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Solutions for Our Climate

SFOC is a nonprofit organization established in 2016 to address the social and environmental impacts of climate change. We conduct research on solutions for reducing greenhouse gas emissions and expanding renewables, and coordinate campaigns with both domestic and international organizations to address the climate crisis.

NOVEMBER 2021

The South Korean Steel Industry and Carbon Neutrality:

Responses, Issues, and Policy Recommendations

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I Introduction

As the climate crisis deepens, major countries have pledged to become carbon neutral and placed carbon neutrality at the top of their national development agendas. Climate crisis response not only has close bearing on a range of government policies and regulations but is also a capital market variable shaping investment decisions.

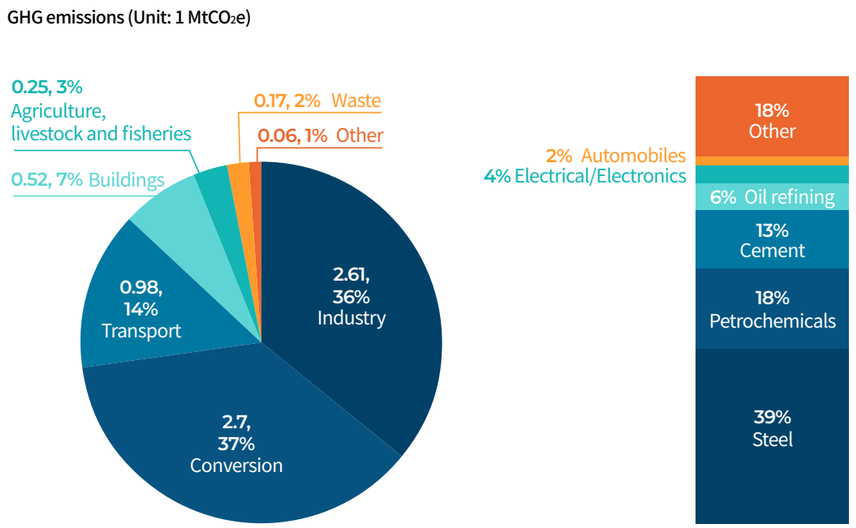
Echoing the global trend, major South Korean steel companies have also declared their commitment to carbon neutrality. The recent launch of the Green Steel Committee with the government and specialized organizations, for instance, appears to reflect this new trajectory. The Korean steel industry is responsible for about 40 percent of the greenhouse gas (GHG) emissions from the country's industrial sector. Success in GHG reduction in the steel industry will therefore be critical to the country's climate crisis response and achievement of carbon neutrality.

Solutions for Our Climate (SFOC) has authored this report to check the current GHG emissions of the Korean steel industry, examine foreign companies' responses, and gain insights to help the country better pursue carbon neutrality. This report, first, provides an overview of the GHG emissions of the Korean steel industry; second, looks into the structure and traits of the Korean steel industry, its key products and leading Korean steel companies, and the industries that it serves; and third, compares foreign and Korean companies, especially in how far they have come in their journeys toward carbon neutrality, in order to suggest issues to consider for the effective delivery of carbon neutrality, as well as providing policy recommendations.

II GHG Emissions: Patterns and Key Traits

1. GHG Emissions

In 2018, South Korea emitted greenhouse gases equivalent to 727 million tons of carbon dioxide, with the industrial sector (including the steel industry) representing about 36 percent of the total. In parallel, the energy conversion sector was responsible for 37 percent of the total emissions. The steel industry is by far the top emitter of greenhouse gases among all industries. In 2018 alone, the industry churned out greenhouse gases equivalent to about 101 million tons of carbon dioxide, accounting for 39.0 percent of the total industrial GHG emissions and 13.1 percent of the total national GHG emissions.



[Figure 1] GHG Emissions by Sector and Steel's Share
Source: Office for Government Policy Coordination 2021

Notably, GHG emissions directly from the steel industry[1] account for more than half (51 percent) of the total GHG emissions from energy use by the Korean manufacturing sector (186 $MtCO_2e$), and the industry's share rose at a faster pace (15.2 percent; see Table 1 below from the Greenhouse Gas Inventory and Research Center (GIR) 2020) than the key manufacturing sector average from 2010 to 2018. There are two key contributing factors. First, the steel industry is by its very nature

1. Excluding indirect emissions from purchase of energy (electricity, heat, etc.) from outside (Scope 2).

energy-intensive. Second, its primary fuel is bituminous coal, which generates a huge volume of carbon emissions per calorie. Bituminous coal produced a staggering 83.6 percent of the energy that the steel industry used in 2017 (GIR 2020).

[Table 1] GHG Emissions from Korean Manufacturing Sectors: Shares and Trends

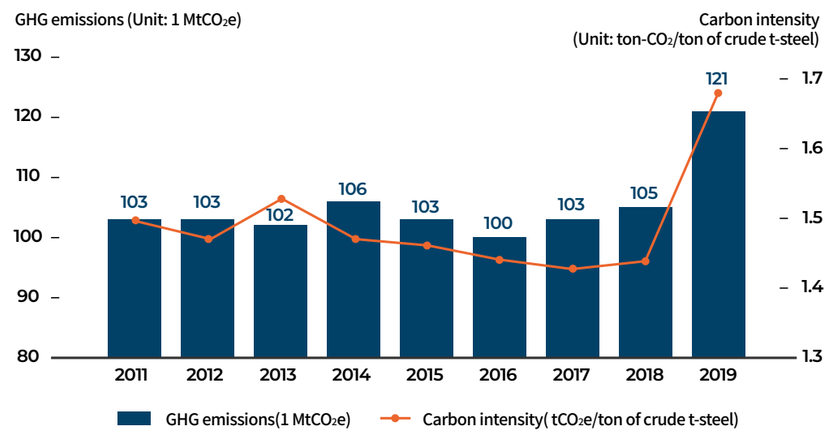
Classification	2010	2012	2014	2016	2018	Share in 2018	10-Year Decrease/ Increase
Steel	76,841	89,290	104,610	93,360	95,288	51.0%	+24.0%
Nonferrous metals	2,344	2,361	2,416	2,674	2,979	1.6%	+27.1%
Chemicals	34,936	40,124	42,602	39,167	45,953	24.6%	+31.5%
Pulp	1,805	1,183	772	646	662	0.4%	-63.3%
Food & Beverages	2,400	2,082	1,842	1,850	1,955	1.0%	-18.5%
Others	43,673	44,568	40,867	43,730	39,759	21.3%	-9.0%
Total	**162,000**	**179,608**	**193,110**	**181,428**	**186,596**	**100.0%**	**+15.2%**

Source: GIR 2020

In 2019, 85 steel companies were listed under South Korea's Greenhouse Gases and Energy Target Management System and its Emission Trading System. Those companies accounted for 99 percent of the GHG emissions from the steel sector in 2019. Their GHG emissions have inched up every year since 2010 at an average pace of 0.27 percent per year, but the carbon emission intensity (or simply emission intensity or carbon intensity) of steel production (which is an indicator that shows the emission rate of carbon relative to the intensity of crude steel production) abated by 0.52 percent every year on average between 2013 and 2018 (see Figure 2 below; Source: GIR and Steel&Metal News 2020).

Figure 2 below may appear puzzling due to the sudden rise in both the GHG emissions and carbon intensity of the steel industry from 2018 to 2019 (which were 14.4 percent and 16.1 percent, respectively). This reversal of the otherwise positive reduction trends can be attributed to the acquisition or rental of additional third-party off-gas power plants by POSCO and Hyundai Steel Co., Ltd. ("Hyundai Steel").[2] Off-gas power plants run on byproduct gases, which include gases produced by blast furnaces (BFG), through the Linz-Donawitz process (LDG), and from coke ovens (COG). As a result of the acquisition and leasehold, the GHG emissions from those off-gas power plants were added to those of the respective acquirer and lessee.

