

Research Report
Cross-Border Environmental Accountability and Industrial
Standards in the Indonesia-Korea of Iron-Steel Integrated Industry



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Aksi Ekologi dan Emansipasi Rakyat (AEER)
and
BigWave / Korean Youth Climate Network

Research Writer:
Mahfita Ardyarum (AEER)
Jasmine Exa Kamilia (AEER)
Hong Dayeh (BigWave)

Reviewer:
Pius Ginting (AEER)

I. Introduction	3
1.1 Background	3
1.2 Problem Statement	4
1.3 Objectives	5
II. RESEARCH METHOD	6
2.1 Data Types and Sources	6
2.2 Data Analysis	6
III. DISCUSSION	8
3.1 Integrated Process and Emission in the Steel Industry	8
3.2 Regulatory and Legal Architecture Iron-Steel Industry in Indonesia-Korea	10
3.2.1 Regulatory and Legal Architecture Iron-Steel Industry in Indonesia	10
3.2.2 Regulatory and Legal Architecture Iron-Steel Industry in South Korea	13
3.2.3 Gap Analysis Regulatory and Legal Architecture Iron-Steel Industry in Indonesia-Korea	26
3.3 Iron-Steel Industry Players in Both Indonesia-Korea	29
3.4 Global Benchmark and Their Reflection in National Regulation	33
3.4.1 IFC EHS Guidelines for Integrated Steel Mills	33
3.4.2 WHO AQG	38
3.4.3 Europeans Best Available Technique (EU BAT)	45
3.4.4 Gap Analysis Global Benchmark and Practices of Iron-Steel Industry of Indonesia-Korea	51
3.5 Regulation that Supports or Impedes Steel Decarbonization	53
3.6 Measure to Strengthen Decarbonization in Cross-Jurisdictional Steel Operation	63
IV. CONCLUSION	69
V. REFERENCES	71

I. Introduction

1.1 Background

Steel is a strategic material that underpins modern economic development and serves as a key component of infrastructure supporting the global energy transition. Global steel demand is projected to continue increasing at an average annual rate of 0.9% through 2030. However, the expansion of steelmaking capacity has outpaced demand growth, resulting in an estimated excess capacity of up to 640 million tonnes in 2025, which is projected to increase to approximately 745 million tonnes by 2028, with Asia accounting for the largest share of this overcapacity¹. Against this backdrop, environmental performance is no longer solely a matter of regulatory compliance, but is increasingly linked to industrial competitiveness, market access, financing strategies, and companies' positions within global value chains.

The Blast Furnace–Basic Oxygen Furnace (BF–BOF) route remains dominant in global steel production. This coal-intensive production route generates substantially higher greenhouse gas emissions than alternative production pathways, such as Scrap–Electric Arc Furnace (EAF) and Direct Reduced Iron–Electric Arc Furnace (DRI–EAF), with emissions of approximately 2.34 tonnes of CO₂ per tonne of crude steel². In addition to greenhouse gas emissions, integrated steelmaking processes generate various other environmental pollutants, including particulate matter (PM), sulfur dioxide (SO₂), nitrogen oxides (NO_x), wastewater, and solid waste.

Growing pressure on the steel industry to transition toward lower-emission production has increased the relevance of international environmental benchmarks. For ambient air quality, the WHO Global Air Quality Guidelines provide health-based guideline levels for pollutants such as particulate matter (PM), SO₂, NO₂, and other air pollutants. At the facility level, the IFC Environmental, Health, and Safety Guidelines for Integrated Steel Mills provide Good International Industry Practice (GIIP) for emission control and environmental management in steelmaking facilities. Meanwhile, the EU Best Available Techniques (BAT) Conclusions for Iron and Steel Production provide benchmarks for Best Available Techniques, associated emission levels, energy efficiency, waste management, and environmental monitoring across different stages of iron and steel production. Although these three frameworks serve different purposes, they are complementary in assessing ambient air quality, facility-level environmental performance, and the technologies and processes employed in steel production.

Indonesia has emerged as one of the locations for expanding steelmaking capacity in Southeast Asia through both domestic and foreign investment. Within the context of cross-border investment in the steel industry, Indonesia–South Korea relations through PT Krakatau Posco represent a strategically relevant case study. PT Krakatau Posco is a joint venture between PT Krakatau Steel and POSCO of South Korea and operates an integrated

steel mill based on the BF–BOF route, with an annual production capacity of approximately 3 million tonnes. The case is particularly relevant given that POSCO in South Korea has established net-zero targets and is developing low-carbon steelmaking technologies, including hydrogen-based production technologies. Accordingly, Krakatau Posco represents an important intersection between a multinational corporation's decarbonization commitments in its home country and the implementation of environmental sustainability practices in its host country.

However, corporate commitments are not necessarily implemented uniformly across global facilities. Differences in regulatory frameworks, installed technologies, investment structures, energy systems, and governance arrangements may result in variations in the implementation of environmental and decarbonization standards. Existing research on the steel industry has predominantly focused on low-carbon technologies and transition policies, while empirical assessments of the consistency of sustainability commitments implemented by multinational corporations across home- and host-country operations remain limited.

Against this background, this study aims to examine the consistency of sustainability and decarbonization standards implemented at PT Krakatau Posco by comparing corporate commitments and operational practices in South Korea and Indonesia. The assessment will cover emissions and ambient air quality, pollutant control, production technologies, and corporate decarbonization commitments, using Indonesian regulations alongside the WHO Global Air Quality Guidelines, IFC Environmental, Health, and Safety Guidelines, and EU BAT Conclusions as reference benchmarks. The study will further identify regulatory, governance, investment, and technological factors that may contribute to differences in implementation between the two countries. The findings are expected to provide a basis for recommendations toward greater harmonization of environmental standards in cross-border steel industry investments.

Accordingly, this study focuses on air emissions as a defined environmental boundary, given the particularly significant contribution of iron and steel production to atmospheric pollution and greenhouse gas emissions, while acknowledging that wastewater, soil contamination, and solid waste generation remain relevant environmental risks outside the scope of the present analysis.

1.2 Problem Statement

Cross-jurisdictional investment in the steel industry is not solely aimed at promoting economic development and facilitating technology adoption among the countries involved. It should also ensure the consistent application of sustainability standards aligned with those of the investing country and more stringent global benchmarks, while still taking into account relevant local regulatory requirements. Therefore, this study seeks to examine how differences in, and the harmonization of, sustainability regulations between Indonesia and South Korea reflect or address the potential for double standards in the cross-jurisdictional steel industry.

Q1: How do Indonesian and South Korean regulations govern the implementation of sustainability standards and decarbonization measures in the steel industry?

Q2: To what extent are these regulations aligned with or different from the WHO Air Quality Guidelines (AQG), IFC Environmental, Health, and Safety (EHS) Guidelines, and EU Best Available Techniques (BAT) Conclusions as global reference standards?

Q3: How can regulatory harmonization and the decarbonization ambitions of the home country be consistently applied to steel industry operations in the host country to prevent double-standard practices?

1.3 Objectives

1. Analyze Indonesian and South Korean regulations governing the implementation of sustainability standards and decarbonization measures in the steel industry.
2. Compare the alignment of both countries' national regulations and steel industry practices with global reference standards, including the WHO Air Quality Guidelines (AQG), IFC Environmental, Health, and Safety (EHS) Guidelines, and EU Best Available Techniques (BAT) Conclusions.
3. Identify approaches for harmonizing regulatory requirements and home-country decarbonization ambitions so that they can be applied consistently to steel industry operations in the host country, thereby preventing double-standard practices in cross-jurisdictional steel investments.

II. RESEARCH METHOD

2.1 Data Types and Sources

This study is a collaborative research project conducted by two research institutions based in Indonesia and South Korea, reflecting the strategic cooperation between the two countries in the steel sector. The study draws on environmental regulations and policy instruments applicable in each jurisdiction to assess the implementation of sustainability standards and steel-industry decarbonization measures. To identify potential double-standard practices in steel operations spanning the two jurisdictions, the analysis uses evidence relating to PT Krakatau POSCO in Indonesia and POSCO's operations in South Korea. The data sources include corporate environmental commitments and Environmental Impact Assessment (EIA) documents, sustainability reports, and/or corporate decarbonization roadmaps.

2.2 Data Analysis

Regulatory provisions governing emission standards (both stack emissions and ambient air quality), pollution control, requirements for transition to environmentally preferable technologies, the investment climate, and supply-chain accountability in Indonesia and South Korea are examined using comparative regulatory analysis and gap analysis. These methods are used to identify gaps between national regulatory requirements and their implementation in practice.

The analysis compares the policy frameworks of the two countries, with Indonesia treated as the host country and South Korea as the home country, in order to assess the consistency of sustainability-standard implementation in cross-jurisdictional steel-industry cooperation. The regulations of both countries are subsequently benchmarked against global reference frameworks, including the WHO Air Quality Guidelines (AQG), IFC Environmental, Health, and Safety (EHS) Guidelines, and EU Best Available Techniques (BAT) Conclusions, to assess their relative levels of environmental protection and emission control.

Each regulatory parameter is classified according to five analytical dimensions:

- **Regulatory coverage:** the existence and scope of relevant regulatory obligations in the host country and home country;
- **Relative regulatory stringency:** a comparison of the requirements or regulatory thresholds applied in Indonesia and South Korea;
- **Stringency relative to global reference standards:** a comparison of Indonesian and South Korean requirements against the WHO AQG, IFC EHS Guidelines, and EU BAT Conclusions, according to the relevance of each parameter;

- **Implementation differences:** a comparison between formal regulatory requirements and evidence of their implementation in home-country and host-country operations; and
- **Potential double standards:** identification of material differences in standards or implementation between home-country and host-country operations that cannot reasonably be explained by differences in regulatory context, technology, or operational characteristics.

The results are used to identify potential double standards more comprehensively and to provide a basis for recommendations on harmonizing sustainability policies in cross-border steel-industry investment.

III. DISCUSSION

3.1 Integrated Process and Emission in the Steel Industry

Steel is produced through a sequence of processes that generally includes pretreatment, ironmaking, steelmaking, casting, and rolling. Before iron oxides are reduced, pretreatment processes such as coke making, sintering, and pelletizing are typically used in ore-based production routes. Coke ovens heat coal at high temperature in the absence of oxygen to produce coke, which functions as a reducing agent, a source of energy and carbon, and a structural support material within the blast furnace. Sintering agglomerates fine iron ore to achieve the particle size, strength, and porosity required for blast-furnace operation. Pelletizing, by contrast, forms concentrated iron ore into pellets with specified dimensions and mechanical strength. These pellets can be used as feedstock for either blast furnaces or direct-reduction processes.

Following pretreatment, ironmaking converts iron oxides (Fe_3O_4 , Fe_2O_3 , or FeO) into metallic iron by removing oxygen. Depending on the reduction mechanism and operating conditions, ironmaking technologies can be grouped into Blast Furnace (BF), Direct Reduction (DR), and Smelting Reduction routes. In a blast furnace, iron-oxide feedstock is smelted with coke and limestone at very high temperatures to produce hot metal containing approximately 4-5% carbon. Limestone decomposes to CaO , which acts as a flux and reacts with impurities, particularly silica, to form slag that separates from the hot metal. In Direct Reduction, iron oxides are reduced in the solid state without being melted, producing Direct Reduced Iron (DRI), also known as sponge iron. Smelting Reduction combines reduction and smelting using non-coking coal, natural gas, and/or hydrogen to produce liquid iron³.

Steelmaking follows ironmaking and is intended to reduce carbon content, remove impurities, and add alloying elements such as manganese, chromium, and nickel to achieve specified technical properties. The two principal steelmaking routes considered in this study are the Basic Oxygen Furnace (BOF) and Electric Arc Furnace (EAF). In the BOF route, high-purity oxygen reacts with carbon and other impurities while the molten iron is converted into steel. Unlike the BOF route, an EAF can use scrap as its primary feedstock, with DRI or liquid iron added as required to control composition and product quality. The EAF uses electrodes to generate an electric arc that melts solid metallic feedstock, thereby avoiding the direct use of coal for melting⁴.

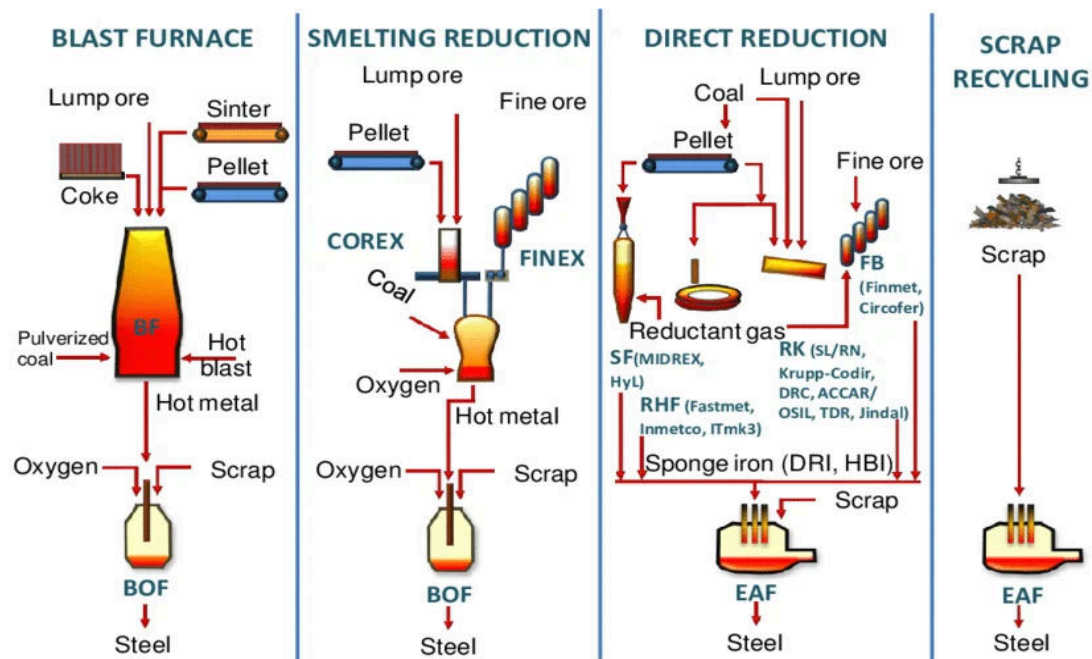


Figure 1. Route of Iron-Steel Making Process^{3,4,6}

After primary steelmaking, liquid steel generally undergoes secondary metallurgy to adjust temperature, chemical composition, and cleanliness before entering continuous casting. During continuous casting, liquid steel is formed into semi-finished products such as slabs, billets, and/or blooms. These products can then undergo hot rolling, cold rolling, and other finishing processes according to final product specifications.

The type and magnitude of emissions generated throughout steel production depend strongly on the technology, feedstock, fuel type, operating conditions, and emission-control systems applied. As illustrated in Figure 1, sintering is a notable source of SO_2 , NO_x , CO , and particulate emissions. CO_2 emissions are particularly significant at coal-intensive process hotspots such as coke ovens, ironmaking, and steelmaking operations that continue to depend on biomass and/or coal⁵. Certain processes may also emit hazardous pollutants, including volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), heavy metals, and polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs). Sintering has been identified as a major hotspot for PCDD/F emissions⁶.

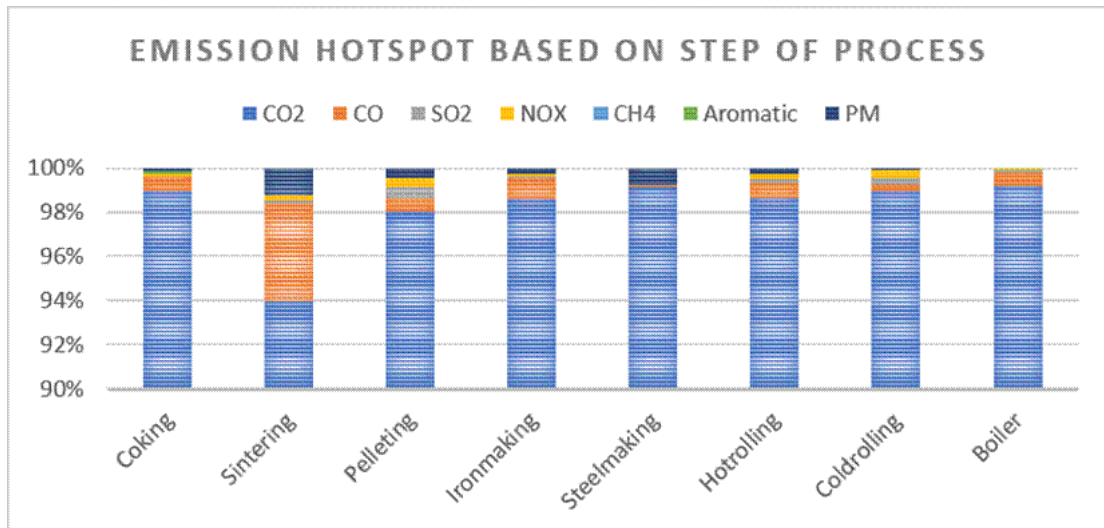


Figure 2. Emission Hotspots by Process Stage of Iron-Steel Industry⁵

Downstream processes such as continuous casting, hot rolling, cold rolling, and annealing can also generate emissions, although their characteristics differ from those of reduction and smelting processes. In hot rolling, for example, a reheating furnace is used to heat slabs or billets before mechanical deformation. Fuel combustion in the reheating furnace generates direct emissions, primarily CO₂, NO_x, CO, and particulate matter, while electricity consumption by the rolling mill produces indirect emissions that depend on the electricity mix. The literature indicates that reheating furnaces can account for approximately 15-20% of total steel-industry energy consumption, particularly at facilities using fossil fuels⁴.

3.2 Regulatory and Legal Architecture Iron-Steel Industry in Indonesia-Korea

3.2.1 Regulatory and Legal Architecture Iron-Steel Industry in Indonesia

1. Process- or Facility-Based Regulation

Since 1995, Indonesia has regulated stationary-source emissions from the iron and steel industry through the Minister of Environment Decree No. 13/1995. Annex I-A specifically established emission limits for iron and steel facilities. The decree was subsequently revised in 2000, with iron- and steel-process emission standards retained in Annex I-B and several emission limits tightened.

Table 1. Changes in Emission Limits for Iron and Steel Facilities between Annex I-A and Annex I-B of Kepmen LH No. 13/1995

Source or process	Param.	Annex I-A (mg/m ³)	Annex I-B (mg/m ³)	Direction

Raw-material handling	PM	600	150	75% tighter
Basic oxygen furnace	PM	600	150	75% tighter
Electric arc furnace	PM	600	150	75% tighter
Reheating furnace	PM	600	150	75% tighter
Annealing furnace	PM	600	150	75% tighter
Pickling and regeneration	PM	600	150	75% tighter
Pickling and regeneration	HCl	10	15	50% weaker
Power boiler	PM	400	230	42.5% tighter
Power boiler	SO ₂	1,200	800	33.3% tighter
Power boiler	NO _x	1,400	1,000	28.6% tighter
Listed sources	Opacity	40%	20%	50% tighter

The limits in Annexes I-A and I-B were expressed under standardized gas conditions of 25°C and one atmosphere. Particulate concentrations from combustion processes were corrected to 10% oxygen, and compliance was required for 95% of normal operating time over a three-month period. The revision therefore did not uniformly tighten every parameter: although most particulate limits became more stringent, the HCl limit was relaxed from 10 to 15 mg/m³.

The decree also allows provincial governors to establish more stringent regional limits and requires the involvement of relevant stakeholders in that process. More stringent requirements contained in an environmental impact assessment or facility-specific approval may supersede the national default. Operators are also required to maintain daily records, submit periodic reports, and report abnormal operating events⁷.

However, the regulation does not disaggregate 'raw-material handling' into process-specific categories such as stockpiling, sintering, and pelletizing. As a result, the particulate-matter requirement remains broad and does not separately address SO₂ and NO_x emissions generated at these process stages. Annexes I-A and I-B primarily regulate conventional air pollutants with direct implications for human health. Other relevant pollutants, including greenhouse gases such as CO₂, as well as

CO, VOCs, and PCDD/Fs, are not incorporated into these process-specific emission limits.

