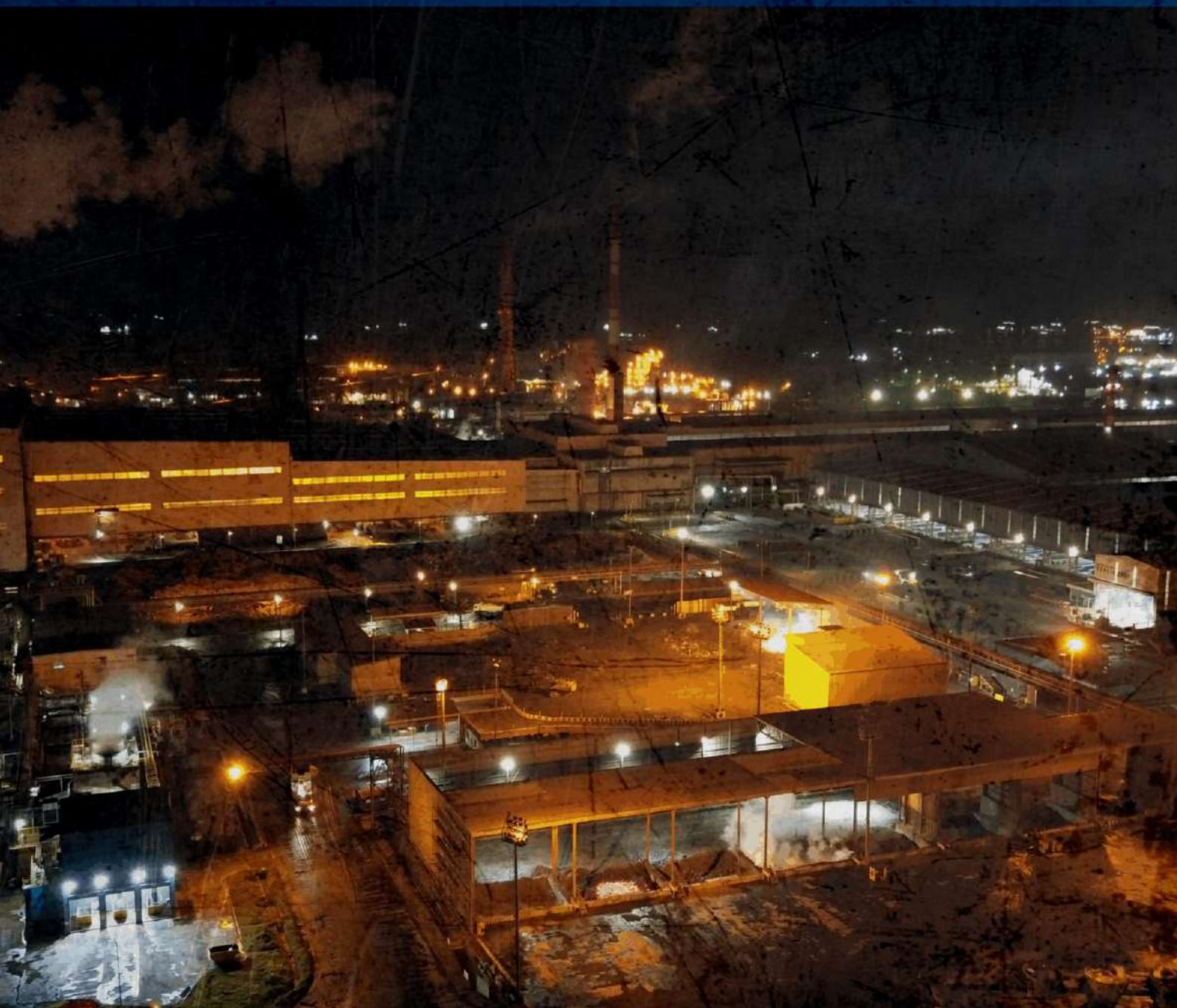


Analyzing the Impact of the Steel Industry on Public Health and Social Conditions in the Decarbonization Era



AEER Research Report

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Authors

AEER's Researchers

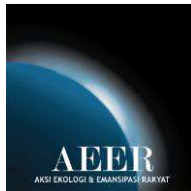
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**Aksi Ekologi dan Emansipasi Rakyat (AEER)
Action for Ecology and People's Emancipation**

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About Action for Ecology and People's Emancipation - Aksi Ekologi dan Emansipasi Rakyat (AEER)

AEER is an Indonesian environmental organization founded in 2017, dedicated to addressing ecological and social justice issues, particularly those exacerbated by unsustainable industrial practices. AEER's mission is to rescue communities impacted by environmental degradation and promote policies that support sustainability. The organization actively campaigns to reduce the country's dependence on fossil fuels, particularly coal, while encouraging a transition to low-carbon energy alternatives. This commitment is reflected in its target to help reduce Indonesia's carbon emissions by 446 million tons of CO₂ in the energy sector by 2060.

The organization collaborates with local and international partners, including community groups, government agencies, and other NGOs, to conduct research and advocacy campaigns. AEER's activities are particularly important in the context of Indonesia's growing nickel industry, which, while playing a crucial role in the global transition to electric vehicles, also poses significant environmental and social challenges. By raising awareness, producing detailed research reports, and engaging in policy dialogue, AEER seeks to mitigate the negative impacts of mining and other industrial activities. The organization also emphasizes the importance of biodiversity conservation and the protection of vital ecosystems, working to ensure that economic development does not compromise environmental integrity.

Praise be to God Almighty for His mercy and grace that this review or peer review on a research report entitled "The Impact of Steel Industry on Public Health and Social Conditions" could be properly completed. This review is an attempt to ensure that the research has scientific quality, accurate methodologies, and relevant results to public health and social issues emerging from steel industry activities. This review is expected to identify a wide range of strengths, weaknesses, and rooms for improvements to enhance the validity and credibility of the research results, allowing them to provide actual contributions in both policy making and scientific development for environmental health and social fields. We would like to express our gratitude to all parties supporting this review process, from providing documents, supporting data, to constructive discussions. We hope the results of this review will give helpful feedback to improve the research and any future scientific publications.

Best regards,

Reviewers



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Ambient air	Open air in the outdoors that will affect the health of humans, other living creatures, and the environment.
ARI (Acute Respiratory Infection)	A disease arising from viruses and bacteria attacking upper respiratory (nose, throat) or lower respiratory (lungs) tracts.
BF-BOF	A series of steelmaking processes using Blast Furnace (BF) and Basic Oxygen Furnace (BOF).
Blast Furnace's Shutdown	Temporary operational suspension of Blast Furnace for furnace core cleaning.
Buffer Zones	Areas separating industrial parks and residential areas (or any other sensitive functions) that work to reduce environmental impacts, such as noises, dust, air pollution, or industrial accident risks.
Carbon	A chemical element that serves as the basis of CO ₂ emissions and an important component in the steel industry.
CBAM (Carbon Border Adjustment Mechanism)	The mechanism of carbon adjustment by the European Union to impose carbon pricing to import goods, such as steel, aluminum, and fertilizer.
CEMS (Continuous Emission Monitoring System)	A continuous monitoring system of emissions from industrial stacks.
CO₂eq	A measurement unit that converts a variety of greenhouse gases into impacts equivalent to CO ₂ .
Coke	Solid carbon fuel made of coal for Blast Furnace.
Coke Oven Plant	An industrial facility producing coke from coal using high-temperature, oxygen-free heating process.
CRC (Cold Rolled Coil)	A type of sheet steel product processed by cold rolling.

CRM (Cold Rolling Mill)	A low-temperature steel rolling facility (under recrystallization), producing steel sheets with highly precise thickness, smooth surface, and higher strength.
Decarbonization	An attempt to reduce carbon emissions from industrial processes, energy, and human activities.
DRI (Direct Reduce Iron)	Direct reduction process of iron ores using natural gases or hydrogen, producing sponge iron.
EAF (Electric Arc Furnace)	Electric arc furnace to produce steel (usually from scrap).
EIA (Environmental Impact Assessment)	A release of chemical substances, gases, or particles to the environment, both naturally and from human activities.
Emission	Gas-gas di atmosfer bumi yang menyebabkan pemanasan global (CO ₂ , CH ₄ , N ₂ O, dll).
Fisher's Exact Test	A statistical test used to examine the relationship between two variables in a contingency table, particularly when the sample size is less than 30 or expected frequency is below 5.
Flux	Additional materials (e.g. limestone) to remove dirt in metallurgic processes.
Foreign Investment	Investment made by foreign parties or companies domestically. In industrial context, Foreign Investment generally refers to any company with foreign capital ownership operating in Indonesia, including manufacturing, mining, steel and energy sectors.
FPFA (Foreign Pollution Free Act)	U.S. policy that requires tracking and verification of low-pollution for imported goods.
Fugitive Emission	Uncontrolled released emissions from leakage, material movement, or open areas.
GDP (Gross Domestic Product)	The total value of good productions/services of a country.
GHG (Green House Gas)	Gases in the atmosphere of the earth causing global warming (CO ₂ , CH ₄ , N ₂ O, etc).
HRC (Hot Rolled Coil)	Steel sheets produced by hot rolling.

Hot Strip Mill/ Hot Rolling Plant	A hot rolling facility to transform slabs into steel sheet rolls (HRC) at high temperature, ideal for high-volume production.
Ironmaking	The process of creating iron in the early phase of steelmaking.
Multistage Random Sampling	Gradual sampling method with random selection at each stage.
NZE (Net Zero Emission)	A condition where produced emissions are equal to the absorbed/balanced emissions.
Plate	A thick steel sheet produced from the rolling of slab steel.
PM2.5	Ultrafine particulate matters with the size of ≤ 2.5 micrometers.
PM10	Fine particulate matters with the size of ≤ 10 micrometers.
Quality standard	The standard or the maximum limit set by regulations to measure the quality of the environment.
Questionnaire	A data collection method consisting of a series of written questions arranged systematically to obtain information from respondents.
Respondents	Anyone asked to give responses to the questions prepared by the researchers, either in the form of questionnaires or by interviews.
Silicosis	A lung disease caused by long-term silica dust exposure.
Sintering	Compaction process of fine ores (fines) into agglomerates through a heating process before entering the Blast Furnace.
Slab Steel	A type of semi-finished steel in the shape of wide and thick beams, a material for HRC, plates, and other sheet products.
SNDC (Second Nationally Determined Contributions)	A climate commitment document of a country to update its mitigation (reducing emissions) and adaptation (increasing resilience) measures for climate change, in accordance with the objectives of the Paris Agreement to contain global warming.

Steelmaking

The process of transforming iron into steel.

Steel slag

Solid waste from the steelmaking process



Steel industry is one of the biggest contributors of greenhouse gas emissions in Indonesia, with a significant contribution to the total national emission of up to 1.36 billion tons of CO₂e in 2023, where industrial sectors contributed 59.85 million tons of CO₂e. The most used technology, Blast Furnace–Basic Oxygen Furnace (BF–BOF), produces an average emission intensity of 2.2 tons of CO₂eq per ton of steel, way higher than the alternative technology Electric Arc Furnace (EAF), which only produces about 0,5 tons of CO₂eq per ton of steel. Nevertheless, 75% of the national steel industry is still using BF–BOF, and the industrial development plan until 2060 shows that this high-emission technology will still dominate the industry, with up to 75% of production capacity. PT Krakatau Posco, as the largest BF–BOF-based integrated steel plant in Indonesia, produces up to 3 million tons of slab steel per year and operates large facilities such as Sinter Plant with the capacity of 9.38 million tons of sinter/year, Blast Furnace with the capacity of 8.26 million tons of hot metal/year, and Coke Oven Plant that produces 2.64 million tons of coke/year. With phase II expansion, the capacity for slab steel reaches 6.0 million tons, HRC reaches 4.5 million tons and CRC achieves 1.8 million tons per year, strengthening its position as one of the largest emission contributors in the manufacturing sector.

At the heart of the steel industry expansion, Tegal Ratu Village, Cilegon Municipality, located in the nearest radius of the industrial park, is facing a high-level of air pollution risk. With a total population of 11,987 people, this region has become the area with highest ARI cases in Cilegon Municipality. Data from Public Health Center (*Puskesmas*) of Ciwandan reveals that ARI was the most prevalent disease in 2016-2024. A survey by AEER involving 94 respondents who had lived there for more than 10 years indicates that many experienced chronic coughing, shortness of breath, and other respiratory complaints related to pollutant exposure. The steel industrial processes produced PM_{2.5}, which recorded in the EIA measurement to have exceeded the quality standard of South Korea in several monitoring spots. In other countries, similar impacts were also recorded, for instance in Pennsylvania, where 70% of children were exposed to higher amount of PM_{2.5} and 22.5% of them were diagnosed with asthma. The global findings show that PM exposure causes the increase of inpatient cases of pneumonia and bronchitis. For silicosis cases, data in Poland indicates that 2,066 workers were suffering from this disease in 2000–2019, showing how high the risk of industrial exposure to lung health is.

Domestically, the demand for steel is projected to drastically increase from 16 million tons in 2023 to 207 million tons in 2060, multiplied by more than 12 times. Without technology transition, the greenhouse gas emission of the steel industry is expected to surge by 11.7 times in 2060, and potentially contribute up to 68.1% of the total national emissions. With KS Group's market share of 34–42% of the national steel production, the increased production of Krakatau Posco will significantly contribute to the surge. On the other hand, the steel export market in Indonesia is facing threats from policies such as European Union's CBAM and U.S.'s FPFA that impose carbon pricing to carbon-intensive steel imports. Krakatau Posco itself exports hundred thousand tons of HRC and plates to Europe and America every year, meaning that high-emission BF–BOF products are likely to be subjected to the carbon tariff, undermining their competitiveness.

The findings of AEER research through emission analysis, EIA review, and field survey highlight the relationship of steel industrial activities with the decreased air quality and the high prevalence of respiratory diseases among Tegal Ratu residents. This research also reveals how unprepared the national steel industry is in facing the global decarbonization era. The technological transformation by switching to low emission route—e.g. renewable energy-based DRI–EAF, scrap recycle capacity increase, air quality regulation enhancement, and public health protection—becomes an urgent need for Indonesia to avoid being trapped in high emission construction route, which may harm the people and the national economic position in long term.



1.1 Background

The climate crisis today has become humanity's greatest challenge. Human activities, such as fossil fuel use and deforestation, have increased Green House Gas (GHG) concentration in the atmosphere. The higher the accumulated GHG emissions, particularly carbon dioxide (CO₂), the stronger the effects of greenhouse gas will be, causing the global temperature to rise significantly. This temperature rise results in serious threats to the ecosystem and the socioeconomic stability, from increased occurrence of natural disasters to health risk due to heatwave and air pollution.

The industry is a key contributor to the national GHG emissions. According to the data of the Ministry of Environment and Forestry, the total national GHG emissions reached 1.36 billion tons of CO₂e in 2023. Industrial activities contributed to 34% of the national emissions, which was 59.85 million tons of CO₂e. The 36% of total industrial emissions were coming from 9 sectors with largest energy consumptions, namely the industry of steel, cement, iron and steel, chemicals, fertilizers, pulp and paper, textiles, glass and ceramics, food and beverages, and automotive. The industry, on one hand, drove the national economy with 18.9% of national GDP, 19.3 millions of workers, and Rp80.5 trillions of foreign investment or 52.3% of national investment in 2022. Therefore, the climate crisis mitigation process becomes a challenge, as well as an opportunity—not only for the industry, but also for Indonesia as a nation (Ministry of Industry, 2025).

The steel industry requires a massive amount of energy and produces a massive amount of emission at the same time, thus it can be classified as a “hard-to-abate” industry. Steel production contributes 10% of global greenhouse gas emissions. (Worldsteel, 2025). Domestically, 75% of the national steel industry is still using Blast Furnace-Blast Oxygen Furnace (BF-BOF) technology, which is high in emissions with up to 2.2 tons of CO₂eq per ton of steel. This technology still relies on fossil fuel—like coking coal for combustion, resulting in high emissions and air pollution in the nearby area.

Another technology, electricity-based Electric Arc Furnace (EAF), generates lower emissions of up to 0.5 tons of CO_{2eq} per ton of steel. However, it is still rarely used in Indonesia, only 25% in total. Unfortunately, the future development plan based on Global Steel Plant Tracker (GSPT) demonstrates that BF-BOF technology will remain on top, with a projected contribution of 75% of the national steel production capacity. It may cause dependence on fossil fuel, which will only hinder the energy transition process and worsen the climate crisis. On the other hand, the residents near the steel factories will suffer the negative impacts. The produced dust and fine particles not only contaminate the air, but also endanger public health.

Both workers and those living around the steel industrial park are at risk of several diseases. Exposure to pollutants such as PM (PM_{2.5} and PM₁₀), gases (SO₂, NO_x), and dust from steel industry may cause Acute Respiratory Infection (ARI), bronchitis, Chronic Obstructive Pulmonary Disease (COPD), and impaired lung function. In Pennsylvania, U.S., it was reported that 70% of children were exposed to PM_{2.5}, which exceeded the quality standard of the steel plant near their school in 2014-2017. Additionally, 22.5% of them were diagnosed with asthma, which was significantly related to the high exposure to pollutants, such as NO_x, sulfur (S), and silica dust (Smit, 2020). Another study in Utah Valley, U.S., stated that there was a surge of inpatient care cases for pneumonia, bronchitis, ARI, and asthma along with the increased PM₁₀ pollutant due to reopening of a steel plant (Pope *et al*, 1989).

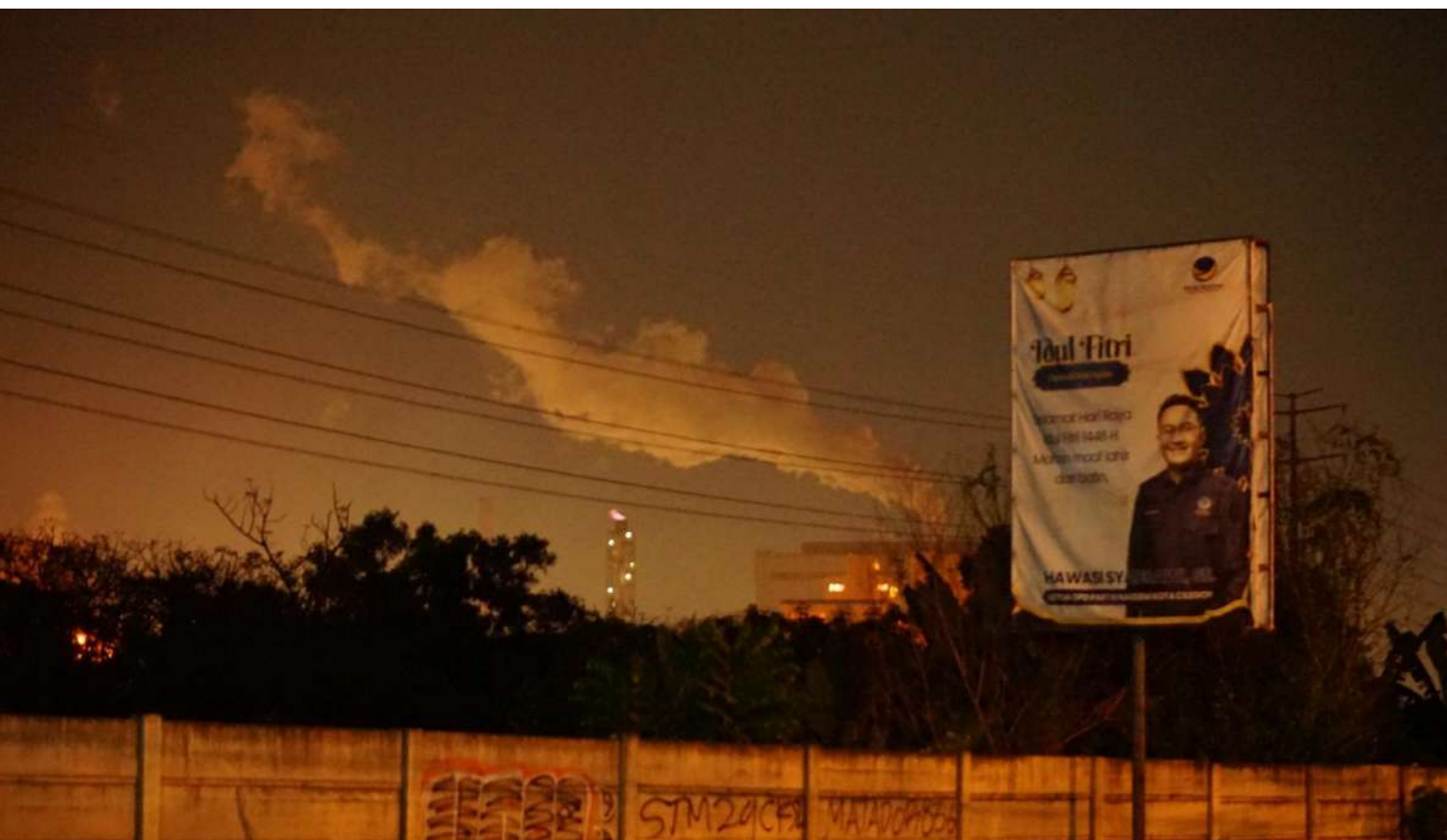
In Poland, based on the data of the Central Register of Occupational Diseases, there were 2,066 silicosis cases among workers of the manufacturing, iron, and steel sectors in 2000–2019. Silicosis contributed 12.8-21.2% to the overall pneumoconiosis cases (a lung disease caused by inhaling hazardous dust in a long period of time, such as coal and silica dust) per year (Nowak-Pasternak J. *et al*, 2022). A study by Dales, *et al* (2013) shows that 61 participants spending most of their time near a steel plant settlement (0.9 km away) for 8 hours a day and 5 consecutive days, experienced a impaired lung function, diffusion capacity, and oxygen saturation compared to when they were in a more distant location (4.5 km away).

Meanwhile in Indonesia, respiratory disease cases and other health problems are frequently reported by the people in the industrial park of Cilegon Municipality. According to the data of Statistics Indonesia (*Badan Pusat Statistik/BPS*) of Cilegon Municipality in 2016-2024, ARI was the most prevalent disease among them. The fluctuation of industrial emissions, such as the surge of PM_{2.5}, is also known to raise the number of outpatient/inpatient care for respiratory cases (pneumonia, bronchitis) among the population who lives near the plant. A research was conducted by Rahmaningsih (2022) in Tegal Ratu Village, through a thesis entitled '*Pajanan PM_{2.5} terhadap Gangguan Fungsi Paru pada Masyarakat yang tinggal di Permukiman sekitar Kawasan Industri Kecamatan Ciwandan Kota Cilegon Tahun 2022*' (The Impact of PM_{2.5} Exposure on Impaired Lung Function of the Residents Near the Industrial Park of Ciwandan Subdistrict, Cilegon Municipality in 2022) and a journal entitled '*Hubungan Pajanan PM_{2.5} terhadap Gangguan Fungsi Paru pada Orang Dewasa di Kecamatan Ciwandan, Kota Cilegon Tahun 2022*' (The Correlation Between PM_{2.5} Exposure on Impaired Lung Function in Adults of Ciwandan Subdistrict, Cilegon Municipality in 2022).

The research results by Rahmaningsih (2022) imply that there is a significant correlation between PM2.5 concentration and impaired lung function in adults living around the industrial area. This study also found that PM2.5 is a significant air pollutant parameter that affects respiratory disorders and human lungs. This <2.5 micrometer particulate matter, if inhaled, may cause ARI.

This is where industrial decarbonization plays an important role. Industrial decarbonization aims to reduce or even eliminate carbon emissions produced by the use of fossil fuel and industrial activities. Decarbonization is an important step in addressing climate change and achieving net zero emission. This is a challenge for Indonesia and the existing companies. Along with Indonesia's economic growth and industrialization plan, there is also a climate change mitigation agenda by reducing fossil energy and using renewable energy. The narrative of green steel becomes more popular globally and in Indonesia, but it does not come hand in hand with any concrete and environmentally friendly initiatives.

Therefore, it is required for the industry in Indonesia to make strategic changes, one of them is by approaching the industry giants. The steel industry giants, such as Krakatau Steel (KS) Group, are dominating the market in Indonesia ($\pm 40\%$ of market share) with massive steel production (3 million tons of steel/year). Other than generating massive GHG emissions, it practically pollutes the nearby environment and adversely impacts the lives of the people in the area.



1.2 Problem Statement

Steel industrial activities in the Ciwandan area, especially around Tegal Ratu Village, is still dominated by the use of Blast Furnace–Basic Oxygen Furnace (BF/BOF) technology, which is energy-intensive and produces high volumes of carbon emissions and air pollutants. Emissions from BF/BOF processes contribute to the increased concentration of ambient pollutants such as PM_{2.5}, silica dust, and heavy metal (Hg and Cd) to the air around the industrial park. The accumulated pollutant has directly caused the decline of air quality around the residential area of Tegal Ratu Village, which is the nearest area to the heart of steel industrial activities.

The declining air quality due to industrial pollution exposure also causes an increased risk of public health issues, particularly Acute Respiratory Infection (ARI). The correlation between industrial emission intensity and public health condition of Tegal Ratu reflects an environmental burden the people must bear due to the industrial activities, which are yet to fully apply decarbonization principles and low-emission technologies. Thus, the study was conducted to analyze the impact of the steel industry on the public health and social condition in Tegal Ratu Village, Ciwandan Subdistrict.

Questions and Hypotheses

1. Question 1: How does Indonesia's steel industry carry out decarbonization?
2. Question 2: What are the differentiating factors of types and levels of air pollutants produced by the steel industry using fossil energy, both directly and indirectly?
3. Hypothesis 1: High-emission technologies, such as blast furnaces, create pollution, and it needs to switch to renewable energy with lower emission and lower pollution.
4. Hypothesis 2: Steel industry activities potentially result in air contamination, which may negatively impact the health of nearby population.



1.3 Objectives

1. To conduct a study on the impact of air pollution from steel industrial activities on social, environmental, and public health conditions around the area.
2. To conduct an investigation that covers emissions from industrial companies (carbon scope 1 and 2).
3. To urge the issuance of regulations on decarbonization of the steel industry sector in Indonesia.
4. To identify existing regulations about air pollution in the steel industry.

In other words, not only aiming to find out how big the impact of steel industry on air, greenhouse gas emissions, and public health, this research also ought to provide scientific basis to redirect the steel industry policies to a more environmentally ethical and greener direction.





II. Research Methodologies

2.1 Research Design

The research by AEER employed a qualitative analysis methodology using primary and secondary data. The primary data consisted of a questionnaire with respondent sample of Tegal Ratu residents, direct interviews with the residents and videos of their daily lives, as well as environmental landscape pictures around Krakatau Posco industrial park. The approach was made by observing the trends/patterns and the causal relationship between the primary and the secondary data.

As for the questionnaire, it applied a cross-sectional study design methodology. This research design was used to identify the issues that occurred in a population. In the cross-section study design, a one-time measurement was applied to all variables at once. On the other hand, the relationship between variables in the questionnaire's data was analyzed using a statistical method using Fisher's Exact Test and binary logistical regression model.

The results of these questionnaire data were then attributed to the secondary data, which consisted of AMDAL (EIA) RKL-RPL (Environmental Management and Monitoring Plan) of PT Krakatau Posco obtained from the Ministry of Environment (*Kementerian Lingkungan Hidup/KLH*), ARI (ISPA) data of Tegal Ratu Village from Public Health Center (*Puskesmas*) of Ciwandan, population demographics of Tegal Ratu Village and Ciwandan Subdistrict, and a list of most common diseases in Ciwandan Subdistrict from Statistics Indonesia (BPS) of Cilegon Municipality.

2025 EIA data of PT Krakatau Posco were obtained by AEER's research team after 2 months of correspondence with the Ministry of Environment (KLH). Prior to receiving the EIA document, AEER's research team also had email correspondence with and visited the Environmental Office (*Dinas Lingkungan Hidup/DLH*) of Banten Province and Cilegon Municipality in August 2025, but no follow-up from the DLH was provided.

As for interviews, 3 informants were chosen. They were the Head of a Neighborhood Association (RT), the Head of a Neighborhood Council (RW), and the Head of a Community Empowerment Institution (*Lembaga Pemberdayaan Masyarakat/LPM*) of Tegal Ratu Village, entrusted by the people to represent and communicate their complaints to PT Krakatau Posco. However, no quantitative approach, such as ambient air measurement and respondents' health sample collection (e.g. blood test), was carried out due to the time limit and financial considerations.

2.2 Research Location and Time

The subjects of this research were the steel industry of PT Krakatau Posco and the people of Tegal Ratu Village, Ciwandan Subdistrict, Cilegon Municipality, Banten Province. However, this AEER research did not include another area far from the location and not exposed to air pollution from the steel industry as a comparison due to the time constraint.

PT Krakatau Posco was chosen as the research location for AEER because Krakatau Posco—a part of KS Group—owns the first blast furnace in Indonesia. Despite coming from a foreign investment from POSCO Korea, PT Krakatau Steel is still involved as a state-owned enterprise (under Indonesia's government) with the ownership share of 50% respectively.



Figure 1. Radial Distance Map from the Outermost Point of PT Krakatau Posco
(Source: processed by Google Earth, 2025)

Apart from that, the selection of Tegal Ratu Village as the research location also stemmed from its status as an EIA monitored area of PT Krakatau Posco, its close distance to the industrial park, and its potential of being highly exposed to the pollutants from the plant.

The research was conducted in August-September 2025.

