Cost Efficient Partial CO_2 Capture at an Integrated Iron and Steel Mill

Maria Sundqvist[1], Maximilian Biermann[2], Hassan Ali[3], Ragnhild Skagestad[4], Fredrik Normann[2], Mikael Larsson[1], Leif Nilsson[4]

[1] Swerea MEFOS AB, Box 812, SE-971 25 Luleå, Sweden
[2] Chalmers University of Technology, SE-412 96 Göteborg, Sweden
[3] University College of Southeast Norway, N-3901 Porsgrunn, Norway
[4] SINTEF Tel-Tek, Kjølnes Ring 30, N-3918 Porsgrunn, Norway
[5] SSAB Europe, SE-971 88 Luleå, Sweden

Decelerating anthropogenic CO_2 emissions is our time most important challenge. For large emission sources, such as the iron and steel industry, implementation of CO_2 capture is often discussed as a mean to achieve low emission targets. However, a major obstacle is the cost associated with large scale capture. The aim of this paper is to show how smart integration of partial CO_2 capture and use of residual energy can help reduce the cost of capture at an integrated iron and steel plant in Sweden. The paper will compare cost of capture for three CO_2 sources, specifically: (1) flue gas from hot stoves (HS), (2) blast furnace gas (BFG), and (3) flue gas from CHP plant.

The reference plant used for this paper is SSAB Europe's integrated iron and steel mill in Luleå, Sweden. It is a well-adapted plant where the surplus of gases goes to a nearby combined heat and power (CHP) plant for production of electricity, and heat for the district heating network. The blast furnace operates with a burden of 100% iron ore pellets, and has a hot metal production of 2-2.5 ktonne per year. The plant's main product is steel slabs, which is transported by train to the southern Sweden for further treatment. A simplified scheme of the steel production, internal gas usage and CO_2 sources can be seen in Figure 1.

The study was carried out using three individual models. The amine capture system was simulated in an Aspen Plus model using a 30-wt.% MEA solvent, and optimized for low energy requirement. The effect of capture on the iron and steel plant was simulated using an in-house model consisting of interlinked energy and mass balances of the process. As for the cost estimation, Aspen In-Plant Cost Estimator and a detailed factor estimation model were used.

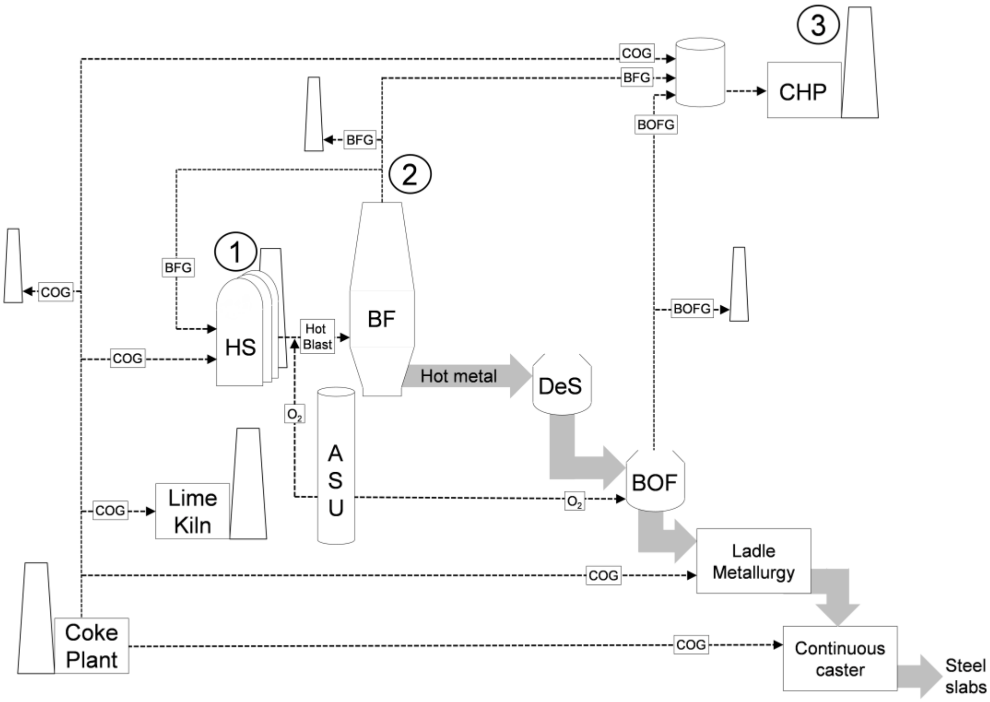

Figure 1. Simplified layout of the iron and steel system with the three CO_2 sources highlighted

In total, five unutilized heat sources have been identified for the investigated iron and steel system, see Table 1, that could be used for powering the reboiler at an amine CO_2 capture unit. The heat recovery potential from each source has been rated according to accessibility, and specific cost of steam has been estimated. The largest, most accessible source of heat is switching turbine operation mode at the CHP plant, producing less electricity to the grid. The second largest is making use of the heat from gas flaring. This is not a continuous process, and usually occurs due to disturbances in the system, or maintenance stops at the CHP plant. Flue gas heat recovery from hot stoves is rated as the third most accessible heat source at the plant, due to its extensive lower heat recovery cost compared to dry coke quenching. Dry coke quenching is a technology that, in addition of better pollution control in the coke production, can recover sensible heat from hot coke.