At the same time, investment in Indonesia's iron and steel industry remains dominated by coal-based production routes. Approximately 80% of ironmaking capacity is estimated to use blast furnaces, while around 70% of steelmaking relies on the Basic Oxygen Furnace, both of which are major CO₂-emission hotspots⁸. Permen LHK No. 5/2021 refers to emissions such as CO₂, CO, VOCs, and other particulate pollutants; however, it does not establish sector-specific emission-limit values for these parameters. Instead, the regulation primarily governs procedures for technical approvals and operational-feasibility certificates in environmental pollution control⁹.

2. Air-Emission Control Regulation

Building on Kepmen LH No. 13/1995, Indonesia subsequently strengthened requirements for automatic and continuous emission monitoring through the Continuous Emissions Monitoring System (CEMS), as regulated by Permen LHK No. 13/2021. CEMS is used to monitor exhaust gases from stationary sources by measuring emission quantity, concentration, and flow rate before release to the atmosphere. The system is integrated with the environmental information platform SISPEK, which is connected to the Ministry of Environment.

CEMS requirements are also embedded in Government Regulation (PP) No. 22/2021, which treats emission monitoring as part of the Environmental Approval framework. Accordingly, PP No. 22/2021 requires exhaust-gas emission monitoring to be considered from the project-planning stage and incorporated into environmental-impact monitoring and management requirements, while Permen LHK No. 13/2021 provides the technical procedures for CEMS implementation.

In general, CEMS is installed downstream of gas-cleaning or dedusting systems. Annexes XI-XIII of Permen LHK No. 5/2021 require technical standards to include the design of emission-control infrastructure and equipment. For particulate matter, the regulation identifies technologies such as electrostatic precipitators (ESPs), baghouse filters, fabric filters, and cyclones. For gaseous pollutants, it identifies technologies including scrubbers, selective catalytic reduction (SCR), selective non-catalytic reduction (SNCR), flue-gas desulfurization (FGD), ammonia scrubbing, and other control technologies, although these provisions are not specific to the iron and steel sector⁹.

Within the technical assessment for emission discharge, the monitoring plan must specify the location and coordinates of monitoring points, stack diameter or dimensions, stack height, and the position of sampling ports for each stack. The referenced provisions place sampling points at locations equivalent to 8D downstream and 2D upstream of flow disturbances, such as bends, expansions, or contractions, in order to obtain samples representative of the emission flow⁹. Consequently, potential unmonitored emission pathways, bypasses, fugitive

emissions, or process sources that are not connected to a CEMS-monitored stack must be assessed on a source-by-source basis rather than through CEMS alone.

A simple count of monitored stacks is not sufficient. CEMS coverage should be evaluated by:

$$CEMS \text{ mass coverage} = \frac{\text{annual pollutant mass from CEMS} - \text{covered sources}}{\text{total annual pollutant mass from all sources}}$$

The higher the mass-coverage value, the greater the share of total emissions that is directly monitored by CEMS, providing an indication of the transparency and effectiveness of industrial emission monitoring.

3. Ambient-Air Quality Regulation

Indonesia's current national ambient-air quality standards are established under PP No. 22/2021. Ambient air quality is causally linked to emissions because pollutants released by industrial activities, vehicles, and other sources affect pollutant concentrations in the surrounding outdoor environment.

Prior to PP No. 22/2021, Indonesia regulated ambient air quality through PP No. 41/1999, which included a 30-day dustfall standard of 10 tonnes/km²/month for residential areas and 20 tonnes/km²/month for industrial areas. It also included total fluoride, fluoride index, chlorine/chlorine dioxide, and sulfate-index parameters. The national ambient-air table under PP No. 22/2021 no longer includes dustfall as a principal national parameter. Nevertheless, PP No. 22/2021 tightened several conventional pollutant limits:

Table 2. Comparison of Ambient-Air Quality Limits under PP No. 41/1999 and PP No. 22/2021

Parameter and period	PP 41/1999	PP 22/2021	Assessment
SO ₂ , one hour	900 µg/m ³	150 µg/m ³	Much tighter
NO ₂ , one hour	400 µg/m ³	200 µg/m ³	Tighter
PM ₁₀ , 24 hours	150 µg/m ³	75 µg/m ³	Tighter
PM _{2.5} , 24 hours	65 µg/m ³	55 µg/m ³	Slightly tighter
PM _{2.5} , annual	15 µg/m ³	15 µg/m ³	Unchanged
TSP, 24 hours	230 µg/m ³	230 µg/m ³	Unchanged
Dustfall, 30 days	10/20 t/km ² /mo	N/A	Coverage lost

The current PP No. 22/2021 table sets SO₂ limits of 150 µg/m³ for one hour, 75 µg/m³ for 24 hours and 45 µg/m³ annually; NO₂ limits of 200, 65 and 50 µg/m³ over the same periods; PM₁₀ limits of 75 µg/m³ over 24 hours and 40 µg/m³ annually; and PM_{2.5} limits of 55 µg/m³ over 24 hours and 15 µg/m³ annually.

Overall, PP No. 22/2021 is more stringent for several major inhalation pollutants, while PP No. 41/1999 provided broader coverage of coarse deposition and certain chemically specific pollutants. Dustfall could therefore serve as a supplementary local or permit-level indicator around integrated steelworks. It should not replace PM_{2.5} or PM₁₀ monitoring, because dustfall predominantly captures depositing coarse material, whereas fine particles remain suspended for longer periods and penetrate more deeply into the respiratory system.

This distinction is particularly relevant to steelmaking, which uses substantial quantities of fine and granular solid materials that can be transported by air. These include process feedstocks such as fine ore, silica, and limestone, as well as energy inputs such as coal. Dust released outside a stack or ducted exhaust system is generally characterized as fugitive emissions. Zhang et al. (2022)¹⁰ report particle sizes associated with iron and steel process materials ranging from approximately 0.1 to 716 µm. Because PP No. 22/2021 regulates particulate fractions up to PM₁₀ as a principal size-based ambient indicator, deposition of coarser particles above 10 µm may remain insufficiently characterized if dustfall or comparable deposition monitoring is not applied.

3.2.2 Regulatory and Legal Architecture Iron-Steel Industry in South Korea

1. Process- or Facility-Based Regulation

Permissible emission standards for air pollutants in Korea are set out in Annex 8 to the Enforcement Rule of the Clean Air Conservation Act. The annex comprises two sets of standards. Section 1 applied until 31 December 2019; Section 2 has applied since 1 January 2020 and is the version in force. The current text took effect on 15 July 2026 as Ordinance No. 49 of the Ministry of Climate, Energy and Environment.

Separately from Annex 8, the Act on the Integrated Control of Pollutant-Discharging Facilities sets facility-specific emission limits. In force since 2017, the Act consolidated permits that had been issued separately for air, water and waste, and requires limits to be calculated individually according to a facility's equipment configuration and abatement performance. Steelmaking is a sector subject to integrated permitting; POSCO's Pohang and Gwangyang works received their permits in December 2021.

Because the uniform standards of Annex 8 and the facility-specific standards of the integrated permit operate in parallel, the obligation on an operator is whichever value is more stringent.

- **Process-level Differentiation**

Section 2 of Annex 8 treats sinter plants, coke ovens, blast furnace hot stoves, basic oxygen furnaces, electric arc furnaces and reheating furnaces as separate entries within steel manufacturing, and sets particulate, sulphur oxide and nitrogen oxide limits together with a reference oxygen concentration for each.

Table 3. Korean emission standards applicable to steelmaking¹¹

Units: particulates mg/Sm³; sulphur oxides and nitrogen oxides ppm. Figures in parentheses are the reference oxygen concentration (%). Where no parentheses appear, no oxygen correction applies.

Emission facility	Pollutant	Installed before 31 Jan 2007	Installed from 1 Feb 2007	Installed from 1 Jan 2015
Sinter plant	Particulates	20(15) ^a	20(15) ^a	10(15)
Sinter plant	Sulphur oxides	140(15)	90(15)	45(15)
Sinter plant	Nitrogen oxides	170(15)	100(15)	60(15)
Raw material charging, sinter post-treatment, roasting furnace, ring furnace	Particulates	20 ^a	20 ^a	10
Coke oven	Particulates	15(7) ^b	15(7) ^b	15(7) ^b
Coke pushing, dry quenching, storage	Particulates	15 ^b	15 ^b	15 ^b
Combustion facilities in coke plants	Sulphur oxides	85(7) ^b	85(7) ^b	85(7) ^b
Combustion facilities in coke plants and related storage	Nitrogen oxides	190(7) ^c	115(7) ^c	115(7) ^c
Cupola, blast furnace, converter,	Particulates	25	15	10

Emission facility	Pollutant	Installed before 31 Jan 2007	Installed from 1 Feb 2007	Installed from 1 Jan 2015
refining furnace, ironmaking furnace, melting furnace				
Combustion gas facilities of roasting furnaces, blast furnaces, cupolas	Sulphur oxides	140	90	45
Combustion gas facilities of roasting furnaces / cupolas	Nitrogen oxides	60	60	60
Electric arc furnace (incl. induction furnace)	Particulates	15 ^d	10 ^d	10
Reheating, heat treatment, annealing, drying furnaces and hot stoves	Particulates	20(11) ^a	20(11) ^a	10(11)
Reheating, heat treatment, annealing, drying furnaces and hot stoves	Nitrogen oxides	150(11)	115(11)	80(11)
Degreasing and acid/alkali treatment in surface treatment facilities	Hydrogen chloride	3	3	3

^a For particulates, the sinter plant and reheating furnace entries are divided only into installations before 31 December 2014 and from 1 January 2015. The first two columns both show the pre-2015 value.

^b Coke oven particulates and coke combustion sulphur oxides carry a single value regardless of installation date.

^c Coke combustion nitrogen oxides are divided at 31 December 2006 and 1 January 2007.

^d Electric arc furnace particulates are divided at 31 December 1998, 1 January 1999 and 1 January 2015.

The dividing dates vary by process and by pollutant. Sulphur oxides and nitrogen oxides from sinter plants are divided into three tiers around 2007, whereas sinter plant particulates form only two tiers around 2014, so that the first two columns of the table carry the same value. Particulates from electric arc furnaces are divided in 1998 and 1999. Applying a single set of dividing dates across processes would therefore be inaccurate.

For facilities installed on or after 1 January 2015, the tier is determined by the date on which the installation permit was issued; for earlier facilities, it is determined by whether installation was under way on the reference date or by when environmental impact assessment consultation was requested.

The notes to Section 2 of Annex 8 include provisions that apply different values to individual facilities, identified by company name and unit number. The general standard for sinter plant nitrogen oxides is 170 ppm (reference oxygen concentration 15%) for facilities installed before 31 January 2007, but sinter plants 2, 3 and 4 at POSCO's Pohang works were subject to 190(15) until 30 June 2020 and to 145(15) from 1 July 2020. Sinter plants installed at Hyundai Steel's Dangjin works in the same period are subject to 150(15). The three units at POSCO Pohang were subject to a value less stringent than the general standard until June 2020 and to a value more stringent than the general standard thereafter, while Hyundai Steel Dangjin has been subject to a value more stringent than the general standard from the outset.

● Specified Hazardous Air Pollutants

Beyond the conventional pollutants, Section 2 of Annex 8 sets separate emission standards for specified hazardous air pollutants. The entries directly relevant to steelmaking are as follows.

Table 4. Emission standards for specified hazardous air pollutants relevant to steelmaking¹¹

Substance	Applicable facilities	Standard (mg/Sm ³)	Facilities emitting 10 t/yr or more
Polycyclic aromatic hydrocarbons (as benzo[a]pyrene)	All emission facilities	0.05	0.03
Beryllium compounds	Roasting furnaces, sinter plants, blast furnaces, melting	0.04	Not applicable

	furnaces, converters and drying furnaces in primary metal manufacturing		
Mercury compounds	Same facilities	0.04(15)	0.02(15)
Lead compounds	Melting furnaces, blast furnaces, crucible furnaces and electrolytic furnaces in primary metal manufacturing	1.5	0.8
Chromium compounds	Other emission facilities	0.4	0.2
Nickel and its compounds	All emission facilities	2	1
Fugitive dust	Other emission facilities	0.4	Not applicable

The emission standards for beryllium compounds and mercury compounds apply to roasting furnaces, sinter plants, blast furnaces, melting furnaces, converters and drying furnaces in primary metal manufacturing; of these, sinter plants and converters are core processes in an integrated steelworks.

Korea sets no emission standard for polychlorinated dibenzo-p-dioxins and dibenzofurans applicable to steel sinter plants. Annex 8-2 gives a dioxin figure of 0.001 ng-TEQ/m³, but this determines whether an installation permit is required and is not an emission standard. Given that the sintering process is identified as a principal source of these substances, and that the IFC EHS Guidelines set a level of 0.1 ng TEQ/Nm³, this item falls short of international benchmarks.

- Facility-Specific Permitted Emission Standards**

Facilities holding an integrated environmental permit are subject to standards derived through a calculation separate from Annex 8. Annex 15 to the Enforcement Rule of the Act on the Integrated Control of Pollutant-Discharging Facilities sets a maximum emission standard; depending on the results of an emission impact analysis, a threshold emission standard at 70% of that value applies; and the permitted emission standard is finally whichever of that result and the permissible emission standard is more stringent.

Annex 15 sets five maximum emission standards for the steel sector: particulates 16(15) and sulphur oxides 100(15) for sinter plants in the ironmaking process; particulates 12(7) for combustion facilities in coke plants; particulates 12 for pushing and quenching facilities; and hydrocarbons 150 for metal surface treatment. No separate maximum emission standard exists for sinter plant nitrogen oxides, blast furnace hot stoves, converters or electric arc furnaces; under Note 3 to Annex 15, the permissible emission standard in Section 2 of Annex 8 serves as the maximum emission standard for these. Annex 15 therefore functions not as a self-contained table but as a layer that takes precedence over Annex 8 only where an entry exists.

Across the 474 stack-and-pollutant combinations recorded in the permit review reports for POSCO's two works, dividing the permitted emission standard by the maximum emission standard yields only four values.

Table 5. Calculation outcomes for permitted emission standards at POSCO's Pohang and Gwangyang works¹²

Ratio of Permitted per maximum emission standard	Stack and Pollution Record Count	Reason
0.7	340	Threshold emission standard applied, so permitted emission lowered to 70% from maximum threshold
1.0	129	Threshold emission standard not applied, so permitted emission equals to maximum threshold
0.625	3	Permissible emission standard lower and therefore adopted
0.49	2	Strict threshold emission standard applied

The two cases at 0.49 are nitrogen oxides and sulphur oxides at the main building of the Pohang technical research centre, calculated from 150 to 73.5 and from 200 to 98 respectively. These follow the rule under which a further 70% of the threshold emission standard applies where the predicted concentration in the emission impact analysis exceeds 2.5 times the environmental quality target. The three cases at 0.625 are particulates in steelmaking processes: 70% of the maximum emission standard of 40 is 28, but the converter-category particulate standard of 25 in Section 2 of Annex 8 is more stringent and was therefore adopted.

The 129 cases where no threshold emission standard applied are ancillary stacks that do not fall under process-specific entries, such as continuous casting, cold rolling, coating, wastewater treatment and on-site transport. These stacks correspond neither to Annex 15 nor to the process entries of Annex 8, so the "other emission facilities" values of particulates 30, sulphur oxides 200 and nitrogen oxides 150 became their maximum emission standards, and no further tightening followed because the emission impact analysis did not cross the applicable threshold.

Table 6. Permitted emission standards for principal processes at POSCO's two works¹²

Units: particulates mg/Sm³; sulphur oxides and nitrogen oxides ppm. Figures in parentheses are the reference oxygen concentration (%). These are the standards for the main stack of each process; a single process may have multiple stacks.

Facility	Particulates	Sulphur oxides	Nitrogen oxides
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Pohang sinter plant 1	18.2(15)	135.1(15)	140.0(15)
Pohang sinter plants 2, 3, 4	18.2(15)	135.1(15)	101.5(15)
Gwangyang sinter plants 1, 2, 3	18.2(15)	135.1(15)	140.0(15)
Gwangyang sinter plant 5	18.2(15)	63.0(15)	70.0(15)
Pohang and Gwangyang coke ovens	10.5(7)	59.5(7)	133.0(7) or 80.5(7)
Pohang and Gwangyang blast furnace hot stoves	14.0(11)	Not applicable	105.0(11)
Pohang new by-product gas combined cycle	7.0(15)	7.0(15)	7.0(15)

Standards differ by facility even within the same works. Gwangyang sinter plant 5 is set at sulphur oxides 63.0 ppm and nitrogen oxides 70.0 ppm (reference oxygen concentration 15%), half the level of sinter plants 1 to 3 at the same works, while the nitrogen oxide value of 101.5 for Pohang sinter plants 2 to 4 is 70% of the 145(15) that the notes to Section 2 of Annex 8 set by naming POSCO's Pohang works explicitly.

The review reports record best available techniques as applied in 104 of 106 items at Pohang and 102 of 105 at Gwangyang. These are the results of the regulator's examination of evidence submitted by the company.

2. Air-Emission Control Regulation

• Stack tele-monitoring

Korea requires large emission facilities to install stack tele-monitoring equipment and to transmit measurements in real time to the control centre of the Korea Environment Corporation. Annex 9 to the Enforcement Rule of the Clean Air Conservation Act sets the operating and management standards for the equipment, and Annex 11 sets the scope, parameters and methods of self-monitoring. Seven substances are measured: particulates, sulphur oxides, nitrogen oxides, hydrogen chloride, hydrogen fluoride, ammonia and carbon monoxide.

Table 7. Facilities and stacks under tele-monitoring¹³

Year	Facilities	Stacks	Total emissions (t)	Per stack (t)
2017	635	1,696		
2020	648	1,791	205,091	114.5
2021	826	2,524	191,825	76
2022	887	2,988	215,205	72

2023	943	3,383	220,441	65
2024	965	3,589	207,724	58
2025	954	3,708	208,937	56

The increase of 733 stacks between 2020 and 2021 followed the nationwide entry into force of the Special Act on the Improvement of Air Quality in Air Control Zones in April 2020, which widened the scope of installation. The deferral granted to stacks at total load management facilities whose annual emissions fell below a given threshold also expired on 31 December 2022.

Section 3 of Annex 8 links measurement to enforcement. Exceedance of a permissible emission standard is judged on each 30-minute mean, and administrative action follows where 30-minute means exceed the standard three or more times consecutively or eight or more times in a week. For carbon monoxide the criterion is three or more consecutive exceedances.

POSCO's two works have 176 tele-monitored stacks at Gwangyang and 139 at Pohang (cleansys.or.kr real-time measurements, as at 3 September 2026). The number of monitored points at Gwangyang rose from 42 in 2020 to 175 in 2024. Coverage by parameter is uneven, independently of the number of monitored stacks. Of the 139 stacks at Pohang, 123 measure nitrogen oxides and 91 measure sulphur oxides, while only 38 measure particulates. At Gwangyang, 49 of 176 stacks measure particulates. Neither works has a stack measuring hydrogen fluoride or ammonia.

- **Total emission load management**

The Special Act on the Improvement of Air Quality in Air Control Zones requires facilities within a zone whose emissions exceed a given level to obtain a total load management facility permit, and allocates an emission cap for each pollutant. With the Act's entry into force in April 2020, total load management, previously confined to the metropolitan area, was extended to the central, south-eastern and southern zones.

POSCO's Pohang works falls within the south-eastern zone and the Gwangyang works within the southern zone, so both are subject to the system. When designating the zones, the Ministry of Environment identified total load management for large facilities including petrochemicals and steelworks in the Yeosu national industrial complex as a priority for the southern zone, and total load management for large facilities in Ulsan, Gumi and Pohang as a priority for the south-eastern zone.

