Scenario for near-term implementation of partial capture from blast furnace gases in Swedish steel industry

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ABSTRACT

Iron-and-steel making is a carbon-intensive industry and responsible for about 8% of global CO_2 emissions. Meeting CO_2 reduction targets is challenging, since carbon is inherent in the dominating production route in blast furnaces. Long-term plans to phase out carbon and change production technique are under way, such as iron ore reduction with hydrogen[1][2] won from renewable energies or electro winning[3], however unlikely to be implemented at scale before 2040 [4]. Until a transition to such technologies is completed, carbon leakage will remain to be a threat to steel industry inside EU ETS system. CCS remains an option for steel industry to comply with reduction targets and meet rising allowance (EUA) prices, currently above 20 €/t. Most studies on CCS propose a capture rate of ≥ 90 %[5–7], however, CCS could be considered as a part of a series of measures (e.g. fuel change, energy efficiency measures) that together achieve a significant reduction in CO_2 emissions until a carbon-neutral production is in place. This line of thought motivates the concept of partial capture, where only the most cost effective part of the CO_2 emissions are separated for storage [8]. In steel industry, high CO_2 concentrations at large flows and the availability of excess heat make partial capture attractive. Previous work on the steel mill in Luleå, Sweden, emits around 3.1 Mt CO_2 per year, has found that 40-45 % of site emissions can be captured fueled by excess heat alone[9]. Therein, five heat recovery technologies were assessed, ranging from back pressure operation of CHP turbine to dry slag granulation. Promising CO_2 sources on site include flue gases from hot stoves and the combined-heat and power plant, and the process gas originating from the blast furnace – blast furnace gas (BFG). BFG is a pressurized, low value fuel used for heating on site. CO_2 separation from BFG requires less reboiler heat for MEA regeneration, and the enhanced heating value of the CO_2 lean BFG increases energy efficiency of the steel mill [9].

This work discusses the near-term (the 2020s) implementation of partial capture at a Swedish steel mill and the economic viability of such implementation dependent on the energy price, carbon price, and required reductions in CO_2 emissions. Based on previous work [9][10,11] on partial capture in steel industry a cost estimation of a capture system for the BFG is conducted including CAPEX and OPEX of the MEA capture unit, gas piping, and recovering heat from the steel mill. The costs are summarized as equivalent annualized capture cost (EAC) and set into relation to transport and storage costs as well as carbon emission costs to form the net abatement cost (NAC) according to Eq. (1)

$$NAC = EAC + \ transport\&storage\ cost\ - carbon\ price \qquad [€/t_{CO_2}] \qquad (1)$$

Figure 1 shows how EAC for BFG varies with the capture rate and the cost of steam for different heat recovery technologies represented by the steps in the curve (see explanation in [9]). Note that partial capture from BFG is more economical than the full capture benchmark. The most cost-efficient case of 28 €/t CO_2 captured is achieved for BFG capture fueled by steam from back-pressure operation (at the expense of electricity production), flue gas heat recovery and flare gas combustion. The transport and storage cost applied in Eq (1) represent ship transport from the Bothnian Bay to a storage site in the Baltic Sea , according to Kjärstad et el.[12]. Transport and storage cost range within 17 – 27 €/t CO_2 depending on scale.
These installation and operation cost for capture, transport and storage are set into relation with various scenarios on future carbon and energy (electricity) prices in Europe and Sweden. For example, *Figure 2* illustrates a scenario in line with IEA's sustainable development scenario to restrict global warming to 2°C. The carbon prices are adapted from WEO 2018 [13] and increase from 20 € to 120 € per tonne CO_2 by 2040 and the electricity prices of 42-52 €/MWh (increasing with time) are based on latest results from the NEPP project [14]. In this scenario, partial capture from BFG could become economic viable in 2029, construction in 2020 with operation from 2022/23 onwards is likely to pay off within a lifetime of 20 years only. This work demonstrates the viability of partial capture as cost-efficient mitigation measure for the steel industry and illustrates conditions for an early implementation in the 2020s.