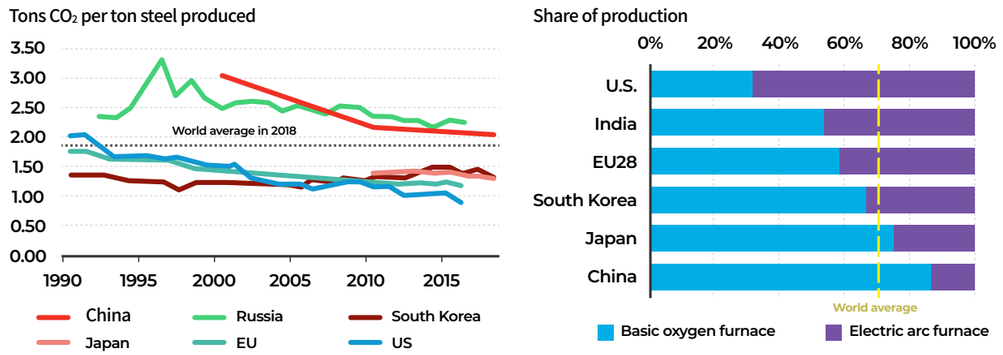
2. In 2019, POSCO took over an off-gas power plant from one of its subsidiaries, POSCO Energy. Hyundai Steel rented from Hyundai Green Power, a joint venture between Hyundai Steel and Korea Midland Power Co., Ltd. (KOMIPO), the off-gas power plant located on the premises of Hyundai Steel Dangjin Steel Mill. Due to this change, the emissions that had previously been attributed to the power generation industry began to be attributed to the steel industry.



[Figure 2] GHG Emissions and Carbon Intensity of the Steel Industry
Based on 2020 data from the GIR and Steel&Metal News

In 2018, South Korean steel companies accounted for about four percent of global crude steel production. Their carbon intensity was 1.45 tCO_2e per ton of crude steel, which was lower than the global average of 1.9 tCO_2e per ton of crude steel. The South Korean steel industry's carbon intensity had been rising steadily since the mid-1990s until it topped in 2014, while the year-on-year declines have not been as impressive as in China, Europe, and the US (see Figure 3 below). Among the major steel producers, China and Russia show the highest carbon intensity of steel production at 2.0 tCO_2e per ton of crude steel, followed by South Korea and Japan (fluctuating around 1.5 tCO_2e per ton of crude steel) and Europe and the US (1.0-1.3 tCO_2e per ton of crude steel). This is not surprising given that China is heavily reliant on blast furnace-basic oxygen furnaces (BF-BOFs) for crude steel production, whereas electric arc furnaces (EAFs) are more widely used in the US and Europe.[3]

3. In 2018, converters were involved in the low 80-percent range of steel production in China, followed by South Korea (the low 60-percent range), Europe (the high 50-percent range), and the US (the low 30-percent range). (Source: Bloomberg New Energy Finance (BNEF), 2021).



[Figure 3] Carbon Intensity Trends in Major Steel Producers
Source: Bloomberg New Energy Finance 2021

In South Korea, 85 steel producers generate over 99 percent of the total GHG emissions from the steel sector. Of these 85 South Korean steel producers, the top two emitters are responsible for about 92 percent of the steel sector's total emissions, and the top ten emitters represent nearly all the emissions from the sector or 96.8 percent (with the remaining 75 companies accounting for only 3.2 percent). The top two emitters are POSCO (66.8 percent) and Hyundai Steel (25.0 percent), and they operate integrated blast furnace-basic oxygen furnaces.

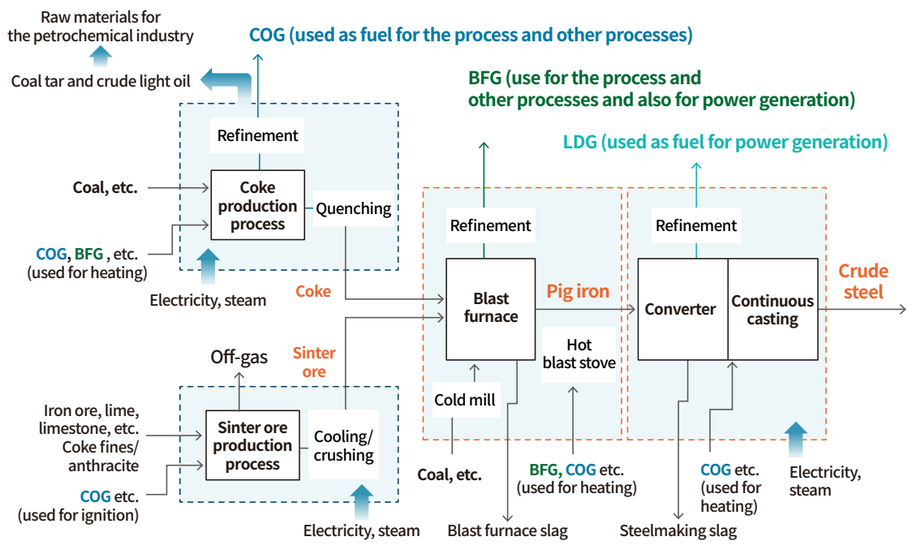
[Table 2] GHG Emissions from South Korean Steel Producers (Unit: 1,000 tCO_2e)

Steel Company	2017	2018	2019	Share in 2019	Remarks
POSCO	71,340	73,121	80,598	66.8%	Blast-converter/electric
Hyundai Steel	21,513	22,514	30,147	25.0%	Blast-converter/ electric
Dongkuk Steel	1,994	1,952	1,879	1.6%	Electric
SěAH Besteel	1,395	1,421	1,228	1.0%	Electric
DB Metal	851	950	778	0.6%	Electric (alloy steels)
SěAH CSS	535	546	511	0.4%	Electric (special steels)
SIMPAC	408	22	463	0.4%	Electric (alloy steels)
KISCO	515	488	399	0.3%	Electric
Daehan Steel	586	412	374	0.3%	Electric
YK Steel	354	352	360	0.3%	Electric
Others (75companies)	3,688	3,745	3,861	3.2%	
Total	**103,180**	**105,526**	**120,597**	**100.0%**	

Source: GIR 2020

Box 1. Off-Gases from the Blast Furnace-Basic Oxygen Furnace and Their Use

- POSCO and Hyundai Steel are the two Korean steel companies that operate blast furnace-basic oxygen furnace (BF-BOF) steel production plants. They use off-gases from the process as fuel for steel production processes and/or power generation.
- POSCO uses 51 percent of the off-gases as fuel directly for production processes and 46 percent for power generation. The remaining three percent is sold to third parties. Some 1.3 GW is produced from off-gases, which covers 91 percent of the electricity that its steelworks consume (Source: POSCO 2021a).
- Hyundai Steel uses 56 percent of the off-gases for hydrogen production or as fuel for steel production and the remaining 44 percent as fuel for its off-gas 800-MW power plant. All electricity produced thereby is used for steel production (Journal of the Electrical World 2017; Hyundai Steel 2021b).
- Off-gases from steel production are less efficient than natural gases and other fuels because they were already combusted while being used for steel production. Therefore, they emit more greenhouse gases than natural gases (3.26 times on average), albeit in different amounts and compositions depending on the type of off-gases (Korea Research Institute of Chemical Technology 2018).



