DECARBONIZING INDIA

IRON AND STEEL SECTOR

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CENTRE FOR SCIENCE AND ENVIRONMENT

Research direction: Sunita Narain and Nivit Kumar Yadav

Author: Parth Kumar

Editors: Arif Ayaz Parrey and Akshat Jain

Design and cover: Ajit Bajaj

Graphics: Sanjit Kumar

Production: Rakesh Shrivastava and Gundhar Das

Advisor: Dr Mukesh Kumar, Director, Steel Research and Technology Mission of India

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Phones: 91-11-40616000
Fax: 91-11-29955879
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1

BACKGROUND AND INTRODUCTION

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1.1 GLOBAL CONTEXT

Combating catastrophic climate change is on the agenda of governments around the world. Calls from climate change prediction agencies to reduce greenhouse gas (GHG) emissions grow more urgent every year. Countries across the globe have decided to act and reduce their emissions drastically, with net zero emission targets in sight. India has announced that it will reach net zero emissions by 2070.

Anthropogenic emissions of carbon dioxide (CO_2) and other greenhouse gases are the primary cause of climate change and one of the most pressing challenges of the contemporary world. Significant quantities of CO_2 and other greenhouse gases are emitted every year. They join historical emissions already present in the atmosphere and will themselves remain in the air for hundreds of years. The increasingly high levels of CO_2 are the cause of rise in average global temperature and are 'forcing' changes in the world's climate.

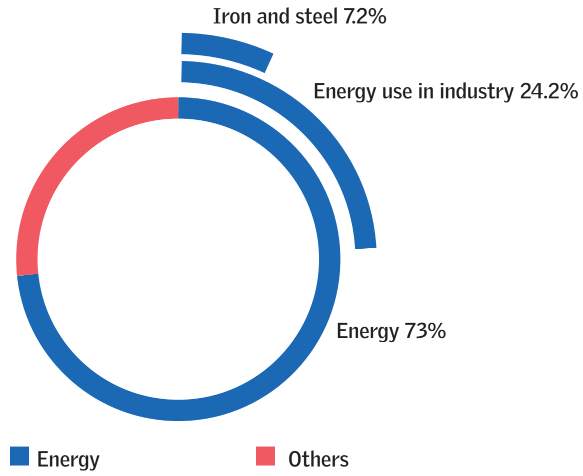
Thus, current global warming is a result of both recent emissions as well as emissions in the past. During the last three decades, there has been a rapid and alarming rise in global CO_2 levels. Annual global GHG emissions have grown by 50 per cent from 1990 to 2018 and are still on the rise.[1] This cannot continue without seriously jeopardizing human survival on this planet.

The significant sectors contributing to GHG emissions worldwide are energy, agriculture, waste, industry, forestry and land use. The energy sector remains the largest contributor—with a 73.2 per cent share (36.2 gigatonne/GT). Of this, the industrial sector contributes 24.2 per cent (12 GT), buildings contribute 17.5 per cent (8.7 GT) and transport contributes 16.2 per cent (8 GT).

Iron and steel is a key sector, as it alone contributed 7.2 per cent (3.5 GT) of total global emissions in 2016 (see *Graph 1*).

Graph 1: Global share of GHG emissions by iron and steel sector in 2016

Iron and steel sector is responsible for almost 7.2 per cent of global GHG emissions



Source: Climate Watch, the World Resources Institute, 2020–21[2]

1.2 INDIA'S GREENHOUSE GAS EMISSIONS

India submits data on its GHG emissions through the Biennial Update Reports (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC). The third such report, submitted in 2021, revealed that India's GHG emissions have been steadily rising with the significant growth in its economy, from 1.4 Gt of carbon dioxide equivalent (CO_2e) in 2005 to 2.8 Gt CO_2e in 2016—this is without accounting for removals from forests and other land-based sinks.

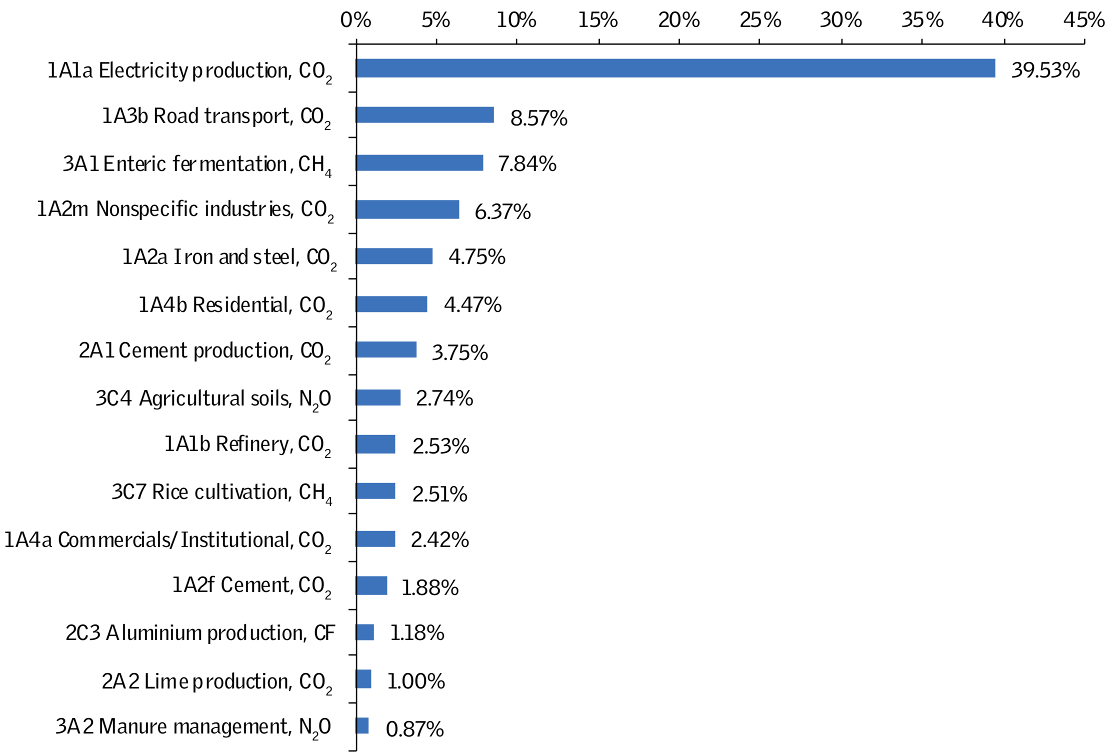
Table 1: GHG emissions in India in 2016 by sector

GHG sources and removals (Gigagramme)	CO_2 emissions	CO_2 removal	CH_4	N_2O	HFC, 23	CF_4	C_2F_6	SF_6	CO_2e
Energy	2,064,840	NO	2072	68	NO	NO	NO	NO	2,129,428
Industrial processes and product use	166,227	NO	187	11	2	4	1	0.004	226,407
Agriculture	NO	NO	14,423	339	NO	NO	NO	NO	407,821
Land use, land-use change and forestry (LULUCF)	21,289	330,765	55	2	NO	NO	NO	NO	-307,820
Waste	NO	NO	2820	52	NO	NO	NO	NO	75,232
Total without LULUCF	2,231,068	---	19,502	469	2	4	1	0.004	2,838,889
Total with LULUCF	2,252,356	330,765	19,557	471	2	4	1	0.004	2,531,069
Memo items	789,305	NO	1	0.13	NO	NO	NO	NO	789,359

NO: Not occurring

Source: India, third Biennial Update Report to the United Nations Framework Convention on Climate Change, page 20[3]

Graph 2: GHG emissions share of key categories in India without LULUCF for 2016



Source: India—Third Biennial Update Report to The United Nations Framework Convention on Climate Change, page 176[4]

The energy sector is the biggest contributor to GHG emissions in India (as it is in the rest of the world)—electricity production alone contributes around 40 per cent of the country's emissions.

The share of industrial processes and product use category in India's GHG emissions is roughly 8 per cent. As per the third BUR, Indian iron and steel sector contributed 135 million tonne, or 4.75 per cent of the countrywide GHG emissions, in 2016.

2

IRON AND STEEL INDUSTRY IN INDIA—PRODUCTION AND POLICY

IRON AND STEEL INDUSTRY IN INDIA—PRODUCTION AND POLICY

China is the largest crude steel producer in the world, followed by India, Japan, Russia and United States—but China is way ahead in terms of production for any comparisons to be meaningful. As of 2020, the production of crude steel in China was almost 10 times that of India, the second largest producer of crude steel in the world (see *Table 2*).

A comparison of the increase in steel consumption in India with the country's GDP clearly shows the dependence of the Indian economy on the steel sector. Steel consumption in India grew from 6.5 MT in 1968 to 98.71 MT in 2018. During the same period, the country's GDP grew from 0.25 trillion to 2.7 trillion. The current direct share of the steel sector in India's GDP is around 2 per cent. The indirect share of this sector in the economy is even bigger because of the dependence of other sectors on steel production.

According to government data, the sector employs half a million people directly and around two million people indirectly.

In 1947, India had only three steel plants—the Tata Iron and Steel Company, the Indian Iron and Steel Company and Visveswaraya Iron and Steel Ltd—and a few electric arc furnace-based plants.

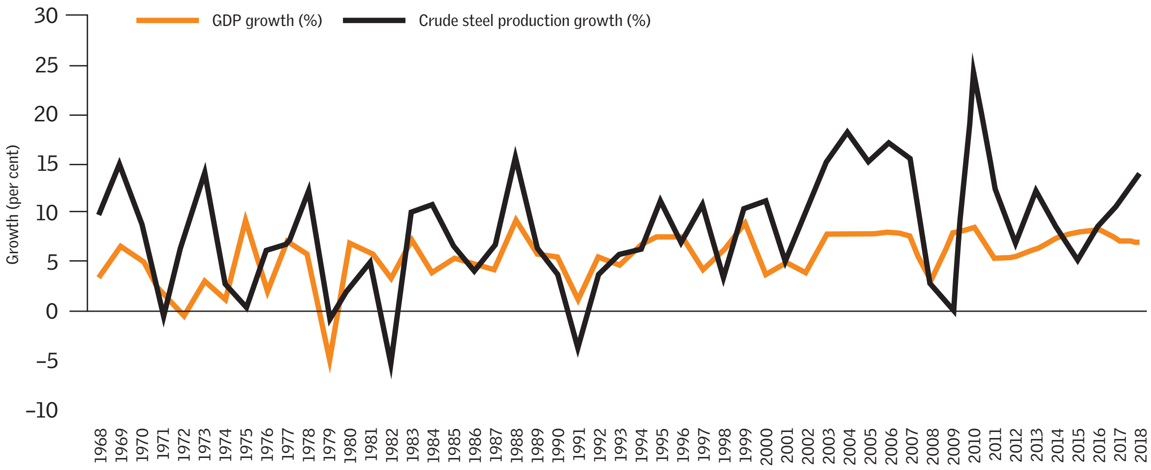
Table 2: Top 10 crude steel producing countries in the world in 2020

Rank	Country	Quantity (in million tonne)*	Per cent change over 2019
1.	China	1,053	5.2
2.	India	99.6	-10.6
3.	Japan	83.2	-16.2
4.	Russia*	73.4	2.6
5.	United States	72.7	-17.2
6.	South Korea	67.1	-6.0
7.	Turkey	35.8	6.0
8.	Germany	35.7	-10.0
9.	Brazil	31.0	-4.9
10.	Iran*	29.0	13.4
	Top ten	1,580	0.4
	World	1,864	-0.9

* Estimate or provisional figure

Source: Annual Report 2020–21, Ministry of Steel, Government of India, page 15[5]

Graph 3: Comparison of growth in steel consumption in India with the GDP of India



Source: Indian Steel Association and PwC report, *The Indian steel industry: Growth, challenges and digital disruption*,[6] page 4, Data from World Bank and World Steel Association, last retrieved on 20 September 2021

The sector witnessed substantial growth as public sector units were set up post-1947. But by the late seventies, the sector's growth turned sluggish due to an economic slowdown, which ended only in 1991–92 when the country moved towards liberalization. This led to a considerable increase in steel capacity of the country with the setting up of large integrated private sector steel plants like ESL Steel Ltd, Ispat Industries, JSW Steel, Tata Steel (India) Ltd, etc.[7]

India's crude steel production rose from 1 million tonne in 1947 to roughly 111 million tonne in 2019.

As of 2020–21, India's steel production capacity was almost 144 million tonne. The country's capacity utilization stood at roughly 70 per cent.

The variety of iron and steel products that the industry manufactures and the different routes to manufacture these products have implications on the environment and the carbon intensity of the sector.

IRON AND STEEL INDUSTRY IN INDIA—PRODUCTION AND POLICY

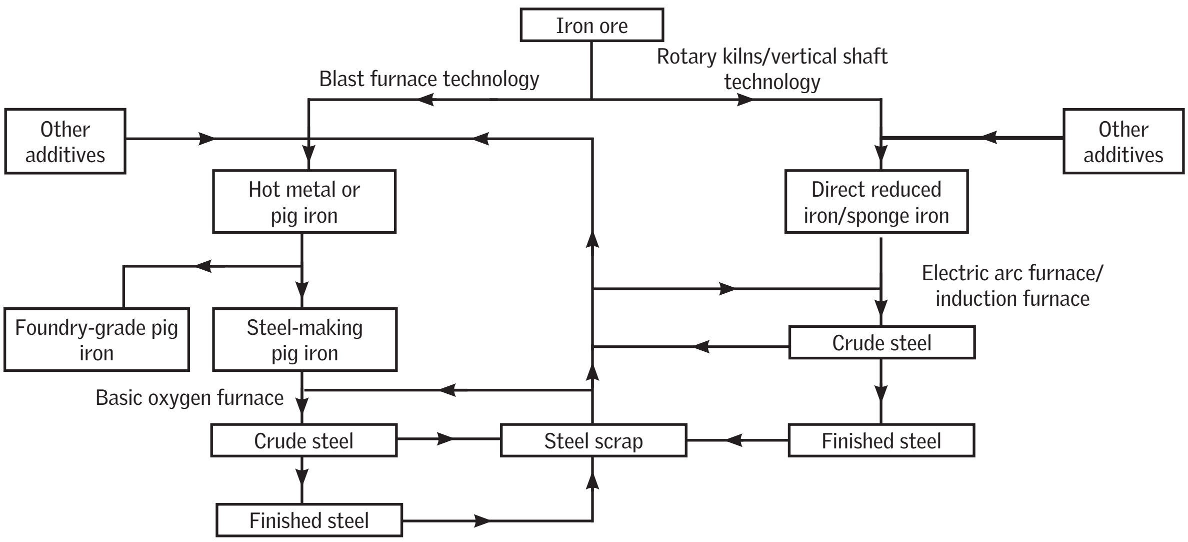
Iron is basically an intermediate product in the manufacture of steel. The primary form of steel produced is known as crude steel, which is further sub-divided into different finished products. All data and figures with respect to steel capacity and production around the world are mostly in terms of crude steel.

Two main types of iron are used to manufacture steel. This distinction is significant because the technologies used to manufacture steel through the two processes differ, which has an impact on their GHG emissions.

The first kind of iron used to manufacture steel is hot metal or pig iron, which is mostly manufactured in blast furnaces (BF). The liquefied form is known as hot metal whereas on solidifying it is called pig iron. This iron is used as a raw material in a basic oxygen furnace (BOF) to make crude steel.

The other method to make crude steel is through the sponge iron route. This is also known as direct reduced iron (DRI). In this process, the iron ore is not liquefied, but iron is extracted from the

Figure 1: Basic production flow diagram of iron and steel



Source: Centre for Science and Environment

ore through reduction with the help of reducing agents in rotary kilns (using coal) or through the vertical shaft technology (using gas). DRI is then used in electric arc furnaces (EAF) or induction furnaces (IF) to make crude steel (see *Figure 1*).

Steel scrap is also used as a raw material in both processes. The only difference is that the basic oxygen furnace technology can use steel scrap only up to a limited share (of around 30 per cent) whereas electric arc furnaces and induction furnaces can run entirely on steel scrap (based on the availability of scrap), as per the World Steel Association (see box on important terms and definitions related to iron and steel).

In 2020, the percentage of steel manufactured in India through basic oxygen furnaces was 45 per cent; while the percentage of steel manufactured by the DRI method through EAF was 28 per cent and through IF was 27 per cent.

2.1 POLICY AND LOW-CARBON GROWTH

The National Steel Policy was created in 2005 to boost the sector. The idea was to make the sector more efficient, productive and at par with global standards. The 2005 policy provides for environmental audit and life cycle assessment of existing steel plants to allow relevant processes to help reduce emissions and effluents, minimize and better manage solid wastes, and improve resource conservation, but it does not mention any specific emissions reduction targets for the sector.

In 2017, the National Steel Policy was reframed to create a new vision for the sector till 2030–31. It sets out the direction of growth as well as climate change targets for the sector.

As per this policy, India's crude steel production capacity is expected to rise to 300 million tonne by 2030—from 144 million tonne currently. The per capita use of steel in India is expected to be 160 kg by 2030–31, up from 74.6 kg in 2019–20. The global per capita use of steel was 229 kg in 2019–20. So, India's per capita steel consumption will continue to be much lower even in 2030 than the global per capita steel use in 2019.[8]

The 2017 policy also projects a GHG trajectory for the sector based on the country's Nationally Determined Contribution (NDC).

According to the policy, by 2030, there will be 2.2–2.4 tonne of CO_2 emissions per tonne of crude steel produced through the blast furnace-basic oxygen furnace (BF-BOF) route.

The direct reduced iron-electric arc furnace (DRI-EAF) route will emit 2.6–2.7 tonne of CO_2 emissions per tonne of crude steel produced. However, the policy states that efforts "will be made to achieve aforesaid targets or even better targets at par with global best practices, wherever possible."

More importantly, the policy recognizes that coal-based steel production has a huge environmental footprint and states that "capacity additions through coal-based routes will have far reaching implications for India in terms of environmental degradation. Hence, necessary efforts will be made to have a judicious mix of production routes to reduce the carbon footprint of steel sector in line with the INDC targets."

IRON AND STEEL: IMPORTANT TERMS AND DEFINITIONS

TERMS RELATED TO IRON

- **Iron ore:** A naturally occurring mineral from which iron (Fe) metal is extracted in various forms, viz., hot metal, DRI, etc.

- **Iron:** Iron is a base metal extracted from iron ore. Pure iron has a melting point of around 1,530°C and a density of 7.86 gm/cc.

- **Hot metal (liquid iron):** It is the hot, liquid, metallic iron product obtained upon reduction of iron ore (normally in a blast furnace or in a Corex furnace). It contains about 93–94 per cent iron (Fe) and other elements and impurities like carbon (4 per cent), silicon (~1 per cent), manganese (+1 per cent) sulphur, phosphorus, etc. Hot metal is the primary input for production of steel in integrated steel plants.

- **Pig iron:** A product in solid (lumpy) form obtained upon solidification of hot metal in a pig casting machine. It is called pig or pig iron because of its typical humpy shape. It is produced in two broad categories or grades:

  Foundry grade pig iron: Pig iron used in foundries for production of cast iron (CI) castings using a Cupola furnace. This is the major use of pig iron.

  Basic or steel-making grade pig iron: Pig iron (including hot metal) used in production of steel.

- **Direct reduced iron (DRI):** Solid metallic iron product obtained upon direct reduction of high grade iron ore in the solid state itself without being converted into liquid form like that in a blast furnace.

- **Sponge iron (SI):** DRI is also known as sponge iron because of its spongy micro-structure.

TERMS RELATED TO STEEL

- **Steel:** Steel is an iron-based alloy containing carbon, silicon, manganese, etc.

- **Crude steel:** The term is internationally used to mean the first solid steel product upon solidification of liquid steel. In other words, it includes ingots (in conventional mills) and semis (in modern mills with continuous casting facility). According to International Iron and Steel Institute (IISI), for statistical purposes, crude steel also includes liquid steel which goes into production of steel castings.

- **Finished steel:** Products obtained upon hot rolling or forging of semi-finished steel (blooms, billets and slabs). These cover two broad categories of products, namely 'long products' and 'flat products'.

Source: Ministry of Steel, Government of India, 2021

3

MANUFACTURING PROCESS AND RELATED GHG EMISSIONS

3.1 MANUFACTURING PROCESS AND RELATED GHG EMISSIONS

The process used to manufacture steel and the fuel used in the process are important determinants of the eventual GHG footprint.

In the blast furnace-basic oxygen furnace (BF-BOF) manufacturing process, iron ore is smelted with heat from burning coal. Coal also acts as a reducing agent to turn the ore into metal. Therefore, due to extensive use of coal in the process, it becomes harder to decarbonize steel production.

In the electric arc furnace (EAF) manufacturing process, steel-making is not dependent on the use of coal, but can use other power and feed materials, which makes it easier to reduce emissions. In this process, steel can also be made using recycled scrap metal.

Around 70 per cent crude steel production in the world and 45 per cent crude steel production in India is through the BF-BOF technology. Coke, sinter, coal injection and, at times, pellets are fed into the blast furnace (see *Figure 2*).