2.3 Research Sample

The sample consisted of questionnaire respondents who were adults living around the industrial park of Tegal Ratu Village, Ciwandan Subdistrict, Cilegon Municipality. The criteria for these analyzed respondents include those who are local residents aged 20-70 years, are females and males, have lived and resided for more than 10 years in Tegal Ratu Village, and are willing to participate as a respondent.

The target number of respondents to fill out the questionnaire was 100 participants. This low number of respondents was due to the time limit. This sample number was still acceptable to represent the variables, which were measured descriptively. The number of samples in the questionnaire was determined based on Slovin formulation by taking a margin of error of 10%.

$$\begin{aligned}n &= \frac{N}{1 + Ne^2} \\&= \frac{11.987}{1 + 11.987 (0,1)^2} \\&= 99,17 \approx 100 \text{ respondents}\end{aligned}$$

Description:

n = number of sample

N = number of population in Tegal Ratu Village in 2024

E = margin of error

2.4 Sample Collection

There were 7 Neighborhood Councils (RW) and 22 Neighborhood Associations (RT) in Tegal Ratu Village. The selection of respondents was conducted using a multistage random sampling method. In the first stage, the population was grouped based on their RW and RT in Tegal Ratu Village, which in total are 22 and 7 respectively. After that, the respondents in each RW who had consented and volunteered to fill out the questionnaire were required to provide confirmation to their RT Head, who would connect them to the AEER team.

No limit was applied to the number of respondents per RT. The respondents that had provided confirmation were required to attend a discussion forum and to complete the questionnaire at the hall of KTKBM Cooperative in Tegal Ratu, Cilegon.

2.5 Research Conceptual Framework

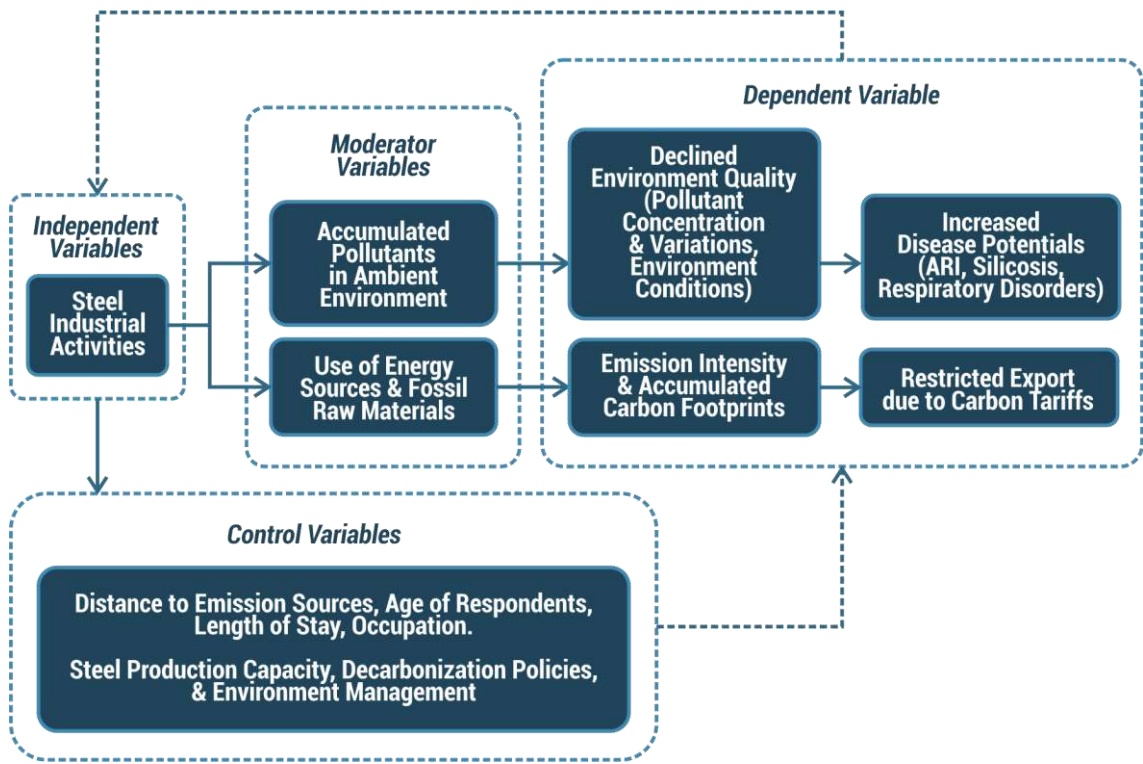


Figure 2. Conceptual Framework of Pollution-Emissions from the Steel Industry

(Source: AEER, 2025)

In the study on steel industry decarbonization, the control variables are the key to ensure that the correlation between the primary variables is free of external influences.

In terms of the environmental aspects, the control variables cover the distance between the residential area and the emission sources, occupation, age of respondents, and their length of stay around the industrial park. These factors are the determinants of the levels of exposure and vulnerability of individuals to air pollution. As for the steel industry, the control variables include the steel production capacity, decarbonization policies, and environment management.

As for the moderator variables, it is the accumulated pollutants in the environment, which will affect the decline of the environment quality, potentially harming the public health and bringing diseases for the people around the industrial park. Other than that, the use of energy resources and fossil raw materials will influence the emission intensity and carbon footprints, resulting in export restrictions due to carbon tariffs.

Controlling the three variable groups allows the research analysis to become more objective and accurate in mapping the relationship between steel industrial activities, decarbonization processes, and their impacts on the people and the environment.

Aside from the research concept, a research framework is also designed for highlighted diseases like ARI and Silicosis. This framework is designed to find the determinants of the specifically occurred sources/causes and impacts.

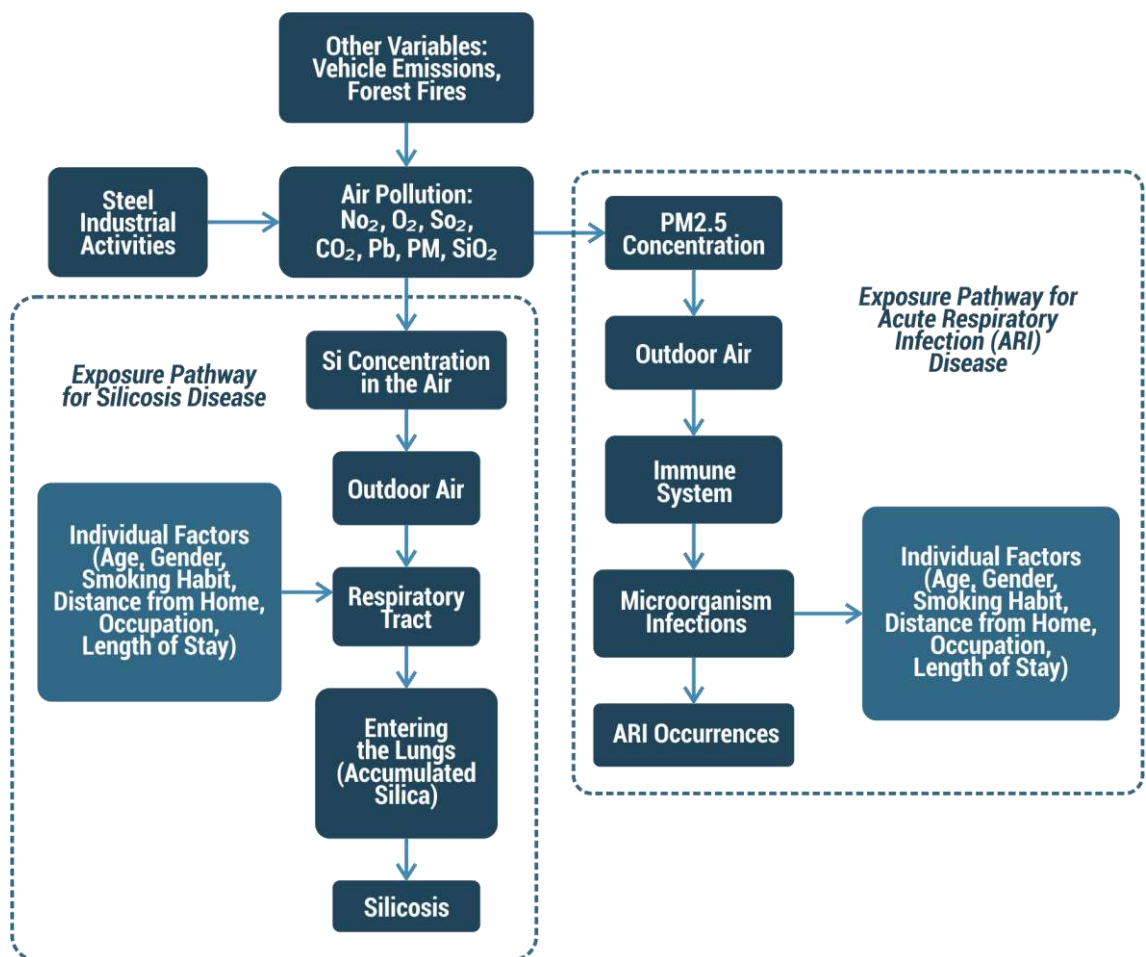


Figure 3. The Exposure Routes for Highlighted Diseases (Silicosis and ARI) in general in Correlation with Steel Industrial Activities

(Source: AEER, 2025)

The individual factor measurement is carried out through the questionnaire. Air pollution is measured from the collected data of PT Krakatau Posco EIA for the studied locations around the industrial park activities. The occurrence of ARI is measured with a cross-sectional method within the questionnaire. However, other variables are not measured and the number of respondents suffering from silicosis is not calculated.

The steel industrial activities could be the primary source of air pollutants contributing to the emergence of ARI and silicosis diseases in the nearby area. In the disease pathway, industrial processes (e.g. smelting, metal cutting, and raw material processing) will produce particulate dust, exhaust gas, and free silica particulate (SiO_2) that will be released to the ambient air. These pollutants will then spread by the wind and contaminate the air around the nearby residential areas. The residents of the steel industrial area get exposed to them via inhalation (respiration) as the main route in the exposure pathway of the two diseases. In high concentration and short-term exposure, the fine particles and pollutant gases may trigger irritation and Acute Respiratory Infection (ARI), particularly in children and elderly with weak immune systems. At the same time, long-term silica dust exposure will lead to accumulated particles inside the lungs, triggering chronic inflammation and scar tissue formation, which may lead to silicosis. Therefore, the steel industrial activities become the starting point of the same exposure pathway, but result in two different health impacts according to their pollutant types, exposure length, and individual vulnerability.



III. Literature Review

3.1 Profile of Tegal Ratu Village

Tegal Ratu Village is one of the 6 villages in Ciwandan Subdistrict, Cilegon Municipality, Banten. The geographical coordinates of Tegal Ratu Village are 6°01'22.0" LS (South Latitude), 105°58'29.6" BT (East Longitude).



Figure 4. Regional Map of Tegal Ratu Village
(Source: BPS of Cilegon Municipality, 2025)

Tegal Ratu Village covers an area of 5.73 km², with a total population of 11,987 people in 2024, consisting of 6,113 males and 5,854 females. Based on these numbers, Tegal Ratu Village is the most populous region in Ciwandan Subdistrict. There are 22 RW and 7 RT in Tegal Ratu Village.

Table 1. Demography of Ciwandan Subdistrict in 2024

Village	Population		
	Male	Female	Total
Gunung Sugih	3,475	3,265	6,740
Kepuh	4,757	4,569	9,326
Randakari	5,037	4,808	9,845
Tegal Ratu	6,133	5,854	11,987
Banjarnegara	4,271	4,204	8,457
Kubangsari	4,219	4,014	8,233
Ciwandan Subdistrict	27,892	26,714	54,606

(Source: BPS of Cilegon Municipality, 2025)

The northern border of Tegal Ratu Village is adjacent to Sunda Strait, the southern side to Serang Village, the western side to Randakari Village, and the eastern side to Kubangsari Village.

Most areas around Ciwandan Subdistrict are dominated by industrial sectors, with 41 large industries and 43 small industries. Tegal Ratu Village is frequently called ring 1 of the industrial park due to its close and adjacent location to large industrial plants in Cilegon Municipality.



Some industrial plants directly adjacent to this village include PT Krakatau Steel, which is the largest steel industrial plant in Indonesia, PT Krakatau Posco, PT Krakatau Semen Indonesia, and PT Krakatau Bandar Samudera (KBS, a subsidiary of Krakatau Steel), PT Linde Indonesia, PT Permata Dunia Sukses Utama - Power Plant, and flour mills like PT Pundi Kencana and PT Cerestar Flour Mills.

3.2 Diseases Caused by Steel Industry Pollutants

Steel industrial activities produce a variety of air pollutant types, which may endanger human health, including fine Particulate Matter (PM_{2.5}), silica dust, and heavy metals such as cadmium (Cd) and mercury (Hg). Short-term exposure to those pollutants may result in acute diseases, while long-term exposure could trigger chronic diseases.

Acute diseases stem from high, rapid, and abrupt exposure. The symptoms appear quickly and clearly, usually within a short period (several hours to several weeks), and can be fully cured if handled properly. Some examples are ARI due to PM_{2.5} and industrial dust exposure, acute bronchitis due to respiratory irritation by SO₂ or NO₂ gases, and heavy metal poisoning (Hg, Cd) from high-concentration inhalation.

Meanwhile, chronic diseases are often initiated by low exposure. The symptoms will gradually develop and often go unnoticed for more than 3 months. If the exposure continues in the long term, however, it may cause chronic diseases that last for years until they permanently damage the body. Some examples are silicosis from silica dust exposure, Chronic Obstructive Pulmonary Disease (COPD) from PM_{2.5} exposure, and kidney failure from cadmium and mercury exposure.

Table 2. List of Air Pollutants, Sources from the Steel Industry, and Triggered Diseases

Hazardous Pollutant	Source from the Steel Industry	Triggered Diseases
PM2.5	Emissions from coke combustion, sintering process, blast furnace/BOF, EAF (Electric Arc Furnace), steel casting and finishing processes, and fugitive dust from material handling.	Short term: irritation of eyes, nose, sore throat, coughing, sneezing, runny nose, shortness of breath, ARI, asthma. Long term: chronic bronchitis, stroke, impaired lung function, lung cancer, heart disease, and increased mortality risk (Cheng, et al. 2012).
Mercury (Hg)	Emissions from coal fuel, iron ores/coke in sintering plant processes and heavy metal smelting.	Central nervous system disorders, tremors, cognitive decline, and kidney damage (Clarkson et al. 2003).
Cadmium (Cd)	Emissions from metal layering (galvanizing), slag, and sinter plants	Chronic kidney damage, osteoporosis, anemia, carcinogenic diseases, lung cancer, and prostate cancer (Godt, et al. 2006).
Silica Dust (SiO ₂)	The use of coal as the raw material and of supporting materials such as iron ores, coke, quartzite, and silica sand in ironmaking	Silicosis, secondary tuberculosis, pneumoconiosis, lung cancer (Hoy et al. 2023).

Acute Respiratory Infection (ARI)

Acute Respiratory Infection or ARI is a clinical/epidemiological term for acute infection to one or more respiratory organs—from nose and throat to bronchi and alveoli (including sinus, middle ear, pleura). ARI becomes one of the main causes of global morbidity and mortality, particularly in toddlers and the elderly.

In Indonesia, ARI commonly infect children. ARI diseases may be classified into 2 types: mild ARI, of which symptoms include runny nose, sore throat, coughing, mild fever; whilst severe ARI or pneumonia has the symptoms of high fever, shortness of breath, to cyanosis or bluish skin due to lack of oxygen in the blood ([Kemenkes, 2023](#)).

ARI may be contracted from viruses and bacteria. For viruses, they are usually rhinovirus, influenza, respiratory syncytial virus (RSV), human metapneumovirus, coronavirus (including SARS-CoV-2), or adenovirus. Viruses are the most common cause of community ARI. As for bacteria, there are *Streptococcus pneumoniae*, non-typable *Haemophilus influenzae*, *Mycoplasma pneumoniae*, which mainly contribute to pneumonia and its secondary complications (Khaless, et al. 2025).

ARI is prevalent among babies and children under 5 years old, the elderly, chronic lung disease sufferers (COPD, asthma), immunocompromise, malnutrition, and pregnant mothers. Based on the social and environmental determinants, ARI tends to infect those who live in densely populated areas with low sanitation and are exposed to cigarette smoke and air pollution (including PM2.5). The increased pollution or PM2.5 is strongly related to the increased occurrence and severity of ARI.

ARI can be diagnosed early by the appearing symptoms, enabling an oxygenation test that indicates a decrease in O₂ saturation. As for severe cases or those requiring inpatient care, they will need chest X-ray, complete blood count, sputum/NP swab culture, and viral panel testing (PCR) if available. It is important to assess the warning signs (difficulty in breathing, low saturation) in order to make decisions on references/treatments ([GBD, 2024](#)).

3.3 General Profile of the Steel Industry

Steel is manufactured by adding metal alloy to molten iron, along with a small amount of carbon. Impurities are removed and the mixed chemical composition is adjusted. The resulting molted steel, also called crude steel, may be transformed into many forms and sizes as needed to become finished products.

Iron is the main ingredient of steel. It could be obtained through two different methods. The first one is by transforming iron ores into iron (also called "pure iron", "ore-based iron", or "metal iron"). Iron ores (iron oxide) are the materials extracted from mines. The process of transforming iron ores into iron is called ironmaking, and 70% of the world's productions are mostly done using a smelting furnace (blast furnace) fueled by coal. The second method is by recycling scrap steel (production residues and recycled materials from old skyscrapers, cars, planes, etc.). However, the amount of available scrap iron is still limited and currently insufficient to satisfy every demand of iron and steel, although this volume is expected to increase. Currently, scrap iron covers about 30% of the total iron use.

In short, steel industry processes include ironmaking (iron ore processing > primary iron/steel) and steelmaking (iron processed into steel). The highest energy consumption and generated emissions occur in ironmaking due to the process of reducing iron ores (hematite-Fe₂O₃ or magnetite-Fe₃O₄) into molten iron (Fe), which requires a high-volume of carbon reductant, making it an energy-intensive and carbon-intensive process. On the other hand, steelmaking produces lower emissions as it only adjusts the composition (level of carbon, sulfur, phosphorus, and other elements) and consumes way less energy compared to ironmaking, which cuts off the bonds of oxygen from the iron ores. In general, there are several routes to take in ironmaking (AEER research only analyzed ironmaking as it has become the hotspot of decarbonization in national steel industry):

1. BF-BOF (*Blast furnace – Basic Oxygen Furnace*)

This route is the most conventional and widely used in the global steel industry. Iron ores and coke are placed inside the Blast Furnace to be reduced into hot metal or molten iron. The molten iron is then poured into a basic oxygen furnace (BOF), where a small amount of steel scraps can be added to control the temperature. Inside BOF, the molten iron will be purified with oxygen to create high-quality molten steel. This process has a large production capacity, but in return, it generates a high volume of carbon emissions due to its heavy reliance on coke. Some Indonesian companies taking this route are PT Krakatau Posco and PT Dexin Steel Indonesia.

2. DRI-EAF (*Direct Reduced Iron – Electric Arc Furnace*)

In this route, the iron ores will be reduced directly using natural gases or hydrogen, creating Direct Reduced Iron (DRI) or sponge iron. After that, DRI will be smelted in Electric Arc Furnace (EAF), typically along with steel scraps. This process is more flexible, environmentally friendly, and generates less carbon emissions, especially if the power source for EAF comes from renewable energy and the reduction is done using green hydrogen. This route is ideal for areas with an abundance of natural gas supply or areas transitioning to green steel. Some Indonesian companies taking this route are PT Krakatau Steel and PT Ispat Indo (one of the routes).

3. DRI – BOF (*Direct Reduced Iron – Basic Oxygen Furnace*)

This route is rarely applied. DRI generated from direct reduction will be put into BOF instead of hot metal from blast furnaces. This method allows plants to reduce their needs of coke and iron ores, as well as to reduce production costs if DRI supply is available. Nonetheless, as it still uses BOF, its carbon footprint is still considered high despite the slightly lower emission compared to the pure BF–BOF. In Indonesia, however, no company takes this route.

4. BF – EAF (*Blast furnace – Electric Arc Furnace*)

In this route, instead of pouring the molten iron (hot metal) from the blast furnace to BOF, it goes directly to EAF. This process may increase the flexibility of production as EAF could also smelt a larger amount of scraps compared to BOF. Therefore, plants may balance the use of hot metal and scraps according to the availability of materials and energy costs. This route might slightly reduce emissions compared to BF–BOF, but still not as clean as DRI–EAF. In Indonesia, however, no company takes this route.

5. Scrap – EAF (*Besi Bekas/rongsok - Electric Arc Furnace*)

This route is fully based on recycling. Steel scraps are directly smelted in EAF to produce new molten steel. It is the lowest carbon emission route, even more so with renewable energy to power EAF. The main challenge is the availability of high quality scraps since the global demand for new steel keeps increasing and not all of them could be fulfilled by scraps. Some companies using this route in Indonesia are PT Gunung Raja Paksi (GRP), PT Ispat Indo, and Jakarta Prima Steel.





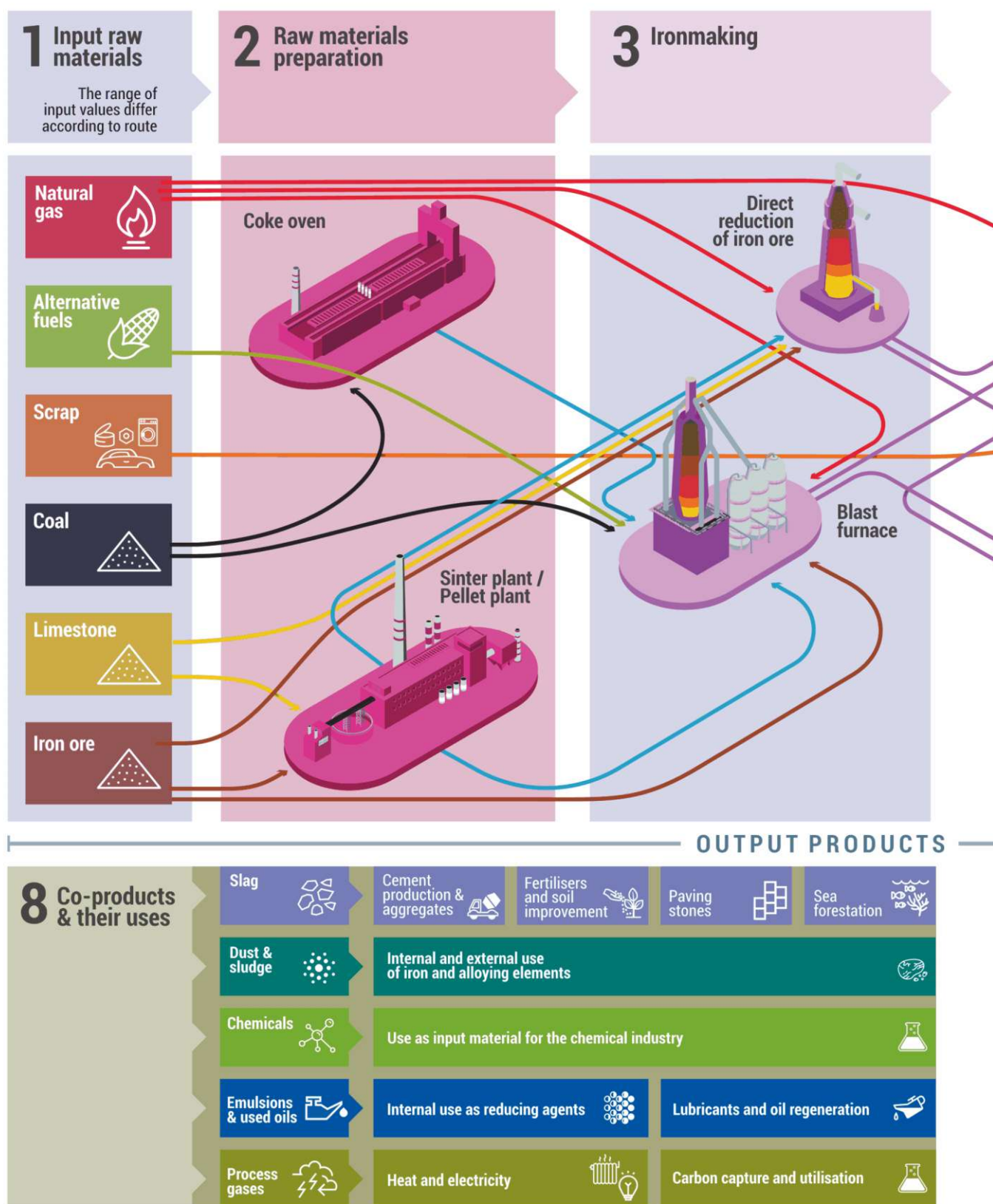
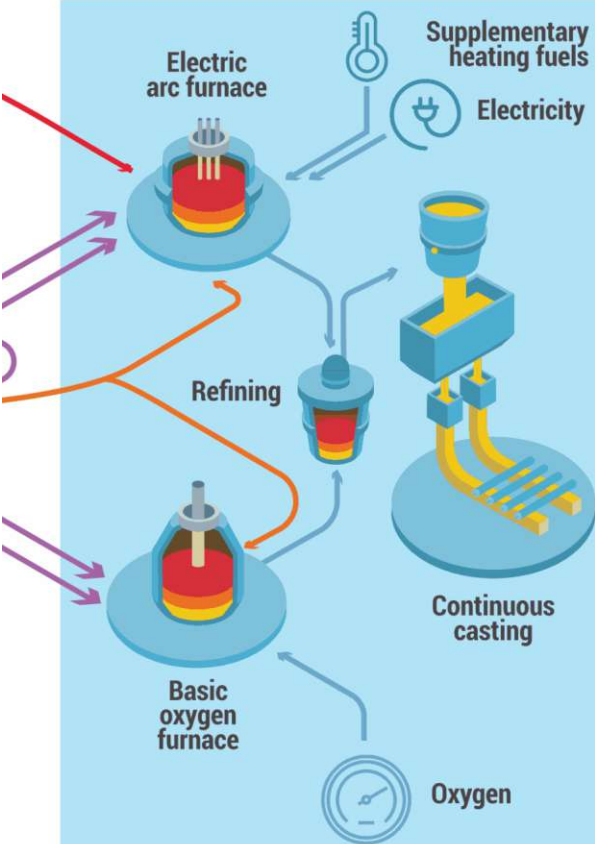


Figure 6. Iron-steelmaking routes
(Source: Worldsteel, 2025)

4 Steelmaking

Two main routes



5 Semi-finished products

Blooms



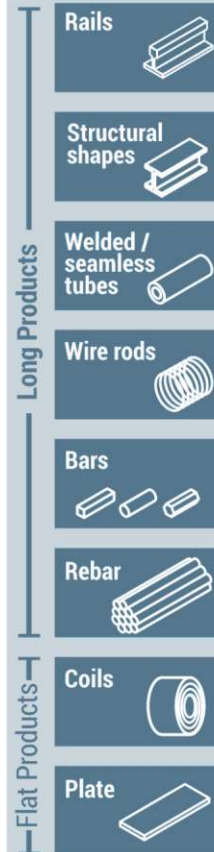
Billets



Slabs



6 Hot-rolled products



7 Finishing operations

Cold rolling



Metal coating



Painting



9 Steel



Ironmaking

Ironmaking is the crucial first stage in the steel production chain as it transforms iron ores into pig iron or sponge iron (Direct Reduced Iron/DRI) through a reduction process. In general, there are three main pathways in ironmaking technology, namely Blast Furnace process, Direct Reduction process, and Direct Reduction Smelting process. Each path has its own work principles, raw material requirements, energy efficiency, and operational challenges, making the selection of technology heavily relies on the availability of resources, energy conditions, and production scales of an area. This is a crucial stage in the decarbonization plan because it produces a large portion of GHG emission of the whole process (70%-80% of the total emissions of the process).

Blast Furnace is the most established and dominating technology in global iron production. In this process, the raw materials—iron ores (in the form of sinter, pellet, or lump), coke, and flux—are poured from the upper part of the furnace, while the hot air is blown from the lower part through a tuyere. Inside the furnace, a gradual reduction reaction occurs with CO gas formed from coke combustion, allowing the iron ores to be reduced and smelted into molten iron. The main product of this process is pig iron, while the secondary ones are slag and furnace gas to be further utilized. Despite its high efficiency, blast furnace operation often faces issues such as material slips, scaffolding on the furnace wall, gas channeling, and breakout risks on the hearth, hence monitoring the reliability of internal conditions and refractory design becomes an important issue highlighted in the research. Moreover, a maintenance process is also performed, generating loud and deafening noises, as well as black smoke and thick dust that can reach the surrounding residential area.

An alternative for Blast Furnace is Direct Reduction (DR) process, a solid reduction method without fully smelting the ores. This process applies reduction gases (CO and H₂) from natural gases or coal to remove oxygen from iron ores at lower temperature. It produces sponge iron (DRI) or in the form of Hot Briquetted Iron (HBI). Direct reduction technologies (such as MIDREX, HYL, and rotary kiln) offer benefits, such as relatively lower energy consumption and less need for expensive coke. However, they still have limitations as they require relatively higher quality ores and precise gas distribution control systems.

Meanwhile, the Direct Reduction Smelting process is a combination of reduction and smelting performed at once. Technologies such as COREX, FINEX, and HISMELT are designed to address the dependency on coke and enable the use of low-quality ores. This process simultaneously generates molten iron and secondary gases that could be used as energy. However, the operational complexities, huge investment requirements, and difficult thermal control hinder this process to be as popular as blast furnace despite its pretty high potentials in the future, mainly in regions with limited coke supply.