[Figure 4] Generation and Use of Off-Gases from the Blast Furnace-Basic Oxygen Furnace

2. South Korea's GHG Reduction Policy

I 2050 Carbon Neutrality and Long-Term Goals for the Steel Industry

In tandem with the changing paradigm of global responses to the climate crisis, the South Korean government declared a national vision of becoming carbon neutral by 2050 in October 2020. Subsequently, in May 2021, the government launched a Presidential Committee on Carbon Neutrality 2050. On October 18, 2021, the committee discussed three carbon neutrality scenarios and, following feedback and revisions, developed two carbon neutrality scenario road maps to be proposed to the government. The two road maps propose that by 2050, the percentage of new and renewable energy use and the penetration of environmentally-friendly automobiles be raised to up to 70.8 percent and 97 percent, respectively, among other targets.

Through these two scenario-based road maps, the Presidential Committee on Carbon Neutrality 2050 proposes that the steel sector's GHG emissions be lowered by expanding electric arc furnace use and completely replacing coal-based steelmaking processes with hydrogen-based direct reduced iron (DRI), which is also known as sponge iron. The scenarios also call for a greater share of new and renewable energy sources, increased production and supply of green hydrogen, infrastructure construction for CCUS[4] technology, advancement and development of technologies for direct reduction of iron ore and other raw materials, and stimulation of green investment, alongside other policy recommendations.

I Use of the Emissions Trading Scheme (ETS) in Reducing the Steel Industry's GHG Emissions

The GHG Reduction Roadmap developed by relevant ministries in 2018 and the Phase-III Emissions Permit Allocation Plan published by the Ministry of Environment in 2020 show that the South Korean government uses the Emissions Trading Scheme (K-ETS) to regulate industrial GHG emissions and that the current 2030 GHG reduction target (a reduction of 26.3 percent from the 2018 level) and the GHG Reduction Roadmap serve as standards for the allocation of emission permits. About 75 percent of the country's total GHG emissions come from the companies and other entities that participate in the Emissions Trading Scheme. In the steel sector, the 85 companies mentioned earlier, that generate more than 99 percent of the sector's total GHG emissions, fall under the scheme. The 2030 GHG reduction target for the entire industrial sector (which includes the steel industry) proposed a reduction of 20.4 percent versus a 2030 business-as-usual (BAU) level. The government allocates emissions permits based on the carbon intensity benchmarks of key production processes. Notably, in October 2021, the government announced that it may increase the 2030 GHG reduction target to a 40 percent reduction from 2018. This ambitious target, if adopted, is expected to lead to a change in the emissions permit allocation target for the steel industry.

4. CCUS stands for carbon capture, utilization, and storage

I Public-Private Partnership (PPP) for Net Zero Emissions

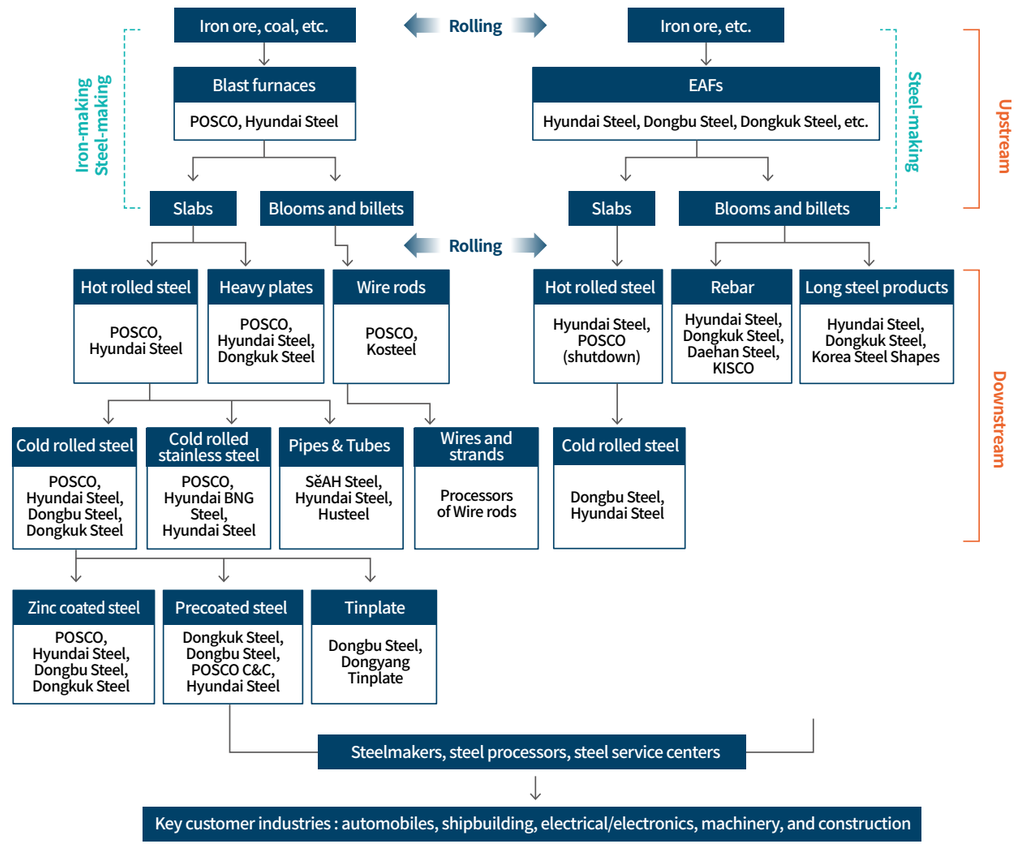
In February 2021, the Ministry of Trade, Industry and Energy formed the Green Steel Committee together with major steel companies and private experts. The committee aims to achieve net zero emissions for the Korean steel industry[5] to facilitate the development of new technology, production structure conversion, information sharing, and international cooperation with the global steel industry. It also aims to help the government develop more effective projects and programs in support of its carbon neutrality policy. The committee's short-term objectives include higher energy efficiency, increased use of low-carbon raw materials, and greater recycling of steel scrap to build a more efficient, circular economy. Its longer-term objectives center around the development of innovative technologies for direct reduced iron (DRI), steel materials for hydrogen storage and transport, and more (Ministry of Trade, Industry and Energy 2021a).

5. Six steel companies POSCO, Hyundai Steel, Dongkuk Steel, KG Dongbu Steel, SěAH Steel, and SIMPAC announced a joint declaration for net zero emissions on February 3, 2021.

III Korean Steel Industry: An Overview and Major Players

1. Structure of the Korean Steel Industry

The steel industry can be broadly divided into two branches - made up of upstream and downstream companies. Upstream steel companies produce pig iron from iron ore using blast furnaces or produce other intermediate inputs from scrap iron, while downstream steel companies process (e.g., roll) intermediate inputs into finished steel products. The upstream route is extremely capital-intensive, so it is a playground for only a handful of big players including POSCO and Hyundai Steel (which use blast furnaces for ironmaking and/or electric arc furnaces for steelmaking) as well as Dongbu Steel and Dongkuk Steel (which produce steel using electric arc furnaces). The downstream, on the other hand, is populated by numerous steel companies (KDB 2020).



[Figure 5] South Korean Steel Industry Ecosystem
Source: KDB 2020

Customer Industries

The automobile, construction, and shipbuilding industries are the three primary customers of South Korean steel companies. These three customer industries consumed about 78 percent of the total steel production in 2018 (KDB 2020). Consequently, the steel industry is very sensitive to changes in these industries. Additionally, electrical/electronics and the machine tool industries are also important customers of South Korean steelmakers.

