it decreases when using hot DRI. This situation depends on the energy needed to melt DRI. The figures above are based on the melting enthalpy shown in figure 6.

Table 4 / CO_2 emissions with DRI reduced with 100% natural gas (NG)

CO_2 emissions / combined supply scrap-DRI																		
Process (3.5%C)		Emissions	Power mix Trad/Renewable		DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	Scrap	Scrap
100% NG	[kWh/t_{HM}]	[kg-CO_2/t_{HM}]	[kg-CO_2/MWh]		10%	90%	10%	90%	25%	75%	25%	75%	50%	50%	50%	50%	100%	100%
Scrap		420				378		378		315		315		210		210	420	420
Pre-treatment		307			31		31		77		77		154		154			
DRI	73	522	460	0	56		52		139		131		278		261			
EAF	480	92	460	0		282		83		235		69		156		46	313	92
Cold DRI	520	CO_2	[kg-CO_2/t_{HM}]			746		544		765		591		798		671	733	512
Hot DRI @ 600°C	-143	Energy (cold DRI)	[kWh/t_{HM}]			**484**		491		**490**		508		**500**		537		**480**
		Energy (hot DRI)	[kWh/t_{HM}]			**470**		477		**454**		473		**429**		465		**480**

The energy consumption (last two rows of the table above) with the addition of cold or hot DRI shows two groups of values, the left values (bold) are without the energy consumption of the DRI reactor, the right values include the DRI reactor. It is interesting that the heat content of the hot DRI which is about 143 kWh/t_{DRI} @600°C compensates for the higher energy requirement for melting DRI. This tendency was confirmed by results from Nucor Arkansas using hot DRI. [vi]

The following 2 tables show the different environmental impact of DRI with a different proportion of the reducing agents NG and H_2. The first table shows the CO_2 emission and energy consumption of a 2.5%C DRI produced with 45% natural gas (NG) and 55% hydrogen (H_2)

Table 5 / CO_2 emissions with DRI reduced with a mix of 45% NG and 55% H_2

CO_2 emissions / combined supply scrap-DRI																		
Process (2.5%C)		Emissions	Power mix Trad./Renewable		DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	Scrap	Scrap
45% NG / 55% H_2	[kWh/t_{HM}]	[kg-CO_2/t_{HM}]	[kg-CO_2/MWh]		10%	90%	10%	90%	25%	75%	25%	75%	50%	50%	50%	50%	100%	100%
Scrap		420				378		378		315		315		210		210	420	420
Pre-treatment		307			31		31		77		77		154		154			
DRI	73	216	460	0	25		22		62		54		125		108			
EAF	480	92	460	0		282		83		235		69		156		46	313	92
Cold DRI	540	CO_2	[kg-CO_2/t_{HM}]			715		513		689		515		645		578	733	512
Hot DRI @ 600°C	-143	Energy (cold DRI)	[kWh/t_{HM}]			**486**		493		**495**		513		**510**		547		**480**
		Energy (hot DRI)	[kWh/t_{HM}]			**472**		479		**459**		478		**439**		475		**480**

And the second table shows the CO_2 emissions and energy input of a 1%C DRI produced with 25% NG and 75% H_2.

Table 6 / CO_2 emissions with DRI reduced with a mix of 25% NG and 75% H_2

CO_2 emissions / combined supply scrap-DRI																		
Process (1%C)		Emissions	Power mix Trad./Renewable		DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	Scrap	Scrap
25% NG / 75% H_2	[kWh/t_{HM}]	[kg-CO_2/t_{HM}]	[kg-CO_2/MWh]		10%	90%	10%	90%	25%	75%	25%	75%	50%	50%	50%	50%	100%	100%
Scrap		420				378		378		315		315		210		210	420	420
Pre-treatment		307			31		31		77		77		80		46			
DRI	73	126	460	0	16		13		40		32		125		108			
EAF	480	92	460	0		282		83		235		69		156		46	313	92
Cold DRI	580	CO_2	[kg-CO_2/t_{HM}]			706		504		666		492		600		473	733	512
Hot DRI @ 600°C	-143	Energy (cold DRI)	[kWh/t_{HM}]			**490**		497		**505**		523		**530**		567		480
		Energy (hot DRI)	[kWh/t_{HM}]			**476**		483		**469**		488		**459**		495		480