Out of these three pathways, it may be concluded that each technology has its own advantages and disadvantages. Blast furnace stands out for large-scale production with established technologies and massive/large production. Direct reduction is more energy efficient and flexible in regions with affordable gas resources. Meanwhile, direct reduction smelting offers the solution to use low quality ores and emission reduction, while demanding a complex control of the process.

Future research may face challenges, e.g. increased energy efficiency and the application of lower carbon reducing agents, such as hydrogen, to reduce CO₂ emissions. Thus, the future development of ironmaking will be significantly influenced by global steel industry demand for energy efficiency, environmental sustainability, and more diverse raw material utilization.

Steelmaking

Basically, there are several routes in steelmaking, i.e. EAF, BOF, and their advanced process is Continuous Casting via an end plant such as Cold Rolling Mill (CRM), Hot Strip Mill (HSM), Billet Center, Wire Rod and Bar Mill, and other mills. Molten iron/hot metal and pig iron are casted into billets (plates, hollow blocks, and blooms) that are easy to roll and shaped. The rolling process is determined by the nature of the final products, e.g. their durability, flexibility, and other characteristics. The last process is coating to layer the steel sheets with high rust resistance. Some other processes include, among others, galvanization, varnish coating, paint coating, and tin coating. These processes only cover 11% of the total emissions in steelmaking process as it requires less power compared to ironmaking ([Worldsteel, 2025](#)).



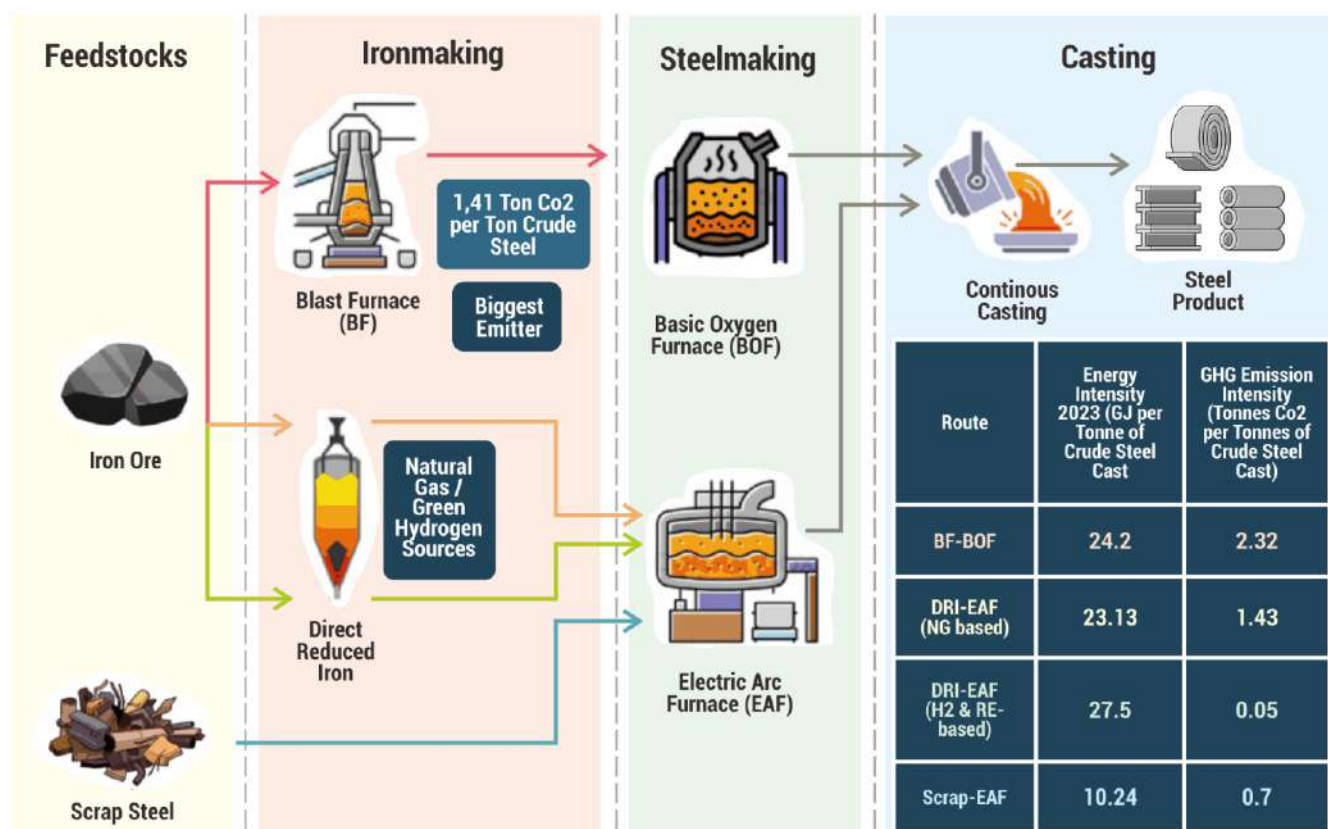


Figure 7. GHG Emissions and Energy Intensity of Each General Route in Steelmaking

(Source: processed by Worldsteel (2025), Agora Industry (2021), IEEFA (2022), Steelwatch (2025))

The increased demand is closely related to the national and global advancement in urbanization and industrialization, given that steel is the most fundamental metal for modern society. In result, a surge of production occurred in the last decades (2000's) due to rapid demand growth within emerging economies, such as in China and India. At least, $\pm 45\%$ of the total Green House Gas (GHG) emissions of the global steel industry occurred after 1990. The previously dominating technologies, such as Puddling, Crucible, Bessemer, Open-hearth furnace, and Ingot casting in the past few decades had almost been fully replaced by alternative technologies, such as BOF and continuous casting (Wang et al, 2021).



a. Total GHG emission from each process (1900-2015)

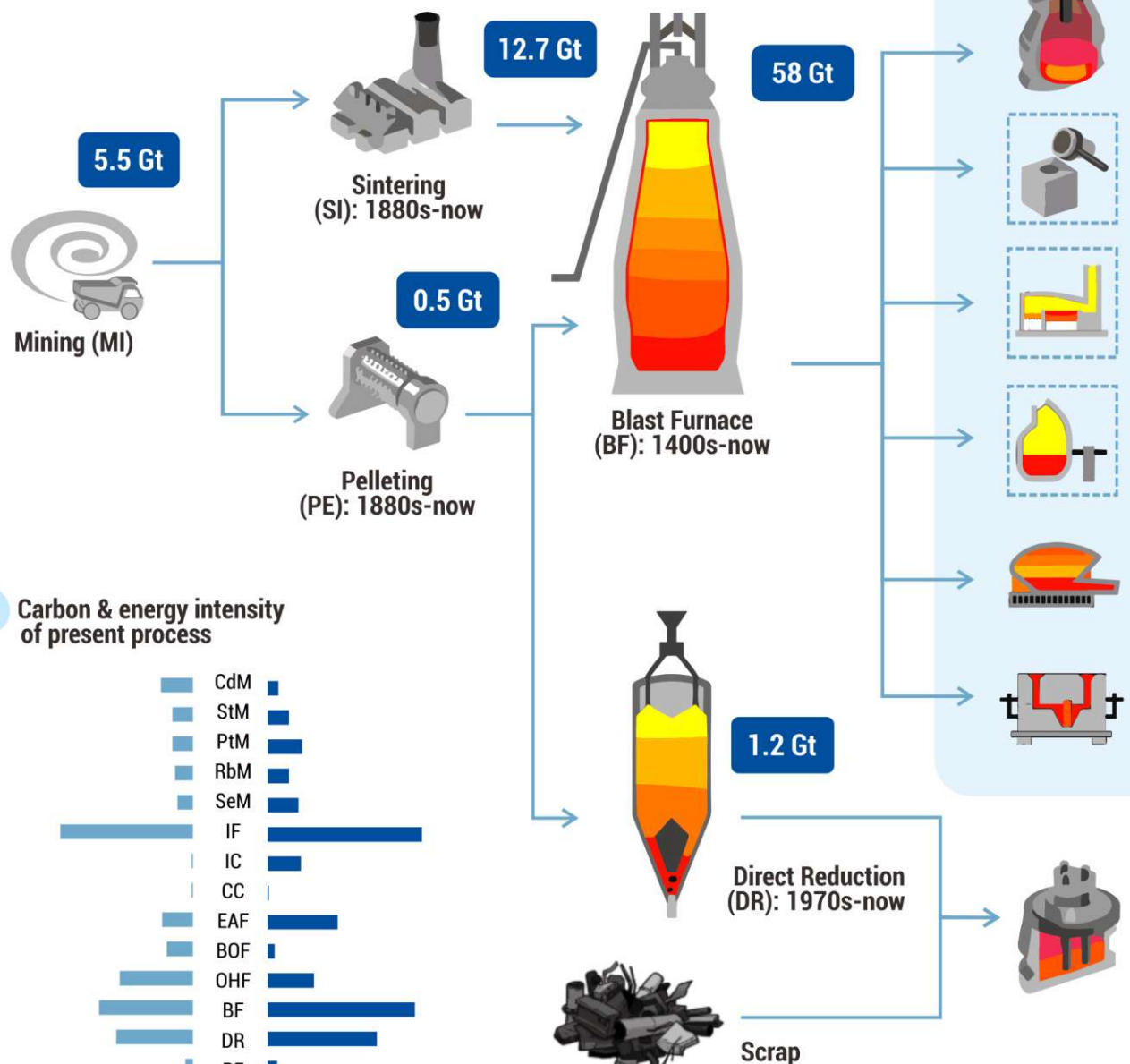
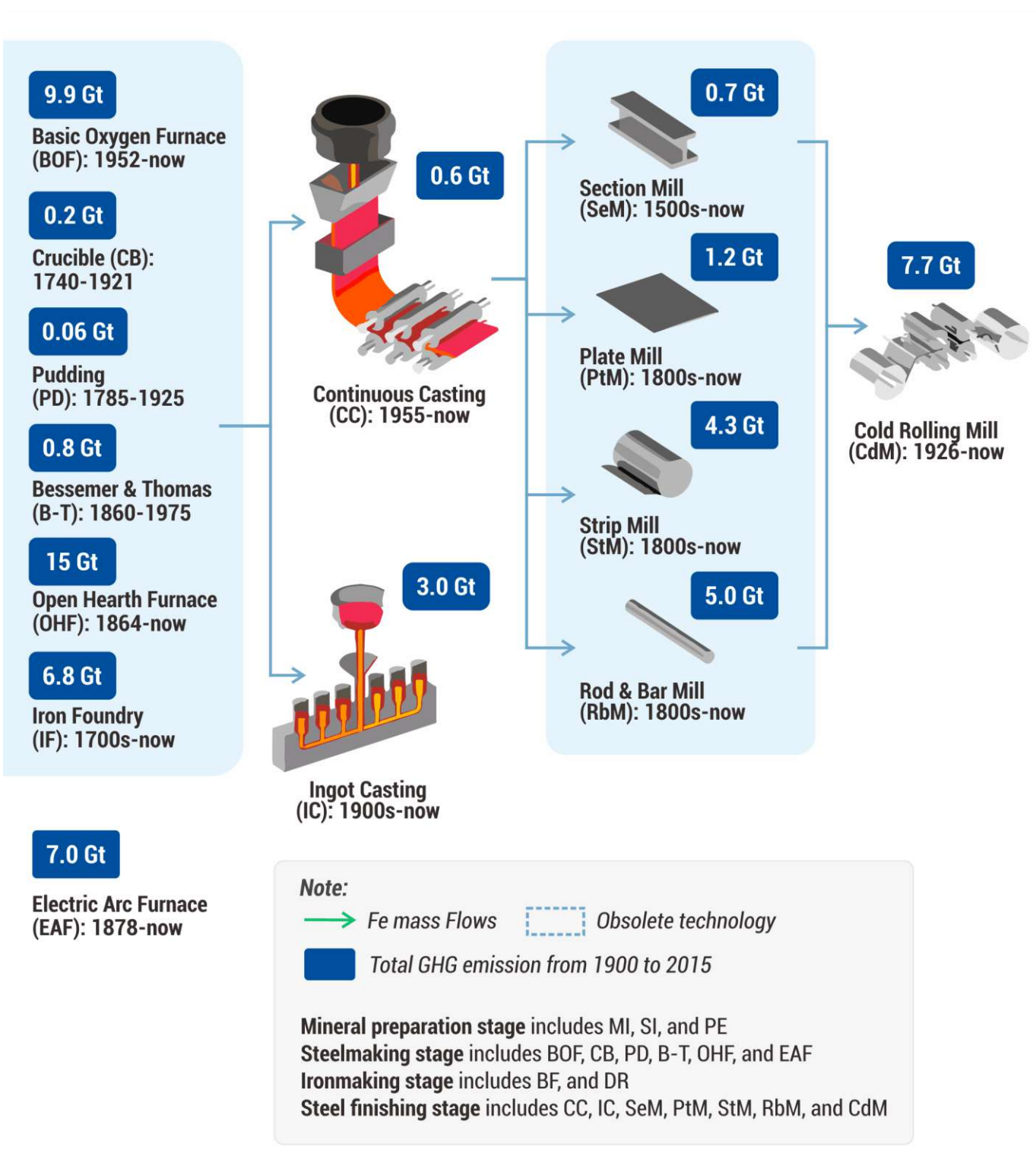


Figure 8. Steel Production Technologies and the Total GHG Emissions in 1900-2015

(Source: Wang et al, 2021)



3.4 Summary of Business Actors and Global Steel Market

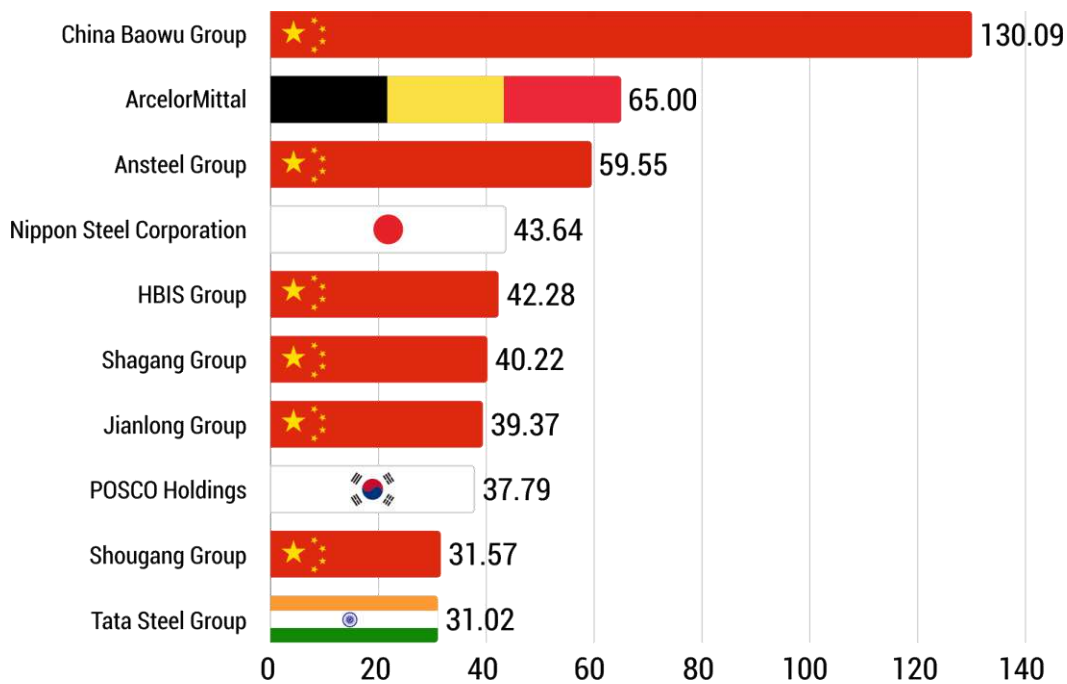


Figure 9. Graphic of the Largest Steel Companies in the World
Based on Their Production Tonnage in 2024 (in million of tons)

(Source: Worldsteel, 2025)

Quite a number of steel producers in the industry have become more prominent after producing steel on a large scale. A Chinese company has become the main steel producer with the total annual production of up to >1 billion tons of steel per year in the whole industry. In addition to that, Pohang Iron and Steel Company (POSCO) as the largest producer in South Korea has become one of the largest steel manufacturers in the world. With its headquarters in Pohang, South Korea, POSCO operates two largest plants in the world, located in Pohang and Gwangyang, which in total produce 33.7 million tons of steel per year. Flat steel, long steel, plates, and wires are its main products. POSCO has a joint venture with Krakatau Steel named PT Krakatau Posco located in Cilegon.

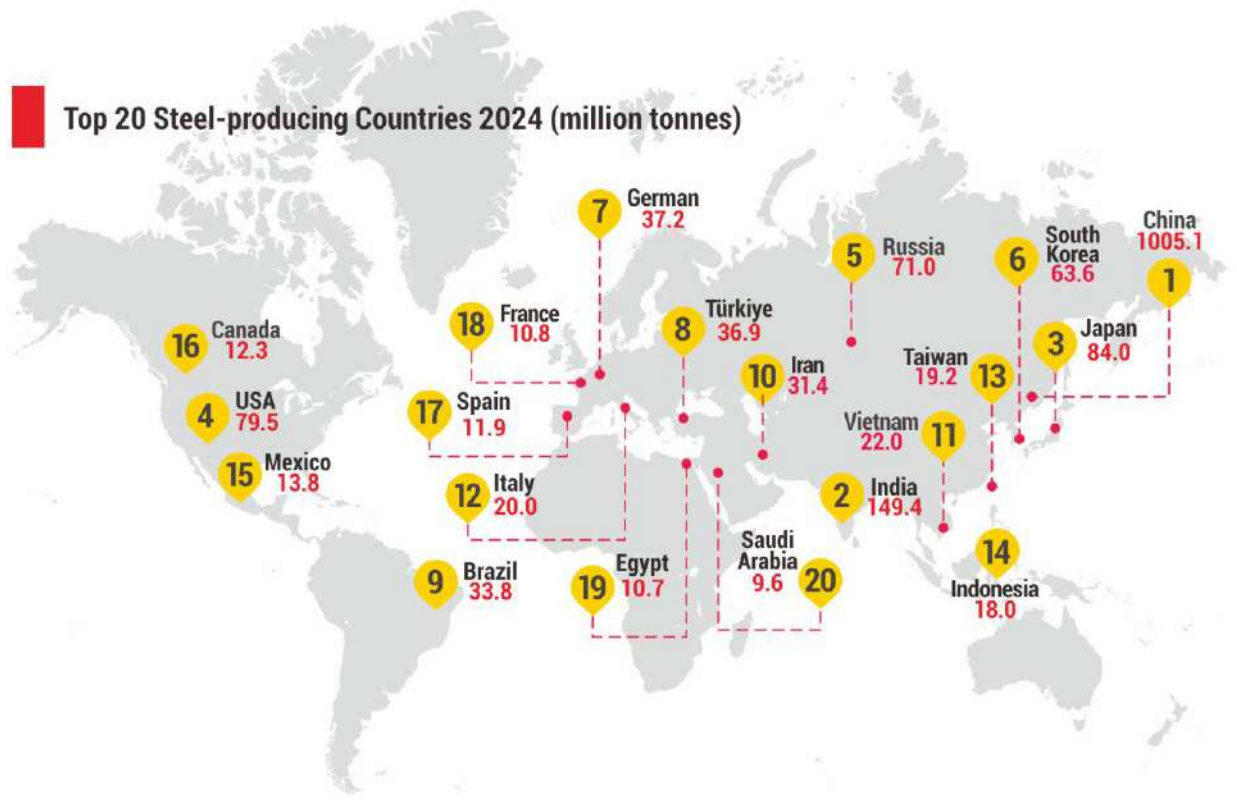


Figure 10. Map of Steel-Producing Countries in the World in 2024

(Source: Worldsteel, 2025)

China, India, and Japan are the top steel producers with a percentage of 65% of the world's production. Indonesia, however, is the 14th largest country in steel production, with 18 million of steel production (both carbon steel and stainless steel).

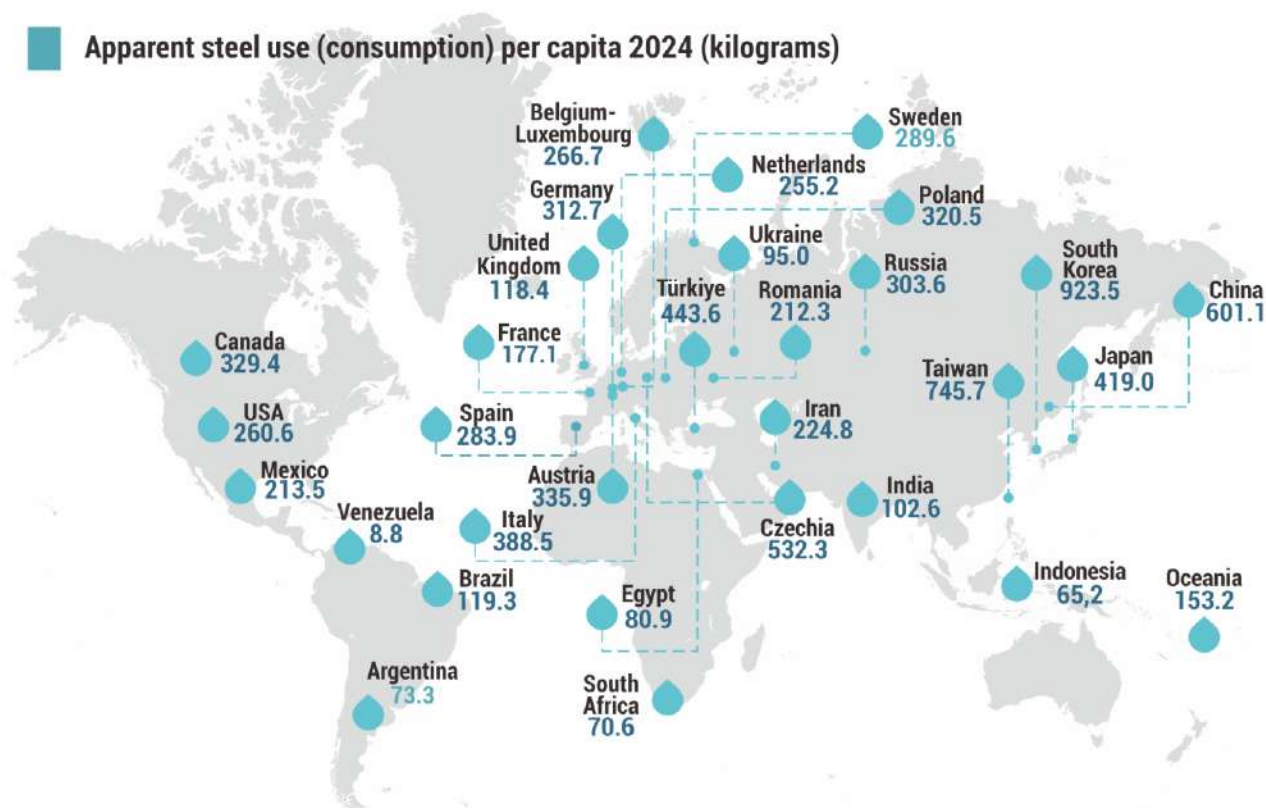


Figure 11. Map of Steel Consumption per Sector-Specific Area in 2024
(Source: worldsteel, 2025)

The largest steel consumption per capita is by Taiwan, South Korea, and China, with an average of 756.3 kg of steel/capita/year. High consumption of steel may be indirectly associated with economic growth through the development of infrastructure, automotive, energy, and transportation. For now, Indonesia has shown a much lower figure compared to other countries within the same continent, with 65.2 kg of steel/capita/year. This ratio is directly proportional to the national steel production and import, but inversely proportional to the total population, where Indonesia has around 5.41% of the steel growth per annum. The increase in consumption stems from economy, industrialization, and infrastructure growth in Indonesia.

3.5 Profile of Carbon Emission 1 and 2

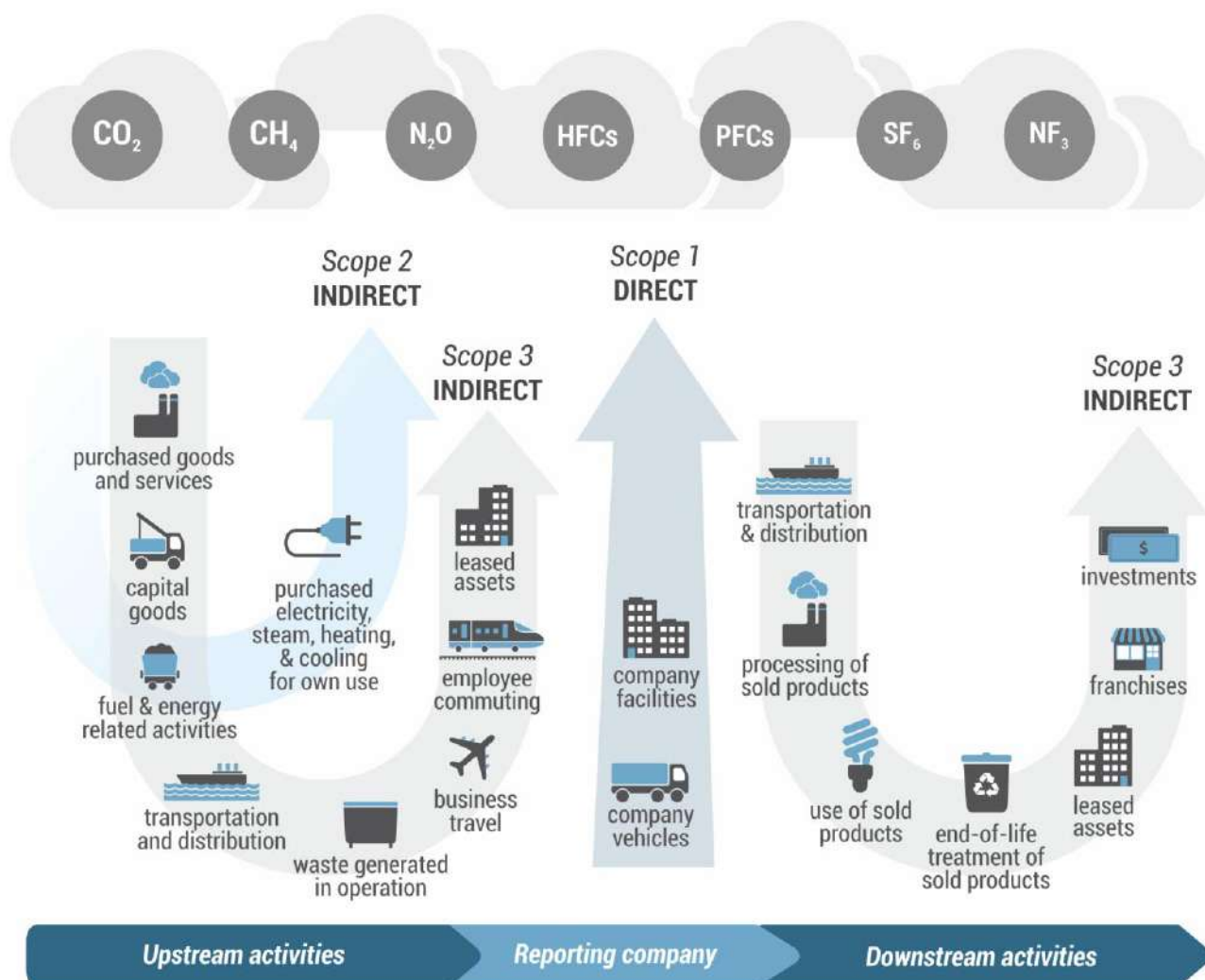


Figure 12. The Scope of GHG Emissions from Business Fields

(Source: GHGProtocol, CO2CRC, 2020)

Scope 1 Greenhouse Gas (GHG) Emissions come from the sources owned or controlled by an organization (CO2CRC, 2020) (GRI 102: Climate Change 2025, Global Reporting Initiative). They consist of emissions released to the atmosphere as a direct result of a certain activity, or a series of facility-scale activities. Scope 1 emissions are also known as direct emissions. For example, in steel production, Scope 1 CO_2 emissions come from fossil fuel and other raw materials used in ironmaking and steelmaking. This includes coal, lime, dolomite, and natural gases.

Scope 2 Greenhouse Gas (GHG) Emissions include emissions from power generation bought or obtained, heating, cooling, and steam consumed by an organization (GRI 102: Climate Change 2025, Global Reporting Initiatives). Scope 2 Green House Gas (GHG) emissions are related to indirect consumption of energy commodities. For example, 'indirect emissions' come from electricity consumption produced in another facility by Bluescope. Scope 2 emissions associated with a facility are part of Scope 1 emissions of the other 'upstream' facility.

The intensity of CO₂ emissions is the total of greenhouse gas emissions of Scope 1 and 2 from steel production, per crude steel unit produced, in the unit (metrics) of ton(s) of CO₂ i.e. equivalent to per ton of crude steel. In the steel industry, the carbon emissions rely on the types of fuel, the mixtures of fuel, and the process modification. Therefore, the energy intensity trend is not always aligned with the carbon emission trend. In 2017, the steel industry contributed 21% of the total industrial energy consumption and 24% of direct CO₂ industrial emissions. The intensity of emissions and energy varies between areas and relies on the quality of the used raw materials (iron ores and coal) and the energy costs. Technologies and the scale of the plants also play a role in the intensity of energy and emissions of the steel plants (CO2CRC, 2020).