According to the Korea Iron and Steel Association (KOSA), 83 million tons of steel were produced in 2019. Of the 83 million tons, 53 million tons (approx. 63.9 percent) were used for manufacturing domestic products and the remaining 30 million tons (approx. 36.1 percent) for exports. About 88 percent of total domestic demand for steel products is met domestically, as seen in Table 3-2 below. Major importers of South Korean steel products include China, Japan, India, the US, and Mexico.

[Table 3-1] Demand for South Korean Steel Products (Units: 1,000 tons, %)

Classification	2017	2018	2019
Demand Total	**87,982 (100.0)**	**84,150 (100.0)**	**83,605 (100.0)**
Domestic Demand	56,314 (64.0)	53,710 (63.8)	53,226 (63.7)
Export Demand	31,668 (36.0)	30,440 (36.3)	30,379 (36.3)

[Table 3-2] Supply of Steel Products in South Korea (Units: 1,000 tons, %)

Classification	2017	2018	2019
Supply Total	**87,982 (100.0)**	**84,150 (100.0)**	**83,605 (100.0)**
Domestic Supply	77,073 (87.6)	75,211 (89.4)	73,561 (88.0)
Import Supply	10,090 (12.4)	8,939 (10.6)	10,044 (12.0)

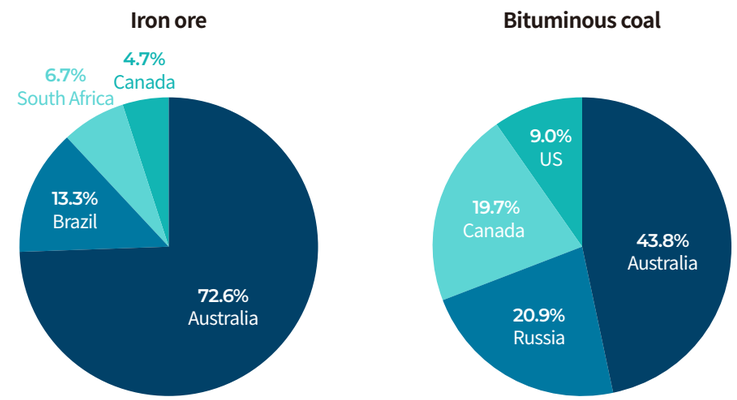
* Domestic demand + export demand = domestic production + imports (excluding semi-finished goods from imports)
Source: KOSA, requoted from KDB 2020

Procurement of Raw Materials

The primary raw materials for the blast furnace-basic oxygen furnace (BF-BOF) steel production process are iron ore and bituminous coal (from which coke is obtained), while steel scrap is the main raw material for electric arc furnaces. All iron ore and bituminous coal that the South Korean steel industry uses are imported. However, about 78 percent of steel scrap is domestically procured in 2021.

In 2019, around 75.6 million tons of iron ore were imported, mostly from Australia (72.6 percent), Brazil (13.3 percent), South Africa (6.7 percent), and Canada (4.7 percent) (KDB 2020). In the same

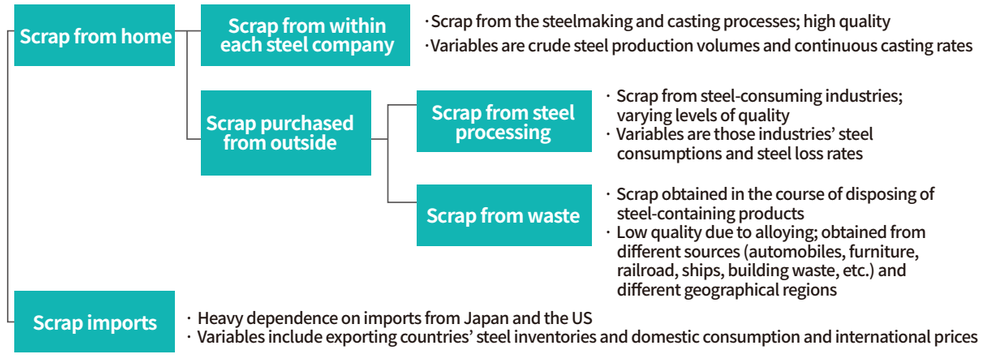
year, about 22.6 million tons of bituminous coal for coke were imported, primarily from Australia (43.8 percent), Russia (20.9 percent), and Canada (19.7 percent) (Korea Institute of Geoscience and Mineral Resources (KIGAM) 2019; see Figure 6 below).



[Figure 6] Major Exporters of Iron Ore and Bituminous Coal to South Korea
Source: KOSA, requoted from KDB 2020

I Steel Scrap

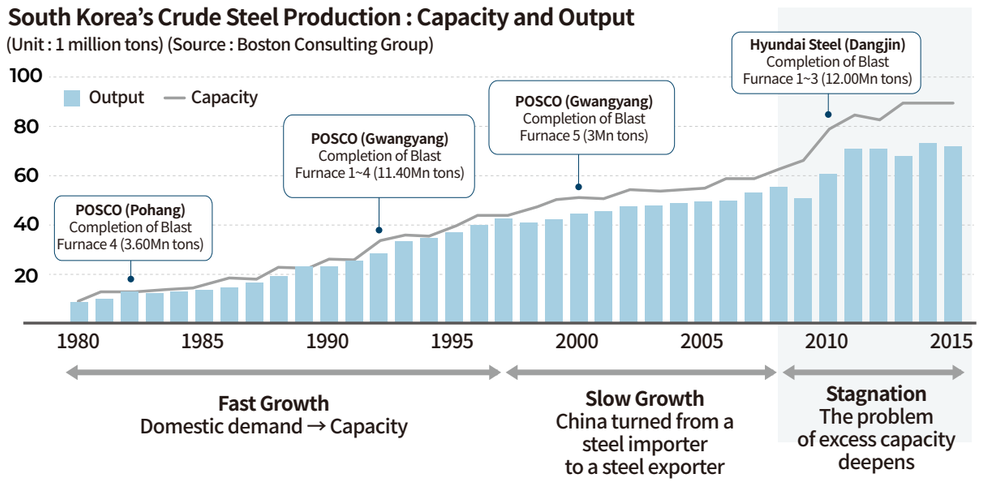
In 2019, 29.0 million tons of steel scrap were used in South Korea, of which 22.7 million tons (78.3 percent) were domestically procured and the remaining approximately six million tons (or 21.7 percent) were imported from Japan, the US, and Russia (KOSA 2020b). There are three major domestic sources of steel scrap: steelmaking by the steel industry, steel processing by steel-consuming industries, and disposal of steel-containing final products. Steel scrap from steelmaking is of relatively high quality, but steel scrap obtained in the course of disposing of steel-containing products is of relatively low quality because the steel is oftentimes in the form of alloys in those products.



[Figure 7] Sources of Steel Scrap and Their Traits
Source: Korea Steel Scrap Industry Association (KOSIA)

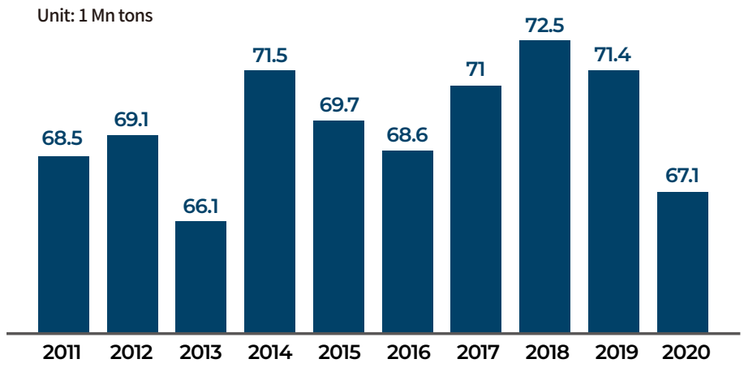
2. Steel Production Capacity and Output

In the mid-1990s, South Korea's crude steel production capacity reached about 40 million tons per year thanks to POSCO's continued investment in steelmaking facilities (e.g., construction of Gwangyang Steelworks) in response to rising domestic demand. This upward momentum slowed down in the late 1990s when China emerged as a strong exporter of steel. In 2009, South Korea's annual crude steel production capacity was about 60 million tons, which grew to about 90 million tons when Hyundai Steel completed construction of the Dangjin Steel Mill in 2013.

