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Decarbonization of the Iron and Steel Sector: Challenges and Opportunities

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Abstract

The iron and steel industry is one of the largest contributors to industrial emissions in the United States (U.S.). As this industry represents an impactful opportunity for industrial decarbonization, this paper presents the techno-economics of retrofitting iron/steel plants in the U.S. with post-combustion carbon dioxide (CO_2) capture technology. For a representative base plant, this analysis considers an integrated steel mill, including a blast furnace (BF) and basic oxygen furnace (BOF), and evaluates CO_2 capture as applied to the three largest and highest concentration emission sources of these facilities. A levelized cost of CO_2 captured (LCOC) of \$80.3/tonne CO_2 and \$80.7/tonne CO_2 was estimated for a retrofit site with 99 and 90 percent capture, respectively.

Keywords: Iron; Steel; CO_2 Capture; Post-Combustion; Techno-Economic Analysis

1. Introduction

With government mandates to reduce greenhouse gas (GHG) emissions, decarbonizing the largest industrial emitters has become an essential research focus. The Environmental Protection Agency (EPA) reported that industrial point sources in the United States (U.S.) emitted 1.45 billion tonnes of carbon dioxide (CO_2) in 2022, accounting for 23 percent of all domestic CO_2 emissions for that year. [1] [2] One of the largest contributors to industrial emissions is the iron and steel industry, which was responsible for 2.5 percent of total U.S. GHG emissions in 2023. [3] Due to the large quantity of emissions available for capture from this industrial sector, iron/steel production facilities present an impactful opportunity for industrial decarbonization.

There are various CO_2 capture technologies that can be deployed in the iron/steel industry, including post-combustion capture with chemical solvents or membranes, pre-combustion capture with chemical solvents or membranes, and capture via calcium looping. There exist various examples of efforts to advance the decarbonization of iron/steel plants. The only operating, commercial-scale CO_2 capture plant in the iron/steel industry is the Al Reyadah facility in the United Arab Emirates. [4] This plant, commissioned in 2016, was initiated as a joint venture between

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Abu Dhabi National Oil Company (ADNOC) and Masdar, and captures CO_2 from a direct reduced iron (DRI)-based steel plant. [4] The capture plant has a nominal capacity of 800,000 tonnes of CO_2 per year and ADNOC asserted in 2023 that the plant enabled capture of 45 percent of emissions from DRI production. [4] The approximately 89 percent pure CO_2 product is dehydrated and used for enhanced oil recovery (EOR) in ADNOC's onshore oil fields. [4] In the U.S., the U.S. Department of Energy (DOE) has sponsored front end engineering design (FEED) studies, pre-FEED studies, and pilot demonstrations examining the addition of capture to iron and steel plants. This includes a pre-FEED study led by Dastur International Inc. in coordination with Cleveland-Cliffs Inc. assessing the implementation of ION Energy's solvent-based, post-combustion capture technology to capture 95 percent of CO_2 from blast furnace (BF) flue gas from a steel plant located in Burns Harbor, Indiana, producing 5 million (M) tonnes of steel per year. A DOE-sponsored FEED study led by The University of Illinois, in partnership with Air Liquide, Visage Energy Corporation, Hatch Associates Consultants Inc., Midrex Technologies Inc., ArcelorMittal, and voestalpine Texas LLC, is examining the use of Air Liquide's Cryocap™ technology to capture 95% of the total CO_2 emissions from a Texas hot briquetted iron plant.[1]

In 2023, the National Energy Technology Laboratory (NETL) released its report, "Cost of Capturing CO_2 from Industrial Sources," (Industrial Sources Report) with the objective of estimating the levelized cost of CO_2 captured (LCOC) from selected industrial processes including iron/steel facilities. [5] A traditional pathway to produce steel from iron ore comprising a BF integrated with a basic oxygen furnace (BOF), also referred to as an integrated steel mill, is considered for this analysis. While integrated steel mills have multiple CO_2 emissions sources, this work focuses on applying capture to the three largest and highest concentration sources. The capture system utilized is the CANSOLV CO_2 capture technology commercially offered by Shell. CANSOLV is an amine-based, acid gas removal (AGR) process designed to recover high purity CO_2 from dilute flue gas streams and is assessed at capture rates of both 90 and 99 percent. The LCOC for this system is estimated using the methodology established in NETL's Quality Guidelines for Energy System Studies (QGESS) document, "Cost Estimation Methodology for NETL Assessments of Power Plant Performance." [6] NETL's 2023 Industrial Sources Report presents the LCOC in December 2018 dollars.

