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Net-Zero Roadmap for Indonesia's Steel Industry

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Executive Summary

Key Takeaways

- The main decarbonization lever to get to Net Zero by 2060 in Indonesia's steel industry is a technology shift to low-carbon production routes, primarily scrap-based Electric Arc Furnaces and green hydrogen-based Direct Reduced Iron (H_2-DRI).
- Green H_2-DRI will be essential for achieving Net Zero but will require major hydrogen cost reductions and infrastructure investments. (It is assumed to represent only 10% of total domestic steel production in 2060.)
- While green steel production using H_2-DRI in Indonesia may carry a large cost premium per ton of steel, the impact on end products is modest, adding about $300 per passenger car or $830 per 50 m^2 residential building unit (assuming a hydrogen price of $5/kg H_2).
- Green iron imports will play an important role in complementing domestic decarbonization efforts, but they account for less than 15% of total emissions reductions in 2060
- CCUS is not a major driver of the Net Zero pathway and contributes relatively little to total emissions reductions in Indonesia's steel industry by 2060

Indonesia has pledged to achieve net-zero greenhouse gas (GHG) emissions by 2060. To meet this target, the steel sector, a major source of industrial emissions in Indonesia, must see its emissions peak and begin to decline. With the dominance of carbon-intensive blast furnace-basic oxygen furnace (BF-BOF) steelmaking and continued investment in new BF capacity, decarbonizing Indonesia's steel sector will be particularly challenging. This report provides an overview of steel production, energy use, and emissions trends in Indonesia and presents a data-driven roadmap for deep decarbonization through to 2060. It evaluates multiple technology and policy pathways through scenario analysis and outlines key milestones for 2030, 2040, 2050, and 2060. The report concludes with actionable policy recommendations for the Indonesian government, steel producers, consumers, and other relevant stakeholders.

While Indonesia produces a relatively small share of the world's total steel, it is the second-largest steel producer in Southeast Asia, the 4th largest exporter of steel globally by value, and the 14th largest steel producing country in the world, with production expected to grow rapidly (IBAI 2024). In 2023, Indonesia's crude steel production reached nearly 17 million tons (Mt) and this is expected to grow to up to 60 Mt per year in 2060. The steel industry plays a critical role in Indonesia's economic development, supporting key sectors such as construction, automotive manufacturing, and infrastructure while contributing to industrial growth and job creation across the country.

This Net-Zero Roadmap for Indonesia's Steel Industry ('Roadmap') describes the current status of Indonesia's steel industry and outlines four future industry development scenarios: Business-as-Usual (BAU), Moderate, Advanced, and Net-Zero, looking at the impacts of these scenarios through to 2060.

The analysis applies five core decarbonization pillars:

1) material efficiency and demand management
2) energy efficiency and electrification of heating
3) fuel switching and cleaner electricity
4) transitioning to low-carbon iron and steelmaking technologies, and
5) carbon capture, utilization, and storage (CCUS).

Under the Net Zero scenario, the steel industry's emissions in Indonesia would be lower by 86% compared to 2023 levels, and by 94% compared to the projected emissions under the BAU scenario in 2060. This outcome is driven by slower growth in crude steel production due to material efficiency and steel demand management in the country, as well as high adoption of low-carbon steelmaking technologies. The Net Zero scenario also incorporates greater deployment of CCUS and energy efficiency improvements relative to other scenarios. In contrast, under the BAU scenario, emissions continue to rise due to growing steel production and limited technological transition.

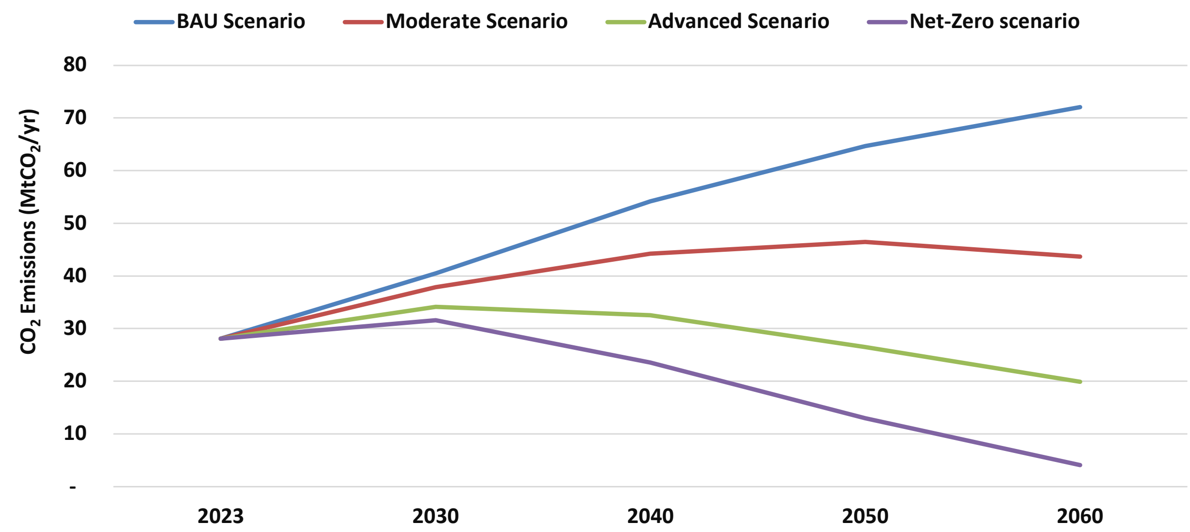

Figure ES1: Total annual CO_2 emissions in the steel industry in Indonesia under four decarbonization scenarios, 2023-2060 (Source: this study)

Each decarbonization pillar plays a distinct role. Under the Net Zero scenario, the pillar for transitioning to low-carbon iron and steel-making technologies delivers the greatest share of emissions reductions relative to BAU, primarily through the adoption of scrap-based EAFs, NG-DRI-EAF, green H_2-DRI-EAF, and iron ore electrolysis. Material efficiency and demand management, energy efficiency and electrification of heating, and fuel switching and cleaner electricity each make similar, moderate contributions, while CCUS plays a smaller role for steel industry decarbonization. We also assumed that Indonesia would import a small amount of green iron produced by green H_2-DRI, which is then used in EAFs to produce steel.

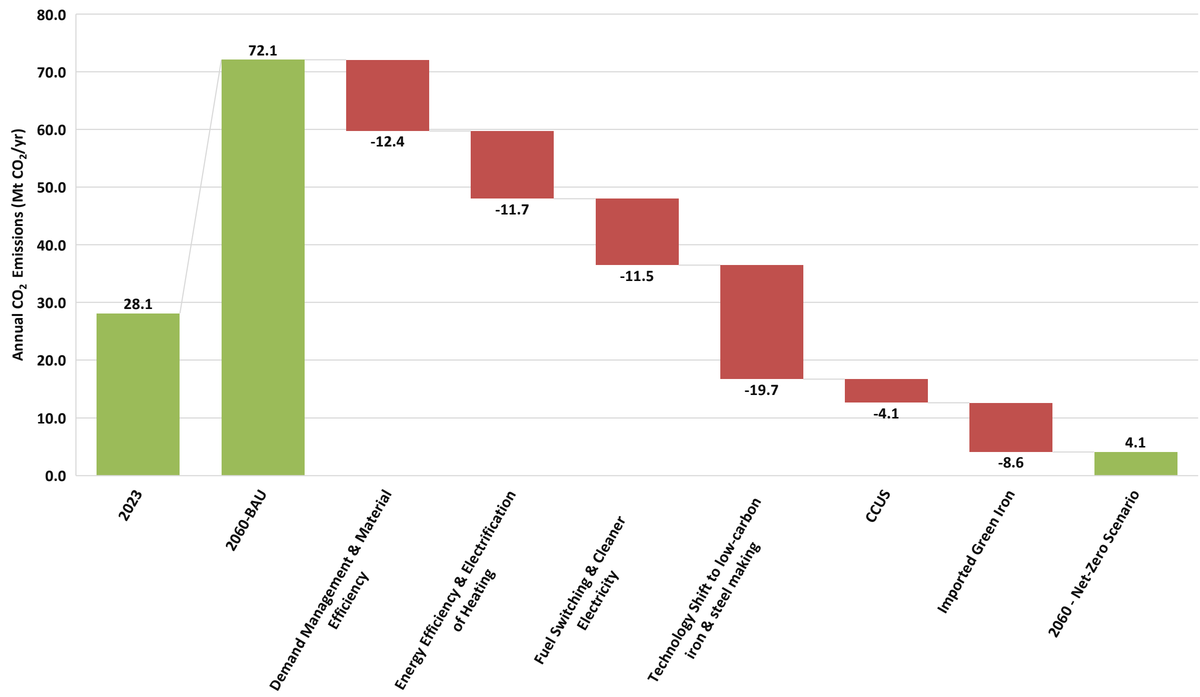

Figure ES2. Impact of each decarbonization pillar on CO_2 emissions of Indonesia's steel industry, Net Zero scenario relative to BAU (Source: this study)

The Roadmap shows the contribution required of each pillar over time to bring the BAU scenario's emissions down to Net Zero levels (Figure ES3). The area of the graph that shows each pillar in different colors shows the cumulative contribution of each decarbonization pillar to the total decarbonization of the steel industry in Indonesia from 2023 to 2060. While material efficiency/demand management, energy efficiency/electrification of heating, and fuel switching/cleaner electricity play a large role between the base year and 2030, from 2030 onwards, the technology shift to low-carbon iron and steelmaking pillar plays the largest role. CCUS and imported green iron are each expected to play a small role with adoption starting in 2030s.

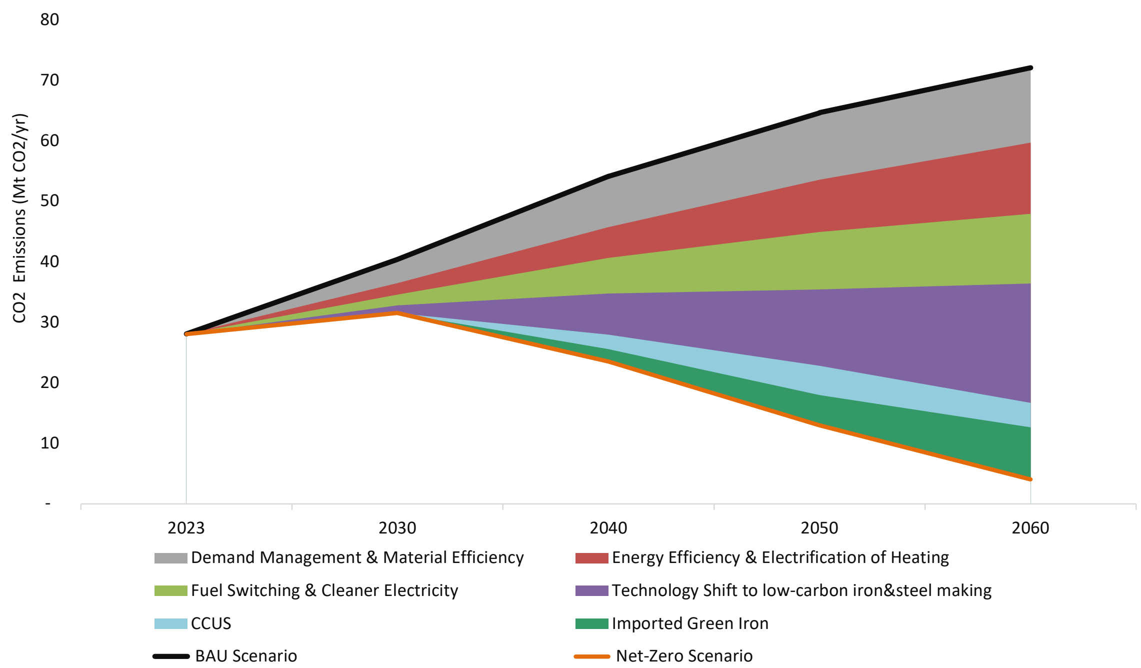

Figure ES3. Impact of decarbonization pillars on CO_2 emissions of Indonesia's steel industry to bring BAU emissions down to the Net Zero scenario's level (Source: this study)

The Roadmap considers the economic feasibility of the lower-carbon scrap-EAF, green H_2-DRI-EAF, and NG-DRI-EAF steel production routes, relative to BF-BOF. Our analysis shows that scrap-based EAF steelmaking in Indonesia is generally more cost-competitive than BF-BOF, even without carbon pricing. The cost structure for EAF is dominated by scrap costs, which make up around 75% of the total Levelized Cost of Steel (LCOS), making scrap supply stability critical for sustaining competitiveness.

Green H_2-DRI-EAF offers up to 97% CO_2 emissions reductions compared with the BF-BOF pathway. We project that green H_2-DRI-EAF will be more expensive than BF-BOF even at a hydrogen price of $1/kg under current input material costs, especially coal and coke prices. However, the gap is expected to narrow as hydrogen costs decline with technological advancement and policy support. In addition, a decrease in the price of coking and thermal coal in the past two years has made BF-BOF production cheaper. Despite this, our analysis finds that while Indonesia faces higher costs for green steel per ton of steel initially due to less mature hydrogen infrastructure, the green premium at the final product level remains small: around $300 per passenger car and $830 per residential building unit (50 m^2), suggesting that green steel adoption would have minimal impact on end-user affordability. Furthermore, carbon pricing mechanisms and long-term reductions in hydrogen costs would make green H_2-DRI-EAF more competitive (Figure ES4).

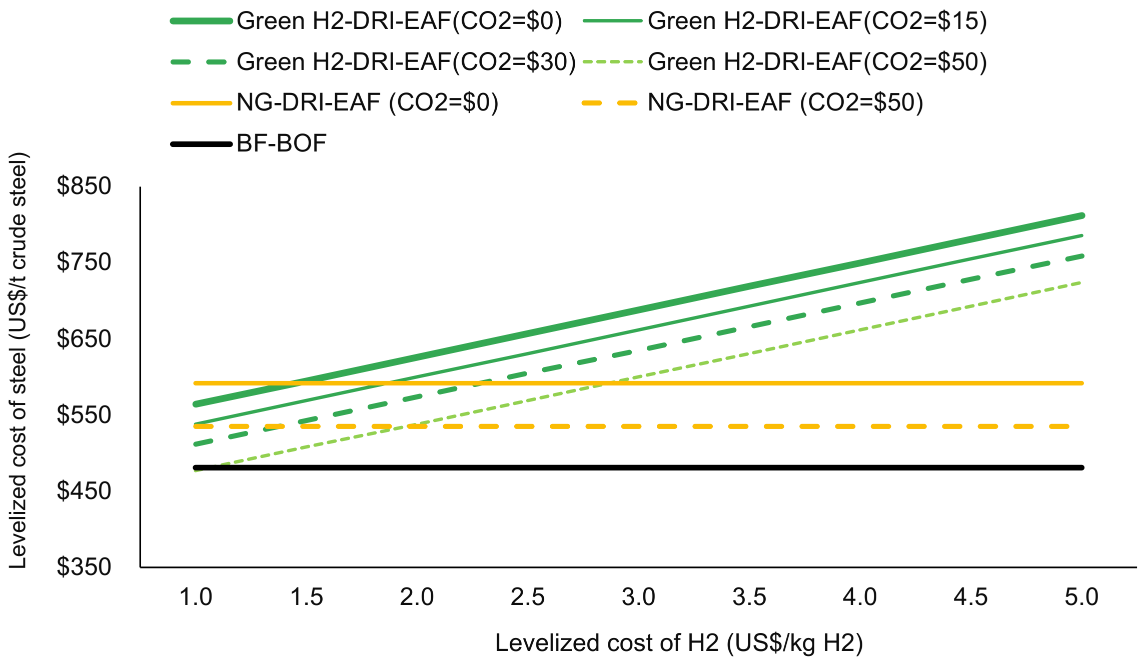

Figure ES4. Levelized Cost of Steel ($/t crude steel) with varied levelized costs of green H_2 at different carbon prices in Indonesia (Source: this study)

Notes: Assumed 5% steel scrap is assumed to be used in both BF-BOF and DRI route. For this analysis, it is assumed that carbon pricing will be applied in the form of credits or allowances for green H2-DRI-EAF plants. Eligible plants would receive carbon credits based on the reduction of their carbon intensity relative to the benchmark set by BF-BOF operations, which can then be traded on the carbon market.

This Roadmap shows that achieving the Net Zero GHG emissions in Indonesia's iron and steel sector requires unprecedented deployment of low-carbon solutions and coordinated action. It presents an action plan tailored to Indonesia's context, detailing what the government, steel producers, consumers, and supporting industries must do to enable this transformation.

Summary of recommendations

Enhancing Material Efficiency and Demand Management:

In the near term (2025–2030), efforts to enhance material efficiency should focus on issuing national guidelines to optimize steel use in construction, integrating material efficiency criteria into public procurement processes to reward reduced steel usage, and running widespread awareness campaigns to promote efficient design practices among architects, engineers, and manufacturers. Steel producers should conduct comprehensive assessments of their production lines to identify material waste and improve yields, develop high-strength lightweight steel grades to reduce steel consumption in end-use applications, and set internal targets for material efficiency to institutionalize best practices across their operations.

For the medium term (2030–2040), Government of Indonesia should establish mandatory material intensity reduction targets for key steel-consuming sectors, update infrastructure design standards to explicitly require material-efficient practices in public projects, and promote industrial symbiosis programs to increase scrap reuse across sectors. Steelmakers should adopt advanced digital tools for real-time yield monitoring to continuously reduce offcuts and waste, and engage in cross-sector industrial networks to exchange scrap and by-products with other industries, maximizing resource efficiency and lowering primary steel demand.

Enhancing Energy Efficiency and Electrification of Heating:

In the near term, the government should mandate plant-wide comprehensive energy audits to establish efficiency baselines, expand support for waste heat recovery systems to capture and reuse heat from steel processes, and develop a guideline for electrifying low- and medium-temperature heating. Steel companies should implement quick-win measures like sealing furnace leaks and upgrading combustion controls, invest in waste heat recovery equipment, and replace outdated burners with modern, high-efficiency models to cut energy use and emissions.

By the medium term, steel companies should adoption of real-time energy monitoring systems in large steel facilities to drive continuous improvement. Steelmakers should electrify rolling mills and finishing lines using clean power sources, adopt AI-enabled energy management systems for optimizing furnace operations, and transition high-impact processes like ladle preheating to electric heating, cutting fossil fuel reliance and emissions.

Enhancing Fuel Switching and Cleaner Electricity:

In the near term, policies should ensure the steel industry's renewable electricity needs are included in power sector expansion plans, establish a clear regulatory framework for corporate renewable PPAs, and streamline processes to make corporate procurement of renewables easier. Steel companies should carry out plant-level feasibility studies for switching from coal to cleaner fuels like natural gas (in the near term as a transition fuel), sign long-term renewable PPAs to secure stable clean energy, and retrofit combustion systems to prepare for future fuel transitions.

For the medium term, the government should require industrial consumers like steel plants to source a growing share of their electricity from renewables, reform tariff structures to incentivize off-peak clean energy use, and modernize the grid and transmission infrastructure with expanded renewable generation to ensure steel producers can access low-carbon power. Establishing a national task force on industrial fuel switching and building on-site hydrogen storage and distribution systems at steel plants will be essential, along with steelmakers committing to science-based emissions reduction targets including clear milestones for switching to cleaner energy.

Transitioning to Low-Carbon Iron and Steelmaking Technologies:

In the near term, the government should restrict new blast furnace approvals, strengthen scrap collection and quality standards to secure high-quality feedstock for EAFs, and provide financial incentives for upgrading or building EAF and DRI facilities. Other critical actions include developing green hydrogen production hubs linked to steel regions, publishing national guidelines for hydrogen-ready DRI plants, and planning for pilot programs to demonstrate low-carbon steel technologies such as H_2-DRI.

For the medium term, the government should plan for a gradual phase-out of high-emission BF-BOF lines beyond set CO_2 benchmarks, support commercial pilot plants for H_2-DRI, promote green iron imports as part of a diversified low-carbon supply strategy, and integrate renewable power directly into EAF operations through infrastructure upgrades and market reforms. Establishing certification systems for green steel and carbon credits are also essential.

Adopting Carbon Capture, Utilization, and Storage (CCUS):

In the near term, the government should publish a national CCUS roadmap with steel-specific priorities, establish clear legal and regulatory frameworks for ownership, liability, and permitting of CO_2 capture and storage, and conduct geological surveys to confirm suitable storage sites. Funding early CCUS pilots in steel plants and having companies perform feasibility studies for implementing capture technologies will build experience and reduce technology risks, while engaging with technology providers will help steelmakers identify optimal capture solutions for their facilities.

In the medium term, efforts should focus on building shared CO_2 transport and storage infrastructure to lower deployment costs and enable CCUS access for multiple emitters. Creating incentives for CO_2 utilization in commercial applications like construction materials or fuels will help offset capture costs, while promoting international cooperation with experienced countries can secure technology transfer and concessional financing. Steel companies should move to full-scale CCUS installations, partner with industrial peers for shared infrastructure, and pilot projects to convert captured CO_2 into valuable products.

Recommendations for Steel Consumers

In the near term, public procurement should mandate the inclusion of Environmental Product Declarations (EPDs) or carbon footprints in tenders, rewarding low-carbon steel producers, while large private buyers should adopt green procurement guidelines favoring suppliers with verified emissions data. Key steel consumers should issue forward-looking purchasing commitments for green steel, sending clear demand signals to steel producers to invest in cleaner technologies.

In the medium term, expanding green public procurement to major infrastructure projects will drive predictable demand for low-carbon steel, and procurement guidelines should incentivize suppliers that exceed sustainability criteria. Coordinating buyer alliances and green steel clubs can aggregate demand for low-carbon steel, while promoting indirect demand signals such as specifying green steel in building codes or investor disclosures will reinforce the market shift towards sustainable steel.

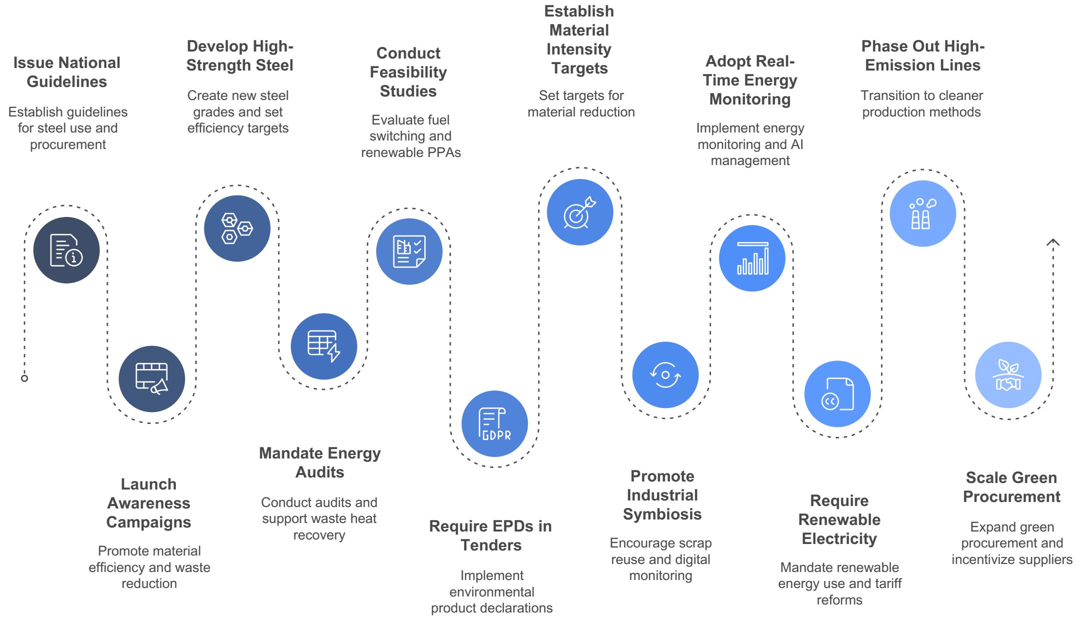

Figure ES5. Examples of recommendations for decarbonizing the steel industry in Indonesia

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1 Introduction

Iron and steel manufacturing is one of the most energy- and carbon-intensive industrial sectors worldwide. The sector's dependence on coal and other fossil fuels makes it one of the largest contributors to industrial CO_2 emissions. Globally, the iron and steel industry is responsible for more than 11% of total CO_2 emissions and about one-quarter of greenhouse gas (GHG) emissions from the manufacturing sector (IEA 2025; Hasanbeigi 2022).

As global steel demand is expected to increase from 1,884 Mt in 2024 to as much as 2,500 Mt by 2050 (IEA 2020), the sector faces mounting pressure to decarbonize or risk a significant rise in emissions. While the Indonesian steel industry accounts for less than 1% of global output, it is undergoing rapid expansion. Between 2014 and 2024, Indonesia's crude steel production quadrupled, reaching nearly 18 Mt annually. This growth has positioned Indonesia as the second-largest steel producer in Southeast Asia and the 14^{th} largest steel-producing country globally.

Steel can be produced through three primary routes: the BF-BOF route, the DRI-EAF route, and the scrap-based EAF (scrap-EAF) route. In the first two methods, iron ore is chemically reduced into iron before being refined into steel. The scrap-EAF route, by contrast, skips the reduction step and melts recycled scrap directly into new steel. Globally, around 70% of crude steel production is through the BF-BOF route, with the remaining 30% produced via EAFs (worldsteel 2024a).

Approximately 32% of Indonesia's 2023 steel production used the scrap-EAF pathway with 68% still relying on BF-BOF technology. BFs can operate for 40+ years so the addition of new unabated BF capacity would lock in high emissions for decades,, posing a challenge to achieving net zero steel sector emissions by 2050 or even 2060.

Indonesia has committed to achieving net-zero GHG emissions by 2060. In support of this goal, policymakers and industry leaders have begun to explore opportunities to transition to lower emissions steel production, given the sector's current emissions and forecast emissions under a BAU growth trajectory. Lower-carbon steelmaking opportunities, include scaling up scrap recycling, improving energy efficiency, and investing in breakthrough technologies such as hydrogen-based direct reduced iron (H_2-DRI) used in combination with EAFs. Green hydrogen produced via electrolysis using renewable electricity offers a pathway to near-zero emissions steel and is currently being deployed in several pilot and demonstration scale steel production projects globally (See Section 5.4.).