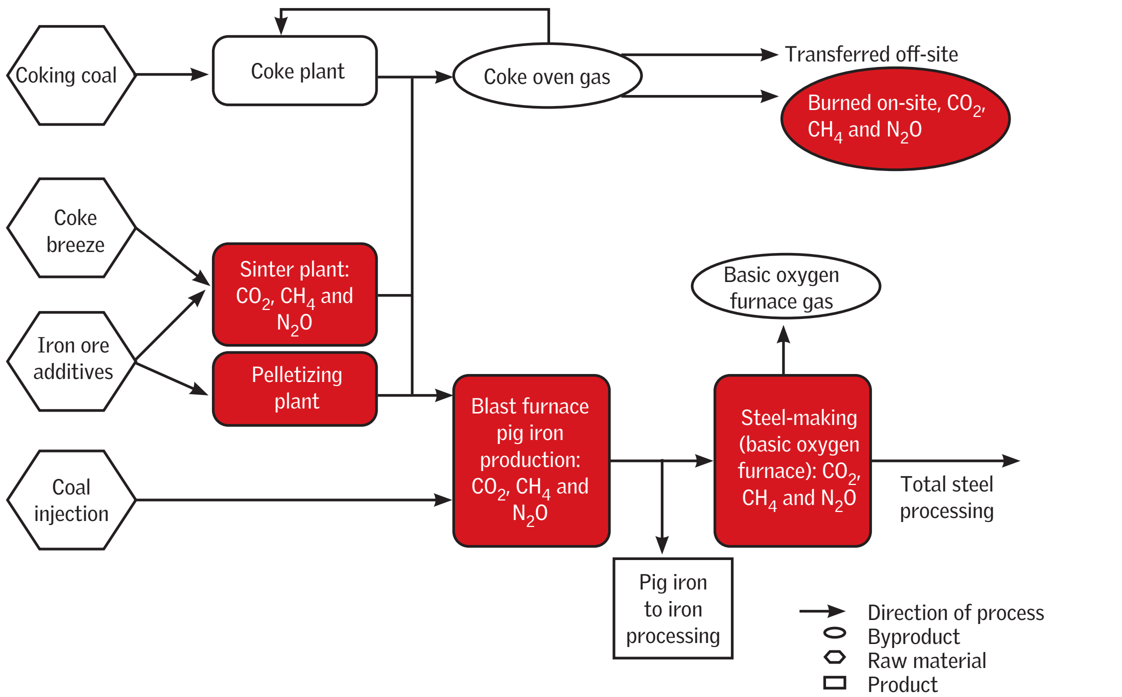
Waste heat from the processes in the coke oven and other parts might also be used in the blast furnace for efficiency. Pig iron is produced from the blast furnace which is then converted to steel through a basic oxygen furnace. The end product is casted and rolled into coils, plates, sections and, mostly, bars.

The major greenhouse gases emitted at different stages are carbon dioxide (99 per cent), methane and nitrous oxide. The important steps of the in situ process of BF-BOF that contribute to GHG emissions are coke production, sinter production and pellet production (if carried out). Blast furnaces and basic oxygen furnaces are also major contributors to greenhouse gas emissions.

In the electric arc furnace process, steel scrap is used as the major raw material. It is melted in an electric furnace. Sponge iron is also

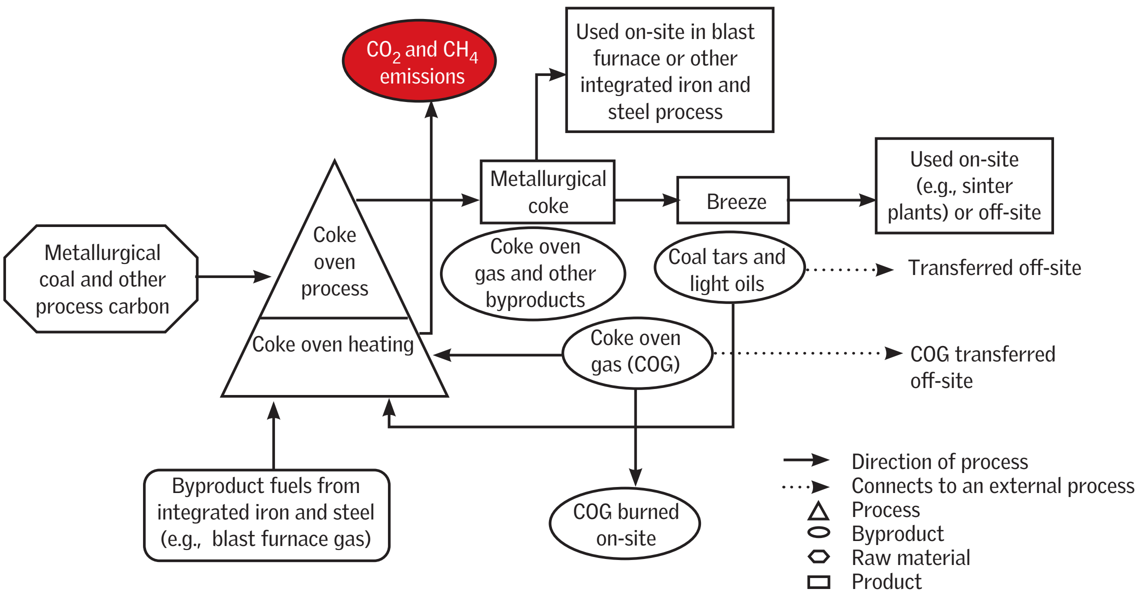
MANUFACTURING PROCESS AND RELATED GHG EMISSIONS

Figure 2: Process flowchart of BF-BOF-based iron and steel production with points of GHG emissions



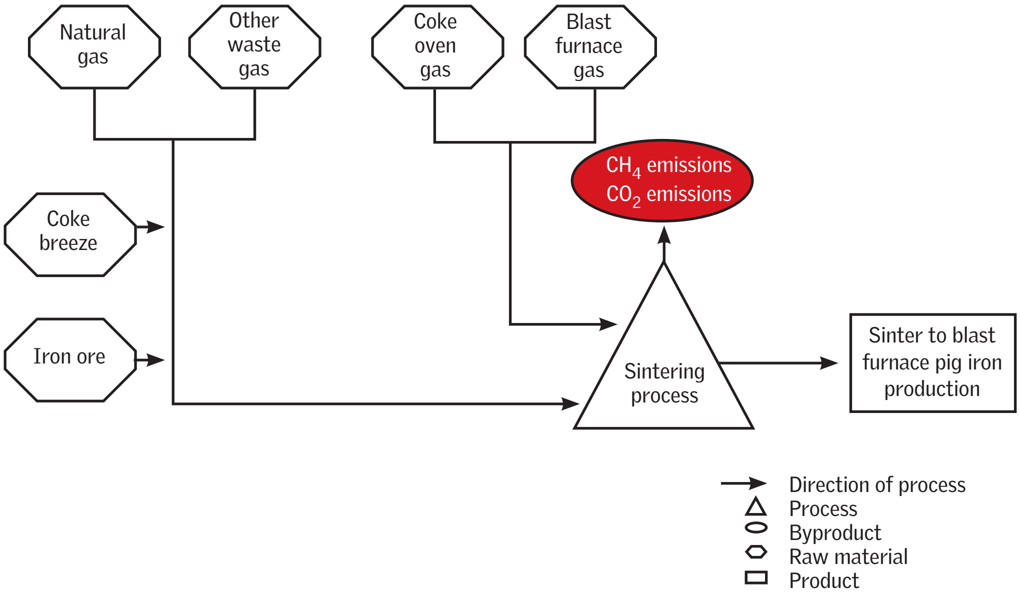
Source: IPCC guidelines for National Greenhouse Gas Inventories, 2006, page 4.13

Figure 3: Coke production process chart with points of GHG emissions



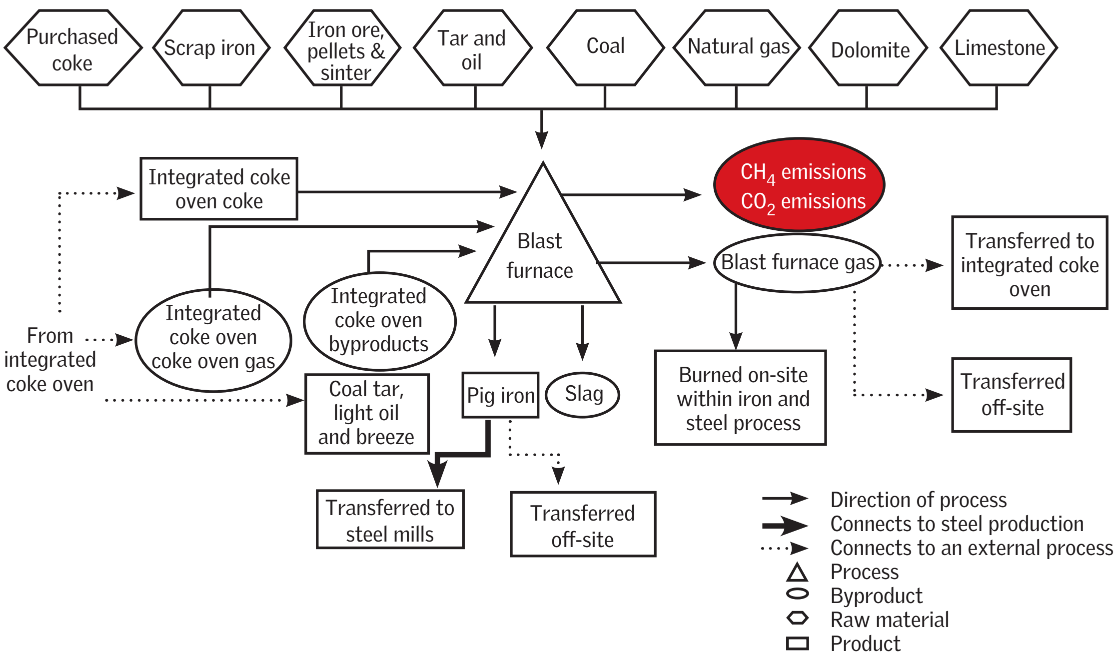
Source: IPCC guidelines for National greenhouse gas inventories, 2006, page 4.14

Figure 4: Sinter production process chart with points of GHG emissions



Source: IPCC guidelines for National greenhouse gas inventories, 2006, page 4.15

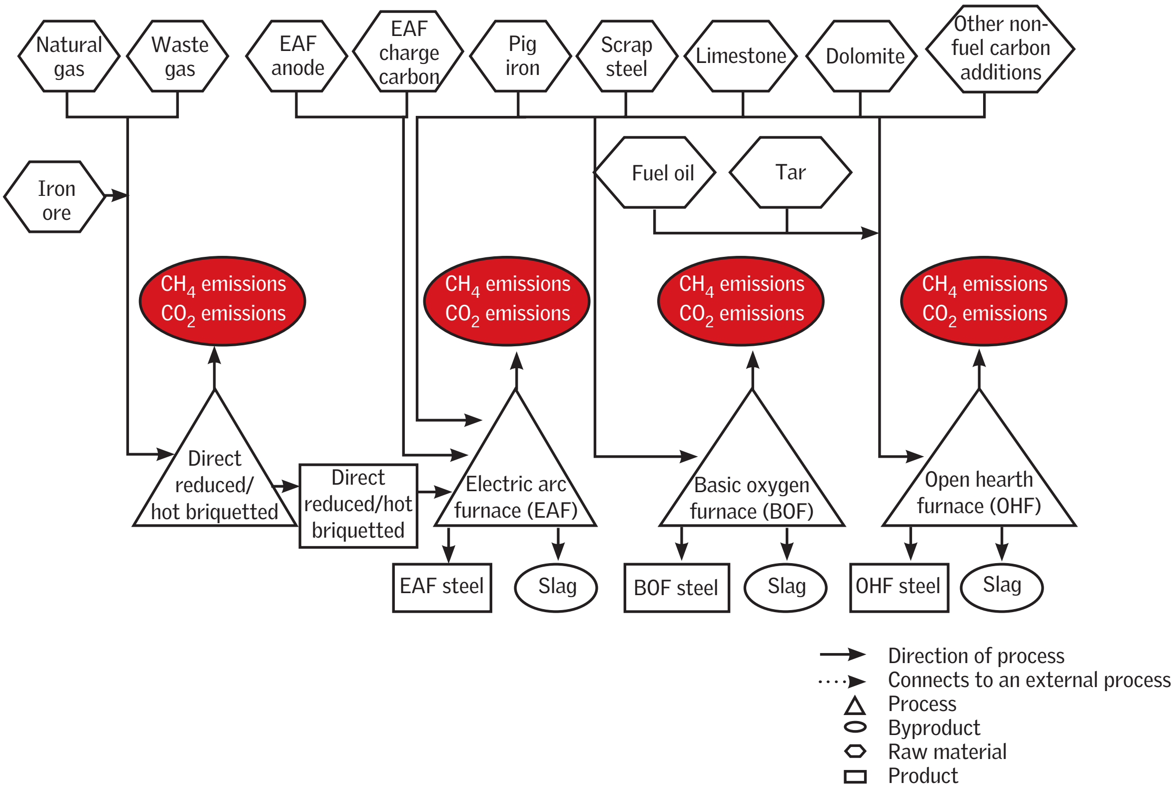
Figure 5: Pig iron production process chart with points of GHG emissions



Source: IPCC guidelines for National greenhouse gas inventories, 2006, page 4.16

MANUFACTURING PROCESS AND RELATED GHG EMISSIONS

Figure 6: Illustration of steel making processes (including EAF and sponge iron manufacture)



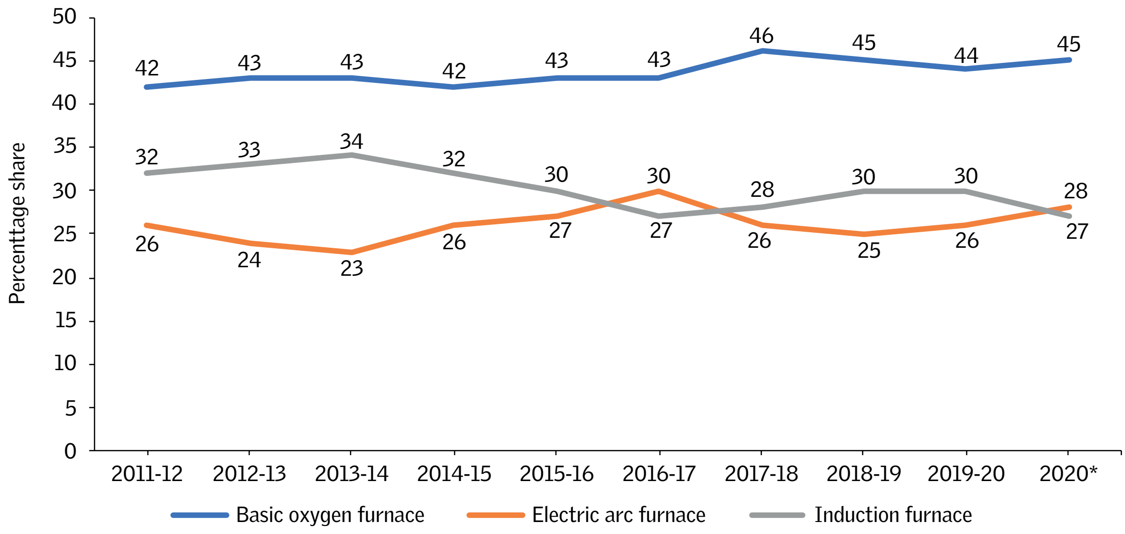
Source: IPCC guidelines for National greenhouse gas inventories, 2006, page 4.17

often used as a raw material in the electric arc furnace process as a replacement for steel scrap. Sponge iron is also known as direct reduced iron (DRI) as direct reduction process is used to manufacture sponge iron. It is a process in which oxygen is removed from iron ore in the solid state without melting it as is done inside blast furnaces. The electric arc furnace process and the production of sponge iron also generate greenhouse gas emissions, majorly CO_2.

3.2 SHARE OF PROCESSES IN CRUDE STEEL

The most popular process is the basic oxygen furnace process which has continued to maintain a share between 42 per cent and 46 per cent in the overall production in India. It was assumed at one point that a majority of steel-making units will shift to the electric arc furnace technology, but that has not happened over

Graph 4: Trends in share of crude steel production processes in India



*Provisional
Source: Ministry of Steel, Government of India

the past decade. One of the reasons could be economic, especially since electricity in India costs more than other easily available fuels like coal. The share of electric arc furnace technology has remained between 23 per cent and 30 per cent. Similarly, the share of induction furnace technology has ranged between 30 per cent and 34 per cent in the past decade (see *Graph 4*).

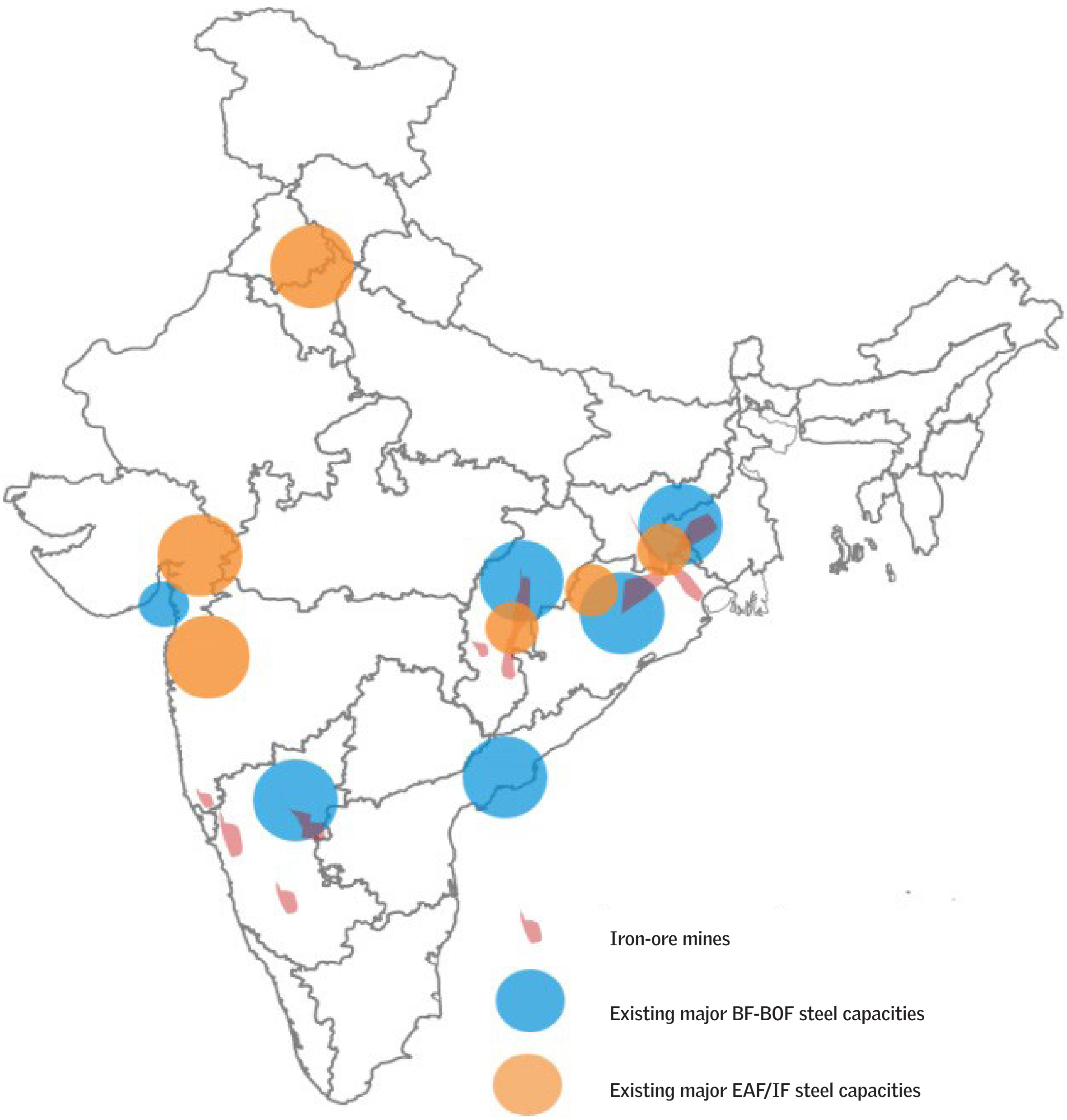
3.3 FUEL CONSUMPTION

According to the third Biennial Update Report submitted by India to the United Nations Framework Convention on Climate Change (UNFCCC) for 2015 and 2016, solid fuels dominate fuel consumption patterns in the country. The consumption of solid fuels went down between 2015 and 2016 and the consumption of gaseous fuels went up marginally, but compared to the quantity of solid fuels (mainly coal) being consumed by the iron and steel sector, this change is almost negligible (see *Graph 5*).