The above discussion concerns normal steel production either in integrated steel mills or in 'mini-mills'. 'Energy-saving' systems such as shaft-furnaces or continuous feeding installations are left out. This is because most of these installations have no real energy saving potential, especially not taking into account the environment. And the environment must be taken into account. However, the combination of economy and ecology is important for the survival of the company and humanity, more important than ever. In times where the ice is melting in Greenland, where the science predicts an ice-free Arctic area within a few years, leading to a sea level rise of about 7m, and all this because of the man-made increase of GHG emissions, it is simply not responsible to make changes, plan conversions or new facilities, or discuss the future of the company, without taking into account the aspects of the environment, otherwise the steel mills can literally disappear, since most steel mills are located near the sea.

Our credo – the combination of economy and ecology – has led us to think about all aspects of energy consumption from the scrap yard to the stack. We evaluated existing plants and designed a new, ground-breaking scrap preheating system that meets our economic and ecological expectations.

The combined scrap preheating system from eco-e tech offers optimum scrap preheating with three separate stages. The scrap preheating is based on a two-container system in which each batch is preheated separately, in which the 'off gas' contaminated with harmful and toxic substances is thermally cleaned in the burner chamber after the first stage, where this additional energy is used for further scrap preheating in the second stage and where the clean residual gas is available for further use. e.g., for steam generation, district heating and other applications that require an "off gas" with an almost constant temperature around 600 °C, including the storage of preheated DRI without ignition risk, as the residual off gas is inert and non-oxidizing (CO_2, NOx and N_2). The third preheating stage takes place in the furnace itself. Thanks to an intelligent new "off gas" guide, better utilization of the off-gas enthalpy can be achieved, the scrap melts more evenly and the electrodes have less burn-up.

Another interesting and in our opinion very important aspect is the possibility of avoiding metallurgical mixing of steel grades in scrap preheating.

The IEA forecasts a horizontal development of steel production. This means that productivity is losing importance and the production of high-quality steels is gaining in importance, i.e., clearly differentiated scrap types and metallurgically clean production units. Most scrap preheating systems are designed for continuous production and high productivity. The eco-e tech can both ensure high productivity and continuous production and meet the differentiated, lower production, since the containers are also thermal storage tanks that allow energy savings over several hours. The aim is to save a large part of the exhaust energy for short- or long-term use.

The environmental load of the scrap preheating system of **eco-e tech is very low and counts in 'scope 1' less than 20 kg CO_2e[vii].**

In our opinion, it is not expedient to consider only the amount "Scope 1", as this only reflects half of the cake, especially in the mixture of supplier quality and origin. Scrap has a different preparation storyboard than the DRI, and to adapt operating practices, it is also important to include DRI quality (C content).

Looking at the entire process from scrap delivery and processing to the tapping of liquid steel, CO_2 emissions of 636 kg CO_2/t_{HM} result with a traditional energy mix, or 520 kg CO_2/t_{HM} with renewable energies.

