TECHNOLOGY FACTSHEET

HISARNA

Date of factsheet	7-9-2020
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Sector	Industry: Iron and steel
ETS / Non-ETS	ETS
Type of Technology	Energy saving
Description	HIsarna is an ironmaking technology based on a smelting reduction process, which reduces energy use and CO2 emissions by eliminating several pre-processing steps that are applied in the conventional primary steelmaking process. The name is based on a mix of "Hismelt" (the name of the melting vessel) and "Isarna" (the ancient celtic word for iron). Smelting reduction combines elements of the smelting process (extraction of metal from its ore using heat and a reductant) and coal gasification. Iron ore is input without pelletizing or sintering, and is smelted into liquid pig iron within the same reactor. At the top of the reactor (called the CCF cyclone), iron ore is injected directly as a powder. The temperature is increased by the addition of oxygen which reacts with carbon monoxide. The turbulent environment in the cyclone allows greater contact time between the hot gases and the iron ore. This leads to melting and partial reduction of iron ore in the cyclone, typically in the range of 10-20% (Junjie, 2018). The molten and partially reduced iron ore then falls to the bottom of the vessel (the smelting bath) and comes into contact with coal powder which is injected at the bottom of the reactor. The reaction of carbon from the powder coal with the molten iron ore completes the reduction and creates liquid iron (and CO2 emissions). The resulting CO2 emissions are a relatively pure stream (~85-95% CO2), which facilitates capture. The temperature in the smelter is around 1400-1450 °C (Junjie, 2018; Tata Steel 2013). The partially combusted gases leave the smelter section of the reactor and circulate upwards to provide hot fuel gas to the cyclone. The liquid iron (also called hot metal or pig iron) is then tapped off at the bottom for further processing (Tata Steel, 2018). The molten, carbon-rich (4-5%) pig iron (also referred to as hot metal) that is produced in the HISarna reactor is then oxidized in a basic oxygen furnace, in an exothermic oxidation reaction as pure, hot oxygen is blown over the metal, to reduce the carbon content to below 2% (often less than 1%, depending on final product specifications). Liquid crude steel is then tapped from the furnace, and slag (a byproduct, a mixture of metal oxides) removed. Slag can be used as an additive to cement, creating concrete mixtures with advantageous properties and reducing the amount of Portland cement needed, or can be sold for liming purposes to the agricultural sector. The process also produces off-gases from the basic oxygen furnace with energy content that can be used. Their composition and calorific value is shown below. They can be used to produce heat and power, and/or used as a feedstock for chemical production. Basic oxygen furnace gas: 57% CO, 14% CO2, 14% N2, 12% H2O, 3% H2; 7.5 MJ/normal cubic meter (LHV)
TRL level 2020	TRL 6 TRL 6 was achieved after the endurance campaign conducted from 2017 to 2018. The existing pilot plant at IJmuiden has been shut down until February 2020 (as of August 2019) due to cost cuts at Tata Steel. Campaign F, including the implementation of CO2 capture at the pilot plant, had been planned to begin in 2019, but has been postponed. There are also reports that the demonstration plant will eventually be constructed in Jamshedspur, India, rather than at IJmuiden as originally expected. The technology is expected to be commercially available (reaching TRL 8-9) around 2030.

TECHNICAL DIMENSIONS

	Functional Unit		Value and Range								
Capacity	Mton crude steel		0.88								
			0.44			-			0.88		
Potential	NL	Mton steel	Current			2030			2050		
			-			6.81			-		
			Min	–	Max	6.81	–	6.81	Min	–	Max
Market share	0	%	-			-			-		
			-	–	-	Min	–	Max	Min	–	Max

Capacity utlization factor	0.87
Full-load running hours per year	
Unit of Activity	Mton crude steel/year
Technical lifetime (years)	20.00
Progress ratio	
Hourly profile	No
Explanation	Original data for capacity and production measured in terms of Mton hot metal (liquid pig iron), and given for mature technology (based on planned scale for demonstration plant). Current pilot plant has a smaller capacity. High capacity factor is expected, but not yet demonstrated. Because the pilot plant at IJmuiden is not currently operating, the market share is 0%, but this facility has 60 kton pig iron/year capacity (~52 kton crude steel/year). Technical potential to replace all existing blast furnaces producing pig iron and account for growth in steel production. The future potential and market share will depend on the progress of the demonstration and the outlook for Dutch (and international) crude steel production. As technically all blast furnace-based steel production could be replaced with the HISarna process, here the potential for 2030 is set equal to total 2018 Dutch steel production, assuming no additional growth by 2030.