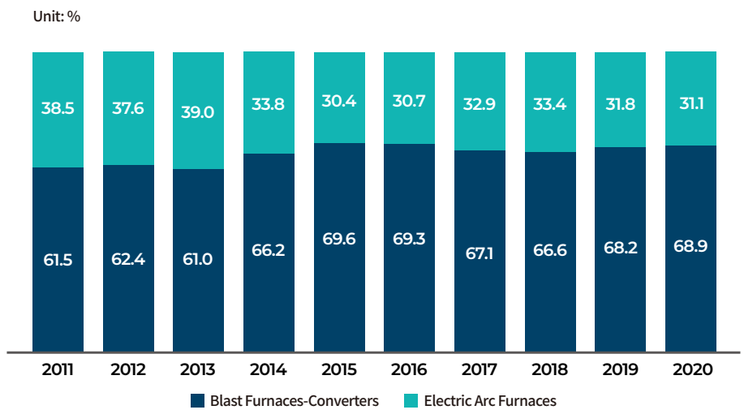


[Figure 8] South Korea's Crude Production Capacity and Actual Output
Source: Maeil Business Newspaper 2016

Until the early 2010s, the country's crude steel output continued to increase as demand for crude steel rose steadily, propelling investment to build or expand facilities. However, crude steel output has remained steady at around 70 million tons per year since 2011 due to a global supply glut. The COVID-19 pandemic has further dampened global demand for crude steel and pulled South Korea's annual crude steel output down to 67 million tons. In 2011, 61 percent of the total crude steel output was produced through the blast furnace-basic oxygen furnace production process. The share rose to about 69 percent in 2013 when Hyundai Steel completed construction of its steel mill in Dangjin, which has three blast furnaces, and has been oscillating between 67 and 69 percent since 2014.



[Figure 9] Crude Steel Output from 2011 to 2020 in South Korea
Source: KOSA 2020



[Figure 10] Steel Output over 2011–2020: Blast Furnaces–Basic Oxygen Furnaces vs. Electric Arc Furnaces
Source: KOSA 2021b

3. Key Steel Products and Customers

South Korea's Key Steel Products

Of the steel products made in South Korea in 2019, hot rolled steel accounted for 22.60 percent (which are primarily used for construction and automobiles), followed by long steel products (13.91 percent), rebar (12.64 percent), cold rolled steel (12.32 percent), medium and heavy plates (12.12 percent), and hot-dip galvanized steel (10.38 percent). Besides these six types of steel products (which represent about 84 percent of all the steel produced in the county), South Korea also produces wire rods, wires and strands, electrogalvanized steel, precoated steel, and tinplate.

[Table 4] 2019 Steel Output and Uses in South Korea (Units: 1,000 tons; %)

Product	Output	Share(%)	Key Uses
Hot rolled (HR)	17,767	22.60	Automobiles, construction, cold rolled steel coils, and wires
Long products	10,937	13.91	Foundation work for plants, buildings, bridges
Rebar	9,938	12.64	Structural materials for civil engineering and construction
Cold rolled (CR)	9,687	12.32	Automobiles, electrical/electronics products; zinc-, tin-, or chromium-coated steel
Medium/heavy plates	9,524	12.12	Ships, bridges, industrial machinery and equipment
Hot-dip galvanized	8,161	10.38	Civil engineering, construction, automobiles and electrical equipment
Wires	4,649	5.91	Carbon steel for boilers, heat exchangers, and piping
Wire rods	3,471	4.42	Assembled metal products, electrical/electronics products; automobiles; general machinery and construction
Precoated	2,235	2.84	Building interiors and exteriors; home appliances
Electrogalvanized	1,635	2.08	Home appliances, computers, office equipment, satellite receivers, safety fences, automotive products, guard rails
Tinplate	606	0.77	Metallic food containers and bottle caps
Total	78,610	100.00	

* Each of the products highlighted in gray represents at least ten percent of the country's total steel output
Source: KOSA 2021b

Hot rolled (HR) steel is produced by rolling steel slabs (semi-finished products usually from the blast furnace-basic oxygen furnace)[6] at high temperature and is used to make automobiles, construction materials, cold rolled steel, and steel wires & strands. Produced by rolling HR steel at room temperature, cold rolled (CR) steel is thinner and easier to process. CR steel is used to make automobiles, electrical/electronics products, and zinc-, tin-, or chromium-coated steel. Heavy plates are produced by rolling slabs and are at least 6 mm-thick. They find general use in shipbuilding and bridge construction. Reinforcing bar (or rebar) refers to thin and long steel bars used to reinforce concrete. Rebar is made by heating and rolling steel billets (semi-finished products produced by melting steel scrap in an electric arc furnace). Long steel products are made by processing molten iron from an electric arc furnace into such shapes as H sections and I sections. Long products are used for foundation work for constructing plants, buildings, and bridges. (KDB 2020)

6. All South Korean steelmakers withdrew from the use of electric arc furnaces for making HR steel because of deteriorating profitability attributable to rising power and scrap prices. In addition, an electric arc furnace cannot produce HR steel of as good quality as that from the blast furnace–converter route (Money Today 2020).

The classification of the aforementioned key product categories is outlined in Table 5 and is dependent on the semi-finished products and production technologies that are used to make them.

[Table 5] Classification of Steel Products by Semi–Finished Product and Technology Used

Steelmaking Technology	Semi-Finished Products	Product Categories
Blast Furnace-Basic Oxygen Furnace (Reduction of Iron Ore)	Slabs	HR steel, heavy plates, pig iron, CR steel, hot-dip galvanized steel, precoated steel, electrogalvanized steel, tinplate
Electric Arc Furnace (Input: Steel Scrap)	Blooms and billets	Long steel products, rebar, wires, and others (alloys, special steel, etc.)

Key Customer Industries: Shares and Traits

In 2019, the three largest customers of the steel industry were construction (30.6 percent), automobiles (27.7 percent), and shipbuilding (19.7 percent). Steel products are also used to manufacture electrical/electronics products, fabricated metal products, and general machinery. Since 2010, the construction and automobile industries have driven demand for steel products, and their shares in the total steel product shipments have risen by 5.2 percentage points and 3.3 percentage points, respectively. In contrast, the shipbuilding portion has declined by about 5.2 percentage points on account of a decade-long slump in the global shipbuilding industry. As shown in the table below, the steel industry remains sensitive to changes in the automobile, construction, and shipbuilding markets.

[Table 6] Shares of Different Customer Industries (Units: %; pp)

Classification	2010	2019	Rise/Fall (pp)
Construction	27.3	30.6	+3.3
Automobiles	22.5	27.7	+5.2
Shipbuilding	24.9	19.7	-5.2
Electrical/Electronics	4.2	5.6	+1.4
Fabricated Metal	8.4	5.3	-3.1
General Machinery	3.4	3.1	-0.3
Others	9.2	8.1	-1.1
Total	100.0	100.0	-

Source: Steel&Metal News 2020

4. Status of POSCO and Hyundai Steel

This section provides a glimpse into POSCO and Hyundai Steel (which account for 90.6 percent of South Korea's crude steel production and more than 92 percent of the GHG emissions from the steel industry) in terms of their business overview, strategies, primary products, target markets, and investments.