Looking at the fuel usage in manufacturing of specific products in this sector, one of the major products is sponge iron, of which

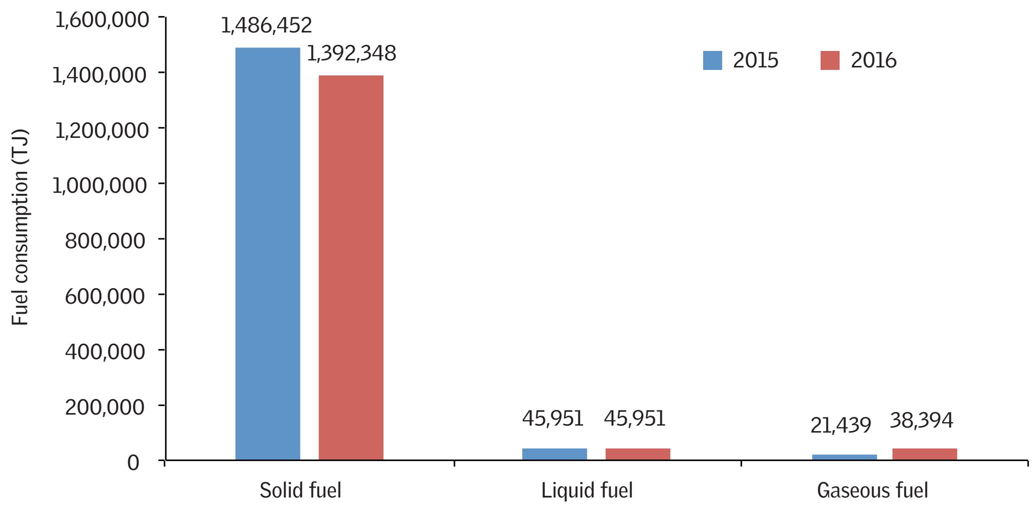
MANUFACTURING PROCESS AND RELATED GHG EMISSIONS

Map 1: Existing major iron ore mines, BF-BOF and EAF/IF capacities in India (2017)



Source: National Steel Policy, 2017

Graph 5: Type of fuel consumption by the iron and steel sector



Source: India, third Biennial Update Report to UNFCCC

Table 3: Production of sponge iron or DRI by fuel

Year	2016	2017	2018	2019	2020*
	In million tonne				
Coal-based	22.62	23.28	27.16	30.12	27.05
Gas-based	4.36	6.22	7.05	6.7	6.07
Total	26.98	29.51	34.21	36.82	33.13

*Provisional
Source: Annual Report 2020-21, page 14, Ministry of Steel, Government of India

India has been the largest producer. A majority of the sponge or direct reduced iron comes from small-scale coal-based units located in mineral rich states of India. Coal-based units were responsible for 82 per cent of the production of sponge iron in 2020, whereas the rest of the production share was gas-based (see *Table 3*).

The share of coal-based production of sponge iron has been quite consistent. One possible reason behind this could be the non-availability of natural gas in major steel-producing regions and the high prices of natural gas in comparison to coal.

4
FUTURE PRODUCTION AND CAPACITY ADDITIONS

4.1 PROJECTION OF FUTURE PRODUCTION

India plans to more than double its crude steel production by 2030, going from 111 million tonne in 2019 to 255 million tonne by 2030–31 (see *Table 4*).

Table 4: Projections of iron and steel production by 2030–31

Parameter	Projections (2030–31)
Total crude steel capacity (in MTPA)	300
Total crude steel demand or production (in MTPA)	255
Total finished steel demand or production (in MTPA)	230
Sponge iron demand or production (in MTPA)	80
Pig iron demand or production (in MTPA)	17
Per capita finished steel consumption (in kg)	158

Source: Annual Report 2020-21, page 19, Ministry of Steel, Government of India

4.2 ADDITIONS AND TYPE

To be able to reach the capacity and production increase targets set under the National Steel Policy, 2017, the big players of the steel sector have already set expansion plans for the upcoming decade (see *Table 5*).

An approximate capacity expansion of more than 120 million tonne per annum over the existing 144 million tonne per annum capacity is already being planned by large-scale steel producers of India at the very beginning of the next decade. This planned capacity expansion becomes even higher if we take the capacity addition of medium- and smaller-scale players into consideration and account for the fact that large-scale steel producing companies are probably going to make announcements of further expansion.

Thus, India will probably be able to meet its steel manufacturing capacity target of 300 million tonne per annum by 2030 as set in the National Steel Policy, 2017.

The only target that India may not be able to meet is limiting the share of BF-BOF steel production route to 65 per cent by that year.

FUTURE PRODUCTION AND CAPACITY ADDITIONS

Table 5: Capacity expansion plans of major steel companies of India

S. no.	Company	Current capacity (in million tonne per annum)	Expansion plans
1.	Steel Authority of India Ltd (SAIL)	19.6	- SAIL is planning to increase its production capacity to 49.6 metric tonne per annum (MTPA), from its current capacity of 19.6 MTPA, by 2030, in two phases. - In the first phase, the capacity will be increased to 35.8 MTPA. - Durgapur Steel Plant's capacity will be enhanced to 7.5 MTPA from 2.5 MTPA in the first phase. - Rourkela Steel Plant's capacity has been proposed to be expanded to 8.8 MTPA from 3.7 MTPA in the first phase. - Bokaro Steel Plant's capacity will be expanded to 9.5 MTPA from the current 3 MTPA in the first phase. - No plans for the Bhilai plant in the first phase, but its capacity is likely to be raised to 12 MTPA from the current 7 MTPA and subsequently to 14 MTPA by 2030. - IISCO plant's capacity will also be raised to 7.3 MTPA from the current 3 MTPA.
2.	Tata Steel (India) Ltd	19.4	- A statement by Tata Steel (India) Ltd in February 2021 says that the company is planning to double its capacity to 40 MTPA. - Tata Steel (India) Ltd has plans to increase its Kalinganagar Steel Plant's capacity by 5 MTPA from its current capacity of 3 MTPA by 2024.
3.	JSW Steel Ltd	18	- JSW Steel is looking to add 14.8 MTPA capacity across its Dolvi plant (Maharashtra), Vijayanagar plant (Karnataka) and Bhushan Power and Steel Facility at Jharsuguda (Odisha) by 2024. - JSW Steel completed its takeover of Bhushan Power and Steel Ltd, whose capacity will be increased to 5 MTPA from 2.7 MTPA. - Vijayanagar plant's production capacity will be increased by 5 MTPA by March 2024, from its current capacity of 12 MTPA. - The Dolvi plant's capacity will be doubled from 5 MTPA to 10 MTPA.
4.	Arcelor Mittal Nippon Steel (AM/ NS) India Ltd	10	- In June 2021, AM/NS India announced plans to increase their capacity to 30 MTPA. - AM/NS are planning to increase the capacity of the Hazira plant in Gujarat by 5 MTPA in the next three years, making its capacity 14 MTPA. In the next phase, they plan to expand its capacity further to 18 MTPA. - AM/NS are also planning to set up a 12 MTPA capacity integrated steel plant in Odisha.

S. no.	Company	Current capacity (in million tonne per annum)	Expansion plans
5.	Jindal Steel and Power Ltd (JSPL)	8.6	- JSPL claims a target to grow its capacity from the current 9.6 MT to 50 MT in 2030. - JSPL is planning to add 6 MTPA capacity at its plant in Angul, Odisha by 2026, which currently has a capacity of 6 MTPA. - This will take JSPL's overall capacity in India to 16 MTPA.
6.	National Mineral Development Corporation (NDMC)		- NMDC's Nagarnar Integrated Steel Plant of 3 MTPA capacity is coming up as well.
7.	Rashtriya Ispat Nigam Ltd (RINL)	6.3	- RINL plans to expand its capacity to 11.7 MTPA. - As a next step it will increase its capacity to 7.3 MTPA[9]
6.	ESL Steel	2.5	- ESL Steel plans to add 4.5 MTPA to its capacity, taking it to a total of 7 TPA.[10]

Source: India Brand Equity,[11] Business Standard,[12] Economic Times,[13] Indian Express,[14] and Financial Express[15]

The majority of the proposed expansion is to happen through the BF-BOF route, despite it being an emission-intensive technology in its current form.

In fact, India might end up with a much bigger share of BF-BOF in steel production by 2030 than targeted. This increase in the share of steel production through the BF-BOF route of production will make it even more challenging for India's steel sector to reduce its overall GHG emissions. The reasons for this increase range from the unavailability of good quality scrap, high price of natural gas to scale of technology (see *Box: Why is future expansion in the steel sector of India mainly through the BF-BOF route?*).

This increase in the share of steel production through the BF-BOF route of production will make it even more challenging for India's steel sector to reduce its overall GHG emissions.

FUTURE PRODUCTION AND CAPACITY ADDITIONS

WHY IS FUTURE EXPANSION IN THE STEEL SECTOR MAINLY THROUGH THE BF-BOF ROUTE?

A few big steel companies and public sector utilities (PSUs) hold a share of around 65 per cent of the current steel production in India. In order to fulfil the capacity and production goals announced in the National Steel Policy of 2017, these steel companies are expected to expand their capacities as much as possible. A majority of the companies are planning to expand through the BF-BOF route.

Technologies like EAF/IF emit lesser CO_2e compared to BF-BOF, but still the big players of the sector are hesitant to invest in such technologies. Why? Some reasons are listed here:

1. **Large-scale production capacity of BF-BOF:** In order to increase production beyond a certain level, it is important that the technology being adopted enables large-scale production. BF-BOF is the only existing technology that enables carrying out production at that scale. The EAF technology experimented with on ground in India has, till date, a much lower production capacity compared to BF-BOF. Induction furnace technology is being utilized at an even lower scale.

2. **Poor quality and non-availability of scrap:** EAF/IF technologies are dependent on scrap as a raw material but the availability of scrap is currently an issue in the country. Even the scrap available is not of the best quality, which can result in poor quality steel production, especially in induction furnaces. This has forced EAF/IF plants to use direct reduced iron or sponge iron in combination with steel scrap.

3. **Non-availability and high prices of natural gas:** Big steel companies would be interested in setting up gas-based DRI plants as they have lower emissions but natural gas pipelines are not available in many parts of the country where these plants are located. The high price of natural gas is another reason that makes it a not-so-preferred option.

4. **High demand for primary steel:** Many major steel consuming sectors are very particular about the quality of steel they are buying and prefer primary steel products over secondary steel products. Sectors like automobile are major primary steel consumers, thus increasing its demand, and since the gas-based DRI-EAF route has issues and no major steel company wants to invest in coal-based DRI further on (due to high emissions), the only major option left for them is the BF-BOF route.

5

GHG EMISSIONS FROM INDIA'S STEEL SECTOR

GHG EMISSIONS FROM INDIA'S STEEL SECTOR

5.1 TREND IN STEEL EMISSIONS

According to the Biennial Update Reports (BUR) submitted by India to UNFCCC, iron and steel production contributed some 135 million tonne or 4.75 per cent of the total emissions in India in 2016.

CSE has calculated GHG emissions using its estimated emission factors for different technologies which are based on declarations and estimations made by the Ministry of Steel and the disclosures made by steel companies (see *Table 6* and *Table 7*).

According to CSE's estimation, emissions from India's iron and steel sector would have been around 250 million tonne in 2016.

The difference in GHG estimations of the iron and steel sector between MOEF&CC and CSE could be because in the Biennial Update Reports the energy usage—for power requirements and for manufacturing in various sectors—has been accounted for differently. In this case, part of the GHG emissions from the iron and steel sector are accounted under energy usage and not the industry, as per the guidelines of IPCC.

Table 6: GHG emissions reported in BUR and estimated by CSE

Year	Production (in million tonne)	GHG emissions reported in BUR (million tonne)	Estimated GHG emissions from the BF-BOF route as per CSE (million tonne)	Estimated GHG emissions from the EAF/IF route as per CSE (million tonne)	Total estimated GHG emissions as per CSE (million tonne)
2010–11	70.67	95.99	79.50	103.52	183.02
2011–12	74.29	119.84	78.00	116.71	194.72
2014–15	88.98	154.67	93.42	147.81	241.24
2016	95.48	135.42	102.64	150.92	253.56

Source: Estimated by Centre for Science and Environment, basic data from all three biennial reports submitted to UNFCCC by India and annual reports of Ministry of Steel

Table 7: Estimated range of CO_2e emissions from major iron and steel manufacturing technologies and their scenario in India

S. no.	Major iron and steel production technologies	Estimated range of CO_2e emissions (in tonne) per tonne of crude steel production	Scenario in India	Average emission factors considered
1.	BF-BOF	2.2–2.6	- Due to their large capacities, they hold almost half of India's production share (45 per cent). - A majority of India's future capacity expansion is planned to happen via this technology.	2.5
2.	Coal-based DRI-EAF/IF	2.8–3.2	- Around 82 per cent of DRI production in India is through coal-based rotary kilns. These are mostly small-scale units with high CO_2e emissions.	3
3.	Gas-based DRI-EAF	1.4–1.8	- Around 18 per cent of DRI production in India is gas-based and its share has not increased much in the past five years due to non-availability and high prices of natural gas.	1.6
4.	Coal gasification-based DRI-EAF/EOF	2.8–3	- Only one plant of JSPL in Angul, Odisha. It uses synthetic gas as produced from gasification of domestic coal for reduction of iron ore, thus preventing use of coke (which is scarce in India) and mostly imported.	2.9
5.	100 per cent scrap-based EAF and IF	0.4–0.8	- It is not happening on the ground in India. Most EAF and IF plants use a combination of scrap and DRI (as scrap availability is an issue).	0.6
6.	Corex-oxygen converter (basic oxygen furnace/ Conarc technology)	2.4–2.8	- This technology is currently in use at the JSW Vijayanagar plant in Karnataka and Arcellor Mittal Nipon Hazira plant in Gujrat. Conarc technology has both an oxygen converter as well as an electric arc furnace.	2.6
7.	BF-EOF (Blast Furnace-Energy Optimization Furnace)	2.5	- Salem Steel Works plant of JSW is known to be using this technology currently. It ends up generating CO_2e emissions almost equivalent to BF-BOF technology.	2.5

Source: Based on declarations by Ministry of Steel, sustainability reports of steel companies in India and research articles (see **Annexure**)

5.2 TYPE OF PRODUCTION AND EMISSIONS

It is understood that the carbon intensity of steel is determined by the process through which finished steel is produced from iron ore and, of course, the fuel used in the manufacture of the product.

The blast furnace-basic oxygen furnace (BF-BOF) technology uses coking coal in its process, not just as a fuel but also as a reducing agent. Doing so makes the technology more polluting than direct reduced iron technology (DRI), which uses electric arc furnaces (EAF) to convert iron into steel (DRI-EAF).

Globally, it is understood that the BF-BOF route is more polluting and much more difficult to decarbonize than the DRI-EAF route.

However, this is not the case in India. The bulk of DRI units in India (responsible for 82 per cent of the country's DRI production) are in the small- and medium-scale sector and they use coal-based rotary kilns to produce iron. DRI is not only used as a raw material in EAF, but often also in induction furnaces that produced as much as 30 per cent of the steel in the country in 2020.

To estimate the emissions intensity of the sector, **CSE** has examined the annual sustainability reports of companies; and consulted the company and government declared emissions intensity factors and sources of the sector (see *Annexure*). It is clear that there is a wide variation in the emission factors between different companies, plants, technologies and sources. Therefore, a range has been taken based on different sources of information.

Data shows that coal-based DRI-EAF and induction furnace technologies have higher CO_2e emissions and gas-based DRI-EAF has lower CO_2e emissions.

The current emission factor of the BF-BOF route in India is close to the 2030 emissions target set out in the National Steel Policy, 2017. As per the policy, emissions through BF-BOF technology would be 2.2–2.4 tonne per tonne of crude steel produced in 2030. Currently, as per information available from the Ministry of Steel, the emissions are 2.5 tonne per tonne of crude steel production.

However, as the bulk of future expansion is also planned through this technological route, it will be critical to see what is possible for an accelerated low-carbon trajectory for the BF-BOF route.

5.3 CURRENT OVERALL EMISSIONS

CSE has calculated the emissions of the iron and steel sector based on voluntary disclosures by the companies and the government. Where company data is not available, estimated emission factors for the technology and production figures have been applied. Where plant-wise production data was unavailable, CSE has used the country average capacity utilization for the plant.

Table 8: Company and plant-wise capacity, production, technology and estimated GHG emissions (2020–21)

S. no.	Company	Production capacity 2020–21 (million tonne)	Production 2020–21 (million tonne)	Iron-making technology	Steel-making technology	Average emission factor (assumed, as it is not declared by company)	Emission factor declared by the company	GHG emissions (million tonne)
	Tata Steel (India) Ltd	19.4	16.92				2.3	38.92
1	Jamshedpur Plant, Jharkhand	11	9.59	Blast Furnace	Basic Oxygen Furnace		2.29	21.96
2	Kalinganagar Plant, Odisha	3	2.62	Blast Furnace	Basic Oxygen Furnace		2.44	6.38
3	Dhenkanal Plant, Odisha	5.6	4.88	Blast Furnace	Basic Oxygen Furnace	2.54		12.21
	Steel Authority of India Ltd	19.6	15.05*				2.4	38.23
1	Bhilai Steel Plant	6	4.24	Blast Furnace	Basic Oxygen Furnace	2.5		10.6
2	Durgapur Steel Plant	2.2	2.08	Blast Furnace	Basic Oxygen Furnace	2.5		5.25
3	Rourkela Steel Plant	3.8	3.49	Blast Furnace	Basic Oxygen Furnace	2.5		8.73
4	Bokaro Steel Plant	4.6	3.38	Blast Furnace	Basic Oxygen Furnace	2.5		8.45

GHG EMISSIONS FROM INDIA'S STEEL SECTOR

S. no.	Company	Production capacity 2020–21 (million tonne)	Production 2020–21 (million tonne)	Iron-making technology	Steel-making technology	Average emission factor (assumed, as it is not declared by company)	Emission factor declared by the company	GHG emissions (million tonne)
5	IISCO Steel Plant, Asansol	2.5	1.84	Blast Furnace	Basic Oxygen Furnace	2.5		4.6
	Rashtriya Ispat Nigam Ltd	6.3	4.3			2.5		10.75
1	Vizag Steel Plant	6.3	4.3	Blast Furnace	Basic Oxygen Furnace	2.5		10.75
	JSW Steel	18	15.08				2.49	37.54
1	Dolvi Plant, Maharashtra.	5	4.19	Blast furnace: 3.5 MT Midrex gas DRI: 1.5 MT	Conarc Technology	BF-Conarc: 2.5 Midrex gas DRI-Conarc: 1.6 Average for plant based on technology: 2.23		9.34
2	Vijayanagar Plant, Karnataka.	12	10.05	Blast Furnace: 9.7 MT Corex gasification: 1.6 MT Midrex gas DRI: 1.2 MT	Basic Oxygen Furnace: 11 MT Electric Arc Furnace: 1 MT	BF-BOF: 2.5 Corex-BOF: 2.6 Midrex DRI-EAF: 1.6 Average for plant based on technology: 2.43		24.4
3	Salem Works, Tamil Nadu	1	0.84	Blast Furnace	Energy Optimization Furnace	2.5**		2.1
	ArcelorMittal Nippon Steel India	10	6.69			1.92		12.86
1	Hazira Plant, Gujarat	10	6.69	Blast Furnace: 1.75 MT Midrex gas DRI: 6.75 MT Corex technology: 1.75 MT	Conarc Technology	BF-Conarc: 2.5 Corex-Conarc: 2.6 Midrex gas DRI-Conarc: 1.6 Average for plant based on technology: 1.92		12.86
	Jindal Steel and Power Ltd	8.6	6.859			2.62		18

S. no.	Company	Production capacity 2020–21 (million tonne)	Production 2020–21 (million tonne)	Iron-making technology	Steel-making technology	Average emission factor (assumed, as it is not declared by company)	Emission factor declared by the company	GHG emissions (million tonne)
1	Angul Plant, Odisha	5	3.98	Blast Furnace: 3.2 MT Coal gasification-based DRI: 1.8 MT	Basic Oxygen Furnace: 3.2 MT Electric Arc Furnace: 1.8 MT	BF-BOF: 2.5 Coal gasification-based DRI-EAF: 2.9 Average for plant based on technology: 2.64		10.52
2	Raigarh Plant, Chhattisgarh	3.6	2.87	Blast furnace: 3.05 MT Coal-based DRI: 1.32 MT	Electric Arc Furnace: 3.6 MT	BF-EAF: 2.5 Coal-based DRI-EAF: 2.85*** Average for plant based on technology: 2.6		7.48
	ESL Steel Limited-Vedanta	1.5	1.05			2.5		2.62
1	Bokaro Plant, Jharkhand	1.5	1.05	Blast Furnace	Basic Oxygen Furnace	2.5		2.63
	Other manufacturers (mostly small-scale)	60.51	37.6	Assumed to be coal-based DRI	Assumed that all the rest of steel manufacturing is from coal-based DRI-EAF/IF	3		112.79
	Total	143.91	103.545					271.04 ~ 271

*SAIL crude steel production is a sum of production from 5 integrated steel plants of SAIL, excluding production data of Salem Steel Plant and Alloy Steel Plant as they are not integrated steel plants producing crude steel

** The emission factor for the Salem Works (plant of JSW Steel) has been taken as 2.5, as the blast furnace and coke oven plant are the major emitters, so energy optimizing furnace's emissions will not differ much from that of a BOF.

*** In Raigarh plant the emission factor for BF-EAF route has been taken as 2.5 (same as BF-BOF) because the hot metal from blast furnace when put into the electric arc furnace needs to go through oxygen lancing process, making it equivalent to emissions from BF-BOF. The emission factor for coal-based DRI-EAF has been taken to be 2.85 (instead of 3 i.e. CSE's estimated factor) as in this case the hot DRI gets mixed with high carbon hot metal from blast furnace while being fed into electric arc furnace, which leads to lesser electricty consumption in the furnace. Also in rotary kilns of above 300 tonne capacity, a waste heat recovery system is usually present which is used to generate electricity that is then used in the electric arc furnace. Therefore, these two reasons bring down the emission factor, which then has been assumed to be 2.85.

Important notes about Table 8:

- The GHG emissions mentioned for the overall company and the sum of its plants might differ as overall average company emission factors (self-declared or estimated) have been considered for calculating company GHG emissions whereas technology specific (see *Table 7*) or self-declared emission factors have been considered plant-wise.
- Some numbers may not match exactly due to rounding off.
- Figures marked in red under the production column show the production figures that have been estimated based on the unit's share in overall production capacity when the total company production is known, or based on country's capacity utilization share (70 per cent) if company's total production is not known (eg: ESL Steel) or share of production apart from the 7 steel companies in India (eg: Other manufacturers).
- Total GHG emissions are a total of plant-wise GHG emissions along with the other manufacturer category

Source: Estimations and calculations by CSE, Joint Plant Committee, declarations sourced from company websites and sustainability reports, and Ministry of Steel

In terms of companies, Tata Steel (India) Ltd, SAIL and Jindal Steel Works are the largest individual contributors to GHG emissions from the sector (being the largest steel producers) in India. However, the small- and medium-scale steel manufacturing units using coal-based DRI remain the major contributors and also highest in terms of their specific emissions.