The current paper leverages the Industrial Sources Report's iron/steel cases, expands the discussion, and provides the LCOC in January 2024 dollars. The financial assumptions are updated with input from NETL's Energy Markets Analysis Team and are based on 2024 iron/steel industrial sector market data.

Nomenclature

AACE	AACE International
ADNOC	Abu Dhabi National Oil Company
AGR	Acid gas removal
BEC	Bare erected cost
BF	Blast furnace
BFD	Block flow diagram
BFS	Blast furnace stove
BOF	Basic oxygen furnace
CCF	Capital charge factor
CF	Capacity factor
COG	Coke oven gas
DOE	U.S. Department of Energy
DRI	Direct reduced iron
EAF	Electric arc furnace
EOR	Enhanced oil recovery
EPA	Environmental Protection Agency
EPC	Engineering, procurement, and construction
EPCC	Engineering, procurement, and construction cost

[1] More details on these DOE sponsored projects can be found here: https://netl.doe.gov/carbon-management/carbon-capture/psc-map

FEED	Front-end engineering design
FOM	Fixed O&M
GHG	Greenhouse gas
hr	Hour
HX	Heat exchanger
LCOC	Levelized Cost of CO_2 capture
M	Million
NETL	National Energy Technology Laboratory
O&M	Operation and maintenance
PPS	Power plant stack
PSG	Power and steam generation
QGESS	Quality Guidelines for Energy System Studies
TASC	Total as-spent cost
TOC	Total overnight cost
TPC	Total plant cost
U.S.	United States
V-L	Vapor-liquid
VOM	Variable O&M

2. Background

2.1. Iron/Steel Production Methods

There are two commercial methods of iron production in operation today: the blast furnace (BF) method and direct reduced iron (DRI) method. In the BF method, coke and sintered iron are fed to the top of the BF while hot blast gas is fed through the side. Coke is oxidized to form CO_2 which subsequently reacts with more coke to produce carbon monoxide (CO). This CO facilitates the reduction of iron oxides to form pig iron, a high carbon iron alloy. In 2023, the U.S. produced 20.6 M tonnes of pig iron and imported an additional 4.4 M tonnes. [7] The DRI method is a newer alternative iron production pathway. DRI is made by reducing iron ore with gas, eliminating some pre-processing steps required for BF operation. [8] Typical reductants used to make DRI are coal syngas, natural gas, or hydrogen (H_2) depending on availability. In 2023, DRI production constituted 5.2 M tonnes of iron production in the U.S. [7]

Steel is produced by reducing the carbon content of iron in a furnace, of which there are two types in commercial operation. Traditionally, a BOF is used to remove carbon by blowing hot oxygen through molten pig iron. A newer alternative is the electric arc furnace (EAF), which uses electricity to melt scraps and recycled steel to form a steel product. While scrap and recycled steel is considered the main feed for EAF mills, some have been configured to use feeds of pig iron or DRI. [8] As of 2023, 31.7 percent of U.S. steel was produced via EAFs, with the remainer produced via BOFs. [7]

The traditional pathway to produce steel from the starting raw material, iron ore, is a BF integrated with a BOF, also referred to as an integrated steel mill. For these facilities, approximately 69 percent of emissions are present in the BF gas, which is often used as a heat source or a low-grade fuel for an integrated power plant. [9] Consequently, there are many different point sources for potential carbon capture in an integrated steel mill resulting in a complex challenge for decarbonization efforts. Researchers have investigated capturing CO_2 from coke ovens, hot stoves, power plant stacks (PPS), and lime kiln emissions to avoid impacting the BF gas and its benefits to the plant. [10] Furthermore, much research has focused on decarbonizing BF gas without directly treating it in a CO_2 capture plant. Replacing coke with biomass is one option, but only 10 percent of coke can feasibly be replaced due to an unsustainable drop in coke strength with higher replacement. [8] Another approach involves the use of H_2 as an additional reducing agent to reduce the amount of coke required. One study looked at using electrolysis-derived H_2 as an auxiliary reductant and found that emissions could be reduced by 21.4 percent under optimized conditions. [11] Due to its widespread commercial usage, the BF-BOF pathway was chosen for analysis in this study.