POSCO

▶ Business Overview

POSCO is South Korea's first-ever integrated steel plant, founded in 1968. It boasts annual production capacity of about 47 million tons of crude steel today. In 2020, it was the world's sixth largest steel company in respect of crude steel production. The business group to which POSCO belongs posted KRW 57 trillion in revenue in 2020, half of which was represented by steel, followed by international trade (34 percent), construction (11 percent), and other income streams (five percent). Shares of POSCO are traded on the Korea Exchange (KRX) and the New York Stock Exchange.[7]

POSCO's Gwangyang Steelworks and Pohang Steelworks are the world's first and second largest steel mills, respectively, in terms of steel output, and their combined capacity represents 90 percent of POSCO's total crude steel production capacity. POSCO also has overseas operations, including stainless steel mills in China, a heavy plate mill in Indonesia, and steel section mills

7. On December 31, 2020, the largest Korean shareholders of POSCO were the National Pension Service (11.75 percent) and POSCO itself (treasury stock; 12.69 percent), and of the foreign shareholders (50.64 percent), two held stakes of at least five percent: BlackRock Fund Advisors (5.23 percent) and Citibank, N.A. (7.61 percent).

in Vietnam. In 2020, POSCO produced 75.6 $MtCO_2e$ of GHG emissions, with a carbon intensity of about 2.11 tCO_2e per ton of steel, both showing a rise from their levels in 2015 (72 $MtCO_2e$ and 1.91 tCO_2e per ton of steel).

▶ Strategic Direction

In the face of the global steel supply glut and ever intensifying competition, POSCO strives (1) to maximize its competitiveness by focusing on highly profitable, high-end steel products; (2) to further expand in promising low-carbon energy businesses such as LNG production and distribution; and (3) to aggressively develop new businesses in green mobility, including production and marketing of hydrogen and battery materials such as cathode and anode materials (POSCO 2021a). Moreover, following its 2050 net zero pledge, POSCO plans to step up its efforts to develop innovative technologies to render its steelmaking environmentally-friendly (POSCO 2021b).

POSCO has set a target of KRW 17 trillion won in annual revenue from green mobility and low-carbon energy materials by 2030. In the long-term, the company envisions a hydrogen value chain encompassing the entire lifecycle of hydrogen—from production to transport to storage to use—with an objective of building a system to supply 5 million tons of green hydrogen by 2050 (POSCO 2021a).[8]

▶ Primary Products and Their Traits

In 2019, POSCO generated KRW 16.5 trillion in revenue from cold rolled steel (used primarily as automotive steel sheets), which represented 33.2 percent of the company's total annual revenue. Stainless steel accounted for 20.4 percent (KRW 10.1 trillion), hot rolled steel for 16.8 percent (KRW 8.3 trillion), and the remainder (e.g., heavy plates, wire rods, galvanized steel) for 29.3 percent (KRW 14.7 trillion). Cold rolled steel represented only 16.1 percent of POSCO's total production, but it raked in 33.2 percent of its revenue. As a high-end product, stainless steel also accounted for a far greater share of revenue (20.4 percent) than its share of production (8.3 percent)—the former being nearly 2.5 times the latter (see Table 7 below). Currently, around 55 percent of the company's steel products are domestically marketed, and the remainder are exported (POSCO 2021b).

8. Roles of Key Affiliates
POSCO: Development of steel products for fuel cells, production of hydrogen as a byproduct, and development of innovative direct iron reduction technologies
POSCO International: Introduction of hydrogen from abroad for reliable domestic supply of hydrogen
POSCO Energy: Establishment of hydrogen terminals and power generation by hydrogen turbines

POSCO is the world's largest seller of automotive steel sheets, commanding about ten percent of the global market. The company supplies automotive steel sheets to the world's top 15 carmakers including BMW, Benz, Volkswagen, Renault Nissan, Hyundai Motor Company, Kia Corporation, Toyota, Honda, Fiat, Ford, and Peugeot Citroen (CEO Score Daily 2021). Interestingly, POSCO makes more sales of automotive steel sheets abroad than at home, with 60-70 percent of high-end ultralight high-strength automotive steel sheets are sold overseas.

[Table 7] Revenue and Production Shares of Key Product Categories of POSCO in 2019
(Units: 1,000 tons; KRW 100 Mn; %)

Classification	Revenue (Share)	Production (Share)	Primary Uses
HR Steel	83,669 (16.8)	8,739 (19.0)	Wires; structural steel for shipbuilding, machinery, construction, and automobiles
CR Steel	165,374 (33.2)	7,191 (16.1)	Automobiles, electronic products
Stainless Steel	101,347 (20.4)	3,850 (8.4)	Automobile exhaust pipes, kitchenware, electronic products, construction materials, electric vehicle battery cases, LNG storage tanks
Others	147,694 (29.6)	26,020 (56.5)	Heavy plates: structural steel for shipbuilding, construction, heavy equipment, marine & wind power; storage tanks and oil pipelines Wire rods: automobiles, construction of buildings and bridges Galvanized steel: civil engineering, construction, automobiles, and home appliances
Total	498,084 (100.0)	46,025 (100.0)	-

Source: POSCO 2021b

Automotive steel sheets are currently the most lucrative income stream for POSCO and share the company's high value-added brand, WTP (World Top Premium)[9] with other premium products, which include upscale steel products for construction. As a global steelmaker, POSCO is keen to meet the needs of its customers, who are increasingly concerned about the environment and sustainability, so its business strategy has naturally become focused on automotive products for electric vehicles (brand: e-Autopos); steel solutions for construction (brand: Innovilt); and wind power generation, fuel cells, LNG carriers and tanks, and other material solutions for environmentally-friendly energy systems and equipment (brand: Eco Energy), with the aim of seizing the first-mover advantage in future markets and improving profitability (POSCO 2021a).

9. This brand is used for a type of products that involve cutting–edge technology or a technology that is as advanced as to rank at least third in the world and profitable enough (at least ten percent more profitable than ordinary products in terms of profit margin). The WTP brand represented about a quarter of POSCO's steel sales (not in value but in quantity) in 2019, the year in which the company sold more than 10 million tons of WTP products.

▶ Key Investments in Facilities

POSCO's 2020 Business Report (POSCO 2021b) implies that the company will likely invest in enhancing existing production facilities in order to improve productivity, capacity, and the working environment, rather than making huge investments in new facilities. The recent CapEx made by the steelmaker include the improvement of Blast Furnace III at its Gwangyang Steelworks in 2020.

Looking ahead, POSCO plans to build Pohang Steelworks' sixth coke oven plant by 2023 (approx. KRW 1.4 trillion), renovate Gwangyang Steelworks' fourth blast furnace, and improve Pohang Steelworks' off-gas power generation by 2024 (approx. 1.2 trillion). With an eye on forward-looking new business, this steelmaking giant is also expected to invest about KRW 950 billion by 2024 to build new production lines for cathodes and anodes, which are used to make secondary batteries. In addition, POSCO is reportedly keen to acquire ownership to or equity stakes in mines in order to secure mineral resources for materials business (e.g., KRW 300 billion for a salt lake in Argentina with lithium deposits in 2018; KRW 270 billion for a nickel mine in Australia in 2021).

▶ POSCO's Net Zero Strategy

In December 2020, POSCO announced its net zero strategy with three major milestones made up of a 20 percent cut in GHG emissions by 2030, a 50 percent cut by 2040, and carbon neutrality by 2050. As its first step toward the 2050 goal, the South Korean steelmaker is now fully harnessing artificial intelligence and available data to improve the efficiency of its operations. The next step in POSCO's further GHG emissions reductions will be powered by the so-called Hyper Blast Furnace-Basic Oxygen Furnace (Hyper BF-BOF) route, which is a blast furnace-based innovation. Eventually, the steel company aims to develop a new FINEX-based technology to produce only direct reduced iron (DRI), adding a final touch to its big picture of net zero steelmaking driven by hydrogen reduction and renewable energy sources.