To highlight the significant emissions benefits of adopting lower carbon steelmaking methods, Figure 1 shows the CO_2 intensity of a typical new primary steel production plant in Indonesia for key production routes. In Indonesia, a new BF-BOF plant produces approximately 1.9 tons of CO_2 per ton of crude steel, not including emissions from rolling and finishing processes. A new NG-DRI-EAF plant using conventional grid electricity can cut emissions to about 1.0 ton of CO_2 per ton of steel, a 46% reduction compared to BF-BOF. If the NG-DRI-EAF route is powered entirely by renewable electricity, emissions can be reduced further to around 0.66 tons CO_2 per ton, achieving a 64% cut relative to BF-BOF. The green H_2-DRI-EAF route offers the most substantial emissions reduction: using 100% green hydrogen slashes CO_2 emissions to less than 0.1 tons CO_2 per ton of steel, a 94% reduction compared to grid-powered NG-

DRI-EAF and a 97% reduction compared to traditional BF-BOF steel. Although CO_2 intensities will vary somewhat across countries, the trend remains clear: increasing the share of green hydrogen within the H_2-DRI-EAF process offers a powerful pathway to decarbonize steel production.

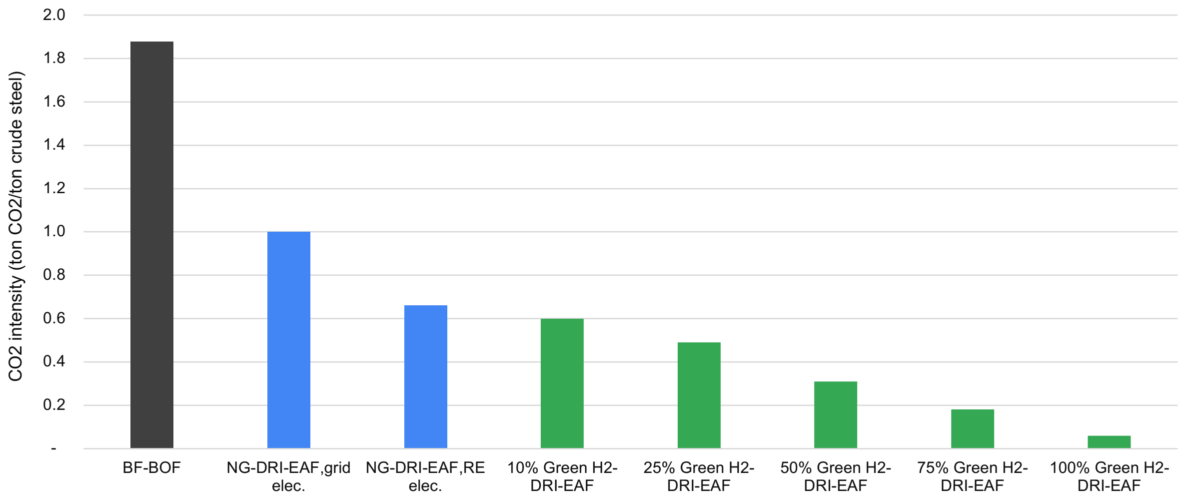


Figure 1. The CO_2 intensity of different new primary crude steel production plants in Indonesia (Source: this study)

Note: this is for crude steel production and does not including rolling and finishing.

This report provides a comprehensive overview of steel production, energy use, and emissions trends in Indonesia and presents a data-driven roadmap for deep decarbonization through to 2060. It evaluates multiple technology and policy pathways through scenario analysis and outlines key milestones for 2030, 2040, 2050, and 2060. The report concludes with actionable policy recommendations for the Indonesian government, steel producers, consumers, and other relevant stakeholders.

2 Indonesia's Steel Industry: Production, Consumption, and Trade

Steel production and consumption
Indonesia is currently the world's 14th-largest steel producer (worldsteel 2024b), and the second-largest steel producer in the Southeast Asia region (SEAISI 2025). Crude steel production in Indonesia has increased steadily over time, with a sharp increase from 2019 onwards as the Dexin Steel plant was commissioned (annual crude steel production capacity of 7 Mt per year) and Indonesia increased its capacity utilization rate (GEM 2025). In 2024, Indonesia's crude steel production levels reached 18 Mt, up from 7.8 Mt in 2019. Production of finished steel products has also increased over time, with the vast majority of finished steel products in the form of hot-rolled products (Figure 2).

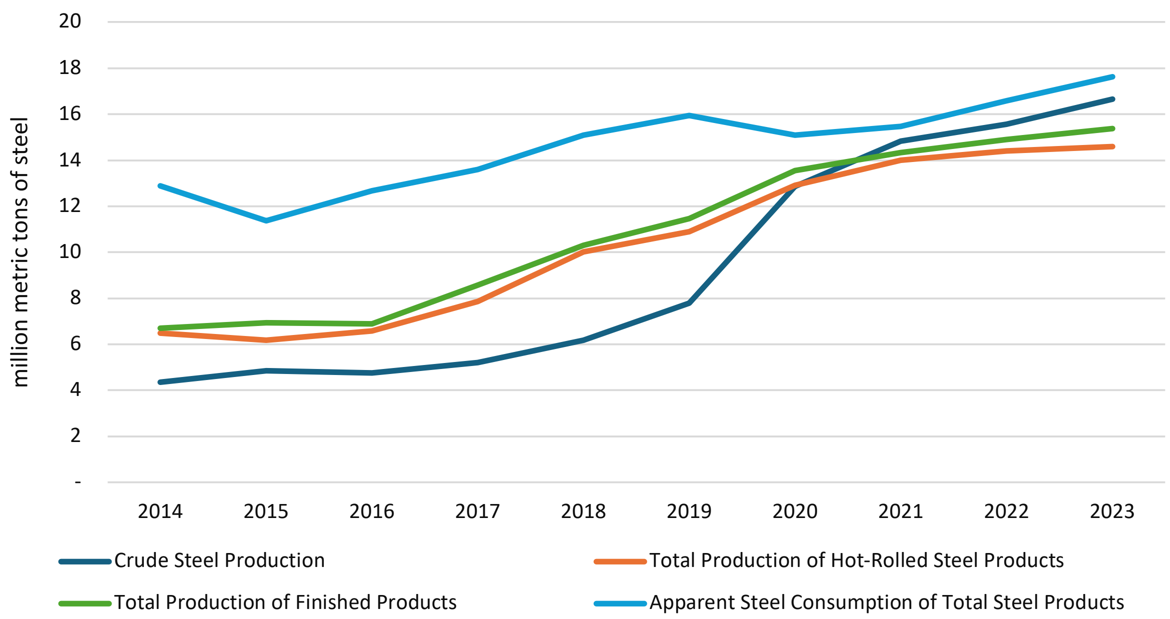


Figure 2: Steel production and consumption in Indonesia, 2014-2023 (Source: SEAISI 2024)

Consistent with the global contribution of the BF-BOF route compared with scrap -EAF, the BF-BOF route accounts for approximately 68% of Indonesia's operational steel production capacity. The EAF route constitutes 32%, primarily relying on imported scrap and grid electricity, which is still largely coal-powered (Swastika and Hasan 2024).

Table 1 below lists Indonesia's operational iron and steel plants. Indonesia's largest steel companies by production capacity are PT Dexin Steel Indonesia and PT Krakatau POSCO, both of which are joint ventures with foreign partners (China's Delong Group and South Korea's POSCO, respectively). There are also large domestic state-owned enterprises, like PT Krakatau Steel and PT Gunung Raja Paksi Tbk. Downstream producers include PT Steel Pipe Industry of Indonesia Tbk and PT Gunawan Dianjaya Steel Tbk, which focus on pipes and plates for construction and infrastructure.

Table 1: Currently operating iron and steel plants in Indonesia (Source: GEM 2025, Adhinegara et al. 2025)

Plant	Year of Commission	Production Route	Estimated Capacity (Mt per annum)	Location
PT Mandan Steel Plant	2014	BF-BOF	1 mtpa (crude steel) 1 mtpa (iron)	South Kalimantan
Dexin Steel Morowali Plant	2020	BF-BOF, DRI-BOF	6.5 mtpa (crude steel) 4.5 mtpa (iron)	Central Sulawesi
Gunung Raja Paksi Steel plant	1986	BF-BOF, DRI-EAF	2.8 mtpa (crude steel) 2 mtpa (iron)	West Java
Jakarta Prima Steel Plant	1972	EAF	0.9 mtpa (crude steel)	Jakarta
Krakatau Steel Cilegon Plant	1977	BF-BOF, EAF	4 mtpa (crude steel) 2.6 mtpa (iron)	Banten
Krakatau POSCO Plant	2013	BF-BOF	3 mtpa (crude steel) 3 mtpa (iron)	Banten
Master Steel Plant	1972	EAF	1.5 mtpa (crude steel)	Jakarta

Note: Some plants have two steel production routes at the same plant.

As Table 1 shows, Indonesia has several older BF-BOF and EAF plants, and several newer BF-BOF plants (e.g. Krakatau POSCO, PT Mandan Steel, and the Dexin Steel Morowali plants). Given that BF-BOF plants typically operate for over 40-50 years, these newer plants represent a significant challenge to decarbonization of Indonesia's steel industry (see Section 5.1. for further discussion on planned steel plants in Indonesia).

Steel consumption in Indonesia, as measured by apparent steel consumption of steel products, has historically been higher than steel production levels, although the gap has nearly closed. Indonesia's steel consumption is predominantly driven by the construction sector, which accounts for approximately 78% of total steel use, including infrastructure (around 40%) and building construction (around 38%) (SEAISI 2022). Other steel-consuming sectors include automotives, oil and gas infrastructure, machinery, and appliances.

Indonesia's steel trade

Indonesia's steel trade has evolved significantly over the past decade, reflecting the country's expanding domestic production. Imports of steel have remained relatively constant, reaching around 12 million metric tons (Mt) by 2023 for semi-finished and finished steel products (Figure 3).

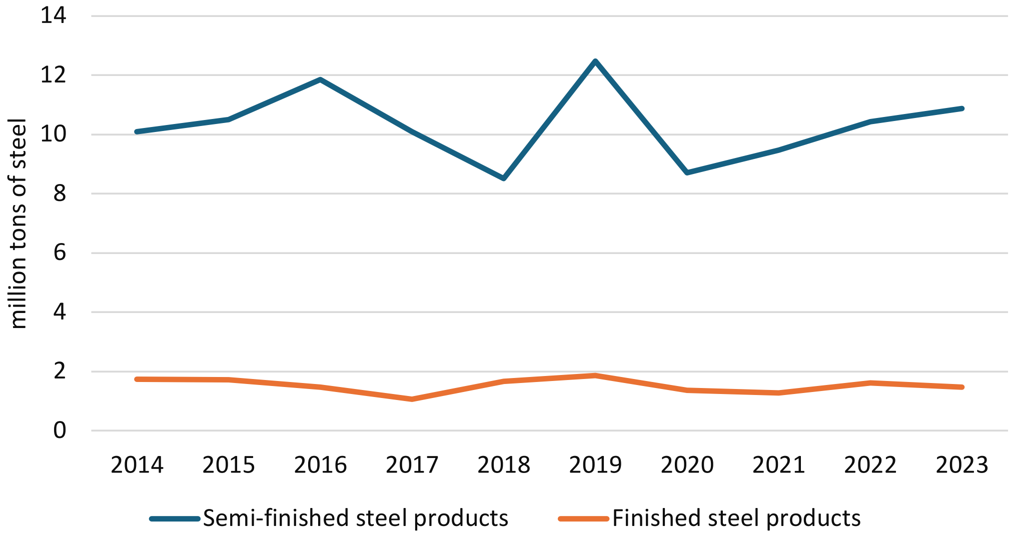


Figure 3: Imports of semi-finished and finished steel products in Indonesia, 2014-2023 (Source: UN Comtrade 2025)
*Note: We extracted UN Comtrade data on HS code 72 for crude and semi-finished steel, excluding pig iron, ferroalloys, direct reduced iron, and ferrous waste; and HS code 73 for finished steel products.

In contrast, exports of semi-finished steel products grew surged sharply from 2014 onward, rising from around 1 Mt in 2014 to 9 Mt by 2021, and remaining relatively constant since then. These trade trends align closely with domestic production developments discussed earlier, with domestic production increasing sharply in 2019. Nevertheless, Indonesia is still a net importer of steel.

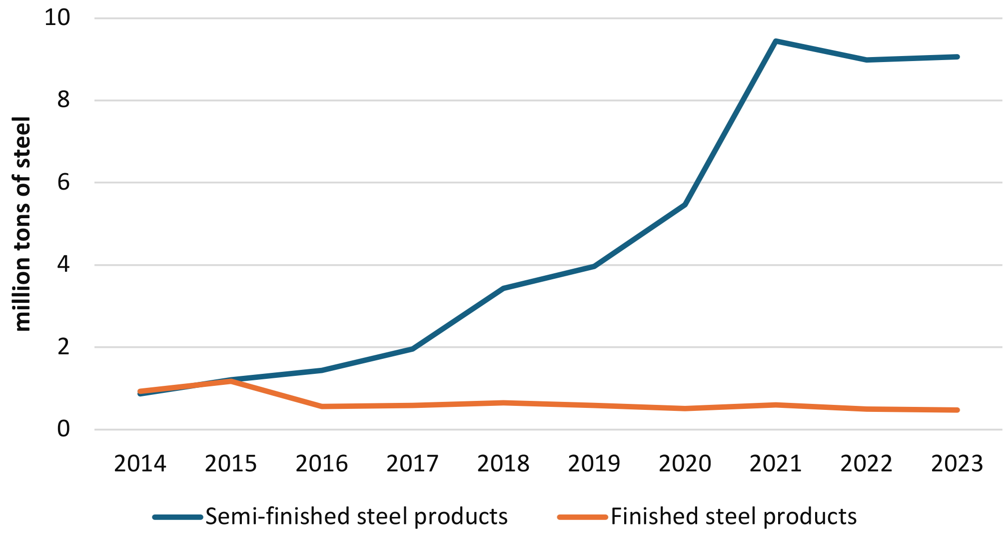


Figure 4: Exports of semi-finished and finished steel products in Indonesia, 2014-2023 (Source: UN Comtrade 2025)
*Note: We extracted UN Comtrade data on HS code 72 for crude and semi-finished steel, excluding pig iron, ferroalloys, direct reduced iron, and ferrous waste; and HS code 73 for finished steel products.

In 2023, Indonesia's steel trade was marked by a heavy reliance on imports of semi-finished and finished steel products from China and Japan. Oman was also a major source of semi-finished steel, while Germany supplied a significant amount of finished steel products (Figure 5).

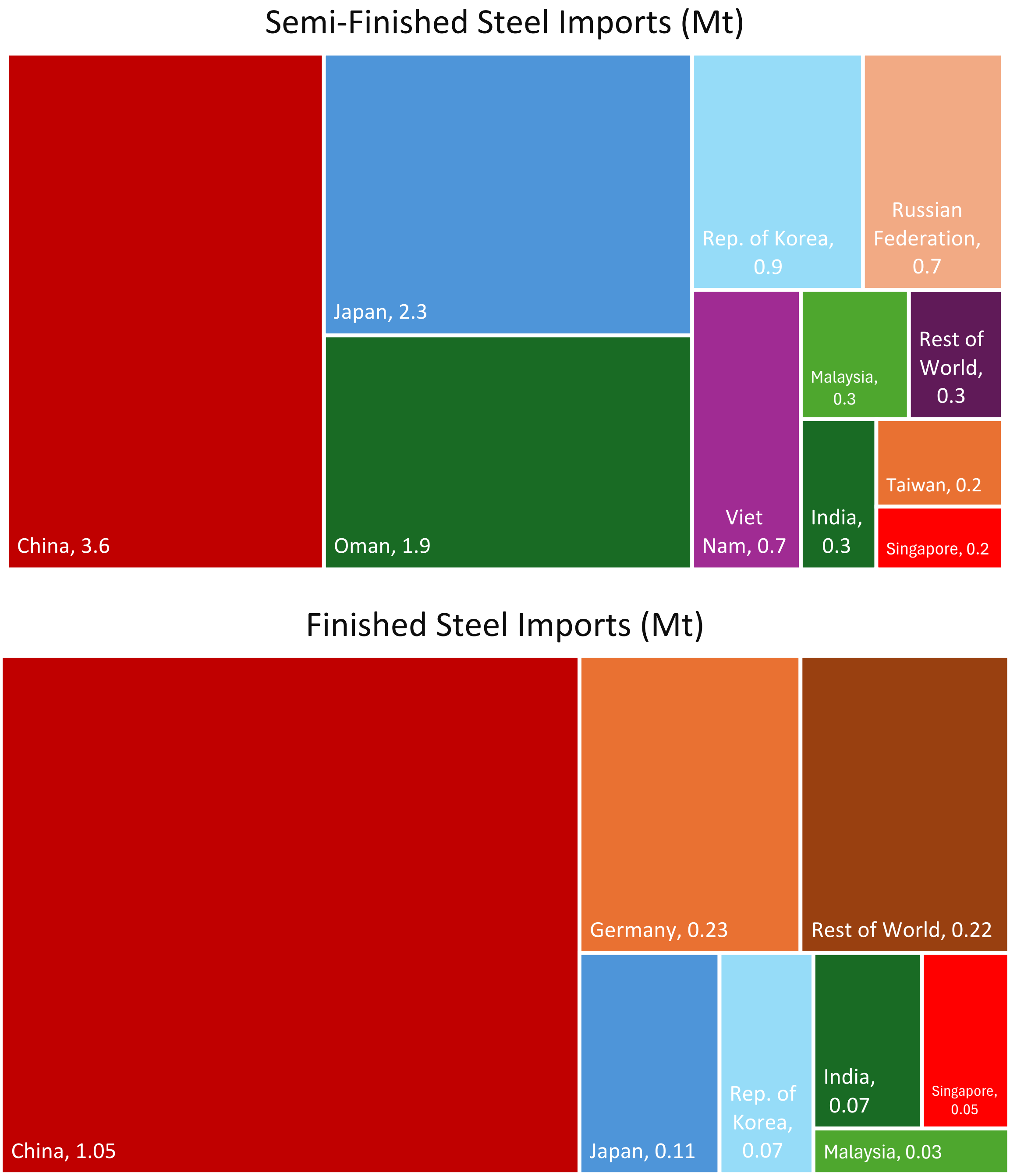
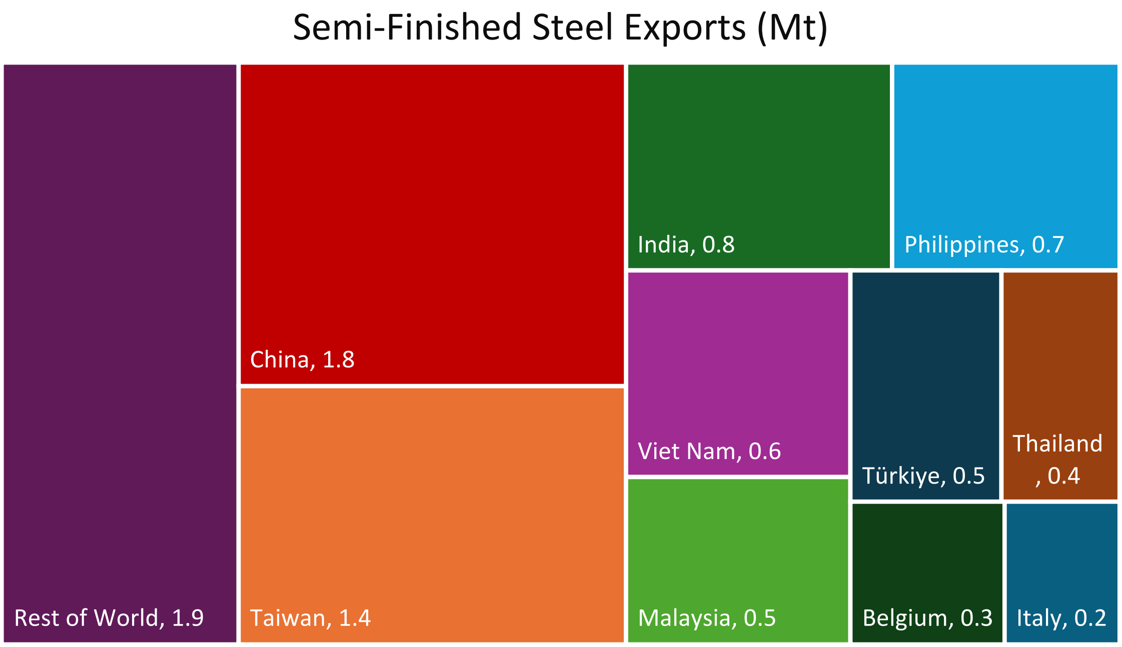


Figure 5: Imports of semi-finished (top) and finished (bottom) steel products into Indonesia in 2023 (Source: UN Comtrade 2025)

*Note: We extracted UN Comtrade data on HS code 72 for crude and semi-finished steel, excluding pig iron, ferroalloys, direct reduced iron, and ferrous waste; and HS code 73 for finished steel products.

Indonesia's steel exports were more geographically diverse and focused on regional and emerging markets. China was both an import and export destination for semi-finished steel. Other ASEAN countries, including the Philippines, Vietnam, Malaysia, Thailand, and Singapore were also major export destinations for Indonesian steel (Figure 6). Indonesia exported 0.9 Mt of semi-finished steel to the EU-27, making the EU CBAM policy a potential risk to Indonesian steel producers, although other markets are much larger export destinations. The US is also considering similar carbon border adjustment mechanisms, and Indonesia exports 0.2 Mt of semi-finished steel and 0.04 Mt of finished steel products to the US in 2023, making it a significant if not dominant market. Indonesian steel exporters will need to stay updated on these evolving policy proposals in the US and EU-27, since they would subject Indonesian steel exports to carbon intensity thresholds.



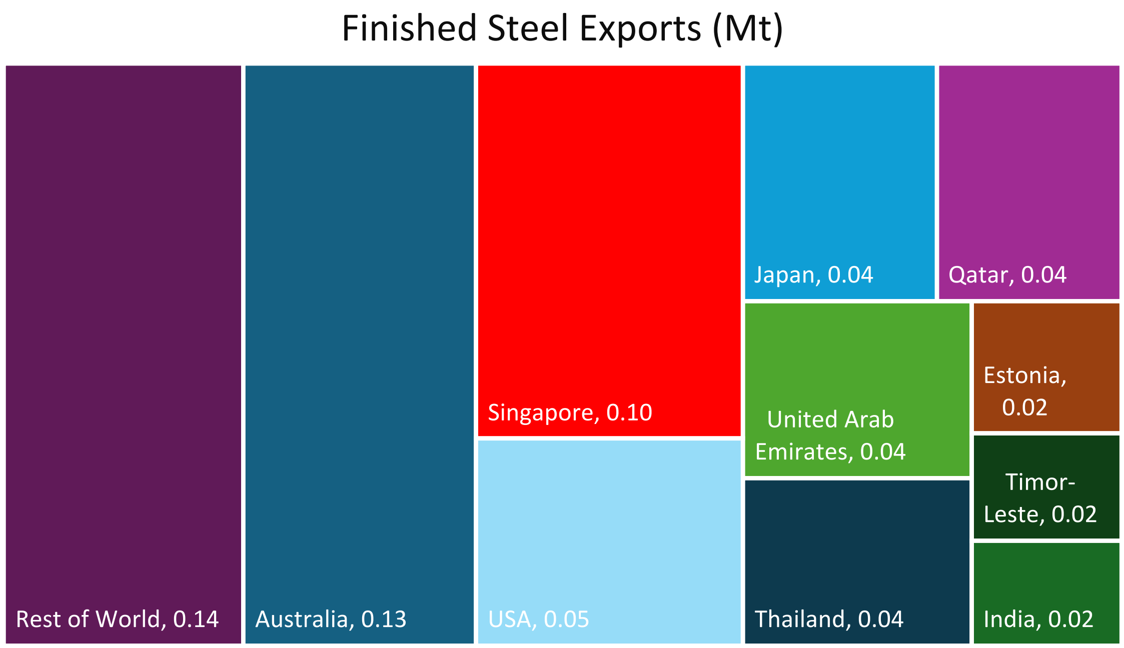


Figure 6: Exports of semi-finished (top) and finished (bottom) steel products from Indonesia in 2023 (Source: UN Comtrade 2025)

*Note: We extracted UN Comtrade data on HS code 72 for crude and semi-finished steel, excluding pig iron, ferroalloys, direct reduced iron, and ferrous waste; and HS code 73 for finished steel products.

3 Energy Use and CO_2 Emissions in Indonesia's Steel Industry

The iron and steel industry is the most energy-intensive sector in Indonesia, making up around 15% of the country's industrial final energy consumption in 2021 (Lu et al. 2024) (UN Energy Balances 2025). This share is poised to substantially increase as steel production increases significantly in the coming decades.

Coal makes up 77% of energy use in Indonesia's steel sector, reflecting the high share of BF-BOF steelmaking relative to EAFs. Indonesia's steel industry used around 7.2 Mt of coal (both coking coal and thermal coal combined) in 2023. A small amount of natural gas (6% of energy use) and petroleum products (4%) were used in Indonesia's steel industry; these fuels tend to be more expensive than coal in Indonesia. Electricity makes up 13% of energy use in Indonesia's steel industry (Figure 7).