Table 9: Company-wise capacity, production, technology and estimated GHG emissions in 2020–21

S. no.	Company	Production capacity 2020–21 (million tonne)	Production 2020–21 (million tonne)	Iron-making technology	Steel-making technology	Average emission factor (assumed, as not declared by the company)	Emission factor declared by the company	GHG emissions (million tonne)
1.	Tata Steel (India) Ltd	19.4	16.9	Blast Furnace	Basic Oxygen Furnace		2.3	38.92
2.	Steel Authority of India Lts	19.6	15.05*	Blast Furnace	Basic Oxygen Furnace		2.54	38.23
3.	Rashtriya Ispat Nigam Lts	6.3	4.3	Blast Furnace	Basic Oxygen Furnace	2.5		10.75
4.	JSW Steel	18	15.08	Blast Furnace, Midrex and Corex technology	Conarc Technology, Basic Oxygen Furnace, Electric Arc Furnace and Energy Optimization Furnace		2.49	37.54
5.	ArcelorMittal Nipon Steel India	10	6.69	Blast Furnace, Midrex and Corex technology	Conarc Technology	1.92		12.86
6.	Jindal Steel and Power Ltd	9.6	6.859	Blast Furnace, coal gasification-based DRI and Coal based DRI technology	Basic Oxygen Furnace and Electric arc furnace	2.62		18
7.	ESL Steel Limited - Vedanta	1.5	1.05	Blast Furnace	Basic Oxygen Furnace	2.5		2.63
8.	Other manufacturers (mostly small/ medium-scale)	60.51	37.6	Assumed to be coal-based DRI	Assumed that all the rest of steel manufacturing is from coal-based DRI-EAF/IF	3		112.79
	Total	143.91	103.545					271.72** ~271

*SAIL crude steel production is a sum of production from 5 integrated steel plants of SAIL, excluding production data of Salem Steel Plant and Alloy Steel Plant as they are not integrated steel plants producing crude steel

** Total GHG emissions are a total of company-wise GHG emissions, including emissions from the other manufacturer category

Source: Estimations and calculations by CSE, Joint Plant Committee, declarations sourced from company websites and sustainability reports and Ministry of Steel

After looking at the company-wise GHG emissions, it is essential to understand the technology-wise share of GHG emissions in the year 2020. As per this analysis, BF-BOF and the coal-based DRI-EAF compete in terms of production share in steel manufacture in the country—both routes with 45 per cent of the total production.

Table 10: Technology-wise production, emission factors and GHG emissions in 2020-21

Technology	Production in 2020–21 (million tonne)*	Percentage share of total production	Average emission factor	GHG emission in 2020–21 (million tonne)
BF-BOF	46.6	45	2.5	116.49
Gas-based DRI-EAF	10.44	10	1.6	16.7
Coal based DRI-EAF/IF	46.51	45	3	139.51
Total	103.54			272.7

Source: Estimations and calculations by CSE, production sourced from Ministry of Steel

*The technology share for 2020–21 has been assumed the same as given for the year 2020 in the Annual Report 2020–21 by Ministry of Steel

But in terms of GHG emissions, the DRI-EAF route is more polluting. Its average emission factor is 3 tonne of CO_2e per tonne of steel and so it produces over half the emissions from the sector.

6
FUTURE EMISSIONS: 2030

Indian steel sector's emissions profile in 2030 will depend on factors like sectoral targets, fuel switch and technology upgradation. We have estimated emissions in four different scenarios by varying and changing these factors.

According to the 2019 Steel Scrap Recycling Policy, 35–40 per cent of the production capacity (of 300 million tonne per year) and production (of 255 million tonne per year) envisaged for 2030 will be based on the electric arc furnace and induction furnace method—this has been considered for all scenarios. Currently, the EAF/IF method is used to produce 55 per cent of the crude steel in the country and it is highly polluting because of the use of coal-based rotary kilns.

Firstly, we have estimated the **business-as-usual (BAU) scenario**. It takes the estimated production growth and technology share for 2030 into account but at current emission factors.

Secondly, we have estimated a scenario which assumes the ability of the steel industry to meet the targets set by the National Steel Policy of 2017 for emissions reduction. **This is the low-carbon growth pathway for 2030.**

This scenario also takes into consideration the current estimated production growth and technology share for 2030 as proposed in the National Steel Policy of 2017. Although within 35 per cent share of DRI-EAF/IF, the share of gas-based steel production has been assumed to increase to 15 per cent share of steel production.

Thirdly, a scenario has been estimated in which the voluntary carbon intensity targets of large steel companies are achieved, further improving the low-carbon growth pathway. **This is the improved low-carbon growth pathway for 2030.** The assumed increment in gas-based DRI-EAF steel production to 15 per cent is estimated in this scenario as well.

Fourthly, there is another scenario that demonstrates even more improvement in the sector. **This is the CSE recommended accelerated low-carbon growth pathway for the Indian steel sector for 2030** (see *Chapter 8*).

6.1 BUSINESS-AS-USUAL SCENARIO

In the BAU scenario, CO_2e emissions projections have been made based on the assumption that the pattern of production will not change and the production figures will be as projected in the National Steel Policy of 2017, i.e., 255 MT of crude steel production annually by 2030.

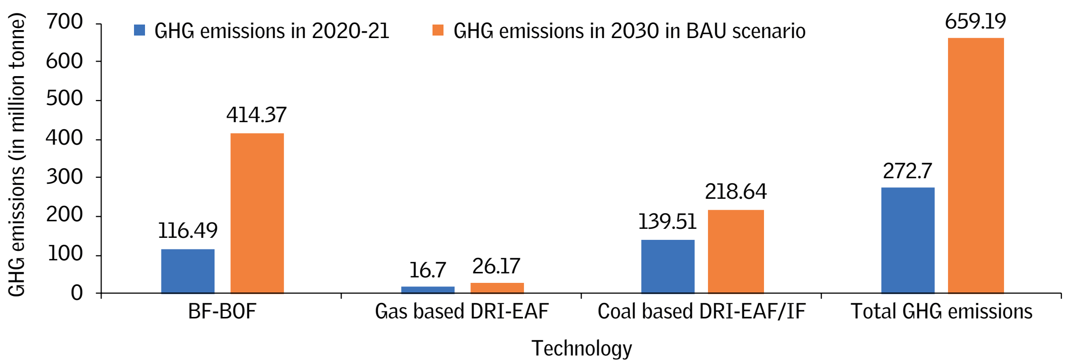
It is also assumed, based on the expansion plans of major steel companies, that the share of BF-BOF in total steel production will be at least 65 per cent (up from the current 45 per cent), while leaving the rest of the share to EAF and IF. The emission factors considered in this scenario would be the same as for 2020–21.

Table 11: GHG emissions in a business-as-usual scenario for 2030

Technology	Production in 2020–21 (million tonne)	GHG emissions in 2020–21 (million tonne)	Estimated production in 2030 (million tonne)	Emission factor considered for 2030 in a BAU scenario	GHG emissionsin 2030 in a BAU scenario (million tonne)
BF-BOF	46.60	116.49	165.75	2.5	414.37
Gas-based DRI-EAF	10.44	16.7	16.35	1.6	26.17
Coal-based DRI-EAF/IF	46.51	139.51	72.88	3	218.64
Total	103.55	272.7	255		659.19

Source: Centre for Science and Environment

Graph 6: GHG emissions in 2020 and 2030 in a business-as-usual scenario by technology



Source: Centre for Science and Environment

The BAU scenario shows almost 2.5 times increase in the overall GHG emissions from the sector compared to emissions in 2020–21. It also shows almost 3.5 times rise in GHG emissions from the BF-BOF route and around 1.6 times increase in GHG emissions from the coal-based DRI-EAF route. This clearly shows that decarbonization of the BF-BOF route is the priority followed by the decarbonization of coal-based DRI-EAF route.

6.2 LOW-CARBON GROWTH PATHWAY

This scenario presents a picture of GHG emissions in 2030 if the steel sector succeeds in achieving the emissions targets set by the government for the different production routes in the National Steel Policy of 2017. The policy aims to reduce greenhouse gas emissions to about 2.2–2.4 tonne of CO_2 per tonne of crude steel produced through the BF-BOF route and 2.6–2.7 tonne of CO_2 per tonne of crude steel produced through the DRI-EAF route by 2030.

Since the National Steel Policy does not mention separate targets for coal-based DRI-EAF/IF production route and the gas-based DRI-EAF route, to keep the estimate more realistic we have assumed in this scenario that the share of gas-based DRI steel production would rise to 15 per cent of the total production by 2030. The emission factor in this case has been taken as 1.6 tonne of emissions per tonne of steel production.

The National Steel Policy states that for the BF-BOF route, emissions will be 2.2–2.4 tonne per tonne of steel production, marginally lower than the current BF-BOF route emissions. The estimated production figures and the share of technology (65 per cent BF-BOF and 35 per cent DRI-EAF/IF) is considered as provided in the National Steel Policy of 2017 (see *Table 12*).

In the low-carbon growth pathway (based on the National Steel Policy of 2017), the reduction will be equal to 82 million tonne over the BAU scenario—a decrease of 12.5 per cent. This is not very high and this is because of the following reasons:

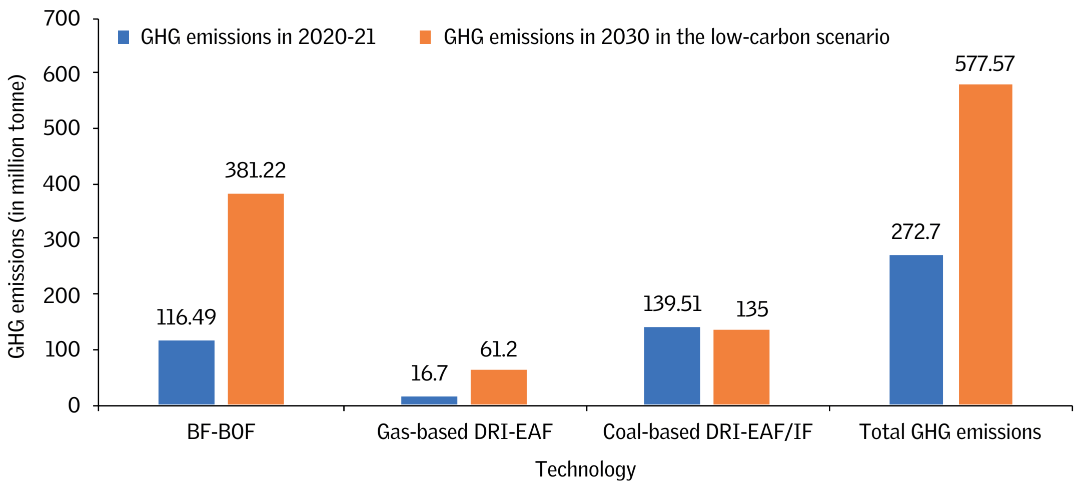
FUTURE EMISSIONS: 2030

Table 12: GHG emissions in a low-carbon growth pathway for 2030 (as per National Steel Policy 2017)

Technology	Production in 2020–21 (million tonne)	GHG emissions in 2020–21 (million tonne)	Production in 2030 (million tonne)	Emission factor considered for 2030 in the low-carbon scenario	GHG emissions in 2030 in the low carbon scenario (million tonne)
BF-BOF	46.60	116.49	165.75	2.3	381.22
Gas-based DRI-EAF	10.44	16.7	38.25	1.6	61.2
Coal-based DRI-EAF/IF	46.51	139.51	51	2.65	135
Total	103.55	272.7	255		577.57

Source: Centre for Science and Environment

Graph 7: GHG emissions in 2020 and on a low-carbon growth pathway for 2030 (as per National Steel Policy 2030)



Source: Centre for Science and Environment

a. Currently, BF-BOF technology contributes roughly 45 per cent to the steel mix in the country. It is assumed that this will go up to 65 per cent by 2030. In this way, GHG emissions from the BF-BOF route will increase by 3.2 times as compared to 2020–21.

b. The emission factors considered for DRI-EAF are higher than global averages and this is partly because the sector continues to be based on coal and there is no clear target for increased usage of recycled material in this scenario. Globally, steel manufacture from DRI-EAF is preferred for emissions reduction, as it can be based on gas and it can use higher proportion of recycled material.

6.3 IMPROVED LOW-CARBON GROWTH PATHWAY FOR 2030

Indian steel industry has set voluntary targets for emissions reduction (see *Table 13*).

The improved low-carbon pathway for 2030 presents a scenario of GHG emissions if voluntary targets of large steel companies are achieved by that year.

In this scenario, it has also been assumed that the share of gas-based DRI would be up by 15 per cent by 2030.

Company-wise production for calculations is based on their future expansion plans but under the overall cap of 255 MT national production.

The emission factors considered for the BF-BOF route are the ones declared as voluntary targets by large companies (see *Table 13*). The emission factors for the estimated gas-based DRI production have been taken from CSE's estimated emission factors (see *Table 7*).

In this improved low-carbon pathway (based on voluntary targets for large steel companies) the reduction will equal to 148 million tonne over the BAU scenario—22.5 per cent reduction by 2030.

The estimates in this scenario show a further decrease in GHG emissions compared to the reduction achieved under the second scenario which was based on National Steel Policy targets. This improvement is a result of higher targets set by Tata Steel (India) Ltd and JSW Steel, which are two of the largest steel producers in the country.

It is significant to mention here that the production from these large steel companies is estimated to grow from around 66 million tonne to around 200 million tonne by 2030.

Table 13: Current emissions and decarbonization targets set by India's major steel producers

S. no.	Steel producer	Current emissions intensity	Target	Target considered for emissions calculation (tonne of CO_2e or CO_2 emissions per tonne of crude steel)
1.	Tata Steel (India) Ltd	- Current emissions intensity is 2.31 tCO_2e per tonne of crude steel produced. Tata Steel Jamshedpur has an emissions intensity of 2.29 tCO_2e per tonne of crude steel produced and Tata Steel Kalinganagar has an emissions intensity of 2.44 tCO_2e per tonne of crude steel produced[16,17]	- Aims to achieve emissions intensity < 2 tCO_2e per tonne of crude steel produced by 2025 and < 1.8 tCO_2e per tonne of crude steel produced by 2030[18,19]	1.79
2.	JSW Steel	- Current GHG emissions intensity is 2.49 tCO_2e per tonne of crude steel produced[20]	- Committed to reducing specific GHG emissions from the three integrated steel plants to < 1.95 tCO_2e per tonne of crude steel produced by 2030[21] - Target to achieve carbon neutrality at JSW Steel Coated Products Ltd by 2030[22]	1.94
3.	Arcelor Mittal Nippon Steel (AM/NS) India Ltd	- Not declared - 1.82 assumed as 30 per cent reduction from 2018 level (which has been taken as 2.6, as the official emission factor for 2015 was 2.65)	- Group targets to bring 30 per cent reduction in its CO_2 emissions over the 2018 level by 2030[23] - Planning to be net zero by 2050[24] - Planning to build world's first full-scale zero-carbon emissions steel plant in Sestao, Spain by 2025	1.82
4.	SAIL	- 2.54 tCO_2e emissions per tonne of crude steel produced as of 2019–2021[25]	- No target specified, assuming they are following the target set in the National Steel Policy, 2017, i.e., 2.2–2.4 tCO_2 emissions per tonne of crude steel produced by 2030 through the BF-BOF route	2.3
5.	JSPL	- Across all operations (which include steel production and power generation), they generated 32.3 $MtCO_2$ in 2019–20	- No specific CO_2 emissions reduction target found on their website and in their annual reports - Hence, 2.3 tCO_2e emissions per tonne of crude steel considered (country target)	2.3
6.	RINL	- Not declared	- No target specified, assuming they are following the target set in the National Steel Policy, 2017, i.e., 2.2–2.4 tCO_2 emissions per tonne of crude steel produced by 2030 through the BF-BOF route - Hence, 2.3 tCO_2e emissions per tonne of crude steel considered (country target)	2.3

S. no.	Steel producer	Current emissions intensity	Target	Target considered for emissions calculation (tonne of CO_2e or CO_2 emissions per tonne of crude steel)
7.	ESL Steel	- Not declared	- No exact target figure declared. Only mention achieving substantial decarbonization by 2050 - Hence, 2.3 tCO_2e emissions per tonne of crude steel considered (country target)	2.3

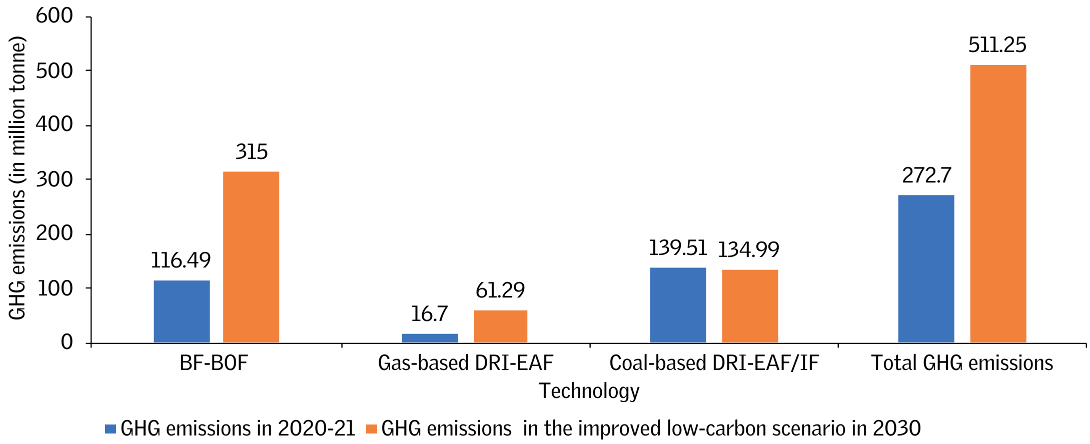
Source: Annual and Sustainability Reports of Steel Companies

Table 14: GHG emissions in an improved low-carbon growth pathway for 2030 (based on voluntary targets by large steel companies)

Technology	Production in 2020–21 (million tonne)	GHG emissions in 2020–21 (million tonne)	Production in 2030 (million tonne)	Emission factor for 2030 in the improved low-carbon scenario	GHG emissions in 2030 in the improved low-carbon scenario (million tonne)
BF-BOF	46.60	116.49	165.75	Company-wise emissions targets (see *Table 13*)	315
Gas-based DRI-EAF	10.44	16.7	38.30	1.6	61.29
Coal-based DRI-EAF	46.51	139.51	50.94	2.65	135
Total	103.54	272.7	255		511.25

Source: Centre for Science and Environment

Graph 8: GHG emissions in 2020–21 and in an improved low-carbon growth pathway for 2030 by technology, (based on voluntary targets by large steel companies)



Source: Centre for Science and Environment

7
PATHWAYS FOR CARBON INTENSITY REDUCTION IN THE STEEL SECTOR

The iron and steel sector needs a clear trajectory for emission reduction, beyond even the best case scenario—the improved low-carbon scenario. To understand the possibilities, we have mapped out the technology options for reduction of emissions in this sector.

7.1 SECTOR-WIDE IMPROVEMENTS

Certain measures or parts of them can be applicable to all production technology routes throughout the steel sector to reduce emissions. Some of these pathways have been discussed in this section.

7.1.1 TECHNOLOGIES FOR EMISSIONS AND RESOURCE-INTENSITY REDUCTION

A number of technologies can help reduce carbon emissions from steel plants and the Ministry of Steel has also compiled a list of such technologies.

This list is as follows:

- Coke dry quenching (CDQ): Power generation from waste heat from CDQ
- Sinter plant heat recovery (power generation from sinter cooler waste heat)
- Bell-less top equipment (BLT) in blast furnace
- Top pressure recovery turbine (TRT) in blast furnace
- Pulverized coal injection (PCI) system in blast furnace
- Hot stove waste heat recovery in blast furnace
- Dry type gas cleaning plant (GCP) in blast furnace
- Cast house or stock-house de-dusting system
- Converter gas recovery in BOF
- Energy monitoring and management system
- Secondary fume extraction system in steel melting shop
- Regenerative burners in re-heating furnaces of rolling mills
- Hot charging process of continuously cast products at higher temperature directly to rolling mills
- Direct rolling process eliminating the need for re-heating furnaces

- Energy efficient technology for hot strip mill: Flexible thin slab casting and rolling
- Near net shape casting: Bloom-cum-beam blank caster, bloom-cum-round caster, etc.
- Adoption of variable voltage variable frequency (VVVF) drives for high capacity electric motors[26]

Ministry of Steel claims that the reduction in CO_2e emissions from the iron and steel sector between 2014 and 2016 is a result of implementation of these technologies on ground.

The Ministry should share a list of plants with a checklist of technologies implemented at each of them in the public domain so that the claims can be verified independently.