The aforementioned Hyper BF-BOF technology is expected to provide a stepping stone in POSCO's journey toward the production of direct reduced iron only until it becomes economically feasible with a reliable supply of green hydrogen and renewable energy-driven power generation. The Hyper BF-BOF route comprises the following three technical means:

I Greater Use of Steel Scrap in the Furnace-Converter Route

The company intends to develop technology that will lower the ratio of hot metal to steel scrap, or the hot metal ratio (HMR), and thereby cut GHG emissions by ten percent. Greater use of steel scrap instead of hot metal also means a reduction in cost since the former is cheaper than the latter. The company also plans to cut GHG emissions by another five percent by developing a technology that will enable direct input of steel scrap into furnaces and the FINEX[10] process.

I Greater Production of DRI Using Pre-Existing Processes

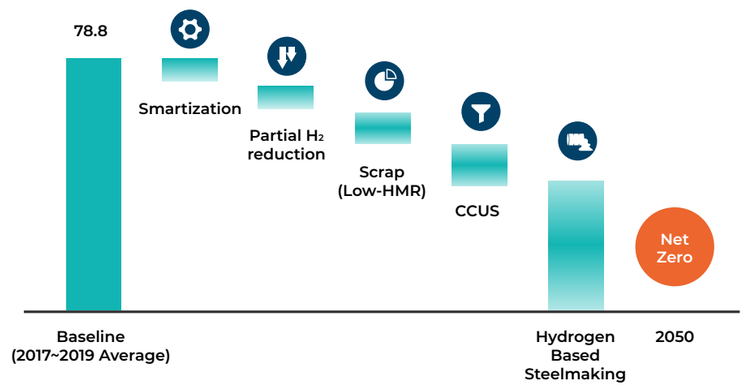
The company seeks to further cut GHG emissions by up to yet another ten percent by applying technologies that will enable the integration of hydrogen-containing off-gases (coke oven gas and off-gases from FINEX) into the traditional blast furnace process and the FINEX process, decreasing the use of bituminous coal for coke production.

I Introduction of CCUS (Carbon Capture, Utilization, and Storage)

The company has already completed a demonstration of a carbon dioxide capture facility of a commercially viable scale. The facility separates carbon dioxide from the off-gases from the FINEX process as the gas mix contains a relatively high level of carbon dioxide, making it easy to capture the primary greenhouse gas. POSCO plans to expand the facility in ten years.

Capitalizing upon the strengths of FINEX, which already integrates hydrogen and DRI technology, POSCO has been working on adopting a more advanced process, HyREX. HyREX inputs green hydrogen into the existing FINEX process, produces direct reduced iron through a cascade of fluidized bed reactors, and melts the direct reduced iron in an electric arc furnace heated by renewable energy sources to produce steel. POSCO plans to gradually increase the concentrations of hydrogen in the two sets of fluidized bed reactors at its Pohang Steelworks plant (annual capacity of 1.5 million tons and 2 million tons, each), complete the development of its HyREX technology in one or two decades, and replace all its blast furnaces with HyREX equipment one after another by 2050.

10. FINEX is a steelmaking process developed by POSCO and Siemens VAI (the predecessor of Primetals Technologies). The process produces molten iron using a series of fluidized bed reactors (FBRs) and a melter–gasifier without charging a blast furnace with iron ore fines and coal. FINEX uses a mix of 25–percent hydrogen and 75–percent carbon monoxide (which are generated during the process) as reducing agents.



[Figure 11] POSCO's Net Zero Roadmap
Source: POSCO 2020

Hyundai Steel

▶ Business Overview

Hyundai Steel was founded under the tradename of Daehan Heavy Industries back in 1953 and is South Korea's oldest steelmaker. The steelmaker is a member of the Hyundai Motor Group and is listed on the Korea Exchange.[11]

In 2020, the company was ranked sixteenth in the world in terms of crude steel production capacity, having produced 19 million tons of crude steel, and generated KRW 18 trillion in revenue. Its annual crude steel production capacity is 24 million tons—12 million tons through the blast furnace-basic oxygen furnace (BF-BOF) and the remaining 12 million tons through electric arc furnaces (EAF).

Hyundai Steel started its operations with electric arc furnaces, but in 2006, the company opened its groundbreaking Dangjin Integrated Steelworks. Two blast furnaces went into operation in 2010 and the final third one in 2013, affording the steelmaker the ability to produce 12 million tons of hot rolled steel and heavy plate steel. By virtue of its merger with Hyundai Hysco's cold rolling division in 2013, the steelmaker's steel production system became all-inclusive. Its plants

11. As of December 31, 2020, the largest shareholder of Hyundai Steel was Kia Corporation (17.27 percent), and the combined stake of the largest shareholder and its related parties totaled 35.97 percent. Besides them, there is one shareholder that retains a stake of at least five percent: the National Pension Service (8.10 percent).

in Incheon, Pohang, Ulsan, Suncheon, and Yesan operate electric arc furnaces. The company also has overseas steel service centers in the US, China, India, the Czech Republic, Slovakia, Russia, Brazil, Turkey, and Mexico where cold rolled steel imports are processed into automotive steel sheets, which is supplied to the local production operations of Hyundai Motor Company and Kia Corporation (Hyundai Steel 2021b).

In 2020, Hyundai Steel generated GHG gases equivalent to 30.1 million tons of carbon dioxide. Overall, its annual volume of GHG emissions has increased since 2016. The company began to rent Hyundai Greenpower's off-gas power plant (located on the premises of the Hyundai Steel Dangjin Steel Mill) for power generation for its own production processes in 2019, and as a result, the year 2019 saw the annual volume jump by 33.9 percent (GIR 2020). The company's carbon intensity of crude steel production is about 1.58 tCO_2e per ton of steel.[12]

▶ Strategic Direction

Hyundai Steel is shifting its strategic focus from quantitative growth in many different areas to focus on several core businesses and high value-added products (for example, it has withdrawn from precoated steel, forging, and wires by, for instance, selling these business units). The steelmaker plans to build a hydrogen production and supply complex, in order to pursue hydrogen business (e.g., materials for hydrogen fuel cells) as a future growth driver in connection with Hyundai Motor Group's strategy for eco-friendly hydrogen vehicles (Hyundai Steel 2021a). The company has also joined hands with five other South Korean steel companies to help the country better respond to climate change and deliver its net zero vision. The six companies expressed their commitment by announcing a joint declaration on carbon neutrality (Ministry of Trade, Industry and Energy 2021a).

▶ Primary Products and Their Traits

More than 60 percent of the total production of Hyundai Steel is dominated by long steel (32.5 percent) and cold rolled steel (29.1 percent). The former is primarily structural steel for civil engineering and construction, and the latter is mostly automotive steel (Hyundai Steel 2020).

The company can produce up to 9.8 million tons of hot rolled steel a year. Its hot rolled steel finds many different industrial applications— including automotive products, structural products, and wires, with hot rolled steel also being used to produce cold rolled steel. The steelmaker's cold rolled steel production capacity is 7 million tons per year. Most of its cold rolled steel products are automotive steel sheets, but also include products for home appliances and exteriors and interiors in construction. The company produces about 5 million tons of automotive steel sheets every year, with over 80 percent of the volume going to Hyundai Motor Company and Kia Corporation. Automotive steel sheets represent over 40 percent of the company's total revenue and over 50 percent of its operating income (E Today 2021; Consumer News, 2020). The Hyundai Steel Dangjin Steel Mill can produce up to 3.5 million tons of heavy steel plates per year, and its heavy plates find a range of applications for shipbuilding, offshore structures, welded structures, oil pipelines, pressure vessels, bridges, and more. More than 85 percent of the company's heavy plates are domestically marketed (Business Watch 2020; Hyundai Steel 2020).