The following figure is a scheme of potential emission sources of scope 1 and 2 in steelmaking within the steel industry:

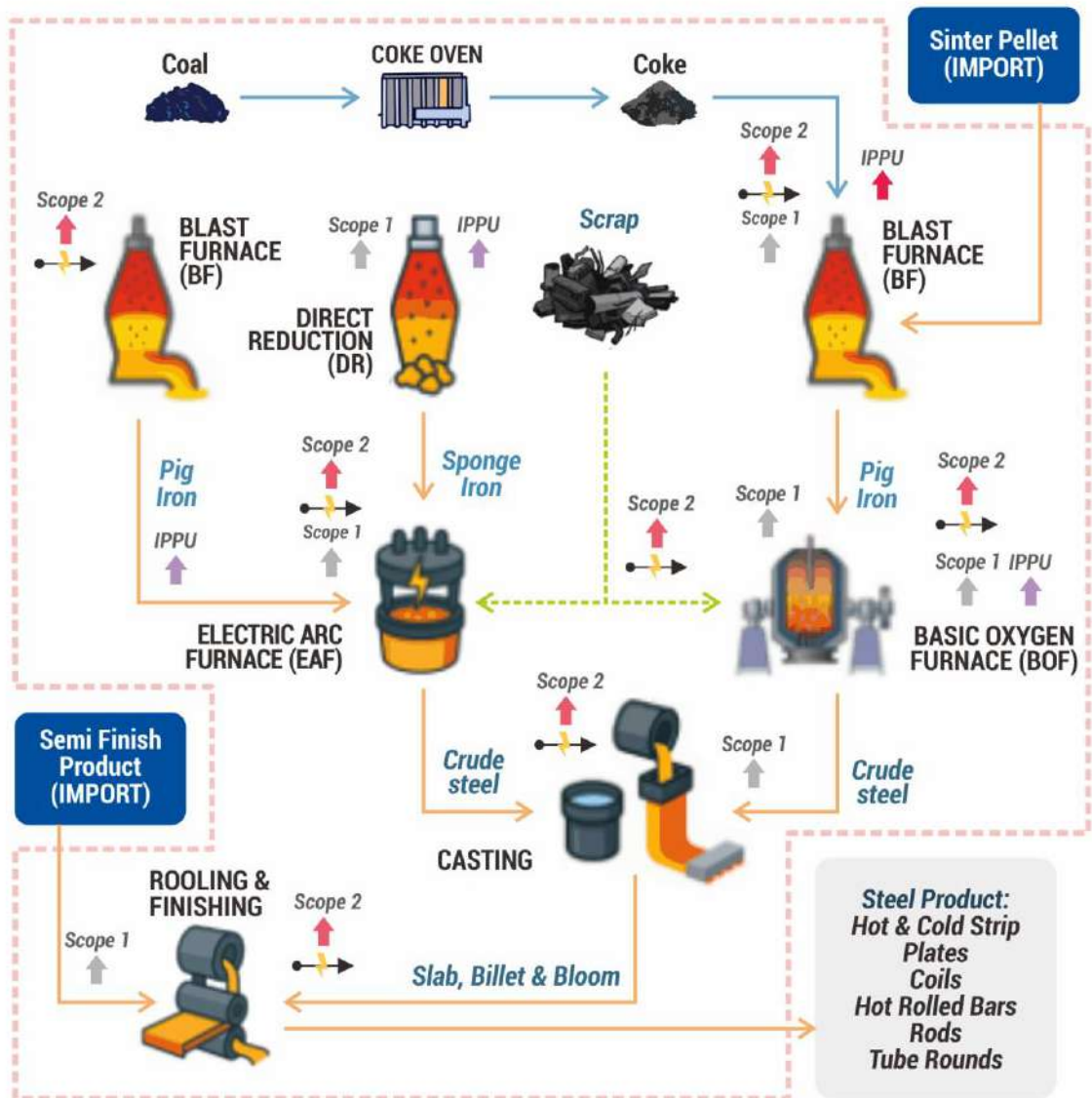


Figure 13. Emission Sources in the Steel Industry within Scope 1 and 2

(Source: Dewi RG, 2025)

3.6 Profile of Krakatau Posco

PT KRAKATAU POSCO is a joint venture between PT Krakatau Steel (Persero) Tbk, Indonesia and POSCO Korea, located in Kawasan Industri Krakatau, Jalan Afrika No.2, Samangraya, Citangkil, Cilegon, Banten. The construction was started in 2011 and completed within 36 months, making KRAKATAU POSCO an Integrated Steel Plant that owns the first Blast Furnace Technology in Indonesia. Commercial production began since early 2014 and has served Indonesia's and regional steel markets.

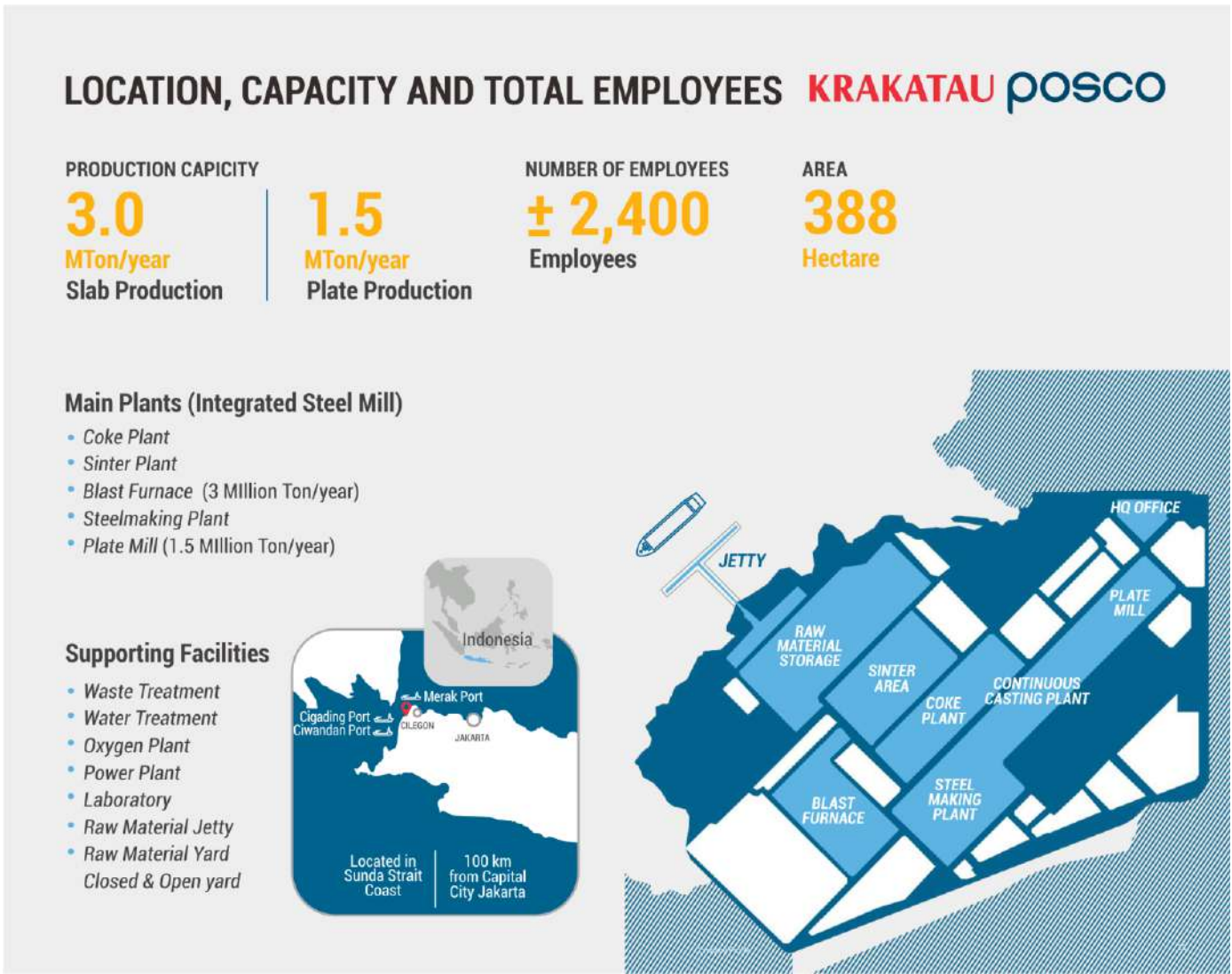


Figure 14. Profile of PT Krakatau Posco
(Sourcer: PT Krakatau Posco, 2025)

The existing steel industry facilities in Krakatau Posco consist of:

1. Coke Oven Plant with a production capacity of 2,642,000 tons of coke/year.
2. Sinter Plant with a production capacity of 9,382,000 tons of sinter ore/year.
3. Blast Furnace with a production capacity of 8,260,000 tons of hot metal/year, and Basic Oxygen Furnace.
4. Steelmaking Plant with a production capacity of 6,000,000 tons of crude steel/year.
5. Continuous Casting Plant with a production capacity of 6,000,000 tons of slab/year.
6. Plate Mill with a production capacity of 4,000,000 tons of steel plate/year.
7. Hot Strip Mill/Hot Rolling Plant (HRP) with a production capacity of 1,500,000 tons of Hot Rolled Coil (HRC)/year.

Along with supporting facilities for production activities within the industrial park, such as:

1. PT Krakatau Posco Energy, PT Krakatau Chandra Energi, and PT PLN (Persero) as the sources of electricity.
2. PT Linde Indonesia as the source of oxygen for PT Krakatau Posco integrated steel industry.
3. PT Krakatau Posco Chemtech Calcination/PT Krakatau Posco Futurem as the supplier of lime calcination for PT Krakatau Posco integrated steel industry.
4. PT Krakatau Poschem Dong-Suh Chemical as the supplier of By Product Plant for PT Krakatau Posco integrated steel industry.

With the target of 6 million tons of steel slab (from continuous casting), PT Krakatau Posco has added a steel production/steelmaking to the area of PT Krakatau Posco named Plant 2 with total steel plate production capacity of 1.5 million tons/year, HRC of 4.5 million tons/year, and CRC of 1.8 million tons/year, which include:

1. Hot Hot Rolling Plant, from inbreng (non-cash capital contribution) of Hot Strip Mills (HSM#2) of PT Krakatau Steel with a capacity of 1.5 million tons of HRC/year.
2. A new Hot Rolling Plant, with a capacity of 1.5 million tons of HRC/year.
3. Cold Rolling Mill development with a capacity of 1.8 million tons of CRC/year..

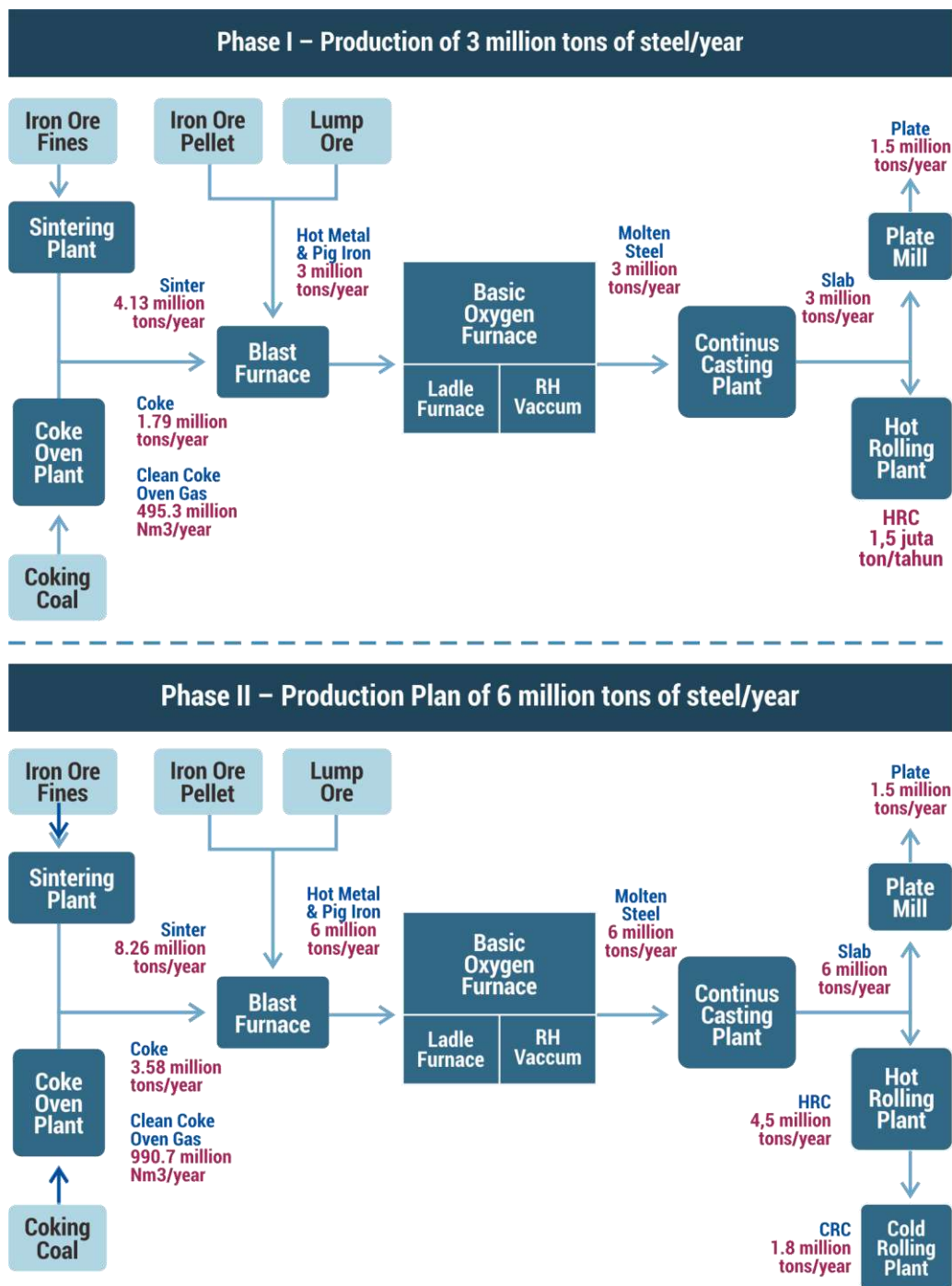


Figure 15. The Difference of Process Phase and Production Volume between Phase I and Phase II in PT Krakatau Posco

(Source: processed from EIA of PT Krakatau Posco, 2025)

In each process, certain materials are consumed, but there are some hazardous materials that may contaminate the environment and contribute to the climate crisis. Further explanation is available in the sub-chapter of Analyzing the Correlation between Hazardous Pollutants with Diseases and the Environment.

Table 3. Raw Materials and Material Consumption by PT Krakatau Posco

Plant	Raw/supporting material function	Raw/Supporting Material Name
Iron Making		
Sinter plant	Raw materials in sinter plant	Iron Ores
	Supporting materials in sinter plant	Fine coke
		Limestone
		Quartz Sand
		Serpentine Rock
		Recycled fine sinter
Recycled raw materials from waste	Iron alloy	
Coke oven plant	Raw materials in coke oven plant	Hard coking coal
	Supporting materials in coke oven plant	Not available
Blast furnace plant	Raw materials in blast furnace plant	Sinter ores
		Iron ore pellets
		Lump ores
	Supporting materials in blast furnace	Coke
		Pulverized coal injection
		Limestone
		Quartz sand
Steel Making		
Basic oxygen furnace (BOF)	Raw materials in BOF plant	Hot molten metal
		Cold pig iron
		Return molten steel (hot scrap)
		Recycled steel
		Steel slag
	Supporting materials in BOF plant	Flux (additional material to bind impurities/slag) consisting of dolomite and limestone
		Ferro Alloy
Continuous casting Plant	Raw materials of continuous casting	Crude/Molten Steel
	Supporting materials of continuous casting	Not available
Rolling		
Plate mill Plant	Raw materials in plate mill	Slab/Semi-finished steel plates
	Supporting materials in plate mill	Not available
Hot Rolling Plant (HRP)	Raw materials in HRP	Slab/Semi-finished steel plates
	Supporting materials in HRP	Not available
Cold Rolling mill	Raw materials in cold rolling mill	Hot Rolled Steel
	Supporting materials in cold rolling mill	Not available

The sources of main raw materials:

1. Fine iron comes from Indonesia and Australia.
2. Lump ore comes from Indonesia.
3. Pellet from Brazil.
4. PCI Coal from Indonesia.
5. Cooking Coke from Australia.
6. Dolomite from Indonesia.



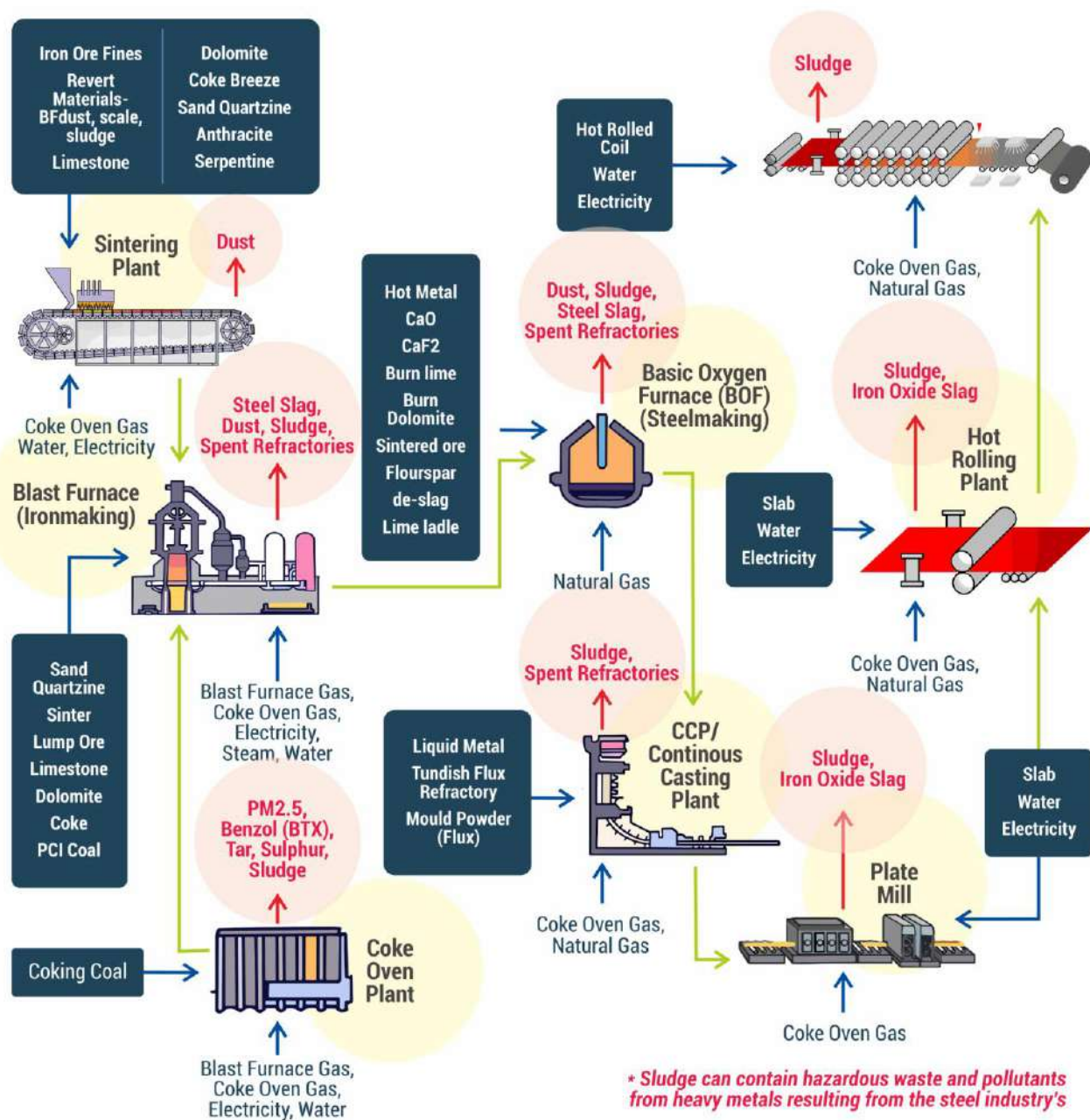


Figure 16. Flowchart of Fuels, Raw Materials, and Waste in Steelmaking Process of PT Krakatau Posco
(Source: processed from EIA of PT Krakatau Posco, 2025)

To conclude, the research object of AEER for industrial decarbonization is PT Krakatau POSCO as they still utilize fossil energy through blast furnaces in steelmaking processes and is one of the biggest actors of the steel industry in Indonesia. Its high development and prospect rates are the reasons why PT Krakatau Posco must be decarbonized, given that their processes will keep continuing and expanding in the future. Other than that, its relation with South Korea's POSCO is another reason why it has become a global-scale company.

Krakatau Posco Energy, as one of the suppliers of electricity for the Integrated Steel Plant of PT Krakatau Posco Energy, utilizes the exhaust gas generated by the Integrated Steel Plant as the main fuel for combustion. The combustion system utilizes exhaust gas from the steel production process and transforms it into steam generated by a boiler, allowing the steam from the boiler to move the turbine to drive the generator. The capacity is 2 x 100 MW and has been established as of 1 August 2011.

3.7 Production Growth Narrative of 6 Million Tons of Slab Steel/Year and National Emissions

Indonesia, in its attempt to reach top 4 in the world's economy, requires steel as one of the most important components. Industrialization narratives, such as manufactures for the improvement of value added to commodities, have become one of the nation's objectives. Steel, however, becomes the main component in developing the industry and its supporting infrastructures (roads, buildings, energy), which will keep increasing every year until 2060 when the Net Zero Emission is expected to be achieved, where renewable energy and green industry should be established with steel materials as the foundations. Nonetheless, according to the data obtained by the AEER team, the national demand and production of steel will at least increase by 12x compared to 2023. This is a big warning because steel is one of the largest emitters of CO₂ in Indonesia and the amount may rise as the production increases.

Table 4. Projection of Iron and Steel Industrial Production in Indonesia up to 2060

Steel Demand-Supply (million tons)	2023	2030	2050	2060
Indonesia	16.0	33.0	125.0	207.0
KS Holding	2.4	-	-	-
KS Affiliation	3.0	13.7	52.5	87.0
Others	10.6	19.3	72.5	120.0
KS Group Steel Supply	34%	42%	42%	42%

(Sourcer: PT Krakatau Steel, 2025)

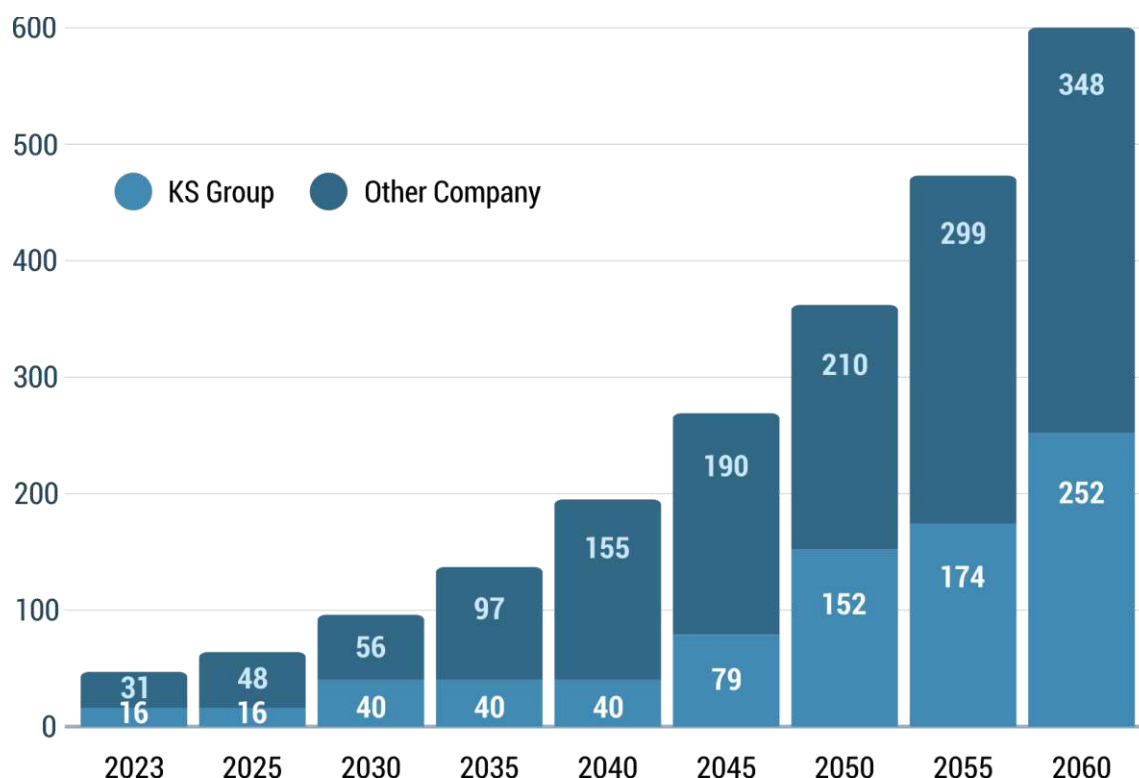


Figure 17. Graphic of Emission Increase Projection in National Steel Industry
(in million tons of CO₂)

(Source: PT Krakatau Steel, 2025)

The iron and steel industry is expected to see an increase in CO₂ emissions of up to 11.7x by 2060 from 2023. Compared to 880 million tons of CO₂ recorded in the national emission data in 2022, the steel industrial emissions will cover 68.1% of the national emissions, making it the main focus to immediately apply the steps of decarbonization. KS Group alone (with Krakatau Posco included) will contribute CO₂ emissions of about 42% per year from 2030. It is indicated from the production expansion plan of up to 6 million tons of steel/year, which implies that the projected increases in production or emissions will become a reality.

3.8 Exportation by Krakatau Posco

The specific details on export destination countries of Krakatau Posco for each year are yet to be made available. Nevertheless, according to the obtained information, PT Krakatau Posco has sent steel to Brazil, Spain, Poland, U.S., Belgium, and Portugal. PT Krakatau Posco is not the direct exporter; it is the subsidiary of PT Krakatau Steel (PTKS), namely PT Krakatau Baja Industri that actually performs the exportation. The materials and products are provided by PT. Krakatau Posco, with a processing collaboration with PTKS and its subsidiary. This is due to the lack of processing facilities owned by PT Krakatau Posco to produce CRC steel, so they use the services of PT KBI. However, it may change if PT Krakatau Posco has its own CRM plants.

Exportation to developed countries in Europe and the U.S. will face a big challenge with the existence of carbon tariff policies, e.g. CBAM in the European Union and Foreign Pollution Fee Act (FPFA) in the US, which regulate carbon duties on high emission steel imports. These policies aim to reduce the number of steel imports with large carbon footprints and may undermine the strength of Indonesia's steel products to compete in the global markets. PT Krakatau Posco, as one of the most notable steel producers in Indonesia, exports its main products, i.e. Hot Rolled Coil (HRC) and plates, to the European Union with the volume of approximately 340 and 480 thousand tons respectively in the last two years (IISIA, 2024). First, the steel exportation to the European Union may become more competitive. Second, if the export quantity declines, the products initially aimed for exportation will be shifted to domestic markets. If the markets are not capable of absorbing them, the industry may see a decrease in operational and financial performance. Third, the application of policies, such as CBAM and FPFA, may also impose additional financial burdens by requiring the purchase of emission certificates and the potential carbon tariffs, causing the production costs to increase for Indonesian steel producers.

In 2022, national steel producers exported 975 thousand tons of steel products to the EU or about 7% of the total exportation volume. In terms of value, the national steel product exportation to the EU has reached USD1.049 million or only 4% of the total steel product exports. The destination countries for national steel product export are China and Taiwan, each with volume of 8.3 (55%) and 1.3 (8%) million tons respectively, with the value of up to USD19 billion (67%) and USD2.2 billion (8%).

The application of CBAM will result in additional costs in the form of carbon emission certificate purchases. These additional costs will heavily depend on the amount of emissions generated by the steel producers. To illustrate, by using the average emission data generated by national steel producers in 2019 and import volume in 2022 that reached 975 thousand tons, the value payable for the certificates will reach €383 million, which equals to €390 per ton of steel products (IISIA, 2024). This certificate is extremely costly and will certainly undermine Indonesia's steel products compared to those of Europe and other countries, which have lower carbon emissions. CBAM also has a carbon protection to apply across the supply chain. So, despite being exported to China for EV production or other processed products, the steel will be charged with tariffs as it is proceeded to be exported to Europe.

3.9 Enforcing Green Steel Production and Potential Consumers at National & Global Levels

The green trend (or green growth) is a global attempt to create an economic development that aligns with environmental sustainability by applying sustainable technologies and practices across sectors. In the industrial sector, green steel technology or green steel is vital in solving the climate crisis. Aside from that, green steel is necessary for several reasons.

First, conventional steelmaking heavily relies on coal (coke) and fossil fuel that produce a high volume of greenhouse gas emissions (such as CO₂), and any other air pollutants (SO₂, NO_x) and heavy metal. Second, these pollutants may cause a number of respiratory problems, e.g. asthma and bronchitis, which will affect the people around the steel industrial area. Lastly, there is a depletion of resources, where the conventional processes consume a large amount of raw new materials and water, threatening the natural resources.

Today, the global steel industry is responsible for 7-8% of Green House Gas (GHG) emissions in the world. About 75% of steel is still produced in a coal-fired blast furnace, which releases a high volume of CO₂ emissions to the atmosphere. The iron and steel industries have also contributed 2,65% of national emissions in 2023 (Kemenperin, 2025).