Another steel production pathway is the mini mill, in which a sole EAF is fed scrap and recycled steel. [9] Mini mills emit approximately 0.6 to 0.9 tonnes of CO_2 per tonne of steel (tonne CO_2/tonne steel), representing a significant reduction compared to 2.2 tonne CO_2/tonne steel for integrated steel mills. [9] However, this reduction is due to the use of scrap and recycled steel which are not available in sufficient quantities to satisfy the entire U.S. steel demand.

A new, alternative pathway being explored is the combination of DRI production with an EAF. [8] [12] In a study from Argonne National Laboratory, a DRI-EAF pathway with no scrap steel feed using grid electricity and natural gas reductant showed a 14.3 percent drop in emissions and an 8.9 percent lower cost compared to BF-BOF steel. [8] The same configuration with a reductant comprising 83 percent renewable H_2 and 17 percent natural gas showed a 46.6 percent reduction in CO_2 emissions and a 6.6 percent greater cost as compared to BF-BOF steel. [8] Other ways to reduce emissions through the DRI pathway involve using renewable natural gas or low-carbon electricity, but these options will incur additional costs.

2.2. Size Range

According to the World Steel Association, the U.S. accounted for approximately 81.4 M tonnes of steel production in 2023. Of these 81.4 M tonnes of steel, 31.7 percent was produced using an EAF and the balance using the more traditional BOF. [7] The resulting steel product from an EAF process contains approximately 100 percent recycled steel, whereas the BOF product contains 25 percent recycled steel on average. [7] The utilization of scrap steel results in lower CO_2 emissions for an EAF process (0.6–0.9 tonne CO_2 per tonne steel) versus the BOF process (2.2 tonne CO_2 per tonne steel). [9] The combination of generally smaller EAF plants and lower concentration of EAF plant CO_2 emissions projects to a higher LCOC from an EAF process. Therefore, this study focuses on CO_2 capture from BOF process steel plants. Furthermore, as no new BOF steel plants are expected to be constructed in the U.S. in the near term, only retrofit application of CO_2 capture is considered. The total production capacity, as given by the World Steel Association for BOF plants in the United States in 2023, was 55.6 M tonnes. [7]

3. Methodology

3.1. CO_2 Point Sources

A study by Wiley, et al., published in 2010, assessed the opportunities for CO_2 capture in Australian iron and steel mills. [9] This study utilized stream data from an Australian BOF steel mill, and within the base plant, the largest source of CO_2 comes from the top gas of the BF as is typical in an integrated steel mill; however, this stream is not directly vented. Instead, the BF gas is cleaned and used in the plant as low-grade fuel, and rather than having a high-content CO_2 point source from the blast furnace gas, the CO_2 is distributed throughout the plant as smaller CO_2 point sources. The resulting CO_2 point sources available to be captured include the PPS, coke oven gas (COG), BF stove (BFS), sinter stack, blown oxygen steelmaking stack, hot strip mill stack, plate mill stack, and lime kiln, based on the configuration detailed by Wiley, et al. [9] The three highest CO_2 concentrations of these point sources are the COG at 27 volume percent, the BFS at 21 volume percent, and the PPS at 23 volume percent. These three point sources are evaluated in this analysis, and their characteristics are described in Table 1.

Table 1. BOF iron and steel plant characteristics. [9]

Description	PPS	COG	BFS
CO_2 Emitted/Tonne Steel produced	0.74	0.35	0.39
Pressure (psia)	14.7	14.7	14.7
Temperature (°F)	572	212	572
Composition (vol %)			
Nitrogen (N_2)	67.0	67.0	68.0
Water (H_2O)	8.0	5.0	10.0
CO_2	23.0	27.0	21.0
O_2	1.0	1.0	1.0

Personal communication with a former U.S. Steel Braddock, PA, facility employee indicated that while the coke ovens are approximately five miles from the BF, the COG is circulated back to the BF to preheat the incoming air Therefore, these two streams are located relatively close to one another and may be combined. As such, this analysis assumes two CO_2 capture units with two corresponding compression trains. Figure 1 is a simplified block flow diagram (BFD) of the Braddock steel mill.