Table 1. Excess heat sources and amount identified together with accumulated heat available depending on heat level (HL)

Source	Heat from Source[1] (GJ/h)	Heat Level No.[2]	Accumulated heat at heat level[3] (GJ/h)
CHP plant	228.1	1	228.1
Gas flaring	152.8	2	380.9
Hot stove flue gas	32.9	3	413.8
Hot coke	41.5	4	455.4

[1] Accessible energy from specific source at reference, i.e. no capture considered
[2] Rating according to accessibility and technology readiness of the heat source
[3] Accumulated accessible heat at the given heat level at reference, i.e. no capture considered

Figure 2 shows the annual cost for capture (primary y-axis, colored bar) and corresponding amount of captured CO_2 (secondary y-axis, black diamond marker) for each of the three CO_2 sources at different heat levels[1]. The capital cost are divided into capital cost for new gas pipe connections at the site (CAPEX connections) and capture unit (CAPEX), whilst the installation cost of heat

[1] Since amine capture requires the gas to be cooled down before entering the absorber, the flue gas heat recovery is rated differently for the hot stoves. Thus composing the modified heat level HL1*, which combines HL1 and HL3 from Table 1

recovery for steam production is comprised under cost of steam. As Figure 2 shows, partial capture fueled by waste heat can achieve significant emissions reductions at moderate cost, especially for the more accessible heat levels (ca. 2 €/t steam for HL1 – HL3). However, capturing more CO_2 will require a more expensive steam production, hence increasing the cost of capture (e.g. HL4 with ca. 7 – 8 €/t steam).

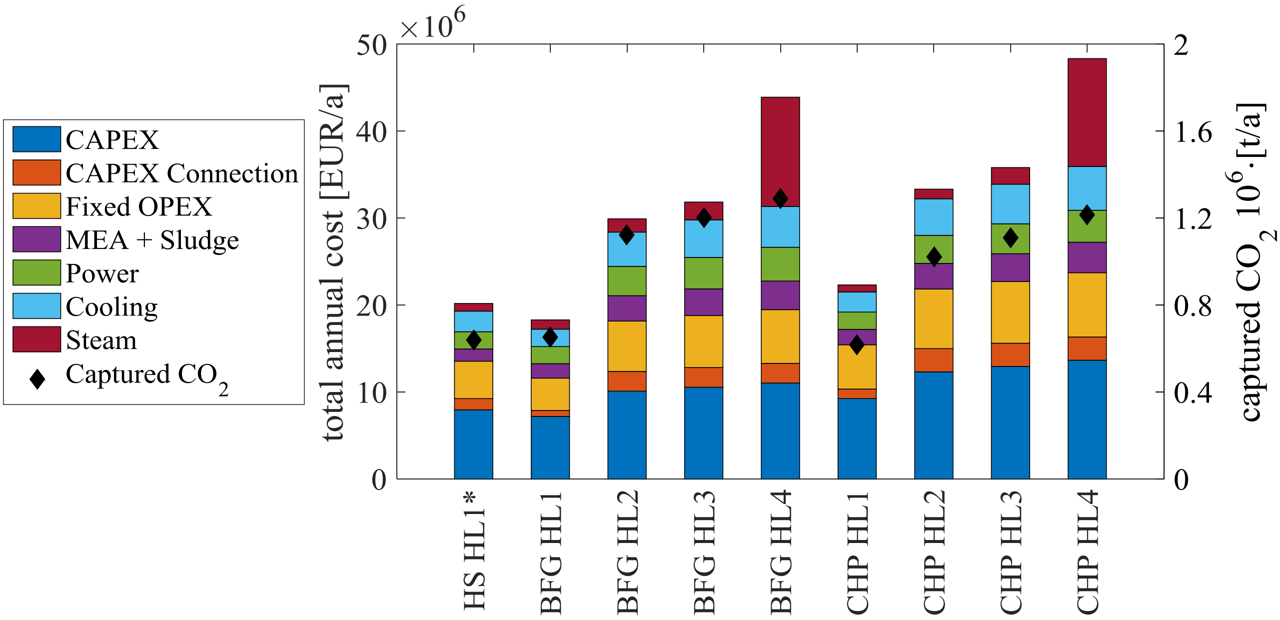

Figure 2. Total annual cost for capture from source 1-3 and at specific heat level

Considering the different CO_2 sources, capture from BFG has lower annual cost at higher capture rates compared to end-of-pipe capture. This is due to: 1) BFG is pressurized, which enhances the CO_2 absorption and reduces the specific heat demand, and 2) CO_2 removal increases the BFG fuel quality, increasing the energy efficiency of the system and releasing more excess energy to recover.

Table 2 shows specific capture cost and demonstrates the cost efficiency of BFG capture. The lowest cost of 26.5 €/t CO_2 captured is found for capturing from BFG fueled by excess heat from the CHP plant, flared gas and flue gas heat recovery.

Table 2. Comparison of scenario 1-3 in total specific capture cost (including pipeline connections, heat recovery, and capture unit with compression up to 110 bar)

	Source 1	**Source 2**				**Source 3**			
	HS HL1*	BFG HL1	BFG HL2	BFG HL3	BFG HL4	CHP HL1	CHP HL2	CHP HL3	CHP HL4
Specific cost €/t CO_2 captured	32.6	28.0	26.7	26.5	33.4	36.2	32.6	32.3	39.7

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