According to the International Energy Agency (IEA), steel-based emissions need to be reduced to 50% by 2050 and gradually decrease afterwards in order to achieve the global climate target. Agus Gumiwang, as the Minister of Industry of the Republic of Indonesia, has also highlighted that the Ministry of Industry (or Kemenperin) will target Net Zero Emission for the manufacturing sector by 2050. It was stated during Annual Indonesia Green Industry Summit (AIGIS) 2025, with the theme of "Driving Industrial Decarbonization Through Green Industry Ecosystem".

The increasingly higher emission value may hinder the achievement of net zero emissions by 2050. Therefore, it is necessary to perform the selected decarbonization strategy for iron and steel industries. The following is the plan collected in AIGIS 2025:

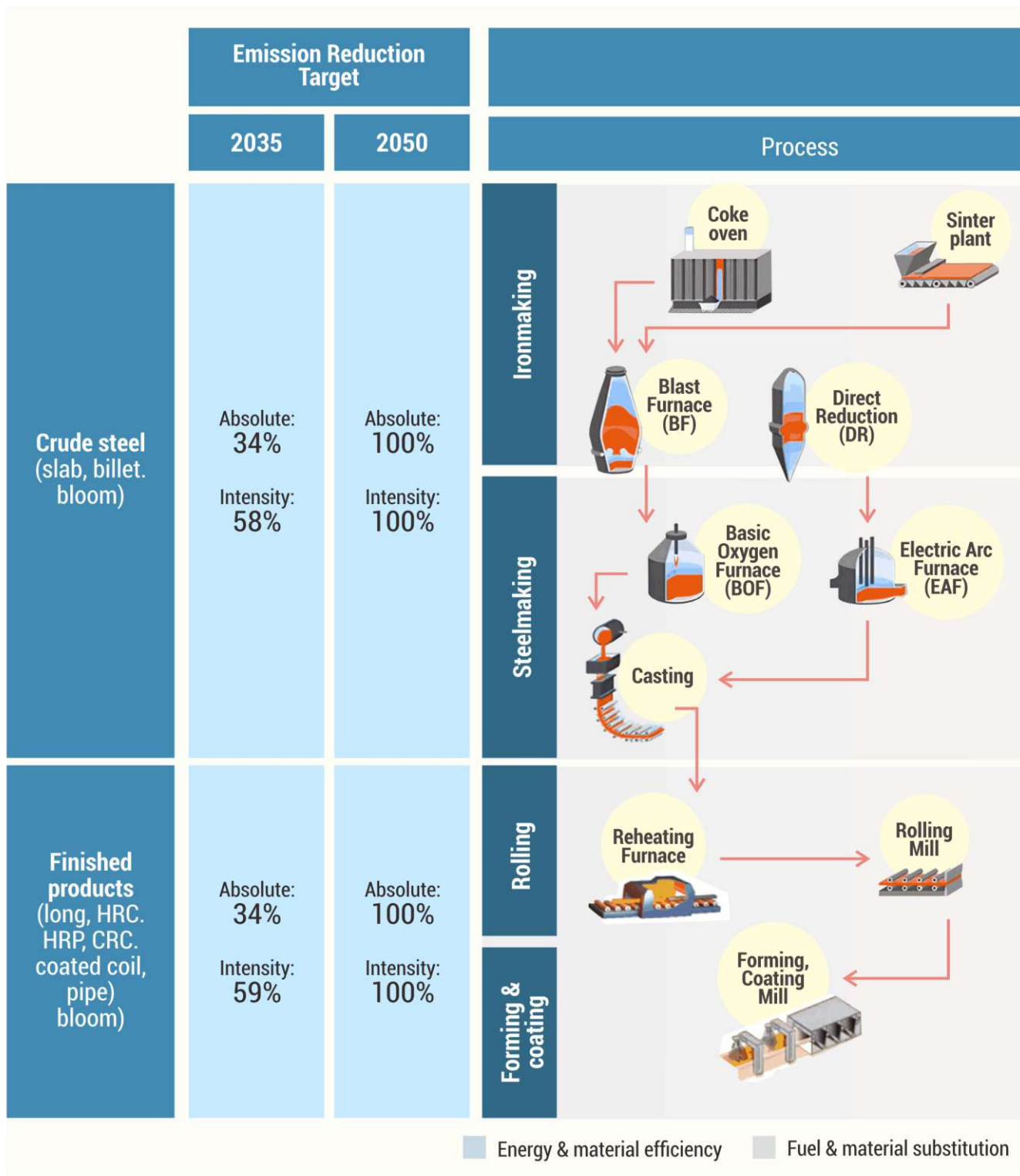


Figure 18. Decarbonization Strategies for Iron and Steel Industries
(Source: Kemenperin, 2025)

Decarbonization strategies

Alternatives

For BF-BOF route:

Waste heat recovery,
meeting global best
available energy
intensity

Switch BF-BOF
to DRI-EAF

For DRI-EAF route:

Natural gas
substitution to
green hydrogen

EAF coke
substitution
with biomass

For DRI-All

Other energy
efficiency measures

Increase scrap ratio

Solar PV installation
(utility)

BF injection
coal substitution
to biomass &
natural gas

Coke substitution
to hydrogen

Increase
scrap ratio

Solar PV
installation

CCU (soda ash)
for DRI & EAF

Grid electricity mix
following RUKN

Offsetting

Purchasing
low carbon
steel input

Offsetting

Diesel substitution
to natural gas

Solar PV
installation

Natural gas substitution to
green hydrogen & biomass

Grid electricity
mix following
RUKN

Process improvement

Low carbon electricity & electrification

Carbon capture & storage

AEER observes that there are several AIGIS's strategies that must be applied to the process of steel industrial decarbonization, among others:

1. Transitioning crude steel production technologies from BF-BOF to DRI-EAF, which will be applicable by 2027 for new BF-BOF plants, and by 2030 for old BF-BOF plants;
2. Streamlining energy consumption in Scrap-EAF plants as of 2026.
3. Replacing natural gas fuel with green hydrogen and coke with biofuel starting from 2035 and 2030 respectively;
4. Purchasing low carbon electricity based on the scenario of National Electricity Master Plan (Rencana Umum Ketenagalistrikan Nasional/RUKN)

Carbon Direct Avoidance (CDA)

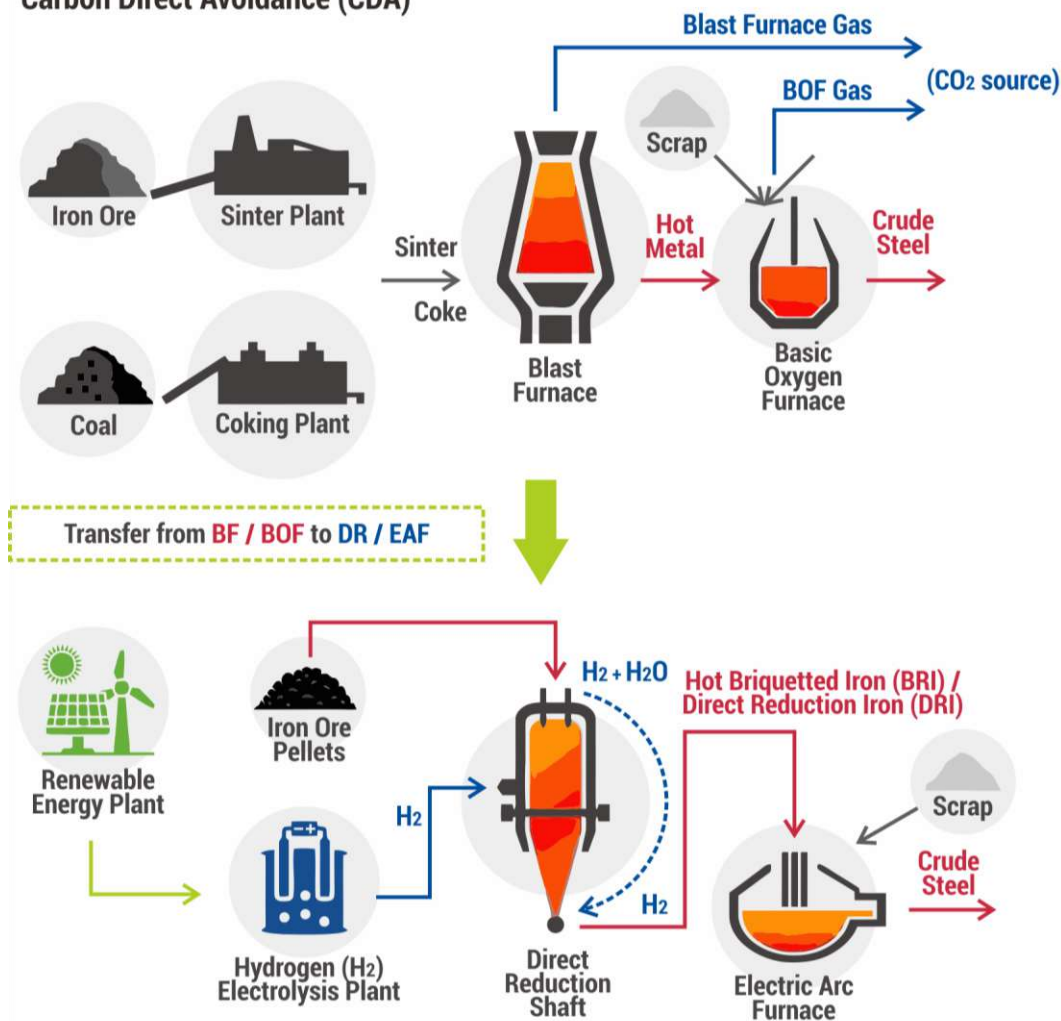


Figure 19. Net Zero Emission (NZE) Technology Options for the Transformation towards Green Steel

(Source: IISIA, 2025)

To execute the technology transition from BF-BOF to Scrap-EAF in 2050, scraps of up to 15.17 million tons per year is required. However, the limited supply of scraps in Indonesia is important to consider when transitioning the raw materials to produce crude steel. In addition to that, the circulation from scrap steel to the industry is still not seamless and the quality still varies, mixed with rust, non-metal, or residual materials. If the scrap is mixed with any heavy metals or hazardous chemicals, it may cause negative impacts on human health. For high-quality steel products, pure scrap is not enough, a mixture of Direct Reduce Iron (DRI) or pig iron is necessary. Therefore, it is better to use DRI-EAF technology as a transitional program replacing Blast Furnace technology.

3.10 Realization of Indonesia's Climate Commitment via Industrial Decarbonization

Indonesia's climate commitment, which is documented in Second Nationally Determined Contributions (SNDC), will be aligned with the global temperature-limiting scenario of 1.5 degree Celsius. It also compares the emission reduction against GHG inventory in 2019 to provide more accurate comparative references across countries. Other than that, SNDC integrates the blue carbon design that adds sector focus to forestry, energy, waste, agriculture, industry, and maritime (DPR, 2024).

Additionally, it is necessary to specify the target for emission reduction of 31.89% independently or 43.2% with international support in 2030, and emission peak in 2035. The industry, as the largest emitter, has to be monitored in terms of its development and steps of decarbonization, particularly the steel industry, to prevent any additional burden to the existing target and climate commitment. The rising emissions to their peak by 2035, NZE target in 2050 for the industry, the increasingly rapid industrial growth through downstream industrialization (*hilirisasi*), and economic growth will challenge the industry in performing decarbonization processes. That being the case, roadmaps, regulations, and strategies are immediately required.



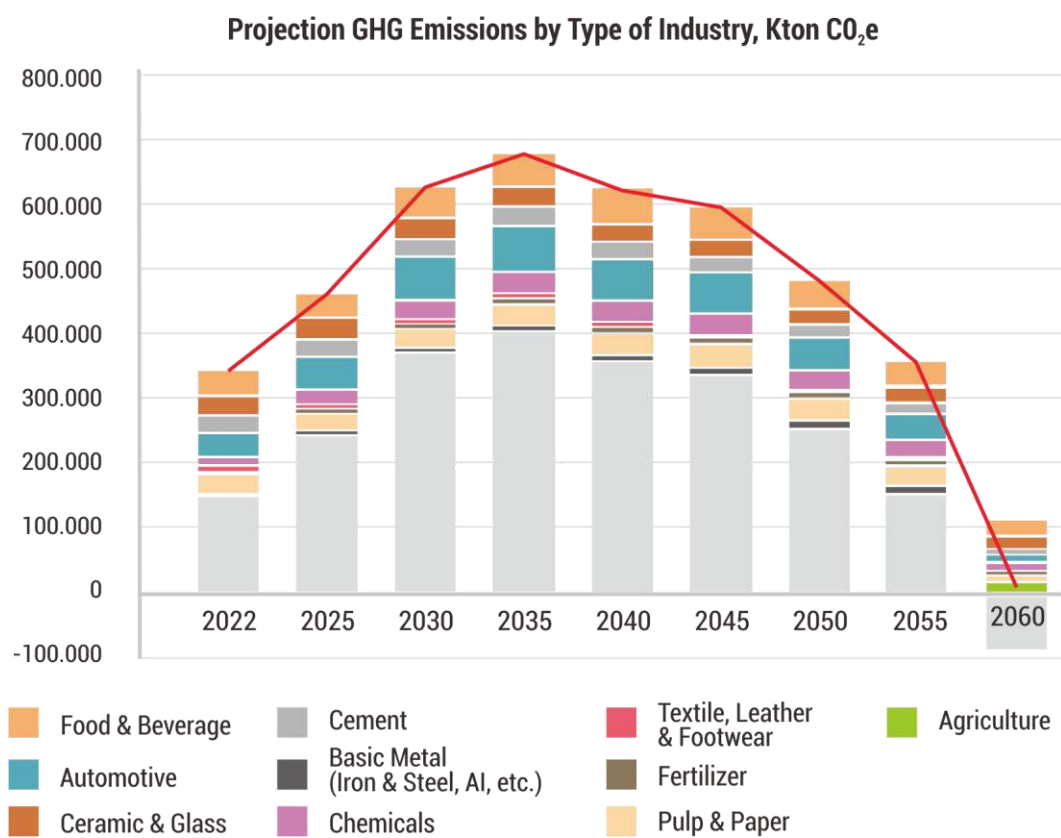


Figure 20. Projection of GHG Emissions by the Type of Industry in Tons of CO₂
(Source: Dewi RG, 2025)



IV. Results and Discussion

4.1 Analysis of Carbon Calculation Result and Climate Hazards

4.1.1 Calculation of GHG emission scopes

The company has independently calculated the annual GHG emissions from its activities. Mathematically, the generated carbon emissions will increase as the production quantity rises. At least the generated carbon emissions will multiply by 2x with the increased production from 3 million tons of steel/year to 6 million tons of steel/year. This should be the main concern of the company or the government as the carbon calculation will weigh down the national carbon trading/credit/tariff and GHG emission inventory.

Table 5. Total GHG in the Steel Industry of PT Krakatau Posco in 2024

No	Plant	Total Greenhouse Gas (TCO ₂ /Year) - Phase I	Total Greenhouse Gas (TCO ₂ /Year) - Phase II	Mathematical Calculation Phase II (TCO ₂ /year)*
1	<i>Sinter Plant</i>	1,419,615	1,419,615	2,839,230
2	<i>Coke oven Plant</i>	1,354,434	1,354,434	2,708,868
3	<i>BF - Steel Making - CCP</i>	2,656,685	2,656,685	5,313,370
	Total	5,430,734	543,0734	10,861,468
<i>*based on the total number of productions</i>				

(Source: processed from EIA of PT Krakatau Posco, 2025)

By assuming that the maximum number of production is 3 million tons of steel/year, the average emissions of PT Krakatau Posco will be 1.81 tons of CO₂/ton of steel or higher than the global average in 2023 (1.92 TCO₂/ton of steel) and national average in 2023 (1.84 TCO₂/ton of steel). The high average of national emissions stems from the increased use of Blast Furnace for carbon steel and coal for stainless steel. Though lower than the average emissions, the company still needs to perform decarbonization and become a pioneer in the national steel industry. It is important to note that the calculation uses the maximum capacity of 3 million tons of steel/year, where the realization might be lower in number and the average emissions could be higher with up to 2 TCO₂/ton of steel, or higher than the national average emissions.

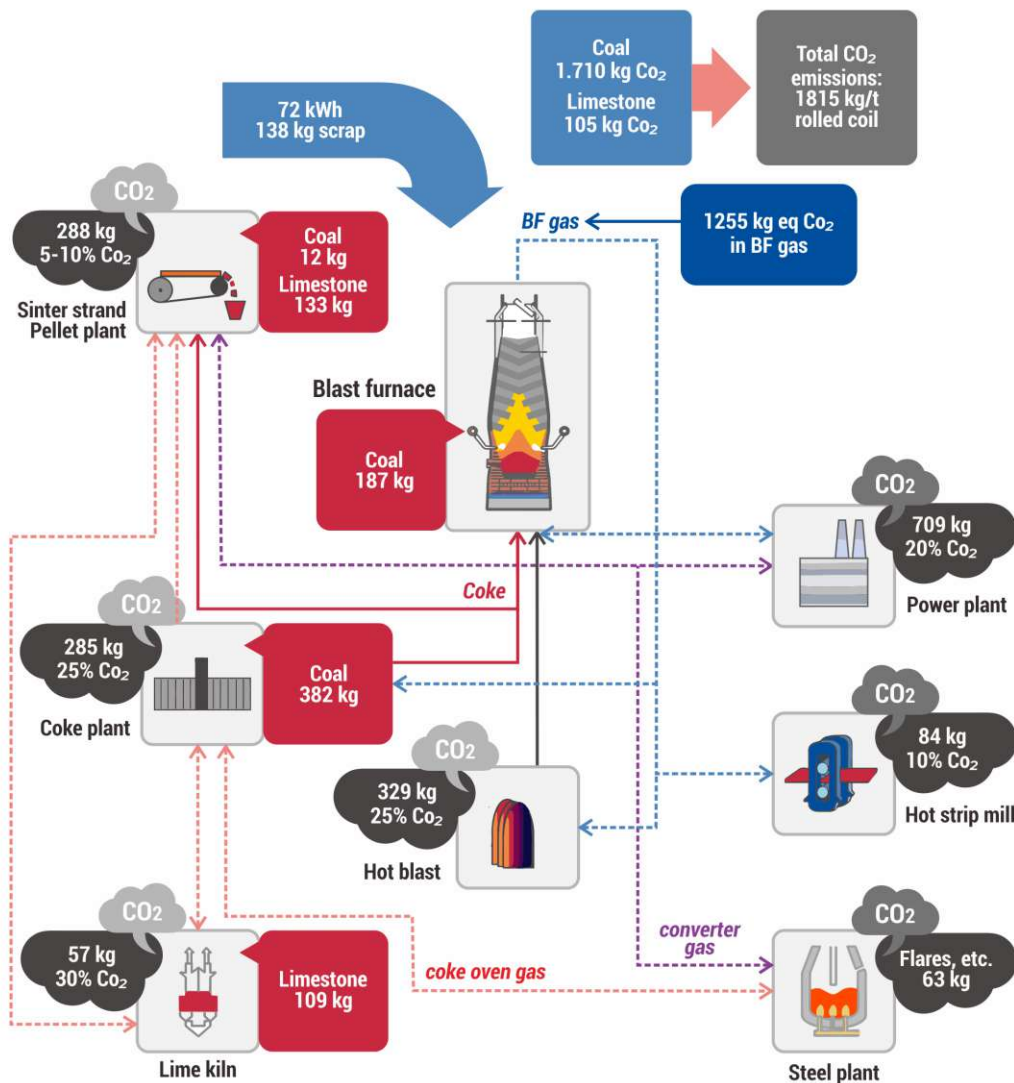


Figure 21. Sources of GHG Emissions in BF-BOF in Ironmaking and Steelmaking Processes
(Source: Aziz et al, 2022)

AEER's calculation was performed to count the estimated CO₂ released by PT Krakatau Posco in its full capacity for a year. The scenarios observed were Phase 1 or existing with a production of 3 million tons of crude steel/slab steel and Phase 2 with a production of 6 million tons of crude steel annually. The calculation was performed based on a Greenhouse Gas Protocol entitled "Calculating Greenhouse Gas Emissions from Iron and Steel Production" through annual production data and the number of materials/raw materials used and containing carbon.

The calculated carbon scopes were scope 1 from the internal process of PT Krakatau Posco and scope 2, i.e. the energy purchased from PT Krakatau Chandra Energi. The calculation only included Sintering, Coke Oven Plant, Blast Furnace, Basic Oxygen Furnace, and Continuous Casting Plant (CCP) and did not cover the rolling stage and scope 3 of the company's supporting activities.

Table 6. Recap of Carbon Calculation

Component	Phase I - 3 million tons of steel slab/year			Phase II - 6 million tons of steel slab/year		
	GHG emissions (metric tonne CO ₂ e)					
	CO ₂ (fossil)	CH ₄ (fossil – combustion & non fossil)	Total anthropogenic emissions from component	CO ₂ (fossil)	CH ₄ (fossil – combustion & non fossil)	Total anthropogenic emissions from component
Stationary combustion (Scope 1)	2,202.17		2,202.2	2,202.17		2,202.2
Stationary combustion (Scope 2)	313,991.70		313,991.7	313,991.70		
Onsite coke production	1,087,979.90	3.67	1,087,983.6	2,181,973.13	7.34	2,181,980.5
Offsite coke production			-			-
Flaring			-			-
Sinter production	1,134,789.99	8,065.89	1,142,855.9	2,269,579.99	16,131.78	2,285,711.8
DRI production						
Iron and Steel production	6,959,890.08	8.23	6,959,898.3	13,930,299.83	16.46	13,930,316.3
Onsite lime production			-			-
Offsite lime production			-			-
	Total of Phase I		9,506,931.63	Total of Phase II		18,400,210.69

(Source: AEER, 2025)

There is a significant difference between the calculation of CO₂ emissions by PT Krakatau Posco and by AEER. This may arise from the different assumptions for the calculation, and the difference in scientific and field analyses. Nonetheless, the urgency is clear, the high carbon emissions have reached million tons. Compared to the total 340 million of national industrial emissions in 2022, phase I of PT Krakatau Posco has reached 2.8% of the total emissions and this number only comes from one company. This should become an urgent call for PT Krakatau Posco to perform decarbonization as soon as possible, given that there is already a plan to increase the capacity development by twofold, which mathematically will also produce double the CO₂ emissions.

4.2 Questionnaire Result Analysis

Decarbonization plays an important role in creating a clean and sustainable development. Not only does it reduce greenhouse gas emissions, but this effort also reduces air pollution, thereby lessening respiratory disease risks, such as ARI and asthma. From an environmental perspective, this step will help maintain the ecosystem, slow the rate of global warming, and preserve natural resources for future generations. From a social perspective, decarbonization helps to improve people's life quality due to the cleaner air, creates green jobs, as well as strengthens the awareness and fairness in the transition towards the low-carbon future.

To understand the relation, the AEER research team conducted questionnaires and statistical analysis to describe the social, health, and environment conditions of Tegal Ratu Village, the nearest village to the steel industrial park, PT Krakatau Posco. The results also portray a comprehensive picture of the steel industry's effects on society.

Out of 100 questionnaires distributed to Tegal Ratu residents, only 94 were completed, which were then used as samples.



Figure 22. Tegal Ratu Resident Forum and Questionnaire Completion

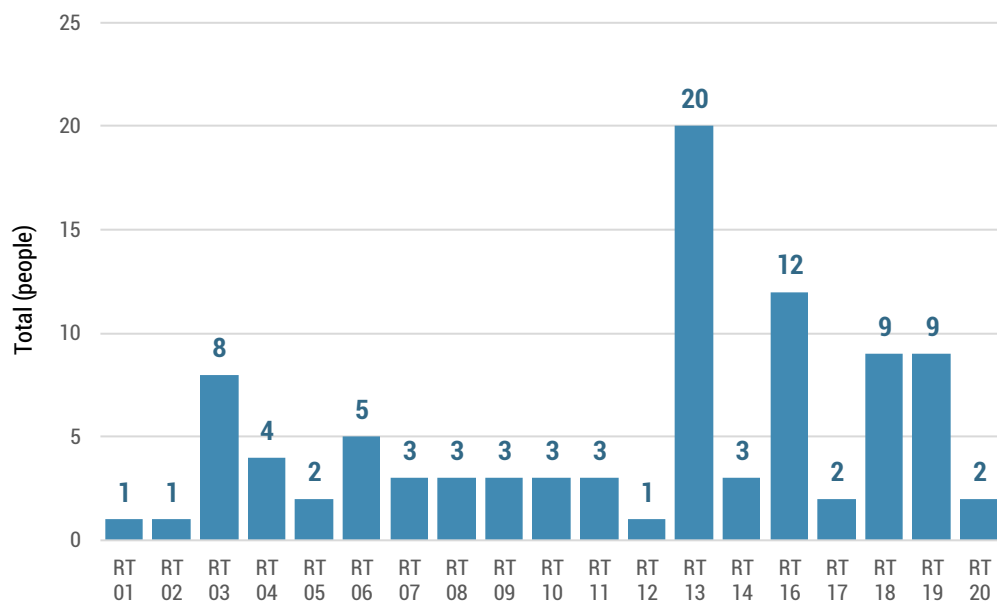
(Source: AEER, 2025)

Respondent Distribution based on the RT

Out of 22 RTs located in Tegal Ratu Village, no one represented RT 15, 21, and 22. The RTs represented in this research were:

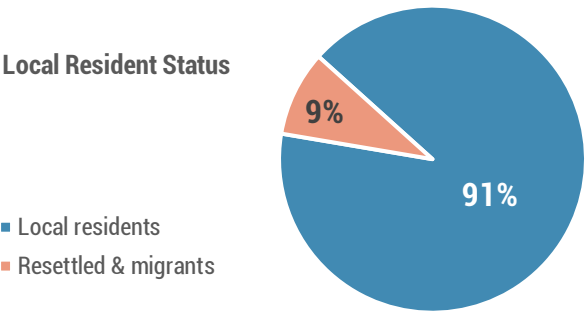
- RW 01: RT 01, RT 02, RT 03
- RW 02: RT 04, RT 05, RT 06
- RW 03: RT 07, RT 08, RT 17
- RW 04: RT 09, RT 20
- RW 05: RT 10, RT 11, RT 18
- RW 06: RT 12, RT 13
- RW 07: RT 14, RT 16, RT 19

Based on the location, the nearest RTs to PT Krakatau Posco are RT 01, 02, 03, 14, 16, and 18. As recorded by the distribution data, RT 01 and 02 each were represented by 1 person, RT 03 had 8 people, RT 14 had 3 people, RT 16 had 12 people, and RT 19 had 9 people.



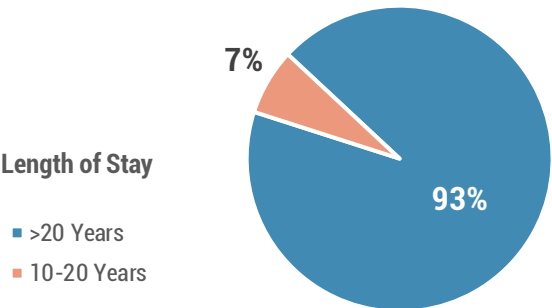
Local Resident Status

Based on the questionnaire results, the majority of the respondents are local residents who were born and reside in Tegal Ratu Village, which are 86 people (91%). On the other hand, 8 respondents (9%) are resettled residents or migrants.



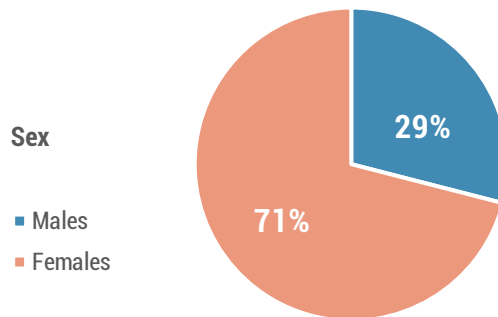
Length of Stay

Based on the questionnaire results, most respondents have been living in Tegal Ratu Village for more than 20 years, with a total 87 people (93%). The other 7 respondents (7%) have been living for 10–20 years. There aren't any respondents who have lived in the village for less than 10 years. The condition shows that the majority of the respondents have lived long enough in the studied area so that they can give an overview of the environmental conditions they've been facing while living around the steel industrial park.



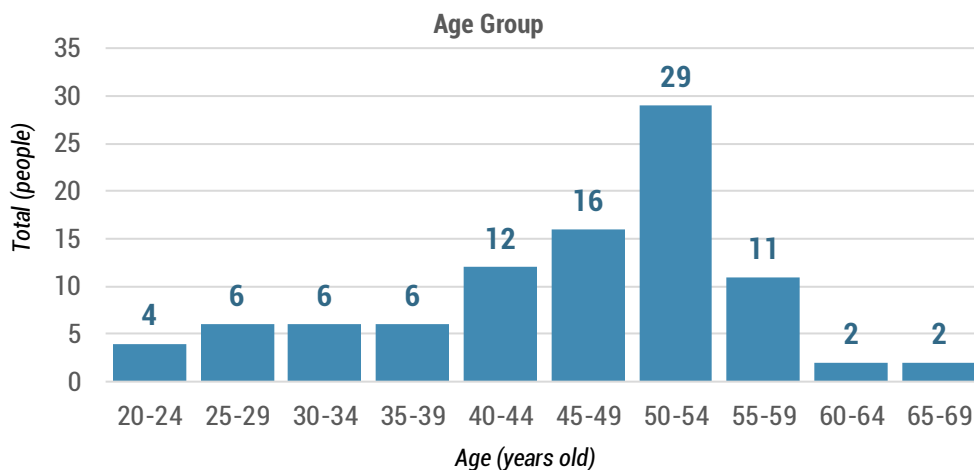
Sex

The respondents in this research are dominated by females, with 67 people (71%). Meanwhile, the males are 27 people (29%). This proportion depicts that females' participation is higher than males in answering the questionnaire.