Looking ahead, Hyundai Steel plans to more aggressively grow and market a range of premium brands including H-CORE (high-performing seismic resistant steel products for construction and civil engineering), RH+ (large steel sections), and H-SOLUTION (ultralight, high-tensile automotive products) in order to bolster its presence in high value-added products.

[Table 8] Hyundai Steel's Major Product Categories' Shares in Production in 2019 (Units: 1,000 tons; %)

Classification	Production	Share	Key Applications
Long Steel	7,573	32.5	Structures and materials for construction
HR Steel	3,347	14.4	Automotive materials, construction materials, industrial equipment
Heavy Plates	2,630	11.3	Structures in civil engineering, shipbuilding
CR Steel	6,772	29.1	Automotive steel sheets, electrical/electronics products, etc.
Wires/Others	2,981	12.8	Piping, industrial equipment
Total	23,303	100.0	-

Source: Hyundai Steel 2020

▶ Key Facility Investments

Since the mid-2010s, Hyundai Steel has focused on improving or adding to the existing production lines rather than building new steel production mills. The investments that the company has made over the decade include adding new lines to its steelworks in Incheon, Pohang, Dangjin, Suncheon, and Ulsan in 2020 (KRW 851.5 billion); replacement of the air pollutant reduction equipment of the sinter furnaces of the Dangjin Integrated Steelworks in 2017-2019 (KRW 403.3 billion); and installment of automotive steel processing lines in the Czech Republic in 2019-2020 (KRW 40.3 billion) (Hyundai Steel 2021a).

12. Hyundai Steel produced 21.56 million tons of crude steel in 2019 (World Steel Association 2020). The reason for its lower carbon intensity than POSCO is its use of electric arc furnaces, as well as blast furnaces

This trend is expected to continue, with the company continuing to invest in infrastructure and equipment improvements with a focus on domestic operations (KRW 1.7 trillion). Additionally, Hyundai Steel is also reviewing the feasibility of investments for more overseas production operations in Mexico and other countries, greater capacity to produce fuel cell separators, and a new production facility to enter hydrogen business (up to KRW 250 billion) (Kiwoom Securities 2021).

IV Conclusion

In 2018, the annual volume of GHG emissions from the South Korean steel industry amounted to about 100 $MtCO_2e$ or 39 percent of the total GHG emissions from all industries, and it s annual emission is increasing faster than the average of the entire manufacturing sector. POSCO and Hyundai Steel are responsible for around 92 percent of the total GHG emissions from the steel industry. The country's crude steel production represents about four percent of the global total, having had grown steadily until 2010 and then stagnated at around 70 million tons per year due to a global supply glut. In 2019, 64 percent of the total production was consumed at home, with 78 percent of the domestically-consumed steel products supplied to the automobile, construction, and shipbuilding industries.

POSCO was ranked as the world's fifth largest crude steel producer in 2019. The company generates 75.6 $MtCO_2e$ per year, accounting for 66.8 percent of the South Korean steel industry's GHG emissions. POSCO's best-selling products are cold rolled automotive steel sheets, which accounted for about 33.2 percent of the company's annual revenue in 2019. Customers include the world's top 15 automakers, such as Volkswagen and Toyota. Hyundai Steel was ranked 16th in crude steel production in the world and generated 30 $MtCO_2e$ of GHG emissions (which accounted for 25.0 percent of the total GHG emissions from the South Korean steel industry) in 2020. Its product portfolio is commanded by long steel for construction and cold rolled automotive steel sheets, which account for 32.5 percent and 29.1 percent of the steelmaker's total production quantity, respectively (their combined share adding up to over 61 percent). Over 80 percent of the five million tons of automotive steel sheets that Hyundai Steel annually produces are sold to Hyundai Motor Company and Kia Corporation, its affiliates.

The South Korean government publicly pledged to realize carbon neutrality by 2050 in October 2020 and published two proposed carbon neutrality scenario-based roadmaps in October 2021. The scenarios suggest that the steel industry should replace the carbon-powered steel production process (the blast furnace-basic oxygen furnace) with a hydrogen-driven process to produce direct reduced iron (DRI) and increase the use of steel scrap and electric arc furnaces to cut the industry's GHG emissions by 2050. In December 2020, POSCO published a strategy and a roadmap outlining its carbon neutrality vision. The roadmap identified three milestones—a 20 percent GHG reduction by 2030, a 50 percent reduction by 2040, and eventually net zero by 2050. In February 2021, six steel companies including POSCO and Hyundai Steel jointly declared their intentions to

reach net zero by 2050.

We cannot forget that the steel industry produces more greenhouse gases than any other industry. For humanity to walk on a 1.5-degree pathway and achieve net zero emissions, the steel industry must make fundamental changes to the way it produces steel. True, technological innovations and trials are being made to expand green technologies such as green hydrogen based direct reduced iron, but the government must play a key role in galvanizing steelmakers into fast action by virtue of the following points:

First, the government needs to pave way for low-carbon, environmentally-friendly steel products to effectively compete in the market. Specifically, the government may want to consider establishing certification systems and sets of criteria to vouch for the quality of environmentally-friendly steel products or introducing environmental criteria for steel products that are procured for public projects. In the US, for example, the governments of California and other major states apply environmental criteria to certain materials used in public projects including steel, and have put in place systems that require bidders to satisfy these standards.

Second, the government needs to bolster renewable energy-driven power generation and support the establishment of diverse distribution channels of renewable energy, which will, in turn, help steelmakers effectively use green hydrogen (which is produced from renewable energy) to produce direct reduced iron. POSCO states that it needs 3.7 million tons of green hydrogen annually to achieve net zero by 2050, and the production of green hydrogen in that amount requires a renewable energy power plant with capacity of about 3.7 GW. These needs cannot be met without improving the way that electric power from renewable energy sources is supplied and the way permits and licenses for renewable energy businesses are issued. It is also important to invest in building a supply chain that secures a reliable supply of green hydrogen from abroad.

Third, it is critical for not only the government but also steel companies to be more proactive. It is true that POSCO has formulated short-, mid-, and long-term plans for net zero by 2050, but these plans are not as concrete as other roadmaps produced by industry players around the globe. For example, ArcelorMittal presents concrete plans for large-scale demonstration projects, follow-up projects, commercial uses, and demonstrates zero-carbon technologies at a certain plant. The world's second largest steelmaker intends to hone those unfinished technologies into commercially viable ones to apply to other business sites within five years. However, POSCO appears to remain focused on the improvement of process efficiency until 2030 and fails to

present any concrete ideas regarding the development and use of low-carbon steelmaking technologies. Other South Korean steel companies are also called upon to flesh out their objectives and business plans to decarbonize their steelmaking processes and forge a genuine pathway to net zero. It goes without saying that the government and the market are urged to provide increased support and monitoring assistance to facilitate this transition to a net zero future.

Lastly, to solidify the cooperation between the public and private sectors, the government should also provide a level of support for the accelerated development of commercially viable carbon-free steelmaking technologies, including innovative DRI technology.

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SFOC is a nonprofit organization established in 2016 to address the social and environmental impacts of climate change. We conduct research on solutions for reducing greenhouse gas emissions and expanding renewables, and coordinate campaigns with both domestic and international organizations to address the climate crisis.