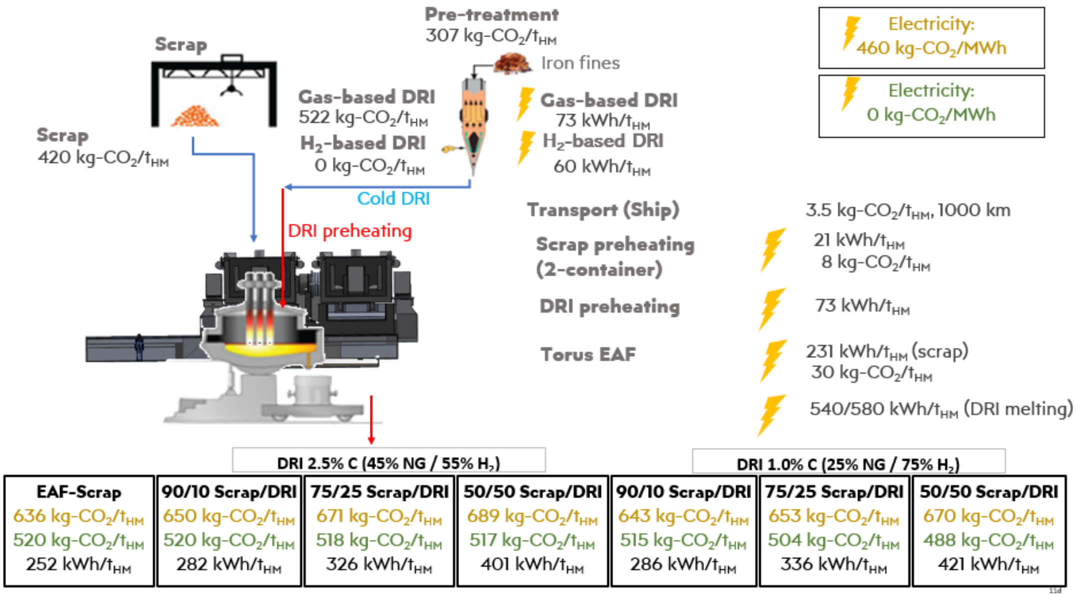

Figure 9 / CO_2 emission and energy input with eco-e tech [11d]

Table 7 / CO_2 emissions - Scrap and DRI preheating

CO_2 emissions / Scrap preheating – DRI preheating																		
Process (2.5%C)		Emissions	Power mix Trad. /Renewable		DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	Scrap	Scrap
45% NG/55% H_2	[kWh/t_{HM}]	[kg-CO_2/t_{HM}]	[kg-CO_2/MWh]		10%	90%	10%	90%	25%	75%	25%	75%	50%	50%	50%	50%	100%	100%
Scrap		420			-	378	-	378	-	315	-	315	-	210	-	210	420	420
Scrap preheating	21	8	460	0	-	16	-	7	-	13	-	6	-	9	-	4	18	8
Pre-treatment		307	460	0	31	-	31	-	77	-	77	-	154	-	154	-	-	-
DRI	73	216	460	0	25	-	22	-	62	-	54	-	108	-	108	-	-	-
DRI preheating	79	0	460	0	4	-	0	-	9	-	0	-	18	-	0	-		
EAF	480	92	460	0	18	178	0	83	46	149	-3	69	91	99	-5	46	198	92
DRI melting	540	CO_2	[kg-CO_2/t_{HM}]			650		520		671		518		689		517	636	520
Hot DRI @ 600°C	-143	Energy	[kWh/t_{HM}]					**282**				**326**				**401**		**252**

CO_2 emissions / Scrap preheating – DRI preheating																		
Process (1%C)		Emissions	Power mix Trad. /Renewable		DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	DRI	Scrap	Scrap	Scrap
25% NG/75% H_2	[kWh/t_{HM}]	[kg-CO_2/t_{HM}]	[kg-CO_2/MWh]		10%	90%	10%	90%	25%	75%	25%	75%	50%	50%	50%	50%	100%	100%
Scrap		420			-	378	-	378	-	315	-	315	-	210	-	210	420	420
Scrap preheating	21	8	460	0	-	16	-	7	-	13	-	6	-	9	-	4	18	8
Pre-treatment		307	460	0	31	-	31	-	77	-	77	-	154	-	154	-	-	-
DRI	73	126	460	0	16	-	16	-	40	-	40	-	80	-	80	-	-	-
DRI preheating	79	0	460	0	4	-	0	-	9	-	0	-	18	-	0	-		
EAF	480	92	460	0	20	178	0	83	50	149	-3	69	101	99	-5	46	198	92
DRI melting	580	CO_2	[kg-CO_2/t_{HM}]			643		515		653		504		670		488	636	520
Hot DRI @ 600°C	-143	Energy	[kWh/t_{HM}]					**286**				**336**				**421**		**252**

With the optional DRI preheater from eco-e tech, the delivery of hot DRI to the furnace is possible without transport problems and connection to a DRI reactor. Without a fourth hole (the torus furnace does not need the fourth hole), there is enough space on the furnace roof to place the funnel and the second DRI preheating unit.

The ranking:

After discussing possible production processes to reduce the carbon footprint of steel, here is the ranking, first the energy savers and then the CO_2 minimizers.