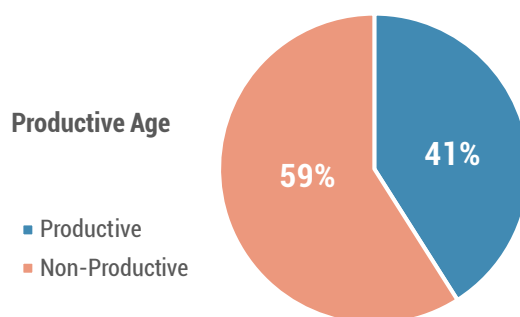


Age

The respondents are from a wide range of ages, from 20 to 69 years old. Respondents aged 50-54 years old are the largest group, with a total of 29 people. It is followed by 16 people from the 45-49 age group, 12 people from the 40-44 age group, and 11 people from the 55-59 age group. Younger respondents are relatively smaller in total. For example, there are only 4 people from the 20-24 age group.



If categorized by the productive age group (20-45 years old) and non-productive age group (46-65 years old), the majority of the respondents are at the non-productive age group with 55 people (59%), while the productive age group has 39 people (41%). It shows that most respondents are in the non-productive age category.



Occupation

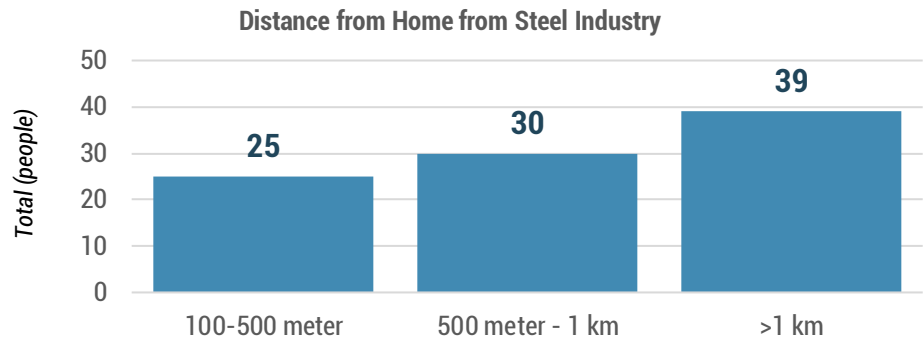
There is a wide range of occupations in this research, from homemakers, civil servants, students, to private-sector employees. Homemakers are the largest respondents, representing 46.5% of them. Meanwhile, the smallest group comes from merchants and retirees, each of them only contributed 1.0%.

The large group of homemakers is in line with the characteristics of respondents based on their sex, in which the majority are females. However, 5 respondents (5.1%) did not fill out their occupations on the questionnaire.

No	Occupation	Total of Respondents	Percentage (%)
1	Homemaker	46	46.5
2	Cadre	11	11.1
3	Laborer	7	7.1
4	Entrepreneur	7	7.1
5	Teacher	4	4.0
6	Private Sector Employee	3	3.0
7	Student	3	3.0
8	Civil Servant	2	2.0
9	Unemployed	2	2.0
10	Casual work	2	2.0
11	Retiree	1	1.0
12	Merchant	1	1.0
13	N/A	5	5.1

Distance from Home

According to the graphic of the distance from home, 25 respondents (27%) live 100–500 meters away from the steel industry, 30 respondents (32%) live around 500 meters to 1 kilometers away, and 39 respondents (41%) live more than a kilometer away. Based on the distance from home and distribution data of the RTs, the nearest RTs to PT Krakatau Posco are RT 01, 02, 03 which are located at RW 01, and RT 14, 16, 19, located at RW 07.



PT Krakatau Posco's EIA document stated that the air quality impact can be felt up to a radius of 500 meters from the plant. Meanwhile, the social impact is studied up to a radius of ± 1 km. This indicates that respondents living within 100–500 meters and 500 meters–1 kilometer of the plants are considered part of the society directly impacted by the industrial activities, including air pollution or other forms of contamination.

The remaining 41% of the respondents live more than 1 km away from the plants. This group is relatively safer. But they can still be impacted indirectly by the steel industry.

4.2.1 Community's Health

The health analysis of Tegal Ratu residents was focused on their respiratory condition, specifically the Acute Respiratory Infection (ARI) cases, which are most likely relevant to the steel industrial activities. The questionnaire results were then compared to the secondary data from BPS of Cilegon Municipality and the Community Health Center (*Puskesmas*) of Ciwandan. This was done to give a more complete picture of the community's health condition around the industrial park.

Health Complaints

No	Symptoms	Total of Respondents
1	Cough/Influenza/Runny nose	78
2	Itching/skin allergy	41
3	Cold	30
4	Shortness of breath	11
5	Headaches	4
6	Hearing impairment	1
7	Never sick	1

The questionnaire results show that almost all respondents have had health problems within the past year. The most common problems are cough/influenza/runny nose, suffered by 78 people. This is followed by 41 people who suffered from itching or skin allergy, and 30 people with a fever. There are also other problems, such as shortness of breath (11 people), headaches (4 people), and hearing impairment (1 person).

Based on the frequency, most respondents were sick within a short duration, around 3–7 days or a week. However, some reported longer duration such as 2 weeks to 1 month. Some respondents also stated that they have fallen sick repeatedly, every month or almost every day. The respondents highlighted that those health problems were related to the decline in air quality, due to so many industries located in the area of Tegal Ratu Village.

Fever, cough, influenza/runny nose, shortness of breath, and sore throat can be early indicators of the respiratory disorders related to ARI. Usually, these symptoms occurred 3 days after the exposure and persisted for 7-10 days (Kemenkes, 2023). These questionnaire results are still subjective, based on the respondents' answers. For a more accurate result, an advanced medical test is needed, such as blood tests to confirm whether the respondents who had those health problems are confirmed to have ARI.

"I sometimes get a cough, runny nose, and itching. My family, especially the kids, frequently have a sore throat. I guess it is because of the (changes in) air quality. We were sick for 1-2 weeks. It stopped, then reoccurred," said Mrs. S, a resident from RT 16..

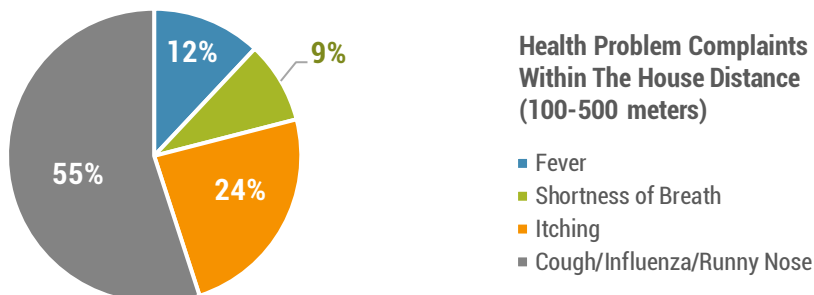
Questionnaires regarding health problems have also been carried out by PT Krakatau Posco in 2024. There were 140 respondents from Kubang Sari Village and Tegal Ratu Village of Ciwandan Subdistrict.

Citangkil Subdistrict, including Samang Raya Village, was represented by 60 respondents. Based on the EIA document, the people claimed to have health problems during the industry's operational activities.

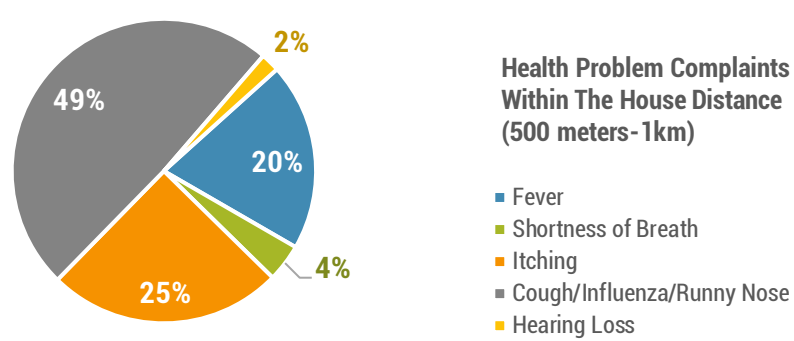
- 94 people (95.92 %) experienced discomfort and health problems.
- 43 people (43.43%) claimed to have respiratory disorders.
- 25 people (25.25%) claimed to have shortness of breath.
- 8 people (8.08%) claimed to experience noise disturbance.
- 23 people (23.23 %) claimed to experience cough, nausea, aching muscles, eyesore, etc.

Distance from Home to the Plants and Health Problems

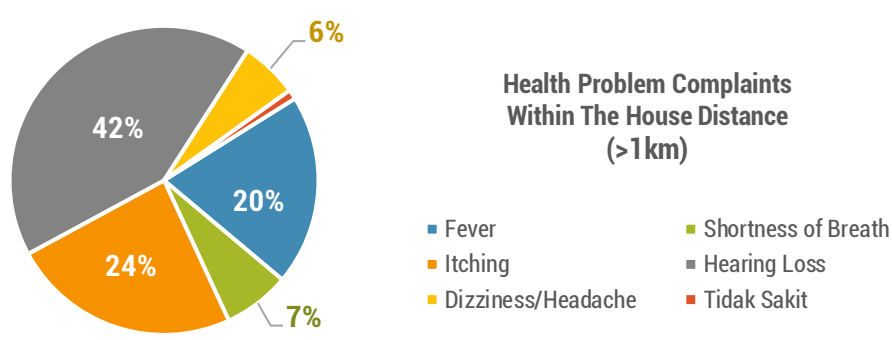
Respondents living 100–500 meters away from the plants (25 people) mostly complain about health problems such as cough/influenza/runny nose, as stated by 23 people (55%). Other than that, 10 people (24%) complain about itching or skin allergy, 5 people (12%) experience a fever, and 4 people (9%) report a shortness of breath.



The group of people who live 500 meters–1 km away from the plants mostly experience health problems such as cough/influenza/runny nose, as stated by 24 people (49%). Besides, there are 12 respondents (25%) who experience itching/skin allergy, 10 respondents (20%) experience a fever, 2 respondents (4%) complain about shortness of breath, and 1 respondent (2%) claims to have hearing loss.



Health problems still occur among the group of respondents living 1 km away from the plants. Cough/influenza/runny nose are reported by 31 respondents (42%), followed by 18 respondents (24%) with itching/skin allergy, 15 respondents (20%) having a fever, and 5 respondents (7%) experiencing shortness of breath. Surprisingly, 4 respondents (6%) report another problem, which is a headache. Meanwhile, 1 respondent (1%) states that they have never had any health problems.



Treatment Pattern

No	Medical Facilities	Total of Respondents	Percentage (%)
1	<i>Puskesmas</i> /Hospitals/Clinics	73	78
2	Drugstores/Kiosks	16	17
3	Not seeking treatments	5	5

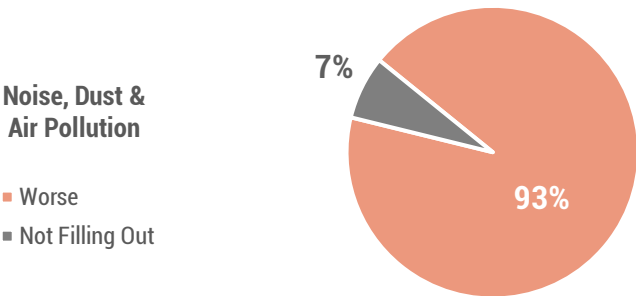
The majority of the respondents, amounting to 73 people (78%), choose to seek medical treatment from formal medical facilities such as *puskesmas*, hospitals, or medical clinics when they experienced the problems. Meanwhile, 21 respondents (22%) do not go to those medical facilities due to several reasons, such as the *puskesmas*' location being faraway and the queues being too-long (most common), short on budgets, minor illness, and ineffective treatment in the past.



4.2.2 Environmental Impact

Noise, Dust, and Air Pollution

As many as 93% of the respondents state that they notice the air pollution. They believe that the current air quality is worse, compared to before the plant existed.



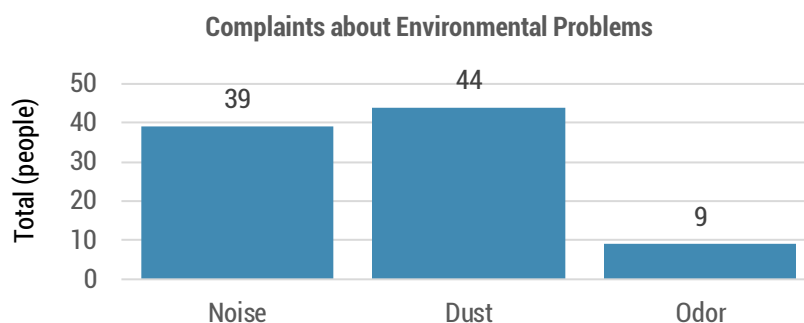
The most common complaints are the polluted air, rising temperature, flying dust, overpowering smell, and the smoke that causes breathing problems. The respondents also point out that the rising health problems like cough, influenza, and itching on the skin are related to the decreasing air quality.

"Back then, before the development of plants and many industries, this place was green with many paddy fields, no noise, and no bad air pollution. Now it's barren," said A, RW Head.

"I used to be able to run on foot to Anyer in 1985. There weren't many cars. The air was still fresh," added U, the RT Head who has lived in Tegal Ratu Village for more than 20 years.

"The area was full of paddy fields, left and right. Pleasant and refreshing. The current air is different. I often get a cough and sore throat because of the dust. It is because my house is near Posco, where they use coal as fuel," stated the Head of Community Empowerment Institution (LPM).

The graphic below shows that the environmental problems faced by Tegal Ratu residents is due to the dust, odor, and noise from the plant activities. Based on the detailed information from the respondents, they complained about the overpowering smell, which comes from the wastewater.



Also, the residents complain about the black dust and black smoke, floating from the plants' chimneys, which then stuck around the houses. There are even people who mention the phenomena of coal dust fall, steel dust fall, and crystal dust.

"As a homemaker, I am very impacted by the dust. It's still filthy even after I sweep the floor. No matter how many times I sweep the floor, (the dust is) still there. It already happened twice in 2025 (dust and noise complaints). In March and last month (July)," said Mrs. A while showing a picture of the black dust exposure in her house.



Figure 24. Air Pollution in the Form of Black Dust Floating into Residents' Houses
(Source: Facebook)

A Head of RT in Tegal Ratu Village also recounted that a cup of coffee put in the front yard of the house was exposed to the industrial dust. "The dust was flying inside the house, even if it was often swept out. If I drink a cup of coffee outside the house without putting a lid on, it can get contaminated. Hung laundry is also full of glimmering dust particles," he said.



Figure 25. The appearance of the smoke from PT Krakatau Posco plants seen outside a resident's house (top) and taken from a drone video (bottom)

(Source: AEER, 2025)

Meanwhile, the noise is reported to be coming from the loud plants, especially at night. The noise causes vibrations in the doors and windows of the houses. Due to the noise, respondents claimed to have poor sleep, especially if there are babies and kids in the house. Among all respondents in the questionnaire results, there is 1 person who complains of having hearing loss.

"After Posco was built the impact was outrageous. People often complained to the RT Head. A lot of kids live around here, clearly, they are disturbed too. When the plants are active, the noise is very loud, especially in RT 14. The smoke can also be seen from the musalla (in front of the house). Those Posco Executives enjoy their night sleeping soundly at home, but we, the residents, cannot sleep until dawn. They should at least try once, hanging out here, drinking coffee at night, to know how it exactly is. The chimneys are clearly visible when they are active, and the noise is too loud," remarked the RT Head.

PT Krakatau Posco's EIA data in Tegal Ratu Village shows that the noise level is above the quality standard value. Referring to Decision of the Minister of Environment No. 48 of 1996, Appendix I Regarding Noise Level Standards, what is allowed for industrial activities is 70 dB (A) and for residential activities is 55 dB (A).

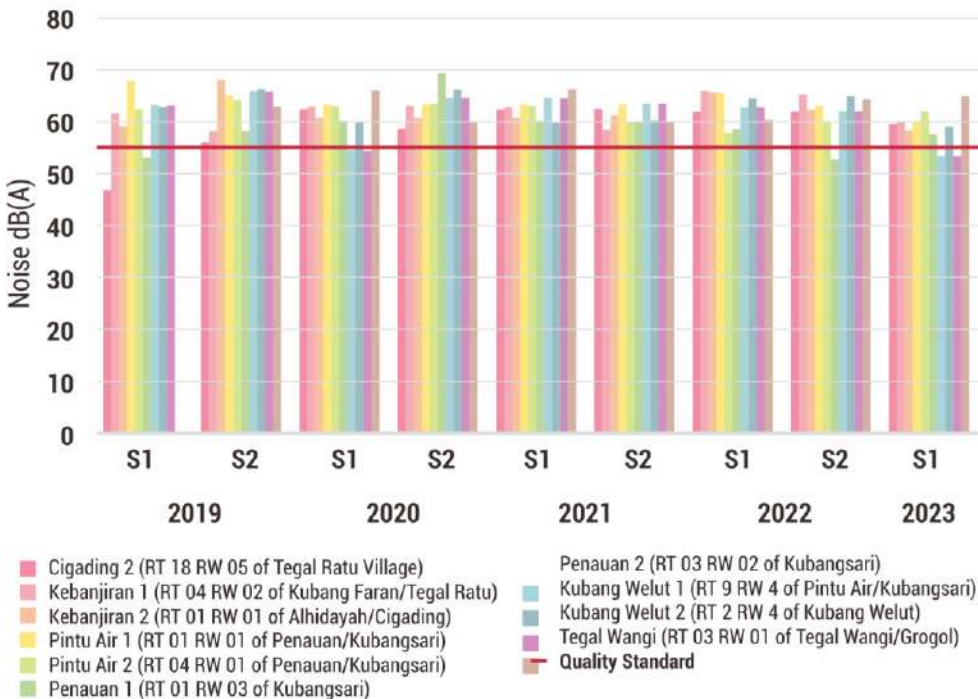


Figure 26. Noise Level in Residential Areas

(Source: PT Krakatau Posco, 2025)

PT Krakatau Posco stated in their EIA documents that the company has carried out noise and dust control through the vehicle emission test, covering the truck beds with tarps, and building the buffer zone between the industry and the residential areas, giving notification prior to the Exhaust activities, as well as informing the procedure for reporting environmental complaints. However, the reality is contrasting.

A, as the RW Head, claimed that they often file complaints on behalf of the residents to PT Krakatau Posco. However, there's never any response. A also mentioned that the notifications sent by PT Krakatau Posco are mostly too sudden. They don't give any notification regarding the noise they make.

"Previously, the notification letter was sent after the chimneys already emitted the smoke. They (Posco) said they forgot to share. We usually file the complaints via the WA group. Starting from the RTs, Villages, to the Subdistricts. However, there weren't any follow-ups."

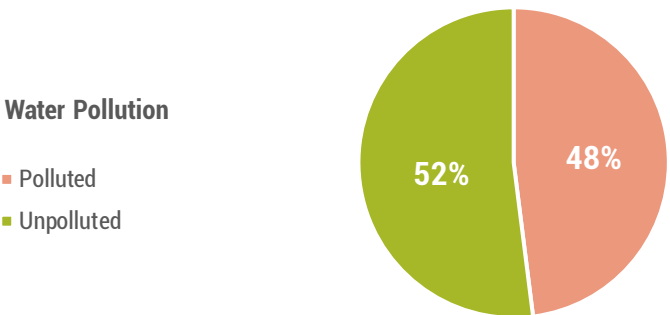
A added that PT Krakatau Posco followed up on the complaints after A contacted the members of the Regional House of Representatives (DPRD). "At most, they adjust the volume (chimney's noise) after they were warned by the DPRD members. Not as noisy as before."

Therefore, though what they claimed in the EIA is complete on paper, the implementation does not meet the residents' expectations. It shows the need for improvement in transparency, monitoring, and community involvement in every company's program.



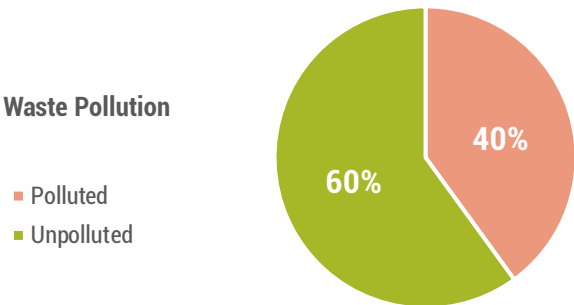
Water Pollution

As many as 45 respondents (48%) state that water sources around their houses have been polluted, while 49 respondents (52%) state there isn't any pollution. It shows that the water pollution is real and experienced by almost half of the respondents, though it is not experienced equally by all the residents.



Waste Pollution

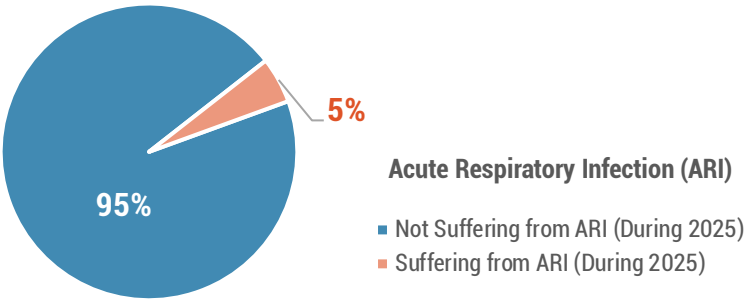
According to the questionnaire results, 38 respondents (40%) claim to have witnessed the industrial waste around their areas, while 56 respondents (60%) remark that the waste never gets near the surrounding environment. The most commonly mentioned waste is the strong-smelling wastewater which flowed into the drainage. Some say that the toilet waste disposal also flows to the residential areas. Other respondents also mention other kinds of waste, such as crystals, sand-like glass shards, and hazardous and toxic waste (B3).



The RT Head said that neither the DLH of Banten Province nor the DLH of Cilegon Municipality surveyed Tegal Ratu Village regarding the steel industry pollution. "Nope, not at all," he briefly said.

4.2.3 ARI Cases

In Ciwandan Subdistrict of Cilegon Municipality, the ARI cases are at the top rank among the ten most dangerous diseases every year (BPS of Cilegon, 2025).



Based on AEER’s research results, most respondents, which are 89 people (95%), do not have any ARI record. Meanwhile, only 5 respondents (5%) are recorded to suffer ARI in 2025, including 1 pneumonia case. This indicates that although many respondents claimed to have respiratory symptoms like cough/influenza/runny nose, or a fever, only a small part of them are reported suffering from ARI.

Table 7. ARI Data in Tegal Ratu Village in 2023-2025

Month	Year		
	2023	2024	2025
January	78	63	98
February	69	85	120
March	53	78	39
April	22	53	34
May	40	80	51
June	53	54	72
July	59	78	132
August	78	126	153
September	65	126	-
October	54	84	-
November	56	120	-
December	38	118	-
Total	665	1065	699

(Source: Ciwandan Puskesmas, 2025)

Table 8. ARI Cases in Tegal Ratu Village, *Puskesmas* Data vs Questionnaire Results in 2025

Area	ARI Cases (<i>Puskesmas</i> data)	ARI Cases (questionnaire results)	Prevalence (%)
Tegal Ratu Village	699 (per August)	5	0.71

In 2025, the ARI cases in Tegal Ratu Village reached 699 people in August, where in the past two months (June-July 2025), the ARI cases hit the highest point. Meanwhile, there are only 5 ARI cases based on the questionnaire results taken by AEER in September 2025.

The prevalence of ARI cases in Tegal Ratu Village, by comparing the Ciwandan *Puskesmas*'s data and AEER questionnaire results, is 0.71%. The low number of ARI cases in Tegal Ratu Village is because 70% of them are children, as stated by the Head of Ciwandan *Puskesmas*, dr. Arief Dharma Hartana. However, the questionnaire respondents for this research are adults above 20 years old.

According to the WHO (2020), AIR is one of the main mortality causes in the world, especially in children. The death toll in ARI has reached 4.25 million every year around the world. In 2020, there were 1,988 young children under five (*balita*) who suffered ARI.

Indonesia is one of the developing countries with the highest ARI cases. The Ministry of Health of the Republic of Indonesia mentioned that *balita* aged 6-23 months are the most vulnerable to ARI. Based on the report of the 2023 Indonesian Health Survey (*Survei Kesehatan Indonesia/SKI*) of the Ministry of Health (*Kemenkes*), the prevalence of ARI in Indonesian *balita* diagnosed by doctors is 4.8%. Banten Province was in the fourth rank, with ARI cases in children reaching 8.7%.

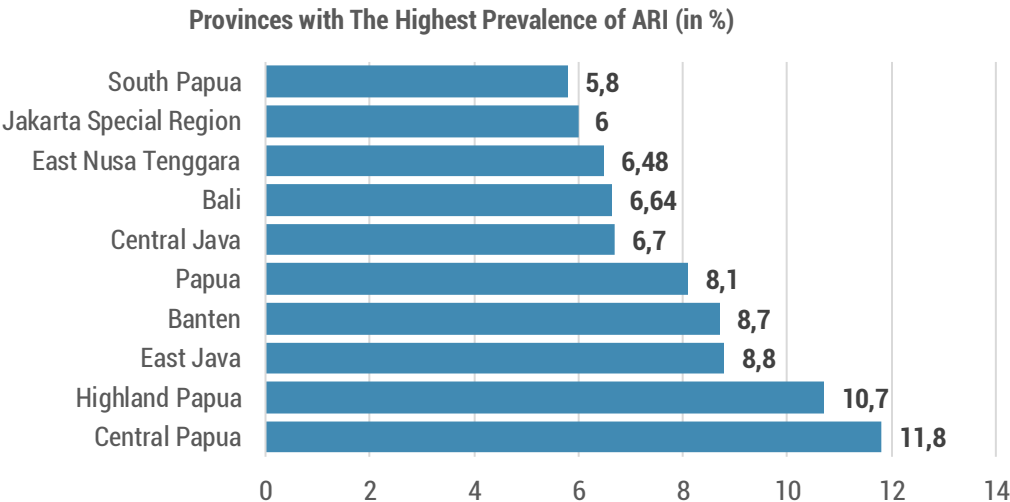


Figure 27. The list of provinces in Indonesia with the highest ARI prevalence in *Balita* (Toddler)
(Source: *Kemenkes RI*, 2023)

Table 9. Official Data of ARI Cases in Tegal Ratu Village and Ciwandan Subdistrict in 2023-2025

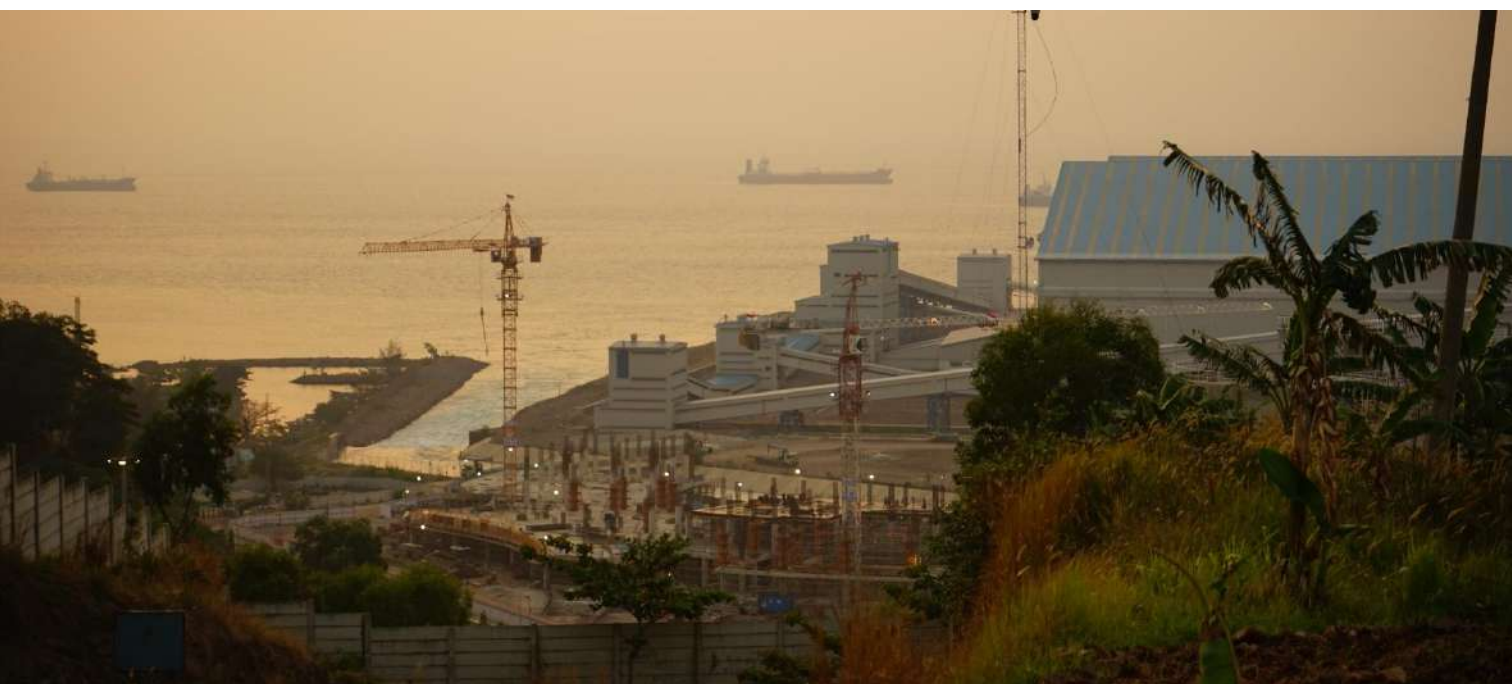
Area	Year	Total number of residents (persons)	ARI Case	Prevalence (%)	Contribution (%)
Ciwandan Subdistrict	2023	53,574	6,514	12.16	100.00
Tegal Ratu Village	2023	11,755	665	5.66	10.21
Ciwandan Subdistrict	2024	54,606	5,091	9.32	100.00
Tegal Ratu Village	2024	11,987	1,065	8.88	20.92
Tegal Ratu Village	2025		699 (per August)		

(Source: BPS Kota Cilegon dan Puskesmas Ciwandan)

The table above shows that there were 6514 cases of ARI in Ciwandan Subdistrict in 2023, and they decreased in 2024 to 5091 cases. On the other hand, Tegal Ratu Village recorded an increase from 665 cases in 2023 to 1065 cases in 2024. In 2025, the ARI Cases in Tegal Ratu Village had decreased to only 699 cases, though the data compiled was only until August 2025.