7.1.2 INCREASING AVAILABILITY OF CLEANER FUEL FOR COMBUSTION

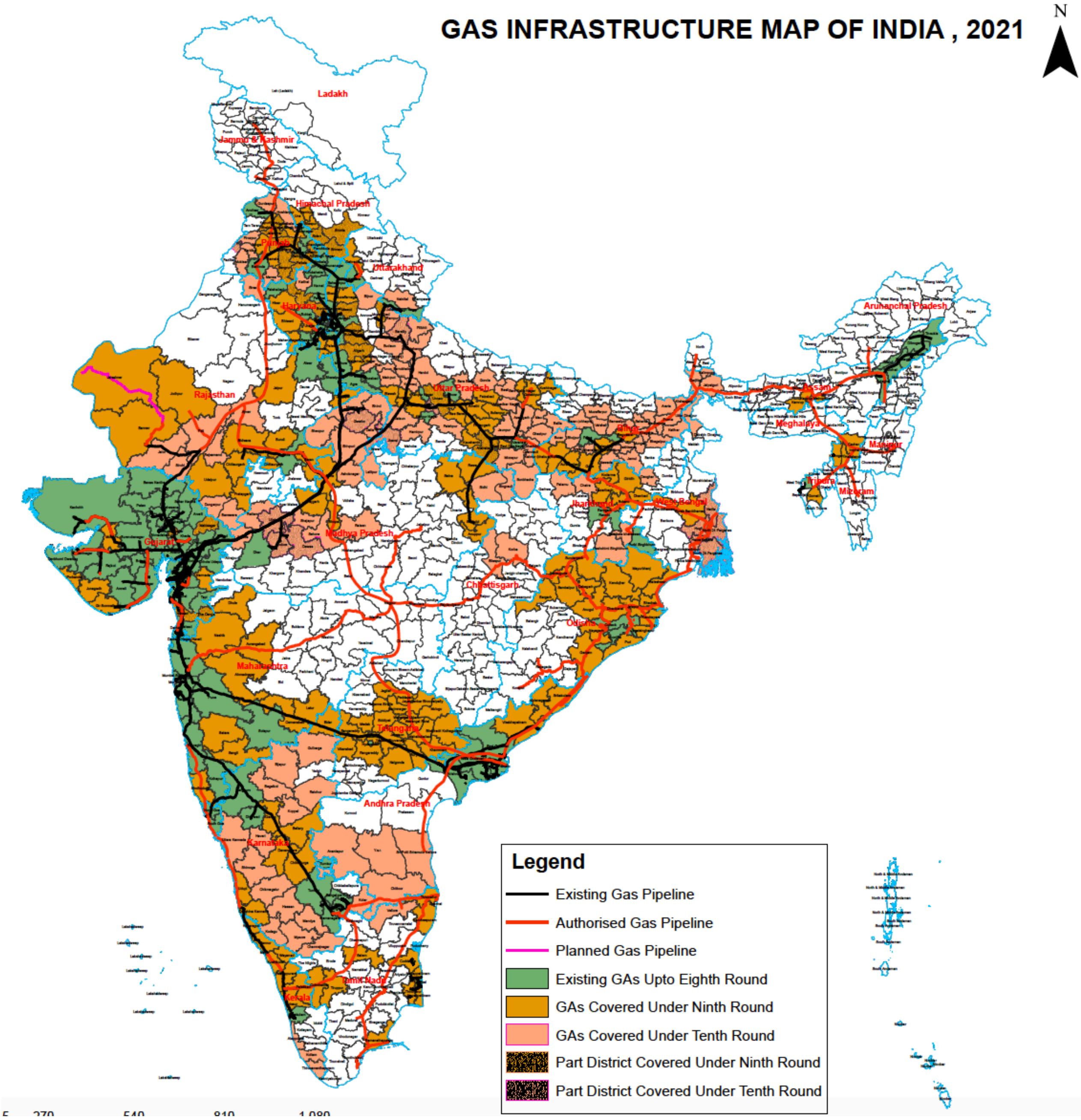
Cleaner fuels like natural gas are still unavailable in many regions of the country. If we look at the gas infrastructure map of India, we can see that large parts of the eastern states, which are a natural source of iron ore and hub of steel production, lack access to natural gas (this can be seen through the smaller number of green coloured districts in eastern India which shows the districts with existing gas infrastructure) (see *Map 2*).

Because of their high prices, cleaner fuels like hydrogen are still far from becoming popular on the ground. The issue with natural gas is not just lack of availability but the continuously increasing price compared to dirty fuels like coal.

7.1.3 INCREASING AVAILABILITY AND SETTING TARGETS FOR USE OF STEEL SCRAP

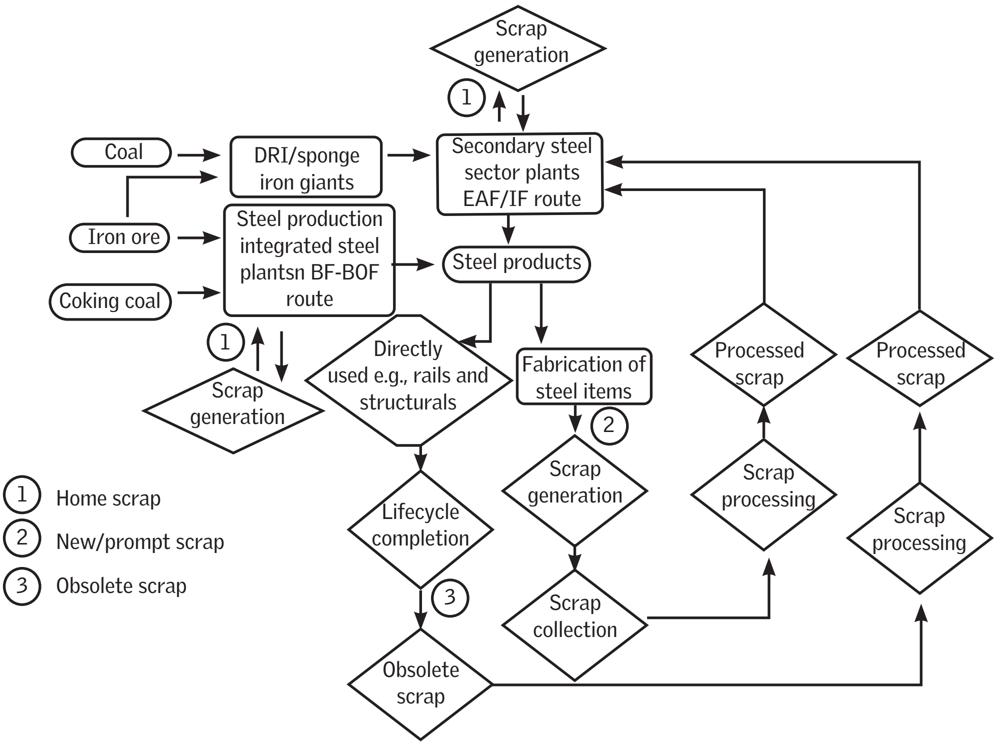
The use of every tonne of steel scrap to produce steel saves 1.1 tonne of iron ore, 630 kg of coking coal and 55 kg of limestone. The specific energy consumption is also reduced by 14 MJ/kg in the BF-BOF route and 11 MJ/kg in the EAF and IF route, i.e., a saving of 16–17 per cent energy. Use of steel scrap in steel production can

Map 2: Gas infrastructure in India in 2021



Source: Petroleum and Natural Gas Regulatory Board, 2021

Figure 7: The cycle of steel recycling



Source: Steel Scrap Recycling Policy, 2019, page 9, Ministry of Steel

reduce water consumption by 40 per cent and GHG emissions by 58 per cent.

Steel scrap is the major raw material for EAF and IF units and it can also be used in basic oxygen furnaces (in up to 30 per cent proportion) to improve efficiency, minimize cost of production and for other processing needs. The cycle of usage and generation of steel scrap has been shown in Figure 7.

According to the Steel Scrap Recycling Policy, 2019 issued by the Ministry of Steel, India generates 25 million tonne of steel scrap and imports around 7 million tonne of scrap every year and through this steel scrap recycling policy, the country wants to close this gap. The World Steel Association estimates that the global ferrous availability stood at 750 million tonne in 2017 and the availability is expected to reach 1 billion tonne in 2030 and 1.3 billion tonne in 2050, growing by more than 500 million tonne within the next 30 years.[27] The Steel Scrap Policy of 2019 envisages a share of 35–40 per cent scrap use in steel production by 2030. It further mentions that achieving this share shall increase the requirement of steel scrap from around the current 30 million tonne to more than 70 million tonne by 2030. Steel Recycling Business, Tata Steel says that the demand for scrap in India is around 30–32 million tonne (as of 2020) and it is expected to grow at 7 per cent per year to reach 40 million tonne by 2025 and around 70 million tonne by 2030, which matches the estimates in the Steel Scrap Policy, 2019.[28] However, there is scope of generating as well as using much more scrap for steel production in the country. **Therefore, the steel scrap policy needs to ensure that it sets a high scrap generation target that enables the country to meet the estimated demand and beyond, and along with this it should also set targets for steel companies for utilization of scrap in the production of steel.**

RISING POTENTIAL OF SCRAP FROM SHIP RECYCLING INDUSTRY IN INDIA

India's ship recycling industry is growing by the day. It is already catering to 1–2 per cent of the current domestic steel demand of the country and around 28 per cent of the country's total exported ferrous scrap. The Finance Minister, in her 2021–22 budget speech, mentioned that the potential of this sector will be doubled by 2024 and attract more end-of-life vessels from Europe and Japan.

India also has the world's largest ship recycling operation—the Alang-Sosiya ship recycling yards—situated on the west coast of Gujarat. Alang has around 120 ship recycling yards dismantling ships to extract various types of scrap for recycling and reuse. These yards are responsible for 47 per cent of all ships being recycled globally which makes India one of the biggest hubs of ship recycling. The facility started in 1982 and has increased its recycling capacity by more than 100 times since then. More than 350 ships are currently being recycled every year in Alang-Sosiya.

Seeing the past and future potential of growth in this industry, ship recycling could be a major source of scrap generation and availability for the steel sector of the country. The need of the hour is a well-defined policy or regulation for the industry to achieve this goal.[29]

The establishment of scrap processing centres and shredders in the right number as proposed in the Steel Scrap Policy, 2019, can mark an increase in the quantity of high-grade steel scrap which can act as a suitable raw material for not only the EAF-IF route but also help increase usage of scrap in the BF-BOF route. Availability of high-grade steel scrap will automatically lead to production of high-grade steel through the EAF and IF routes.[30]

7.1.4 CARBON CAPTURE, UTILIZATION AND STORAGE

Implementation of carbon capture, utilization and storage (CCUS) in steel plants of India is largely dependent on how the high costs involved will be met. Big players of the sector like Tata Steel (India) Ltd, JSW Steel and SAIL have already started (or are about to start) carbon capture and utilization initiatives at a small-scale. JSW Steel is already doing CCU at its DRI plant in Sarav, Maharashtra and SAIL is planning to build a carbon

SOME INITIATIVES OF CARBON CAPTURE AND UTILIZATION BY STEEL PLANTS IN INDIA

1. **JSW Steel carbon capture and utilization at the DRI Plant at Salav, Maharashtra**: In the direct reduced iron reduction process, CO and H_2 are passed through iron ore pellets and lump-ore to facilitate the process of reduction. Waste gas that is rich in carbon is recovered and sent to absorbers that treat it counter-current with Giammarco Vetro (G.V.) coke solution forming a rich solution. G.V. and CO_2 get separated due to treatment of the rich solution in regenerators. CO_2 recovery and production capacity of this unit is 100 TPD. CO_2 is then captured, stored and transported for usage in food and beverage industry.[31]

The DRI plant with carbon capture at Salav, Maharashtra

Source: Jindal Steelworks [32]

2. **SAIL is planning to install India's first gas-to-ethanol plant at Chandrapur:** With the help of the Central government, SAIL is planning to set up India's first gas-to-ethanol plant at its ferro-alloy unit in Chandrapur. This will be the fourth plant of its kind in the world. Currently, this technology is in use at two plants in China and at an Arcellor Mittal plant in Belgium. The technology will help reduce dependence on imported crude oil on one hand and reduce carbon emissions on the other hand. Steel Research and Technology Mission of India is helping SAIL set up the plant. The project cost is estimated to be Rs 400 crore, of which 20 per cent funding will be provided by the Central government under the National Policy on Bio-fuels, 2018.

   The plant will capture hot gases like CO_2, CO and H_2 that are emitted from the ferro-alloy plant's submerged arc furnace and convert them into ethanol using fermentation technology. There is scope of producing 50,000 litres of ethanol per day from about 10,000 normal metre cube (NMC) per hour gas produced at Chandrapur.[33]

3. **Carbon capture and utilization (CCU) unit at Tata Steel, Jamshedpur:** Tata Steel commissioned a 5 tonne per day carbon capture plant at its Jamshedpur unit in September 2021. Tata Steel claims it to be the country's first carbon capture technology plant that captures CO_2 from blast furnace gas. It is a step towards promoting circular carbon economy. The CCU facility uses amine-based technology and makes captured carbon available for on-site use. Depleted CO_2 gas is sent back to the gas network with increased calorific value. The captured CO_2 is used for water treatment at a steel-making unit. Carbon Clean (a manufacturer of low-cost CO_2 capture technologies) has provided technological support for the execution of this project.

A CCU unit at Tata Steel's Jamshedpur plant

Source: Tata Steel[34]

capture unit that will produce ethanol at its Chandrapur plant. They are planning the same at two other plants as well. Tata Steel (India) Ltd has established pilot projects for carbon capture at its Jamshedpur plant and also at one of its ferro-chrome plant[35] (see *Box: Some initiatives of carbon capture and utilization by steel plants in India*).

Carbon storage capacity is one of the key challenges in this strategy. Tata Steel Europe has started a permit process at its Ijmuiden plant in the Netherlands for installation of carbon capture infrastructure which is linked with a pipeline to transport CO_2 to be stored under the North Sea in empty gas fields, 50 kilometres from the coast. By capturing and storing CO_2, the Tata Plant in Ijmuiden, Netherlands plans to reduce its emissions by 40 per cent by 2030.[36]

Such kind of storage solutions need to be explored in India as well, though it seems challenging due to the distance between the location of a majority of steel plants in India (mostly in Central and Eastern parts of India) and the probable storage options, which are oilfields (mostly in the western part of India).

7.1.5 HYDROGEN TO REPLACE COAL AND GAS AS A REDUCING AGENT

With the announcement of the National Hydrogen Mission by the Prime Minister, with the express aim of making the country a hub of production and export of green hydrogen, there is renewed hope. It is expected that after so much talk about hydrogen usage over the years, its use will soon be a reality in many sectors, including the iron and steel sector.

It is important to understand that hydrogen can be used in two ways in the steel-making process.

Firstly, it can be used as an auxiliary reducing agent in the BF-BOF route (H_2-BF). Currently, only pulverized coal, natural gas and oil are used as auxiliary reducing agents and they produce CO_2 as the byproduct, whereas hydrogen will produce water as a byproduct, reducing CO_2 emissions. Due to certain technical reasons, it may be feasible to use only hydrogen in blast furnaces; therefore it is looked at more as a transition towards H_2-DRI.

Secondly, it can be used as the sole reducing agent in the direct reduction of iron processes (H_2-DRI).

In Netherlands, Tata Steel is already taking steps to develop a hydrogen plant at the Ijmuiden site which will produce 100,000 tonne of hydrogen every year.[37] Arcelor Mittal is also developing a new innovation project in Hamburg, Germany which aims to use DRI made with 100 per cent hydrogen as a reducing agent with an annual production of 100,000 tonne of steel.[38]

Table 15: Steel plants planning to use H_2-BF technology

Steel company	Plant location	Electrolyzer	Renewable
Arcelor Mittal	Bremen, Germany	Yes	Unclear
Arcelor Mittal	Dunkirk, France	No	Not known
Arcelor Mittal	Asturias, Spain	No	Not known
Arcelor Mittal	Fos-Sur-Mer, France	Yes	Yes
Voestalpine	Linz, Austria	Yes	Yes
Thyssenkrup	Duisburg, Germany	No	Not known
Tata	Ijmuiden, Netherlands	Yes	Yes
Dillinger/ Saarstahl	Dillingen, Germany	No	Not known

Source: Bellona.org[39]

THE COST DYNAMICS OF STEEL PRODUCTION WITH HYDROGEN

Currently, the cost of green hydrogen is around US $3.5–5 per kg. Green hydrogen-based DRI process would approximately increase the cost of steel production by US $150–250 compared to the cost of gas-based DRI. To become cost-competitive with gas-based DRI, the price of H_2 needs to drop to US $1 per kg in Europe and US $0.7 per kg in the US.

The highest contributor to green hydrogen cost is the cost of renewable energy. If the cost of renewable energy continues to drop, it is estimated that cost of hydrogen would drop to US $1.5 per kg by 2030. Even then, hydrogen initiatives would require financial support as they will still be higher in cost compared to other carbon-neutral steel making technologies. Although at this cost it will start to be competitive with fossil fuel in steel making.[40]

Another aspect that needs to be understood is that the process of production of hydrogen to be used will define the amount of reduction one can achieve by adopting hydrogen for steel production. If hydrogen is produced through electrolysis using renewable energy, **it can achieve emissions reduction of around 21 per cent on the BF-BOF route.**[41]

The H_2-DRI route, if using green hydrogen, can achieve up to 95 per cent reduction in CO_2 emissions. This is one of the cleanest steel-making routes.[42]

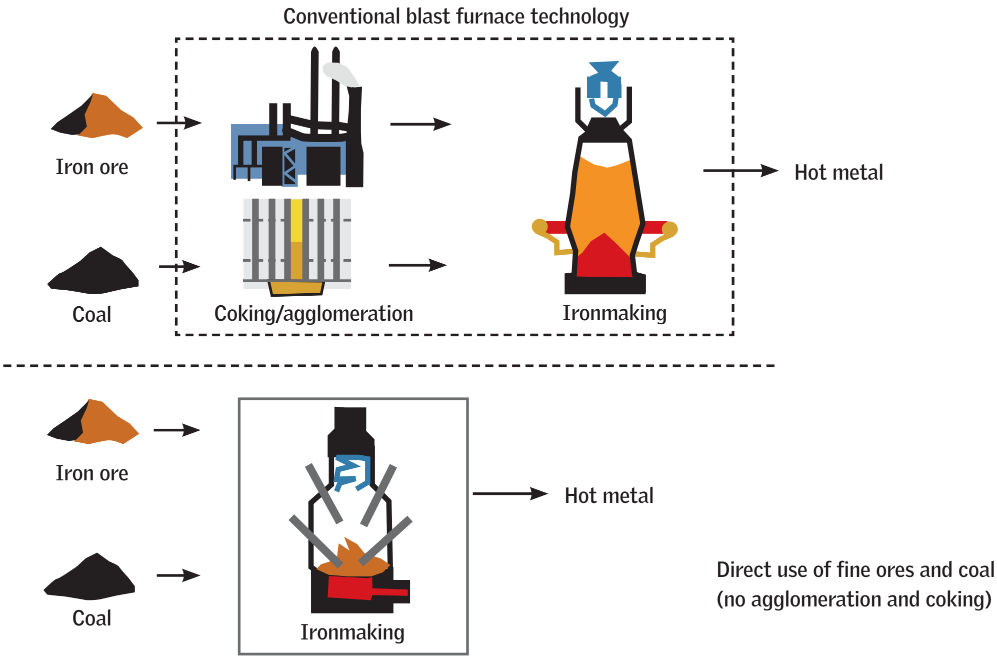
7.1.6 HISARNA TECHNOLOGY

In 2004, a group of European steel companies, with help from the European Union, started an ultra-low CO_2 steel-making (UCLOS) project. Their objective was to come up with technologies that will reduce CO_2 emissions from steel-making by 50 per cent by 2050. HIsarna is one of the technologies developed by them. Its test installation was done at the Tata Steel site in Netherlands in 2010. By 2018, the installation had become a part of the production chain and the pilot campaign was successfully concluded in 2019. **This technology reduces CO_2 emissions by at least 20 per cent**. As the Tata Netherlands plant is also implementing CCS, when combined with HIsarna, it could reduce CO_2 emissions by at least 80 per cent.[43]

HIsarna uses powdered iron ore and powdered coal directly in the steel-making process, thereby eliminating the processes of coking and agglomeration (sinter and pellet making, etc.) which are used to charge the blast furnace in the conventional process. This cuts down the need for big plants, raw material processing cost and the CO_2 emissions from processes like coking, sinter and pellet making (see *Figure 8*). This technology is also suitable for low-grade raw materials.

HIsarna also allows the use of steel scrap and biomass in steel production. With the use of biomass and steel scrap together in the best combination (i.e., 45 per cent biomass and 53 per cent

Figure 8: Comparison between conventional blast furnace and HIsarna showing how HIsarna eliminates coking and agglomeration



Source: Presentation by Johan van Boggelen, Operations and Technology Manager at HIsarna Pilot Plant, Netherland, 16 September 2021

steel scrap), up to 50 per cent CO_2 emissions reduction can be achieved even without CCS. Through the use of carbon capture in this combination, one could even achieve negative emissions.

With the addition of a carbon capture unit to a HIsarna plant, CO_2 goes directly into the liquefaction plant for storage and usage, so basically, it is a plant without any stack. Therefore, not only has the plant no CO_2 emissions but it also emits no SO_X, NO_X or PM. This technology also facilitates zinc recovery from steel scrap as galvanized steel is used in a lot of steel products like cars. Zinc scrap is usually downcycled in electric arc furnaces. EAF dust can contain about 20–35 per cent zinc, which is then upcycled to extract zinc. Whereas if the content of zinc is less than 20 per cent, the dust is land-filled.