CO_2 emissions and energy input; energy ranking

Process	Addition	%C	DRI	Mix [%]	Energy	kg-CO_2/t_{HM}	kWh/t_{HM}
eco-e tech			no	100/0	Renewable	520	252
eco-e tech			no	100/0	Traditional mix	636	252
eco-e tech	DRI preh.	2.50%	Cold	90/10	Renewable	520	282
eco-e tech	DRI preh.	2.50%	Cold	90/10	Traditional mix	650	282
eco-e tech	DRI preh.	1.00%	Cold	90/10	Renewable	515	286
eco-e tech	DRI preh.	1.00%	Cold	90/10	Traditional mix	643	286
eco-e tech	DRI preh.	2.50%	Cold	75/25	Renewable	518	326
eco-e tech	DRI preh.	2.50%	Cold	75/25	Traditional mix	671	326
eco-e tech	DRI preh.	1.00%	Cold	75/25	Renewable	504	336
eco-e tech	DRI preh.	1.00%	Cold	75/25	Traditional mix	653	336
BF-BOF				-	Renewable	2061	356
BF-BOF				-	Traditional mix	2225	356
eco-e tech	DRI preh.	2.50%	Cold	50/50	Renewable	517	401
eco-e tech	DRI preh.	2.50%	Cold	50/50	Traditional mix	689	401
eco-e tech	DRI preh.	1.00%	Cold	50/50	Renewable	488	421
eco-e tech	DRI preh.	1.00%	Cold	50/50	Traditional mix	670	421
EAF- DRI		3.50%	Hot	50/50	Renewable	671	465
EAF- DRI		3.50%	Hot	50/50	Traditional mix	798	465
EAF- DRI		3.50%	Hot	75/25	Renewable	591	473
EAF- DRI		3.50%	Hot	75/25	Traditional mix	765	473
EAF- DRI		2.50%	Hot	50/50	Renewable	518	475
EAF- DRI		3.50%	Hot	90/10	Renewable	544	477
EAF- DRI		3.50%	Hot	90/10	Traditional mix	746	477
EAF- DRI		2.50%	Hot	75/25	Renewable	515	478
EAF- DRI		2.50%	Hot	90/10	Renewable	513	479
EAF			no	100/0	Renewable	512	480
EAF			no	100/0	Traditional mix	733	480
EAF- DRI		1.00%	Hot	90/10	Renewable	504	483
EAF- DRI		1.00%	Hot	75/25	Renewable	492	488
EAF- DRI		3.50%	Cold	90/10	Traditional mix	746	491
EAF- DRI		2.50%	Cold	90/10	Traditional mix	715	493
EAF- DRI		1.00%	Hot	50/50	Renewable	473	495
EAF- DRI		1.00%	Cold	90/10	Traditional mix	715	497
EAF- DRI		3.50%	Cold	75/25	Traditional mix	765	508
EAF- DRI		2.50%	Cold	75/25	Traditional mix	689	513
EAF- DRI		1.00%	Cold	75/25	Traditional mix	666	523
EAF- DRI		3.50%	Cold	50/50	Traditional mix	798	537
EAF- DRI		2.50%	Cold	50/50	Traditional mix	645	547
SAF-DRI	H_2	0.00%	Hot	0/100	Renewable	500	547
SAF-DRI	H_3	0.00%	Hot	0/100	Traditional mix	752	547
SAF-DRI	CH_4	2.50%	Hot	0/100	Renewable	1022	560
SAF-DRI	CH_4	2.50%	Hot	0/100	Traditional mix	1280	560
EAF-DRI		1.00%	Cold	50/50	Traditional mix	600	567
SAF-DRI	Coal	4.00%	Hot	0/100	Renewable	1548	587
SAF-DRI	Coal	4.00%	Hot	0/100	Traditional mix	1818	587

Eco-e tech, the versatile and easy-to-install scrap preheating unit in combination with the new torus-off gas system, makes a normal traditional EAF with 4th hole and sparkling chamber, also called post-combustion chamber, an energy saver that beats all other melting combinations. Note that converting a normal, traditional furnace into an eco-e tech system does not require new buildings, a change in the shape of the furnace, a change in tilting motion, a change in electrode lifting and no change in the electrical system, e.g., transformer, control system, etc. The scrap preheating unit usually fits the size of the existing sparkling chamber, the torus encloses the furnace and can be easily raised for access to the panels. Thanks to the new off-gas flow, radiation from the arc to the panels is reduced, resulting in fewer maintenance interruptions and leakage.