Whereas permissible emission standards set a ceiling on concentration, total load management sets a ceiling on mass. Where exhaust flow increases, total emitted mass rises even if concentration remains below the standard, and concentration-based regulation alone does not control this pathway. Article 121 of

Indonesia's Government Regulation No. 22/2021 provides for the allocation of water pollution loads. No mechanism allocating facility-level emission caps for air has been identified at the same level.

- **Regulation of abnormal operating periods**

Section 3 of Annex 8 sets, for each process, both the period during which exceedance of the permissible emission standard is allowed at start-up and shutdown, and the point from which that period is counted.

Table 8. Allowed exceedance periods for primary metal manufacturing facilities¹⁴

Emission facility	Start-up / restart	Shutdown	Counting begins (start-up)	Counting begins (shutdown)
Coke or related product manufacturing	8 hours	6 hours	Burner ignition	Raw material feed stops
Sinter plant	6 hours	4 hours	Raw feed material	Raw material feed stops
Reheating furnace	5 hours	5 hours	Raw feed material	Raw material feed stops
Electric furnace (arc furnace)	2 hours	2 hours	Raw feed material	Raw material feed stops
Blast furnace, cupola, converter, melting furnace, roasting furnace	2 hours	4 hours	Raw feed material	Raw material feed stops
Acid treatment facility	3 hours	2 hours	Raw feed material	Raw material feed stops
Foundry sand treatment	2 hours	2 hours	Raw feed material	Raw material feed stops

Operators must notify the control centre of the schedule at least eight hours before start-up, shutdown or restart in order to benefit from these allowances. Where a standard is exceeded because of equipment failure, the operator must restore normal operation within eight hours and notify the cause and the measures taken within 48 hours in order to be excluded from administrative action; excluded from that exemption are cases where standby equipment was available, where the same equipment fails repeatedly, and where the failure resulted from inadequate operation.

Additional provisions apply to facilities subject to a reference oxygen concentration. Where the value calculated from the reference and measured oxygen concentrations reaches three or above because oxygen content in the exhaust gas has risen during start-up, restart or shutdown, the regulation addresses this separately and requires

supporting data to be submitted to the control centre in cases of sudden equipment failure or the restart of part of a facility.

Indonesia's 1995 Ministerial Decree requires compliance for 95% of normal operating hours over a three-month period. Under this approach it is difficult to identify when and by how much an exceedance occurred.

- **Enforcement and charges**

Exceeding a permissible emission standard results in an improvement order and an excess emission charge, and failure to comply with the order is followed by suspension of operations. Even where emissions remain within the permissible standard, a basic emission charge applies to particulates, sulphur oxides and nitrogen oxides. Where a total load management facility exceeds its allocated emission cap, an excess load penalty applies.

The method for calculating the confirmed emission volume on which charges are based is set out in Annex 6 to the Enforcement Decree of the Act on the Integrated Control of Pollutant-Discharging Facilities. For stacks that measure and transmit through automatic monitoring equipment, the emission volume is calculated by multiplying each transmitted 30-minute mean concentration by the exhaust gas flow during that 30 minutes, and summing over the charging period. For stacks not subject to automatic monitoring, where self-monitoring results exist the daily mean emission is multiplied by actual operating days; where they do not, the volume is calculated by multiplying an emission factor by fuel consumption, raw material input, product output and similar variables.

This calculation method accumulates emissions converted to mass rather than concentration, so that at the same concentration a larger exhaust flow produces a larger chargeable mass. The design points in the same direction as total load management.

Indonesia's Ministerial Regulation No. 6 of 2026 provides for written warnings, government enforcement action, administrative fines, and suspension or revocation of business permits. The two countries do not differ in whether sanctions exist; what has not been identified is a standing charge applied while a facility remains in compliance.

- **Coverage of measurement**

The share of total emissions captured by stack tele-monitoring differs by substance.

Table 9. Mass coverage of stack tele-monitoring¹⁵

Unit: tonnes per year, 2023.

Substance	CAPSS (stack and non-stack)	SEMS (stack emissions)	TMS (tele-monitored)	TMS SEMS /	Non-stack share

Total	360,118	255,208	217,628	85.3%	29.1%
Particulates	24,090	13,867	4,606	33.2%	42.4%
Sulphur oxides	110,931	68,769	62,878	91.4%	38.0%
Nitrogen oxides	225,097	172,572	150,144	87.0%	23.3%

On a stack emissions basis, 91.4% of sulphur oxides and 87.0% of nitrogen oxides fall within the scope of automatic monitoring, compared with 33.2% of particulates. Measured against total emissions, the automatically monitored share of particulates falls to 19.1%. Some 42.4% of particulate emissions are released without passing through a stack. These are fugitive emissions from stockyards, conveyors, transfer points and similar sources. Annex 10-2 to the Enforcement Rule of the Clean Air Conservation Act sets facility management standards for reducing fugitive emissions, and Annexes 13 to 15 set standards for activities generating fugitive dust and for suppression equipment. The pattern of coverage varying by substance is also visible in individual facility data.

Table 10. POSCO's own reporting compared with tele-monitoring data¹⁶

Unit: tonnes, 2025, Pohang and Gwangyang works combined.

Substance	Company report	Tele-monitoring	Share captured by monitoring
Nitrogen oxides	25,798	24,906	96.5%
Sulphur oxides	25,090	24,907	99.3%
Particulates	3,019	870	28.8%
Total	53,907	50,683	94.0%

The two sources agree within 96% to 99% for nitrogen oxides and sulphur oxides, but only to 28.8% for particulates. This corresponds to the national figure of 33.2% for the mass coverage of particulate tele-monitoring. Korea's continuous monitoring system captures most of the emitted mass for gaseous substances, but only about one third for particulate matter.

Substances for which a permitted emission standard has been set may also fall outside the scope of tele-monitoring. POSCO's two works are subject to a permitted emission standard of 1.0 ppm for fluorine compounds at their principal stacks, including sinter plants, coke ovens, blast furnaces, electric furnaces, hot rolling, cold rolling and coating. Neither works has a stack that tele-monitors this parameter.

- **Scope of disclosure**

Disclosure occurs at two levels. Integrated environmental permit review reports are published, allowing the permitted emission standard, abatement configuration and

application of best available techniques to be verified for each stack; and cleansys.or.kr publishes annual emissions by facility and by substance, retrievable and downloadable by year. Real-time measurements are also displayed alongside the applicable permissible emission standard.

The annual reports submitted under the integrated permit are more limited. Most of the 1,238 permit condition compliance entries for POSCO's two works state that permit conditions are being lawfully observed or that there are no notable matters; the number of exceedances, the compliance rate and measured values cannot be established from this document.

3. Ambient-Air Quality Regulation

- **Ambient air quality standards**

Ambient air quality standards are set out in Annex 1 to the Enforcement Decree of the Framework Act on Environmental Policy. Unlike permissible emission standards, they impose no direct compliance obligation on operators and function as a policy objective. In this respect they are comparable to the ambient standards under Indonesia's Government Regulation No. 22/2021.

Table 11. Korean ambient air quality standards

Parameter	Annual	24-hour	8-hour	1-hour
Sulphur dioxide	0.02 ppm	0.05 ppm	-	0.15 ppm
Nitrogen dioxide	0.03 ppm	0.06 ppm	-	0.10 ppm
PM-10	50 µg/m ³	100 µg/m ³	-	-
PM-2.5	15 µg/m ³	35 µg/m ³	-	-
Carbon monoxide	-	-	9 ppm	25 ppm
Ozone	-	-	0.06 ppm	0.1 ppm
Lead	0.5 µg/m ³	-	-	-
Benzene	5 µg/m ³	-	-	-

Nb : For 1-hour means the 99.9th percentile value must not exceed the standard; for 8-hour and 24-hour means the 99th percentile value must not exceed it.

- **Comparison with Indonesian standards**

Setting the ambient standards for particulate matter in the two countries against the World Health Organization guidelines gives the following.

Table 12. Ambient standards for particulate matter compared^{17,18}

Unit: µg/m³.

Parameter	Korea	Indonesia	WHO guideline (2021)
PM-2.5 annual	15	15	5
PM-2.5 24-hour	35	55	15
PM-10 annual	50	40	15
PM-10 24-hour	100	75	45

Of the four parameters, Korea sets the lower value in only one, the 24-hour PM-2.5 standard; the annual PM-2.5 standard is the same in both countries; and Indonesia sets the lower value for PM-10 on both the annual and 24-hour basis. Neither country's standards meet the World Health Organization guidelines. The annual PM-2.5 standard is three times the guideline in both countries.

Korean ambient standards cannot therefore be said to be consistently stricter than Indonesian ones. The basis for a double standard must be sought in the process-level differentiation of emission standards, in facility-specific calculation, and in the way measurement is linked to enforcement.

- **Measurement results at Pohang and Gwangyang**

Classifying the monitoring stations in the two cities by the land use data in the annexes to the Annual Report of Air Quality, the industrial-area stations are Cheongnim-dong (industrial land 33.4%, about 1.5 km from the works), Jecheol-dong (26.0%, about 1.5 km) and Jangheung-dong (22.7%, about 2.7 km) in Pohang, and Taein-dong (25.0%, about 2.0 km) in Gwangyang. The stations closest to background conditions are Yangdeok-dong in Pohang (industrial land 2.7%) and Bonggang-myeon in Gwangyang (industrial land 0%, forest 73.8%).

In 2024, nine of Pohang's eleven monitoring stations exceeded the national annual PM-2.5 standard of 15 $\mu\text{g}/\text{m}^3$. Jecheol-dong and Ocheon-eup recorded the highest values at 20 $\mu\text{g}/\text{m}^3$, Daesong-myeon equalled the standard at 15 $\mu\text{g}/\text{m}^3$, and Jangryang-dong recorded 14 $\mu\text{g}/\text{m}^3$. All five stations in Gwangyang met the national standard, with Gwangyang-eup highest at 14 $\mu\text{g}/\text{m}^3$ and Taein-dong lowest at 10 $\mu\text{g}/\text{m}^3$.

The 24-hour standard of 35 $\mu\text{g}/\text{m}^3$ was exceeded on 24 days at Jecheol-dong, the highest count, followed by 20 days at Ocheon-eup and 19 days at Cheongnim-dong. In Gwangyang the highest count was four days at Bonggang-myeon. Pohang Port, a harbour monitoring station, recorded 45 days, more than any urban station in either city.

Both cities met the national annual PM-10 standard of 50 $\mu\text{g}/\text{m}^3$. The highest values were 41 $\mu\text{g}/\text{m}^3$ at Cheongnim-dong and 25 $\mu\text{g}/\text{m}^3$ at Gwangyang-eup.

All stations in both cities met the national standards for sulphur dioxide and nitrogen dioxide. The highest 2024 annual means were 0.0046 ppm for sulphur dioxide at Cheongnim-dong in Pohang, 23% of the annual standard of 0.02 ppm, and 0.0163 ppm for nitrogen dioxide at the same station, 54% of the annual standard of 0.03 ppm. There were no exceedances of the 24-hour or 1-hour standards. Carbon monoxide likewise recorded no exceedances.

Ambient heavy metal concentrations have declined over the long term. Iron at Jangheung-dong in Pohang fell from 6.570 $\mu\text{g}/\text{m}^3$ in 2005 to 0.915 $\mu\text{g}/\text{m}^3$ in 2024, and lead from 0.1165 $\mu\text{g}/\text{m}^3$ in 2001 to 0.02323 $\mu\text{g}/\text{m}^3$ in 2024. Over the same period the emission standards for steelmaking were tightened repeatedly and investment in abatement equipment expanded. Even in 2024, however, iron at Pohang Industrial Complex 3 stood at 1.640 $\mu\text{g}/\text{m}^3$, higher than the 0.333 $\mu\text{g}/\text{m}^3$ recorded at Duam-dong in Gwangju, an urban background site. Lead was below 5% of the ambient standard of 0.5 $\mu\text{g}/\text{m}^3$, with no exceedance.

These measurements come from the national air quality monitoring network and are not specific to the steelworks. Steel industrial complex tenants and port facilities are located near Pohang Industrial Complex 3 and Jangheung-dong, so the contribution of any individual facility cannot be isolated.

3.2.3 Gap Analysis Regulatory and Legal Architecture Iron-Steel Industry in Indonesia-Korea

1. Process- or Facility-Based Regulation

Gap 1: Regulatory Coverage Differs in the Level of Process Differentiation

Indonesia regulates several major steelmaking sources, including raw-material handling, BOF, EAF, reheating, annealing, and pickling processes. However, some upstream activities remain grouped under broader categories such as raw-material handling. South Korea applies more differentiated classifications for sinter plants, coke ovens, blast-furnace-related facilities, converters, EAFs, and reheating furnaces. The principal gap therefore concerns the granularity of process-specific regulation, rather than the absence of regulation in either country.

Gap type: Regulatory coverage differs in the level of process-specific differentiation.

Gap 2: Relative Stringency Is Process- and Pollutant-Dependent

Emission-limit stringency cannot be characterized simply as one country being uniformly stricter. Indonesian standards apply relatively uniform limits to several steelmaking processes, whereas Korean limits vary according to process, pollutant, installation date, and reference oxygen concentration. Therefore, relative stringency must be assessed on an equivalent process and normalized measurement basis.

Gap type: Relative regulatory stringency is differentiated rather than uniformly stronger in one jurisdiction.

Gap 3: Facility-Specific Regulation Is More Developed in South Korea

Indonesia allows stricter requirements through environmental approvals and facility-specific conditions, while South Korea formally combines national standards with integrated permits calculated according to facility configuration, abatement performance, and emission-impact analysis. The difference lies in how systematically general regulatory limits are translated into facility- or stack-specific requirements.

Gap type: Implementation architecture differs in the degree of facility-specific regulatory adjustment.

2. Air-Emission Control Regulation

Gap 1 : Both Countries Require Continuous Monitoring, but Their Regulatory Architecture Differs

Indonesia uses CEMS integrated with SISPEK, while South Korea requires tele-monitoring for large facilities with real-time transmission to the Korea Environment Corporation. Therefore, the gap is not the existence of automatic monitoring, but differences in monitoring scope, pollutant coverage, data transmission, and its integration with regulatory supervision.

Gap type: Comparable monitoring obligations exist, but regulatory design and coverage differ.

Gap 2: Enforcement Linkage Is More Time-Specific in South Korea

South Korea assesses exceedances using 30-minute mean concentrations and links repeated exceedances directly to administrative action. Indonesia's older sectoral standard requires compliance for 95% of normal operating time over a three-month period, which provides less temporal detail on when individual exceedances occur.

Gap type: Implementation difference in the temporal linkage between monitoring and enforcement.

Gap 3: Concentration-Based and Mass-Based Controls Are Not Equivalent

Both countries regulate emission concentrations, but South Korea additionally applies total emission-load management to large facilities in designated air-control zones, including Pohang and Gwangyang. An equivalent facility-level air-emission cap has not been identified in the Indonesian regulations reviewed in this study.

Gap type: Regulatory coverage differs between concentration control and total emission-mass management.

Gap 4: Fugitive Emission Monitoring Remains a Challenge in Both Systems

Both countries recognize non-stack or fugitive emissions, but continuous monitoring predominantly captures channelled emissions. Korean data themselves show relatively low particulate coverage through tele-monitoring and a substantial non-stack particulate share, demonstrating that stronger monitoring architecture does not necessarily mean complete emission coverage.

Gap type: Implementation gap in capturing fugitive and non-stack particulate emissions in both jurisdictions.

Gap 5: Potential Double Standard Lies More in Control Architecture Than in CEMS Existence

Because both Indonesia and South Korea already require automatic emission monitoring, the double-standard assessment should focus on whether comparable operations receive materially different levels of monitoring coverage, enforcement linkage, fugitive-emission control, emission-load management, or disclosure. The issue is therefore the depth and enforceability of emission control, not simply whether CEMS exists.

Gap type: Potential double standard in the comprehensiveness and enforceability of emission-control systems.

3. Ambient-Air Quality Regulation

Gap 1: Ambient-Air Standards Show Mixed Relative Stringency

Neither country is consistently more stringent for ambient particulate standards. Korea applies a lower 24-hour $PM_{2.5}$ limit, both countries use the same annual $PM_{2.5}$ limit, while Indonesia applies lower annual and 24-hour PM_{10} limits. Therefore, ambient-air regulation does not support a general characterization of Korean standards as uniformly stricter.

Gap type: Mixed relative regulatory stringency across pollutants and averaging periods.

Gap 2: Pollutant Coverage Has Different Strengths and Limitations

Indonesia's current ambient-air framework strengthened several inhalation-related pollutant limits but removed the former national dustfall parameter. This creates a specific coverage issue for coarse deposited particles around industries handling large quantities of ore, coal, limestone, and other bulk materials, while fine particulate standards remain regulated.

Gap type: Regulatory coverage differs by pollutant fraction and environmental pathway.

Gap 3: Ambient Monitoring Does Not Establish Facility Attribution

Monitoring around Pohang and Gwangyang provides information on surrounding air quality, but the results cannot isolate POSCO's contribution because other industrial, port, and urban emission sources are also present. The same principle should apply when interpreting ambient data around Krakatau POSCO: ambient exceedance alone does not demonstrate facility-specific responsibility.

Gap type: Implementation and evidence gap between ambient-air conditions and source attribution.

Gap 4: Ambient-Air Regulation Alone Provides Limited Evidence of a Double Standard

Because Indonesia and South Korea show mixed ambient-standard stringency, differences in ambient-air limits alone are insufficient to establish a double standard. The stronger analytical basis lies in whether differences in process-level limits, abatement systems, monitoring, and enforcement produce materially different levels of environmental protection around comparable facilities.

Gap type: Limited evidence of double standards from ambient standards alone; stronger relevance arises when combined with source-level regulation and implementation.

3.3 Iron-Steel Industry Players in Both Indonesia-Korea

In general, iron and steel industry operations can be classified into upstream activities, including ironmaking and/or steelmaking, and downstream activities that produce finished products through processes such as rolling, pipe manufacturing, coating, and fabrication.

Indonesia

Indonesia's upstream iron and steel sector has developed through a relatively diverse set of production technologies. PT Krakatau Steel began steel-industry development in 1977 and pioneered the use of the DRI-EAF route, with sponge-iron production capacity reaching approximately 2 million tonnes per year. In 2022, PT Krakatau Steel subsequently developed a 1.2-million-tonne-per-year blast-furnace ironmaking facility, which is currently inactive. At present, PT Krakatau Steel relies on PT Krakatau Posco for upstream products and focuses more strongly on EAF steelmaking and downstream rolling operations (PT Krakatau Steel Annual Report 2025).

Since then, Indonesia's iron and steel industry has continued to expand. Facilities focused primarily on ironmaking have included PT Meratus Jaya, PT Delta Prima, and Indoferro, which used rotary-kiln direct-reduction technologies to produce sponge iron, pig iron, and/or DRI; these facilities are currently no longer operating^{19,20,21}. Steelmakers producing secondary steel from scrap through steelmaking and casting include PT Krakatau Steel, Master Steel Jakarta, Jakarta Prima Steel Industry, and PT Gunung Raja Paksi in West Java. Although EAF technology has been introduced at several production facilities, the decarbonization benefit remains partial where emissions are shifted to the energy-supply system and accounted for as Scope 2 GHG emissions. This is illustrated by the continued use of a 150 MW coal-fired power plant associated with PT Krakatau Steel. Other producers rely on natural gas and electricity supplied by Perusahaan Listrik Negara (PLN), whose electricity mix is not yet fully free of fossil-fuel generation²².

The carbon vulnerability of steel production is particularly evident in integrated Blast Furnace-Basic Oxygen Furnace (BF-BOF) routes because of their high dependence on coal. In Indonesia, three companies are identified in this draft as currently operating integrated BF-BOF facilities: PT Mandan Steel, PT Dexin Steel, and PT Krakatau Posco, with respective crude-steel capacities of approximately 1 million, 7 million, and 3 million tonnes per year.