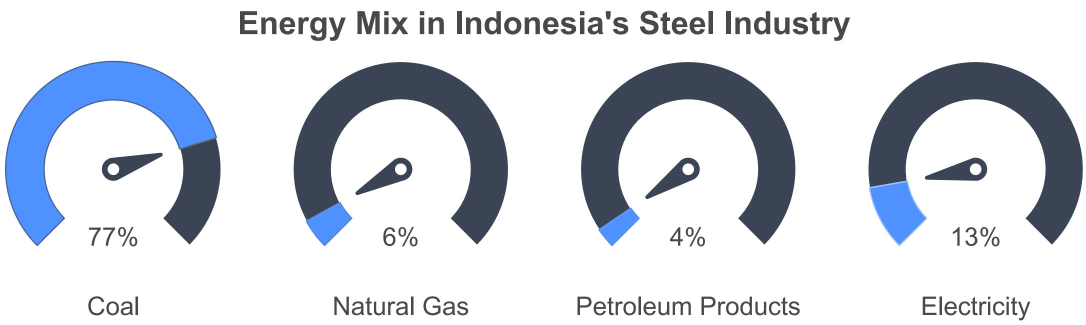


Figure 7. Energy mix in Indonesia's steel industry in 2023 (GEI analysis based on IEA 2025)

In 2023, Indonesia's steel industry emitted approximately 28 Mt of CO_2. Of this, around 23 Mt of CO_2 were fuel-related emissions, largely resulting from the use of coal and coke in BF-BOF plants. These fuels release substantial CO_2 during both combustion and the chemical reduction of iron ore. The remaining 5 Mt of CO_2 came from electricity-related emissions, driven by the use of grid electricity in EAFs and other processing systems (Figure 8). As Indonesia's power grid is also heavily dependent on fossil fuels, especially coal, electricity consumption accounts for 18% of the sector's total emissions.

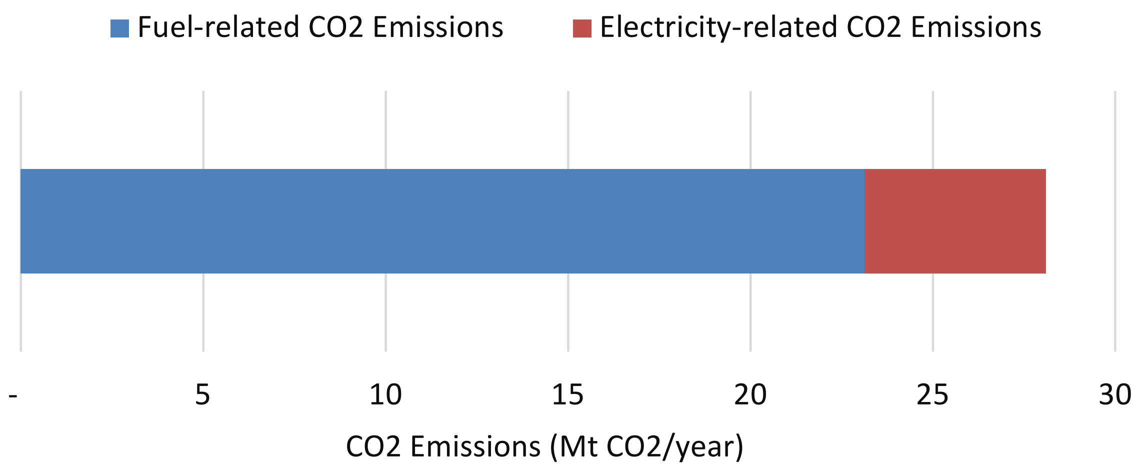


Figure 8. Annual CO_2 emissions in Indonesia's steel industry in 2023 (GEI analysis based on IEA 2025)

4 Net-Zero Roadmap for Indonesia's Steel Industry

4.1. Decarbonization Scenarios

After assessing the current status of Indonesia's steel industry, including its energy use and CO_2 emissions, we developed a decarbonization roadmap through to 2060 based on four main scenarios:

1. **Business as Usual (BAU) scenario:** This scenario reflects existing business practices, policies, and regulations. It assumes only gradual improvements in energy efficiency and fuel switching and slow adoption of carbon capture, utilization, and storage (CCUS) technologies.
2. **Moderate Technology and Policy (Moderate) scenario:** This scenario envisions moderate progress, including greater energy efficiency gains, more fuel switching to lower-carbon options, a modest increase in the use of EAF and other production routes, and limited adoption of CCUS technologies.
3. **Advanced Technology and Policy (Advanced) scenario:** This scenario assumes substantial improvements in energy efficiency, more aggressive fuel switching, a significant shift to scrap-based EAF steelmaking, and the early-stage adoption of breakthrough technologies such as NG-DRI, green H_2-DRI, and iron ore electrolysis (post 2050).
4. **Net-Zero scenario:** The most ambitious scenario, it assumes the highest levels of energy efficiency improvement, widespread fuel switching, a major shift to scrap-based EAF production, and moderate deployment of transformative iron and steelmaking technologies.

4.2. Decarbonization Pathways for Indonesia's Steel Industry

Our analysis is structured around five key decarbonization pillars:

1) material efficiency and demand management
2) energy efficiency and electrification of heating
3) fuel switching and cleaner electricity
4) transitioning to low-carbon iron and steelmaking technologies, and
5) carbon capture, utilization, and storage (CCUS).

The impact of each of these pillars on the decarbonization of Indonesia's steel industry is explored in detail in the following chapter.

We estimated the total final energy use and CO_2 emissions of the steel industry in Indonesia through to 2060 under each of the described scenarios. Figure 9 shows the projected emissions trajectory for Indonesia's steel industry under each scenario.

In the BAU scenario, emissions from the steel industry are projected to grow through to 2060, driven by significant growth in crude steel production with only moderate levels of energy efficiency improvement and technology shifting. Under the BAU scenario, Indonesia's steel industry emissions are projected to reach nearly 72 Mt CO_2/year by 2060, an increase of nearly 160% from 2023. Under the other scenarios, emissions peak and then decline (varying by year of emissions peaking), with the Advanced and Net Zero scenarios projected to have emissions reductions relative to the base year (2023) by 2060.

The Net Zero scenario has the greatest reduction in emissions for Indonesia's steel industry, based on slower growth in crude steel production, aggressive energy efficiency measures, more CCUS, and the highest adoption of transformative green steelmaking technologies like green H_2-DRI-EAF and electrolysis of iron ore. Under the Net Zero scenario, the total CO_2 emissions of Indonesia's steel industry would decrease by 86% relative to the base year, and by 94% relative to the BAU scenario in 2060.[1]

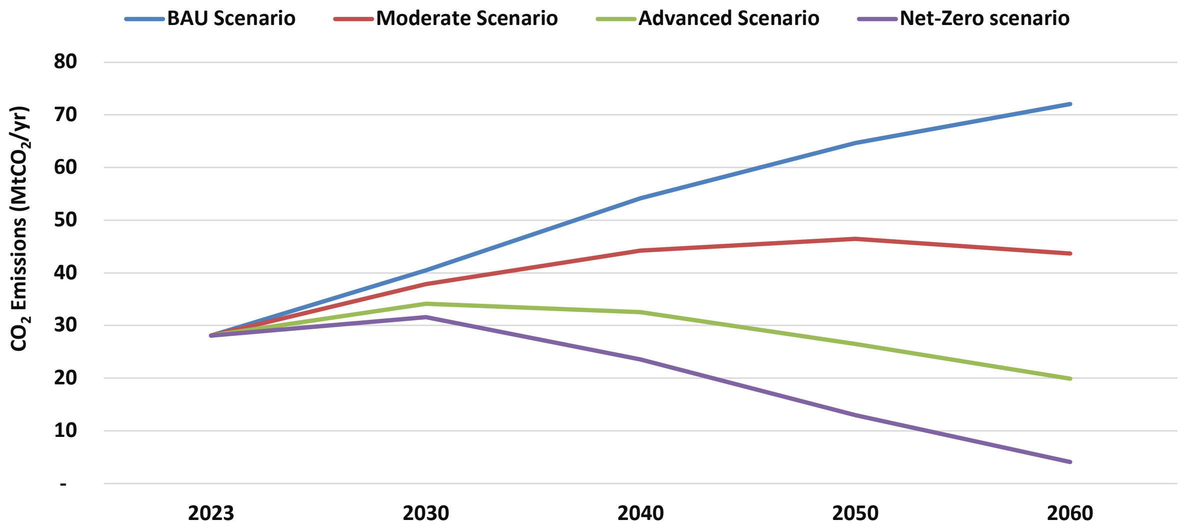


Figure 9: Total annual CO_2 emissions in the steel industry in Indonesia under four decarbonization scenarios, 2023-2060 (Source: this study)

Each decarbonization pillar plays a different role in reducing total emissions. Figure 10 illustrates the contribution of each pillar to emissions reductions in the Net Zero scenario for 2060, compared to BAU scenario's emissions in the same year. The largest share of reductions is expected to come from the technology shift pillar, which includes the adoption of lower-carbon steelmaking methods such as scrap-based EAF, green hydrogen-based DRI-EAF, and iron ore electrolysis. Material efficiency/demand management, energy efficiency and electrification, and fuel switching/cleaner electricity offer similar levels of emissions reductions. CCUS is projected to provide a more limited reduction impact relative to the other pillars. A small contribution also comes from the use of imported green iron in EAF-based steel production.

1 Note that the Net Zero scenario still has a small amount of residual emissions in 2060. Achieving net zero is possible with additional measures outside of the steel industry, such as such as leveraging Indonesia's abundant bio-based resources and carbon sinks through mechanisms like carbon offsetting, sustainable bioenergy with carbon capture and storage (BECCS), and afforestation or reforestation programs.

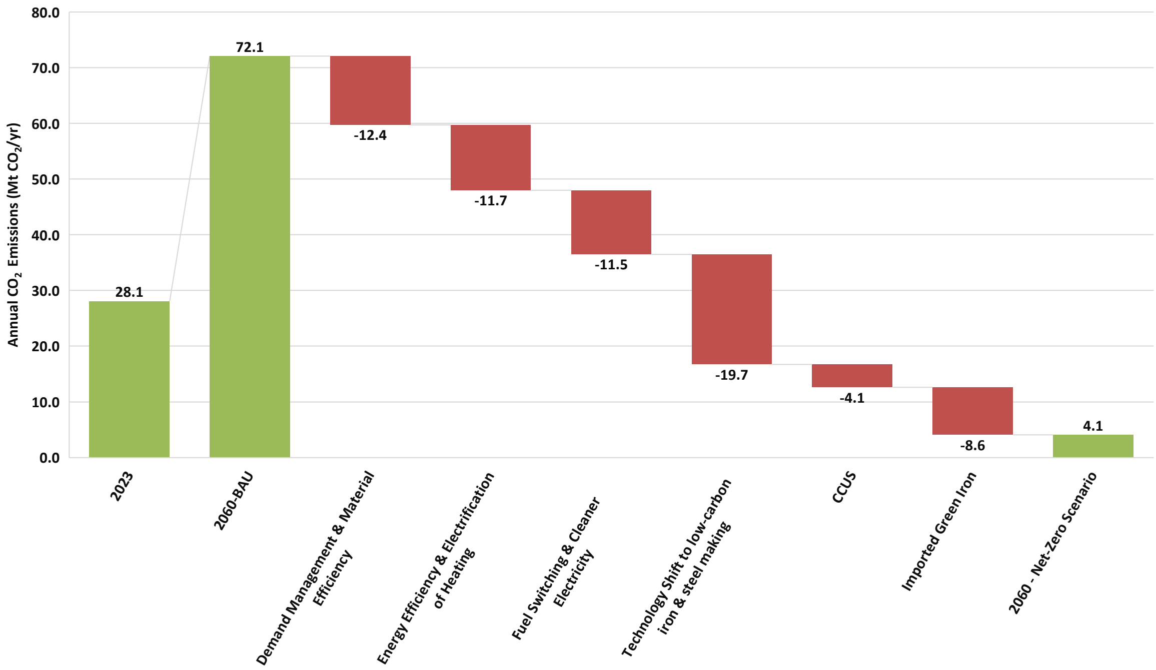


Figure 10. Impact of each decarbonization pillar on CO_2 emissions of Indonesia's steel industry, Net Zero scenario relative to BAU (Source: this study)

We also analyzed the contribution of each pillar over time in terms of bringing the BAU scenario's emissions down to Net Zero levels (Figure 11). The area of the graph that shows each pillar in different colors shows the cumulative contribution of each decarbonization pillar to the total decarbonization of the steel industry in Indonesia from 2023 to 2060. While demand management, energy efficiency, and fuel switching play the main roles between the base year and 2030, from 2030 onwards, the technology shift pillar plays the largest role. CCUS and imported green iron are also expected to play a small role with adoption after 2030.

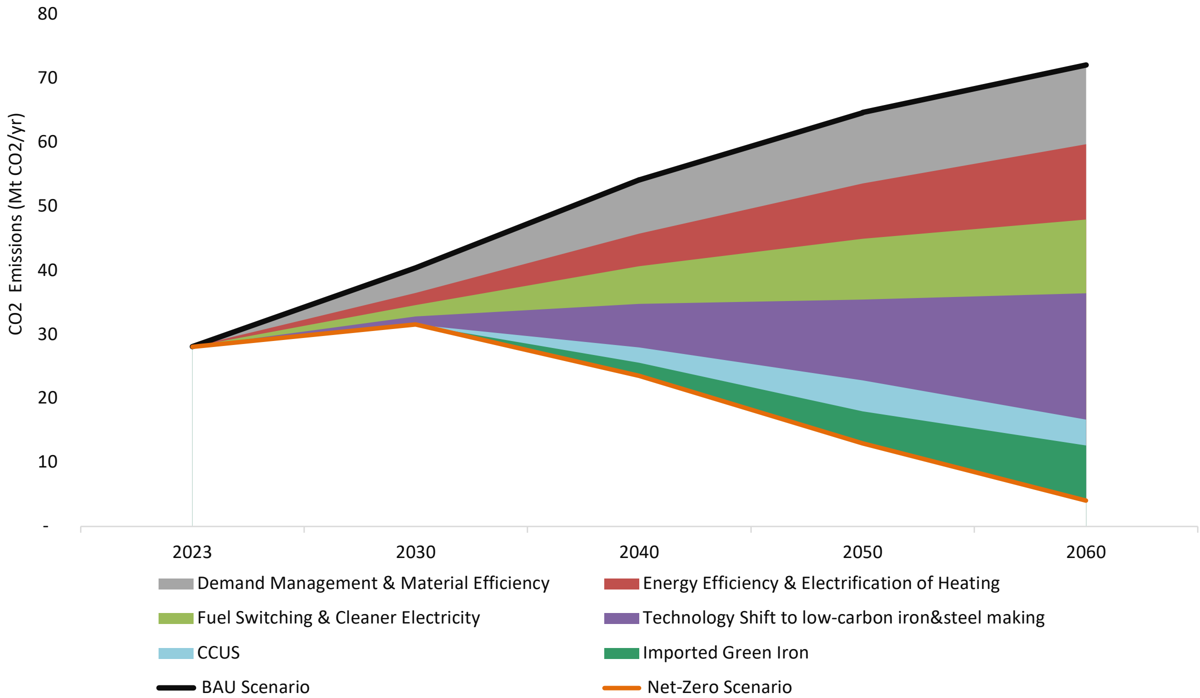


Figure 11: Impact of decarbonization pillars on CO_2 emissions of Indonesia's steel industry to bring BAU emissions down to the Net Zero scenario's level (Source: this study)

5 The Impact of Decarbonization Pillars on Indonesia's Steel Industry

5.1. Material Efficiency and Demand Management

Material efficiency involves delivering goods and services using less material, thereby reducing crude steel demand along with the energy use and emissions tied to its production. Across the steel value chain, various strategies can help achieve this. At the design stage, strategies such as lightweighting and material optimization allow for fewer materials to provide the same service, while designing for long life may initially increase material requirements but lead to overall lifecycle emissions savings. Using lightweight materials, optimizing material use, and incorporating circular design principles can cut material demand by up to 13%, especially in buildings, vehicles, and finished steel products (Zhou et al. 2019). In some cases, steel-frame buildings contain almost twice as much steel as necessary for structural performance, with beams carrying only half the load they were designed for. This over-provision occurs primarily to minimize labor costs rather than optimize material use. Construction emissions could be reduced by approximately 50% through more efficient steel use in building design (Moynihan and Allwood 2014)

In the fabrication stage, manufacturers can reduce waste and overuse through more precise production techniques and construction practices, while also substituting higher-emissions materials with lower-emissions alternatives where possible. Improving semi-manufacturing yields can lead to a 7% material savings, while enhancing final product yields can reduce use by another 13% (Mission Possible Partnership 2021).

During the use stage, intensifying the use of steel products and extending the lifespan of buildings and goods through maintenance, repair, and refurbishment can lower the need for new materials. Extending the lifespan of steel-intensive assets like buildings and vehicles could reduce steel demand by 25% (Hertwich et al. 2019), and replacing steel with mass timber in building construction may lower demand by as much as 50% (Dong et al. 2019).

At the end-of-life stage, reusing steel components helps reduce the need for virgin material. Direct reuse of components without melting can yield a further 15% reduction in steel demand, particularly in construction and industrial sectors (Eberhardt et al. 2019). While recycling enables the use of lower-emission secondary steelmaking processes, for the steel industry, we categorize these types of actions as related to scrap-EAF production as discussed in Section 5.4.

Figure 12 lists general interventions to improve material efficiency for the supply chains of industrial products like steel.

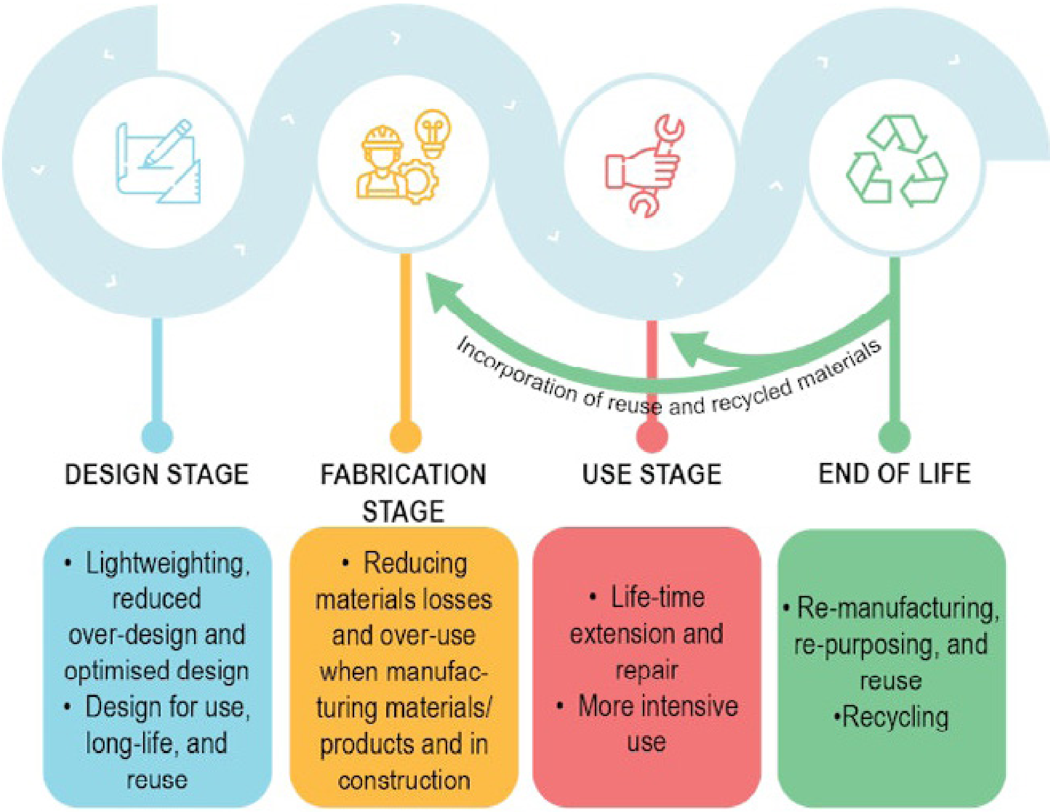


Figure 12: Schematic of material efficiency strategies for industrial supply chains (Source: International Energy Agency 2019)

Material Efficiency and Demand Management in Indonesia's Steel Industry

As Indonesia's economy develops and its population grows, both steel production and consumption are expected to increase. Without material efficiency and demand management measures, these increases in production and consumption will drive energy use and emissions from Indonesia's steel industry. Demonstrating the possible scale of future steel production in Indonesia, Indonesia has an additional 21 Mt of announced BOF capacity, and 7 Mt of ironmaking capacity via blast furnaces that is announced or under construction (Figure 13). A small amount of EAF capacity has been announced (approximately 1.2 Mt). Assuming all of this capacity comes online and is used at an average capacity utilization rate, these additions could more than double Indonesia's crude steel production. However, it is important to note that the planned capacity here could be an overestimate, as global trends show that roughly 25% of announced steel projects are eventually cancelled or indefinitely postponed, and Indonesia faces additional risks such as environmental permitting delays, local community opposition, infrastructure constraints, and uncertainty around raw material supply.

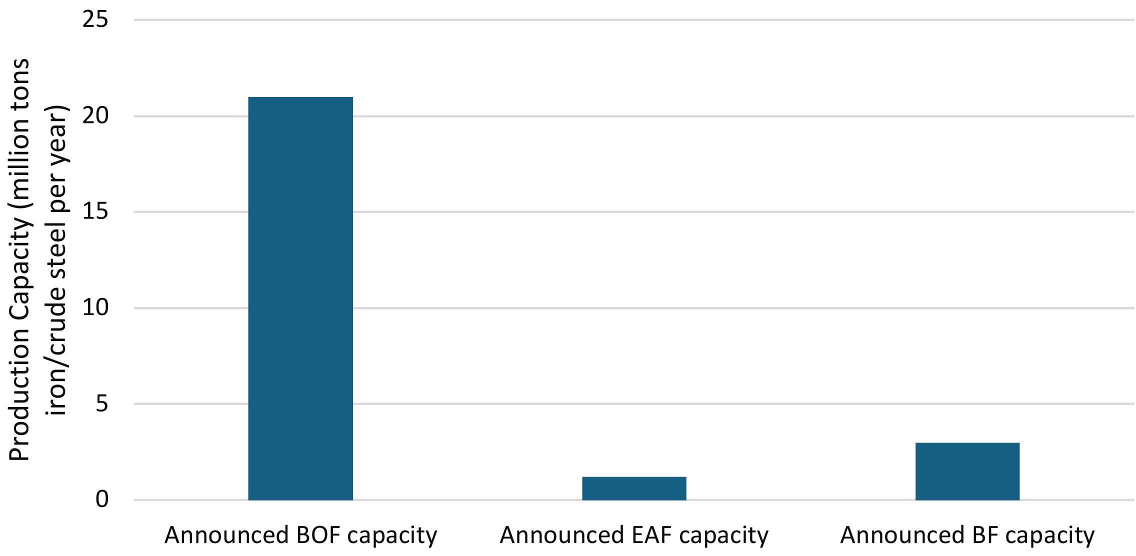


Figure 13: Announced iron and steelmaking capacity in Indonesia by production route (Source: Grigsby-Schulte et al. 2025)

Projections for crude steel production in Indonesia vary significantly across studies, reflecting differences in demand assumptions, policy environments, and infrastructure growth expectations. This wide range underscores the uncertainty with respect to future steel production. For example:

- 2030: the International Energy Agency (IEA) forecasts Indonesia's steel production to reach 19.3 Mt by 2030 under a net-zero aligned roadmap (International Energy Agency 2022), whereas the Institute for Essential Services Reform (IESR) reports a production capacity of 34 Mt for the same year.

- 2050: production *capacity* forecasts range from 25 Mt/year (Swiss Global Enterprise, 2025) to as high as 156 Mt (Shanghai Metals Market, SMM). Production projections also diverge in 2050: Dewi et al. 2024 estimate 50 Mt, while the Lawrence Berkeley National Laboratory study outlines a range from 22 Mt in a steady demand scenario to 35 Mt in a high-demand scenario (Lu et al. 2024).

On the consumption side, Indonesia's apparent steel consumption has risen slowly but steadily over the past decade (Figure 14), however, consumption is expected to significantly increase as the economy develops. The Center for Research on Energy and Clean Air (CREA) estimates that Indonesia's steel consumption will grow from nearly 18 Mt/year in 2024 to 100 Mt by 2050 (Swastika and Hasan 2024), while the Shanghai Metals Market (SMM) projects steel consumption to rise to 125 Mt by 2050, reflecting a scenario of significant infrastructure expansion and urbanization. It is worth noting the consumption forecasts are more aligned than the projections for production capacity and actual output.

Because steel consumption and production are key drivers of the forecast growth in the Indonesian steel industry's CO_2 emissions, material efficiency and demand management can play a direct role in decarbonization of Indonesia's steel industry.

Modeling Inputs

The first step in developing decarbonization pathways was to develop projections for steel production over the study period (2023 through 2060). Given the ongoing importance of Indonesia's steel industry to the domestic economy, and rapid projected growth in steel consumption, we projected Indonesia's steel production through to 2060 under the four different scenarios in this study, drawing from the data sources mentioned above and our expert assessment. Material efficiency and demand management measures drive the lower production forecasts in the Moderate, Advanced, and Net-Zero scenarios, relative to the BAU scenario. Under the BAU scenario, we project that Indonesia's annual steel production could nearly quadruple, from 16.6 Mt in 2023 to 60 Mt by 2060. All scenarios have significant growth in production, underscoring the need for decarbonization.