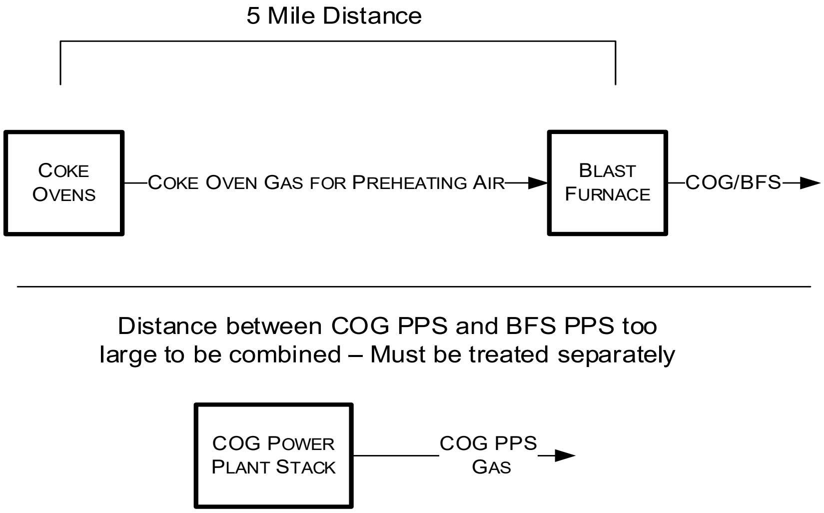

Fig. 1. Braddock steel mill plot plan.

3.2. Design Input and Assumptions

The following is a list of design inputs and assumptions specific to the iron/steel process that were made for the purpose of this study:

- The representative BOF integrated steel mill has a production capacity of 2.54 M tonnes/year
- The CO_2 generated is 3,738,928 tonnes CO_2/year at 100 percent capacity factor (CF)
- There are three high purity sources: COG, BFS, and COG PPS. The COG and BFS are combined into one stream due to plot plan and total 1,864,388 tonnes CO_2/year (at 100 percent CF); COG PPS utilizes its own separation and compression facility and generates 1,874,540 tonnes CO_2/year (at 100 percent CF)
- Since there are two separate capture systems, 4.6 operators are considered (i.e., 2.3 operators per capture system)
- As a low purity source, separation, compression, and cooling are required. Separation is accomplished using Shell's CANSOLV solvent-based CO_2 capture system
- CO_2 capture rates of 90 and 99 percent are evaluated
- The CO_2 quality is based on the EOR pipeline standard as mentioned in NETL's QGESS for CO_2 Impurity Design Parameters [13]

3.3. CO_2 Capture System

The AGR system utilized is the CANSOLV CO_2 capture technology commercially offered by Shell. This amine-based, post-combustion process is designed to recover high purity CO_2 from dilute streams that contain O_2, such as flue gas from coal-fired power plants, combustion turbine exhaust gas, and other industrial waste streams. The AGR unit also provides polishing of residual sulfur components in the CO_2 capture stream. A dedicated natural gas-fired boiler is also included to generate the steam required for the capture system, but the flue gas from the boiler is not routed to the CO_2 capture system. The performance and cost information for the AGR units employed herein are based on data provided by Shell in 2021. The CO_2 removal efficiency of the AGR unit is represented at two rates, 90 and 99 percent for each case. A typical flowsheet for the process is shown in Figure 2.