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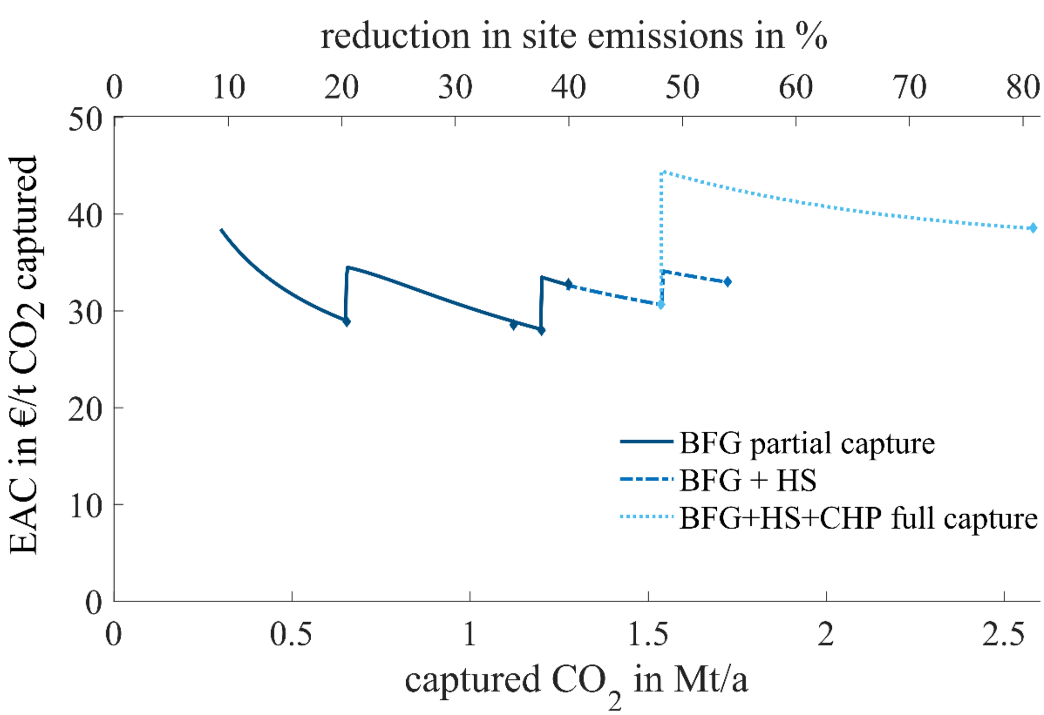

Figure 1: Equivalent annualized capture cost (EAC) for partial capture from the blast furnace gas and full capture benchmark, i.e. capture from the blast furnace gas, hot stoves, and combined heat and power plant. The steps in the graph represent investment into a new heat source. The electricity price is set to 30 €/MWh

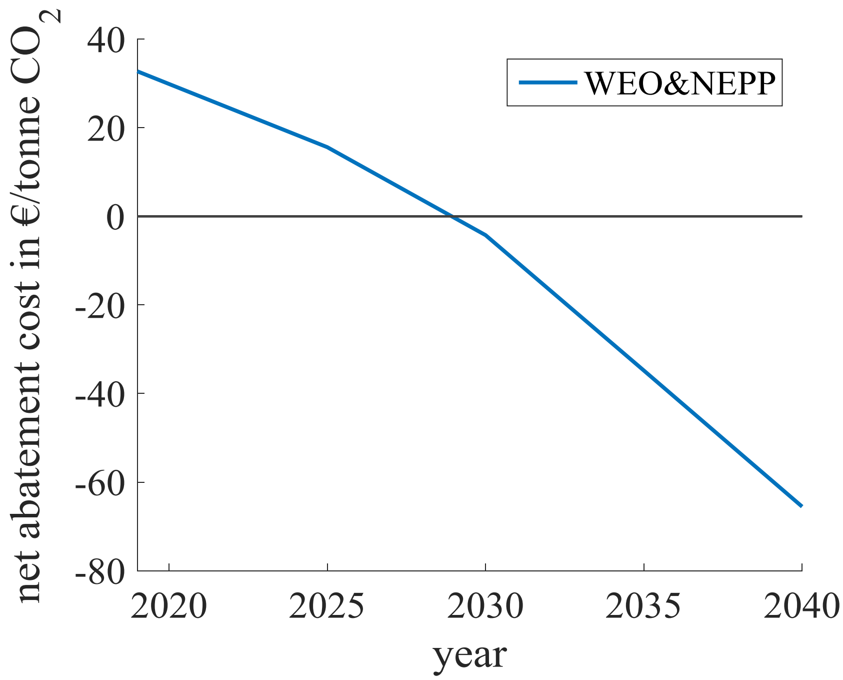

Figure 2: Net abatement cost for steel industry based on partial capture from BFG with excess heat from back-pressure operation, flue gas heat recovery, flare gases and the sustainable development scenario based on WEO and NEPP[13–15].

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