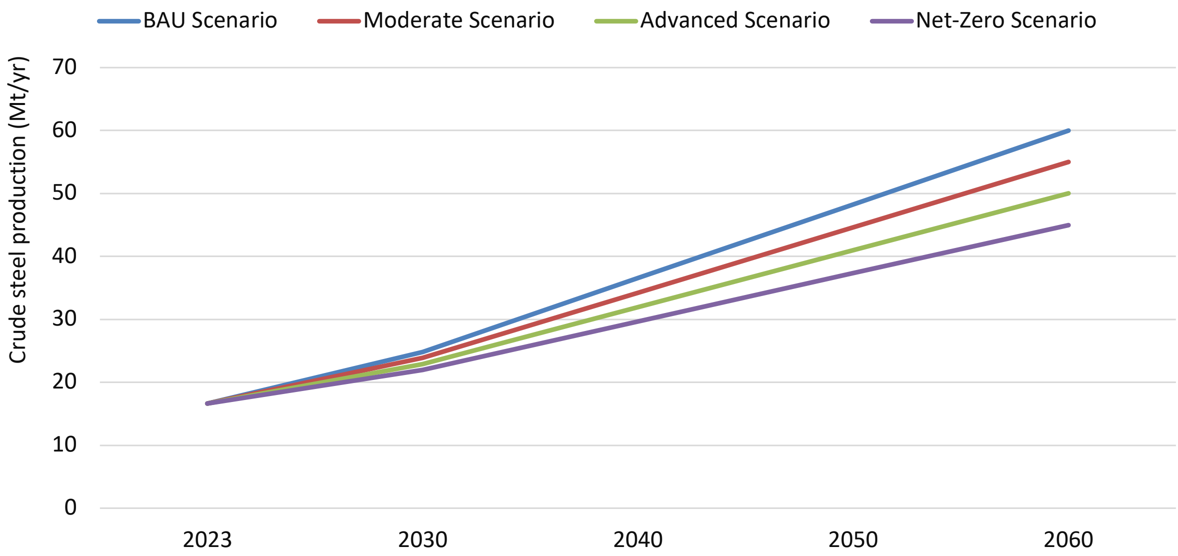


Figure 14: Annual steel production forecasts in Indonesia by scenario for this study, 2023-2060 (Source: this study)

Modeling Results

We find that material efficiency and demand reduction could contribute to 12.4 Mt CO_2 emissions reductions in 2060 under the Net Zero scenario relative to the BAU scenario (Figure 10), driven directly by the lower production assumed under the Net Zero scenario. This is more emissions reductions than are expected to be contributed by CCUS and imported green iron. Figure 11 shows the contribution of this pillar over time to emissions reductions under the Net Zero scenario relative to BAU.

Barriers and Solutions for Material Efficiency in Indonesia's Steel Industry

Material efficiency strategies such as lightweighting, design optimization, and product life extension can significantly reduce steel demand and associated emissions. However, these strategies often involve complex trade-offs. For instance,:

- measures to improve operational energy performance in buildings, like enhanced insulation or thermal storage, can increase material use during construction.

- extending building lifespans may reduce material needs but can lead to higher lifetime energy consumption if retrofits are not undertaken.
- Substituting steel with materials like mass timber can cut emissions but raises sustainability concerns related to deforestation, biodiversity loss, and soil carbon impacts, especially if forest governance is weak.

Because of these trade-offs, full life-cycle assessments are essential to determine the net environmental benefits of material efficiency strategies. Although economic data remains sparse, studies suggest a wide cost range for steel-related material efficiency from negative costs (net savings) to several hundred dollars per ton of CO_2 avoided, depending on the context (Durant et al. 2019).

In Indonesia, the adoption of material efficiency strategies remains limited across the steel value chain. There is little evidence of national policies or industry initiatives that promote lightweight material use, steel design optimization, or lifecycle-based procurement. *While manufacturing yield improvements are occasionally addressed, the design stage remains largely unexplored. Similarly, the extension of product and building lifespans is not prioritized.* Indonesia's Circular Economy Roadmap briefly mentions reuse and refurbishment but focuses on sectors such as textiles and packaging rather than steel-intensive applications like construction or industrial machinery. Substitution of steel with alternative materials such as mass timber is also absent from official guidance (Ministry of National Development Planning 2024).

Barriers specific to Indonesia include the absence of integrated national design standards for material-efficient buildings and infrastructure, a public procurement system that favors low upfront costs over life-cycle performance, and high material losses in small and medium steel enterprises due to outdated fabrication technologies. Regulatory fragmentation and lack of cross-sector coordination further weaken incentives for reuse, recycling, and substitution. These systemic gaps hinder the emergence of a coherent material efficiency framework and limit opportunities to scale promising strategies.

Addressing these challenges requires a coordinated policy response. Government agencies such as the Ministry of Public Works and Housing (PUPR), the Ministry of Industry (The Ministry of Industry), and the Ministry of Environment and Forestry (KLHK) should integrate material efficiency into infrastructure planning, building codes, and public procurement guidelines. Demonstration projects, particularly within the Nusantara capital development, could showcase design-for-efficiency principles and steel-alternative construction methods. In manufacturing, fiscal incentives and concessional loans can support SMEs in adopting precision fabrication technologies and digital inventory management to reduce yield losses. End-of-life reuse could be enabled through centralized deconstruction hubs, supported by technical standards from the National Standardization Agency (BSN) and coordinated with IISIA. Finally, embedding life-cycle thinking across public and private decision-making will be essential to guide trade-offs between material and energy efficiency.

5.2. Energy Efficiency and Electrification of Heating

Numerous energy efficiency technologies are already commercially available for use in the steel industry. These include well-established solutions such as waste heat recovery systems, coke dry quenching (CDQ), and Top-Pressure Recovery Turbine (TRT) plants (JISF 2022). Beyond conventional technologies, advancements in smart manufacturing and the Internet of Things are enabling the deployment of tools like predictive maintenance, machine learning, and digital twins, all of which can enhance process control and support robust energy management systems (Hasanbeigi et al. 2013).

Evidence from steel producers indicates that even relatively modest investments in energy efficiency can deliver considerable energy and cost savings, often with payback periods of less than three years. For larger upgrades, however, the required capital investments may be harder to justify through energy savings alone. Nonetheless, energy efficiency improvements provide additional benefits, including reduced vulnerability to energy price fluctuations, improved product quality, greater productivity, access to higher-value markets, and decreased compliance costs due to lower emissions of GHG and other pollutants.

Table 2 provides an overview of some commercialized energy efficiency technologies suited to the iron and steel sector. It is important to recognize, however, that each steel facility has its own operational characteristics, and selecting the most appropriate energy-saving measures must be based on a careful assessment of the plant's specific design and conditions.

Electrification refers to replacing fuel-based technologies with electrically powered alternatives, for example electrifying reheating furnaces, expanding the use of electric induction furnaces, and electrifying ladle and tundish heating using resistance, infrared, or plasma heating technologies. Although EAF steel production is inherently an electrified process, in this analysis it is categorized under the technology shift pillar rather than electrification. This is because switching from the blast furnace route to EAFs represents a fundamental shift in the steelmaking process from primary production using iron ore to secondary production using scrap, making it more of a structural transformation than a simple energy substitution.

Electrifying heating in steel production, particularly in rolling and finishing processes, can significantly enhance energy efficiency and support decarbonization efforts. These processes require reheating steel billets, blooms, or slabs to around 1,200°C to make the material pliable for shaping into final products such as sheets, bars, and rods. Conventional gas-fired reheating furnaces are a major source of emissions. In contrast, electric reheating furnaces use resistance heating elements to achieve the same temperatures more efficiently. When powered by clean electricity, electric furnaces eliminate direct CO_2 emissions entirely.

Table 2. Examples of commercialized energy efficiency measures and technologies for the iron and steel industry (JISF 2022, Hasanbeigi et al. 2013)

Relevant Steel Production Step	Energy Efficiency Measure/Technology
Sintering	Heat recovery from the sinter cooler
	Reduction of air leakage
	Increasing bed depth
	Use of waste fuel in sinter plant
	Improve charging method
	Improve ignition oven efficiency
Coke Making	Coal moisture control
	Programmed heating in coke oven
	Variable speed drive on coke oven gas compressors
	Coke dry quenching (CDQ)
Iron Making - BF	Injection of pulverized coal in BF to 130 kg/t hot metal
	Injection of natural gas in BF
	Injection of oil in BF
	Injection of coke oven gas in BF
	Top-pressure recovery turbines (TRT)
	Recovery of blast furnace gas
	Improved blast furnace control
	Preheating of fuel for hot blast stove
	Improvement of combustion in hot blast stove
	Improved hot blast stove control
Steelmaking - BOF	Recovery of BOF gas and sensible heat
	Variable speed drive on ventilation fans
	Control system for oxygen supply to BOF process
	Programmed and efficient ladle heating
Steelmaking - EAF	Converting the furnace operation to ultra-high power (UHP)
	Adjustable speed drives (ASDs) on flue gas fans
	Oxy-fuel burners/lancing
	Post-combustion of flue gases
Cross-Cutting	Preventative maintenance
	Energy monitoring and management systems

Energy Efficiency and Electrification of Heating in Indonesia's Steel Industry

Some of Indonesia's largest steel companies have made demonstrated progress in adopting energy efficiency technologies. Krakatau POSCO, a joint venture between POSCO and PT Krakatau Steel, has adopted CDQ technology using nitrogen instead of water (Sambodo et al. 2024). This implementation provides better heat recovery and energy efficiency compared to the water quenching method, with the hot coke cooled rapidly using nitrogen to allow for efficient heat exchange and energy recovery.

In partnership with Nippon Steel and Japan's Ministry of Economy, Trade and Industry (METI), Indonesia was selected in 2022 for feasibility studies on tundish plasma heater installation at EAFs in the country. The Tundish Plasma Heating System (NS-TPH) maintains constant temperature of molten steel in continuous casting operations. This technology can reduce energy consumption rates across entire steelmaking plants and is expected to reduce CO_2 emissions by approximately 6% per ton of production (Nippon Steel 2022).

PT Krakatau Steel has obtained ISO 50001:2018 certification for Energy Management, representing an international standard focused on energy management systems and resource management (Tonce 2025). This certification demonstrates systematic implementation of energy efficiency measures across steel production operations.

At a broader level, Indonesia has launched comprehensive smart manufacturing initiatives across its industrial sector. The Ministry of Industry has partnered with various technology providers to implement smart manufacturing technologies aligned with the Making Indonesia 4.0 strategy. This national framework specifically targets the manufacturing sector for digital transformation (Intimedia 2024).

Modeling Inputs

Energy efficiency was modeled by assumed reduction rates in the fuel intensity and electricity intensity of crude steel production, which were specific to each production process and scenario (i.e. the Net Zero scenario had the most aggressive improvements in fuel and electricity intensity of steel production). These rates were determined based on our assessment of the total energy efficiency potential across commercialized steel technologies. We also assumed that electrification of rolling and finishing for EAFs would contribute to energy efficiency, because electrified rolling and finishing processes have an energy intensity of 550 kWh per ton of crude steel, compared to over 800 kWh per ton for gas systems (Hasanbeigi, Springer, et al. 2024).

Modeling Results

We find that energy efficiency and electrification of heating could contribute to 11.7 Mt CO_2 emissions reductions in 2060 under the Net Zero scenario relative to the BAU scenario (Figure 10). Only slightly lower than emissions reductions potential from material efficiency/demand management, the energy efficiency and electrification pillar represents the third largest source of emissions reductions in 2060 relative to BAU. Figure 11 shows the contribution of this pillar over time to emissions reductions under the Net Zero scenario relative to BAU.

Barriers and Solutions for Energy Efficiency in Indonesia's Steel Industry

Indonesia's steel industry faces significant challenges in implementing energy efficiency technologies, despite the availability of commercially proven solutions. High initial capital costs represent the most significant barrier to energy efficiency adoption in Indonesia's steel industry. The slow rate of return on investment and hidden costs of production disruption create additional financial obstacles. These financial constraints are particularly challenging given that energy costs account for 20-35% of total production costs in Indonesian steel operations (Soepardi, Pratikto, Santoso, Tama, et al. 2018)energy end-use efficiency is a crucial measure that is used to reduce energy intensity and decrease production costs. This article aims to investigate the relationships among different barriers to energy efficiency improvement (EEI.

Another barrier to improving energy efficiency in Indonesia's steel industry is the lack of information and technical skills. Many companies don't have access to reliable information about new technologies, or they find the available information confusing or hard to apply. Even when companies are aware of new technologies, they may consider their current systems "good enough," or believe that newer options won't work well at their specific sites (Soepardi, Pratikto et al. 2018). Other challenges include limited availability of advanced technology, concerns about whether new equipment will fit with existing systems, and uncertainty about future standards. In some cases, companies also lack the skilled workers needed to install or operate new technologies, or they worry that installation will take too long. These knowledge and skill gaps make it much harder for firms to adopt more efficient practices.

Government financial support mechanisms are being developed to address capital barriers. The International Finance Corporation (IFC) has provided $60 million in green financing to PT Gunung Raja Paksi (GRP) to expand low-carbon flat steel production using EAF technology, demonstrating the potential for international financing (International Finance Corporation 2024). Tax exemptions and fiscal Incentives are available for imports of energy-saving equipment and appliances, along with special low-interest rates on investments in energy conservation (IEA 2017). However, many fiscal incentives for promoting energy efficiency among industrial energy users have yet to be fully implemented.

Since lack of reliable information access about new technologies can inhibit energy efficiency technology adoption, establishing comprehensive information systems and technology transfer mechanisms could help resolve this barrier. Indonesia's steel industry faces complex interconnected barriers to energy efficiency implementation, ranging from financial constraints and technology lock-in to workforce skill gaps and information access challenges. However, comprehensive solutions exist across policy, technology, and capacity building domains. Success requires coordinated action among government agencies, industry players, and international partners to address the fundamental barrier of information access while simultaneously developing financial mechanisms, regulatory frameworks, and technical capabilities.

5.3. Fuel Switching and Decarbonization of Electricity Supply

The decarbonization pillar of fuel switching and decarbonization of electricity supply includes a range of strategies aimed at reducing the carbon intensity of the energy sources used in iron and steel production. Fuel switching involves replacing high-carbon fuels like coal and coke with lower-carbon alternatives such as natural gas, biomass, or biogas. In the longer term, hydrogen, particularly green hydrogen, also holds significant potential as a clean fuel and reducing agent in steelmaking.

In terms of decarbonization of electricity supply, all processes in steel production that use electricity can be decarbonized by using lower-carbon grid electricity, or even directly procured renewable electricity. When paired with electrification, fuel use and associated emissions can be significantly reduced.

Fuel and Electricity Supply in Indonesia

Indonesia is a global coal powerhouse, with production reaching record levels in recent years and maintaining its position as the world's largest exporter of thermal coal (Reuters 2025). For natural gas, domestic production is predicted to decline even as demand increases, leading to Indonesia recently diverting LNG exports for domestic consumption (Churchman 2025).

As discussed in Chapter 3, fuel use, predominantly coal (coking coal and thermal coal), makes up 87% of energy use in Indonesia's steel sector, driven by BF-BOF steelmaking. A small amount of natural gas (6%) and petroleum products (4%) were used in Indonesia's steel industry; and electricity makes up 13% of energy use.

Low-carbon electricity supply will be critical for decarbonizing Indonesia's steel industry. Currently, Indonesia's electricity grid remains highly reliant on coal, which accounted for over 60% of the country's power generation mix in 2023 due to the significant domestic availability of low-cost coal (Ember Climate 2025). This high carbon intensity poses a significant challenge for industrial decarbonization, including for the steel sector.

Only 0.4% of Indonesia's renewable energy (RE) potential has been developed to date (14 GW out of an estimated 3,600 GW) (ESDM 2025). This underutilization highlights the significant opportunity for scaling up renewables. Indonesia has abundant solar, wind, hydro, and geothermal resources, but much of this potential is located far from major industrial centers, particularly in the eastern islands. As a result, expanding and modernizing Indonesia's transmission and distribution infrastructure will be essential to deliver clean electricity to industrial zones. PLN recently released the Electricity Supply Plan (RUPTL) for 2025-2034, which plans for an additional 42.6 GW of RE capacity addition over the next 10 years. In addition, the Just Energy Transition Partnership (JETP) seeks to leverage international support to build out this infrastructure, improve grid reliability, and accelerate renewable integration.

Another critical enabler of industrial electrification is energy storage, which helps manage variability in renewable generation. While Indonesia has not yet set large-scale battery storage targets, it has ambitions to become a global battery exporter by 2030, capitalizing on its vast nickel reserves. The government is actively attracting international investment to establish domestic battery manufacturing capabilities. These developments could reduce battery costs over time, enabling greater deployment of storage solutions domestically to support industrial loads like EAFs and enhance renewable grid integration.

Grid modernization and electricity market reform can increase the economic and emissions benefits of transitioning to EAFs, green H_2-DRI, and other steel electrification technologies. Indonesia's electricity market remains centralized and regulated, with limited mechanisms for dynamic pricing, regional energy trading, or demand-side participation. Reforming these systems could allow for greater flexibility, enabling large industrial users like steelmakers to respond to grid signals and support RE uptake.

Given ongoing reforms needed to decarbonize grid electricity, it is important to note that Indonesia's steel companies could obtain low-carbon electricity by directly procuring RE. Corporate RE procurement in Indonesia is still at an early stage, but recent developments show a growing commitment from industrial players to shift toward cleaner power sources. In 2022, Amazon signed a landmark agreement with Indonesia's state-owned utility PLN to procure 210 MW of solar power from four utility-scale projects located in Java and Bali. This agreement was the first of its kind in the country and will supply renewable electricity to Amazon Web Services data centers and other local operations, advancing Amazon's global net-zero goals and helping Indonesia move closer to its 23% RE target by 2025 (Technode Global 2022).

The mining sector has also demonstrated early leadership in corporate RE procurement. Nickel Industries Ltd, a major producer operating in the Morowali Industrial Park, secured a 25-year power purchase agreement (PPA) for a 200 MW solar project, supported by a

20 MWh battery storage system. The project is designed to reduce reliance on diesel and lower emissions associated with nickel production, while also offering electricity prices below prevailing market rates (RenewablesNow 2022). These types of long-term PPAs signal increasing willingness from industry to invest in low-carbon electricity supply.

Indonesia's RE Certificate (REC) market, introduced by PLN in 2020, offers another mechanism for corporate RE procurement. The program targets industrial users, particularly in Java and Jakarta, and has seen rapid growth: PLN reported a 75% increase in REC usage in 2023 compared to 2022, with cumulative sales reaching over 5 TWh (Antara News 2024). RECs allow companies to validate the renewable origin of the electricity they consume, helping them meet internal sustainability targets and increasing demand for clean power generation. Despite strong demand, Indonesia faces a mismatch between REC issuance and redemption volumes, highlighting the need for expanding RE projects, particularly in grids outside of Java (ACE 2025).

Despite this progress, several barriers still limit large-scale corporate procurement of renewables in Indonesia. These include restrictions on private power supply in PLN's service areas, limited renewable project availability, and regulatory uncertainty. Nevertheless, the rise in corporate interest, PLN's growing engagement with independent producers, and support from international partnerships such as the Just Energy Transition Partnership (JETP) suggest strong potential for future growth in Indonesia's corporate RE procurement market. Continued reform and investment in grid infrastructure and RE capacity will be crucial to scale these efforts.

Modeling Inputs

In our analysis of the effects of fuel switching and decarbonized electricity, we projected the energy mix for Indonesia's steel industry under the four scenarios by modeling a transition toward greater use of cleaner electricity and lower-carbon fuels. By 2060, under the Net Zero scenario, we assume that coking coal use is significantly reduced, primarily due to the increased reliance on electricity and natural gas driven by a shift to alternative ironmaking technologies. The rise in electricity consumption is also driven by a shift in production methods, particularly the transition to EAFs and green H_2-DRI. Our analysis shows that electricity's share of total energy use in steel production will grow from 13% in 2023 to 57% by 2060. At the same time, natural gas is expected to play a larger role, fueled by its use in natural gas-based DRI-EAF production and as a replacement for coal in other processes.

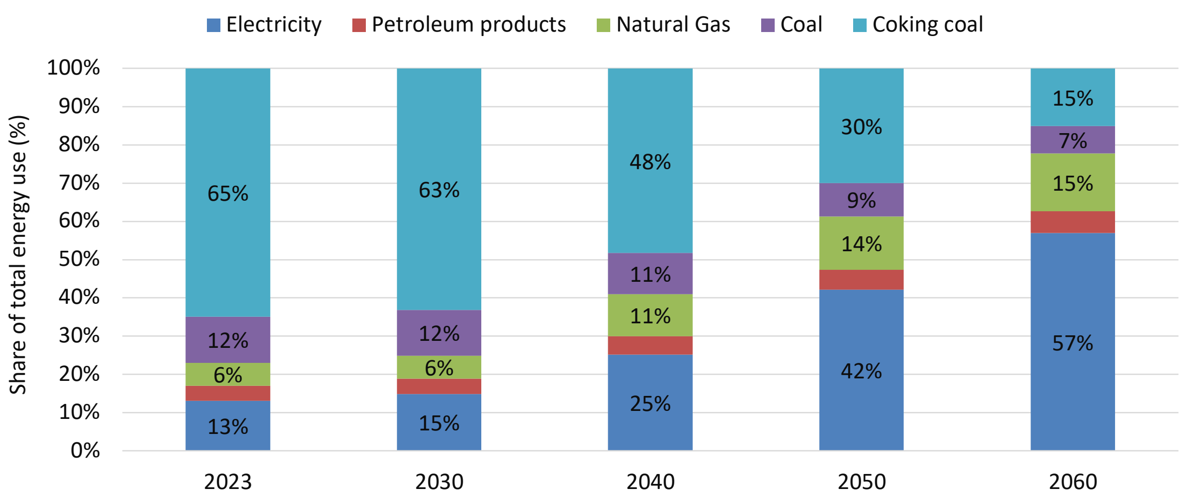


Figure 15. Projected energy mix for Indonesia's steel industry under the Net-Zero scenario, 2023-2060 (Source: this study)

Note: The electricity demand to produce green hydrogen that is used as a reducing agent in green H_2-DRI is shown under "electricity" in this figure.

Another key factor in the decarbonization of Indonesia's steel industry is the carbon intensity of grid electricity, which was 682 kg CO_2/MWh in 2023. Despite this being a slight decrease from previous years, Indonesia still has one of the highest grid emissions factors in the world because of its heavy reliance on coal for power generation. Of the major steel-producing countries, only India has a higher grid emissions factor.

As Indonesia shifts to more EAF and electrified steel production, the CO_2 emissions intensity of electricity will become even more important for the steel industry's overall emissions impacts. Figure 16 shows the power sector's CO_2 emissions intensity forecast in Indonesia under the different scenarios used in this study. In order to develop these forecasts, we assumed that Indonesia's power sector will achieve carbon neutrality by 2060 under the Net-Zero scenario, which is in line with Indonesia's 2060 net zero target. However, even under the BAU scenario, we project that the grid emissions factor will drop significantly, even if Indonesia does not reach Net Zero by then, due to integration of lower-carbon sources of energy into the grid mix.

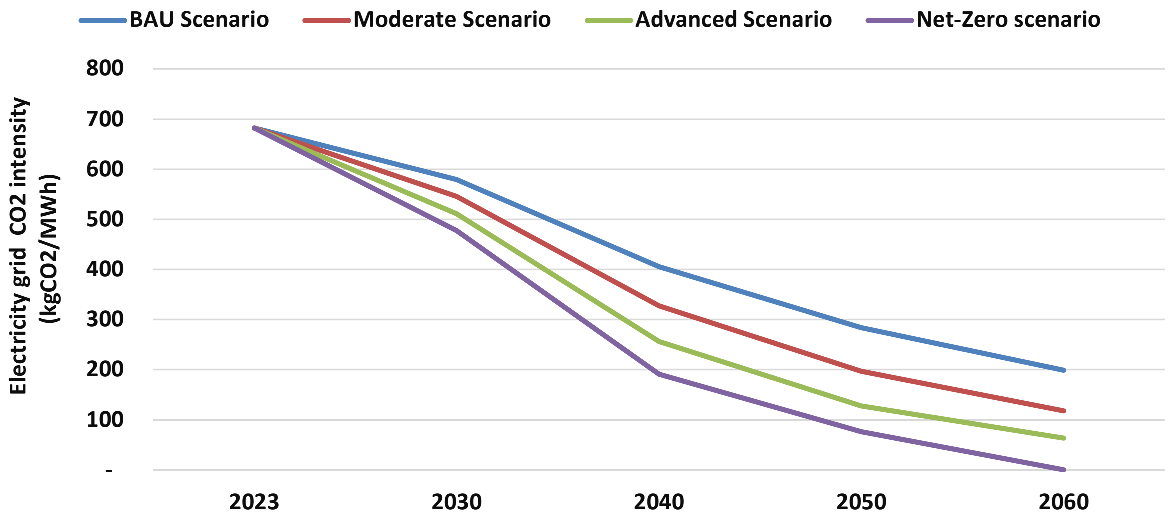


Figure 16. Electricity grid CO_2 emissions intensity forecast in Indonesia under different scenarios (Source: this study)

Modeling Results

Our results show that by 2060, Indonesia's steel industry will use much less thermal coal and coking coal than 2023. This happens because the share of BF-BOF steelmaking will fall sharply. At the same time, electricity use will rise since more steel will come from scrap-based EAF and H_2-DRI-EAF, both of which need more electricity. Despite a substantial increase in electricity use, the total energy demand of the steel industry will rise by only 19% in 2060 compared to 2023, even though steel production is projected to increase by 170% over the same period under the Net Zero scenario (Figure 17). This reflects improved energy efficiency and a shift to cleaner steelmaking methods with lower energy demand per ton of steel produced under the net zero scenario.

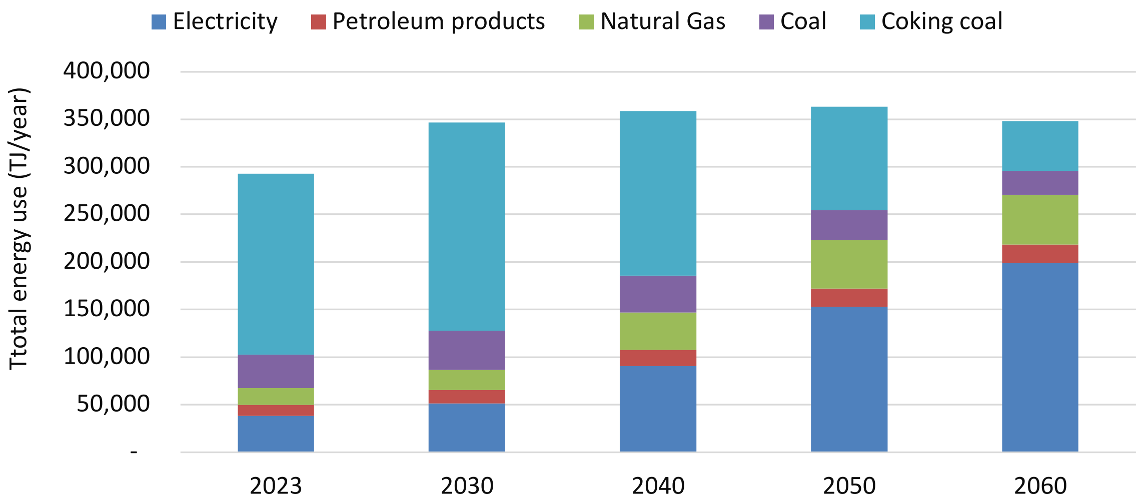


Figure 17. Projected energy use by energy type in Indonesia's steel industry under the Net-Zero scenario, 2023-2060 (Source: this study)
Note: The electricity demand to produce green hydrogen that is used as a reducing agent in green H_2-DRI is shown under "electricity" in this figure.