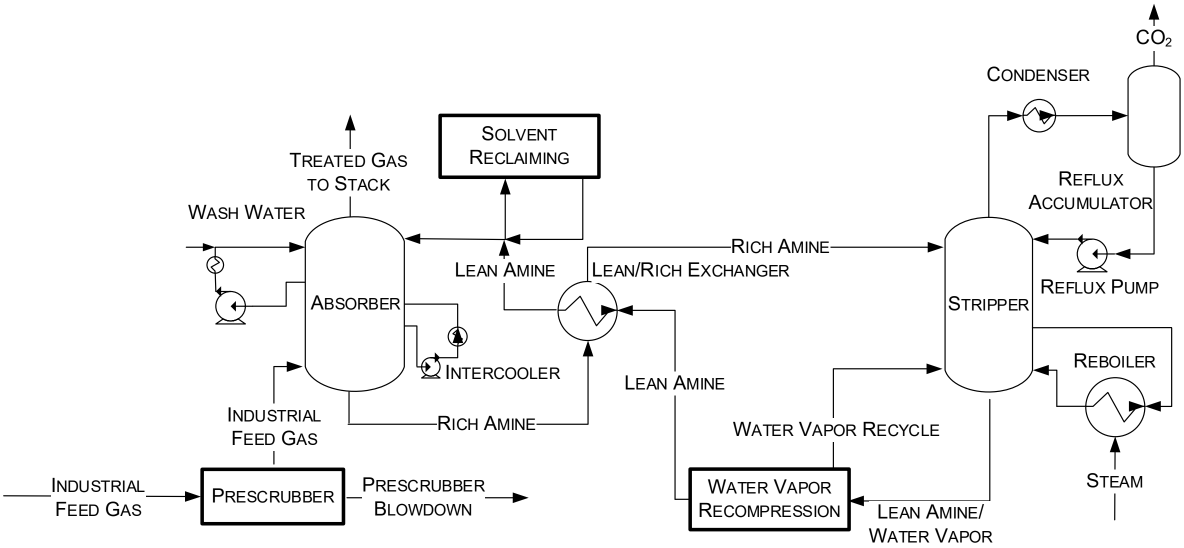

Fig. 2. Shell's CANSOLV CO_2 capture system typical process flow diagram.

3.4. Centrifugal Compressor

Compression of the CO_2 product is required for pipeline transportation and storage or use. As such, integrally geared centrifugal compression trains (8 stages each) are included with each CO_2 product stream. All compressors discharge at a pressure of 2,214.7 psia (2,200 psig). This is the pipeline pressure specification as stated in NETL's QGESS for CO_2 Impurity Design Parameters. [13] However, it should be noted that pressure requirements can vary by location, and pressures as low as 1,200 may be acceptable. [14] A quote provided for the development of NETL's "Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity," Revision 4, was utilized to represent the cost for this equipment. [15]

3.5. Cost Estimation Methodology and Financial Assumptions

To the extent possible, cost results for this analysis are estimated using the methodology established in NETL's Quality Guidelines for Energy System Studies (QGESS) document, "Cost Estimation Methodology for NETL Assessments of Power Plant Performance." [6] Detailed information pertaining to topics such as contracting strategy; engineering, procurement, and construction (EPC) contractor services; estimation of capital cost contingencies; owner's costs; cost estimate scope; economic assumptions; and finance structures are available in this document. The financial assumptions employed were developed by NETL's Energy Markets Analysis Team in 2024 based on market data reflective of the iron/steel industrial sector.

3.5.1. Levelized Cost of CO_2 Captured

The LCOC as defined by Equation 1, considers the equipment required for CO_2 removal and compression, as well as the balance of plant equipment, operation and maintenance, purchased power, and fuel costs:

$$LCOC\left(\frac{\$}{tonne\ CO_2}\right) = \frac{TOC*CCF+FOM+VOM+PSG}{CF*tonnes\ CO_2\ captured\ per\ year} \tag{1}$$

Where TOC is the total overnight costs of CO_2 capture equipment, CCF is the capital charge factor, FOM is the annual fixed operation and maintenance (O&M) costs, VOM –is the annual variable O&M costs, PSG is power and steam generation (natural gas purchase) costs, and CF is the capacity factor (85% assumed).

4. Results and Discussion

4.1. Block Flow Diagrams and Stream Tables

For the COG/BFS case, the COG stream and BFS stream are mixed and sent to the CO_2 capture system. Water and solids recovered from the capture system are sent to waste treatment. The CO_2 stream is then compressed with interstage cooling and after-cooled before reaching the EOR pipeline. Figure 3 shows the BFD for this process, and Table 2 and Table 3 show the stream table for this process with 99 percent and 90 percent capture, respectively.

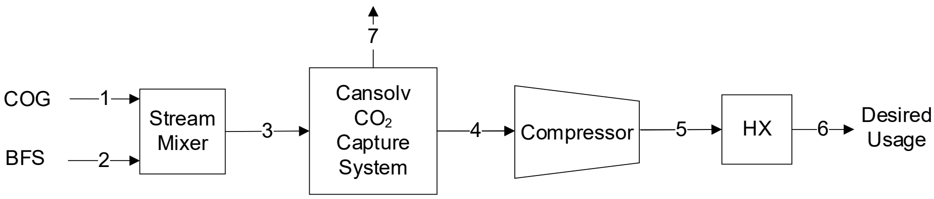

Fig. 3 CO_2 capture BFD for COG/BFS.