Figure 3. Evolution of the Iron and Steel Industry in Indonesia^{22,23,24}

Although PT Krakatau Posco is not currently Indonesia's largest integrated steel producer by capacity, it was the first company in the country to operate an integrated BF-BOF production route, beginning in 2013. The facility is also located within an industrial area close to densely populated communities. In 2024, Statistics Indonesia (BPS) recorded population densities across Cilegon City ranging from approximately 1,830 to 6,475 people per km², while Citangkil District had a population of 85,662²³. Citangkil is relevant because it includes areas adjacent to PT Krakatau Posco's operations. High population density can increase the number of people exposed to elevated pollutant concentrations and repeated industrial emissions, particularly where flue-gas treatment or emission controls are not fully effective²⁴.

PT Krakatau Posco is a joint venture between Indonesia's PT Krakatau Steel and South Korea's POSCO. At the time of establishment, POSCO held a 70% ownership interest; in 2022, the ownership structure changed to an equal 50:50 share between the parties. Without disregarding environmental risks associated with other iron and steel facilities, this study focuses on PT Krakatau POSCO to examine the extent to which its decarbonization measures and regulatory practices are aligned with standards and ambitions applied in the home country, South Korea.

South Korea

Korea produced 62.20 million tonnes of crude steel in 2025, sixth in the world. Output has been declining since a peak in 2018¹. POSCO produced 37.36 million tonnes in 2025, eighth globally, and Hyundai Steel 17.95 million tonnes, twentieth. Together they account for about 84% of Korean crude steel output. POSCO's output has fallen by 5.76 million tonnes over six years from 43.12 million tonnes in 2019, and its global ranking has moved from second in 2000 and fourth in 2015 to eighth in 2024 and 2025. Hyundai Steel reached 20.48 million tonnes and thirteenth place in 2015, falling to twenty-first in 2024.

POSCO's domestic crude steel capacity declined from 40.46 million tonnes in 2024 to 39.81 million tonnes in 2025. This reflects capacity reductions including the closure of Pohang blast furnace 1 in 2021, while over the same period the company stated its intention to build overseas capacity to 10 million tonnes by 2031.

The blast furnace and basic oxygen furnace route predominates in Korea as elsewhere. POSCO operates integrated works at Pohang and Gwangyang, both on this route. Hyundai Steel operates the blast furnace route at Dangjin and electric arc furnaces at Incheon, Pohang and Suncheon, combining both routes.

In June 2026 POSCO commissioned an electric arc furnace with an annual capacity of 2.5 million tonnes at the Gwangyang works. It is the largest single installation of its kind in Korea and will initially operate by blending hot metal from the blast furnace with molten steel from the electric furnace. The difference in production route is reflected in emission intensity.

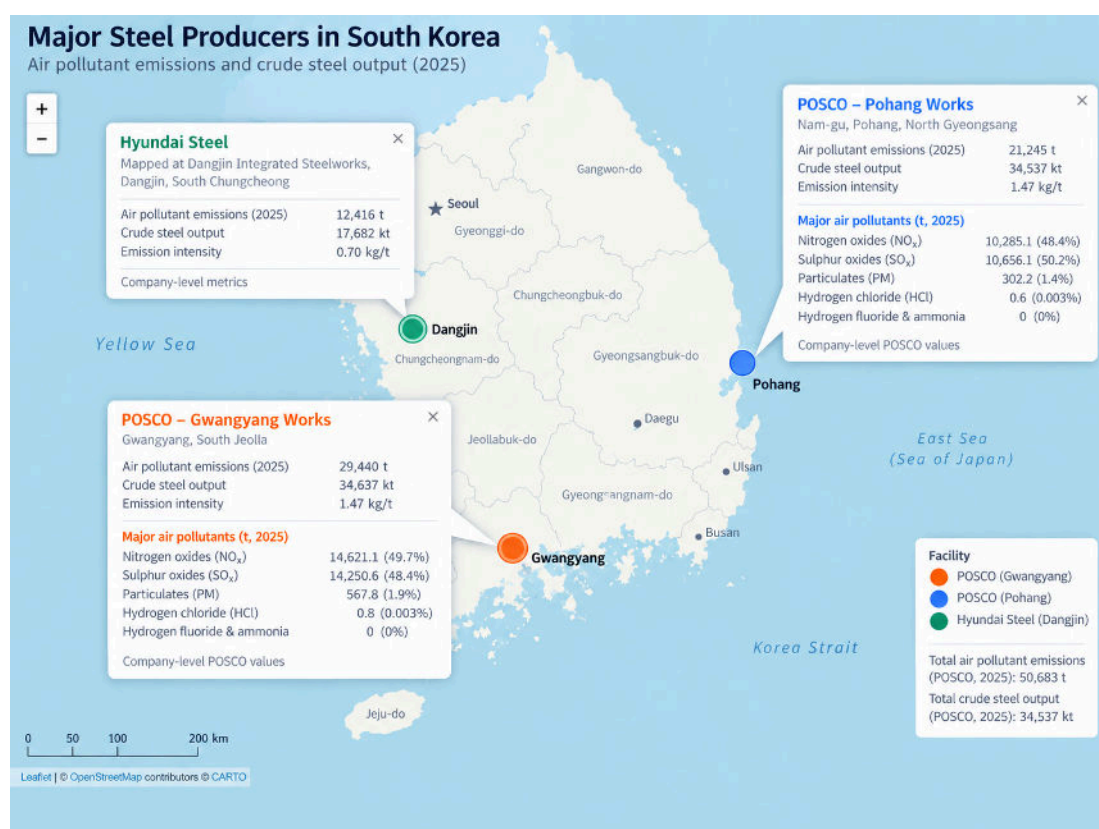


Figure 4 Emission intensity at domestic facilities^{25, 26}

The difference between the two companies reflects the composition of their production routes but is not explained by that alone. Tele-monitored emissions cover only stacks fitted with automatic monitoring equipment and are therefore not total emissions, and emissions arising from the generation of electricity used in the electric furnace route are not included in these figures. A direct comparison of the

two companies' performance would require the emission scope and calculation boundary to be aligned.

The generation figure is the value before abatement and is used to classify emission facilities. As the threshold for a Class 1 air emission facility is annual generation of 80 tonnes, the Gwangyang works stands at 7,660 times that threshold. The figure is calculated using emission factors and similar methods and is of a different order from measured emissions. The Gwangyang works has ranked first nationally in emissions for seven consecutive years since 2019, with the Pohang works second. Until 2018 Gwangyang ranked third and Pohang fourth.

Sulphur oxides and nitrogen oxides account for 98% of emissions at both works, and particulates for under 2%. The same structure holds for the iron and steel sector as a whole: of 70,962 tonnes emitted in 2025, sulphur oxides accounted for 32,521 tonnes, nitrogen oxides for 37,061 tonnes and particulates for 1,376 tonnes¹³.

That the actual composition of emissions from an integrated steelworks is not centred on particulates has a bearing on how the scope of regulated parameters should be assessed. Where Annex I-B to Indonesia's Ministerial Decree No. 13 of 1995 sets no sulphur oxide or nitrogen oxide standards for sinter plants and coke ovens, this means that the two substances making up most of an integrated works' emissions are outside the scope of regulation for its principal processes.

Emissions at both works rose between 2024 and 2025. Gwangyang increased by 2,521 tonnes from 26,919 to 29,440 tonnes, and Pohang by 3,521 tonnes from 17,723 to 21,245 tonnes. Over the same period national emissions rose by 0.6% from 207,724 to 208,937 tonnes, while emissions per stack fell from 58 to 56 tonnes. The number of tele-monitored stacks at Gwangyang was 175 in 2024 and 176 as at September 2026, essentially unchanged. Converted to emissions per stack, the figure rose from 153.8 to 167.3 tonnes, moving in the opposite direction to the 3.4% decline in the national average. The increase is not explained by an expansion of monitoring coverage.

At provincial level, emissions in North Gyeongsang rose by 3,430 tonnes from 21,709 to 25,139 tonnes, while the increase at the Pohang works alone was 3,521 tonnes; in South Jeolla emissions rose by 2,497 tonnes from 40,809 to 43,306 tonnes, while the increase at the Gwangyang works was 2,521 tonnes. In both provinces, emissions from all other facilities combined declined.

The Ministry of Climate, Energy and Environment attributed the national increase in 2025 to the growth in the number of monitored stacks and to a shortage of high-quality low-sulphur fuel. It noted that difficulties in securing high-quality low-sulphur anthracite from Russia have persisted since May 2024 following United States trade sanctions arising from the Russia-Ukraine war.

3.4 Global Benchmark and Their Reflection in National Regulation

3.4.1 IFC EHS Guidelines for Integrated Steel Mills

The International Finance Corporation (IFC) Environmental, Health, and Safety Guidelines for Integrated Steel Mills provide a global reference for environmentally sound operational practice in integrated iron and steel facilities. The IFC EHS Guidelines address air and water emissions associated with steel production, provide recommended emission levels, and identify pollution-prevention and control measures²⁷.

To address these risks, the IFC EHS Guidelines specify recommended stack-emission levels under reference conditions of 0°C and 1 atmosphere, with oxygen correction to 3% for combustion using liquid or gaseous fuels and 6% for combustion using solid fuels, including coal.

For combustion processes requiring oxygen correction, the following normalization is applied²⁸:

$$C_{reference} = C_{measured} \times \frac{21 - O_{2,reference}}{21 - O_{2,measured}}$$

For non-combustion processes, normalization to the reference temperature is applied as follows:

$$C_{0C} = C_{25C} \times \frac{298.15 \text{ (Kelvin)}}{273.15 \text{ (Kelvin)}}$$

Assessment of the 2007 IFC EHS Guidelines against Indonesian Regulation

When compared with Indonesian stack-emission limits under Kepmen LH No. 13/1995, which use reference conditions of 25°C, 1 atmosphere, and a 10% oxygen correction, the resulting differences are presented in Table 13.

Overall, Kepmen LH No. 13/1995 and the 2007 IFC EHS Guidelines adopt different approaches to setting emission limits. Kepmen LH No. 13/1995 establishes limits by process unit, but the regulated parameters are dominated by particulate matter, SO₂, and NO_x. The IFC EHS Guidelines do not always specify emission limits for every individual process unit in the same manner, but cover a broader range of pollutants, including airborne heavy metals, volatile organic compounds, PCDD/Fs, and H₂S. Table 3 therefore compares only sources and parameters that are sufficiently corresponding between Kepmen LH No. 13/1995 and the 2007 IFC EHS Guidelines.

Table 13. Comparison of IFC EHS and Kepmen LH No. 13/1995 Emission Limits after Normalization

Source - Parameter	IFC (mg/Nm ³)	Indonesia Kepmen 13/1995 Annex I-B (mg/m ³)	Indonesia in Equalizing to IFC (mg/Nm ³)	Assessment of Indonesian Regulation
Raw material handling - PM	20-50	150	164	3.3 - 8.2 times less stringent
BOF - PM	20-50	150	164*	
EAF - PM	20-50	150	164*	
Reheating Furnace - PM, Solid Fuel	20-50	150 (O ₂ 10%)	223 (O ₂ 6%)	4.5 - 11.2 times less stringent
Reheating Furnace - PM, gas/liquid Fuel	20-50	150 (O ₂ 10%)	268 (O ₂ 3%)	5.4 - 13.4 times less stringent
Pickling - HCL	10	5	5.46	Indonesia numerically stricter
Boiler - SO ₂	500	800	873*	1.75 times less stringent
Boiler - NO _x /NO ₂	500	1000	1092*	2.2 times less stringent

*Not normalized for oxygen concentration because the actual stack classification is required.

For emission control at integrated iron and steel facilities, the IFC EHS Guidelines distinguish between stack emissions and fugitive/secondary emissions. For stack emissions, recommended control technologies such as ESPs, bag filters, scrubbers, hoods, and ducts generally have counterparts in Permen LHK No. 5/2021.

For fugitive emissions, however, the IFC EHS Guidelines provide more detailed source mapping for process-specific emission pathways, including coke-oven door and charging-hole leakage, coke pushing and quenching, blast-furnace tapping, BOF charging and tapping, and molten-metal transfer. Indonesian regulations, including

Permen LHK No. 5/2021, Permen LH/BPLH No. 5/2026, and Permenperin No. 45/2024, recognize fugitive emissions and provide controls particularly for stockpiles and material handling, but do not yet explicitly regulate all process-specific fugitive-emission pathways in an integrated, sector-specific manner comparable to the IFC EHS Guidelines.

Although the national regulatory assessment indicates that Kepmen LH No. 13/1995 generally provides less stringent particulate-emission limits and regulates a narrower range of pollutants than the IFC EHS Guidelines, the emission-control system currently applied by PT Krakatau Posco should not be assessed solely against Kepmen LH No. 13/1995. The 2025 Addendum EIA specifies that stack-emission management is subject to the company-specific Technical Approval for Emission Standards (Peretujuan Teknis Pemenuhan Baku Mutu Emisi) No. S.1921/PPKL/PPU/PKL.3.11/15/10/2024.

At the technology level, the PT Krakatau Posco's EIA/Environmental Impact Assessment (EIA) documents the use of bag filters, electrostatic precipitators, dedusting systems, gas-cleaning systems, scrubbers, and combustion controls across the coke oven, sinter plant, blast furnace, BOF, casting, and rolling processes. These measures are broadly consistent with several pollution-control techniques recommended by the IFC EHS Guidelines. Nevertheless, differences remain in the level of source-specific control documented, particularly for coke-oven leakage and quenching, secondary BOF emissions, multi-stage sinter off-gas treatment, and the control of pollutants beyond particulate matter, including VOCs, acid gases, heavy metals, and PCDD/F.

Assessment of the 2007 IFC EHS Guidelines against Korea Regulation

Korean values are for facilities installed on or after 1 January 2015. Figures in parentheses are the reference oxygen concentration. Conversion to IFC conditions applies an oxygen concentration of 6% for solid fuel combustion gases.

Table 14. Comparison of IFC EHS and Korea's Regulation Emission Limits after Normalization

Parameter	Korean standard	Converted to IFC conditions	IFC level	Assessment
Sinter plant particulates	10 mg/Sm ³ (15%)	25.0	20–50	Within range
Sinter plant sulphur oxides	45 ppm (15%)	321.7 mg/Nm ³	500	64% of IFC
Sinter plant nitrogen oxides	60 ppm (15%)	308.1 mg/Nm ³	500	62% of IFC
Coke oven particulates	15 mg/Sm ³ (7%)	16.1 (5%)	20–50	Below lower bound

Coke combustion sulphur oxides	85 ppm (7%)	260.5 mg/Nm ³ (5%)	500	52% of IFC
Coke combustion nitrogen oxides	115 ppm (7%)	253.1 mg/Nm ³ (5%)	750	34% of IFC
Blast furnace hot stove particulates	10 mg/Sm ³ (11%)	15.0 (3%)	20–50	Below lower bound
Blast furnace hot stove nitrogen oxides	80 ppm (11%)	246.5 mg/Nm ³ (3%)	500	49% of IFC
Converter particulates	10 mg/Sm ³	10	20–50	Half the lower bound
Electric arc furnace particulates	10 mg/Sm ³	10	20–50	Half the lower bound
Raw material charging particulates	10 mg/Sm ³	10	20–50	Half the lower bound
Pickling hydrogen chloride	3 ppm	4.9 mg/Nm ³	10	49% of IFC

Nb : Sinter plants are treated as combustion gas sources, since coke breeze is combusted in the process, and the solid fuel oxygen concentration of 6% has been applied. The IFC Guidelines express nitrogen oxides as NO_x and sulphur dioxide as SO₂; Korean emission standards express nitrogen oxides as nitrogen dioxide and sulphur oxides as sulphur dioxide, so the conversion basis is the same in both.

Korean emission standards are at or below the IFC levels for every parameter that can be compared. Sinter plant particulates fall within the recommended range once the oxygen conditions are aligned. Beyond conventional pollutants, the IFC EHS Guidelines set levels for heavy metals, volatile organic compounds, polychlorinated dibenzo-p-dioxins and dibenzofurans, and hydrogen sulphide.

Korea regulates much of this range in Section 2 of Annex 8. Polycyclic aromatic hydrocarbons are set at 0.05 mg/Sm³ as benzo[a]pyrene, beryllium compounds at 0.04 and mercury compounds at 0.04(15); beryllium and mercury name roasting furnaces, sinter plants, blast furnaces, melting furnaces, converters and drying furnaces in primary metal manufacturing as the applicable facilities. Lead, chromium and nickel also have emission standards.

For specified hazardous air pollutants Korea generally sets lower values. Polycyclic aromatic hydrocarbons are set at 0.05 mg/Sm³ as benzo[a]pyrene, half the IFC level of 0.1; chromium at 0.4, a tenth of the IFC level of 4; and lead at 1.5, below the IFC level of 2. Nickel is the same in both at 2. The IFC EHS Guidelines set a level of 0.1 ng TEQ/Nm³ for polychlorinated dibenzo-p-dioxins and dibenzofurans and identify sinter plants as a significant potential source. Korea sets no emission standard for these substances applicable to steel sinter plants. Annex 8-2 gives a dioxin figure of 0.001 ng-TEQ/m³, but this determines whether an installation permit is required and is not an emission standard.

For fugitive sources, the IFC EHS Guidelines set out recommended techniques for emission pathways including leakage from coke oven doors and charging holes, coke pushing and quenching, blast furnace tapping, converter charging and tapping, and molten metal transfer. In Korea, Annex 10-2 to the Enforcement Rule of the Clean Air Conservation Act sets facility management standards for iron and steel manufacturing covering sinter plants, coke ovens, and blast furnaces, converters and electric arc furnaces separately, and includes all of the pathways listed by the IFC. Annexes 13 to 15 set standards for activities generating fugitive dust and for suppression equipment.

The two differ in their regulatory approach. Annex 10-2 requires negative pressure inside the coke oven during charging of at least –25 mmH₂O for facilities installed on or after 1 January 2015, and sets the opacity of fugitive emissions from coke ovens and from blast furnaces, converters and electric arc furnaces at 20%, or 35% during coke pushing. Inspection intervals are also prescribed: cleaning around the sealing doors twice weekly, inspection of leakage in the wall between the carbonisation and heating chambers weekly, and opacity inspection monthly, with results recorded in an operating log and submitted in an annual inspection report. For sinter plants, the maintenance of negative pressure at the top of the sinter bed must be continuously monitored.

Where the IFC Guidelines set out recommended techniques, Annex 10-2 prescribes compliance obligations and inspection intervals in numerical terms. Viewed in terms of measurement coverage, 42.4% of Korean particulate emissions are released without passing through a stack. Independently of the existence of rules on fugitive sources, this share lies outside the stack measurement system.

3.4.2 WHO AQG

Stack standards and ambient health guidelines serve different purposes. A stack concentration in mg/Nm³ cannot be compared directly with a WHO ambient guideline in µg/m³. Stack concentration must first be converted to an emission rate using exhaust-gas flow, modeled through atmospheric dispersion and added to background concentrations.

The governing relationship is:

$$Q_{\text{pollutant}} = C_{\text{stack}} \times F_{\text{gas}}$$

where the first term represents the mass emission rate and the second represents the normalized exhaust-gas flow. Two stacks with the same concentration can have substantially different total emissions if their gas-flow rates differ.

Table 15. Parameter and Source of Pollutant that Effect Health Outcomes

Parameter	Sources Related to Steelmaking	Health outcomes	Exp. period
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PM _{2.5}	Combustion, sinter, coke	CVD, stroke, COPD, cancer	24h/annual
PM ₁₀	Handling, stockyards, sinter	Resp. symptoms, asthma	24h/annual
TPM	Conveyors, furnaces	Total particle loading indicator	Stack/24h
Dustfall	Fugitive dust, roads	Soiling, ingestion pathway	30 days
SO ₂	Fuel, coke, sinter	Bronchoconstriction	1h/24h
NO ₂ /NO _x	Furnaces, sinter, boilers	Airway irritation, asthma	1h/24h/ann
HCl	Pickling systems	Throat irritation, edema	Acute/chronic
CO	Incomplete combustion	Reduced oxygen delivery	15m/1h/8h/24h
Benzene/PAH	Coke ovens/leakage	Toxicity, cancer risk	Chronic
Metals	Ore, sinter, furnace dust	Neurological, renal effects	Chronic

WHO concludes that PM_{2.5} can penetrate deeply into the lungs and enter the bloodstream, affecting major organs and contributing to cardiovascular and respiratory disease, stroke, COPD, and lung cancer. WHO recognizes both acute and chronic exposure pathways²⁹.