We find that fuel switching and decarbonization of electricity supply could contribute to 11.5 Mt CO_2 emissions reductions in 2060 under the Net Zero scenario relative to the BAU scenario (Figure 10). This is roughly on par with estimated emissions reductions potential from material efficiency and demand management, and energy efficiency, but it is greater than emissions reductions from imported green iron or CCUS. Figure 11 shows the contribution of this pillar over time to emissions reductions under the Net Zero scenario relative to BAU.

5.4. Technology Shift to Low-Carbon Steel Production Technologies

We explore several low-carbon steel production routes in this report: scrap-EAF steelmaking, DRI-EAF steelmaking (either green H_2-DRI-EAF or NG-DRI-EAF), imported green iron-EAF, and electrolysis of iron ore. Each production technology is introduced below, plus the relevant modeling inputs. Technology shares used in the model and the final results for this pillar are discussed at the end of the chapter.

5.4.1. Scrap-EAF Steelmaking

EAFs are primarily used to produce steel by recycling ferrous scrap, but they can also incorporate DRI, pig iron, or even molten iron up to about 30 percent of the feed mix. EAFs function by generating heat through electric arcs formed between carbon electrodes inserted through the furnace roof, which are adjusted to efficiently melt the charge. Compared to the BF-BOF and DRI-EAF routes, scrap-EAF requires significantly less energy, since the energy-intensive reduction of iron ore is not needed for scrap-based steelmaking. After melting in the EAF, the molten steel is usually sent to a ladle metallurgy station (LMS) for refining to meet specific quality standards. Using EAFs to recycle scrap conserves virgin raw materials, lowers energy use, and significantly reduces the CO_2 intensity of steel production.

Steel Scrap Supply and Demand in Indonesia
In 2023, Indonesia's steel scrap demand grew by 10.7% year-on-year, reaching 18.5 Mt. This rising demand was mostly met by domestic sources, with scrap imports declining by 8.5% to 1.1 Mt (SEAISI 2024). The top sources for imported scrap were Australia, Hong Kong, and Singapore. During the COVID-19 pandemic, scrap was in short supply and domestic scrap prices surged, driven by reduced generation from shuttered factories and fabrication businesses. Mills reported tighter inventories and increased competition for limited scrap, and scrap shortages limited overall steel production. As a result, in 2020, the Indonesian government announced plans to ease import restrictions on scrap metal to boost domestic steel production and reduce dependence on steel imports. Removing scrap from the hazardous waste list and relaxing the contamination limit was meant to simplify import licensing and unlock access to more material for steelmakers. Since the pandemic and these measures, domestic scrap has been better able to meet demand.

As infrastructure in Indonesia reaches the end of its useful life, it presents a significant opportunity to boost domestic steel scrap supply. Much of Indonesia's built environment, including roads, bridges, ports, railways, and industrial facilities, was developed decades ago and is now beginning to age. These aging assets will gradually be decommissioned or replaced, making them potential sources of recyclable steel. However, the long lifespan of infrastructure, often ranging from 40 to 100 years, means that the availability of recoverable scrap will increase slowly over time rather than all at once. Additionally, capturing this scrap for industrial reuse requires significant investment in collection networks, transportation, and processing infrastructure. Without better systems in place to recover and sort scrap efficiently, much of the potential resource could be lost to informal or unregulated channels. Strengthening these systems will be essential for meeting the scrap demand of Indonesia's growing EAF steelmaking.

Modeling Inputs
Based on the share of EAF production in Indonesia's steel industry and the assumed scrap usage rates in both EAFs and BOFs under different scenarios, we estimated the total scrap demand from 2023 to 2060 for each pathway. Under the Net-Zero scenario, scrap demand

reaches approximately 22 Mt by 2060. The Moderate scenario shows the highest scrap demand overall, driven by both a relatively high steel production forecast and greater adoption of the scrap-EAF route. The BAU scenario has more projected scrap than the Net Zero scenario, even though it has lower rates of scrap-EAF adoption, due to the higher overall crude steel production projection compared to Net Zero, which assumes more material efficiency and demand management.

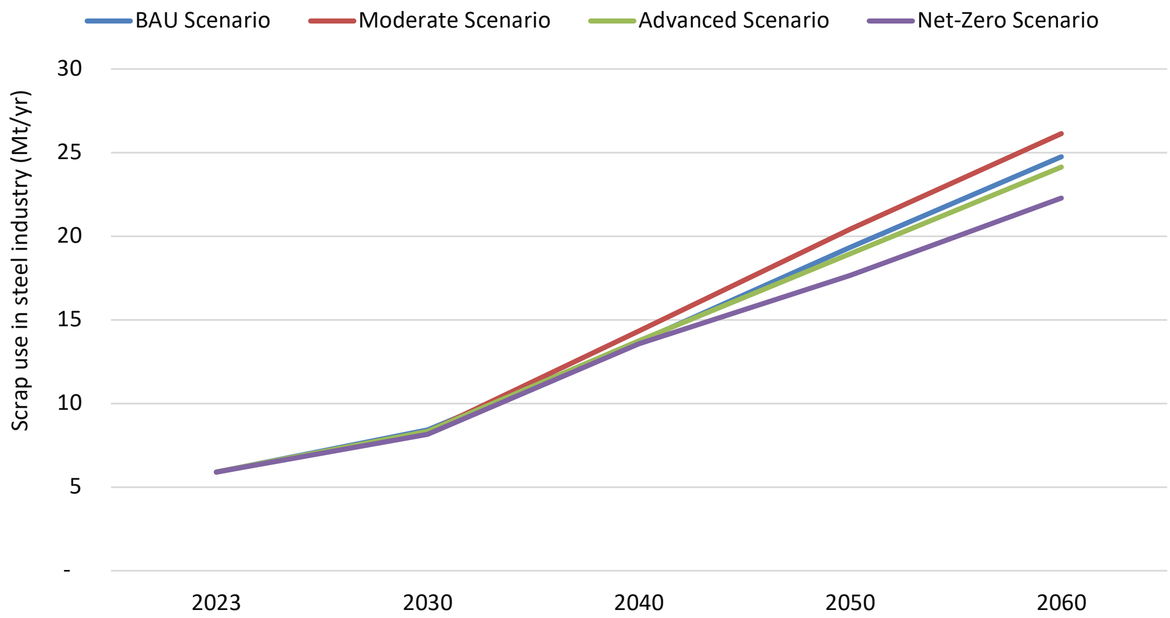


Figure 18. Scrap consumption forecast for Indonesia's steel industry, 2023-2060

Barriers and Solutions for Scrap-EAF Adoption in Indonesia's Steel Industry

The economic feasibility of scrap-based EAF production in Indonesia is closely tied to the availability and price of scrap. While EAF steelmaking can be cost-competitive under favorable conditions, it remains highly sensitive to fluctuations in scrap prices. In the near term, local scrap supply remains constrained by still-developing collection and processing infrastructure, driving up prices and contributing to volatility in scrap availability. In addition, Japan and other countries are increasingly placing restrictions on scrap exports as they work to decarbonize their domestic steelmaking and meet their 2050 climate targets. Geographic disparities further complicate scrap-EAF adoption. In regions with higher scrap availability and better logistics infrastructure, EAF steelmaking is more viable. But in many parts of Indonesia, especially outside Java, collection networks are weak, and transportation costs are high, raising the delivered cost of scrap. Indonesia can stabilize scrap supply and pricing by investing in a national scrap collection and processing strategy. This could include establishing regional scrap aggregation centers, subsidizing sorting and shredding technologies, and supporting professionalization of the scrap trade.

Indonesia also faces structural challenges for its steel industry. Indonesia's steel industry has an average capacity factor of 62%, well below the typical 80% (Swastika and Hasan 2024). This is driven by high import volumes of low-cost steel from China, as well as market disruptions from illegal products. With many facilities operating below capacity and facing slim profit margins, especially in the wake of global steel oversupply and economic uncertainty, steelmakers may be hesitant to invest in new EAF capacity or upgrades to existing equipment.

The regulatory and institutional landscape also presents obstacles. While the government has eased scrap import rules and clarified standards, market participants still face barriers due to the fragmented oversight of scrap processing and recycling. Indonesia's steel scrap industry has formal companies operating alongside informal players. Formal entities are incorporated businesses with structured operations, often adhering to industry standards. These companies are typically involved in large-scale collection, processing, and trading, with clear legal and operational frameworks. In contrast, informal operations include smaller collectors and individual sellers. Informal recycling practices are a challenge, since they often lack proper safety measures, posing environmental and health risks (6Wresearch 2023). Stronger coordination between ministries can streamline scrap industry oversight and formalize standards across the value chain. Training and incentive programs for informal scrap workers to join formal cooperatives or licensed businesses can raise safety and environmental compliance while improving supply chain reliability.

5.4.2. Direct Reduced Iron (DRI) Production

The MIDREX and HYL/Energiron processes are the most commercially mature and widely implemented direct reduction (DR) technologies serving as alternatives to traditional BF ironmaking. Both technologies produce DRI by reducing iron ore in the solid state, eliminating the need for coke and thereby avoiding some of the carbon-intensive steps involved in BF-BOF steelmaking.

The MIDREX process uses a vertical shaft furnace where iron ore pellets or lump ore are introduced from the top and reduced by a hot gas, typically a blend of H_2 and carbon monoxide (CO) derived from natural gas, flowing upward from the bottom. This reduction occurs at temperatures between 800 and 1,050°C, below the melting point of iron. The HYL process (also branded as Energiron) similarly uses a shaft furnace but allows more flexible operation, accommodating a wider range of feedstocks and gas compositions. When DRI from either MIDREX or HYL is melted in an EAF, the overall CO_2 emissions are much lower than in BF-BOF steelmaking, especially if the EAF is powered by low-carbon electricity.

H_2-DRI represents a pathway to near-zero-emissions ironmaking when green H_2 is used as the reducing agent. Producing one ton of steel via H_2-DRI typically requires about 50 to 70 kilograms of hydrogen (Vogl et al., 2018). However, the vast majority of hydrogen produced globally today is derived from fossil fuels using methods like steam methane reforming, autothermal reforming, and coal gasification, all of which are carbon-intensive. Green hydrogen still accounts for only a small fraction of total hydrogen production (Wang et al., 2021), making its limited availability a major hurdle to the wide-scale adoption of H_2-DRI technology.
While shaft furnace technologies like MIDREX and Energiron dominate the current DRI market, they are not the only reduction pathways available.

Fluidized bed DRI technologies, such as FINMET and Circored, offer an alternative route with distinct advantages, particularly in their ability to operate at lower hydrogen concentrations (30–70%) compared to shaft furnaces (which typically require 60–95%) (IEA 2020). This flexibility could be advantageous in early transition phases when green hydrogen supply is constrained or blended with natural gas. Fluidized bed systems also tend to have lower capital costs and offer higher reactivity due to finer ore particles, though they generally require more advanced process control and consistent power supply. These technologies may be better suited for Indonesia's domestic iron ore resources, which are often low in grade or fines-dominant, posing compatibility issues with shaft furnaces that require high-quality pellets or lump ore. In addition, it is important to emphasize that not all DRI technologies deliver the same emissions benefits. For example, rotary kiln-based DRI production typically relies on coal as the reductant and is not compatible with green hydrogen conversion.

Several large-scale H_2-DRI projects are already underway. In Sweden, the HYBRIT initiative, led by SSAB, LKAB, and Vattenfall, launched a pilot plant in Luleå in 2021 and plans a full-scale demonstration facility in Gällivare by 2026. Several DRI projects were under development but were recently paused, including ArcelorMittal's full-scale green H_2-DRI capacity in Gijon, Spain, along with other projects in France (using blue hydrogen) and Germany (pilot scale). Fortescue in Australia and POSCO in South Korea are also pursuing a small pilot hydrogen-based steelmaking project. In China, HBIS Group is building a two-stage DRI facility initially using coke oven gas, with plans to transition to green hydrogen, while Baowu Steel is constructing a 1 Mt/year green H_2-DRI plant in Zhanjiang. Other notable efforts include Rizhao Steel's use of industrial byproduct syngas and Jianlong Steel's pilot project using coke oven gas, aiming for a 0.3 Mt/year capacity (Hasanbeigi et al. 2023).

The Hydrogen Landscape in Indonesia

Indonesia's hydrogen market is emerging as a strategic component of its energy transition. National energy company Pertamina, Pupuk Indonesia fertilizer company, and utility provider PT PLN are spearheading initiatives, though most projects remain in conceptual or feasibility stages. Indonesia's unique geothermal energy resources are being utilized for green hydrogen production. Pertamina Geothermal Energy firm has launched a pilot project in Ulubelu using 300 kW of geothermal capacity to produce around 100 kg per day of green hydrogen, while PT PLN operates Southeast Asia's first geothermal-based hydrogen facility at Kamojang, generating 4.3 tons annually (Argus 2024) (Indonesia Business Post 2024).

By 2050, hydrogen and hydrogen-based fuels including synthetic methane are expected to drive 25% of emissions reductions in the country (Nugraha and Singh 2024). Regional production estimates for 2060 position Nusa Tenggara, South Sumatra, and Riau to be primary development centers for the country's projected low-carbon hydrogen manufacturing potential (Recessary 2024). Domestic consumption of hydrogen lands is currently about 1.75 Mt per year, with a majority of blue and grey hydrogen supply being used as feedstock for the ammonia, fertilizer, and oil refining industries (GH2 2025). Adoption of green hydrogen is gaining momentum through infrastructure like Indonesia's first Hydrogen Refueling Station (HRS) for fuel-cell vehicles which opened in Senayan, Jakarta in February 2024, supporting the growth of an ecosystem for zero-emission transportation using PLN's geothermal-derived hydrogen (Fuel Cell Works 2024). Despite some advances in the transport sector, there is still limited adoption within industrial sectors like steel (IESR 2025).

Indonesia is strategically positioning itself as a regional hydrogen exporter, capitalizing on proximity to high-demand markets like Singapore, Japan, and South Korea. Five major export-oriented projects have been announced, including solar-based hydrogen in Batam for Singapore memorialized through a joint Memorandum of Understanding between the countries promoting green energy trade corridors (Tan 2024). Enabling policies and infrastructure development close to demand for the green hydrogen market is an essential component to compete with blue and grey hydrogen in the long-run, while ensuring supply of a low-carbon feedstock for industry and transportation (IESR 2025). Successful implementation of its hydrogen roadmap could establish Indonesia as a critical supplier in Southeast Asia's decarbonization efforts, provided it addresses gaps between production potential and project execution timelines.

Hydrogen is an important part of Indonesia's 2060 Net Zero Emissions target. The Energy and Mineral Resources Ministry of Indonesia published the National Hydrogen Strategy report in 2023, which outlines a focus on domestic market development, global export ambitions, and energy security (Nugraha and Singh 2024). This was followed by the National Hydrogen and Ammonia Roadmap Book 2025-2060 in 2025, which outlines four sectors that will utilize hydrogen (the industrial sector, power generation, gas networks, and transportation). Based on this roadmap, the steel industry is slated to begin using clean hydrogen in 2025 (Hasjanah 2025).

Strategic collaborations reflect Indonesia's multi-stakeholder approach to green hydrogen development. Notable projects include the $1.2 billion Sarulla Block Initiative in North Sumatra, supported by Samsung and Hyundai, which aims to supply green hydrogen to local steel and cement industries (H_2 Tech 2022). State-owned Pertamina has committed $11 billion to develop green hydrogen and ammonia value chains (Hydrogen Industry Leaders 2025). These efforts align with plans to capitalize on Indonesia's 3,687 HW RE capacity, with a focus on solar and geothermal resources.

The green hydrogen sector faces hurdles from subsidized natural gas, which has a market price of $6 per MMBtu, making fossil-based hydrogen more economically viable in the near term. Insufficient buildout of infrastructure for hydrogen distribution and storage in the country is another significant challenge the industry faces.

Table 3: Announced green hydrogen production capacity in Indonesia by province

Province/Region	Project Name/Details	Timeline	Associated Entities	Announced Hydrogen Production Capacity
Riau Archipelago	10 MW Feasibility	N/A	ReNu - Countrywide Hydrogen - Anantara Energy Holdings MoU	2 kt/yr
Ulubelu	Ulubelu geothermal plant 0.21 MW FID	N/A	Pertamina	<0.01 kt/yr
North Sumatra	Sarulla Block Initiative	N/A	Samsung Hyundai Global Green Growth Institute (GGGI)	N/A
West Java	Garuda Hidrogen Hijau (GH_2) Project Large scale H_2 project	2026	ACWA Power PT PLN PT Pupuk Indonesia	866 kt/yr
Sumba	RENEWSTABLE SUMBA Concept	N/A	N/A	N/A
Borneo	Danish nuclear in Indonesia Concept 1,000 MW	2028	Copenhagen Atomics, Aalborg CSP, Alfa Laval, Topsoe Pupuk Kalimantan Timur (PKT) Pertamina New & RE	205 kt/yr
Central Sulawesi	PT Panca Amara Utama (PAU) Banggai ammonia plant, Luwuk Central Sulawesi Feasibility			126 kt/yr
Jakarta	Co-firing pilot		PLN Indonesia Power	5,800 t/yr
Bali	Co-firing pilot		PLN Indonesia Power	300 t/yr

Sources: World Nuclear News 2022, Chrisna et al. 2025

Modeling Inputs

We assumed that each scenario in this roadmap would have varying levels of adoption for NG-DRI-EAF and green H_2-DRI-EAF over time, with the Net Zero scenario having the most ambitious shares of production from these routes, displacing BF-BOF production. These shares, plus those for other production routes, are shown at the end of this chapter.

Barriers and Solutions for H_2-DRI Development in Indonesia's Steel Industry

Iron Ore Availability and Quality for DRI

The availability and quality of iron ore are key to the successful deployment of H_2-DRI technology. Consistent, high-grade ore is essential to maintain process efficiency and produce high-quality steel in EAFs. DR-grade iron ore, which averages about 67% iron content, is the preferred feedstock for H_2-DRI. However, it currently accounts for only around 4% of global iron ore shipments (IEEFA 2022), and overall ore quality has declined in several regions. This creates a significant constraint, as lower-grade ores with higher impurities can reduce DRI plant productivity and result in greater slag generation and more defects in steel produced via EAFs.

To address these limitations, a number of technical solutions are being pursued. In situations where DR-grade ore is in short supply, alternative materials like BF-grade pellets or fines may be used, though this typically requires added processing to manage impurities and prevent sticking in shaft furnaces. Process adaptations, such as operating DRI plants at different temperatures or employing fluidized bed reactors, can help accommodate lower-quality inputs. Beneficiation techniques, including magnetic separation, flotation, and gravity separation, can upgrade lower-grade ores by removing gangue materials. Blending higher-grade and lower-grade ores is another strategy to meet quality requirements more cost-effectively.

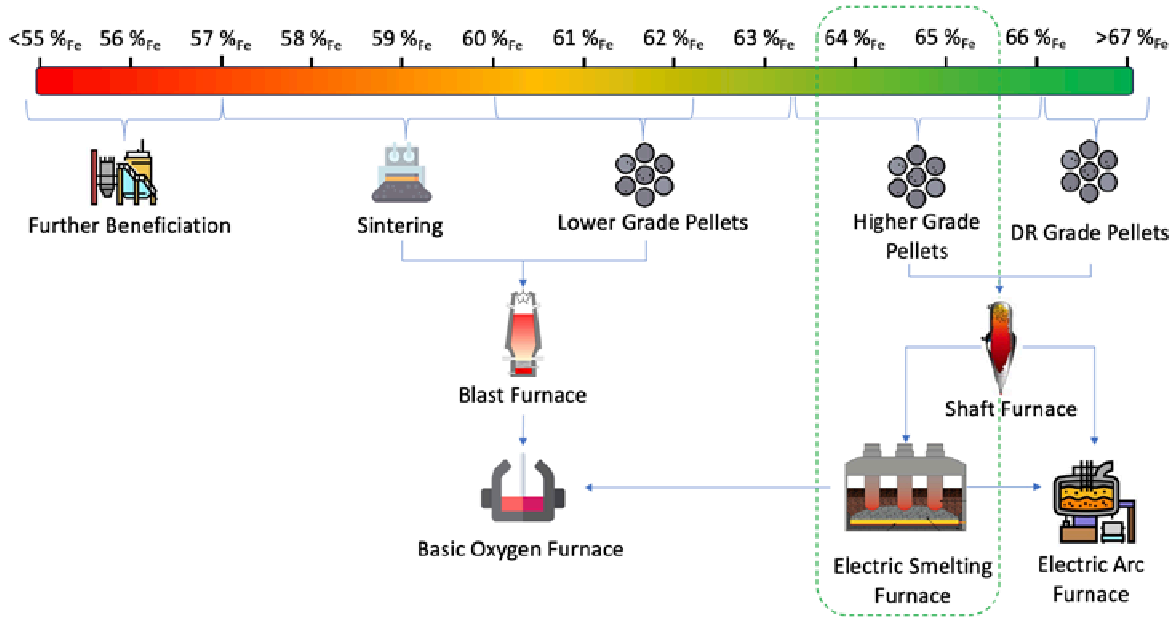


Figure 19. Iron ore grade and steel production routes (Stewart 2023)

Ensuring product quality in H_2-DRI also relies on precise process control and real-time monitoring. Upstream screening systems, frequent material analysis, and automated control technologies help maintain stability and manage challenges such as nitrogen absorption, slag foaming, and bath-mixing, which are issues that become more pronounced when using variable or lower-quality ore. In EAFs, further metallurgical adjustments can help address these challenges. These include adding small amounts of biocarbon, using top lances and bottom stirring for improved mixing, applying slag modifiers to enhance slag behavior, and using techniques like hot heel operation to retain protective slag during arcing.

Looking ahead, improving ore preparation, refining process flexibility, and advancing control systems will be essential to overcoming iron ore quality constraints and enabling the broader deployment of H_2-DRI in green steel production. Indonesia should work with countries like India and Australia, which also have low-quality iron ores, to run joint research on better ore beneficiation and agglomeration methods. They should set up pilot projects to test refining and DRI processes using locally available low-grade ores with hydrogen.

Other Challenges and Solutions

Scaling up green hydrogen and H_2-DRI in Indonesia faces a series of interconnected challenges. The primary barrier to adopting green H_2-DRI in Indonesia is cost. Hydrogen production using renewable electricity remains expensive, with hydrogen costs comprising nearly half of H_2-DRI production costs (Hasanbeigi et al. 2024). This is compounded by relatively high costs of solar and wind power integration and the current absence of a carbon pricing mechanism to level the playing field. There is an estimated $25.2 billion USD in private sector investments needed to reach Indonesia's targets for sustained green hydrogen market expansion by 2060 (The Gulf Observer 2024). Estimated 2040 production costs for green hydrogen in Indonesia fall within a range of $1.90 to $3.90 per kg (Argus 2024), a relatively low price based on global market projections and one that could lead to cost competitiveness with NG-DRI and other steelmaking routes under certain scenarios. Yet, it is projected that the cost of renewable electricity will need to fall below $0.02/kWh to make green hydrogen competitive with blue and grey hydrogen in Indonesia, alongside scaling efficiency of electrolyzers. Potential carbon market and pricing proposals are considered as a pathway to achieve lower prices, along with corporate incentives and subsidies for hydrogen ventures to increase overall domestic supply (ISER 2025).

Another challenge is metallurgical and technical complexities. Adapting Indonesia's existing BF-BOF steel infrastructure to accommodate H_2-DRI will be a massive undertaking. Challenges include poor slag foaming without carbon, variations in DRI melting behavior, and limitations in using low-grade domestic iron ore. Indonesian producers will need to invest in furnace retrofits, material handling systems, and biocarbon injection methods, while improving pellet quality through beneficiation or blending.

In addition, there are significant clean energy and infrastructure requirements for green hydrogen production. Green hydrogen production is highly energy- and water-intensive, requiring large-scale RE deployment and transmission systems. For Indonesia, with its abundant but unevenly distributed solar and wind resources, this means building integrated hubs where renewable power, electrolysis, and steel production co-locate. Infrastructure for water treatment, hydrogen storage, and long-distance transport must also be developed.

Green H_2-DRI steelmaking also needs strong support from regulation, standards, and policy alignment. Indonesia lacks a dedicated regulatory framework for hydrogen production, safety, and use in steelmaking. Without clear emissions benchmarks or green certification schemes, producers lack market signals to invest in cleaner pathways. Introducing H_2-DRI-specific safety codes, creating standards for green hydrogen classification, and aligning industrial policy with RE and emissions trading frameworks will be necessary.

Finally, stakeholder engagement and skill development pose a challenge to scaling up green H_2-DRI steelmaking. Green H_2-DRI steelmaking scale-up will depend on building public and private sector awareness and capabilities. Indonesia's workforce will need targeted training in hydrogen safety, electrolyzer operation, and EAF process optimization, while managerial staff will benefit from training on green steel technologies and their multiple advantages. Figure 20 below provides a visual summary of these challenges and potential solutions. Solutions and recommendations are discussed further in Chapter 7.