Table 2. Iron/steel COG/BFS stream table with 99 percent capture.

	1	2	3	4	5	6	7
V-L Mole Fraction							
CO_2	0.2700	0.2100	0.2345	0.9879	0.9995	0.9995	0.0034
H_2O	0.0500	0.1000	0.0795	0.0121	0.0005	0.0005	0.0237
N_2	0.6700	0.6800	0.6759	0.0000	0.0000	0.0000	0.9588
O_2	0.0100	0.0100	0.0100	0.0000	0.0000	0.0000	0.0141
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	8,443	12,173	20,616	4,845	4,788	4,788	14,533
V-L Flowrate (kg/hr)	269,106	370,224	639,331	211,692	210,637	210,637	405,309
Temperature (°C)	100	300	219	31	80	30	38
Pressure (MPa, abs)	0.10	0.1	0.1	0.2	15.3	15.3	0.1
Steam Table Enthalpy (kJ/kg)	3,700	3,593	3,638	8,793	8,758	8,755	309.0
Aspen Plus Enthalpy (kJ/kg)	-3,638	-3,217	-3,394	-8,961	-9,042	-9,195	-240.1
Density (kg/m^3)	1.0	0.6	0.8	3.5	432.5	630.1	1.1
V-L Molecular Weight	31.9	30.4	31.0	43.7	44.0	44.0	27.9

Table 3. Iron/steel COG/BFS stream table with 90 percent capture.

	1	2	3	4	5	6	7
V-L Mole Fraction							
CO_2	0.2700	0.2100	0.2346	0.9881	0.9995	0.9995	0.0322
H_2O	0.0500	0.1000	0.0795	0.0119	0.0005	0.0005	0.0237
N_2	0.6700	0.6800	0.6759	0.0000	0.0000	0.0000	0.9303
O_2	0.0100	0.0100	0.0100	0.0000	0.0000	0.0000	0.0137
Total	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	8,443	12,173	20,616	4,405	4,354	4,354	14,978
V-L Flowrate (kg/hr)	269,106	370,224	639,331	192,516	191,573	191,573	424,582
Temperature (°C)	100	300	219	31	80	30	38
Pressure (MPa, abs)	0.10	0.1	0.1	0.2	15.3	15.3	0.1
Steam Table Enthalpy (kJ/kg)	3,700	3,593	3,638	8,793	8,758	8,755	691.0
Aspen Plus Enthalpy (kJ/kg)	-3,638	-3,217	-3,394	-8,960	-9,042	-9,195	-636.8
Density (kg/m^3)	1.0	0.6	0.8	3.5	432.5	630.1	1.1
V-L Molecular Weight	31.9	30.4	31.0	43.7	44.0	44.0	28.3

In the same manner, the COG PPS stream is sent to the CANSOLV CO_2 capture system. Water and solids recovered from the capture process are sent to waste treatment. The CO_2 stream is then compressed with interstage cooling and after-cooled before reaching the EOR pipeline. Figure 4 shows the BFD for this process, and Table 4 and Table 5 show the stream table for this process with 99 percent and 90 percent capture, respectively.

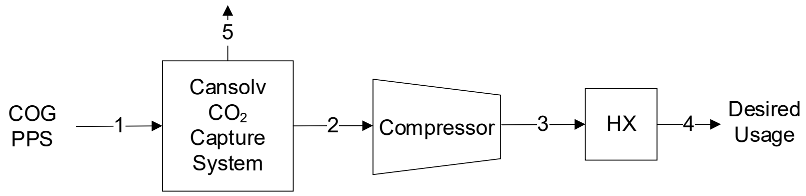

Fig. 4 CO_2 capture BFD for COG PPS.

Table 4. Iron/steel COG PPS stream table with 99 percent capture.