ARI prevalence in 2023 in Ciwandan Subdistrict was 12.16%, higher than in Tegal Ratu Village, which was only 5.66%. In 2024, the ARI prevalence in Ciwandan Subdistrict was recorded at 9.32%, while in Tegal Ratu Village was at 8.88%.

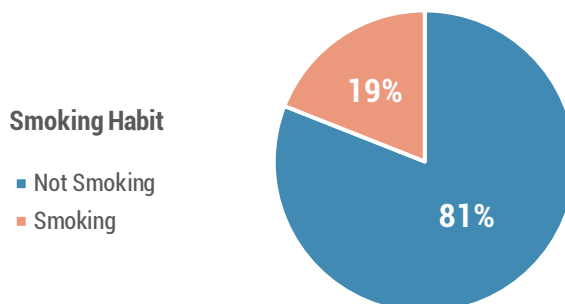
Although the prevalence in Tegal Ratu was relatively lower, the area still recorded around 10.21% of ARI cases in Ciwandan Subdistrict in 2023. It even increased to 20.9% in 2024.



Smoking Habit

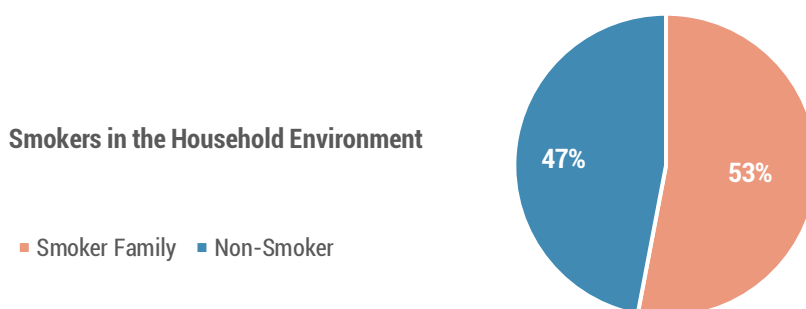
Smoker Respondents

The questionnaire results show that most respondents (76 people) do not have any smoking habits. On the other hand, 18 respondents (19%) are smokers. Among the 18 respondents, 2 are females and the others are males. The 19% of the smoker respondents should be taken into consideration because they might have increased health problem risks, particularly respiratory diseases like ARI.



Smokers in the Household Environment

The questionnaire shows that 50 respondents (53%) live together with smokers in their household, while the other 44 respondents (47%) state that there is no smoker in their homes. According to the collected information, the commonly mentioned smoker family members are husbands, followed by children, fathers, and siblings, both older and younger. This indicates the relations of smoking habits within family members, where one person's smoking habit tends to influence the household environment. As a result, other family members will be exposed to cigarette smoke, which can potentially increase the respiratory problem risks, such as ARI, especially towards the vulnerable groups like children and the elderly.



Statistical Analysis of the Correlation between Variables and ARI Cases

Analysis of the correlation between the variables and ARI Cases is carried out using Fisher's Exact Test. The test is used because the total ARI Cases in the research samples are too small (only 5 people out of 94 respondents), thereby many cells in the contingency table have the expected count of less than 5. The condition causes the Chi-Square test to be less valid. Therefore, Fisher's Exact Test is used as a more precise alternative for a 2x2 table with small data.

Moreover, this correlation test uses H0 and H1 hypotheses, where in H0, there is no correlation between the X variable and ARI Cases, while in H1, there is a correlation between the X variable and ARI Cases. The type I error level (α error) used is 5% or 0.05. If p-value > 0.05, the result is considered statistically insignificant. All statistical analysis results of the correlation between several variables and ARI Cases in this research are insignificant. This is because the total number of ARI cases in this sample is too small or too low.



The Correlation between Smoking and ARI

Characteristics of the Respondents	Suffers from ARI		Does not suffer from ARI		P-Value Fisher's Exact Test	Odds Ratio (CI 95%)	Remarks
Smoking habit	(N)	(%)	(N)	(%)			
Smoking habit	1	1.1	17	18.1	1.00	1.05 (0.11 – 10.22)	Insignificance
Present	4	4.2	72	76.6			
Not present	5	5.3	89	94.7			

The result of Fisher's Exact Test shows that there is no significant correlation between smoking habits and ARI occurrences in this research sample. The Odds Ratio (OR) of 1.05 with 95% (0.11–10.22) confidence interval shows the probability of ARI occurrence is almost the same between the smoker and nonsmoker respondents. The same result is also demonstrated in a research conducted by Rahmaningsih (2022) which shows that there is no significant correlation between the smoking status and lung function disorder.

Meanwhile, Pope, et al (2002) stated that cigarettes contain 12 mg PM_{2.5} intake in every stick. Thus, PM_{2.5} intakes in adult smokers are higher than those of nonsmokers. Swiatkowska, et al (2015) suggested that the lung function might weaken if someone consumed an average of 20 cigarettes a day.

The Existence of a Smoker Family Member in the Household and ARI

Characteristics of the Respondents	Suffers from ARI		Does not suffer from ARI		P-Value Fisher's Exact Test	Odds Ratio (CI 95%)	Remarks
Smoker in the household	(N)	(%)	(N)	(%)			
Present	3	3.2	47	50	1.00	1.33 (0.26 – 6.94)	Insignificance
Not present	2	2.1	42	44.7			
Total	5	5.3	89	94.7			

The results show that there is no significant correlation between a smoker family member in the household and ARI occurrences. The Odds Ratio (OR) of 1.33 with 95% (0.26–6.94) confidence interval indeed shows a higher probability of ARI for respondents who live with a smoker. However, this result can not yet become a strong basis to conclude a correlation because the confidence interval is too wide.

On the other hand, based on research by Rahmaningsih (2022) that was also carried out in Tegal Ratu Village, adults who are exposed to cigarette smoke have 1.69 times higher risks of suffering from lung function disorder, compared to adults who are not exposed to cigarette smoke in their household.

The Correlation between Sex and ARI

Characteristics of the Respondents	Suffers from ARI		Does not suffer from ARI		P-Value Fisher's Exact Test	Odds Ratio (CI 95%)	Remarks
	(N)	(%)	(N)	(%)			
Male	1	1.1	26	27.6	1.00	0.61 (0.06 – 5.85)	Insignificance
Female	4	4.2	63	67.1			
Total	5	5.3	89	94.7			

The results show that there is no significant correlation between sex and ARI occurrences in this research sample. The Odds Ratio (OR) of 0.61 shows that males have a smaller probability of suffering from ARI, compared to females. However, this result is statistically insignificant.

Putri (2012) noted that the total number of males suffering from lung function disorder is smaller than females. This happens because females are more vulnerable to any health problem than males.

The Correlation between Age and ARI

Characteristics of the Respondents	Suffers from ARI		Does not suffer from ARI		P-Value Fisher's Exact Test	Odds Ratio (CI 95%)	Remarks
	(N)	(%)	(N)	(%)			
Productive (20-45 years old)	3	3.2	36	38.3	0.65	2.21 (0.35 – 13.7)	Insignificance
Non-productive (46-69 years old)	2	2.1	53	56.4			
Total	5	5.3	89	94.7			

The result of Fisher's Exact Test shows that there is no significant correlation between age and ARI occurrences in this research sample. The Odds Ratio (OR) of 2.21 shows that respondents in their productive age are twice as likely to suffer from ARI, compared to the non-productive age group. However, this result is statistically insignificant.

Alternatively, based on the research by Rahmaningsih (2022), there is a significant correlation between respondents' age and lung function disorder. The average age of respondents suffering from lung function impairment is 42 years old.

The Correlation between Homemaker Occupation Status and ARI

Characteristics of the Respondents	Suffers from ARI		Does not suffer from ARI		P-Value Fisher's Exact Test	Odds Ratio (CI 95%)	Remarks
	(N)	(%)	(N)	(%)			
Homemaker	4	4.2	42	44.7	0.19	4.48 (0.48 – 41.8)	Insignificance
Non-homemaker	1	1.1	47	50			
Total	5	5.3	89	94.7			

The result of Fisher's Exact Test shows that there is no significant correlation between a homemaker occupation status and ARI occurrences. The Odds Ratio (OR) of 4.48 shows that respondents as homemakers have 4.48 times higher risks of suffering from ARI, compared to respondents who are not homemakers. However, this result is statistically insignificant.

This result is in line with research by Putra (2015), stating that a homemaker is at risk of lung function impairment caused by the exposure to PM_{2.5} concentration in their houses.

The Correlation between Home Distance and ARI

Characteristics of the Respondents	Suffers from ARI		Does not suffer from ARI		P-Value Fisher's Exact Test	Odds Ratio (CI 95%)	Remarks
	(N)	(%)	(N)	(%)			
Home distance					0.65	2.21 (0.35 – 13.89)	Insignificance
≤1 km	2	2.1	53	56.4			
>1 km	3	3.2	36	38.3			
Total	5	5.3	89	94.7			

The result shows that there is no significant correlation between home distances and ARI occurrences. The Odds Ratio (OR) of 2.2 shows that respondents who live ≤1 km away have 2.2 times higher probability of suffering from ARI. However, this result is statistically insignificant due to the wide confidence interval that includes the number 1.

The Correlation between Air Pollutants and ARI

The analysis of the correlation between air pollutant concentration (PM2.5) and ARI occurrences is carried out using binary logistic regression. This method is used because the dependent variables are binary data, which are the ARI status categorized as 0 = not ARI and 1 = ARI. Binary logistic regression is suitable to be used to analyze the impact of one or more independent variables on the probability of occurrences with two possible outcomes.

The independent variable in this research is the air pollutant concentration (PM2.5). This is because PM2.5 has a big impact on the respiratory disorder risks, especially ARI, due to its very tiny particle size so that it will easily go inside the lungs. Additionally, other control variables considered to potentially impact ARI risks are added, such as age, sex, smoking habits, the existence of smokers in the household, and length of stay in the research area.

The Correlation between PM2.5 and ARI

Variable	B	p-value	Exp(B)	95% CI Exp(B)
PM2.5	-0.072	0.106	0.931	0.857 – 1.012
Age Category (productive vs non)	-1.081	0.321	0.339	0.031 – 3.739
Sex	0.788	0.642	2.198	0.065 – 74.165
Home distance (≤ 1 km vs > 1 km)	1.255	0.265	3.507	0.377 – 32.620
Smoking	1.164	0.488	3.203	0.064 – 160.655
Smoker in the household	-0.517	0.658	0.596	0.043 – 8.323
Duration of residency	-1.372	0.325	0.253	0.014 – 4.612

The logistic regression model (logit) is as follows: $\text{Logit}(p) = 1.555 - 0.072 \times \text{PM2.5} - 1.081 \times \text{Age} + 0.788 \times \text{Sex} + 1.255 \times \text{Home Distance} + 1.164 \times \text{Smoking} - 0.517 \times \text{Smokers at Home} - 1.372 \times \text{Length of Stay}$.

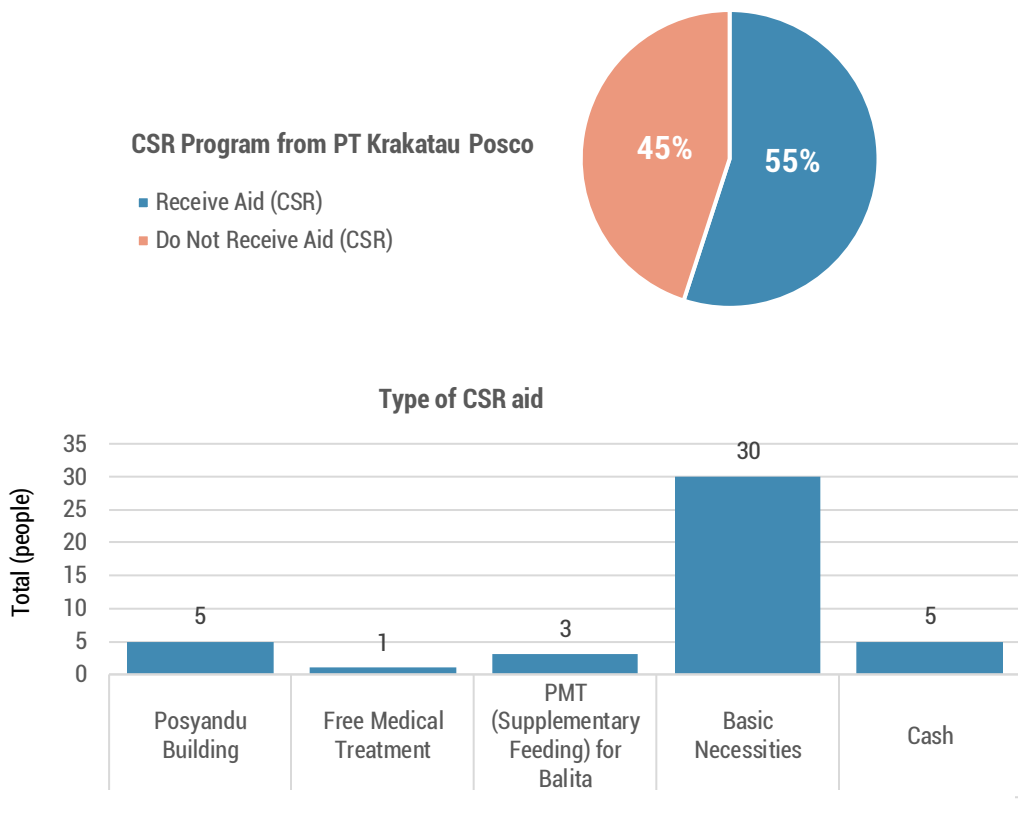
According to the logistic regression result table, the PM2.5 variable has an odds ratio (Exp(B)) of 0.931 and a 0.106 p-value. The numbers indicate that the higher the PM2.5 concentration, the smaller the ARI probability risks (around 0.93 times). However, this result is statistically insignificant ($p > 0.05$), so the correlation cannot yet be confirmed. Also, control variables, such as age, sex, home distance, smoking habits, the existence of smokers in the households, and the length of stay do not show a significant correlation to ARI.

The logistic regression analysis is also carried out for PM10 and PM100 variables. The results show that both have no significant correlation to any ARI occurrences ($p > 0.05$). On the other hand, Zhang et al (2016) stated that the increase in PM2.5 concentration in ambient air as much as $10\mu\text{g}/\text{m}^3$ is significantly relevant to 3.4% decrease of the lungs' forced vital capacity. Whereas, Agustan J (2024) in his research remarked that PM2.5 dan PM10 can worsen the condition and increase the risks of ARI, especially to the vulnerable population.

4.2.4 Social-Economic Impacts

Corporate Philanthropy/CSR

According to the questionnaire results, most respondents, 52 people (55%), state they have received aid or a CSR program from PT Krakatau Posco, while the other 42 people (45%) state otherwise. It shows that the company's CSR program has reached more than half of the residents, but the distribution is not yet equal because almost half of the respondents haven't received the direct benefit.



CSR aid received by the residents of Tegal Ratu Village is predominantly consisted of basic necessities or *sembako* (30 respondents), *posyandu* (Integrated Health Post) buildings (5 respondents), cash (5 respondents), PMT (supplementary feeding) for *balita* (3 respondents), and free medical treatments (1 respondent). The trend shows that this program tends to focus more on consumptive aid. In comparison, the realization of the health sector and social development is relatively limited.

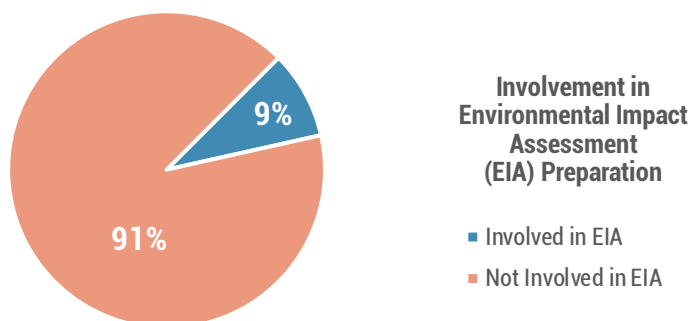
In their EIA document, PT Krakatau Posco included many CSR programs for the community around the industrial park, such as *sembako* distribution, cash, scholarships, the school's sports facility provision, nutritious food trial distribution, etc.

"Dear government and the company, please provide (free) health care posts for the community to handle the (health) complaints. Do not say that the puskesmas is near. For example, a week in this area, and the following week in another area. So that our (health) condition is under control," proposed S, a resident of RT 16.

"Please pay more attention to health care, such as providing free health care posts. Maybe every 3 months, 6 months, or even annually. That is already such a great idea," added A, RW Head.

Involvement in EIA Preparation

Based on the questionnaire results, the majority of Tegal Ratu residents (91%) declare not being involved in the preparation or socialization of PT Krakatau Posco's EIA. Only a small group of them (9%) has participated. It shows the low level of community involvement, whether in the preparation process or in the evaluation of the environmental impact.

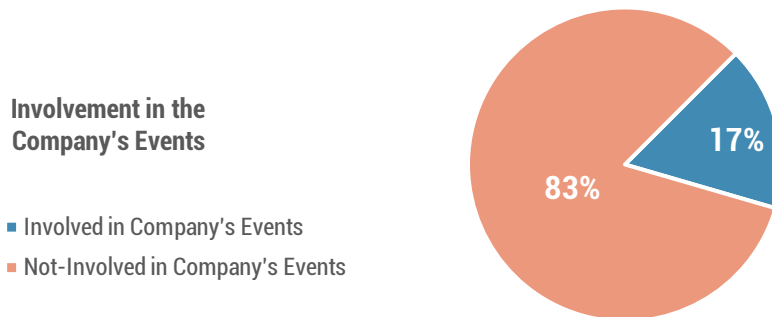


In contrast to this, PT Krakatau Posco reported in their EIA document that the company has engaged the community as the external stakeholders by dividing respondents in several areas, including Tegal Ratu Village, to share their perceptions towards the company.

Thus, there is a gap between the questionnaire data and the company's claim in their EIA. The EIA positioned the community as an active player. However, the AEER questionnaire shows that most residents have never had the opportunity to participate. It raises questions on the actual implementation of EIA in real life, especially regarding the transparency, accountability, and equal involvement of the impacted residents.

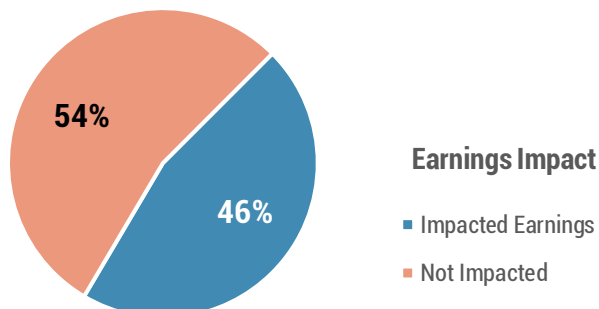
Involvement in the Company's Events

The questionnaire results report that the majority, 83% of the residents (78 respondents) have never been involved in the company's social events, such as community service, anniversary, or other community activities.



Earnings Impact

According to the questionnaire results, 51 respondents (54%) mention that they do not experience any positive impact on their earnings after the steel plant was built. Meanwhile, 43 people (46%) state that there is an increase in their incomes. It indicates the economic impact is relatively equal, though there are a bit more people who are directly impacted.



Qualitatively, several respondents point out that the company hasn't yet given a full opportunity for the locals to work due to the large number of employees recruited from outside the area. Some also complain that the locals are given the opportunity to work only as contract workers or manual laborers, while full-time employee status is hard to achieve. As a result, some of the residents believe that the company does not significantly contribute to reducing unemployment in its area.

"They open job vacancies every year, but only for training. They don't call, or offer a full-time position," revealed A, RW Head.

On the other hand, the residents who are working in the company feel that the existence of the steel industry provides tangible benefits, in the form of increased earnings, working opportunities for the family members, and an improved economic condition in the households. In other words, although there is an employment absorption, the opportunity for the surrounding community is limited and unequal.

4.3 Dangerous Pollutants Analysis

Proses industri baja di Cilegon selain menggunakan bahan bakar fosil juga menggunakan material yang mengandung polutan berbahaya untuk lingkungan dan kesehatan manusia. Polutan tersebut logam berat merkuri (Hg), kadmium (Cd), serta *partikulat matter* berupa debu silika (SiO₂) dan PM_{2,5}.

Table 10. List of Dangerous Pollutants from the BF-BOF-based Steel Industrial Activities, Environment Media Exposed and the Emission Burdens

Dangerous Pollutants	Exposed/contaminated environmental media	Emission burden/year (tons) in (mg/Nm ³)		
		2021	2022	2023
Mercury (Hg)	wastewater, ambient air, soil, marine sediment	0.21	1.02	0.22
Cadmium (Cd)	wastewater, ambient air, surface water, soil	0.34	1.72	0.35
Silica dust (SiO ₂)	ambient air, soil	N/A	N/A	N/A
PM	ambient air, soil, surface water	963.1	995.9	647.7

(Source: Environmental Impact Assessment (EIA) and Electronic Environmental Reporting Information System (SIMPEL) of PT Krakatau Posco, 2025)

4.3.1 Mercury (Hg)

In the steel industry, the mercury contained is usually in the form of gaseous elemental mercury Hg^0 and inorganic mercury Hg^{2+} . The mercury is exposed from 4 locations, which are the chimneys that release it to the air, wastewater, solid residues, and the by-products of slag or pig iron. Even though the gaseous mercury dispersed to the air is low level (only 1% - 5% of the total concentration), it will accumulate over time and gradually worsen the health risks, resulting in chronic diseases.

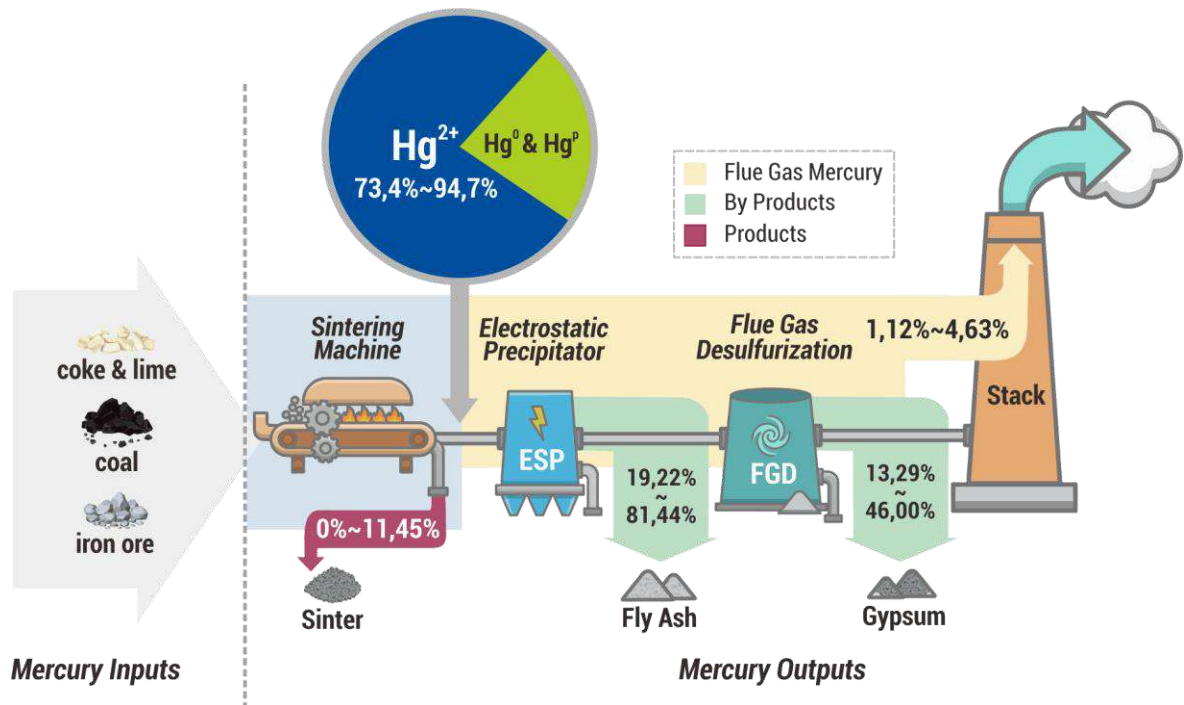


Figure 28. The Inputs and Outputs of Mercury in the Steel Industry
(Source: Xu et al, 2017)

Reported in the EIA of PT Krakatau Posco, the wastewater quality measurement result in 2023 indicates that the mercury (Hg) content is nearing the quality standard, which is <0.0017 mg/L out of 0,002 mg/L. This is in line with Government Regulation Number 22 of 2021 on General Wastewater Quality Standards, which stipulates the concentration limit allowed for several business types/industrial activities.

Table 11. Measurement Results on Wastewater Quality in the 2nd Semester of 2023 at Effluent Final Wastewater Treatment Plant to the Sea

Parameter	Jul	Aug	Sept	Oct	Nov	Dec	Quality Standard (mg/L)
Mercury (Hg)	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	<0.0017	0.002

(Source: EIA of PT Krakatau Posco, 2025)

The biggest airborne emission from mercury is sourced from two places, the sinter plant that contributes 46%–50% and the coal gas combustion that contributes 17%–49% to the plant's total emission.

Research by Wang et al (2016) reported that the mercury emissions from Blast Furnaces are twice as high as those from Electric Arc Furnaces (EAFs). The total mercury emission from coke oven, sintering, and blast furnace reaches 0.047-0.039 g Hg/ton of steel, while from EAF is 0.021 g Hg/ton of steel. Blast furnace dust also contains quite a huge amount of mercury, ~27–36% of the total plants' Hg outputs.

4.3.2 Cadmium (Cd)

Cadmium (Cd) is not deliberately used in the steel industry. It is contained in the raw materials, such as iron ore, coal/coke, flux (limestone/dolomite), and recycled steel scrap. Due to its low boiling point (767 °C), Cd is easy to evaporate. Thus, during the steel smelting process which reaches 1500–1700 °C, most Cd evaporates to metal vapor (Cd(g)) or oxide (CdO) and is carried along the dust residue and in the exhaust gas system.

Table 12. Cadmium (Cd) Emission Factors from the European Iron and Steel Industry

Process	Emission Factors (g Cd/t steel product)		
	Atmosphere	Solid waste	Slag
Sintering	0.08	0	0
Ironmaking	0	0.67	(N/A)
Basic Oxygen Steelmaking	0.02	0.36	1.11
Electric Arc Steelmaking	0.40	3.65	0.29

(Source: Hutton, 1983)

Based on the research conducted by Izquierdo & Querol (2012), the Cd found in the combustion residue of coal and sinter ash range from 0.1-3 mg/kg. During the Blast Furnace step, the reduction reaction and the ore smelting at >1500 °C cause the Cd to totally evaporate. The Cd vapor is carried along with the top gas, and is captured by the dust collector (ESP/bag filter) so that the remaining Cd in the slag is less than 1%.

Meanwhile, Cd in the Electric Arc Furnace (EAF) comes from the recycled steel scrap, which is from the electronic component and used galvanized products. Similar to Blast Furnace, scrap smelting during the EAF step at >1600 °C will evaporate Cd into Cd(g) or CdO. The Cd vapor will then be captured by the dust collector (ESP/Bag filter), with 10–300 mg/kg Cd contained. On the other hand, on slag and liquid steel, Cd contamination is low (<1 mg/kg) due to its high volatility.

4.3.3 Silica Dust

The silica dust (SiO₂) particles have a relatively high concentration in the air, making workers and the surrounding residents inadvertently inhale them. In a long period of time, the more one inhales silica dust, the higher the risks of suffering from chronic diseases, such as pneumoconiosis and silicosis.