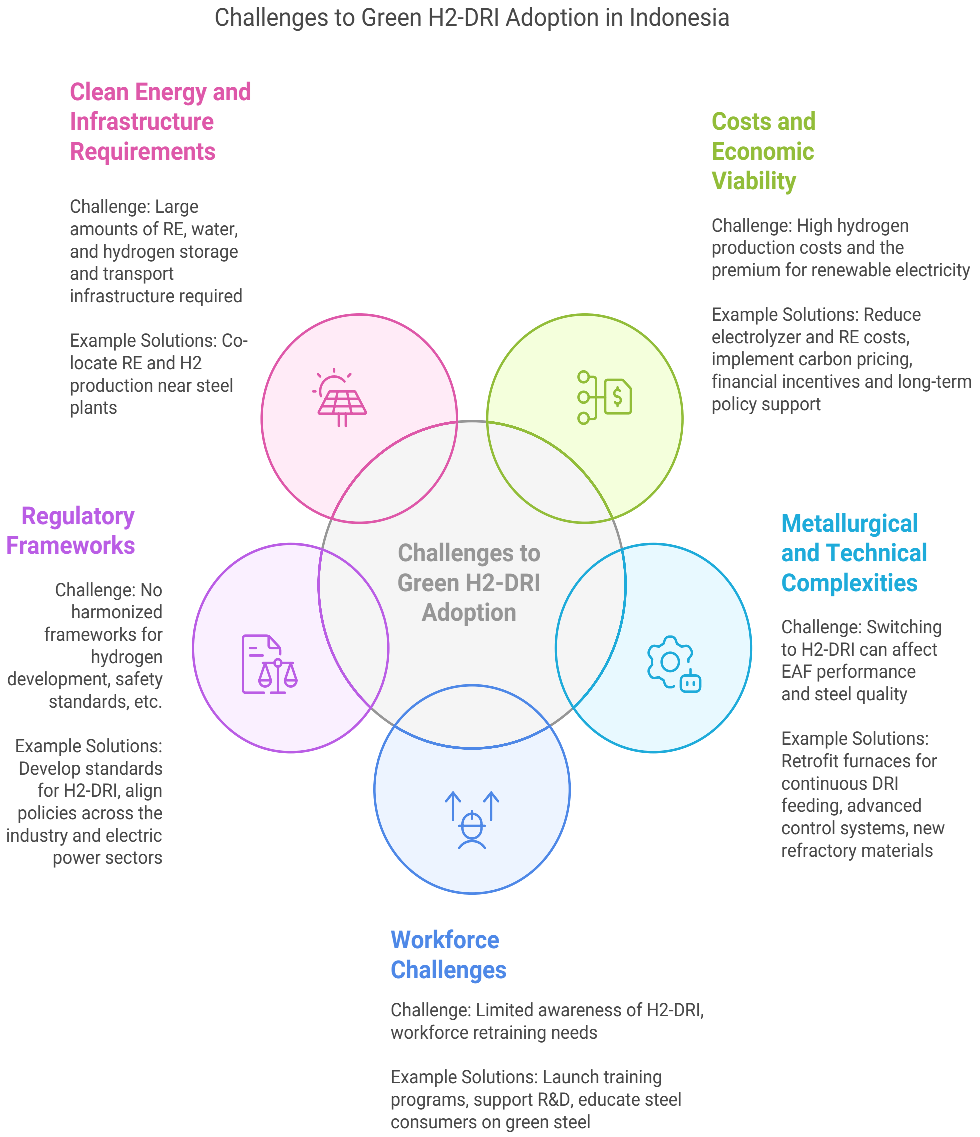


Figure 20: Summary of challenges to green H_2-DRI adoption (Source: adapted based on Hasanbeigi et al. 2024)

5.4.3. Green Iron Trade

Importing green iron, especially green H_2-DRI or hot briquetted iron (HBI), can be a key lever for the decarbonization of Indonesia's steel industry. The ability to access low-carbon iron inputs can enable a faster, more cost-effective shift to low-carbon steelmaking. By substituting carbon-intensive domestic iron with imported green HBI or DRI, Indonesia can avoid the technical and infrastructure challenges of domestic green hydrogen production in the near term while still achieving substantial CO_2 reductions. There could also be cost advantages for importing green iron from producing countries that can scaled up their green hydrogen production and infrastructure at a lower cost.

There are multiple forms of iron traded internationally, including iron ore, pelletized iron ore, DRI, and HBI. HBI is particularly attractive for Indonesia because it is denser and safer to transport over long distances, and it can be easily fed into EAFs to produce high-quality steel with minimal additional processing. Key current and emerging exporters of green iron and DR-grade pellets include Australia, Brazil, Canada, and South Africa. Australia, in particular, is investing heavily in green iron production projects such as Fortescue's Green Metals project, which is piloting green hydrogen to produce sponge iron and green iron metal and plants with the goal of eventually exporting 100 Mt of green iron per year to China (Fortescue Metals 2025). The NeoSmelt project is another initiative in Australia aiming to produce low-emissions green iron by transforming Pilbara iron ore using an electric smelting furnace (ESF) at Kwinana Industrial Area. Developed by a consortium including BlueScope, Rio Tinto, BHP, and Woodside, NeoSmelt will initially use natural gas as a reductant with plans to transition to green hydrogen over time (SEAISI 2025).

Brazil's Vale is also developing a global network of "mega hubs", including in Saudi Arabia, Oman, and the UAE, to produce low-carbon briquetted iron for regional and international markets, leveraging abundant RE resources in the selected hub locations to decarbonize iron production at scale (Vale 2024). Vale's hubs concentrate iron ore processing near renewable or lower-carbon energy sources, produce briquetted green iron, and then export it to steelmakers for EAF production. Initially powered by natural gas in some regions, these hubs aim to transition to green hydrogen as costs decline, and infrastructure matures.

Modeling Inputs
For the scenarios in this model, we assume a small share of imported green iron from 2040 onwards for the Moderate, Advanced, and Net Zero scenarios, with the Net Zero scenario having the highest shares, displacing BF-BOF production. These shares, plus those for other production routes, are shown at the end of this chapter.

Barriers and Solutions for Green Iron Import in Indonesia's Steel Industry
Despite the potential benefits of green iron imports for decarbonizing Indonesia's steel industry, several challenges could hinder uptake. First, Indonesia currently lacks a clear policy or regulatory framework that recognizes green iron as a strategic input for industrial decarbonization, making it difficult to integrate imports into national planning or secure targeted incentives. Trade barriers such as existing tariffs and customs classifications may further disincentivize imports unless they are revised to account for the climate benefits of certified low-carbon materials. Infrastructure gaps, such as inadequate port facilities, specialized storage capacity, and safety protocols for handling green iron, could also delay or complicate deployment.

To fully realize the safety, economic, and environmental benefits of green iron trade, several measures should be prioritized. First, green iron imports should be incorporated into national and sectoral decarbonization strategies, complementing domestic scrap use in the transition toward lower-emission steel production. Trade and industrial policies can play an important role by facilitating green iron imports, such as through tariff adjustments and incentives for the use of certified low-carbon inputs. There will need to be regulations for the safe handling, transportation, and storage of green iron in order to safeguard environmental and operational integrity. Finally, early engagement with major exporting countries and project developers can help secure reliable, sustainable supply arrangements and technical collaboration to support the broader shift toward a low-carbon steel industry.

5.4.4. Electrolysis of Iron Ore

Electrolytic processes use electricity to break the chemical bonds between iron and oxygen in iron ore, producing metallic iron and oxygen gas as the sole byproduct. When powered by renewable electricity, this process can achieve eliminate CO_2 emissions compared to conventional BF-BOF production.

Molten oxide electrolysis currently represents the most advanced high-temperature electrolytic approach to iron production. In this process, iron ore is dissolved in a molten electrolyte solution at temperatures around 1,600°C, above the melting point of iron. An electric current is passed through the solution, causing iron ions to migrate to the cathode where they are reduced to liquid metallic iron, while oxygen ions move to the anode and are released as oxygen gas. Boston Metal has pioneered this technology, developing modular MOE cells that can process all grades of iron ore directly into high-purity liquid metal (Winn 2024). The process produces liquid iron that can be sent directly to ladle metallurgy without the need for reheating, offering significant process simplification.

Low-temperature electrowinning processes operate at much lower temperatures compared to MOE, typically between 25-110°C, using aqueous electrolyte solutions. In the ULCOWIN process developed under the European ULCOS project, iron ore particles are suspended in an alkaline electrolyte solution at approximately 100-110°C. Electric current passes through the solution, attracting oxygen particles to the anode while elemental iron forms crystals on the cathode surface. ArcelorMittal's Siderwin project is developing a three-meter industrial pilot cell for this technology (U.S. Department of Energy 2022). The process has demonstrated the ability to operate in a highly flexible start/stop mode, making it ideal for power grids dependent on intermittent RE sources. Companies like Electra have developed novel electrowinning processes that can handle lower-grade ores, heating the solution to about 60°C and producing iron plates ideal for electric arc furnaces (Chant 2025).

Modeling Inputs
For the scenarios in this model, we assume that electrolysis of iron ore could account for a very small share of steel production in Indonesia from 2050 under the Moderate and Advanced scenarios, and from 2040 under the Net Zero scenario. These shares, plus those for other production routes, are shown at the end of this chapter.

Barriers and Solutions to Electrolysis of Iron Ore
The primary technical challenges for electrolytic ironmaking center on scale, throughput, and energy efficiency. The largest bottleneck is that iron production rate is limited by current density delivered from electrode surface area (Chang et al. 2021)wherein coke reduces iron ore to iron. The global steel industry is developing ironmaking decarbonization strategies,

but significant challenges remain, particularly developing solutions at a cost that would incentivize blast furnace retrofit or replacement. We analyze new technology concepts that could completely decarbonize ironmaking if demonstrated and scaled. First, we present the energy-emissions-cost tradespace of existing and pilot-scale ironmaking technologies and identify whitespace opportunities. Then, we propose three requirements for any candidate technology to decarbonize ironmaking at scale: levelized cost of steel, GHG intensity, and the future scalability of all inputs. Next, we evaluate several early clean ironmaking technology categories that could meet these criteria: (1. For high-temperature processes like MOE, challenges include the high upfront capital costs, baseload electricity requirements to maintain molten conditions, and the need for inert anodes that can withstand extreme operating conditions. Low-temperature processes face challenges related to potentially slower reaction rates and the need for intermittent operation optimization.

Current commercial readiness varies significantly across technologies. Boston Metal has already begun producing liquid iron and ferroalloys in demonstration plants, with commercial operations planned for the coming years. Low-temperature electrowinning processes like Siderwin have progressed to Technology Readiness Level 4-6, with industrial pilots under construction (worldsteel association 2021).

In countries like Indonesia, scaling up electrolytic ironmaking presents additional challenges beyond the core technical hurdles of throughput and efficiency. First, electrolytic processes require access to large volumes of low-cost, reliable, and preferably renewable electricity, something that remains a constraint in many parts of Indonesia due to grid limitations and reliance on fossil-based generation (see Section 5.3.). Developing the infrastructure to support high-temperature electrolysis, such as facilities that can maintain stable molten oxide conditions, is capital-intensive and may be infeasible in regions with limited industrial baseload capacity. Furthermore, Indonesia lacks a domestic supply chain for critical components like inert anodes and corrosion-resistant materials, increasing dependence on imports and driving up costs. These barriers are compounded by limited domestic research and development capacity in electrochemical metallurgy, slowing technology adaptation and localization. Given the early-stage status of this technology, we do not anticipate significant adoption for at least several more decades.

5.4.5. The Impact of the Technology Shift Pillar on the Steel Industry

To model the emissions impacts of the technology shift pillar, we assumed different shares of different steel production routes in Indonesia's total steel output through 2060. Figure 21 presents the assumed contribution of each route across all scenarios. In the BAU scenario, BF-BOF production continues to rise steadily. However, in the Moderate, Advanced, and Net Zero scenarios, BF-BOF output increases through 2030, reflecting existing capacity plans, before declining significantly in the Advanced and Net Zero pathways. Meanwhile, scrap-EAF production increases substantially across all scenarios, playing a larger role in the country's steel production mix.

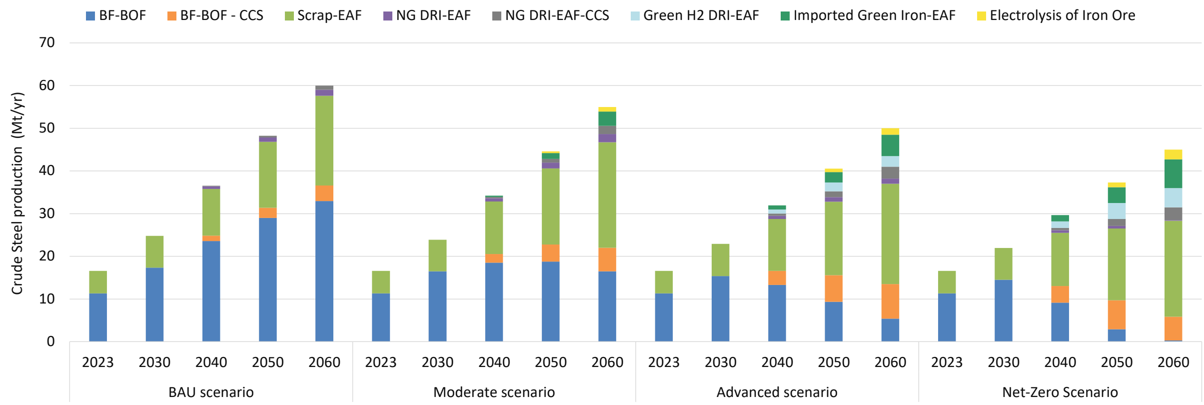


Figure 21. Crude steel production by technology type under each scenario, 2023-2060 (Source: this study)

Figure 22 presents the share of each steelmaking technology in total steel production under the Net-Zero scenario. Under the Net Zero scenario, we project that the scrap-based EAF production route will account for 50% of total steel production in Indonesia by 2050. BF-BOF production with CCUS will account for 12% of production, while unmitigated BF-BOF production will almost be entirely displaced. Low-carbon steelmaking technologies other than scrap-EAF will make up 37% of steel production combined. These technologies include NG-DRI-EAF with CCUS (7% in 2060), green H_2-DRI EAF (10%), electrolysis of iron ore (5%), and imported green iron-EAF (15%), wherein the imported green iron was produced via green H_2-DRI in another country before being melted into steel in an EAF in Indonesia.

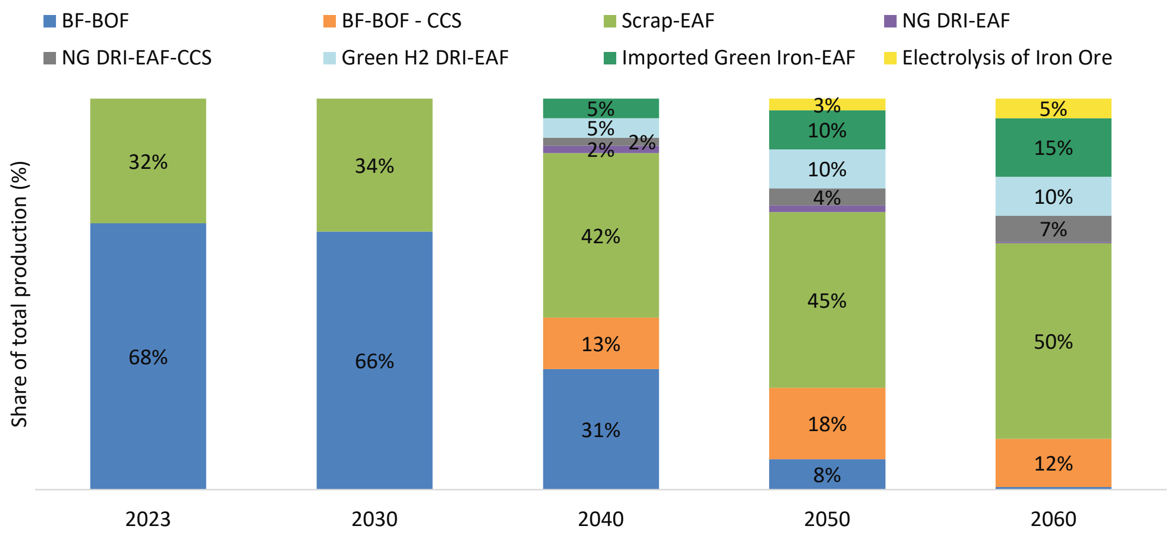


Figure 22. Share of steel production technologies under the Net Zero scenario up to 2060 (Source: this study)

Modeling Results

Technology shifting toward lower-carbon iron and steel production routes is the largest driver of emissions reductions in the Net Zero scenario, as detailed in Section 4.2, accounting for 20 Mt of emissions reductions in 2060 relative to the BAU scenario from scrap-EAF, NG-DRI-EAF and green H_2-DRI-EAF, and electrolysis of iron ore. This amount is almost double the emissions reductions delivered by each of the preceding three pillars (material efficiency, energy efficiency, and fuel switching/electricity decarbonization). In addition, our modeling results presented in Section 4.2. show that green iron import in Indonesia could reduce 2060 BAU emissions by 8 Mt CO_2/year under the Net Zero scenario, a larger amount than CCUS.

Two low-carbon steelmaking technologies that are quite impactful in our roadmap to reduce GHG emissions in Indonesia's steel industry are scrap-based EAF and green H_2-DRI-EAF steelmaking. Results for these two technologies are further broken down below.

Green H_2 Production, Electricity, and Electrolyzers for Indonesia's Steel Industry

A substantial amount of hydrogen production is needed to supply hydrogen for H_2-DRI-based steel production processes. Figure 23 shows the total hydrogen demand for Indonesia's steel industry under the different scenarios. In the Net Zero scenario, we project that hydrogen demand could start at 89 kilotons (kton) per year in 2040 and increase to 270 kton by 2060. Note that the BAU and Moderate scenarios assume no H_2-DRI steel production.

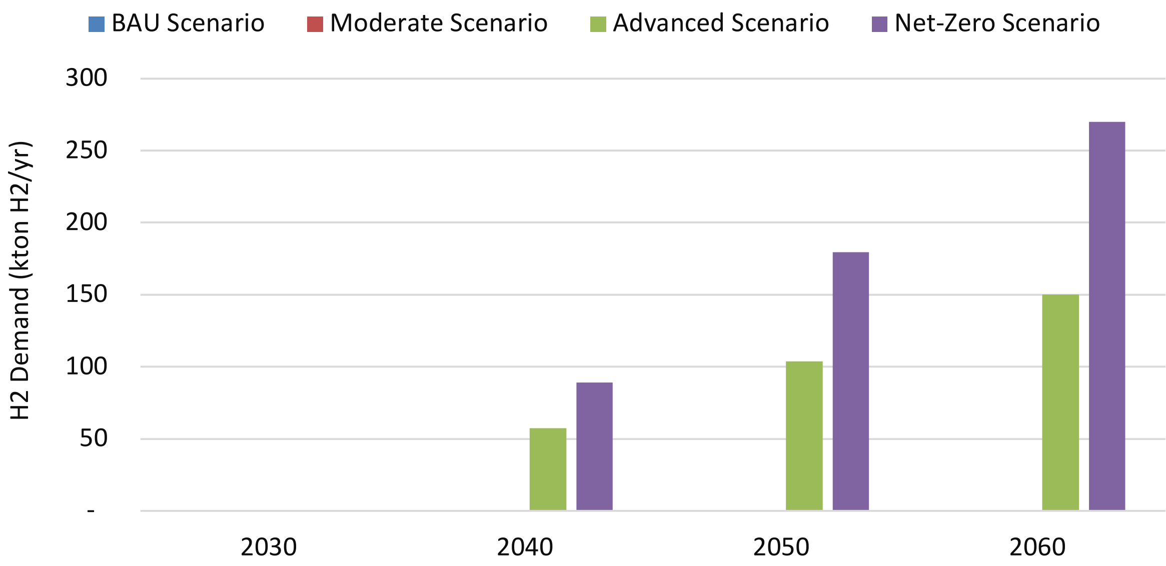


Figure 23. Total additional hydrogen demand for Indonesia's steel industry under different scenarios (Source: this study)

For our analysis, we assumed that the hydrogen used in Indonesia's steel industry will be green hydrogen. Green hydrogen decreases CO_2 emissions but increases electricity demand. Figure 24 shows the additional annual electricity consumption for green hydrogen production for Indonesia's steel industry under the different scenarios. Green hydrogen production to meet the steel industry's demand in Indonesia increases annual electricity consumption by 5, 10, and 15 TWh/year in 2040, 2050, and 2060, respectively, under the Net-Zero scenario. For comparison, Indonesia generated 344 TWh of electricity in 2024, indicating that future green hydrogen production would only make up a very small share of demand for growing electricity production.

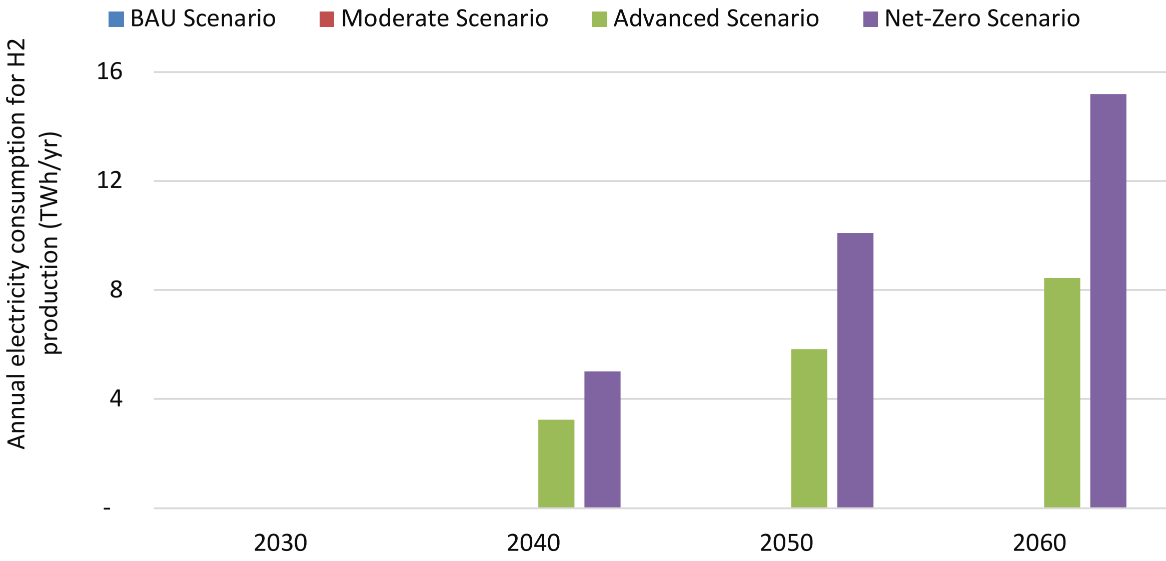


Figure 24. Additional annual electricity consumption for green hydrogen production for Indonesia's steel industry under different scenarios (Source: this study)
Note that the BAU and Moderate scenarios assume no H_2-DRI steel production.

To maximize the decarbonization benefits of H_2-DRI, additional investment is needed in renewable power generation, distribution, and green hydrogen production capacity in Indonesia. Figure 25 shows our estimate of total electrolyzer capacity needed for green hydrogen production for Indonesia's steel industry under different scenarios. For example, under the Net Zero scenario, about 4.3 GW of electrolyzer capacity (equivalent to over 430 units of 10 MW electrolyzers if this module sizes are used) would need to be built by 2060 to meet green hydrogen demand. We assumed a 40% capacity factor for electrolyzers when estimating the required MW.

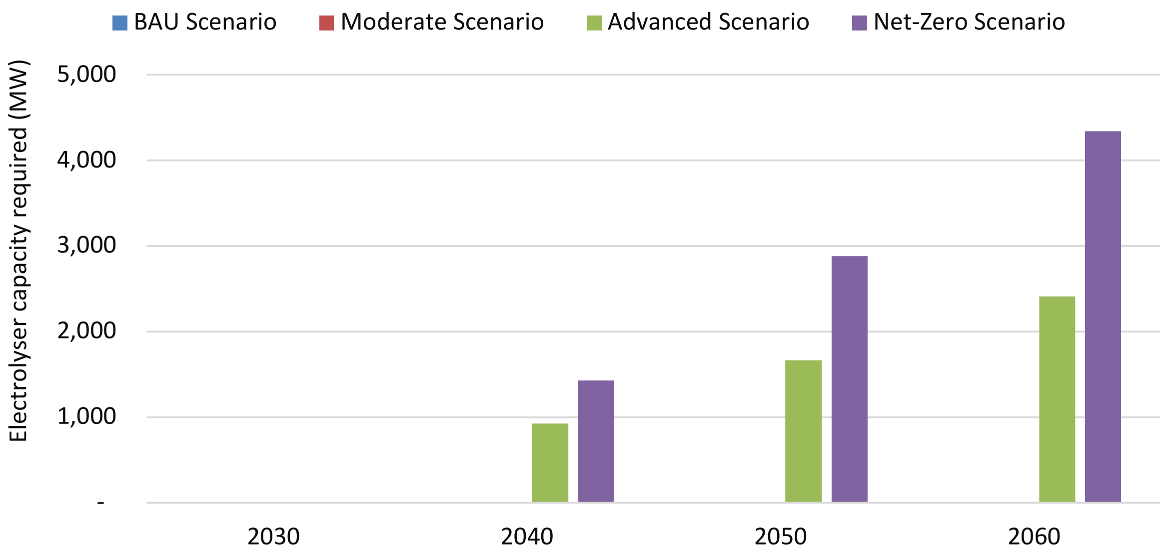


Figure 25. Electrolyzers capacity required for hydrogen production for Indonesia's steel industry under different scenarios (assuming 40% capacity factor for electrolyzers) (Source: this study)
Note that the BAU and Moderate scenarios assume no H_2-DRI steel production.

Optimal Siting of EAFs in Indonesia
Current EAF operations in Indonesia rely heavily on imported scrap and localized prompt scrap from local manufacturing. To optimize EAF viability, facilities should be sited near industrial hubs like Banten or East Java, where automotive and machinery sectors generate prompt scrap, and close to major ports such as Jakarta or Surabaya to streamline scrap imports. Centralized scrap processing centers in these regions could reduce scrap transportation costs.

Indonesia's archipelago geography makes proximity to ports and rail networks critical for EAFs that need constant scrap supply. Special Economic Zones (SEZs) in Batam and Banten can offer established infrastructure, including deep-sea ports and inter-island connectivity, which are essential for importing high-quality scrap and transporting finished steel domestically or internationally. Energy availability is another key constraint. Siting EAFs near RE projects, such as solar farms in East Nusa Tenggara or hydropower in North Sumatra, could align with the need for electricity decarbonization (discussed further in Section 5.3.).