	1	2	3	4	5
V-L Mole Fraction					
CO_2	0.2700	0.2100	0.2345	0.9879	0.9995
H_2O	0.0500	0.1000	0.0795	0.0121	0.0005
N_2	0.6700	0.6800	0.6759	0.0000	0.0000
O_2	0.0100	0.0100	0.0100	0.0000	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	8,443	12,173	20,616	4,845	4,788
V-L Flowrate (kg/hr)	269,106	370,224	639,331	211,692	210,637
Temperature (°C)	100	300	219	31	80
Pressure (MPa, abs)	0.10	0.1	0.1	0.2	15.3
Steam Table Enthalpy (kJ/kg)	3,700	3,593	3,638	8,793	8,758
Aspen Plus Enthalpy (kJ/kg)	-3,638	-3,217	-3,394	-8,961	-9,042
Density (kg/m^3)	1.0	0.6	0.8	3.5	432.5
V-L Molecular Weight	31.9	30.4	31.0	43.7	44.0

Table 5. Iron/steel COG PPS stream table with 90 percent capture.

	1	2	3	4	5
V-L Mole Fraction					
CO_2	0.2700	0.2100	0.2345	0.9879	0.9995
H_2O	0.0500	0.1000	0.0795	0.0121	0.0005
N_2	0.6700	0.6800	0.6759	0.0000	0.0000
O_2	0.0100	0.0100	0.0100	0.0000	0.0000
Total	1.0000	1.0000	1.0000	1.0000	1.0000
V-L Flowrate (kg_{mol}/hr)	8,443	12,173	20,616	4,845	4,788
V-L Flowrate (kg/hr)	269,106	370,224	639,331	211,692	210,637
Temperature (°C)	100	300	219	31	80
Pressure (MPa, abs)	0.10	0.1	0.1	0.2	15.3
Steam Table Enthalpy (kJ/kg)	3,700	3,593	3,638	8,793	8,758
Aspen Plus Enthalpy (kJ/kg)	-3,638	-3,217	-3,394	-8,961	-9,042
Density (kg/m^3)	1.0	0.6	0.8	3.5	432.5
V-L Molecular Weight	31.9	30.4	31.0	43.7	44.0

4.2. Performance Summary

The performance summary for both 90 and 99 percent capture cases in the COG/BFS section of the steel mill is provided in Table 6, while that of the COG PPS section is shown in Table 7.

Table 6. Performance summary for iron/steel COG/BFS section.

Item	2.54 M tonne steel/year with 90 percent CO_2 capture (kWe)	2.54 M tonne steel/year with 99 percent CO_2 capture (kWe)
CO_2 Capture Auxiliaries	4,800	5,400
Steam Boiler Auxiliaries	510	560
CO_2 Compressor	14,660	16,120
Circulating Water Pumps	1,480	1,610
Cooling Tower Fans	770	830
Total Auxiliary Load	22,220	24,520

Table 7. Performance summary for iron/steel COG PPS section.

Item	2.54 M tonne steel/year with 90 percent CO_2 capture (kWe)	2.54 M tonne steel/year with 99 percent CO_2 capture (kWe)
CO_2 Capture Auxiliaries	4,900	5,400
Steam Boiler Auxiliaries	520	570
CO_2 Compressor	14,750	16,210
Circulating Water Pumps	1,490	1,620
Cooling Tower Fans	770	830
Total Auxiliary Load	22,430	24,630

4.3. Cost Results

The cost results for CO_2 capture retrofit in an integrated steel mill are presented in this section. The LCOC for the total capture system at both 99 and 90 percent capture in January 2024 real dollars is presented in Figure 5. LCOC is broken down into its components: capital, fixed O&M, variable O&M, and purchased power and fuel. Figure 6 presents the sensitivity of LCOC to steel plant scale. For comparison, Figure 7 provides insight into the decarbonization potential of applying capture to different industries and the cost associated with the different applications.