Short-term SO₂ exposure can adversely affect the respiratory system and make breathing difficult, particularly for people with asthma and for children. Short-term NO₂ exposure can irritate the airways and aggravate asthma, while longer-term exposure may contribute to asthma development and increased susceptibility to respiratory infections³⁰.

Hydrogen chloride is corrosive. Short-term exposure to low concentrations can irritate the throat, while higher concentrations may cause bronchial constriction, pulmonary edema, and potentially fatal respiratory injury. Prolonged low-level exposure may affect the respiratory system, eyes, and skin. Coke-oven emissions warrant particular attention beyond conventional PM, SO₂, and NO_x. Workers around coke ovens may be exposed to PAHs and metals including arsenic, cadmium, lead,

and nickel; modernization and effective capture systems can reduce these exposures³¹.

Assessment of the WHO AQG against Indonesian Regulation

The WHO AQG framework distinguishes between interim targets and the final AQG levels. Interim targets are transitional pollutant-concentration benchmarks that can be adopted progressively by countries or regions with high pollution levels to reduce exposure before attaining the more stringent AQG levels.

Under PP No. 22/2021, Indonesia's ambient-air limits for the pollutants assessed in this study have not yet reached the WHO AQG levels for either annual or 24-hour averaging periods. Nevertheless, several Indonesian limits correspond to WHO interim-target levels, indicating an intermediate regulatory position on the pathway toward the final AQG values.

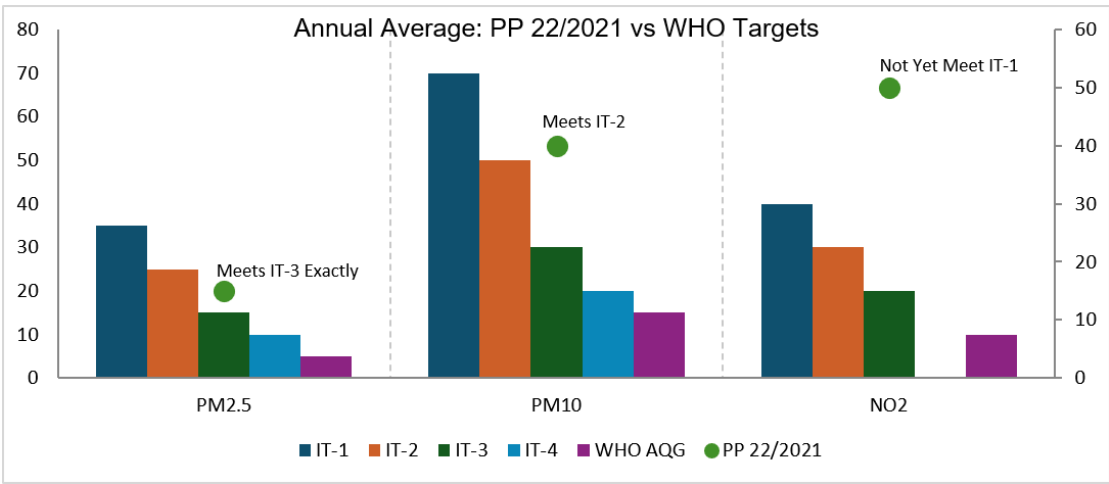


Figure 5. Assessment of the WHO AQG against Indonesian Regulation (Annual)

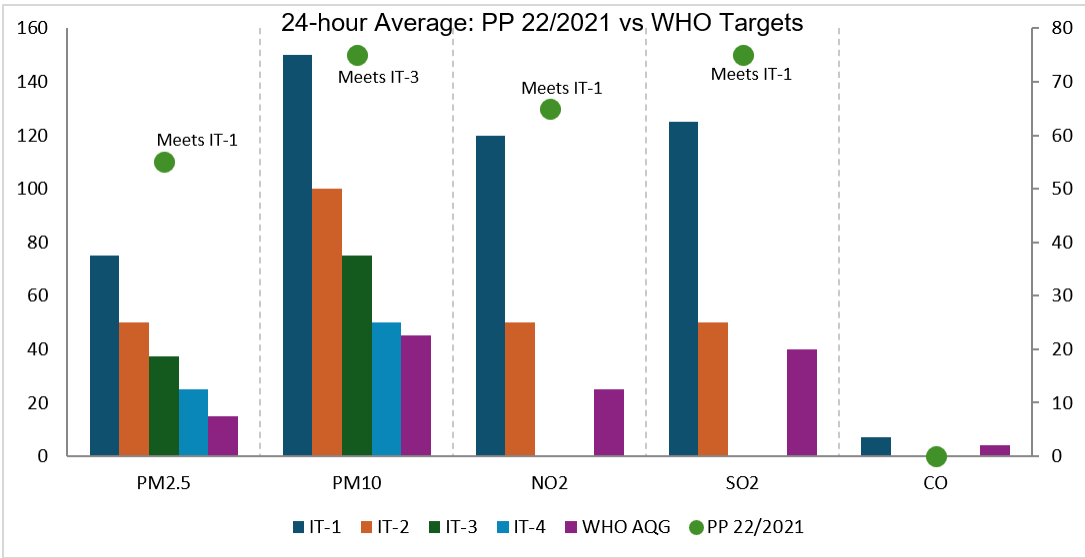


Figure 6. Assessment of the WHO AQG against Indonesian Regulation (24 Hour)

According to PT Krakatau Posco's EIA documentation, ambient-air quality around the industrial area is monitored at 11 sampling points per semester. These broadly cover Cigading/Tegal Ratu, Kubangsari/Penauan, Kubang Welut, and Tegal Wangi/Grogol, which are communities adjoining or intersecting the project area. However, the EIA documentation reviewed in this draft does not clearly state whether each measurement is conducted over a full 24-hour sampling period in accordance with the averaging period specified under PP No. 22/2021.

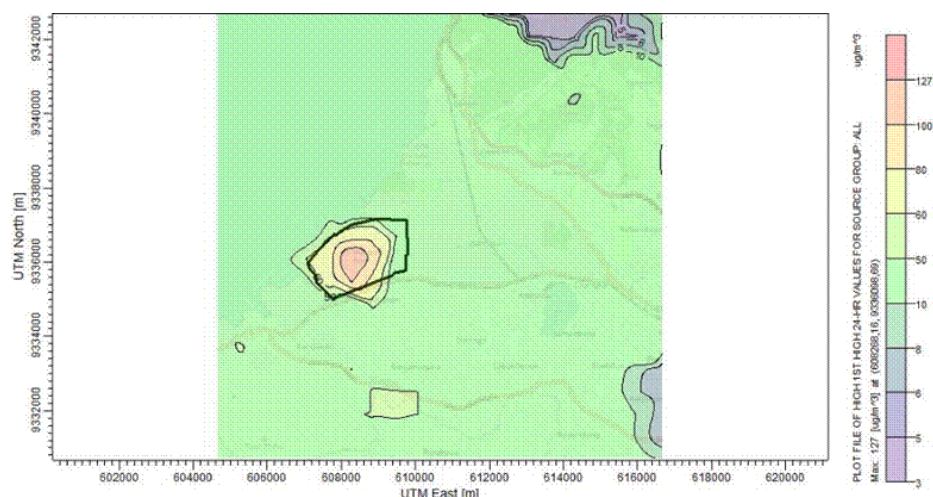


Figure 7. 24-hour PM10 Concentration Isopleth

Ambient-air measurements can also be influenced by sources outside the main project boundary, including heavy-vehicle traffic and surrounding industrial activities. PT Krakatau POSCO's EIA identifies emission loads from 49 stacks; AERMOD modeling can therefore be used to estimate the contribution of the existing project sources to ambient-air quality while accounting for meteorological conditions and excluding unrelated off-site activities from the modeled source inventory. Based on the modeling results presented in the draft, peak PM10 and PM2.5 concentrations exceeded the ambient-air quality thresholds under PP No. 22/2021 on several occasions during 2025.

Table 16. Peak 24-hour PM10 Concentrations

Date	Concentration (µg/m³)	Coordinates (°)		Location Description
		Latitude	Longitude	
29 August 2025	127,07	-6.00543	105.9783	Project Site, Kubangsari Urban Village, Ciwandan District, Cilegon City

29 January 2025	101,99	-6.01085	105.9783	Project Site, Kubangsari Urban Village, Ciwandan District, Cilegon City
7 November 2025	94,83	-6.00542	105.9837	Project Site, Samangraya Urban Village, Citangkil District, Cilegon City

The table and figure indicate that low wind speeds can reduce atmospheric dispersion and dilution, resulting in concentrations above ambient-air quality limits at several locations around the project area. These high-concentration episodes are particularly concentrated around Kubangsari and Samangraya.

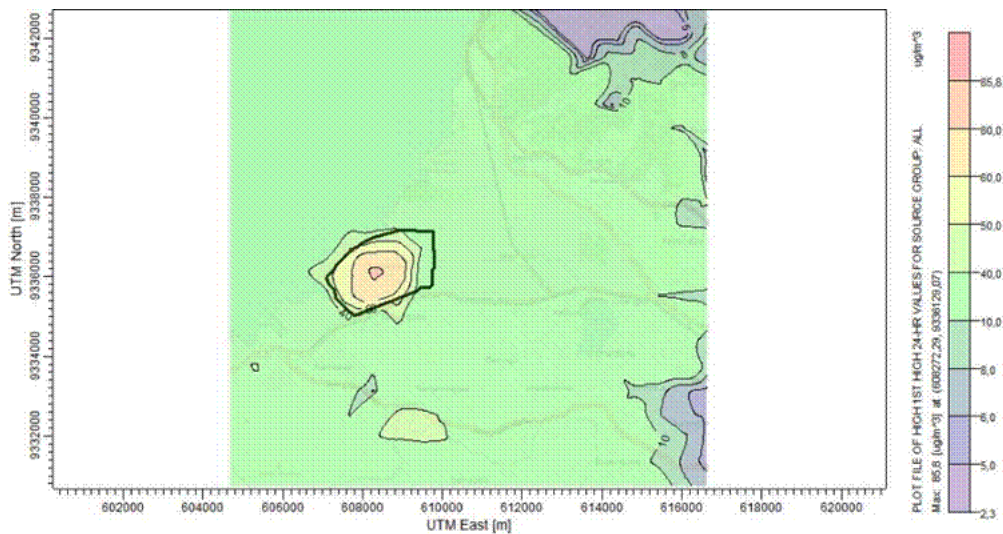


Figure 8. 24-hour PM2.5 Concentration Isopleth

Table 17. Peak 24-hour PM2.5 Concentrations

Date	Concentration ($\mu\text{g}/\text{m}^3$)	Coordinates (°)		Location Description
		Latitude	Longitude	
29 August 2025	85,83	-6.00515	105.9783	Project Site, Kubangsari Urban Village, Ciwandan District, Cilegon City
7 November 2025	73,16	-6.00514	105.9837	Project Site, Samangraya Urban Village, Citangkil District, Cilegon City
30 January 2025	71,14	-6.01058	105.9783	Project Site, Kubangsari Urban Village, Ciwandan District, Cilegon City
23 June 2025	59,71	-6.01059	105.9729	Project Site, Kubangsari Urban Village, Ciwandan District, Cilegon City
14 June 2025	58,45	-6.00516	105.9729	Project Site, Kubangsari Urban Village, Ciwandan District, Cilegon City

Assessment of the WHO AQG against Korea Regulation

Table 17. WHO guidelines and the ambient standards of the two countries

Unit: $\mu\text{g}/\text{m}^3$. Korean values expressed in ppm have been converted at 20°C and 1013 hPa, the conditions specified by the World Health Organization.

Parameter	WHO guideline (2021)	Korea	Ratio to guideline	Indonesia	Ratio to guideline
PM-2.5 annual	5	15	3.0×	15	3.0×
PM-2.5 24-hour	15	35	2.3×	55	3.7×

PM-10 annual	15	50	3.3×	40	2.7×
PM-10 24-hour	45	100	2.2×	75	1.7×
Nitrogen dioxide annual	10	57.4	5.7×	50	5.0×
Sulphur dioxide 24-hour	40	133	3.3×	75	1.9×

Neither country's ambient standards meet the World Health Organization guidelines. By parameter, Korea sets the lower value for the 24-hour PM-2.5 standard, Indonesia sets the lower value for PM-10 on both the annual and 24-hour basis, and Indonesia also sets lower values for nitrogen dioxide and sulphur dioxide.

Table 18. WHO guidelines and measurement results at Pohang and Gwangyang

Unit: $\mu\text{g}/\text{m}^3$, 2024 annual means. Station names in parentheses.

Parameter	WHO guideline	Korean standard	Pohang highest	Pohang background	Gwangyang highest	Gwangyang background
PM-2.5	5	15	20 (Jecheol-dong)	14 (Jangryang-dong)	14 (Gwangyang-eup)	13 (Bonggang-myeon)
Nitrogen dioxide	10	57.4	31.2 (Cheongnim-dong)	10.7 (Yangdeok-dong)	29.9 (Jinwol-myeon)	9.2 (Bonggang-myeon)

Nb: Nitrogen dioxide values expressed in ppm have been converted at 20°C and 1013 hPa. "Highest" is the highest concentration among the monitoring stations in each city; "background" is the value at the station with the lowest share of industrial land use, closest to background conditions. These are Yangdeok-dong in Pohang (industrial land 2.7%) and Bonggang-myeon in Gwangyang (industrial land 0%, forest 73.8%).

Nine of Pohang's eleven monitoring stations exceeded the national annual PM-2.5 standard. The highest value, 20 $\mu\text{g}/\text{m}^3$ at Jecheol-dong, is four times the World Health Organization guideline of 5 $\mu\text{g}/\text{m}^3$. All stations in Gwangyang met the national standard but stood at two to 2.8 times the guideline.

All stations in both cities met the national standard for nitrogen dioxide. Measured against the World Health Organization guideline of 10 $\mu\text{g}/\text{m}^3$, however, ten of Pohang's eleven stations exceeded it, with the highest, Cheongnim-dong, at 3.1 times the guideline. Yangdeok-dong, closest to background conditions, recorded 10.7 $\mu\text{g}/\text{m}^3$, at the level of the guideline. In Gwangyang, Jinwol-myeon recorded 29.9 $\mu\text{g}/\text{m}^3$, three times the guideline, and Bonggang-myeon 9.2 $\mu\text{g}/\text{m}^3$.

All stations in both cities met the national standard for sulphur dioxide. The World Health Organization sets no annual guideline for sulphur dioxide, setting a 24-hour guideline of 40 $\mu\text{g}/\text{m}^3$; the annual mean data in the Annual Report of Air Quality cannot be compared against this guideline. Exceedances of 24-hour standards occurred only for PM-2.5. There were no exceedances of sulphur dioxide, nitrogen dioxide or carbon monoxide at any station in either city.

The distribution of nitrogen dioxide differs between the two cities. In Pohang the three stations with the highest industrial land shares, Cheongnim-dong, Jecheol-dong and Jangheung-dong, are also the three with the highest concentrations. In Gwangyang the highest value is at Jinwol-myeon, away from the steelworks, while Taein-dong near the works recorded 18.8 µg/m³. Because mobile road sources contribute substantially to nitrogen dioxide, the distribution varies with conditions around each station.

3.4.3 Europeans Best Available Technique (EU BAT)

The European Union's BAT Conclusions for Iron and Steel Production were adopted on 28 February 2012 under the Industrial Emissions Directive (Commission Implementing Decision 2012/135/EU). They cover coke production, the roasting and sintering of metal ores, and the production of pig iron and steel, and set out best available techniques and their associated emission levels by process.

Three differences in the basis of comparison must be assumed. First, BAT-associated emission levels are ranges achievable when a given technique is applied; they are not legal ceilings. The Conclusions themselves attribute their expression as ranges rather than single values to differences in the design, size and capacity of installations and in product grade. Korean permissible emission standards are legal ceilings, exceedance of which brings administrative action and charges.

Second, the averaging periods differ. The European Union Conclusions mostly use daily means, with some parameters averaged over the sampling period. Korea determines exceedance on 30-minute means at facilities under tele-monitoring.

Third, the Korean instrument corresponding directly to the concept of best available techniques is the maximum emission standard in Annex 15 to the Enforcement Rule of the Act on the Integrated Control of Pollutant-Discharging Facilities. Annex 15 sets only five entries for the steel sector, however, and for other processes and substances the values in Section 2 of Annex 8 serve as the maximum emission standard. The comparison below is therefore based on Section 2 of Annex 8, with Annex 15 values shown where entries exist.

The reference conditions are the same. The European Union Conclusions express values at 273.15 K and 101.3 kPa after deduction of water vapour, and convert nitrogen oxides to nitrogen dioxide and sulphur oxides to sulphur dioxide, matching Korean practice.

The Conclusions have not been amended since their adoption in February 2012. The European Union provides for BAT reference documents to be reviewed roughly every eight years, but the review for the iron and steel sector began only in March 2026, and the plant information underlying the current Conclusions dates from before 2007.

Assessment EU BAT to Indonesia's Regulatory

A comparison between Indonesian iron and steel emission limits under Kepmen LH No. 13/1995 and the EU BAT-AELs for Iron and Steel Production (2012/2013) is presented below. The comparison indicates that many process-specific Best Available Technique benchmarks covered by the EU BAT framework are not explicitly represented in Kepmen LH No. 13/1995.

For BOF secondary dedusting, the Indonesian particulate limit is several times higher than the BAT-associated emission levels achievable using bag filters or electrostatic precipitators.

Table 19. Comparison of EU BAT to Indonesia's Regulatory

Process and parameter	Indonesia standard (Kepmen 13/1995)	Converted to EU conditions	EU BAT-AEL 2012/2013 Emission Level
Sinter plant particulates	No specific process standard	NA	Bag filter 1–15 mg/Nm ³ , advanced ESP 20–40 mg/Nm ³
Sinter plant sulphur oxides	No specific process standard	NA	General techniques 350–500, RAC 100
Sinter plant nitrogen oxides	No specific process standard	NA	Process-integrated 500, RAC 250, SCR 120
Coke oven particulates	No specific process standard	NA	1–20
Coke combustion sulphur oxides	No specific process standard	NA	200–500
Coke combustion nitrogen oxides	No specific process standard	NA	New 350–500, existing 500–650
Blast furnace hot stove particulates	No explicit BF hot-stove	NA	10
Blast furnace hot stove nitrogen oxides	No explicit BF hot-stove	NA	100
Blast furnace hot stove sulphur oxides	No explicit BF hot-stove	NA	200
BOF Secondary dedusting particulates	150 mg/m ³	164 mg/Nm ³	Bag filter 1–15, ESP 20
Electric Arc Furnace Particulate	150 mg/m ³ at 10% O ₂	164 mg/Nm ³	5
Reheating furnace particulates - solid fuels	150 mg/m ³ at 10% O ₂	223 mg/Nm ³ @ 6% O ₂	Process/BAT typically substantially lower depending furnace/control

Process and parameter	Indonesia standard (Kepmen 13/1995)	Converted to EU conditions	EU BAT-AEL 2012/2013 Emission Level
Reheating furnace particulates - gas/liquid fuels	150 mg/m ³ at 10% O ₂	268 mg/Nm ³ @ 3% O ₂	BAT generally based on combustion optimisation / low-dust fuels

For PT Krakatau POSCO specifically, the EIA documentation indicates that a secondary bag filter is applied to sinter-plant dust with an emission limit of 75 mg/Nm³. This value is half the particulate limit referenced under Kepmen LH No. 13/1995, but remains higher than the relevant EU BAT-AEL range.

To assess the potential reduction in particulate impacts under a technology-transition scenario based on Best Available Techniques, AERMOD modeling was conducted using low, medium, and high transition scenarios. The scenarios assume that 10%, 25%, and 60%, respectively, of total crude-steel production is shifted to the Scrap-EAF route, thereby reducing emissions associated with coke making, sintering, the blast furnace, and the BOF.