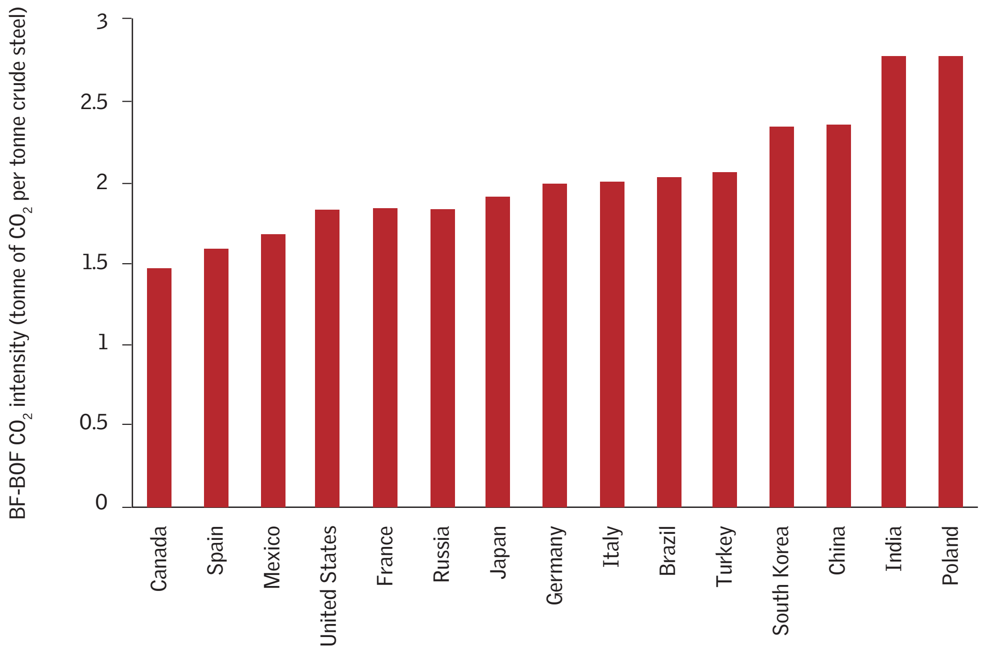
Regarding costing, this technology has much lower capital expenditure as the land area required is less, plus coke and sinter plants are not required. Along with this, it is energy efficient, it can work on low-cost and low-grade raw materials, and it can use waste oxides and BOF slag as well. Hence, it has low capital expenditure (CAPEX) along with low operating expenditure (OPEX).

Therefore, HIsarna is a promising technology that can be adopted by upcoming steel plants in India as it addresses the issue of GHG emissions, air pollution and material circularity while being a cost-feasible option. The technology has been in the news for about a decade but its actual adoption on the ground remains to be seen.

7.2 LOW CARBON PATHWAY OPTIONS FOR BLAST FURNACE–BASIC OXYGEN FURNACE ROUTES

As per the Ministry of Steel,[44] India has already achieved 2.5 tonne of CO_2 emissions per tonne of crude steel produced through the BF-BOF route in 2020.

Graph 9: Country-wise comparison of average CO_2 emissions from the BF-BOF route (2020)



Source: Global Efficiency Intel[45]

Moreover, private steel producers in India, like Tata Steel (India) Ltd and JSW Steel, have set out to achieve CO_2e emissions targets of 2 tonne or less per tonne of crude steel produced by 2030.

Average global CO_2 emissions from the steel sector were at 1.89 tonne per tonne of crude steel produced in 2020 (as per the World Steel Association).[46] This emission intensity is expected to decrease further by 2030.

As of 2020, some countries like Canada and Spain had already achieved an average emission factor of around 1.5 tonne of CO_2 per tonne of steel produced through the BF-BOF route.
Countries like Mexico, United States, France and Russia have a country average well below 2 tonne of CO_2 emissions per tonne of steel produced (see *Graph 9*).

This sends a clear message of reconsideration to the Government of India that has planned its country average emission factor though the BF-BOF route as 2.3 tonne CO_2e emissions per tonne of crude steel and also for the top Indian steel companies that are targeting an emission factor of around 2 tonne CO_2e emissions per tonne of crude steel. The whole country average in so many countries in less than these emission targets. India can, and must, do more.

- **Action 1: Promoting use of alternative fuels and other reducing agents in blast furnaces:** The blast furnace is one of the most emissions-intensive processes in steel-making and the reducing agent it uses is coke, of which India has low reserves. Therefore, the country depends on expensive imports. To reduce import dependency, energy consumption and GHG emissions, it is essential that steel plants increase use of alternative reducing agents like biomass, biochar, natural gas, hydrogen, waste plastic and fuel oil. The use of these alternative reducing agents depends on their availability; therefore, the appropriate reducing agent may differ from region to region.[47]

7.3 LOW CARBON PATHWAY OPTIONS FOR DRI–EAF AND INDUCTION FURNACE

The National Steel Policy, 2017 has fixed the emissions reduction target for the DRI-EAF route at 2.6–2.7 tonne of CO_2 per tonne of steel. Small-scale coal-based DRI production in India makes this one of the most polluting routes, with emission factors ranging between 2.8–3.1 tonne of CO_2 per tonne of steel produced.

In many Western and Middle Eastern countries, DRI-EAF is a popular route for steel making, but through gas-based DRI, as gas is easily available in those countries. Large future expansions are being planned through this route in these countries. Moreover, scrap is easily available in these countries, which reduces the dependence of electric arc furnaces on DRI.

Globally, CO_2 emissions from coal-based DRI-EAF are around 1.9 tonne per tonne of steel produced (though the coal-based route is prominent only in India), whereas CO_2 emissions for gas-based DRI-EAF are 1.3 tonne per tonne of steel produced.[48] This clearly stands much below the target set by the Government of India in the National Steel Policy in 2017.

7.3.1 OPTIONS FOR DRI-EAF

The problem with the DRI industry in India is that around 82 per cent of DRI is produced in coal-based rotary kilns that have high levels of emissions. Usually, these coal-based rotary kilns are small-scale (with around 200 to 500 tonne per day production) compared to gas-based DRI production plants (with a capacity of around 8,000 tonne per day or more).

Gas-based DRI plants use vertical shaft technology in steel making. This is different from small-scale DRI plants that use rotary kiln technology. This difference in scale, capacity and technology makes it difficult to push coal-based rotaries to convert to gas-based DRI units. It may not be economically feasible to convert the whole plant into a much larger facility as that would require large investments.

Therefore, some steps that can be taken for carbon reduction in coal-based DRI-EAF plants of India are:

- **Action 1: Use of natural-gas or coal-bed methane injections in coal-based DRI plants**: One step could be to introduce partial or full natural-gas injections in these coal-based rotary kilns. Coal-bed methane (CBM) fields have been discovered in eastern India in the recent past. This region is also a hub of iron ore and steel manufacturing; therefore **CBM could also be an alternative to natural gas in the region** as its price would be lesser than that of natural gas. Model rotary kilns should be set up to experiment with natural gas and CBM as fuels. The ultimate goal would be to shift coal-based rotary kilns completely to gas or other alternate cleaner fuels using appropriate and affordable technological interventions.

- **Action 2: Making waste heat recovery boilers and systems mandatory in coal-based DRI plants:** Rotary kilns used in coal-based DRI plants often use non-coking coal due to the low investment needed. The energy balance of rotary kilns shows an energy efficiency of around 37 to 55 per cent.

  A major factor behind this low energy efficiency is the non-utilization of waste heat contained in outgoing gases.

  In the usual process, these high temperature gases need to be cooled down to be sent to electrostatic precipitators and further out through stacks at a much lower temperature. Instead of cooling these gases, if their heat can be used by waste heat boilers in generating steam, it could help in power generation, the plant could become more energy efficient and also accrue the co-benefit of meeting internal electricity needs with waste heat or sell the electricity for additional revenue.[49]

  Many coal-based DRI plants in India have already installed waste heat recovery systems. Others need to follow suit.

Such systems should be made mandatory for all plants with immediate effect.

- **Action 3: Increasing the share of scrap-based EAF and gas-based DRI-EAF steel in overall steel production in India:** A major strategy should be to increase the share of scrap-based EAF and gas-based DRI-EAF steel production in India. Natural gas-based DRI-EAF process reduces emissions by 42 per cent compared to BF-BOF,[50] and 100 per cent scrap-based EAF production has the potential to bring down emissions by more than one-fourth compared to the BF-BOF route.

  If the electricity source turns renewable, process emissions might come down to almost nil. These two paths of steel production are the cleanest ones currently available. Hindrances that are preventing their wider adoption should be removed on a priority basis.

7.3.2 OPTIONS FOR INDUCTION FURNACES

Induction furnaces have a 30 per cent share in India's steel production (as of 2020–21). One drawback of induction furnace technology is that it lacks refining capacity, which means that raw materials need to be of good quality and without impurities or else it may lead to production of lower quality steel. Currently, scrap is not easily available in India as per demand. The quality of scrap available is also not good. Therefore, induction furnaces often end up producing low-quality steel.

With the growing demand for steel in India, various steel consuming sectors are setting high standards for the quality of steel they use. As of June 2019, the Ministry of Steel had mandated compulsory Bureau of Indian Standards (BIS) certificates for 53 of the 140 categories of steel products and has asked secondary steel producers to voluntarily take BIS certificates for the rest of the categories. The challenge for induction furnace producers is to be able to meet these high-quality standards.

CHINA'S CRACKDOWN ON INDUCTION FURNACE STEEL

China had designated the steel industry as a driver of its economy way back in 2005. It would meet the government's plan for modernization of infrastructure, manufacturing and construction. By 2006, the country became the world's largest steel exporter, rising from being the fifth-largest in 2005. Gradually, it became the largest producer of steel in the world, which it remains till today. The Chinese government gave huge subsidies to the steel sector to increase production, which enabled Chinese producers to sell their steel at cheaper rates than other countries. A majority of these subsidies were on coal. However, due to rampant production, the quality of the steel went down.

This overproduction turned to be problematic in 2014. The domestic demand in China went down by 3.4 per cent as the country's construction boom came to an end, which forced steel producers to sell their surplus steel to foreign buyers at throwaway prices. This led to a sharp decline in steel prices globally. In order to protect domestic steel producers from this catastrophic phenomenon, other countries took around 400 trade actions, a majority of them focusing on Chinese steel. These actions were mostly taken as a safeguard against the entry of sub-standard steel coming from China. For example, the US imposed countervailing duties as high as 236 per cent on steel from China. The problem of excess capacity was highlighted across the world.

Due to mounting international pressure, China decided to cut down its steel production by 150 million tonne by 2020. The idea was to shut down outdated and excess capacity. As a result, China started coming down heavily on induction furnace operators across the country as inspections by various provincial governments led to the finding that induction furnaces were the primary producers of polluting sub-standard steel. In January 2017, the Chinese government set a deadline of 30 June 2017 to eliminate induction furnaces entirely from China. The country's Ministry of Industry prohibited sale of steel scrap to induction furnace operators, thus starving them of their main raw material. China, way ahead of its target, was successful in cutting down its steel capacity by 155 million tonne between 2016 and 2018, out of which 140 million tonne was low-grade steel capacity from induction furnaces.[51] A lot of the induction furnace plants eliminated from China have found their way into Southeast Asian countries like Indonesia and Philippines. China continues to cut down its steel capacity, now keeping in mind the carbon neutrality target it has committed to by 2060. It is further promoting scrap-based electric arc furnaces (EAF) as they are less polluting compared to traditional blast furnaces and use steel scrap as raw material instead of iron ore. Units with EAF also produce better quality steel than induction furnaces.

Therefore, to be able to maintain the quality of steel, induction furnaces in India should be eliminated (see *Box: China's crackdown on induction furnace steel*). Or, at the very least, they should be required to install refining technologies like ladle-refining furnace and gas oxygen refining. One such example of an induction furnace that has installed a refining facility is Kashi Vishwanath Steel in Kashipur, Uttarakhand.

8

CSE PROPOSAL FOR STEEL SECTOR'S DECARBONIZATION: ACCELERATED LOW-CARBON SCENARIO

The iron and steel sector is essential for economic growth as we understand it today. The problem is that it is very hard to decarbonize. Though there are options that exist, so that even as India grows and reaches the steel production target of 255 MT by 2030, the emissions curve can be bent even further. Our objective has to be to de-link the growth of this sector with the growth in emissions.

CSE proposes three CO_2e reduction scenarios, based on the current three major transformations—fuel change, high steel scrap utilization, and adoption of carbon capture and utilization in steel production. These scenarios are followed by a fourth scenario which combines all three of them.

Ideally, India should change the technology/production route for steel manufacturing from BF-BOF to DRI-EAF as this would enable deeper emissions reductions.

However, because of the current limitation in the availability of natural gas and good quality recycled scrap, most of the expansion is happening through the BF-BOF route. Therefore, we have assumed that till 2030 the proportion would remain as targeted by the National Steel Policy, 2017 (BF-BOF: 65 per cent and DRI-EAF: 35 per cent).

8.1 REPLACING COAL WITH GAS AND OTHER CLEANER FUELS BY 2030

Currently, natural gas is one of the major cleaner fuels available in India that can replace coal.

Natural gas can be used in both the steel production routes; but, in the BF-BOF route, its usage is limited to a certain share which is still being experimented with in other parts of the world. As natural gas (methane) cannot be used directly in a blast furnace, a steam reformer is used to convert it into synthetic gas which is then used in the blast furnace. Recently, some companies, like the Energe Iron Company in the US, have attempted to use natural gas directly in the blast furnace without reforming. Paul Wurth—an engineering

Table 16: GHG emissions in a BAU scenario and scenario of fuel change by 2030

Technology	Estimated production in 2030 (in million tonne)	Emission factor (BAU scenario)	GHG emissions in 2030—BAU scenario (in million tonne)	Action taken for 2030	Emission factor (improved)	GHG emissions (in million tonne) in 2030 with Action 1—fuel change
BF-BOF	165.75 (65 per cent production)	2.5	414.37	Introduction of natural gas injection or hydrogen across all production	2.024	335.47
DRI-EAF	89.25 (35 per cent production)	3-3.2 (with coal) 1.6 (with gas)	244.81	100 per cent production switches to gas	1.6 (with gas) for the entire production through this route	142.8
Total	255		659.19			478.27

Source: Centre for Science and Environment

company providing technology for the global iron and steel making industry—claims a reduction of 28 per cent in CO_2e emissions if natural gas-based synthetic gas is injected in the blast furnace.

The other option in the BF-BOF route is to use hydrogen—which is still in the development stage. Therefore, in this scenario, CSE has assumed that all BF-BOF route production in India implements natural gas-based injections or introduces hydrogen.

For the DRI-EAF route, it has been assumed in this scenario that 100 per cent production shifts to gas-based DRI route.

The fuel change strategy would lead to reduction from 659 million tonne in a BAU scenario to around 478 million tonne. Clearly, this will make a huge difference, particularly for the extremely polluting DRI-EAF manufacturing route.

8.2 INCREASE SCRAP UTILIZATION IN STEEL MANUFACTURE TO REDUCE CARBON INTENSITY BY 2030

A major second step that can be taken to reduce GHG emissions from the iron and steel sector is maximizing the usage of scrap in iron and steel manufacturing. Both the technology routes have the potential to use scrap.

This is a big game-changer as increased use of scrap will reduce the carbon intensity of this industry. Use of scrap is also important in terms of circular economy targets of the country.

As per the Steel Scrap Policy, the country produces some 25 million tonne of steel scrap and imports an additional 7 million tonne. It can be assumed that this quantity of 32 million tonne is used in the production of 103 million tonne of steel—roughly 30 per cent of the country's overall production.

The BF-BOF technology can use up to 30 per cent scrap in BOF along with hot metal, whereas the electric arc furnace technology can use 100 per cent scrap as a raw material replacing DRI completely.

By mandating the use of 30 per cent scrap in the BF-BOF route, CO_2e reduction will be equivalent to the scrap used, i.e., 30 per cent.

By undertaking this action to mandate highest usage of scrap in 2030, this sector will see reduction in emissions from around 659 million tonne in BAU scenario to 343 million tonne.

Table 17: GHG emissions in a BAU scenario and as per Action 2—high scrap utilization, in 2030

Technology	Estimated production in 2030 (in million tonne)	Emission factor (BAU scenario)	GHG emissions in 2030—BAU scenario (in million tonne)	Action taken for 2030	Scrap requirement (in million tonne)	Emission factor (improved)	GHG emissions (in million tonne) in 2030 with Action 2—increased scrap utilization
BF-BOF	165.75 (65 per cent production)	2.5	414.37	Introduction of 30 per cent scrap input in the BF-BOF route	50	1.75	290.06
DRI-EAF	89.25 (35 per cent production)	3–3.2 (with coal) 1.6 (with gas)	244.81	100 per cent scrap based-EAF production	90	0.6 (for the entire production through this route)	53.55
Total	255		659.19		140		343.61

Source: Centre for Science and Environment

In order to achieve complete scrap-based production through the electric arc furnace route and partial scrap-based production through the BF-BOF route (as demonstrated in this scenario), more than 140 million tonne of scrap will be required by 2030. To obtain this quantity of raw material, the country will need to set up systems for increasing the collection of good quality scrap—particularly from the automobile and ship-building sectors.

8.3 IMPLEMENT CARBON CAPTURE AND UTILIZATION BY 2030

Another option that has the potential to bring down CO_2e emissions from the industry (at least from the bigger steel plants) is carbon capture and utilization (CCU). CCU is expensive, but big players of the sector have already started using it at many of their plants.

The Tata Steel plant at Jamshedpur is already capturing around 5 per cent of its daily CO_2 emissions through CCU technology. With green hydrogen costs likely to remain high in the near future, a large portion of GHG emissions can be brought down through CCU.

Therefore, under this proposal, CSE has assumed at least 30 per cent CO_2e reduction through CCU through the overall BF-BOF route by 2030.

Table 18: GHG emissions in a BAU scenario and with implementation of CCU in BF-BOF route by 2030

Technology	Estimated production in 2030 (in million tonne)	Emission factor (BAU scenario)	GHG emissions in 2030–BAU scenario (in million tonne)	Action taken for 2030	Emission factor (improved)	GHG emissions (in million tonne) in 2030 with Action 3—implementation of CCU
BF-BOF	165.75 (65 per cent production)	2.5	414.37	30 per cent CCU for whole production through this route	1.75	290.06
DRI-EAF	89.25 (35 per cent production)	3–3.2 (with coal) 1.6 (with gas)	244.81	N.A.	N.A.	244.81
Total	255		659.19			534.87

N.A. = Not available

Source: Centre for Science and Environment

This is important. as in the BF-BOF route, other options for reducing carbon intensity—change of fuel or the use of 100 per cent scrap—are limited. Therefore, CCU is the one technological option that would drastically reduce emissions.

As the cost of CCU is high, it would also be important for this sector to look into the possibility of generating international climate finance.

If CCU is implemented in the BF-BOF production route, and 30 per cent CO_2 emissions are captured, GHG emissions can be expected to abate from 659 million tonne in a BAU scenario to around 548 million tonne by 2030.

For this, CCU needs to be made mandatory for large steel plants and clear targets need to be set for CCU, along with provisions of finance to enable this transition.

8.4 OVERALL COMBINED ACCELERATED LOW-CARBON SCENARIO IN 2030

In this scenario, CSE has projected the CO_2e emissions reduction that can be achieved by the sector by 2030 if all three major CO_2e emissions reduction steps discussed above are combined.

For the DRI-EAF route, two pathways or options have been shown. Option 1 is that all production is from the scrap-EAF route and option 2 is total shift of this route to gas-based DRI production.

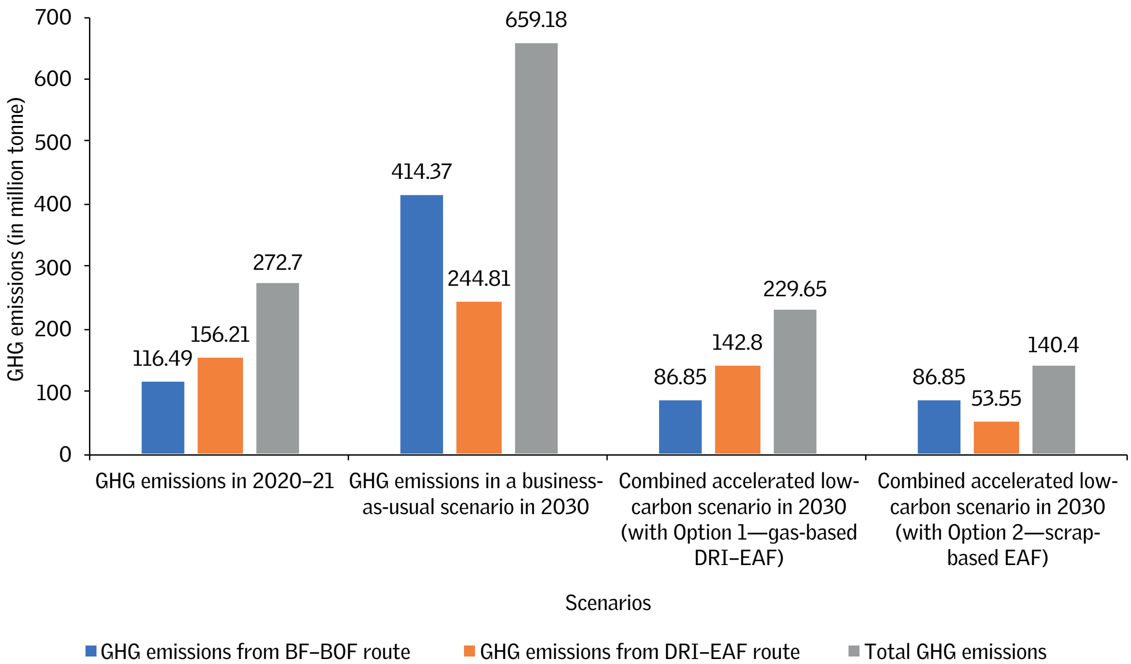
For the BF-BOF route, the options of scrap utilization and gas injections are the same. In addition, there is a third option of implementing CCU.