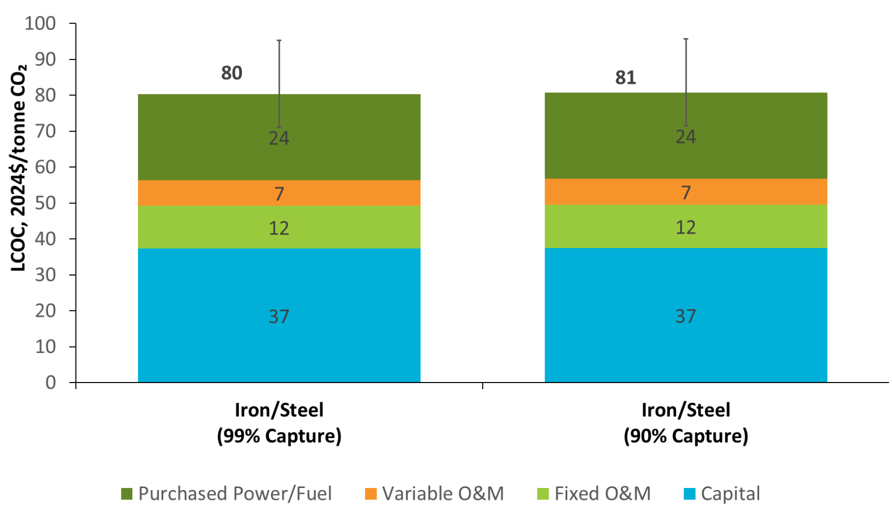

Fig. 5. LCOC for 2.54 M tonne/year iron/steel retrofit cases.

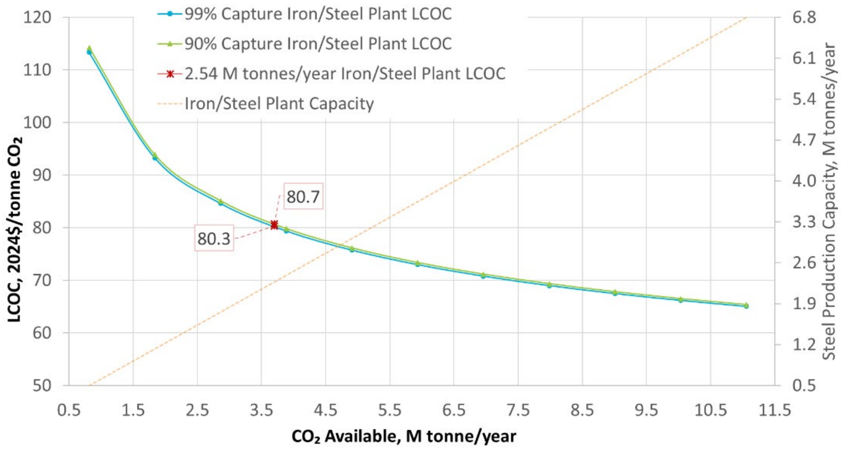

Fig. 6. LCOC sensitivity to iron/steel retrofit scale.

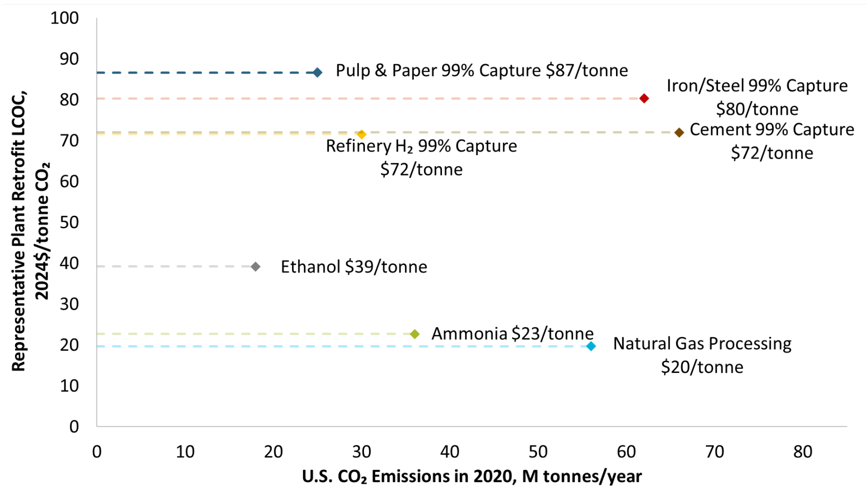

Fig. 7. LCOC and decarbonization potential of applying capture at different industrial applications.

5. Conclusions

Two CO_2 capture and compression systems for a 2.54 M tonnes/year integrated steel mill were modeled to estimate the LCOC from the COG and BFS combined flue gas stream and from the COG PPS exhaust. The results showed the LCOC of CO_2 to be $80.3/tonne CO_2 and $80.7/tonne CO_2 for a retrofit site with 99 and 90 percent capture, respectively. While the LCOC for retrofitting iron/steel mills is higher compared to other point sources evaluated in the Industrial Sources Report, mainly due to the relatively lower purity CO_2 available, the quantity of CO_2 to be captured from such a process makes adding capture to iron/steel plants attractive as it would represent a significant GHG reduction.

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