The modeling results show that increasing BAT implementation through a transition to the Scrap-EAF route consistently reduces PM₁₀ and PM_{2.5} concentrations across the study area. Higher levels of BAT implementation produce progressively larger reductions in both emission loads and ambient particulate concentrations.

Under the low-BAT scenario, the emission load is reduced by 59% relative to the existing condition. Average PM₁₀ and PM_{2.5} concentrations decline by approximately 39%. Despite this improvement, several locations still show maximum PM₁₀ and PM_{2.5} concentrations above the applicable ambient-air quality standards.

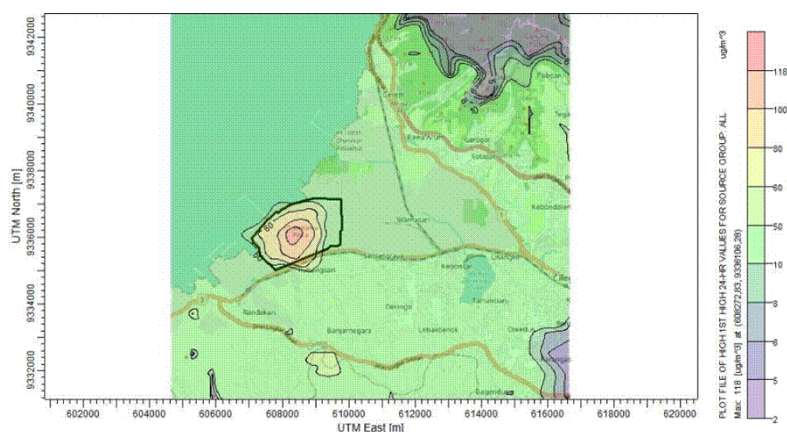


Figure 9. 24-hour PM₁₀ Isopleth under the Low-BAT Scenario

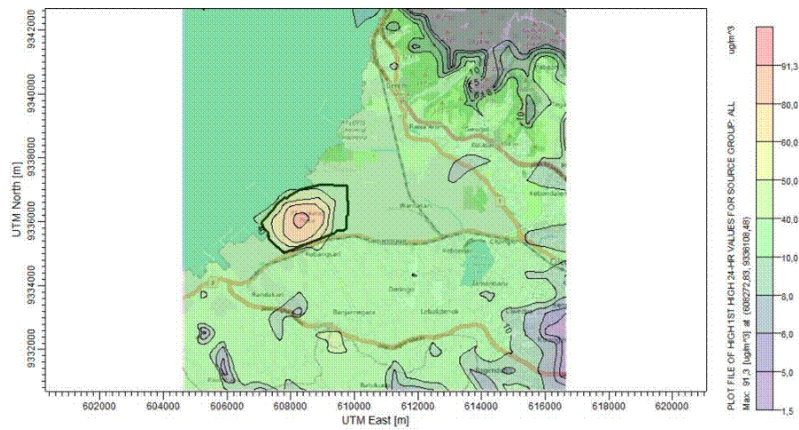


Figure 10. 24-hour PM_{2.5} Isopleth under the Low-BAT Scenario

Under the medium-BAT scenario, the emission load is reduced by 81% relative to the existing condition, while average PM₁₀ and PM_{2.5} concentrations decline by approximately 73%. The five maximum modeled concentrations for both PM₁₀ and PM_{2.5} are below the ambient-air quality standards under PP No. 22/2021, and the high-concentration areas shown on the dispersion maps decrease substantially. This scenario can therefore be considered a potentially effective minimum transition level for controlling particulate impacts from industrial activity.

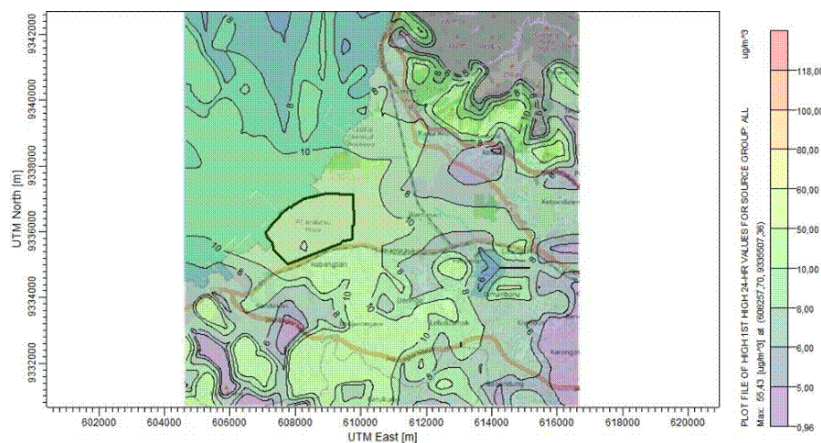


Figure 11. 24-hour PM₁₀ Isopleth under the Medium-BAT Scenario

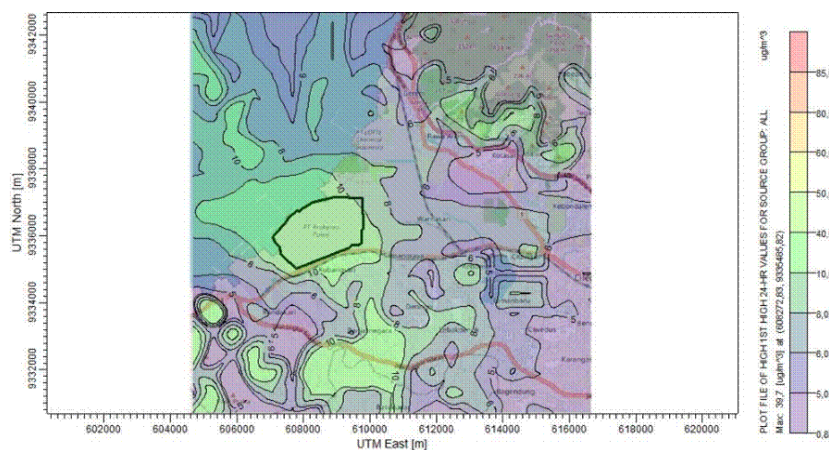


Figure 12. 24-hour PM_{2.5} Isopleth under the Medium-BAT Scenario

Under the high-BAT scenario, the modeled emission-load reduction reaches 97% relative to the existing condition. Maximum PM₁₀ and PM_{2.5} concentrations are substantially lower than under both the existing condition and the other transition scenarios. All simulated concentrations remain well below Indonesian ambient-air quality standards, providing the largest modeled margin of protection and control against particulate pollution.

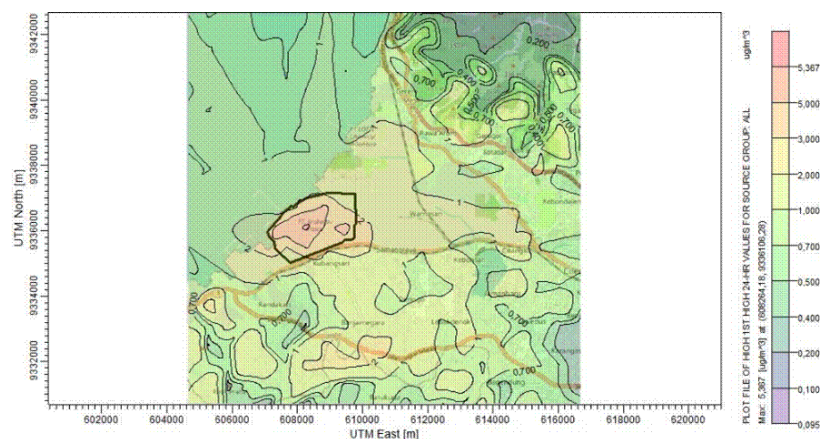


Figure 13. 24-hour PM10 Isopleth under the High-BAT Scenario

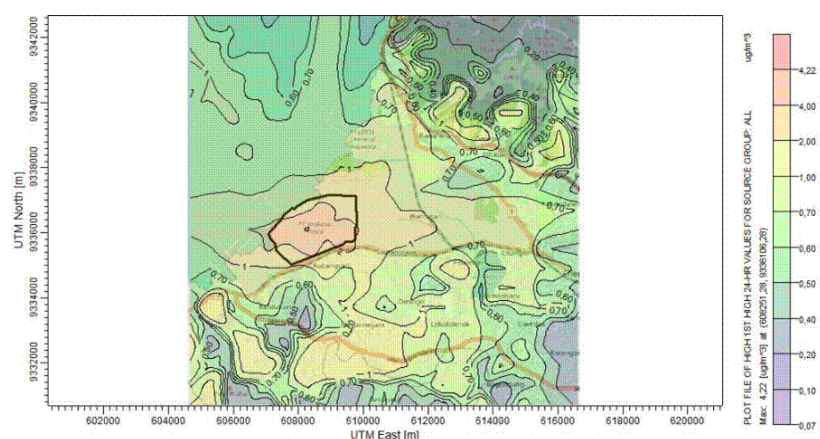


Figure 14. 24-hour PM2.5 Isopleth under the High-BAT Scenario

Assessment EU BAT to Korea's Regulatory

Table 20. EU BAT-associated emission levels compared with Korean emission standards^{11,33}

Korean values are for facilities installed on or after 1 January 2015. Figures in parentheses are the reference oxygen concentration; where the oxygen concentration differs, the value converted to European Union conditions is also shown.

Process and parameter	Korean standard	Converted to EU conditions	EU emission level (mg/Nm ³)	Assessment
Sinter plant particulates	10 mg/Sm ³ (15%)	10	Bag filter 1–15, advanced ESP 20–40	Within bag filter range
Sinter plant sulphur oxides	45 ppm (15%)	128.7 mg/Nm ³	General techniques 350–500, RAC 100	Below general technique range

Process and parameter	Korean standard	Converted to EU conditions	EU emission level (mg/Nm ³)	Assessment
Sinter plant nitrogen oxides	60 ppm (15%)	123.2 mg/Nm ³	Process-integrated 500, RAC 250, SCR 120	Close to the SCR level
Coke oven particulates	15 mg/Sm ³ (7%)	17.1 (5%)	1–20	Within range
Coke combustion sulphur oxides	85 ppm (7%)	277.8 mg/Nm ³ (5%)	200–500	Within range
Coke combustion nitrogen oxides	115 ppm (7%)	270.0 mg/Nm ³ (5%)	New 350–500, existing 500–650	Below the level for new plants
Blast furnace hot stove particulates	10 mg/Sm ³ (11%)	18.0 (3%)	10	Above the EU level
Blast furnace hot stove nitrogen oxides	80 ppm (11%)	295.8 mg/Nm ³ (3%)	100	About three times the EU level
Blast furnace hot stove sulphur oxides	No standard		200	No corresponding entry in Korea
Converter secondary dedusting particulates	10 mg/Sm ³	10	Bag filter 1–15, ESP 20	Within bag filter range
Electric arc furnace particulates	10 mg/Sm ³	10	5	Twice the EU level

Nb: All European Union values are upper limits and are expressed in the original text with a "less than" sign. Sinter plant nitrogen oxides are referenced to an oxygen concentration of 15% in the European Union Conclusions as well, so no conversion is required. No oxygen correction applies to the particulate standards for converters and electric arc furnaces in either system.

Two entries exist in Annex 15. The maximum emission standard for sinter plant particulates is 16 mg/Sm³ (15%), at the level of the upper bound of the European Union bag filter range, and the maximum emission standard for sinter plant sulphur oxides of 100 ppm (15%) equals 286.0 mg/Nm³, within the European Union general technique range.

For sinter plants and coke ovens, Korean standards fall within or below the European Union emission levels. For sinter plant nitrogen oxides, the Korean standard of 123.2 mg/Nm³ approaches the 120 mg/Nm³ that the European Union presents as achievable with selective catalytic reduction.

For blast furnace hot stoves the position is reversed. The European Union treats the use of desulphurised and dedusted coke oven gas, dedusted blast furnace gas, basic oxygen furnace gas and natural gas as best available techniques for hot stoves, and sets particulates at 10, nitrogen oxides at 100 and sulphur oxides at 200 mg/Nm³ referenced to an oxygen concentration of 3%. Converting the Korean hot stove standards to the same conditions gives particulates 18.0 and nitrogen oxides 295.8 mg/Nm³. Annex 8 contains no hot stove entry for sulphur oxides.

For electric arc furnaces particulates the Korean standard of 10 mg/Sm³ is likewise twice the European Union emission level of 5 mg/Nm³. The European Union treats the achievement of a collection efficiency above 98% through direct extraction, hoods, doghouse systems or total building evacuation, followed by treatment in a bag filter, as best available techniques.

For specific substances the position is as follows. Korea sets mercury at 0.04 mg/Sm³ (reference oxygen concentration 15%) for sinter plants and similar facilities in primary metal manufacturing, and the European Union sets 0.03-0.05 mg/Nm³ for the sintering process, a comparable level. No oxygen correction applies to the European Union value, however, so a direct comparison has limits. For polychlorinated dibenzo-p-dioxins and dibenzofurans the European Union sets 0.05–0.2 ng I-TEQ/Nm³ for sinter plants using a bag filter, 0.2–0.4 with advanced electrostatic precipitation, and 0.1 ng I-TEQ/Nm³ for electric arc furnaces. Korea sets no emission standard for these substances in steelmaking processes.

Korea's integrated environmental permit system was designed with reference to the European Union's Industrial Emissions Directive. Both consolidate permits previously issued by medium and calculate standards by examining the application of best available techniques at each facility.

The scope of application differs. The European Union Conclusions set emission levels and techniques for air, water, residues and energy for each of the sintering, pelletisation, coke oven, blast furnace, converter and electric arc furnace processes. Korea's Annex 15 sets only five entries for the steel sector, with the permissible emission standards of Annex 8 serving as maximum emission standards for the remainder.

The parameters for which the European Union Conclusions require continuous measurement also differ from Korea. Particulates, nitrogen oxides and sulphur dioxide from sinter strands, particulates from blast furnace cast houses, secondary particulate emissions from basic oxygen furnaces, and particulates from large electric arc furnaces are listed as subject to continuous measurement. Korea determines the scope of tele-monitoring by facility size and emission volume, and stacks measuring particulates at POSCO's two works account for 27% to 28% of all tele-monitored stacks.

3.4.4 Gap Analysis Global Benchmark and Practices of Iron-Steel Industry of Indonesia-Korea

Gap 1: Ambient-Air Standards in Both Countries Remain Above WHO AQG Levels

Both Indonesia and South Korea regulate major ambient-air pollutants, but their standards remain only partially aligned with the WHO AQG. For PM_{2.5}, both countries set an annual limit of 15 µg/m³, three times the WHO guideline of 5 µg/m³. Korea is closer to WHO for 24-hour PM_{2.5}, while Indonesia is closer for annual and 24-hour PM₁₀. The gap therefore does not indicate that one country is consistently stronger, but that both national standards remain less stringent than the WHO health-based benchmark, with different degrees of divergence by pollutant and averaging period.

Gap type: Stringency relative to global reference, there's partial alignment with WHO AQG in both countries.

Gap 2: Indonesia Shows a Wider Gap with IFC Stack-Emission Levels for Several Steelmaking Sources

Indonesia's process-based emission limits cover several major steelmaking sources, but after normalization, particulate limits for several processes and SO₂/NO_x boiler limits remain above IFC EHS recommended levels. However, alignment is parameter-specific; for example, the Indonesian HCl limit for pickling is numerically more stringent than the IFC value. The regulatory gap therefore reflects uneven alignment with IFC emission levels rather than a uniform deficiency across all pollutants.

Gap type: Stringency relative to global reference there's mixed alignment, with larger gaps for several conventional stack emissions.

Gap 3: South Korean Stack-Emission Standards Are Generally Closer to IFC EHS Levels, but Coverage Gaps Remain

For parameters that can be directly compared, Korean steel-sector emission standards are generally at or below IFC EHS recommended levels after reference conditions are aligned. Korea also regulates several hazardous pollutants covered by IFC. Nevertheless, alignment is incomplete, particularly because no steel-sinter-specific PCDD/F emission standard equivalent to the IFC guideline was identified. Thus, higher numerical alignment does not imply complete regulatory equivalence with IFC EHS.

Gap type: Regulatory coverage and global-reference alignment due to relatively high alignment with IFC, with remaining pollutant-specific gaps.

Gap 4: Fugitive-Emission Regulation Shows Different Degrees of Alignment with IFC EHS

The IFC EHS Guidelines identify process-specific fugitive-emission pathways including coke-oven leakage, pushing and quenching, blast-furnace tapping, BOF charging and tapping, and molten-metal transfer. Indonesian regulations recognize fugitive emissions and prescribe controls for stockpiles and material handling, but do not yet cover all these pathways in an integrated steel-specific framework. South Korean regulation more explicitly covers these process pathways. The gap therefore lies primarily in the completeness of source-specific fugitive-emission management relative to IFC good international industry practice.

Gap type: Regulatory coverage shows by different degrees of alignment with IFC fugitive-emission control practices.

Gap 5: Alignment with EU BAT Is Stronger Where Regulation Is Process- and Facility-Specific

EU BAT provides a more process-specific benchmark by linking techniques, emission levels, monitoring, and operational performance to individual steelmaking processes. South Korea's differentiated process standards, integrated permitting, and facility-specific limits more closely resemble this regulatory structure, while Indonesia's national standards remain broader across several process categories. However, the relevant gap is structural alignment

with the BAT approach, not simply whether Korean numerical limits are always lower than Indonesian limits.

Gap type: Regulatory coverage and implementation, different degrees of structural alignment with EU BAT-based regulation.

Gap 6: Formal Regulatory Alignment Does Not Necessarily Equal Implementation Alignment

Global benchmarks address not only numerical limits but also pollution-control technology, monitoring coverage, and operational management. Indonesia already recognizes several IFC-compatible control technologies, including ESPs, bag filters, scrubbers, and related systems, while South Korea applies integrated permitting and BAT-oriented review. At the same time, Korean tele-monitoring data show incomplete particulate coverage, demonstrating that even a framework relatively aligned with global benchmarks may retain implementation gaps.

Gap type: Implementation difference, formal alignment with global benchmarks is stronger than demonstrated implementation in some areas.

3.5 Regulation that Supports or Impedes Steel Decarbonization

Indonesia

At present, Indonesia already has a regulatory basis that can support steel decarbonization, but it is still fragmented across industrial policy, electricity, carbon governance, trade, and environmental regulation. The main barrier is therefore not the complete absence of regulation, but the lack of a single binding transition architecture that links technology choice, low-carbon electricity, scrap/DRI feedstock, carbon intensity standards, and green-steel demand.

1. Technology and production route

At the technology level, the strongest support comes from the Green Industry Standards issued by the Ministry of Industry. Permenperin No. 41/2024 establishes the Green Industry Standard for steel bars, while Permenperin No. 45/2024 covers steel slab, plate, hot-rolled coil and cold-rolled coil³⁴. The latter explicitly assesses raw materials, energy, production processes, waste management and GHG emissions, meaning that Indonesian regulation has started to incorporate carbon performance into steel-sector industrial standards rather than treating environmental performance only as conventional air-pollution compliance. More broadly, PP No. 29/2018 recognizes cleaner production, energy conservation, resource efficiency, recycling and low-carbon technology as elements of Green Industry implementation³⁵.

The limitation is that these instruments primarily function as standards and certification frameworks, not as a mandatory technology-transition pathway. They do not require an integrated BF–BOF producer to retire coke ovens, sinter plants or blast

furnaces by a particular year, nor do they establish compulsory shares for Scrap-EAF, DRI-EAF, hydrogen-based DRI or other near-zero-emission routes. This matters because a plant can theoretically improve energy efficiency and meet progressively better Green Industry indicators while remaining structurally dependent on BF–BOF. In other words, existing regulation supports incremental process improvement, but does not yet create a strong regulatory signal for production-route substitution.

There is also a related environmental-regulation issue. Indonesia's conventional steel emission framework still contains legacy requirements such as Kepmen LH No. 13/1995, while more stringent requirements may be imposed through facility-specific technical approvals.