This shows the possibility of drastic reductions. If all the best-available technology options are implemented, then GHG emissions can be reduced down to 140–230 tonne by 2030. This is a reduction of close to 80 per cent over the BAU in the best case scenario.

Table 19: Total and technology-wise actions, GHG emissions and percentage reduction achieved under the accelerated low-carbon scenario

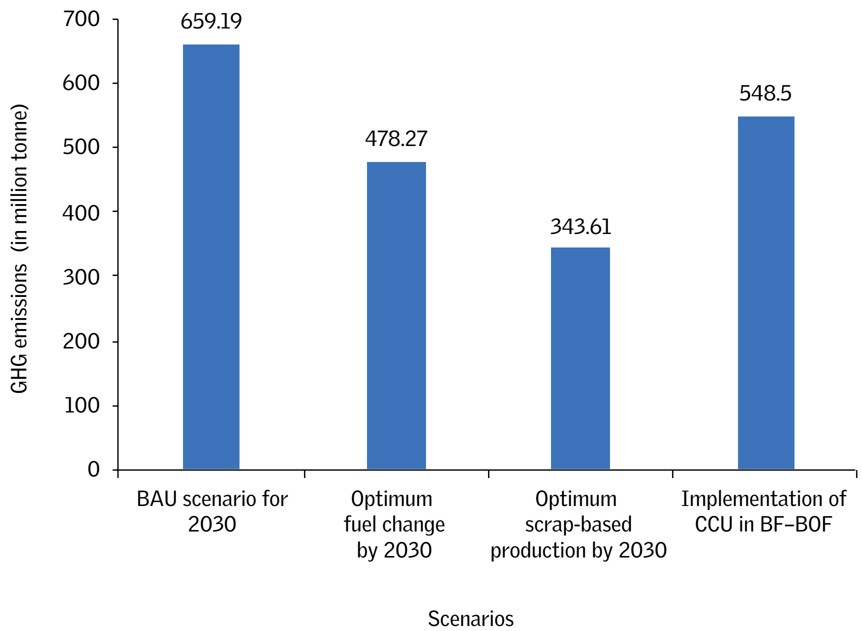
Technology	S. no.	Action	Emission factors	GHG emissions in the accelerated low-carbon scenario in 2030 (in million tonne)	Percentage reduction over GHG emissions in a BAU scenario in 2030
BF-BOF	1.	28 per cent natural gas injection	2	335.47	19
	2.	30 per cent scrap utilization	1.75	290.06	30
	3.	30 per cent CCU	1.75	290.06	30
	4.	With all the above actions		86.85	79
DRI-EAF	1.	100 per cent gas for production	1.6	142.8	41.6
		or			
	2.	100 per cent scrap-based production	0.6	53.55	78
Total with Option 1—gas-based DRI-EAF				229.65	
Total with Option 2—scrap-based EAF				140.4	

Graph 10: Technology-wise GHG emissions in 2020–21, BAU scenario (2030) and combined accelerated low-carbon scenario—Options 1 and 2, 2030



Source: Centre for Science and Environment

Graph 11: GHG emissions in a BAU scenario, and separate and combined steps of accelerated low-carbon scenario by 2030



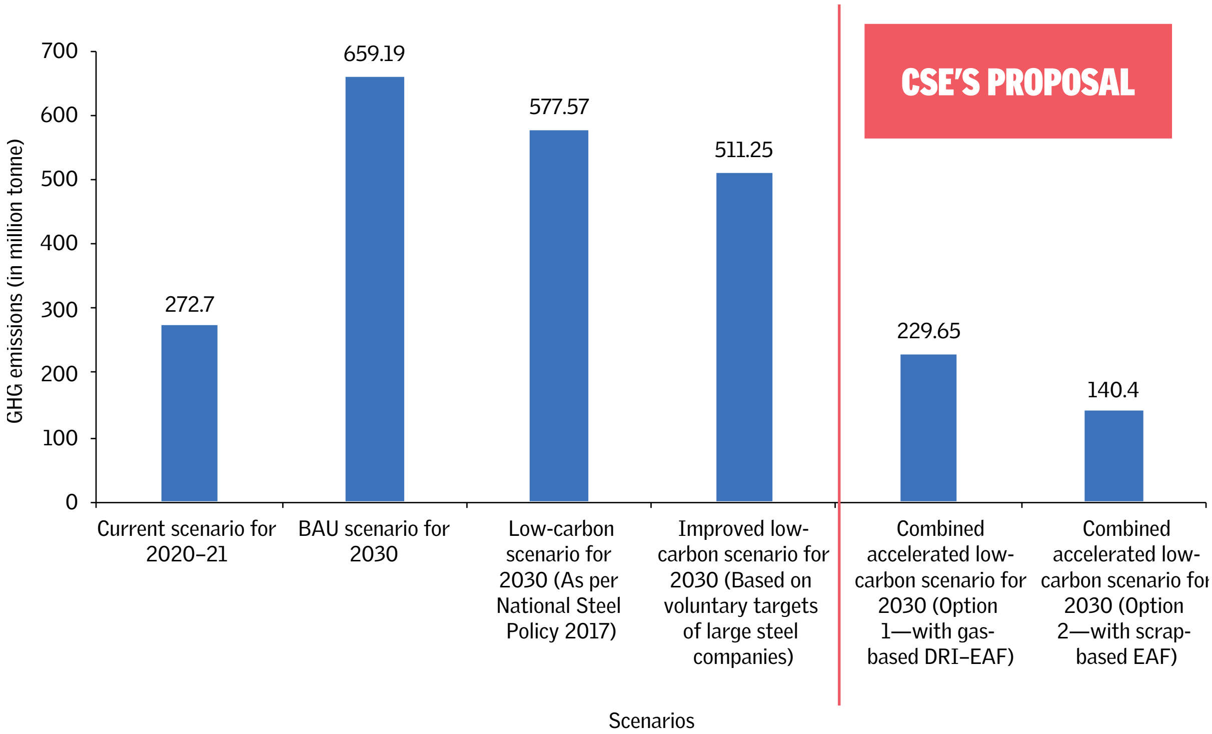
Source: Centre for Science and Environment

This shows the impact these three major decarbonization strategies could have on the sector and why the government should immediately set compelling targets for this industry and enable the transition with respect to fuel change, scrap availability and finance.

This estimation shows how the CO_2e emissions reduction potential assumed by the government under the low-carbon scenario for 2030 and by large steel companies under the improved low-carbon scenario for 2030 is far too little compared to what can actually be achieved. It clearly shows that the future growth of the steel industry of the country can be delinked from greenhouse gas emissions. If net zero has to be achieved by India in 2070, accelerated low-carbon strategies are required for this and other carbon-intensive sectors of the country. This is the need of the hour, and needs a steely resolve to be fulfilled.

CSE PROPOSAL FOR STEEL SECTOR'S DECARBONIZATION

Graph 12: GHG emissions in current scenario for 2020–21 and in different scenarios in 2030



Source: Centre for Science and Environment

9

DECARBONIZING INDIA'S IRON AND STEEL SECTOR: KEY FINDINGS AND RECOMMENDATIONS

DECARBONIZING INDIA'S IRON AND STEEL SECTOR: KEY FINDINGS AND RECOMMENDATIONS

Iron and steel is a hard to decarbonize sector, but also critical as it contributes to both economic development in countries and global greenhouse gas emissions. In a world that is facing an existential threat because of climate change, it is clear that much more needs to be done to reduce emissions from all sectors—the iron and steel industry is, therefore, key.

The iron and steel sector contributed 7.2 per cent of total global emissions in 2016; while the Indian iron and steel sector contributed 4.75 per cent of the country's GHG emissions.

China is the world's largest crude steel producer, followed by India. But there is little comparison between the two as China produces 10 times as much crude steel as India. China's production in 2019 stood at 1,000 million tonne—over half the world's total steel production. In the same year, India produced 100 million tonne of steel.

As per National Steel Policy, 2017, India's expected steel production capacity will be 300 million tonne and India's steel production will be 255 million tonne by 2030.

The per capita steel consumption in India is expected to be 160 kg by 2030–31—up from 74.6 kg in 2019–20. But even in 2030, with this increase, India's per capita steel consumption will be lower than the global per capita of 2019–20, which was 229 kg.

POLICY, TECHNOLOGY AND EMISSIONS

Iron is majorly of two types—hot iron or pig iron (produced through blast furnace to produce steel through basic oxygen furnace) and direct reduced iron or sponge iron (to produce steel through electric arc furnace or induction furnace).

The reason it is important to understand the process of iron and steel making is because it is directly linked to emissions.

Two major routes of steel production in India are through the blast furnace-basic oxygen furnace (BF-BOF) technology and scrap/direct reduced iron-electric arc furnace/induction furnace (scrap/DRI-EAF/IF) technology.

Around 70 per cent of the crude steel production in the world and 45 per cent of the crude steel production in India was done through the BF-BOF route in 2020. Of the remaining 55 per cent, the electric arc furnace manufactured 28 per cent and the induction furnace manufactured 27 per cent. India is the largest producer of sponge iron or direct reduced iron and around 82 per cent of its production is from coal-based small-scale units (which have much higher emissions than gas-based units).

The major greenhouse gasses emitted during the process are carbon dioxide (99 per cent), methane and nitrous oxide.

The National Steel Policy, 2017 includes targets for GHG reduction for this industry. It projects a target of 2.2 to 2.4 tonne of CO_2e emissions per tonne of crude steel produced through BF-BOF route and 2.6 to 2.7 tonne of CO_2e emissions per tonne of crude steel produced through DRI-EAF route in India by 2030.

As per the National Steel Policy, 2017, crude steel production in India is projected to more than double by 2030–31. More than 120 million tonne of crude steel production capacity expansion has already been planned by the large scale steel players in India.

The problem is that the bulk of the proposed capacity expansion is being planned through the BF-BOF route in India—which is not only more carbon intensive but also more difficult to decarbonize. In BF-BOF, coal is used as a reducing agent to turn ore into metal and so it is difficult to substitute. This technology also has limitations in the use of scrap as a raw material. The reasons why India is moving towards BF-BOF are unavailability of good quality scrap, high prices of natural gas and the large-scale potential of BF-BOF technology. Given the projects that are underway and expansion planned, India may not be able to meet its target to limit the share of BF-BOF steel production to 65 per cent by 2030.

ESTIMATED EMISSIONS FROM INDIA'S STEEL SECTOR 2020–21

While India reported 135 million tonne of GHG emissions from the steel sector in the third BUR for the year 2016, CSE estimated GHG emissions from the iron and steel sector in India to be around 250 million tonne in 2016. The difference is possibly because of how the energy emissions are accounted for in the BUR methodology. CSE has calculated GHG emissions of the steel sector using its estimated emission factors for different technologies which are based on declarations and estimations made by Ministry of Steel and disclosures made by steel companies.

Based on this data, CSE has put forward the estimated range of CO_2e emissions from major iron and steel manufacturing technologies in India (see *Table 10* on page 39). It finds that in the case of BF-BOF, the range of CO_2e emissions is between 2.2–2.6 tonne per tonne of crude steel production. The Ministry of Steel has declared that India has already achieved GHG emission factor of 2.5 for the BF-BOF route as of 2020, somewhat close to the 2030 target.

The most polluting manufacturing technology remains the coal-based DRI-EAF/IF—the range here is between 2.8–3.2 tonne of CO_2e emissions per tonne of crude steel manufactured. The problem is that 82 per cent of the DRI production in India is through coal-based rotary kilns, which are small-scale with high CO_2e emissions.

The lowest emissions are from gas-based DRI-EAF—between 1.4–1.8 tonne of CO_2e per tonne of crude steel manufactured. But only around 18 per cent of the DRI production in India is gas-based and its share has not increased due to non-availability and high price of natural gas.

CSE has also calculated the emissions of each iron and steel plant in the country as technologies differ and so do the emissions (see *Table 8* on page 35). If the company has declared its emission factor, this has been used in the computation. Otherwise, the emission factor for the particular technology used by the company has been used for computation.

CSE has also taken into account the production capacity of small-scale manufacturers as per government estimates. They have been assumed to be using coal-based DRI-EAF/IF technology for iron and steel manufacturing. The average emissions are taken to be 3 tonne of CO_2e per tonne of crude steel manufactured. Small-scale manufacturers produced between 37–47 million tonne of crude steel in 2020–21 (depending on various estimates). Based on these figures, this segment emitted between 112.78–139.51 million tonne of CO_2e—roughly 41–51 per cent of the total emissions from the iron and steel sector.

This is also evident in the 2020–21 technology-wise GHG emission estimation. This shows that the contribution of coal-based DRI-EAF/IF units is even higher than the contribution from BF-BOF technology in the country—which is contrary to the global experience, where this technology scores higher in terms of emission profile.

The aggregation of estimated plant-wise data reveals that India's iron and steel industry with a production of 104 million tonne emitted 267.48 million tonne of CO_2e in 2020–21.

CSE has estimated the company-wise GHG emission profile as well (see *Table 9* on page 37). This follows the production of the companies.

Tata Steel, India's largest steel company, contributes some 14.5 per cent of the total emissions from this sector; closely followed by the public sector SAIL and JSW Steel.

The three top companies—Tata Steel (India) Ltd, SAIL and JSW Steel—with a combined 47.05 million tonne of production in 2020–21 (45 per cent of the country's production) contributed 43 per cent of the emissions.

The sponge iron companies (DRI-EAF/IF), mostly operating in the medium- and small-scale sectors, contributed 41–51 per cent of the GHG emissions with some 37–47 million tonne of production in 2020–21.

This clearly shows where the priority for improvement for emission reduction must be—the big three and the small and medium producers.

FUTURE EMISSIONS: IN 2030

CSE has projected four GHG emission scenarios for the sector for 2030:

a. Business-as-usual (BAU) based on production in 2030 and current technology
b. Low-carbon growth pathway based on emission targets set the National Steel Policy, 2017
c. Improved low-carbon growth pathway based on voluntary targets by large steel companies (as publicly declared)
d. Accelerated low-carbon growth pathway, which is CSE's proposal based on the best available technologies and options for de-carbonizing the sector.

As per this we find:

In the BAU scenario, GHG emissions from the iron and steel sector will grow 2.5 times by 2030 compared to 2020–21—from 272.7 million tonne to 659.19 million tonne.

In the low-carbon growth pathway, there is a reduction of 12.5 per cent (82 million tonne) compared to the BAU scenario.

In the improved low-carbon growth pathway, there is a reduction of 22.5 per cent (148 million tonne) compared to the BAU scenario. This is because of the enhanced emission reduction targets declared by Tata Steel (India) Ltd, JSW Steel and AM/NS India Ltd. But the total emissions would still be 511.25 million tonne of CO_2e—which is just a little less than double of current emissions.

The question then is what more can be done to decarbonize the Indian iron and steel sector? What are the fuel and technology options that would allow the country to bend the curve of its emission trajectory, without losing out on the development opportunities that this sector provides?

Global average CO_2e emissions from the steel sector were 1.89 tonne per tonne of crude steel produced in 2020, according to the World Steel Association. These are expected to go down further by 2030. Countries like Canada and Spain have achieved average emission factor of 1.5 tonne of CO_2e per tonne of steel produced through BF-BOF route—which is more difficult to decarbonize than DRI-EAF.

Gas based DRI-EAF and scrap-based EAF are the lower-carbon steel production technologies currently available. Globally, CO_2e emissions from coal-based DRI-EAF technology have been shown to be around 1.9 tonne per tonne of steel production, clearly much below the target set up in National Steel Policy, 2017.

PATHWAYS FOR REDUCING CARBON INTENSITY

CSE has assessed the different options for reduced carbon intensity in this industrial sector. The sector-wide emission reduction options are:

1. To introduce technologies for increased fuel efficiency and recovery (the Union Ministry of Steel has compiled a list of such technologies). But these need to be mandated. For instance, energy efficiency of rotary kilns in coal-based DRI units is hardly 37 to 55 per cent due to non-utilization of waste heat, therefore waste heat recovery systems should be made mandatory for coal-based DRI units. Similarly, induction furnaces in India should be restricted (to prevent excess of poor quality steel) or at the very least be required to install refining technologies like ladle refining furnace and gas oxygen refining.

2. To increase availability of cleaner fuel for combustion so that coal is substituted by natural gas or hydrogen. Use of green hydrogen in steel production can achieve up to 21 per cent CO_2e reduction through the BF-BOF route and up to 95 per cent CO_2e reduction through the DRI-EAF route.

3. To increase availability of good quality steel scrap for material and energy saving and reduction of carbon intensity. Every tonne of steel scrap used to produce steel saves 1.1 tonne of iron ore, 630 kg of coking coal and 55 kg of limestone. It can reduce GHG emissions by close to 60 per cent. The Steel Scrap Policy needs to ensure high scrap generation and utilization targets.

4. To use carbon capture, utilization and storage (CCUS), particularly for BF-BOF process in which substituting coal is difficult. Therefore, the option is to upscale the implementation of CCUS, which is being tried out by big players like Tata Steel (India) Ltd, JSW Steel and SAIL in their manufacturing plants.

5. To examine the use of ultra-low CO_2e steel-making technologies for their application and use in India.

CSE'S PROPOSAL FOR ACCELERATED LOW CARBON GROWTH SCENARIO

Ideally, India should change the production route for steel manufacturing from BF-BOF to cleaner DRI-EAF to enable deeper emission cuts.

Strategy 1: Switch to clean fuel: Emissions reduction of 181 million tonne compared to the BAU scenario can be achieved through an optimal fuel change across the technology routes in the sector. GHG emissions from the iron and steel sector would go down from 659.19 million tonne in BAU scenario to 478.27 million tonne in 2030. In this case, the BF-BOF route would have to implement natural-gas based injection or use hydrogen as fuel. The DRI-EAF route would have to shift completely to gas-based production.

Strategy 2: Increase use of scrap: Emissions reduction of 316 million tonne compared to the BAU scenario can be achieved through optimal scrap utilization across the technology routes in the sector. GHG emissions from the iron and steel sector would be roughly halved from 659.19 million tonne in BAU scenario to 343.61 million tonne in 2030. In this case, the BF-BOF route would be mandated to use 30 per cent scrap and DRI-EAF route would shift completely to scrap-based production.

Strategy 3: Implementation of carbon capture and utilization: Emissions reduction of 111 million tonne from the BAU scenario can be achieved in the sector by implementing CCU in 30 per cent of total production. In this case, emissions in the BF-BOF route would go down from 414.37 million tonne in BAU scenario to 290.06 million tonne in 2030.

CSE has then combined the different strategies for the sector's low-carbon trajectory. It finds that GHG reductions of up to 429 and 519 million tonne can be achieved in the two options proposed by CSE in the accelerated low-carbon growth scenario (see *Table 19* and *Graph 10* on page 72).

The emissions in the two options under the accelerated low-carbon growth pathway scenario will be lesser than the current emissions of the sector (2020–21).

The findings of this report show that the future growth of the steel industry of the country can be de-linked from greenhouse gas emissions but that this will require a roadmap for technology changes, infrastructure and funds.

The game-changing options are:

1. **To switch fuel:** Particularly to move towards gas-based DRI-EAF production. And to introduce hydrogen in BF-BOF.
2. **To implement scrap-based production:** Complete switch in DRI-EAF and 30 per cent in BF-BOF.
3. **Implementing CCU in BF-BOF** for reducing 30 per cent of the emissions.

RECOMMENDATIONS

It is clear that there are opportunities for reduced carbon intensity, even in this hard to decarbonize industrial sector. The technology options provided in this report suggest the various interventions that are possible. We realize that the roadmap provided in this report may be overly ambitious—but given the challenge of climate change and the existential threat it poses, it is also clear that we must move beyond the ordinary to the extra-ordinary and that business-as-usual must become unusual. Our attempt is to understand what the possibilities are. To see how we can achieve this plan in the coming years, we recommend the following:

1. The infrastructure for clean fuel and scrap availability is key and this needs government intervention.

2. The Union Ministry of Steel should mandate the optimal use of steel scrap by 2030—with a clear roadmap for 30 per cent and 100 per cent switch. This will provide the right signals to the market for sourcing good quality scrap. This will also move India towards a circular economy and reduce waste and improve resource utilization.

3. The switch to the use of hydrogen and CCUS in the BF-BOF route will require international finance. The government and steel industry should work towards a combined proposal for climate finance with targets for 2030.

4. The big opportunity is to re-work the DRI-EAF route. This would require working with the medium- and small-scale plants so that they are enabled to either make the switch to cleaner fuel (natural gas) or move towards 100 per cent use of scrap material for steel production. This requires a steel mission for sponge-iron plants so that they are provided the assistance to make this transition.

The low-carbon pathway has the opportunity to create economic wellbeing but not at the cost of the planet.