COSTS

Year of Euro	2015

	Euro per Functional Unit	Current			2030			2050		
Investment costs	mln. € / Mton crude steel	550.00			356.00			308.33		
		341.00	–	821.00	225.00	–	588.00	225.00	–	354.00
Other costs per year	mln. € / Mton crude steel	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max
Fixed operational costs per year (excl. fuel costs)	mln. € / Mton crude steel	68.00			60.00			40.50		
		12.00	–	99.00	11.00	–	87.00	11.00	–	70.00
Variable costs per year	mln. € / Mton crude steel	-			-			-		
		Min	–	Max	Min	–	Max	Min	–	Max

Costs explanation	Values for 2020 refer to cost estimates for a 0.5-1 Mt/year demonstration plant that has yet to be built, but also include costs for the BOF to produce crude steel from pig iron (full greenfield steel plant). Because Hisarna does not require sintering or pelletizing of iron ore, nor coke ovens to produce coking coal, there will likely be significant reductions in CAPEX compared to the conventional BF-BOF process. However, at this stage it is difficult to predict costs for a full-scale, commercial plant, and there is a large range of estimates with considerable uncertainty. One estimate claims it will reduce CAPEX by 25% compared to a conventional blast furnace (CE Delft, 2010). 2050 values assume that the technology will reach the range of the lowest 2030 estimate for CAPEX or the current level of CAPEX for commercialized smelting reduction ironmaking technologies such as Finex (using fine iron ore; commercialized by POSCO at plants in Korea) and Corex (using lump iron ore; commercialized by Siemens VAI at plants in South Africa, India and China) (Siemens VAI 2013). European Commission (2016) provides annualized capital investment costs, without specifying a discount rate or equipment lifetime. The capital costs from this source given in this factsheet were derived from the annualized costs assuming a range of discount rates of 5%-10% and equipment economic lifetimes of 10-20 years. Material and energy costs are not included above. However, there could be additional potential cost reductions relative to conventional basic oxygen steelmaking related to the use of less costly material and energy inputs (iron ore fines, rather than pellets or sinter - potentially of lower quality - and coal rather than coke).

ENERGY IN- AND OUTPUTS

	Energy carrier	Unit	Current			2030			2050		
Energy carriers (per unit of main output)	*Main output:* Coal	PJ		12.70			-			-	
			11.44	–	15.24	*Min*	–	*Max*	*Min*	–	*Max*
	Natural gas	PJ		0.95			-			-	
			0.95	–	2.01	*Min*	–	*Max*	*Min*	–	*Max*
	Electricity	PJ		0.95			-			-	
			0.93	–	0.95	*Min*	–	*Max*	*Min*	–	*Max*
		PJ		-			-			-	
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Energy in- and Outputs explanation	No prospective future values for specific energy consumption were found. Potential future energy consumption reductions will depend on operational experience. Values are given in terms of tonnes of crude steel, assuming a conventional basic oxygen furnace, and cover energy consumption for both ironmaking and steelmaking. Energy outputs (off-gases from the furnaces) are not shown here, as no data sources were available; with operational experience more data will become available on net energy flows. Electricity consumption assumes that oxygen is purchased (no electricity use for an air separation unit is included).										

MATERIAL FLOWS (OPTIONAL)

	Material	Unit	Current			2030			2050		
Material flows	Iron ore	Mton		1.42			-			-	
			1.32	–	1.42	*Min*	–	*Max*	*Min*	–	*Max*
	Oxygen	Nm3		764.00			-			-	
			764.00	–	764.00	*Min*	–	*Max*	*Min*	–	*Max*
Material flows explanation	The HIsarna process does not require sintering or pelletizing like a conventional blast furnace, but rather allows direct injection of iron ore fines (a powder of iron ore). Here it has been assumed that the quantity of iron ore fines used will be similar to the quantity of sinter, pellets and lump ore used in a blast furnace. The Hisarna process also allows the use of lower quality ores without processing (i.e. those with higher concentrations of P, Zn, S and alkalis) (Burns, 2018). Oxygen is also used in the HIsarna process, injected both at the top of the smelting vessel in the cyclone converter furnace phase and closer to the bottom, just above the bath smelting phase. The injected oxygen facilitates combustion of off-gases moving upwards from the bath, creating heat that melts iron ore fines (iron oxide), which is also injected at the top in the cyclone converter furnace, and creating the necessary temperature conditions for reduction of iron oxide into pure iron and CO2 in the smelting bath below. Oxygen could potentially be produced on-site with an air separation unit, but this factsheet assumes oxygen will be purchased. Future evolution of material flows in the HIsarna process, like energy inputs, will depend on operational experience. Values are given in terms of tonnes of crude steel (assuming a conventional basic oxygen furnace).										

EMISSIONS (Non-fuel/energy-related emissions or emissions reductions (e.g. CCS)

	Substance	Unit	Current			2030			2050		
Emissions				-			-			-	
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
				-			-			-	
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
				-			-			-	
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
				-			-			-	
			Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Emissions explanation	The total CO2 emissions from this process are estimated between 1.1-1.5 tCO2/t crude steel (Junjie 2018; Tata Steel 2015; CE Delft 2010; Keys, van Hout, and Daniels 2019). Data on the split between energy-related and process CO2 emissions were unavailable. No data was available regarding NOx and SO2 emissions from this process. CO2 emissions are more concentrated than with the traditional BF-BOF steelmaking route, which facilitates the deployment of carbon capture along with the Hisarna ironmaking process, which would further reduce CO2 emissions compared to conventional steelmaking.										

OTHER

Parameter	Unit	Current			2030			2050		
Flux	Mton		0.03			-			-	
		0.03	–	0.03	*Min*	–	*Max*	*Min*	–	*Max*
Crude steel	Mton		-1.00			-			-	
		-1.00	–	-1.00	*Min*	–	*Max*	*Min*	–	*Max*
Slag	Mton		-0.31			-			-	
		-0.31	–	-0.31	*Min*	–	*Max*	*Min*	–	*Max*
			-			-			-	
		Min	–	*Max*	*Min*	–	*Max*	*Min*	–	*Max*
Explanation	.									

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