2. Scrap and raw-material availability

For Scrap-EAF, Indonesia has a potentially supportive but administratively constrained raw-material framework. Permenperin No. 39/2024 regulates recommendations for importing non-hazardous waste as industrial raw material, expressly aiming to support industrial growth and raw-material availability while maintaining environmental safeguards. This is now complemented by Permendag No. 24/2025, which regulates imports of used goods and non-B3 waste^{36,37}.

This framework has a dual effect. On the supportive side, it provides a legal channel for importing eligible scrap when domestic collection cannot supply sufficient quantity or quality. On the barrier side, because scrap is regulated partly through the waste-import control architecture, EAF feedstock procurement carries permitting, verification and contamination-control requirements that primary iron ore does not face in the same way. For high-quality flat steel, this becomes particularly relevant because EAF operators need reliable scrap chemistry and control of residual elements such as Cu, Sn and other tramp elements.

3. Renewable electricity supply and Green Hydrogen

Electricity regulation is a key enabler for steel decarbonization because EAF and DRI-EAF deliver greater emissions reductions only when supplied with low-carbon electricity. Perpres No. 112/2022, Permen ESDM No. 10/2025, and the RUPTL PLN 2025–2034 support renewable-energy expansion, coal retirement, grid development, and the use of renewable electricity for green hydrogen and ammonia³⁸.

However, the transition remains constrained by continued additions of coal and gas capacity, the absence of a clear power-wheeling framework for direct access to off-site renewable electricity, and incomplete rules for green hydrogen certification, additionality, infrastructure, safety, pricing, and fiscal support. Therefore, electrification alone does not guarantee steel decarbonization; a credible EAF and hydrogen-DRI transition requires reliable access to verified low-carbon electricity and a more complete enabling regulatory framework.

4. Market creation for green steel

Indonesia is beginning to create the regulatory basis for product differentiation through the Green Industry Standards. Permenperin No. 45/2024 is particularly relevant because it covers slab, plate, HRC and CRC and includes GHG emissions among the technical criteria. This can eventually support a domestic definition or certification system for lower-carbon steel and reduce information asymmetry between conventional and lower-emission producers.

The market barrier is that certification does not automatically generate demand. Indonesia still lacks a broad mandatory requirement that major purchasers procure steel below a specified embodied-carbon threshold. The 2025–2029 RPJMN does point in this direction: it includes development of environmentally friendly product certification and specifically identifies sustainable government procurement as a priority program. However, the RPJMN also lists the preparation of further government-procurement regulations for environmentally friendly/sustainable products, indicating that this market-pull architecture is still developing. Green public procurement, embodied-carbon criteria for infrastructure, and long-term offtake commitments could therefore be as important as technology subsidies.

South Korea

Korea has operated an emissions trading scheme since 2015 under the Act on the Allocation and Trading of Greenhouse Gas Emission Permits (the Emissions Trading Act). It is a cap-and-trade system that sets a national emissions cap and distributes it among covered entities, distinct from intensity-based systems that issue permits in proportion to emissions. The scheme operates in planning periods, and the fourth planning period (2026–2030) is currently in force.

Allocation methods are distinguished by their calculation basis.

Table 21. Allocation methods

Method	Calculation basis	Characteristics
Benchmark (BM)	Emissions divided by product output or fuel consumption	Favours facilities with better emission efficiency
Grandfathering (GF)	Average actual emissions in the base period	Higher past emissions yield a larger allocation

The steel sector is allocated primarily on a benchmark basis. Benchmark coefficients are set for each process, including sintering, coke making, blast furnaces, converters and electric arc furnaces, and are calculated from the distribution of emission intensities among domestic operators.

The Fourth Planning Period (2026–2030) National Emission Permit Allocation Plan, finalised by the Ministry of Climate, Energy and Environment in November 2025, provides for the steel sector to retain 100% free allocation throughout the period. The basis is designation as a sector at risk of carbon leakage, which refers to the relocation of production from countries with strict emission regulation to countries with weaker regulation. Article 12(5)1 of the Emissions Trading Act provides for free allocation to facilities in sectors at risk of carbon leakage. The determination is made by whether the product of a sector's carbon intensity

and trade intensity is 0.1 or above. For primary steel manufacturing (Korean Standard Industrial Classification 241) the value is 1.408, placing it within the category (same plan, p. 6 and Attachment 3).

1. Conditions under which abatement incentives form

Abatement incentives under an emissions trading scheme arise from the supply and demand for permits across all participating companies; the scheme is not designed around individual sectors. The scale of the incentive actually formed in the steel sector can therefore be examined through four elements: the free allocation ratio, the degree to which benchmark coefficients are tightened, the relationship between allocations and actual emissions, and the level of permit prices.

First, the free allocation ratio remains at 100% throughout the fourth planning period. The auctioned share is 0% over the five years, while over the same period sectors not at risk of carbon leakage face auctioning of 15% to 50% in the power sector and 15% outside it (same plan, p. 25). The steel sector was also entirely within free allocation in the third planning period. The test then was whether the product of cost impact and trade intensity reached 0.2% or above, and the value for primary steel manufacturing was 4.959% (Third Planning Period National Emission Permit Allocation Plan, p. 9). The allocation plan states only that a transition to auctioning will be considered for the fifth planning period (2031–2035).

Second, benchmark coefficients are tightened only to a limited degree. The allocation plan provides for coefficients to be tightened in stages from the average emission efficiency level in 2026 to the top 20% level in 2030, with the top 20% level derived from the distribution of emission intensities from 2022 to 2024 among entities receiving advance allocation in the fourth planning period (same plan, p. 19). According to Attachment 4, over the five years the coefficient for pig iron production tightens from 1.2464 to 1.2249, a change of 1.7%, and for integrated pig iron production using iron ore from 1.6995 to 1.6663, a change of 2.0%. The coefficient for semi-finished crude steel production using converters remains at 0.15714, unchanged over the five years. The process with the largest coefficient shows the smallest tightening. Where the number of covered facilities is small and processes are homogeneous, a calculation method that relies solely on the domestic distribution does not translate into substantive change in the coefficients.

Third, a persistent gap existed between allocations and actual emissions. According to material submitted by the Ministry of Climate, Energy and Environment to the National Assembly, POSCO's final free allocation exceeded its actual emissions for three consecutive years.

Table 20. POSCO's final free allocation and actual emissions

Year	Final free allocation	Actual emissions	Difference
2022	77.14 Mt	70.18 Mt	6.96 Mt

2023	77.14 Mt	71.97 Mt	5.17 Mt
2024	76.42 Mt	71.06 Mt	5.36 Mt

The base period underlying allocations in the third planning period was 2017 to 2019, and Korean greenhouse gas emissions peaked in 2018. The decline in emissions in 2022 had a temporary cause in the disruption to operations at the Pohang works caused by Typhoon Hinnamnor.^[^3] In 2023 and 2024, however, emissions exceeded the 2022 level while allocations were not adjusted, so the gap persisted. No mechanism for adjusting gaps at the level of individual entities during a planning period was applied. The criteria for cancelling allocations were tightened in the fourth planning period. In the third period, allocations were cancelled where emissions in a compliance year fell 50% or more below the advance allocation because of the suspension, halt or closure of facilities; in the fourth period, reduced operating rates were added as a ground, the criterion was widened to emissions at or below 85% of the advance allocation, and correction factors apply by band of reduction (same plan, p. 29). This measure applies from the fourth planning period³⁹.

Fourth, permit prices have not reached a level that triggers process transformation. The low prices in the latter part of the third planning period reflect the oversupply arising from the gap between allocations and actual emissions. In auctions of paid allocations from July to December 2025, KAU25 clearing prices remained between KRW 8,950 and KRW 10,700 per tonne. Bids fell short of the volume offered in the auctions of 12 November and 17 December, and in the 17 December auction only 350,000 of the one million tonnes offered were sold. Prices rose from March 2026, with the August auction clearing at KRW 27,900, and the number of bidders rose from between four and nine in the second half of 2025 to twenty in August 2026. The structural background to this increase is the reduction of the fourth planning period cap to 2,537.29 Mt, 16.8% below the third period⁴⁰. The steel sector, however, retains 100% free allocation, so this price signal is not transmitted directly, and the current level induces only investment within the range of energy efficiency improvements whose marginal abatement cost is below the permit price

2. Comparison with the Indonesian scheme

As at January 2026 Indonesia had conducted no auctions, and the 2025 allocation of permits was postponed pending regulatory amendment. The Indonesian scheme applies to coal-fired power plants, with emission intensity ceilings set according to plant type and capacity⁴¹. Those ceilings are set high, so few installations exceed them, and demand for permits and participation in trading have been weak. Steel is scheduled for inclusion in 2027, so emissions from Krakatau POSCO currently receive a price signal under neither scheme⁴².

Table 22. Korean and Indonesian emissions trading schemes compared⁴³

Item	Korea (K-ETS)	Indonesia (NEK)
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Introduced	2015	2023
Approach	Cap-based	Intensity-based (no absolute cap)
Coverage of steel	Covered, 100% free allocation	Inclusion scheduled for 2027
Auctions	In operation	Not conducted

Neither scheme creates substantive abatement pressure on the steel sector. In Korea this is because of 100% free allocation and stagnant benchmark coefficients; in Indonesia because steel is not yet covered and because, even in the power sector where the scheme operates, ceilings are set loosely. The two schemes differ in maturity in terms of when they were introduced and whether an absolute cap exists, but neither Krakatau POSCO nor POSCO's domestic works faces a cost proportionate to emissions, and no price signal has formed that would justify the investment required for process transformation.

3. The K-Steel Act

The Act on Strengthening the Competitiveness of the Steel Industry and Supporting Its Carbon Neutral Transition (the "K-Steel Act", Act No. 21202) was enacted on 16 December 2025 and took effect on 17 June 2026 together with its Enforcement Decree. It is the first special statute directed at the steel industry since the repeal of the Steel Industry Promotion Act in 1986. The Act establishes a Special Committee on Steel Industry Competitiveness chaired by the Prime Minister, and requires the government to adopt a five-year basic plan and annual implementation plans (Articles 5, 6 and 9).

The support framework for carbon neutral transition runs from technology selection through to demand creation. The Minister of Trade, Industry and Resources designates low-carbon steel technologies and supports research, development and facility installation (Articles 10 and 11), and certifies steel that meets the certification criteria as low-carbon steel (Article 17). For certified products, the Minister may request that state agencies, local governments and public institutions establish preferential procurement plans, and institutions receiving such a request must establish and implement them (Article 22).

This framework operates on the premise of certification criteria, the content of which has not been set. The Enforcement Decree provides that the criteria shall be those published by the Minister of Trade, Industry and Resources, taking into account production methods, applied technologies and the resulting greenhouse gas emissions and reductions (Enforcement Decree, Article 23). As of 7 September 2026 no such notification has been issued, and the notifications issued on the date the Act took effect concern procedures only. Since preferential procurement applies to certified steel, Article 22 cannot take effect before the criteria are set. Emissions intensity benchmarks are already applied in international markets by the EU Carbon Border Adjustment Mechanism and by private procurement initiatives, and it has been argued that if Korea's certification criteria fall short of these thresholds the Act risks remaining a declaratory framework.⁴⁵

The Act takes precedence over other statutes with respect to special exceptions and regulatory relief (Article 4). The regulatory exceptions include the consolidation or

simplification of permitting procedures relating to the construction and expansion of production facilities and the closure of equipment; the environmental field is among those covered. The Act also provides for exceptions concerning exceedances of environmental standards that unavoidably arise in the course of industrial restructuring (Article 36(1), subparagraphs 1 and 2). The Enforcement Decree specifies the standards concerned as the permissible emission levels for air pollutants under Article 16 of the Clean Air Conservation Act, the permissible discharge limits for water pollutants under Article 32 of the Water Environment Conservation Act, and the permissible discharge standards under Article 8 of the Act on the Integrated Control of Pollutant-Discharging Facilities (Enforcement Decree, Article 47(1)). A steel business seeking such an exception submits to the Minister of Climate, Energy and Environment a statement of necessity and expected effects together with an environmental management plan, and the Minister replies with the outcome of review within thirty days (Enforcement Decree, Article 47(3) and (4)). The substance of the exceptions is to be published by the Minister of Trade, Industry and Resources in consultation with the heads of relevant central administrative agencies; this notification has likewise not been issued.

The Act thus combines a framework supporting low-carbon transition with exceptions permitting exceedances of environmental standards, and the substance of both has been delegated to ministerial notifications that remain unissued. Because the exceptions apply to emission standards under domestic environmental law, they do not extend to emissions from Krakatau POSCO.

4. Obligations of the parent company - Parent and subsidiary under company law

Korean commercial law takes the individual legal person as its unit of regulation and does not treat a consolidated entity as a single regulated object. The concept of an affiliated company is set out in competition law and is not defined in the Commercial Act. The terms parent and subsidiary appear only in Article 342-2, which restricts a subsidiary's acquisition of parent company shares and defines the relationship by holdings exceeding 50% of total issued shares; there is no independent provision governing the parent-subsidiary relationship.

The Commercial Act contains no provision giving a parent company grounds to exercise authority over a subsidiary or imposing any obligation on it to do so. Article 15 of the Financial Holding Companies Act and Article 11 of its Enforcement Decree confine the business of a financial holding company to management functions such as setting business objectives for subsidiaries, approving business plans, evaluating performance and determining governance structures, but no corresponding provision exists for non-financial holding companies. A management right of supervision over subsidiaries may be derived by interpretation from structures in which holding company officers concurrently serve as subsidiary directors, or from internal rules such as a corporate governance charter, but these are grounds for the existence of authority, not for the existence of an obligation⁴⁴.

The OECD Guidelines for Multinational Enterprises on Responsible Business Conduct require enterprises to cease and remediate adverse impacts arising from their own activities. The European Union Corporate Sustainability Due Diligence Directive (Directive (EU) 2024/1760) includes the activities of subsidiaries within the scope of due diligence and imposes obligations to prevent potential impacts and to bring actual impacts to an end and remediate them. Korean commercial law imposes no

obligation on a parent company to identify or manage the environmental impacts of a subsidiary.

The current company law framework provides no basis on which an external stakeholder may require a company to disclose environmental information about an overseas facility. For a domestic facility, a complaint or report could be filed on the basis of an exceedance of emission standards and material could be obtained through an administrative investigation, but Korean environmental law does not apply to overseas subsidiaries.

Directors owe a duty to monitor the performance of other directors and of management, and liability may be established where a director did not detect or control unlawful conduct through internal control mechanisms even without direct involvement. Cases in which this liability has been established in Korea are limited, and the mere absence of an item from disclosed board agendas is not sufficient to establish liability. The question shifts to whether the internal control system actually functioned.

The policies adopted by POSCO Holdings take the same form across all fields with respect to affiliated companies. The environmental policy defines its scope as applying to POSCO Holdings, and states with respect to affiliates and suppliers that they are encouraged to comply with the policy or with a policy of a comparable standard. The policies on biodiversity, green procurement, occupational safety and health, human rights management, responsible minerals and the supply chain take the same form¹⁶.

5. How regulation operates with respect to overseas facilities - Shareholding structure and control for accounting purposes

POSCO Holdings holds 100% of POSCO, and POSCO holds 50% of Krakatau POSCO. The remaining 50% is held by Krakatau Steel, the Indonesian state-owned steel company. This shareholding was transferred from POSCO Holdings to POSCO in September 2023.

Although the shareholding falls short of a majority, both companies classify the facility as a consolidated subsidiary. In the notes to its audit report, POSCO states that although it holds less than a majority of voting rights, it judges that it holds control after taking into account additional facts and circumstances including the relative size of its voting rights, the dispersion of other holders of voting rights, and the composition of the board (POSCO 4th fiscal year audit report, note 10, 2025). In its half-year report, POSCO Holdings records the basis of control for this subsidiary as de facto control, an exception among the subsidiaries it discloses, most of which are recorded as held through a majority of voting rights (POSCO Holdings half-year report, 14 August 2026).

Control under IFRS 10 is a concept for financial reporting. It determines which companies are included in consolidated financial statements and is not intended to allocate authority and responsibility. Recognition of control for accounting purposes is the company's own confirmation that POSCO is able to direct this facility, but no legal responsibility follows from it.

While ownership of the steelworks itself is divided equally, POSCO holds a majority in the entities supplying it with power and raw materials. Krakatau POSCO Energy operates two 100 MW by-product gas power plants and is 55% owned by POSCO

International. The current structure arose when POSCO International sold a 35% holding in June 2023 (POSCO International half-year report, 14 August 2026). All electricity generated at these plants is supplied to Krakatau POSCO, at a price set to recover generation costs and a rate of return on capital investment. The contracts expire in February 2039 for unit 1 and March 2039 for unit 2. Krakatau POSCO Chemical, which supplies quicklime, is 80% owned by POSCO Future M and holds contracts to supply 208,496 tonnes of quicklime and 38,116 tonnes of powdered limestone annually (POSCO Holdings half-year report, 14 August 2026).

6. Scope of application of schemes and voluntary mechanisms

The Korean emissions trading scheme applies to domestic facilities. Because the designation of covered entities and the calculation of emissions presuppose facilities located in Korea, emissions from Krakatau POSCO are not subject to the scheme. Under the Indonesian scheme the steel sector is scheduled for inclusion in 2027 and is therefore not currently covered either.

POSCO Holdings' carbon neutrality roadmap is likewise framed around domestic facilities and sets out no separate abatement pathway for emissions from overseas operations. In its replies to shareholder letters in 2023 and 2024 the company stated that it would establish and disclose a carbon neutrality roadmap for the steel division covering overseas operations; as of September 2026 no such roadmap has been identified in public sources.

POSCO states that it has operated an internal carbon price since 2024, but does not disclose the price level and confines its use to the economic assessment of investments and projects (2025 POSCO Sustainability Report, p. 26). POSCO Holdings states that it is refining the internal carbon price so that carbon costs can be substantively reflected in investment decisions (2025 POSCO Holdings Sustainability Report, p. 43).

7. Scope of emissions disclosure

Emissions information disclosed under the current framework is limited to the level of the legal entity, and facility-level emissions depend on reports the company publishes voluntarily. In financial disclosure Krakatau POSCO is a consolidated subsidiary, with its revenue and assets included in the consolidated financial statements. The sustainability report presents domestic and overseas emissions separately, but the emissions of the two overseas integrated mills are aggregated so that individual figures are not visible. Nor are the overseas figures subject to third-party verification by a greenhouse gas verification body (2025 POSCO Holdings Sustainability Report, pp. 104–105).

Table 23. Crude steel output and emissions of the POSCO group steel division, 2025 (emissions in tCO₂e)

Category	Crude steel output (kt)	Scope 1	Scope 2	Total	Emission intensity
Korea (Pohang, Gwangyang)	34,537	68,443,247	1,402,809	69,846,050	2.02
Overseas integrated mills	3,384	6,416,236	771,170	7,187,406	2.12

Air pollutants are reported in the same way. The reporting boundaries differ: domestic figures cover facilities subject to the environmental information disclosure system, and overseas figures cover facilities holding government environmental permits (same report, p. 106). Particulate emissions from the overseas integrated mills rose from 1,688 tonnes in 2024 to 3,670 tonnes in 2025, a change that occurred while the number of reporting entities fell from three to two.

Table 24. Air pollutant emissions and intensity, 2025¹⁶

Indicator	Korea (Pohang, Gwangyang)	Overseas integrated mills
NOx (t)	25,798	4,471
NOx intensity (t per kt)	0.75	1.32
SOx (t)	25,090	2,814
SOx intensity (t per kt)	0.73	0.83
Dust (t)	3,019	3,670
Dust intensity (t per kt)*	0.087	1.085

The intensity gap differs by substance. Nitrogen oxides overseas are 1.8 times the domestic level and sulphur oxides 1.1 times, whereas particulates are about twelve times. In absolute terms, the overseas integrated mills produced 9.8% of domestic crude steel output while emitting 651 tonnes more particulates than the domestic works.

The overseas integrated mills figure aggregates Krakatau POSCO and Yamato Vina. Given that Yamato Vina operates an electric arc furnace route with lower emission intensity, Krakatau POSCO's individual intensity is likely to be above 1.085, but this cannot be confirmed because the company does not disclose figures by facility. As with greenhouse gases, emission levels at overseas facilities cannot be established at the level of the individual entity for air pollutants either.