CO_2 emissions and energy input; CO_2 emission ranking

Process	Addition	%C	DRI	Mix [%]	Energy	kg-CO_2/t_{HM}	kWh/t_{HM}
EAF- DRI		1.00%	Hot	50/50	Renewable	473	495
eco-e tech	DRI preh.	1.00%	Cold	50/50	Renewable	488	421
EAF- DRI		1.00%	Hot	75/25	Renewable	492	488
SAF-DRI	H_2	0.00%	Hot	0/100	Renewable	500	547
eco-e tech	DRI preh.	1.00%	Cold	75/25	Renewable	504	336
EAF- DRI		1.00%	Hot	90/10	Renewable	504	483
EAF			no	100/0	Renewable	512	480
EAF- DRI		2.50%	Hot	90/10	Renewable	513	479
eco-e tech	DRI preh.	1.00%	Cold	90/10	Renewable	515	286
EAF- DRI		2.50%	Hot	75/25	Renewable	515	478
eco-e tech	DRI preh.	2.50%	Cold	50/50	Renewable	517	401
EAF- DRI		2.50%	Hot	50/50	Renewable	518	475
eco-e tech	DRI preh.	2.50%	Cold	75/25	Renewable	518	326
eco-e tech			no	100/0	Renewable	520	252
eco-e tech	DRI preh.	2.50%	Cold	90/10	Renewable	520	282
EAF- DRI		3.50%	Hot	90/10	Renewable	544	477
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EAF-DRI		1.00%	Cold	50/50	Traditional mix	600	567
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eco-e tech	DRI preh.	1.00%	Cold	90/10	Traditional mix	643	286
EAF- DRI		2.50%	Cold	50/50	Traditional mix	645	547
eco-e tech	DRI preh.	2.50%	Cold	90/10	Traditional mix	650	282
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EAF			no	100/0	Traditional mix	733	480
EAF- DRI		3.50%	Hot	90/10	Traditional mix	746	477
EAF- DRI		3.50%	Cold	90/10	Traditional mix	746	491
SAF-DRI	H_3	0.00%	Hot	0/100	Traditional mix	752	547
EAF- DRI		3.50%	Hot	75/25	Traditional mix	765	473
EAF- DRI		3.50%	Cold	75/25	Traditional mix	765	508
EAF- DRI		3.50%	Hot	50/50	Traditional mix	798	465
EAF- DRI		3.50%	Cold	50/50	Traditional mix	798	537
SAF-DRI	CH_4	2.50%	Hot	0/100	Renewable	1022	560
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SAF-DRI	Coal	4.00%	Hot	0/100	Renewable	1548	587
SAF-DRI	Coal	4.00%	Hot	0/100	Traditional mix	1818	587
BF-BOF				-	Renewable	2061	356
BF-BOF				-	Traditional mix	2225	356

Here we see a slightly different situation. The eco-e Tech solution is still one of the CO_2 minimizers, but not as overwhelming as with the energy savers. First and foremost, with very few exceptions, are the processes that are carried out with renewable energy. First and foremost are the processes in which DRI is introduced hot. However, the steel mills that operate DRI reactors and normal electric furnaces are relatively rare, as some factors have to interact ore deposits - sufficient renewable energy - good transport possibilities, e.g., Australia, North Africa and similar areas.

The values of the various consumers outside scope 1, such as scrap processing and pre-treatment of ore, have the potential to reduce their CO_2 emissions if renewable energy is used for all types of kinetics.

The conclusion:

Given the efforts of some steel-producing countries to renew their steel industry and convert their integrated steel mills into 'integrated electric steel mills', it is not difficult to predict that scrap will soon become a prestigious raw material, and since scrap cannot be produced but accumulates – scrap is cyclical waste from produced steel – the demand for DRI as a 'filler' or scrap substitute will increase dramatically. DRI will therefore definitely become a vital addition to the scrap for the electric arc furnace of the future.

If you bet on the right horse today, then you can easily access the encore in due course.

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