ANNEXURE

Table: Emission factors estimated by CSE for this report and the assumptions and sources referred to for them

S. no.	Major iron and steel production technologies	Estimated average CO_2e emission factor (in tonne) per tonne of crude steel production, as of 2020	Reference (based on which the range of emission factor was decided)
1.	BF-BOF	2.5	- Lowest publicly declared BF-BOF plant emission factor is 2.29.[52] - JSW Steel has declared its company's average emission factor as 2.49. - SAIL has declared it as 2.54. - The CO_2 emission factor declared by the Ministry of Environment, India for BF-BOF route is 2.5, as of 2020. - Therefore, CO_2e emission factor for BF-BOF route has been taken as 2.5 tonne CO_2e per tonne of steel produced.
2.	Coal-based DRI-EAF/IF	3	- Assumptions made by Ministry of Steel for arriving at INDC values in 2014–15 mention emission factor for coal-based DRI-EAF/IF in the range of 3–3.2 tonne and assume that it would become 2.8–2.9 tonne in 2020 on adoption of relevant technologies. - Since adoption of relevant technologies in coal-based DRI was not as assumed, the emission factor range assumed is 2.8 to 3.2. Therefore, the average emission factor taken for coal-based DRI-EAF/IF route is 3 tonne CO_2e per tonne of steel produced.
3.	Gas-based DRI-EAF	1.6	- A research article by Zhiyuan Fan and Julio Friedmann published on the website of Columbia University's Centre on Global Energy Policy mentions CO_2 emission factor for this technology as 1.39 tonne of CO_2 per tonne of steel produced.[53] - An article by Ben Ellis and Wenjun Bao on the Broken Hill Proprietary Company website mentions the CO_2 emission factor for this technology as 1.4.[54] - A research article, "Influence of direct reduced iron on the energy balance of the electric arc furnace in steel production" on ResearchGate mentions CO_2 emissions from gas-based DRI-EAF in different ranges for different sets of samples based on the emissions from generation of electricity in different locations. Since India largely produces coal-dependent electricity and most of the gas-based DRI plants source energy from the grid, two of the highest emission factors given have been considered, i.e., 1.4 and 1.8.[55] - Therefore, the emission factor for gas-based DRI-EAF has been assumed as an average of 1.4 and 1.8, i.e., 1.6.
4.	Coal gasification-based DRI-EAF/EOF	2.9	- Since only one plant in India is running on this technology (JSPL plant), and the plant emission factor has not been declared publicly, therefore the emission factor was sourced from Steel Research and Technology Mission of India, which mentions that it is in the range of 2.8–3 tonne of CO_2 emissions per tonne of steel produced. Therefore, the average of 2.9 has been considered for this technology.

S. no.	Major iron and steel production technologies	Estimated average CO_2e emission factor (in tonne) per tonne of crude steel production, as of 2020	Reference (based on which the range of emission factor was decided)
5.	100 per cent scrap-based EAF and IF	0.6	- An article by Dr Ben Ellis and Wenjun Bao on the BHP website mentions the CO_2 emission factor for this technology as 0.456 - A research article by Zhiyuan Fan and Dr Julio Friedmann published on the website of Columbia University's Centre on Global Energy Policy mentions CO_2 emission factor for this technology as 0.84 tonne of CO_2 per tonne steel produced.[57] - Therefore, the range assumed is 0.4–0.8 tonne CO_2e per tonne of steel produced and the CO_2e emission factor for scrap-based EAF has been taken as 0.6.
6.	Corex—oxygen converter (basic oxygen furnace/Conarc technology)	2.6	- Compared to conventional blast furnace iron-making system, direct CO_2 emissions of Corex are higher. Considering the credits of export gases for power generation, the total CO_2 emissions of Corex have advantages only when the Corex is joined with high-efficiency generating units whose efficiency is greater than 45 per cent and when the CO_2 emission factor of the grid is higher than 0.9 kg CO_2/kWh.[58] - As per the Steel Research and Technology Mission of India, Corex basically consists of a gasifier and produces corex gas ($CO + H_2$). If this gas is exported and used in power generation at an electric arc furnace (with midrex or conarc tech) with the prescribed efficiency, it can have CO_2 emissions a little less or equivalent to a blast furnace, i.e., around 2.4, else if the corex gas is not being utilized, emissions are higher than that of a blast furnace, i.e., around 2.8. Since we do not know whether the current corex technology in JSW Steel and ArcelorMittal Nippon Steel India plant is using the gases in prescribed efficiency or not, we have considered an average of 2.4 and 2.8, i.e., 2.6.
7.	BF-EOF	2.5	- Energy optimization furnace technology allows oxygen lancing from the side unlike BOF in which it is done from the top. This allows reduction in O_2 usage in the process but the reduction achieved in CO_2 emissions compared to BOF is hardly 1–2 per cent, therefore CO_2 emissions of this technology can be considered equivalent to BF-BOF in this case, i.e. 2.5.

REFERENCES

1. Kate Larsen, H. P. (2021). China's Greenhouse Gas Emissions Exceeded the Developed World for the First Time in 2019. Retrieved from rhg.com: https://rhg.com/research/chinas-emissions-surpass-developed-countries/, as accessed on 12 November 2021

2. Roser, H. R. (2016). Emissions by sector. Retrieved from ourworldindata.org: https://ourworldindata.org/emissions-by-sector, as accessed on 15 November 2021

3. Anon (2021). India Third Biennial Update Report to The United Nations Framework Convention on Climate Change, Ministry of Environment Forest and Climate Change, New Delhi. Retrieved from unfccc.int: https://unfccc.int/sites/default/files/resource/INDIA_%20BUR-3_20.02.2021_High.pdf, as accessed on 15 November 2021

4. Ibid.

5. Anon (2021). Annual Report—2020–21. Ministry of Steel. Retrieved from steel.gov.in: https://steel. gov.in/sites/default/files/Annual%20Report-Ministry%20of%20Steel%202020-21.pdf, as accessed on 14 September 2021

6. Anon (2019). The Indian steel industry: Growth, challenges and digital disruption. pwc & Indian Steel Association. Retrieved from www.pwc.in: https://www.pwc.in/assets/pdfs/consulting/technology/the-indian-steel-industry-growth-challenges-and-digital-disruption.pdf, as accessed on 05 November 2021

7. Anon (2018). Annual Report—2017–18. Ministry of Steel, Retrieved from steel.gov.in: https://steel.gov.in/sites/default/files/annual_Report_E_07March2018.pdf, as accessed on 10 November 2021

8. Anon (2021). Per Capita Steel Consumption, Ministry of Steel. Retrieved from: pib.gov. in: https://pib.gov.in/PressReleasePage.aspx?PRID=1705404, as accessed on 5 October 2021

9. Mookerji, Madhumita (2019). "Expansion targets, cost economics on RINL's Radar", Steel-360 India. Retrieved from www.steel-360.com: https://www.steel-360.com/personality/expansion-targets-cost-economics-on-rinls-radar, as accessed on 10 January 2022

10. Anon (2018). "Vedanta to set up 4.5 million tonne steel plant in Jharkhand", Businesstoday.in. Retrieved from https://www.businesstoday.in/: https://www.businesstoday.in/latest/corporate/story/vedanta-to-set-up-45-million-tonne-steel-plant-in-jharkhand-125607-2018-12-25, as accessed on 10 January 2022

11. Anon (2021). Iron & Steel Industry in India, India Brand Equity Foundation. Retrieved from www. ibef.org: https://www.ibef.org/industry/steel.aspx, as accessed on 10 January 2022

12. Dutt, I. A. (2021). "Steel companies likely to add 29 million tonnes capacity in five years", Business Standard. Retrieved from www.business-

standard. com: https://www.business-standard.com/article/companies/steel-companies-likely-to-add-29-million-tonnes-capacity-in-five-years-121052700654_1.html, as accessed on 10 January 2022

13. Dilipkumar, B. (2021). "Tata Steel bets on expanding steel demand to double its capacity", Economic Times. Retrieved from economictimes.indiatimes.com: https://economictimes.indiatimes.com/industry/indl-goods/svs/steel/tata-steel-bets-on-expanding-steel-demand-to-double-its-capacity/articleshow/80912225.cms?from=mdr, as accessed on 10 January 2022

14. Mondal, D. (2021). "Jindal Steel and Power Limited eyes 50 MT annual capacity by 2030; to reduce carbon emission", New Indian Express. Retrieved from www.newindianexpress.com: https://www.newindianexpress.com/business/2021/jul/28/jindal-steel-and-power-limited-eyes-50-mt-annual-capacity-by-2030-to-reduce-carbon-emission-2336509.html, as accessed on 10 January 2022

15. Ray, S. S. (2020). "SAIL proposes to increase capacity to 49.6 MTPA by 2030", Financial Express. Retrieved from www.financialexpress.com: https:// www.financialexpress.com/industry/sail-proposes-to-increase-capacity-to-49-6-mtpa-by-2030/1911618/, as accessed on 10 January 2022

16. Anon (2019–20). Sustainability, Tata Steel. Retrieved from www.tatasteel.com: https://www.tatasteel.com/tata-steel-brochure-2020-21/sustainability.html, as accessed on 15 January 2022

17. Anon (2021). Integrated Report & Annual Accounts 2020–21, Tata Steel. Retrieved from www.tatasteel.com: https://www.tatasteel.com/media/13915/tsl_ir21_final.pdf, as accessed on 15 January 2022

18. Anon (2019–20). Sustainability, Tata Steel. Retrieved from www.tatasteel.com: https://www.tatasteel.com/tata-steel-brochure-2020-21/sustainability.html, as accessed on 15 January 2022

19. Anon (2021). Integrated Report & Annual Accounts 2020–21, Tata Steel. Retrieved from www.tatasteel.com: https://www.tatasteel.com/media/13915/tsl_ir21_final.pdf, as accessed on 15 January 2022

20. Anon (2020). Environment, JSW Steel. Retrieved from www.jsw.in: https://www.jsw.in/sites/default/files/assets/downloads/steel/IR/Financial%20Performance/Annual%20Reports%20 Steel/jsw-steel-19-20/environment.html, as accessed on 15 January 2022

21. Anon (2020). Annual Report 2019–20, JSW. Retrieved from www.jsw.in: https://https://www. jsw.in/sites/default/files/assets/downloads/steel/IR/Financial%20Performance/Annual%20 Reports%20Steel/jswste/sites/default/ files/assets/downloads/steel/IR/Financial%20Performance/Annual%20 Reports%20Steel/jswsteel-19-20/ environment.html, as accessed on 15 January 2022

22. Anon (2020). Environment, JSW Steel. Retrieved from www.jsw.in: https://www.jsw.in/sites/default/files/assets/downloads/steel/IR/Financial%20Performance/Annual%20Reports%20 Steel/jsw-steel-19-20/environment.html, as accessed on 15 January 2022

23. Anon (2021). Climate Change, Arcellor Mittal. Retrieved from https://corporate.arcelormittal.com:https://corporate.arcelormittal.com/sustainability/approach/climate-change, as accessed on 15 January 2022

24. Ibid.

25. Anon (2020). Corporate Sustainability Report 2020, Steel Authority of India Limited. Retrieved from sail.co.in: https://sail.co.in/sites/default/files/2020-10/SAIL-Sustainability-Report-2019-20-17.pdf, as accessed on 16 January 2022

26. Anon (2021). Energy and Environment Management in Iron & Steel Sector, Ministry of Steel. Retrieved from https://steel.gov.in:https://steel.gov.in/technicalwing/energy-and-environment-management-iron-steel-sector, as accessed on 5 February 2022

27. Ciftci, B. (2018), Blog: The future of global scrap availability, World Steel Association. Retrieved from: worldsteel.org: https://worldsteel.org/media-centre/blog/2018/future-of-global-scrap-availability/#:~:text=Our%20estimates%20 suggest%20that%20global,1.3%20billion%20 tonnes%20in%20 2050., as accessed on 21 March 2022

28. Mookerjee, M. (2020). "Indian steel scrap demand may touch 70 mn t by 2030", Steel Mint. Retrieved from www.steelmint.com: https://www.steelmint.com/insights/indian-steel-scrap-demand-may-touch-70-mn-t-by-2030-189812, as accessed on 6 January 2022

29. Singh, R. (2021). "Doubling ship recycling capacity by 2024: Are we ready?", Down to Earth, New Delhi. Retrieved from www.downtoearth.org: https://www.downtoearth.org.in/blog/environment/doubling-ship-recycling-capacity-by-2024-are-we-ready-75494, as accessed on 8 November 2021

30. Friedmann, Z. F. (2021). Low-Carbon Production of Iron & Steel: Technology Options, Economic Assessment, and Policy, Columbia, SIPA; Centre on Global Energy Policy. Retrieved from www.energypolicy.columbia.edu: https://www.energypolicy.columbia.edu/research/article/low-carbon-production-iron-steel-technology-options-economic-assessment-and-policy, as accessed on 8 November 2021

31. Anon (2021). JSW Steel Limited Corporate Presentation, Jindal Steel Works. Retrieved from www.jsw.in: https://www.jsw.in/sites/default/files/assets/downloads/steel/IR/JSW%20Steel%20Investor%20Presentation/JSW%20Steel_corp%20 July%202021%20Final.pdf, as accessed on 15 November 2021

32. Anon (2021). JSW Steel Limited Corporate Presentation, Jindal Steel Works. Retrieved from www.jsw.in: https://www.jsw.in/sites/default/files/assets/downloads/steel/IR/JSW%20Steel%20Investor%20Presentation/JSW%20Steel_corp%20 July%202021%20Final.pdf, as accessed on 15 November 2021

33. Anon (2021). "SAIL planning to set up India's first gas-to-ethanol plant in Chandrapur", Economic Times. Retrieved from economictimes.indiatimes.com: https://economictimes.indiatimes.com/industry/indl-goods/svs/steel/sail-planning-to-set-up-indias-first-gas-to-ethanol-plant-in-chandrapur/articleshow/80431844.cms?from=mdr, as accessed on 15 November 2021

REFERENCES

34. Anon (2021). "Tata Steel commissions India's first plant for CO2 capture from Blast Furnace gas at Jamshedpur", Press Release, Tata Steel. Retrieved from www.tatasteel.com: https://www.tatasteel.com/media/newsroom/press-releases/india/2021/tata-steel-commissions-india-s-first-plant-for-co2-capture-from-blast-furnace-gas-at-jamshedpur/, as accessed on 16 November 2021

35. Tata Steel (2020). "Tata Steel and Council of Scientific & Industrial Research (CSIR) sign MoU to collaborate in the area of Carbon Capture, Utilisation & Storage (CCUS)", Press Releases, Tata Steel. Retrieved from www.tatasteel.com: https://www.tatasteel.com/media/newsroom/press-releases/india/2020/tata-steel-and-council-of-scientific-industrial-research-csir-sign-mou-to-collaborate-in-the-area-of-carbon-capture-utilisation-storage-ccus/, as accessed on 10 November 2021

36. Anon (2021). Carbon Neutral Steel-making, Tata Steel Europe. Retrieved from www.tatasteeleurope.com: https://www.tatasteeleurope.com/sustainability/carbon-neutral-steel, as accessed on 10 November 2021

37. Ibid.

38. Anon (2021). Climate Action Report 2, Arcelor Mittal. Retrieved from corporate-media.arcelormittal.com: https://corporate-media.arcelormittal.com/media/ob3lpdom/car_2.pdf, as accessed on 18 November 2021

39. Anon (2021). Hydrogen in steel production: what is happening in Europe—part one, Bellona Europa. Retrieved from bellona.org: https://bellona.org/news/climate change/2021-03-hydrogen-in-steel-production-what-is happening-in-europe-part-one, as accessed on 20 November 2021

40. Anon (2021). Climate Action Report 2, Arcelor Mittal. Retrieved from corporate-media. arcelormittal.com: https://corporate-media.arcelormittal.com/media/ob3lpdom/car_2.pdf, as accessed on 18 November 2021

41. Anon (2021). Hydrogen in steel production: what is happening in Europe—part one, Bellona Europa. Retrieved from bellona.org:https://bellona.org/news/climate change/2021-03-hydrogen-in-steel-production-what-is happening-in-europe-part-one, as accessed on 20 November 2021

42. Anon (2021). Hydrogen in steel production: what is happening in Europe—part two, Bellona Europa. Retrieved from bellona.org: https://bellona.org/news/industrial-pollution/2021-05-hydrogen-in-steel-production-what-is-happening-in-europe-part-two, as accessed on 20 November 2021

43. Anon (2020). Hisarna—Building a sustainable steel industry, Tata Steel. Retrieved from www.tatasteeleurope.com: https://www.tatasteeleurope.com/sites/default/files/TS%20Factsheet%20Hisarna%20ENG%20jan2020%20Vfinal03%204%20pag%20digital.pdf, as accessed on 18 November 2021

44. Anon (2021). Energy and Environment Management in Iron & Steel Sector, Ministry of Steel. Retrieved from https://steel.gov.in:https://steel.gov.in/technicalwing/energy-and-environment-management-iron-steel-sector, as accessed on 5 February 2022

45. Hasanbeigi, A. (2020). Part 1: Cleanest and Dirtiest Countries for Primary Steel Production, Global Efficiency Intelligence. Retrieved from www.globalefficiencyintel.com: https://www.globalefficiencyintel.com/new-blog/2020/cleanest-dirtiest-countries-primary-steel-production-energy-co2benchmarking#:~:text=Figure%203%20shows%20the%20weighted,fuels%20in%20the%20steel%20industry, as accessed on 10 January 2022

46. Anon (2020). Our Performance, World Steel Association. Retrieved from www.worldsteel.org: https://www.worldsteel.org/steel-by-topic/sustainability/sustainability-indicators.html, as accessed on 5 October 2021

47. Fabritius, H. S. (2011). "Effects of Biomass Use in Integrated Steel Plant–Gate-to-gate Life Cycle Inventory Method", ISIJ International. Retrieved from www.jstage.jst.go.jp: https://www.jstage.jst.go.jp/article/isijinternational/52/5/52_779/_pdf, as accessed on 5 January 2022

48. Friedmann, Z. F. (2021). Low-Carbon Production of Iron & Steel: Technology Options, Economic Assessment, and Policy, Columbia, SIPA; Centre on Global Energy Policy. Retrieved from www.energypolicy.columbia.edu: https://www.energypolicy.columbia.edu/research/article/low-carbon-production-iron-steel-technology-options-economic-assessment-and-policy, as accessed on 8 November 2021

49. Mohan, A., Vasudevan, N. & Kumar, S. (2021). Energy-Efficient Technology Options for Direct Reduction of Iron Process, The Energy and Resource Institute. Retrieved from www.teriin.org: https://www.teriin.org/sites/default/files/2021-08/Direct%20Reduction%20of%20 Iron%20Process.pdf, as accessed on 8 February 2022

50. Anon (2021). Hydrogen in steel production: what is happening in Europe—part two. Bellona Europa. Retrieved from bellona.org: https://bellona.org/news/industrial-pollution/2021-05-hydrogen-in-steel-production-whatis-happening-in-europe-part-two, as accessed on 8 October 2021

51. Anon (2019). "China announced 200 mn t/ yr of steel projects in 2018", Argusmedia. Retrieved from www.argusmedia.com: https://www.argusmedia.com/en/news/1874392-chinaannounced-200mn-tyr-of-steel-projects-in-2018, as accessed on 8 December 2021

52. Anon (2019–20). Sustainability, Tata steel. Retrieved from www.tatasteel.com: https://www.tatasteel.com/tata-steel-brochure-19-20/sustainability.html, as accessed on 8 February 2021

53. Friedmann, Z. F. (2021). Low-Carbon Production of Iron & Steel: Technology Options, Economic Assessment, and Policy, Columbia, SIPA; Centre on Global Energy Policy. Retrieved from www. energypolicy.columbia.edu: https://www.energypolicy.columbia.edu/research/article/low-carbon-production-iron-steel-technology-options-economic-assessment-and-policy, as accessed on 8 November 2021

54. Bao, D. B. (2020). Pathways to decarbonization episode two: steel-making technology, Broken Hill Proprietary Company. Retrieved from www.bhp.com: https://www.bhp.com/news/prospects/2020/11/pathways-to-decarbonisation-episode-two-steelmaking-technology, as accessed on 8 November 2021

REFERENCES

55. Marcus Kirchen, K. B. (2011). "Influence of direct reduced iron on the energy balance of the electric arc furnace in steel industry", ResearchGate. Retrieved from https://www.researchgate.net/: https://www.researchgate.net/publication/238001283_Influence_of_direct_ reduced_iron_on_the_energy_ balance_of_ the_electric_arc_furnace_in_steel_industry, as accessed on 8 November 2021

56. Bao, D. B. (2020). "Pathways to decarbonization episode two: steel-making technology", BHP. Retrieved from www.bhp.com: https://www. bhp.com/news/prospects/2020/11/pathways-to-decarbonisation-episode-two-steelmaking-technology, as accessed on 8 November 2021

57. Friedmann, Z. F. (2021). Low-Carbon Production of Iron & Steel: Technology Options, Economic Assessment, and Policy, Columbia, SIPA; Centre on Global Energy Policy. Retrieved from www. energypolicy.columbia.edu: https://www. energypolicy.columbia.edu/research/article/low-carbon-production-iron-steel-technology-options-economic-assessment-and-policy, as accessed on 8 November 2021

58. Chunxia Zhang, Z. L. (2009). Comparison of CO2 emission between Corex and blast furnace iron-making system. Retrieved from https://www.sciencedirect.com/: https://www.sciencedirect.com/science/article/abs/pii/S1001074209600528, as accessed on 10 February 2022

India is the second largest producer of crude steel in the world and plans to almost triple its production by 2030. Under a business-as-usual scenario, the CO_2 emissions from crude steel production are estimated to grow to almost 2.5 times by 2030. This report provides a detailed insight into the current status of the iron and steel sector and its GHG emissions in India. It suggests a roadmap for the sector, highlighting the pathways for GHG emissions reduction.

Centre for Science and Environment
41, Tughlakabad Institutional Area, New Delhi 110 062
Phones: 91-11-40616000 Fax: 91-11-29955879
Website: www.cseindia.org