8. Routes of oversight over affiliated companies

POSCO Holdings discloses its routes of oversight over affiliated companies. Significant matters concerning the operation of affiliates are listed among items reported to the board, and significant ESG matters concerning affiliates among items reported to the ESG Committee, and the company states that the ESG Secretariat manages the ESG risk status of each operating company on a monthly basis (POSCO Holdings Corporate Governance Report, 29 May 2026, sub-principles 3-1 and 3-3).

The disclosed records of committee meetings contain no evidence that this route of oversight has operated with respect to greenhouse gas or air pollutant emissions at Krakatau POSCO. The agendas of the eight ESG Committee meetings held between January 2025 and May 2026 consist of internal transaction reviews such as participation in affiliate rights issues, payment guarantees and construction contracts, along with charitable contributions, report publication plans and quarterly group ESG performance reporting (POSCO Holdings Corporate Governance Report,

29 May 2026, sub-principle 8-2). In 2023 the committee received reports on the rolling of the 2050 carbon neutrality roadmap, a comparison of hydrogen reduction steelmaking technology development, and the results of physical risk analysis at major sites with response measures; from 2024 onwards the recorded agendas concern the establishment of disclosure systems and responses to assessments (POSCO Holdings Corporate Governance Reports, 31 May 2024 and 30 May 2025, sub-principle 8-2).

Indonesian operations have appeared on the agenda. In June 2023 the committee received reports on investment in a hydrometallurgical nickel refining project for batteries and on a joint venture in upstream stainless steel (POSCO Holdings Corporate Governance Report, 31 May 2024, sub-principle 8-2). In October 2023 it received the results of physical risk analysis at major sites with response measures, and in February 2024 the results of a correction to those values; Krakatau POSCO is among the sites covered by that analysis (2025 POSCO Holdings Sustainability Report, p. 44). The company records the maintenance of flood gates, flood walls and drainage facilities at this site as a response activity for 2025 (2025 POSCO Holdings Sustainability Report, p. 45). The former case concerns new investment and the latter the financial impact of climate change on a site. No agenda item addressing emissions management at the site appears in the meeting records.

3.6 Measure to Strengthen Decarbonization in Cross-Jurisdictional Steel Operation

POSCO's decarbonization strategy is significantly more advanced and structurally transformative than the measures currently disclosed for PT Krakatau POSCO (PTKP). At the group level, POSCO has moved beyond incremental efficiency improvements and is pursuing a staged transition from the conventional BF–BOF route toward lower-carbon steelmaking through increased scrap use, low-HMR operation, large-scale EAF deployment, CCUS, and ultimately HyREX. POSCO has already completed a 2.5 Mtpa EAF at Gwangyang and is developing HyREX as its long-term replacement pathway for blast-furnace ironmaking.

The HyREX program has progressed from laboratory-scale hydrogen reduction testing to a 1 t/h electric smelting furnace test facility and is now moving toward a 300,000 t/y demonstration plant, with technology validation targeted around 2030 before broader commercial deployment. In contrast, PTKP remains predominantly within the BF–BOF configuration and its publicly disclosed decarbonization measures are concentrated on efficiency and bridge solutions, including by-product gas recovery through PT Krakatau Posco Energy, rooftop solar installation, circular utilization of slag, dust and scale, Green Industry certification, and carbon-management studies.

POSCO International's 2025 sustainability report confirms that PT Krakatau Posco Energy operates a 200 MW power facility using BF gas, coke oven gas and LD gas from PTKP, thereby improving energy and resource efficiency, while the wider POSCO International portfolio is simultaneously expanding renewable energy, clean hydrogen and CCS capabilities. The clearest area where PTKP has begun to follow POSCO Group's deeper decarbonization pathway is CCS. The CCS project progressed from a preliminary feasibility study in 2024 to a full feasibility study in 2025, indicating movement beyond a conceptual MoU toward a more detailed implementation assessment. However, public disclosures do not yet show a final investment decision, construction schedule, capture capacity, or commercial deployment.

Likewise, there is currently no public evidence that PTKP has initiated an EAF or HyREX feasibility study. PTKP has adopted several elements of the POSCO Group decarbonization approach, particularly energy efficiency, by-product utilization, renewable energy, circularity, and CCS assessment. However, the most transformative measures—large-scale EAF deployment, hydrogen-based ironmaking, and HyREX-led replacement of the blast-furnace route—remain concentrated in POSCO's Korean operations rather than being replicated at PTKP. The practical gap is therefore not an absence of decarbonization activity at PTKP, but the fact that current efforts remain predominantly incremental and transitional, whereas POSCO's domestic strategy has already entered the stage of production-route transformation¹⁶.

A parent company holds shareholder agreements and the right to nominate directors as instruments through which it can affect the environmental performance of a subsidiary. A shareholder agreement may make compliance with local environmental regulation a contractual obligation. The right to nominate directors is exercised in the form of declining to reappoint, at the end of their term, directors who do not follow group policy.

Corporate human rights and environmental due diligence legislation

Measures at company level depend on the company's own discretion. Due diligence legislation is the route by which these become obligations. Three bills mandating corporate human rights and environmental due diligence are pending in the National Assembly, differing in how they define environmental harm, how they capture subsidiaries, and how they design access to information.

Table 25. Three corporate human rights and environmental due diligence bills compared

Item	Jung Tae-ho	Park Hong-bae	Park Ji-hye
Bill number	2210837	2213897	2220854
Introduced	13 Jun 2025	4 Nov 2025	27 Aug 2026
Status	Referred to subcommittee (8 Sep 2025)	Referred to subcommittee (23 Feb 2026)	Received by committee (28 Aug 2026)
Scope of application	Non-SME companies with 500 or more employees or KRW 200 bn or more in revenue (Art. 5)	Companies with fewer than 1,000 employees or under KRW 500 bn in revenue excluded (Art. 6)	Non-SME companies with 1,000 or more employees or KRW 500 bn or more in revenue (Art. 6)
Capture of subsidiaries	Controlled companies defined as subsidiaries under the External Audit Act and de facto controlled companies under competition law (Art. 2(3))	Relationships of control included in the definition of supply chain, scope delegated to enforcement decree (Art. 2(3))	Controlled companies defined as subsidiaries under the External Audit Act and de facto controlled companies under competition law (Art. 2(6))

Definition of environmental harm	Ten international environmental conventions listed in Annex 3 (Art. 2(4)(b), Annex 3)	Comprehensive definition of "adverse impacts on human rights and the environment" (Art. 2(4))	Environmental damage under the Environmental Dispute Adjustment Act and climate crisis under the Carbon Neutrality Framework Act (Art. 2(8))
Air pollution	No relevant convention	Not specified	Included
Climate and greenhouse gases	UNFCCC and Paris Agreement absent	Not specified	Included
Right to request information	Art. 16	Art. 16	Art. 17
Sanctions	Up to 5 years' imprisonment or a fine of up to KRW 50 m for failure to comply with a corrective order (Art. 41); administrative fine of up to KRW 50 m for failure to conduct due diligence (Art. 43)	Administrative fine of up to KRW 10 m (Art. 35)	Administrative fine of up to KRW 50 m for failure to conduct due diligence and up to KRW 30 m for failure to comply with a corrective order (Art. 42)

Source: original bill texts, National Assembly Bill Information System.

The bills differ in how they define the scope of application. The Jung Tae-ho and Park Ji-hye bills apply where either the employee or the revenue threshold is met, with the Jung bill setting the lowest thresholds at 500 employees or KRW 200 billion (Jung bill Art. 5; Park Ji-hye bill Art. 6). The Park Hong-bae bill excludes companies with fewer than 1,000 employees or under KRW 500 billion in revenue, so that both conditions must be met for the Act to apply (Park Hong-bae bill Art. 6).

On the capture of subsidiaries, the Jung Tae-ho and Park Ji-hye bills take the same approach. Both define controlled companies as subsidiaries under the External Audit Act and similar categories, thereby capturing subsidiaries expressly (Jung bill Art. 2(3); Park Ji-hye bill Art. 2(6)). The Park Hong-bae bill does not treat subsidiaries as a separate concept but includes them in the definition of supply chain, delegating the specific scope to the enforcement decree (Park Hong-bae bill Art. 2(3)).

The ordering differs again on the definition of environmental harm. The Jung Tae-ho bill confines environmental harm to violations of the conventions listed in an annex, and that list does not include the UNFCCC, the Paris Agreement or conventions concerning air pollution (Jung bill Art. 2(4)(b) and Annex 3). The Park Hong-bae bill defines human rights and environmental risk comprehensively as adverse impacts on human rights and the environment, so that air pollution and greenhouse gases are not excluded (Park Hong-bae bill Art. 2(4)). The Park Ji-hye bill names climate expressly by referring to environmental damage under the Environmental Dispute Adjustment Act and the climate crisis under the Carbon Neutrality Framework Act (Park Ji-hye bill Art. 2(8)).

The design of information access shows yet another ordering. Article 16 of the Jung Tae-ho bill allows stakeholders to request disclosure of information concerning due diligence, and provides that information must be disclosed where disclosure is necessary to protect life,

person or health from adverse impacts arising from the activities of the company itself, a controlled company or a company within its supply chain, even where the information constitutes a trade secret. Article 17 of the Park Ji-hye bill has the same structure but does not name controlled companies in the provision. Article 16 of the Park Hong-bae bill provides a right to request but adds national security to the grounds for refusal, and delegates to presidential decree the scope of information that must be disclosed rather than defining it separately.

The European Union Corporate Sustainability Due Diligence Directive includes the activities of subsidiaries within the scope of due diligence and lists international conventions in an annex with respect to environmental impacts. The obligation to adopt and implement a climate change mitigation transition plan, set out in Article 22 as enacted in 2024, was deleted by the amending Directive of February 2026 (Directive (EU) 2026/470).

All three bills fall under the Finance and Economic Planning Committee. As at 3 September 2026 the Jung Tae-ho and Park Hong-bae bills are at the subcommittee review stage.

The committee review reports record the view that the thresholds for application are low relative to the European Union directive currently under amendment, and the views of relevant agencies that the definitions of adverse impact, stakeholder and supply chain are broad. On the exception to refusal of disclosure in the Jung Tae-ho bill, the review noted that the scope of the necessity of disclosure is ambiguous and may give rise to disputes (Finance and Economic Planning Committee, review reports on each bill).

Where several bills of the same purport are pending, the standing committee ordinarily consolidates them into a single alternative and the original bills lapse as incorporated. Which definitional approach and which design of information access are adopted in that consolidation will determine the effectiveness of the resulting framework.

Mandatory sustainability disclosure

Unlike the due diligence bills, which remain under review in the National Assembly, the timing and scope of mandatory disclosure have been settled. Under the final plan for institutionalising sustainability disclosure announced on 8 July 2026, from 2028, that is from the 2027 financial year, 107 KOSPI-listed companies with consolidated total assets of KRW 10 trillion or more must disclose sustainability information in the business reports required under the Financial Investment Services and Capital Markets Act. The scope of disclosure includes climate risks and opportunities, transition risks and greenhouse gas emissions of subsidiaries where these are expected to affect the finances of the controlling company (Financial Services Commission, final plan for institutionalising sustainability disclosure, 8 July 2026).

Standard No. 1 of the Korea Sustainability Standards Board provides that the reporting entity for sustainability-related financial disclosures must be the same as the reporting entity for the related financial statements (paragraph 20). Because consolidated financial statements prepared under K-IFRS provide information about the controlling company and its subsidiaries as a single reporting entity, sustainability disclosures must be provided on the same basis (B38). During the standard-setting process a comment was submitted requesting that the reporting entity be confined to domestic subsidiaries, but the Board did not accept it on the ground that limiting the scope could be used to avoid disclosing information about certain subsidiaries and thereby give rise to greenwashing (Basis for Conclusions BC63, BC65)⁴⁶.

POSCO Holdings' consolidated total assets stood at KRW 105.19 trillion at the end of 2025, placing it within the first tranche. Krakatau POSCO is a consolidated subsidiary with total assets of KRW 3.23 trillion (POSCO Holdings half-year report, 14 August 2026).

Whether this facility's emissions will be identifiable through disclosure depends on two things. The first is the scope of disclosure. For the first year only, subsidiaries whose assets and revenue are both below 10% of the consolidated figures are excluded from the scope, and Krakatau POSCO's assets are around 3% of consolidated assets. Greenhouse gas emissions are to be disclosed using figures verified by a verification body under the Emissions Trading Act, but because the emissions trading scheme covers only domestic facilities, the basis on which emissions of overseas subsidiaries are to be calculated has not been settled. The second is the scope of exemption. For the first three years of the framework, liability for damages, administrative sanctions and criminal penalties are waived in respect of all disclosed information, and where an overseas subsidiary cannot provide data under local law, the information is thereafter treated as collected from an uncontrollable third party and the exemption continues to apply. Third-party assurance is to be introduced from 2030.

POSCO Holdings states that it has formed a climate disclosure task force in preparation for mandatory sustainability disclosure in 2028 and is establishing a system for calculating and managing greenhouse gas emissions on a group consolidated basis (2025 POSCO Holdings Sustainability Report, p. 43). Mandatory disclosure is a precondition for facility-level emissions to become identifiable, but under the current design there remains scope for overseas emissions not to be revealed. Whether substantive change follows depends on how the scope of disclosure and the basis for calculating emissions are specified.

Channels for shareholder engagement

The prevailing view is that under the current Commercial Act a shareholder proposal may be made only in respect of matters requiring approval by the general meeting, so that in practice no channel exists to table matters within the board's discretion, such as environmental management at overseas facilities⁴⁷. An alternative reading holds that this is possible under current law, since the Commercial Act permits shareholder proposals broadly and enumerates only the grounds for exclusion⁴⁸.

An advisory shareholder proposal is a mechanism by which shareholders may table matters that are not subject to approval by the general meeting, within limits that preserve the board's authority, with no binding effect even if the proposal carries. The United States operates such a mechanism under Rule 14a-8 of the federal regulations, and 388 ESG shareholder proposals were put to a vote in the first half of 2026 alone. France pursued an amendment to its commercial code in 2023 that would have required listed company boards to establish climate and sustainability strategies and submit them to an advisory vote at the general meeting, but the proposal was withdrawn during Senate deliberations.

In Korea, attempts have followed since March 2022, when Solidarity for Economic Reform, acting on a mandate from the investment company of the Dutch civil servants' pension fund, proposed that the former HDC Hyundai Development Company introduce a right of advisory shareholder proposal into its articles of association; at the 2026 annual general meetings, five proposals to create such a right and fifteen advisory items were tabled at eight companies. Proposals concerning the environment or social matters, however, were almost absent.

If this channel opens, it becomes possible to table an item requiring disclosure of a decarbonisation roadmap covering overseas facilities. Proposed amendments to the

Commercial Act would create the advisory shareholder proposal, require the board to publish within two months of a proposal carrying its review opinion and its decision on implementation, and, where it decides to implement, to report the implementation plan or outcome at the first annual general meeting thereafter. On the shareholding thresholds that restrict the right of proposal, an accompanying proposal would state an absolute monetary threshold alongside the percentage threshold.

Engagement by the National Pension Service

The National Pension Service has been the largest shareholder of POSCO Holdings since January 2007, with a holding of 8.17% as at the end of June 2026 (POSCO Holdings half-year report, 14 August 2026). The stated purpose of the holding was changed from general investment to simple investment in October 2024 and reverted to general investment in June 2026. Under the general investment classification, shareholder proposals and public demands are available⁴⁹.

When the guidelines on stewardship activities of the National Pension Fund were amended in March 2023, the management of climate change-related risk was added as a focus area. Focus areas set out the grounds on which the fund initiates dialogue with an investee company, in a structure that begins with private dialogue and escalates, where no improvement follows, to designation as a private focus company, then a public focus company, and finally a shareholder proposal. Because the final stage is confined to matters requiring approval by the general meeting, however, environmental management at overseas facilities cannot be tabled.

Engagement has declined since the guidelines were amended. The number of companies with which dialogue took place on climate change grounds fell from 29 in 2024 to 13 in 2025, and letters sent fell from three to none. Over the same period, dialogue on industrial safety rose from 10 companies to 14 (2025 Annual Report on Stewardship Activities of the National Pension Fund, p. 40). The companies engaged are not disclosed, so engagement with any individual company cannot be verified externally.

The purpose of stewardship activity is to improve the fund's returns and grow its assets. Presenting an environmental matter as grounds for engagement therefore requires a prior argument connecting it to financial risk. The basis for engagement is established where a pathway is set out by which environmental harm arising in Indonesia creates regulatory risk for the operation of the facility and that risk translates into financial loss for the parent company.

IV. CONCLUSION

Below is a conclusion structured directly around the three research questions.

Q1. How do Indonesian and South Korean regulations govern sustainability standards and decarbonization measures in the steel industry?

Both Indonesia and South Korea have regulatory frameworks covering air emissions, monitoring, ambient-air quality, industrial efficiency, and emerging decarbonization measures, but they differ in regulatory architecture. Indonesia has progressively strengthened environmental and green-industry regulation, including CEMS, Green Industry Standards, renewable-energy policy, and provisions supporting EAF, scrap use, and green hydrogen. However, these instruments remain fragmented and largely support incremental improvement rather than establishing a binding pathway for replacing carbon-intensive BF–BOF production.

South Korea applies a more process- and facility-specific approach through differentiated emission standards, integrated permitting, real-time tele-monitoring, total-emission-load management, and an established emissions-trading system. Nevertheless, Korea also retains limitations, including incomplete particulate monitoring coverage and weak carbon-price pressure on the steel sector.

Q2. To what extent are both regulatory systems aligned with WHO AQG, IFC EHS Guidelines, and EU BAT Conclusions?

Alignment is partial and uneven in both countries. Neither Indonesia nor South Korea fully aligns its ambient-air standards with WHO AQG; Korea is closer for 24-hour $PM_{2.5}$, while Indonesia is closer for PM_{10} . At the facility level, Indonesian emission standards show wider gaps from IFC EHS values for several particulate, SO_2 , and NO_x parameters, although some parameters such as HCl are comparatively stringent. Korean stack standards generally align more closely with IFC EHS and cover a wider range of hazardous pollutants and fugitive-emission pathways, although gaps remain, including PCDD/F regulation for sinter plants.

Korea's process differentiation and integrated permitting also more closely resemble the EU BAT approach, while Indonesia's framework remains broader and less process-specific. Therefore, global benchmarking identifies different degrees of alignment by pollutant, process, monitoring system, and regulatory mechanism.

Q3. How can regulatory harmonization and home-country decarbonization ambitions be applied consistently in the host country to prevent double standards?

The research indicates that preventing double standards requires moving beyond compliance with the minimum host-country standard toward a common cross-jurisdictional performance baseline. For POSCO–Krakatau POSCO, this would mean applying comparable process-specific emission controls, BAT-oriented pollution prevention, monitoring and disclosure practices, and decarbonization criteria wherever technically applicable, while

using WHO AQG, IFC EHS, and EU BAT as independent reference points where national standards differ.

Harmonization should also connect environmental control with the decarbonization pathway: low-carbon electricity, EAF/DRI transition, green hydrogen, credible carbon-intensity standards, and green-steel demand need to be integrated rather than regulated separately. Indonesia already has enabling policies, but lacks a binding transition architecture, while POSCO's current carbon-neutrality roadmap and Korean ETS primarily apply to domestic operations rather than establishing an equivalent pathway for overseas integrated facilities.

Overall, the research does not demonstrate that every regulatory difference between Indonesia and South Korea constitutes a double standard. The stronger evidence of potential double standards arises where comparable operations under the same corporate group are subject to materially different levels of process-specific control, monitoring, disclosure, or decarbonization ambition that cannot be reasonably explained by technology, facility age, operational conditions, or regulatory context. The central policy implication is therefore that cross-border steel investment should maintain a consistent minimum environmental and decarbonization performance standard based on the stronger applicable national requirement or relevant international benchmark. This would allow legitimate regulatory differences while reducing the risk that weaker host-country requirements become the effective ceiling for environmental performance.

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