5.5. Carbon Capture, Utilization, and Storage (CCUS)

The implementation of CCUS systems can decarbonize various steel production routes, such as top-gas recycling in blast furnaces with CCUS, DRI with post-combustion CCUS, and oxygen-rich smelt reduction with CCUS. These CCUS technologies vary greatly in their commercialization status, with most of them currently at the pilot stage. The CO_2 emissions captured from iron and steel production can be permanently stored underground (storage), or used to produce chemicals, fuels, construction materials, etc. (utilization).

CCUS applications in the steel industry are currently almost entirely at the pilot or early development stage. As of late 2024, only one commercial-scale CCUS facility (Al Reyadah in the UAE) operates in conjunction with a steel plant, capturing 26.6% of that plant's total emissions. No commercial CCUS facilities exist for blast furnace-based steelmaking, the sector's most carbon-intensive process. Of the six commercial-scale steel-related CCUS projects in the global pipeline, nearly all lack confirmed timelines, capture capacities, or clear storage strategies.

Carbon utilization offers a complementary pathway to CCUS for decarbonizing the steel industry by converting CO_2 emissions into valuable products rather than treating CO_2 as waste. In steel production, captured CO_2 can be used to produce chemicals, fuels such as ethanol, and construction materials like carbonated slag for cement and concrete. Technologies like ArcelorMittal's partnership with LanzaTech, where carbon monoxide from blast furnace waste gases is converted by microbes into ethanol, demonstrate the potential of industrial-scale carbon utilization. However, while some applications like slag carbonation are already commercialized, most carbon utilization technologies remain at early stages of development, facing technical, economic, and scalability challenges. Significant RD&D is needed to lower costs, improve material performance, develop standards, and better integrate carbon utilization into industrial operations (U.S. Department of Energy 2022).

One of the key challenges to steel sector CCUS is the high cost and complexity of CCUS infrastructure. Capturing emissions from multiple point sources in a BF-BOF facility requires substantial retrofitting, and the logistics of CO_2 transport and storage add further cost and uncertainty. Even when capture is technically feasible, as in gas-based DRI plants, the overall emissions reduction can be modest once upstream methane leakage and energy use are factored in. Recent data from pilot projects in the U.S. and China show that real-world capture rates often fall well below design expectations. Furthermore, many projects rely on enhanced oil recovery (EOR) to justify their economics, undercutting their net decarbonization benefit.

Despite this, several major steelmakers, including Nippon Steel, ArcelorMittal, and BHP, continue to promote CCUS in. However, most new low-carbon steelmaking capacity announced globally through 2030 is based on hydrogen-based DRI, not CCUS. The project pipeline for green DRI is 96 Mt per year, dwarfing the 1 Mt/year pipeline for steel-related CCUS (Nicholas and Basirat 2024).

A helpful framework for assessing CCUS deployment potential is the "CCUS Ladder" (Figure 26). The ladder ranks industrial subsectors by how suitable they are for CCUS based on five key criteria: technical feasibility, mitigation potential, availability of alternative decarbonization technologies, risk of locking in fossil fuel use, and geographic concentration of emissions sources. Steelmaking consistently ranks low on this ladder due to its complex emission profile, abundance of cleaner alternatives like green hydrogen DRI, and the dispersed nature of emissions across processes and facilities. As a result, even organizations like the International Energy Agency (IEA) have scaled back projections for steel-sector CCUS.

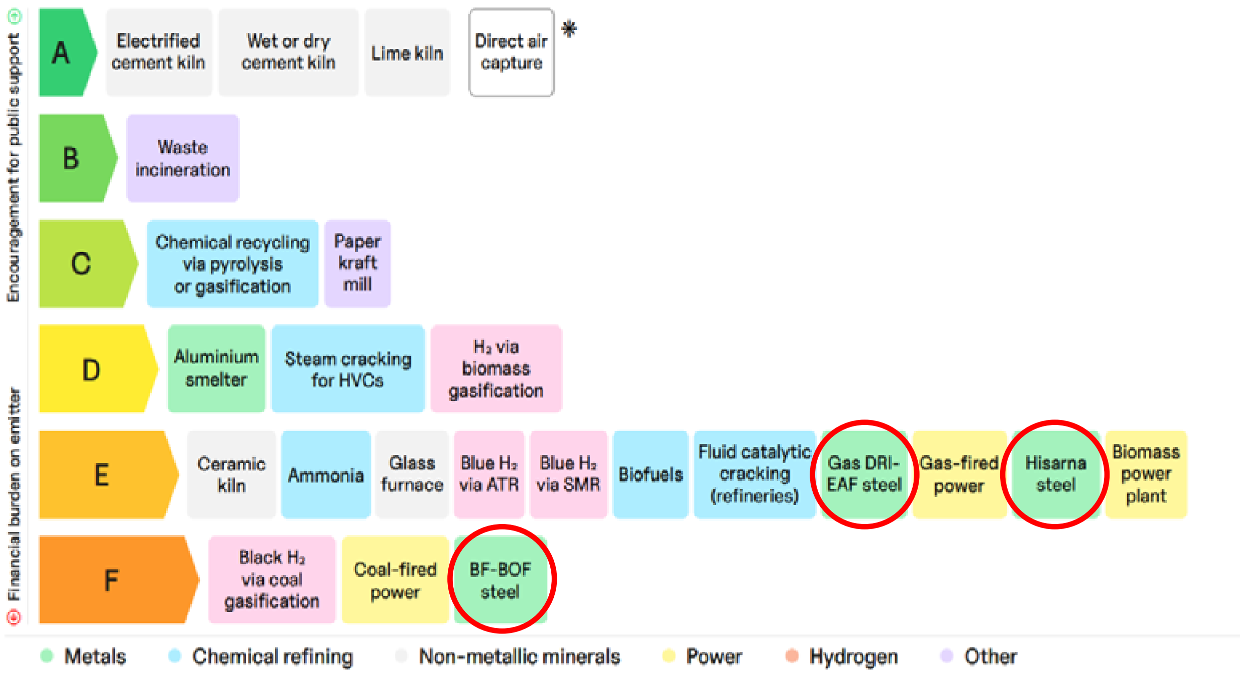


Figure 26: CCUS Ladder for long-term viability of CCUS technologies (Source: E3G and Bellona via Nicholas and Basirat 2024); steel production processes circled

While niche applications of CCUS may emerge in specific contexts, such as NG-DRI plants with co-located storage sites, its broader role in steel sector decarbonization appears increasingly limited. High capture costs, low rates of actual emissions reduction, infrastructure delays, and limited learning spillovers make it a risky bet compared to electrification and green hydrogen. Given these realities, steelmakers and policymakers should prioritize technologies with greater potential to scale, such as H_2-DRI and scrap-based EAF production powered by renewable electricity, while reserving CCUS only for highly constrained use cases.

CCUS in Indonesia

Indonesia's CCUS project pipeline is growing, driven by regulatory reforms and cross-border partnerships. Second only to China, Indonesia ranks highly in the share of total CCUS projects across Asia. Future projections estimate a future project growth rate of 200% as pilots, demonstrations, and partnerships accelerate scaling and commercialization (Rara Energy Consulting 2025), with key examples like ExxonMobil's investment in a CCUS facility and petrochemical plant (Bo-yu 2025). However, the entirety of Indonesian CCUS projects in the operation and development stage are currently for the oil and gas sector, and as of 2024, no dedicated CCUS projects in the steel sector have been announced. However, broader CCUS projects could eventually incorporate management of steel emissions.

The storage potential for captured CO_2 from steelmaking is strong due to Indonesia's extensive network of saline aquifers and depleted oil and gas reservoirs, which host a potential CO_2 storage capacity of 400 to 600 gigatons (Rara Energy Consulting 2025). The unique geographical advantages of the archipelago allow for a vast supply of geological storage capacity. An expanding network of fifteen CCUS sites, eight of which will be coming online by 2035, may lower storage costs compared to other regions and position it as a regional carbon storage hub. Indonesia's recent MEMR Regulation 2/2204 allows contractors to use new wells or converted old wells for CCUS, in addition to state-owned saline aquifers or depleted reservoirs, after engineering studies and small-scale tests for CCUS storage are completed (Ashurst 2024). A projected 68.2 Mt of cumulative CO_2 is expected to be stored across fifteen projects in the country by 2035 (Asia CCUS Network 2024).

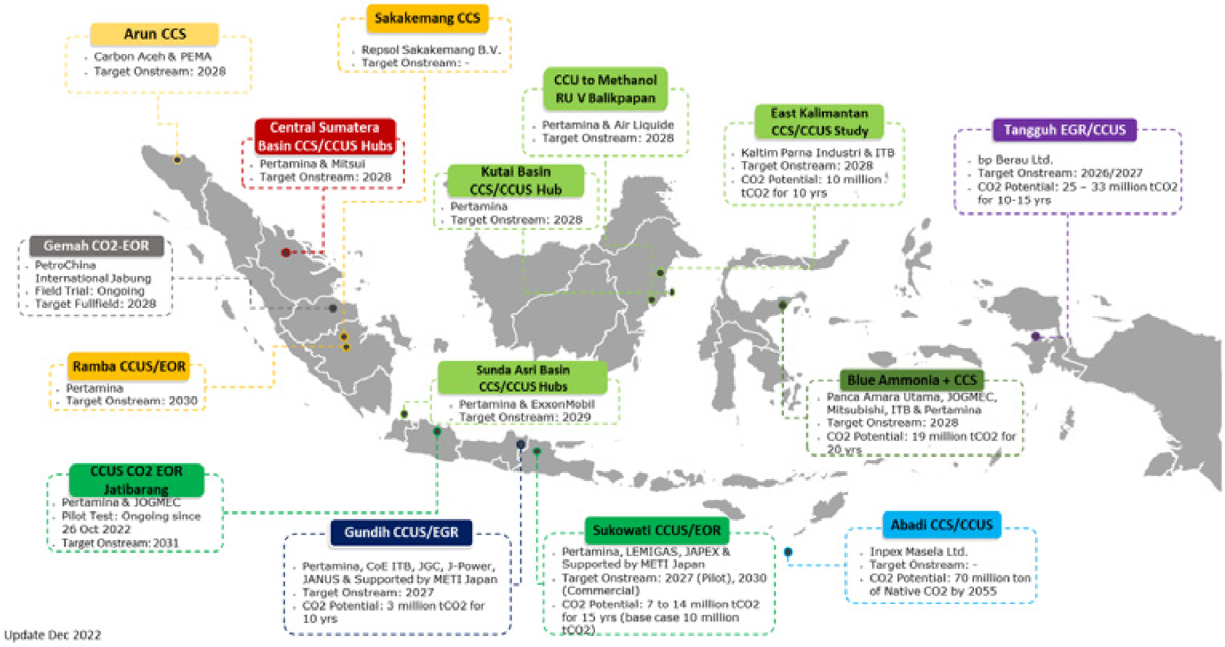


Figure 27. CCUS Projects under development in Indonesia. Source: Asia CCUS Network 2024, IEA 2023.

There is potential alignment between CCUS projects under development and crude steel production facilities in Indonesia based on geographic proximity and project readiness. Several regional pairings offer opportunities to expand CCUS pipelines to the steel sector, with many CCUS projects located in CO_2-EOR (extended oil recovery) sites, or depleted oil reservoirs. A key region for development is Java, particularly Central and West Java, where major steel production clusters are located near advanced CCUS projects including Gundih, Jatibarang, and the Sunda Asri Basin. These projects are already in pilot or near-development stages and offer sufficient CO_2 storage potential for partnerships with steel producers. Other feasible regions are North Sumatra and Aceh, where steel facilities are located close to the Arun CSS, Central Sumatera Basin, and Sakakemang projects, all expected to come online around 2028. In contrast, regions like East Kalimantan, Sulawesi, and Papua show high CCUS potential but have fewer or more dispersed steel facilities, making them less optimal for steel-derived CCUS deployment.

The cumulative CO_2 storage capacity in Indonesia's saline aquifers is projected at 276,017 Mt CO_2. Basin level assessment finds key basins in Borneo including Kutai, Tarakan, and Barito, collectively contributing about 415 Mt of CO_2 storage capacity (Romal et al. 2024). Overall, much more effort has been dedicated to development of depleted reservoirs for CCUS rather than saline aquifers in Indonesia.

Table 4. CCUS capacity of saline aquifers in Indonesia

Basin	CO_2 Storage Capacity (Mt)	Region
Central Sumatra	11,032	Sumatra
South Sumatra	26,954	Sumatra
West Natuna	38,255	Natuna
North Sumatra	111,990	Sumatra
Northwest Java	27,842	Java
East Natuna	59,944	Natuna
Kutai	44,550	Borneo
Tarakan	7,061	Borneo
Barito	8,256	Borneo
Total	276,017	

Source: Zhang and Lau, 2022.

According to PLN, capture costs for CO_2 from coal plants in Indonesia are estimated at $40 per ton, which is higher than for gas plants and other mitigation measures (Bo-yu 2025). Studies on the cost implications of CCUS in Indonesia's steel industry are currently lacking, with most of the economic feasibility research centered on natural gas processing sites (Romal et al. 2024). Capture of CO_2 from low concentration stream activities such as steel is typically more costly and would require additional upfront investment to implement, potentially deterring steel companies from CCUS projects (IEA 2023).

Modeling Inputs

In our analysis, we assumed various adoption rates of CCUS technologies in Indonesia's steel industry across scenarios for BF-BOF steelmaking and conventional DRI plants. Under the Net-Zero scenario, we assumed that 95% of BFs and NG-DRI plants would adopt CCUS by 2060. We assumed capture efficiency would increase over time, reaching 70% by 2060 for BFs and 80% for NG-DRI plants in 2060, which will be newer and more efficient. We also assumed that CCUS would be applied to residual emissions after other technologies were adopted.

Modeling Results
We estimate that CCUS could reduce CO_2 emissions by 6 Mt under the Net Zero scenario and by 2 Mt the BAU scenario in 2060. Figure 28 shows the CO_2 emissions captured by the adoption of CCUS in Indonesia's steel industry.

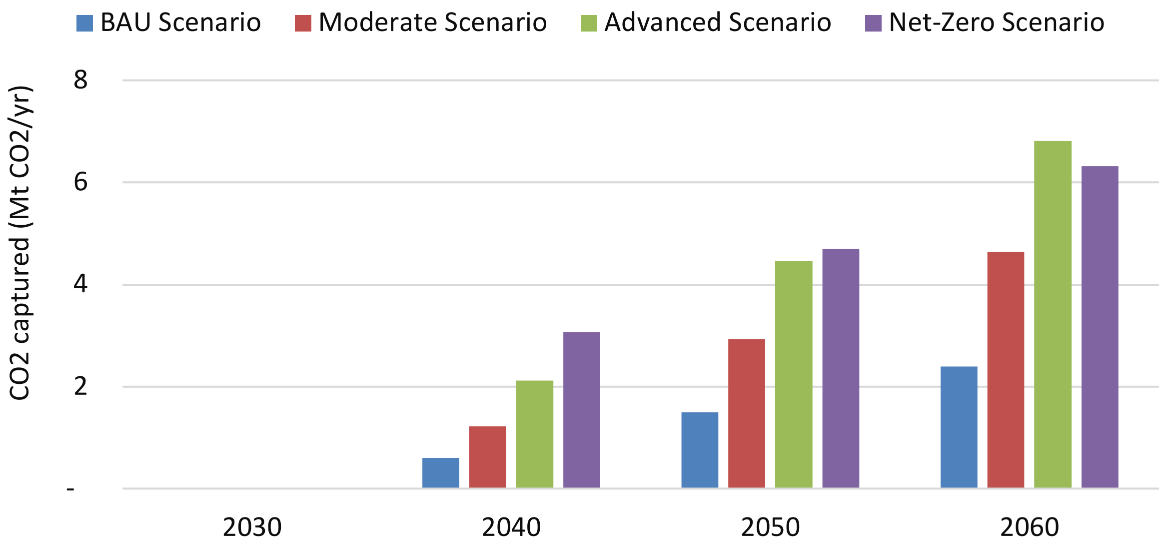


Figure 28. CO_2 emissions captured by the adoption of CCUS in Indonesia's steel industry (CCUS is applied after the adoption of other decarbonization technologies) (Source: this study).

However, as our analysis in Section 4.2 has shown, low-carbon iron and steelmaking technologies such as scrap-based EAF and H_2-DRI steelmaking have greater overall decarbonization potential for Indonesia's steel industry, and the role of CCUS may be limited. Another reason is that CCUS will not have 100% capture rates. Post-combustion carbon capture technologies can theoretically reach up to 95% capture efficiency, but because of the structure of steel plants, different emissions point sources in production, and the leakage that happens during carbon capture, this maximum efficiency has not been achieved in practice.

Barriers and Solutions for CCUS in Indonesia's Steel Industry
Indonesia's steel industry faces significant financial barriers in adopting CCUS, including high upfront infrastructure costs, lack of sector-specific incentive mechanisms, and technology adoption rates. The lack of competitive CCUS investment frameworks for steel compared to neighboring countries exacerbates funding uncertainties, particularly for private companies including Gunung Steel Group and POSCO's Indonesia ventures, which lead in production capacity expansions (CREA 2024). The International Energy Agency (IEA) acknowledges CCUS's potential to abate a significant amount of steel sector emissions but emphasizes Indonesia's need for private partnerships and economic instruments to bridge financial gaps (IEA 2023).

Indonesia has established a CCUS regulatory framework through Presidential Regulation 14/2024 and MEMR 16/2024, becoming the first Southeast Asian nation to implement policies regarding the emerging carbon management technology. The regulation focuses on safe CO_2 storage through detailed monitoring, reporting, and verification requirements, while partnering with upstream oil and gas contractors for project development under production sharing contracts (International Energy Agency 2023). However, its scope is centered on CCUS for oil and gas operations, and briefly outlines that CO_2 sourced from other industries, like cement and steel, must undergo a joint study with the emitter and supplier to establish feasibility and availability of CO_2. The carbon trading monetization scheme detailed in the regulation also solely applies to CO_2 emissions from upstream oil and gas (Ashurst 2024). To accelerate progress towards decarbonization goals, Indonesia's strategy must expand its suite of CCUS regulations and policies beyond oil and gas industries to include iron and steelmaking. The creation of frameworks for permitting and licensing CO_2 storage outside oil and gas zones while incentivizing participation of non-oil and gas companies can ensure broader implementation (Rara Energy Consulting 2025).

6 Economic Feasibility of Low-Carbon Steel Production in Indonesia

6.1. Economic Feasibility of EAF Steel Production in Indonesia

We also examined the levelized cost of steel (LCOS) production for a typical scrap-based EAF steelmaking facility in Indonesia, assuming an annual steel output of one million tons. This analysis compares the scrap-EAF route to the BF-BOF route. We developed a detailed financial model to evaluate these routes, incorporating key cost components such as capital expenditures (CAPEX), raw material inputs (scrap, iron ore), fuel, labor, operations and maintenance (O&M), and electricity, sourced both from the grid and renewables, alongside other necessary inputs like oxygen, alloys, and lime. The model is designed to adjust for varying scrap prices and includes future projections.

The LCOS calculation spreads CAPEX over the plant's economic lifespan and uses net present value (NPV) accounting to evaluate costs over time, discounting future costs to present value. Operating costs are projected annually over a 20-year analysis horizon, reflecting expected input price changes. This approach enables assessment of the low-carbon steel premium by comparing the levelized costs of scrap-EAF steel with those of primary steelmaking routes. We find that the LCOS scrap-EAF steel is slightly higher than BF-BOF steelmaking in Indonesia.

A comparison of production cost structures across the BF-BOF and scrap-EAF routes reveals differences in dominant cost drivers. For a BF-BOF plant in Indonesia, fuel and fossil reductants (mainly coal and coke) contribute about 29% of total LCOS, followed by iron ore (31%) and other materials and O&M (19%).

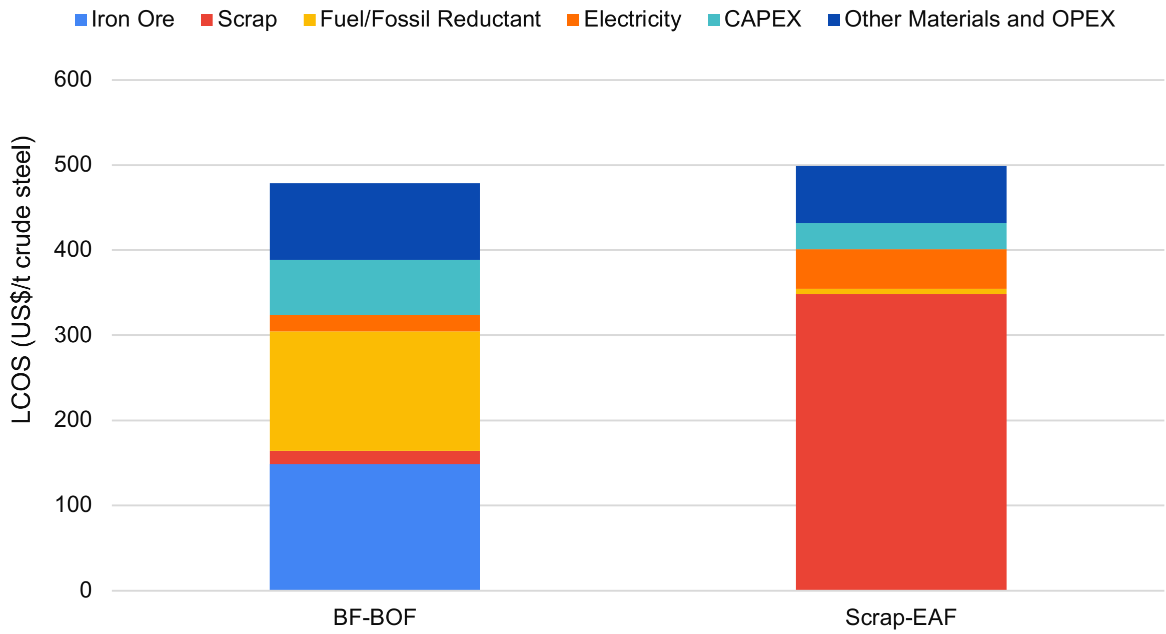
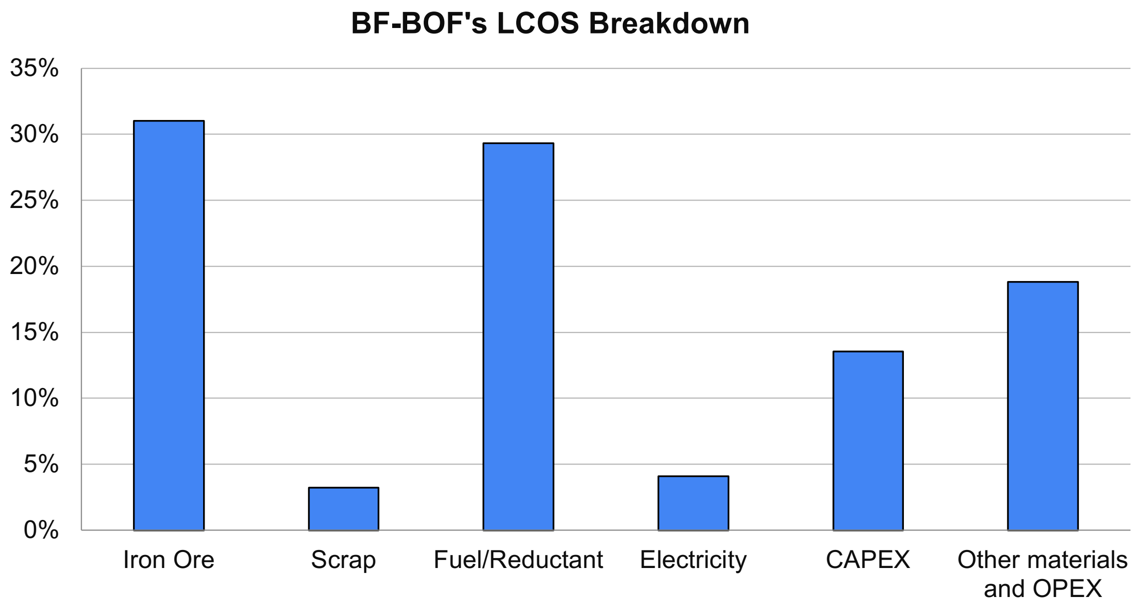


Figure 29. Breakdown of LCOS components by BF-BOF and scrap-EAF routes in Indonesia (Source: this study)

In contrast, scrap costs make up the vast majority of total costs for a scrap-EAF facility at 70%, while electricity makes up just 9%. CAPEX and other materials/O&M make up 6% and 14%, respectively. The shift from coal and iron ore dependency in BF-BOF to scrap dependency in EAF underscores the need for a reliable and stable scrap supply to maintain cost competitiveness.