Free silica dust is easily found in the iron and steel industry, including PT Krakatau Posco. Raw and supporting materials for the ironmaking and steelmaking processes in PT Krakatau Posco have high SiO₂ content, such as:

- coal, with a specific consumption of 4,640,000 tons/year
- iron ore, with a specific consumption of 9,860,000 tons/year
- coke breeze, with a specific consumption of 413,000 tons/year
- quartzite, with a specific consumption of 91,778 tons/year
- silica sand, with a specific consumption of 91,778 tons/year

Table 13. Silica Dust Consumption in PT Krakatau Posco in 2024

Details	Daily consumption (ton/day)			Specific consumption (ton/day)		
	Plant 1	Plant 2	Total	Plant 1	Plant 2	Total
Silica Dust	17	17	34	6,000	6,000	12,000

(Source: EIA of PT Krakatau Posco, 2025)

The residents complain about the appearance of silicon particles during the plant shutdown. It is known that PT Krakatau Posco conducts maintenance by doing a draining process twice a month for up to 16 hours each. The process is marked by a huge explosion and a white particle explosion, which spreads to the residence area, including Tegal Ratu Village of Cilegon Municipality. This white particle is believed to be the silicon particles that are dangerous if inhaled by the surrounding residents. This issue requires serious attention from both the company and the government.

PT Krakatau Posco is known to own the dust collector called dedusting. The dust is sucked and then filtered using the bag filter before being released through a dedusting chimney. The maximum dust content being released through the chimney is 35 mg/Nm³ at the maximum. Meanwhile, the applicable quality standard is at 75 mg/Nm³.

PT Krakatau Posco also owns 67 dedusting chimneys during the operational stage. However, in the realization of the Environmental Management Plan (EMP), the company stated that only 4 chimneys are added with the CEMS tool and integrated into the Continuous Industrial Emission Monitoring Information System (SISPEK) of the Ministry of the Environment and Forestry, which are COP 9, SP3, SMP 3, and BF2. Also, in their EIA documents, PT Krakatau Posco only enclosed the report of emission burden (ton/year) per parameter from only 49 chimneys' existing activities, which indicates that there are unmonitored emission sources.

Coal usage as the main fuel and raw material results in a lot of free silica dust (SiO₂). When coal is burned during the coke oven plant process, silica dust will be released and dispersed to the air with other particles, such as alumina dust, iron oxide, and carbon, which then accumulate into ashes. In addition to that, silica dust is also contained in other raw materials during the ironmaking process, such as iron ore, coke, quartzite, and silica sand.

The total composition of silica (SiO₂) and aluminum oxide (Al₂O₃) in the steel slag during the ironmaking process is very high because they contribute to the durability and stability of the slag. Silica composition in a steel slag is at 15% - 19.1% (Aziz et al, 2022). During the sintering process, the silica released from the raw materials is also high.

Table 14. Silica Composition in the Raw Materials of the Sintering Process (in %)

Raw Materials	TFe*	SiO ₂	CaO	MgO	Al ₂ O ₃	LOI**	Total raw materials proportions
Mixed iron ore	60.26	3.95	0.93	0.36	1.87	4.54	81.60
Limestone	2.08	2.12	48.87	3.05	0.53	42.00	4.9
Dolomite	1.38	5.59	26.40	21.14	1.13	42.06	4.0
Burnt lime	0.26	2.94	74.27	4.82	0.70	14.18	5.0
Coke	2.92	7.47	0.55	0.20	4.39	83.22	4.5
Remains of smooth materials from the sintering process	56.07	4.55	9.12	1.76	2.06	0.0	10.0
Mixed raw materials	56.18	4.52	9.03	1.75	2.04	-	-
* TFe: total iron composition ** LOI: mass loss on ignition at 950 °C.							

(Source: Liu et al, 2023)

Blast Furnace (BF) process will produce pig iron (95% Fe, 3.5% C) and slag (Al_2O_3 , CaSiO_3 , coke dust, CaCO_3). Slag is usually used in construction and mixed cement. Meanwhile, during the Basic Oxygen Furnace (BOF) process, pig iron from the BF process is molten, and then given a pure oxygen to oxidize and remove any impurities (Si, C, P, Mn). The reaction forms an oxide compound (CaO-SiO_2 , MnO , FeO , etc.). Scraps are also added to make it efficient. Meanwhile, calcium carbonate (CaCO_3) is used to bind silicon dioxide (SiO_2).

4.3.4 PM_{2.5}

As reported in the EIA document, PT Krakatau Posco had measured the ambient air quality in 2019-2023. The measurement was done in 4 (four) air sampling points and 2 (locations) in Tegal Ratu Village, which were Cigading and Kebanjiran areas. Based on Government Regulation No. 22/2021, the quality standard for PM_{2.5} is 55 $\mu\text{g}/\text{m}^3$. The results show that several PM_{2.5} parameters were close to the quality standards (See Table 17-20).

Attempts to control PM_{2.5} include the use of baghouse, ESP, enclosure, and dust suppression to reduce fugitive emissions. On the emission quality, if the hotspot (sinter/BOF/EAF) is uncontrolled, PM_{2.5} can reach hundreds of mg/Nm^3 out of total PM. On the other hand, a proper baghouse/ESP handling will reduce it to less than 10–20 mg/Nm^3 . Based on their EIA, to control the dust and PM_{2.5} particulates, PT Krakatau Posco had implemented fugitive measures, such as bag filter, chimneys, ESP, spraying gun, wet scrubber, and cleaning plant.

Particulate Matter (PM) exposure is a dangerous pollutant that will cause high mortality. Particulate Matter is a pollutant coming from a mixture of complex particles, such as smoke, dust, dirt, soot, and very small liquid droplets found in the air (IDEM, 2015). One of them is the PM_{2.5}, defined as an ambient air particle measuring 2.5 microns. PM_{2.5} is considered more dangerous than PM₁₀ or PM₁₀₀. That is because it is very small and microscopic in size, 2.5 micrometers, which makes it possible for the particle to get into the bloodstream and flow to the respiratory system and the whole body, affecting the health.

The main source of PM_{2.5} in the steel industry is the sinter plant, coke oven, blast furnace/BOF, EAF, pouring and finishing processes, as well as from the fugitive dust during material handling. Mixed sinter burning process in the sinter plant will release fine particles and precursor gas (SO_2 , No_x), which will become the secondary source of PM_{2.5}. Meanwhile, on the coke oven, PM_{2.5} and Polycyclic Aromatic Hydrocarbon (PAH) compounds arise during the stages of charging and pushing, as well as from the leakage of the door and lid.

The characteristic composition of PM_{2.5} comes from iron oxide ($\text{Fe}_2\text{O}_3/\text{Fe}_3\text{O}_4$), sulfate/nitrate, carbon (organic and black carbon), Polycyclic Aromatic Hydrocarbon (PAH) from coke, and trace metals (Zn, Pb, Mn, Cr, Ni). PM_{2.5} composition usually reaches 20–50% of the total particulate (TSP), depending on the process and applicable control system (Yang et al, 2015).

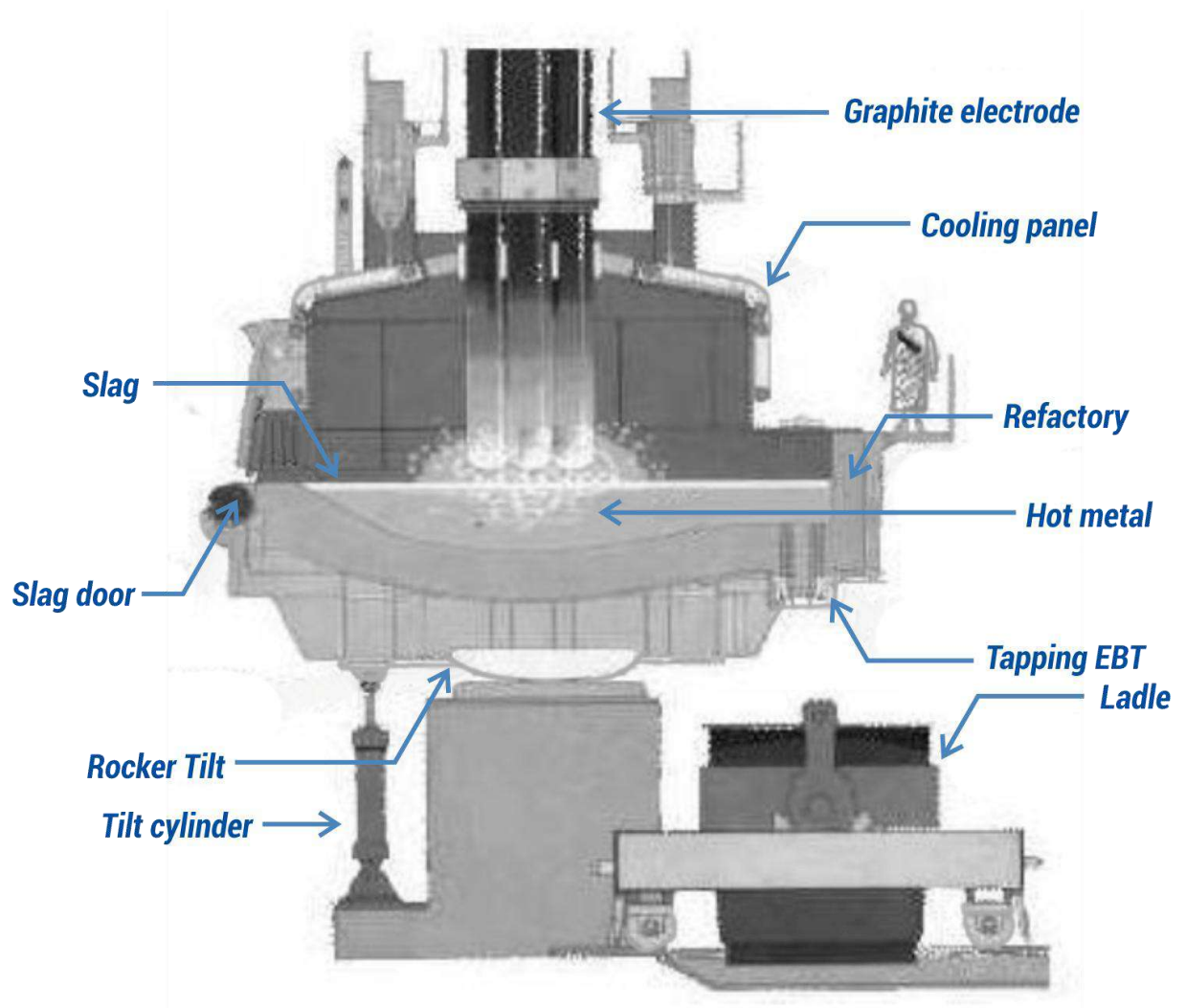
4.4 The Urgency to Change into Environmentally Friendly and Low-Carbon Steel Industrial Processes

Table 15. The Advantages and Disadvantages of Electronic and Fossil-Based Steel Processing Technology

Ironmaking - Steelmaking Route	Advantages	Disadvantages
DRI-EAF / Scrap-EAF	• Sponge iron (DRI) and scrap utilization, thus the raw materials usage is more flexible • Lower carbon emissions and pollutants, compared to BF–BOF. • Smaller initial investment	• High consumption of electrical energy • Steel quality depends on the scrap or DRI quality being used • Smaller production capacity, compared to BF–BOF
BF -BOF	• High temperature efficiency • High productivity • Long usage period	• High-quality raw materials • Coke and sinter needs • High pollutant emission • High investment cost

(Source: fajarmuktiana, 2020)

Dangerous materials and fossil fuels should be replaced immediately with a cleaner and more sustainable one. Decarbonization in the steel industry requires a change, from using fossil fuels to sustainable energy. Materials such as quartz sand and dolomite for the flux in the blast furnace should be replaced since they pollute the environment with their dangerous substances. The materials used in EAF do not contain those dangerous substances and instead, it depends on scrap, DRI, Hot Briquette Iron, hot metal, oxygen, and quicklime. Even though scrap is used, the substances still need to be monitored. Environmental management should also be done properly, through management of air pollution and wastewater which will be released into the environment. One such case is what happened in September 2025 in Banten where there was radioactive-contaminated material in the scrap. This proved that the environmental regulation in the steel industry in Indonesia is weak, thus improvement and decarbonization must be done (Hanung and Uli, 2025).



Raw materials:

- Scrap, DRI, HBI
- Hot metal as an additive
- Oxygen
- Burnt lime

Heat source:

Electrical Energy

Products:

- Crude steel
- Slag
- Exhaust gas

Composition of EAF Crude Molten Steel:

C = 0.04 ~ 0.1%; Mn = 0.1%

Si = 0.005%, P = 0.02%, S=0.015%

Figure 29. An Overview of EAF Production

(Source: fajarmuktiana, 2020)

4.5 A Comparison of Ambient Air Quality Standards between South Korea and Indonesia

PT Krakatau Posco, as a joint venture company between POSCO Korea and an Indonesian state-owned-enterprise, should have high environmental quality standards. South Korea is a developed country with high world-class environmental quality. However, in reality, there were times when the environmental measurement results were above the environmental quality standard. They were even above Indonesia's standard in ambient air, which is lower than South Korea's.

Below is a comparison table between Korea's ambient air quality standards (**AirKorea**) and Indonesia's (Government Regulation No. 22/2021, Appendix VII). The measurement unit follows the original source (Korea uses ppm, while Indonesia uses $\mu\text{g}/\text{m}^3$).

Table 16. Comparison of Ambient Air Standard Quality between Indonesia and South Korea

Parameter	Average Time	Korea (AirKorea)	Indonesia (Government Regulation No. 22/2021)
PM _{2.5}	24 hours	$\leq 35 \mu\text{g}/\text{m}^3$	$\leq 55 \mu\text{g}/\text{m}^3$
	1 year	$\leq 15 \mu\text{g}/\text{m}^3$	$\leq 15 \mu\text{g}/\text{m}^3$
PM ₁₀	24 hours	$\leq 100 \mu\text{g}/\text{m}^3$	$\leq 75 \mu\text{g}/\text{m}^3$
	1 year	$\leq 50 \mu\text{g}/\text{m}^3$	$\leq 40 \mu\text{g}/\text{m}^3$
O ₃	1 hour	$0.1 \text{ ppm} \times 1,963 = 196 \mu\text{g}/\text{m}^3$	$\leq 150 \mu\text{g}/\text{m}^3$
	8 hours	$0.06 \text{ ppm} \times 1,963 = 118 \mu\text{g}/\text{m}^3$	$\leq 100 \mu\text{g}/\text{m}^3$
	1 year	—	$\leq 35 \mu\text{g}/\text{m}^3$
NO ₂	1 hour	$0.1 \text{ ppm} \times 1,882 = 188 \mu\text{g}/\text{m}^3$	$\leq 200 \mu\text{g}/\text{m}^3$
	24 hours	$0.06 \text{ ppm} \times 1,882 = 113 \mu\text{g}/\text{m}^3$	$\leq 65 \mu\text{g}/\text{m}^3$
	1 year	$0.03 \text{ ppm} \times 1,882 = 56 \mu\text{g}/\text{m}^3$	$\leq 50 \mu\text{g}/\text{m}^3$
SO ₂	1 hour	$0.15 \text{ ppm} \times 2,616 = 392 \mu\text{g}/\text{m}^3$	$\leq 150 \mu\text{g}/\text{m}^3$
	24 hours	$0.05 \text{ ppm} \times 2,616 = 131 \mu\text{g}/\text{m}^3$	$\leq 75 \mu\text{g}/\text{m}^3$
	1 year	$0.02 \text{ ppm} \times 2,616 = 52 \mu\text{g}/\text{m}^3$	$\leq 45 \mu\text{g}/\text{m}^3$
CO	1 hour	$25 \text{ ppm} \times 1,145 = 28.625 \mu\text{g}/\text{m}^3$	$\leq 10,000 \mu\text{g}/\text{m}^3$
	8 hours	$9 \text{ ppm} \times 1,145 = 10.305 \mu\text{g}/\text{m}^3$	$\leq 4,000 \mu\text{g}/\text{m}^3$
Pb	1 year (KR)	$\leq 0.5 \mu\text{g}/\text{m}^3$	$\leq 2 \mu\text{g}/\text{m}^3$ (24 hours)
Benzena	1 year	$\leq 5 \mu\text{g}/\text{m}^3$	—
NMHC	—	—	$\leq 160 \mu\text{g}/\text{m}^3$ (3 hours)
TSP (<100 μm)	—	—	$\leq 230 \mu\text{g}/\text{m}^3$ (24 hours)

Compared to South Korea's ambient quality standards, three parameters were lower than those of Indonesia's, which were PM_{2.5} (24 hours), NO₂ (1 hour), and Pb.

After that, an analysis was conducted to determine whether the parameters exceeded the quality standards or not. The analysis was done during the [Analysis of Environmental Parameters of PT Krakatau Posco.xlsx](#).

After the analysis, several parameters were found to be near or exceed the ambient air quality standards of both Indonesia and South Korea, especially from 2019 to 2023. There were 4 (four) ambient air sampling points and 2 (locations) that exceed the standard in the analysis, which were Cigading and Kebanjiran, both in Tegal Ratu Village.

The highlighted parameters were TSP/Total Suspended Particulate, namely PM10, PM2.5, and PM100. Among these 3 parameters, some exceed Indonesia's and Korea's quality standards, some near Indonesia's and Korea's quality standards, and some only exceed Korea's quality standards. Air status when it exceeded the quality standards was considered moderate (9.1 - 35 µg/m³) and unhealthy (55 - 125 µg/m³).

Table 17. Results of the Residential Area's Ambient Air Quality Analysis, Cigading 1 Sample Point

No	Parameter	Indonesia's Quality Standards	Korea's Quality Standards	Unit	Cigading 1 (RT 18 RW 05 of Tegal Ratu Village)								
					2019-S1	2019-S2	2020-S1	2020-S2	2021-S1	2021-S2	2022-S1	2022-S2	2023-S1
1	Pm <100 µm (TSP)	230		µg/m ³	6	45	47	152	33	17	89	7	180
2	Pm <10 µm (TSP)	75	100	µg/m ³	4	30	30	99	26	3	29	5	37
3	Pm <2,5 µm (TSP)	55	35	µg/m ³	2	12	13	43	7	6	21	2	25
	Note:												
	Grey:	Exceeding Indonesia's quality standards & nearing Korea's quality standards											
	Blue:	Exceeding Korea's quality standards & nearing Indonesia's quality standards											

(Source: EIA of PT Krakatau Posco, 2025)

Table 18. Results of the Residential Area's Ambient Air Quality Analysis, Cigading 2 Sample Point

No	Parameter	Indonesia's Quality Standards	Korea's Quality Standards	Unit	Cigading 2 (RT 18 RW 05 of Tegal Ratu Village)								
					2019-S1	2019-S2	2020-S1	2020-S2	2021-S1	2021-S2	2022-S1	2022-S2	2023-S1
1	Pm <100 µm (TSP)	230		µg/m ³	9	46	30	164	192	20	122	9	136
2	Pm <10 µm (TSP)	75	100	µg/m ³	6	33	20	107	65	4	40	6	27
3	Pm <2,5 µm (TSP)	55	35	µg/m ³	3	11	8	46	29	11	29	2	16
	Note:												
	Purple:	Exceeding Indonesia's quality standards & exceeding Korea's quality standards											
	Yellow:	Nearing Indonesia's quality standards											
	Blue:	Exceeding Korea's quality standards & nearing Indonesia's quality standards											
	Green:	Nearing Korea's quality standards											

(Source: EIA of PT Krakatau Posco, 2025)

Table 19. Results of the Residential Area's Ambient Air Quality Analysis, Kebanjiran 1 Sample Point

No	Parameter	Indonesia's Quality Standards	Korea's Quality Standards	Unit	Kebanjiran 1 (RT 04 RW 02 of Kubang Faran/Tegal Ratu)								
					2019-S1	2019-S2	2020-S1	2020-S2	2021-S1	2021-S2	2022-S1	2022-S2	2023-S1
1	Pm <100 µm (TSP)	230		µg/m³	10	29	44	120	52	31	164	32	189
2	Pm <10 µm (TSP)	75	100	µg/m³	7	20	29	78	27	10	70	11	62
3	Pm <2,5 µm (TSP)	55	35	µg/m³	2	7	13	34	22	9	52	8	45
<i>Note:</i>													
	<i>Red:</i>	Exceeding Indonesia's quality standards											
	<i>Yellow:</i>	Nearing Indonesia's quality standards											
	<i>Green:</i>	Nearing Korea's quality standards											
	<i>Blue:</i>	Exceeding Korea's quality standards & nearing Indonesia's quality standards											

(Source: EIA of PT Krakatau Posco, 2025)

Table 20. Results of the Residential Area's Ambient Air Quality Analysis, Kebanjiran 2 Sample Point

No	Parameter	Indonesia's Quality Standards	Korea's Quality Standards	Unit	Kebanjiran 2 (RT01 RW01 of Alhidayah / Cigading)								
					2019-S1	2019-S2	2020-S1	2020-S2	2021-S1	2021-S2	2022-S1	2022-S2	2023-S1
1	Pm <100 µm (TSP)	230		µg/m³	4	22	99	225	75	35	129	30	189
2	Pm <10 µm (TSP)	75	100	µg/m³	2	14	65	32	46	19	64	10	62
3	Pm <2,5 µm (TSP)	55	35	µg/m³	1	8	28	43	24	8	36	7	45
<i>Keterangan:</i>													
	<i>Kuning :</i>	Mendekati BM Indonesia											
	<i>Hijau :</i>	Mendekati BM Korea											
	<i>Biru :</i>	Melebihi BM Korea & Mendekati BM Indonesia											

(Source: EIA of PT Krakatau Posco, 2025)

V. Recommendation

In realizing the steel industry's decarbonization, AEER offers recommendations in several aspects to reduce the environmental pollution and carbon emissions towards the Net Zero Emission (NZE), for the fossil-fueled steel industry like PT Krakatau Posco. They are:

1. The Aspect of Processes and Energy Resources

a. Technology transformation from BF-BOF to DRI-EAF/Scrap-EAF

Focusing on early prevention of carbon emission by replacing the carbon-based reductant in the Blast Furnace process to hydrogen in Direct Reduced Iron (DRI) technology. The iron produced in this reduction is then melted in the Electric Arc Furnace (EAF) to create steel. It has lower CO₂ emissions compared to the conventional process.

The usage of new and renewable energy as power source in the electric arc furnace will definitely decrease the carbon emissions by more than 95%, compared to the fossil-fueled BF-BOF. Moreover, the usage of green hydrogen (which also comes and is created by EBT) in iron ore reduction will also lower carbon emissions from the steel industry.

b. Material and fuel replacement for the processes

Dangerous materials and fossil fuels should be replaced immediately with cleaner and more sustainable ones. Decarbonization in the steel industry needs to replace fossil fuels with renewable energy sources, such as solar and wind. Moreover, the use of hazardous materials, such as dolomite, quartz sand, limestone, and flux materials/materials containing dangerous substances, should immediately be replaced with more environmentally friendly or recyclable ones.

2. The Aspect of Policy and Governance

a. Enhancement and Enforcement of Circular Regulation of Scrap Steel

Steel scrap is going to be an important material in steel decarbonization. It will also lessen iron mining intensity and will increase the circular economy in the national steel supply chain. Thus, regulations in the management/material reuse, such as steel scrap, and enhancement in supervision are needed to avoid radioactive contamination or embezzlement/stockpiling of scraps by the collector which will hinder the management circulation in Indonesia.

b. Regulation Drafting of Industrial Decarbonization

Decarbonization should be based on real regulation, such as a decarbonization road map, that should be legislated as a government regulation and obeyed by the whole industry. Also, decarbonization efforts must also address the fossil-fueled steel plant moratorium so that it will not place a burden on the upcoming NZE in 2050 for the industry.

c. Carbon Border Establishment to Protect Indonesia's Steel Products in Domestic and Global Markets

The steel oversupply from China, which is projected to increase by 750 million globally, has decreased the competitiveness of the national steel industry due to its low price but high carbon footprint. If it continues, Indonesia's steel industry will be weakened. Decarbonization rate will also become slower with the usage of high-carbon but low-cost technology like the blast furnace (to counterbalance the low-cost steel products from China). Therefore, carbon protection is needed for steel products in Indonesia to overcome the imported steel products from China. This is also to avoid mass dumping.

d. Buffer Zone Development around the Industrial Park

Simply put, a buffer zone is an area chosen to separate the industry operations from other land uses. It is aimed to provide a transition and minimize the negative effects of the industry on its surrounding area. This is crucial for pollution mitigation, ecological protection, and the health and well-being of the community.

The ideal distance between industry and residential area is 2 (two) kilometers at a minimum, based on Regulation of the Minister of Industry of the Republic of Indonesia Number 35 of 2010 on the Technical Guidelines on the Industrial Park. However, in the case of PT Krakatau Posco, there are residents who live within the radius of 100 - 500 meters from the industrial areas. This will increase the potential for pollutant exposure and environmental contamination due to its very short distance. If the industry fails to find an alternative for more environmentally friendly materials and fuels, the residents should be relocated with a safe buffer zone in between to lessen the risk of disease exposure due to environmental contamination.

3. Social Aspect

a. Regular medical checkups for the impacted community

The government and the industry have to be more active and vigilant in monitoring environmental quality. If the quality standard is exceeded, a suitable mitigation can be done.

b. Audience and socialization of company events, whether an expansion or processes that may harm the people and the environment

The steel industry should be more communicative and transparent in informing the processes that are potentially harming the community, such as the BF shutdown. An industrial expansion should also involve the surrounding community. This is important so the residents can adapt and prepare themselves based on the information.

c. The transition of steel industry workers from fossil to renewable energy

The decarbonization process in the future should be supported by improved worker capacity. Companies should be ready to move to a greener industry, whether from an industry perspective or the resources. It can be done by providing reskilling or knowledge enrichment for the steel industry's workers.



VI. Conclusion

Steel processing technology by the BF-BOF route used at PT Krakatau Posco has a significant impact on the environment, whether environmental pollution or greenhouse gas emissions. This is due to the process method and the materials being used. After being examined, the materials used contain dangerous substances and pollutants, which are released as the industry's byproducts. These byproducts spread along Tegal Ratu Village, and some other villages around it, which is located very near the plants (<500 meters), risking long-term chronic diseases due to the accumulated industrial processes. Materials such as quartz sand, silica, and coke contain carbon and release CO₂ emissions, but also include dangerous pollutants.

In detail, sintering, coke oven plant, and blast furnace processes become the hotspot of decarbonization, whether for carbon emission, or air pollutant exposure. These three processes rely on fossil fuels and inorganic materials containing toxic substances for the body. The cleaning process of the blast furnace generates a very loud noise. It also disperses dust and fine particles, which are believed to be silica and PM2.5. It becomes a huge concern for the Tegal Ratu residents.

Based on the questionnaire results, Tegal Ratu residents claim to have a weaker immunity, resulting in the health problems they suffered, such as cough, runny nose, itching, and shortness of breath. Those problems are suspected to be the result of pollutant exposure as the number of industries in their area increased. Some of them also mention the history of respiratory health problems, such as ARI, over the past year.

Environmental damages by industrial activities, such as air, water, and land pollution can cause a huge impact should they be compounded. As a result, the resident's quality of life decreases, leading to their weaker immunity which causes them to be prone to illness. It indirectly violates the 1945 Constitution of the Republic of Indonesia, Article 28H, paragraph (1), stating that every citizen is entitled to have a proper and healthy environment. Ignoring environmental damages until they exceed natural capacity limits means violating citizen's constitutional rights.

Therefore, the government must urge companies to promptly implement the decarbonization and green practices. This is due to the increasingly severe climate crisis, green competitiveness among industries including green steel, carbon steel import restrictions, as well as public and environmental health, both locally and globally.



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The current climate crisis is one of the greatest challenges facing humanity. Human activities such as the burning of fossil fuels and deforestation have increased the concentration of greenhouse gases (GHGs) in the atmosphere. The higher the accumulation of GHG emissions, especially carbon dioxide (CO₂), the stronger the greenhouse effect, leading to a significant increase in global temperatures. This temperature increase poses serious threats to ecosystems and socio-economic stability, ranging from increased frequency of natural disasters to health risks due to heat waves and air pollution.

Industry is a key contributor to national GHG emissions. Based on data from the Ministry of Environment and Forestry, total national GHG emissions reached 1.36 billion tons of CO₂e in 2023. Of this, 34% of national emissions originated from industrial activities, amounting to 59.85 million tons of CO₂e. A total of 36% of these industrial emissions came from 9 of the most energy-intensive sectors, namely the steel, cement, iron and steel, chemical, fertilizer, pulp and paper, textile, glass and ceramics, food and beverage, and automotive industries. On one hand, industry acts as a driver of the national economy, contributing 18.9% to national GDP, employing 19.3 million workers, and attracting Rp 80.5 trillion in foreign direct investment (FDI) or 52.3% of the national total in 2022. Therefore, mitigating the climate crisis is a challenge, but also an opportunity not only for the industry but also for Indonesia nationally (Ministry of Industry, 2025).

The steel industry is emission-intensive but also energy-intensive, making it a hard-to-abate industry. Steel production accounts for 10% of global greenhouse gas emissions (Worldsteel, 2025). Nationally, 75% of the national steel industry still uses Blast Furnace - Blast Oxygen Furnace (BF-BOF) technology, which has high emissions, up to 2.2 tons of CO₂eq per ton of steel. This technology still relies on fossil fuels such as coking coal for combustion, resulting in high emissions and causing air pollution in the surrounding areas.

Another technology, the electric arc furnace (EAF), which is electricity-based, produces lower emissions, reaching 0.5 tons of CO₂eq per ton of steel. However, its use in Indonesia is still very low, only 25%. Unfortunately, future development plans based on the Global Steel Plant Tracker (GSPT) show that BF-BOF technology will continue to dominate, with projections indicating that this technology will account for 75% of the country's steel production capacity. This will trigger a dependence on fossil fuels, hindering the energy transition process and exacerbating the climate crisis. On the other hand, residents living near steel plants have to bear the negative impacts. The dust and fine particles produced not only pollute the air but also endanger public health.



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