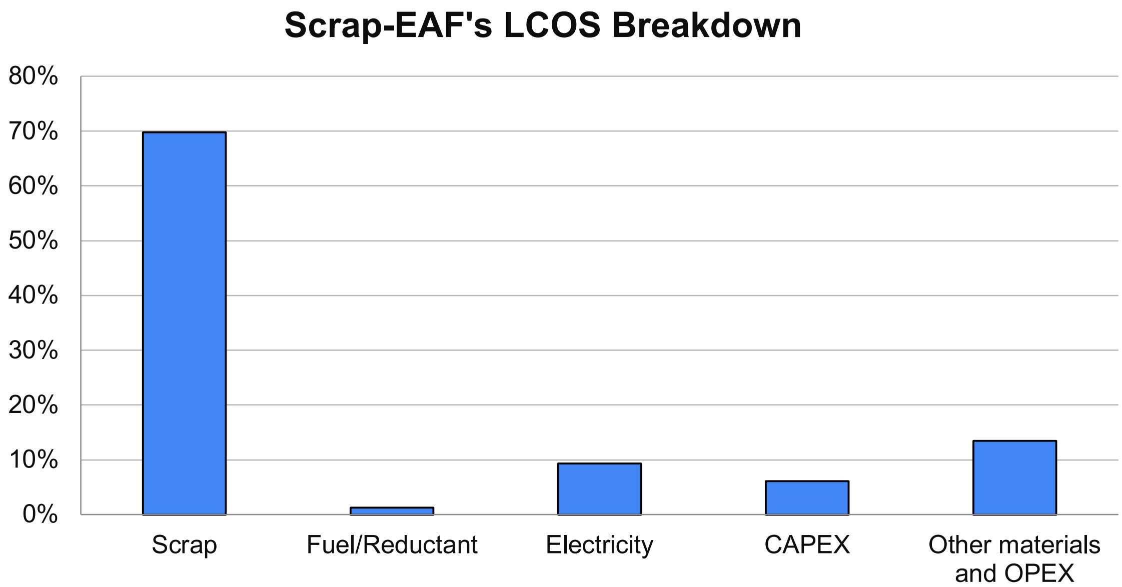


Figure 30. Share of cost components in BF-BOF and scrap-EAF LCOS (Indonesia) (Source: this study)

6.2. Economic Feasibility of NG-DRI-EAF and Green H_2-DRI EAF Steelmaking in Indonesia

This section compares the LCOS for green hydrogen-based steelmaking in Indonesia against BF-BOF and NG-DRI-EAF. Our approach for analyzing LCOS follows a similar approach as for scrap-EAFs in Section 5.4.1., using a standardized plant with an annual output of one million tons. The model allows for different levels of hydrogen substitution in DRI production and conducts a sensitivity analysis of hydrogen costs. In this study, the levelized cost of hydrogen reflects the full delivered cost to steel plants, inclusive of production, transportation, and storage.

For green H_2-DRI-EAF to compete with NG-DRI-EAF, hydrogen prices will likely need to go below $2/kg. Achieving this price point will require bringing electrolyzer capital costs below $400/kW and securing electricity at or under $0.02/kWh (Bataille et al., 2021). Broader price competitiveness is expected to emerge across most markets by 2035, driven by technological advancements, economies of scale, and targeted public policy support. These trends are supported by major policy initiatives such as the U.S. hydrogen hubs and the European Union's Hydrogen Bank, both of which aim to catalyze commercial-scale green hydrogen deployment through subsidies and incentives. These programs are projected to help bring green hydrogen costs down to $1–$2/kg during the 2030s.

Globally, green hydrogen costs are not competitive with gray hydrogen or blue hydrogen (NG-based H_2 production with CCUS) in different markets (BloombergNEF 2023) Projections out to 2030s suggest continued reductions in the levelized cost of green hydrogen, with further gains expected from expanded electrolyzer manufacturing, renewable generation, and supportive infrastructure. These improvements will be key for Indonesia to scale up investment in green H_2-DRI steelmaking and align with long-term decarbonization goals.

Our analysis indicates that green H_2 integration into steelmaking in Indonesia would still be more expensive than BF-BOF production even at the lowest H_2 price points, but that at some lower price points green H_2 steelmaking will be cheaper relative to NG-DRI-EAF. For Indonesia, green H_2-DRI-EAF steelmaking is initially more costly than both BF-BOF and NG-DRI-EAF at current hydrogen prices, requiring a hydrogen price of approximately $1.5/kg to achieve parity with NG-DRI-EAF, and not achieving parity with BF-BOF production without a carbon price. Only with a carbon price of $50 per ton of CO_2 and $1/kg H_2 can H_2-DRI-EAF achieve cost parity with BF-BOF steelmaking (Figure 32). However, the green premium of higher-LCOS green steel in final products is quite low, as discussed further below. These results highlight the importance of policy support and investment in green H_2 infrastructure.

As shown above, carbon pricing can also play a key role in enhancing the economic feasibility of green steel in Indonesia. For this study, we assume that carbon pricing takes the form of tradable credits or allowances, allocated based on the emissions intensity reduction achieved relative to a BF-BOF benchmark. These credits could be monetized through carbon markets, offering a direct financial benefit to green steel producers.

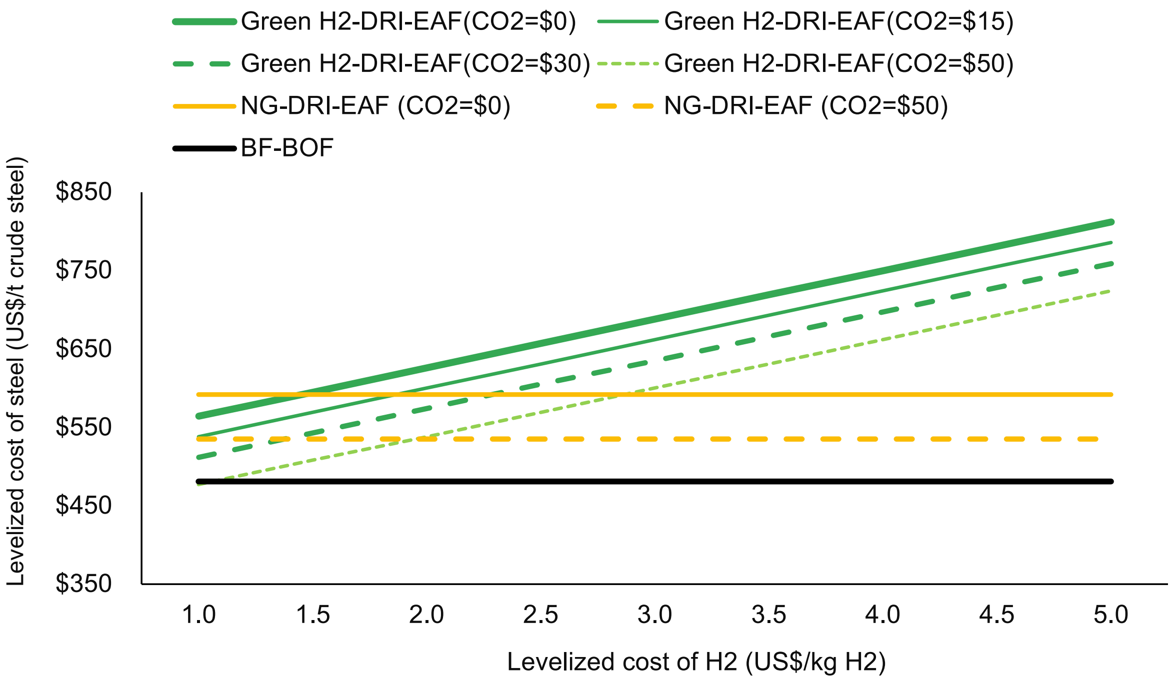


Figure 32. Levelized Cost of Steel ($/t crude steel) with varied levelized costs of H_2 at different carbon prices in Indonesia (Source: this study)

Notes: Assumed 5% steel scrap is assumed to be used in both BF-BOF and DRI route. For this analysis, it is assumed that carbon pricing will be applied in the form of credits or allowances for green H_2-DRI-EAF plants. Eligible plants would receive carbon credits based on the reduction of their carbon intensity relative to the benchmark set by BF-BOF operations, which can then be traded on the carbon market.

The composition of the LCOS for green H_2-DRI-EAF is very different from BF-BOF route, where coal and coke as fuel and reductant are the dominant inputs (in addition to iron ore). The cost structure for NG-DRI-EAF steel is also primarily driven by fuel and reductant inputs, as well as iron ore costs (Figure 33).

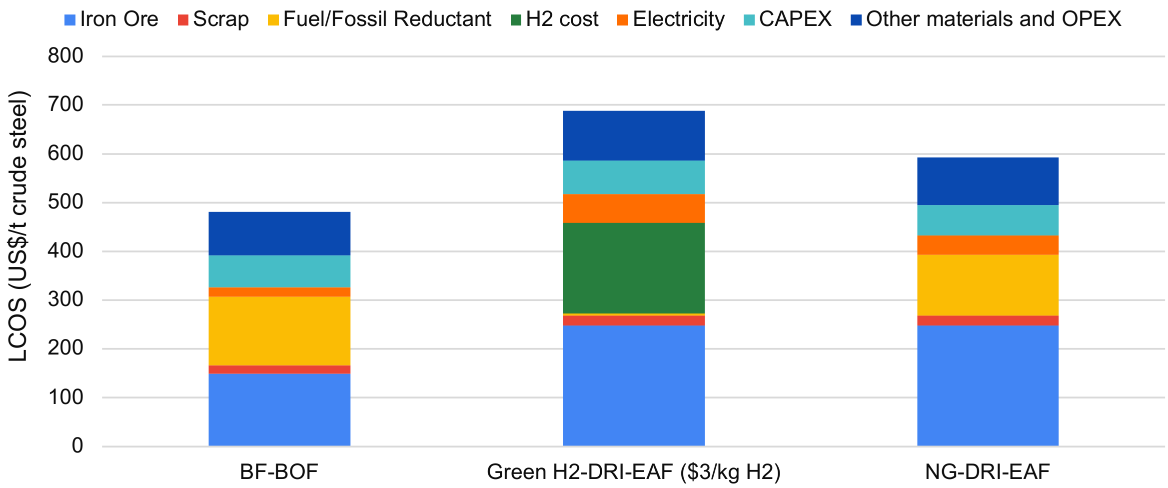


Figure 33: Breakdown of LCOS components by steelmaking route (Indonesia) (Source: this study)

The cost of green hydrogen production remains the most critical determinant of the economic feasibility of green H_2-DRI steelmaking for Indonesia, after the cost of iron ore (Figure 34). These two inputs together make up 63% of the production cost (at $3/kg H_2). Other cost components are significantly smaller in comparison. Capital expenditures (CAPEX) each contribute around 10%, while other materials and operational expenditures (OPEX) account for roughly 15%. For BF-BOF and NG-DRI-EAF production, iron ore and fuel/reductant make up the largest share of LCOS, with NG-DRI-EAFs incurring a higher share of iron ore costs relative to natural gas costs.

This analysis shows that green H_2-DRI-EAF steelmaking remains more expensive than traditional BF-BOF even at a hydrogen price of $1/kg in Indonesia. Despite other studies showing that H_2-DRI-EAF can be competitive with BF-BOF steelmaking at higher hydrogen prices than $1/kg, more recent market conditions, particularly the relatively low cost of coal, underscore the current challenge for green H_2-DRI-EAF steelmaking economics.

Nevertheless, green H_2-DRI remains an essential decarbonization pathway for the steel industry. The current green premium per ton of steel has a minimal impact at the product level, discussed in the next section. This indicates that the green premium can be absorbed by end-users or supply chains without significantly affecting affordability or competitiveness.

Moreover, while fossil fuel prices are currently low, they are volatile. In contrast, the cost trajectory for green hydrogen is expected to continue declining due to technological improvements, scaling of electrolyzer production, and growing RE deployment. As hydrogen production costs fall further, the competitiveness of green H_2-DRI steelmaking is likely to improve substantially. In this sense, investment in H_2-DRI today positions the steel industry to avoid future exposure to fossil fuel price volatility and regulatory risks associated with carbon-intensive production.

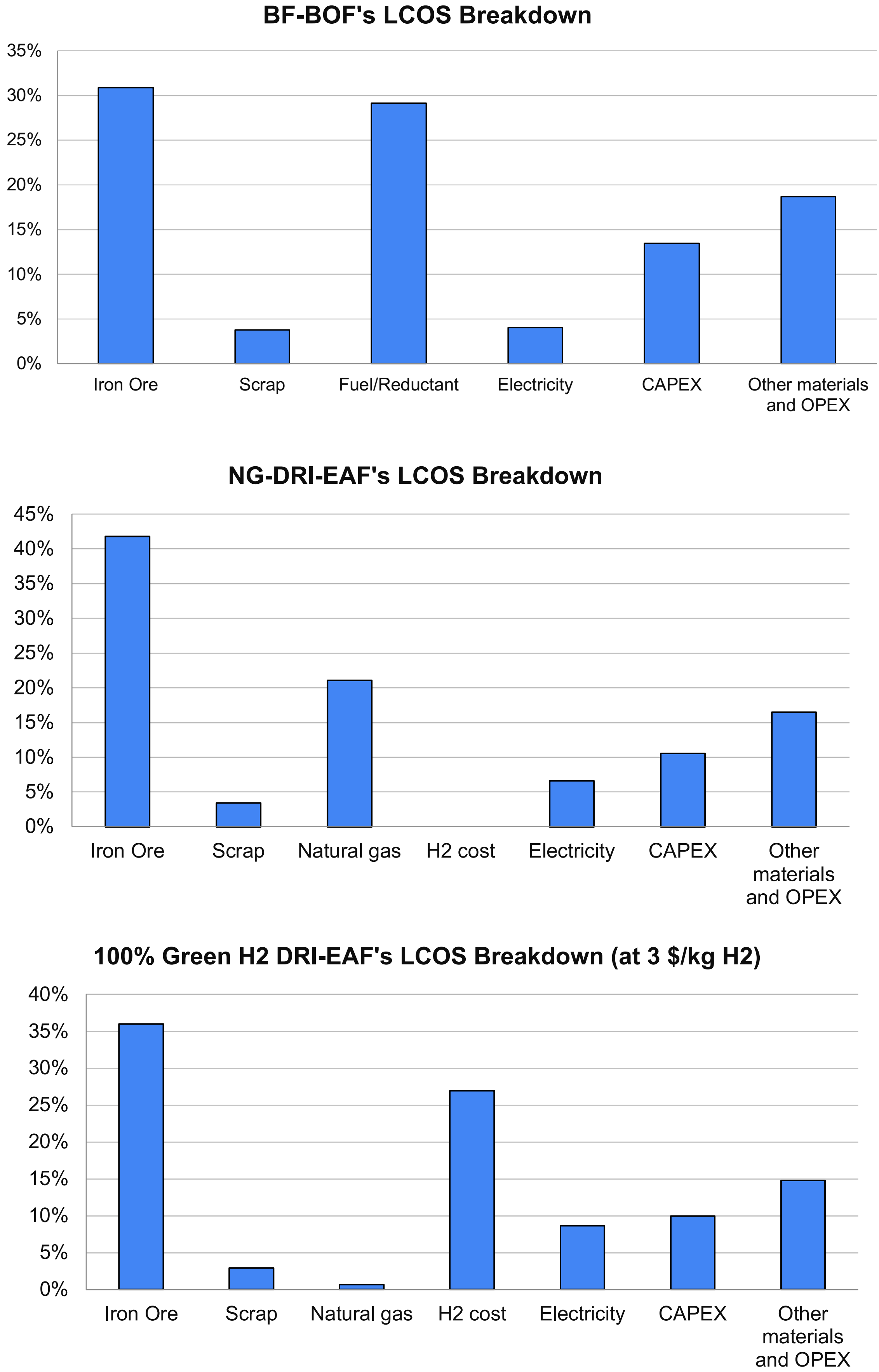


Figure 34. Share of each cost component in the LCOS of a new BF-BOF, NG-DRI-EAF, and green H_2-DRI-EAF plant in Indonesia at $3/kg H_2 (100% green hydrogen) (Source: this study)

In addition, the environmental benefits of H_2-DRI are substantial. Green H_2-DRI can reduce CO_2 emissions from steelmaking by up to 97% compared to the BF-BOF route. In climate policy terms, this equates to a highly cost-effective emissions reduction measure when evaluated in terms of cost per ton of CO_2 abated. The green H_2-DRI route also has substantially lower air pollution than the traditional BF-BOF route, and this translates to lower health costs and other societal benefits. Even with current green premiums, the implied abatement costs are well within the range considered acceptable under carbon pricing schemes or social cost of carbon estimates. Furthermore, as governments continue to strengthen carbon markets, border adjustment mechanisms, and green procurement policies, the financial case for low-carbon steel will become increasingly aligned with regulatory and market realities.

Finally, early investment in H_2-DRI offers strategic advantages beyond cost. It enables steel producers to lead in emerging green steel markets, secure long-term supply contracts with sustainability-driven customers, and strengthen energy security by relying on domestically produced RE rather than imported fossil fuels. Despite current cost challenges, green H_2-DRI remains the most important credible and scalable technology for achieving net-zero steel by 2050. Thus, today's investments are not just about short-term cost parity, they are about future-proofing the industry, capturing environmental value, and maintaining global competitiveness in a decarbonizing economy.

The Green Steel Premium

The "green premium" for green H_2-DRI steel is represented by the higher LCOS compared to traditional BF-BOF methods. However, this premium is often overstated by steel-intensive industries. A clearer understanding of the potential cost implications of green steel can guide both public and private procurement policies and inform downstream sectors on how to support the transition. Therefore, we analyzed the impact of the green steel premium from H_2-DRI-EAF steelmaking on passenger car pricing and building construction in Indonesia.

The automotive sector accounts for approximately 12% of global steel demand (worldsteel 2023) and is poised to be an early adopter of green steel due to its climate commitments. The additional cost from using green H_2-DRI-EAF steel in passenger vehicles is modest and aligns with recent studies suggesting minimal consumer impact. For instance, in Indonesia, at a hydrogen price of $5/kg, the green premium for green steel is roughly $331 per ton of steel (i.e. steel produced via the green H_2-DRI-EAF route at $5/kg H_2 has a levelized cost $331 higher than that of BF-BOF steel per ton of steel). Assuming that an average car uses about 0.9 tons of steel, this would translate to a cost increase of around $298 per vehicle. With an average car price of approximately $12,000 in Indonesia, this results in a 2.5% price increase, which is generally a small margin that would not affect overall affordability relative to other typical market fluctuations. Future reductions in hydrogen prices, potentially down to $1/kg, could significantly decrease this premium. Moreover, the introduction of carbon pricing or credit mechanisms could reduce the green premium further, accelerating the adoption of low-emission materials in the auto industry.

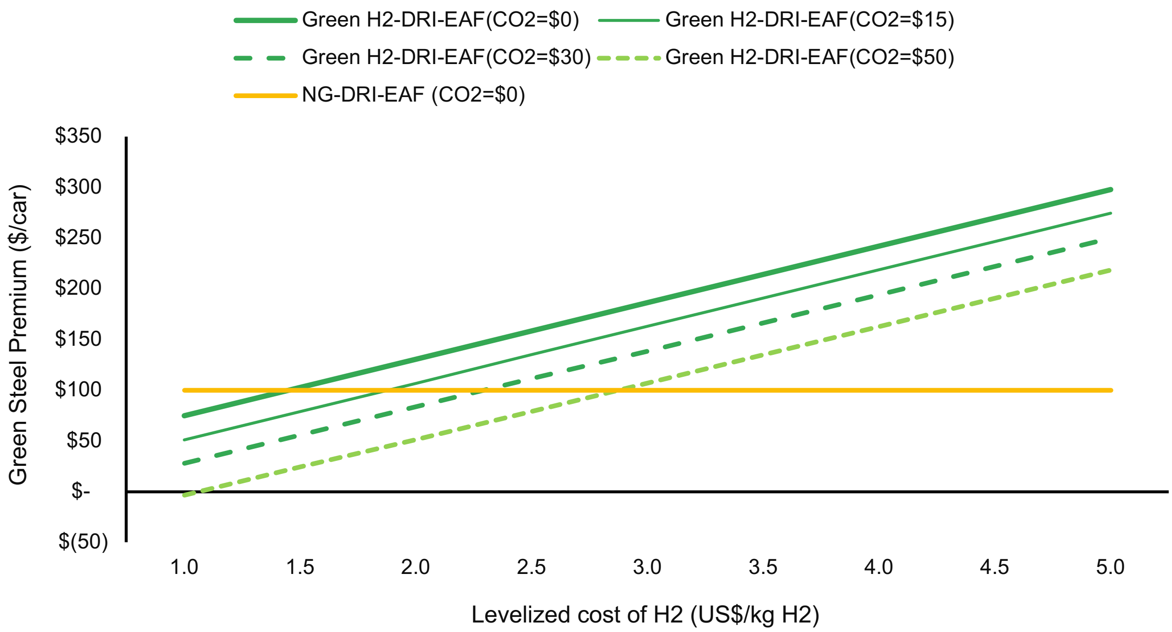


Figure 35. Impact of green steel premium on passenger car prices in Indonesia under different H_2 and carbon prices

The construction sector, including buildings and infrastructure, represents more than half of global steel demand (worldsteel 2023). In the context of low- to mid-rise residential buildings in Indonesia, using green H_2-DRI-EAF steel adds a relatively small cost compared to conventional BF-BOF steel. At a hydrogen price of $5/kg and the green steel premium of $331 per ton, this equates to a $828 increase in the cost of constructing a 50 m^2 residential unit. This cost increment is marginal relative to the total construction budget and could diminish or disappear altogether with future decreases in hydrogen costs or the implementation of carbon pricing mechanisms.

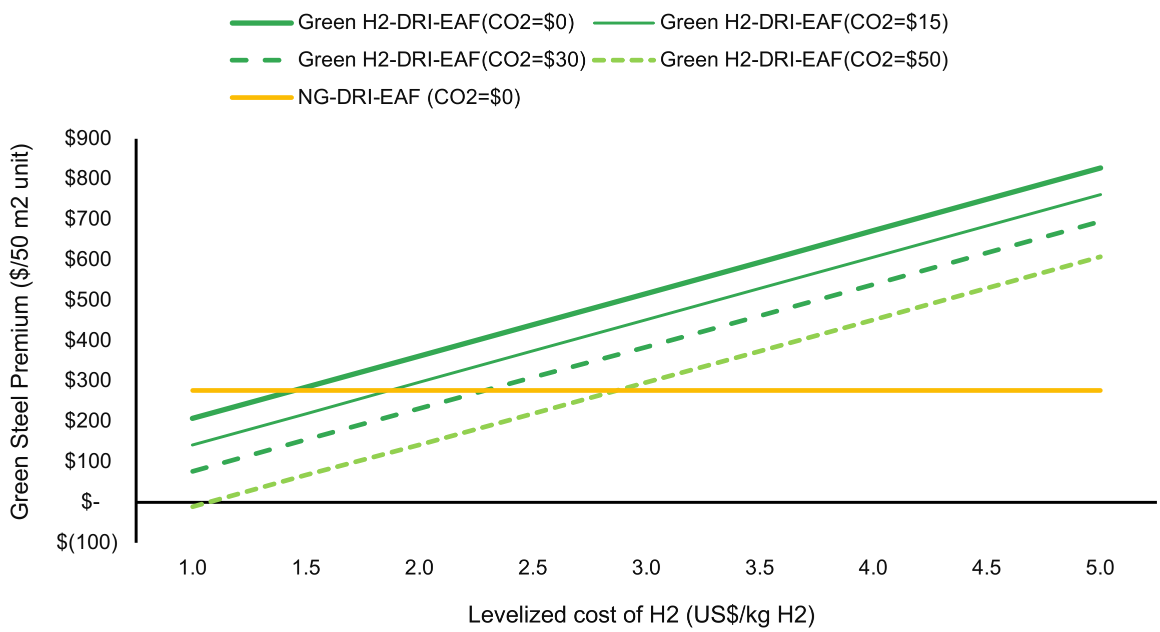


Figure 36. Impact of green steel premium on residential building (50 m^2 unit) construction cost in Indonesia under different H_2 and carbon prices.

Note: This is for a 50 m^2 residential building unit assuming 50 kg steel per m^2 used for a low to mid-rise residential building.

6.3. International Experiences with Financing of Green H_2-DRI Plants

Given the higher costs of green H_2-DRI-EAF steel discussed above, the financing of green H_2-DRI technology will be key to the steel industry's transition to low-carbon production. Due to the high capital costs of these projects, innovative financing approaches are essential. Companies are tapping into a mix of public funding, private investment, and strategic alliances to bring these initiatives to life. Public sector support through grants, subsidies, and tax incentives has been especially influential, helping reduce the financial risk of adopting first-of-its-kind decarbonization technologies. This has been particularly evident in large-scale H_2-DRI projects across Europe and the United States.

On the private side, funding comes from both direct equity contributions and long-term offtake agreements, which help guarantee predictable revenue streams. Stegra, formerly H_2 Green Steel (H_2GS), for instance, has secured multi-year supply deals with leading automotive firms, helping anchor market demand for its green steel products. The following examples highlight a range of financing strategies used by H_2-DRI projects globally.

In 2023, Stegra raised €1.5 billion in equity for its flagship plant in Sweden and, in early 2024, secured an additional €4 billion in debt financing. The company also received a €250 million grant from the EU Innovation Fund. Its long-term contracts with Volvo, Scania, Mercedes-Benz, and KIRCHHOFF Automotive (the latter valued at €130 million) further enhance financial stability. A raw material supply agreement with Rio Tinto for DR-grade iron ore pellets also strengthens the company's operational foundation. Initial production at its Boden plant is set at 2.5 Mt per year, with plans to scale to 5 Mt (Stegra 2025).

Germany's Salzgitter AG, through its SALCOS® program, has secured approximately €1 billion in public subsidies, matched by over €1 billion in company funds to construct a H_2-DRI plant using the Energiron ZR® technology (Salzgitter AG 2023).

In Sweden, the HYBRIT initiative, developed by SSAB, LKAB, and Vattenfall, received SEK 3.1 billion (US$ 282 million) from the Swedish Energy Agency's Industrial Leap program. The majority (about 75%) of the project's financing is provided by the owner companies themselves (Hybrit 2023).

Thyssenkrupp has pledged €2 billion toward decarbonizing its steelmaking operations by building a H_2-DRI facility with a capacity of 2.5 Mt per year. Further funding from public and private sources is expected to supplement the project (thyssenkrupp 2022).

In South Korea, POSCO is moving forward with its HyREX project, which uses a hydrogen-based fluidized bed reduction process. The initiative is supported by KRW 26.9 billion (around USD 20.4 million) in government funding between 2023 and 2025 (Kweon 2024).

Table 5. Summary of financing details for various international H_2-DRI projects

Project	Location	Equity Funding	Debt Financing	Subsidies	Total Funding
Stegra	Europe	€1.5 billion raised in equity	Over €4 billion secured in debt (2024)	€250 million from EU Innovation Fund	>€5.75 billion
Salzgitter AG - SALCOS®	Germany	>€1 billion in company investment	Not specified	~€1 billion from federal and state subsidies	>€2 billion
SSAB H_2 DRI - HYBRIT	Sweden	Primarily from SSAB, LKAB, and Vattenfall	Not specified	SEK 3.1 billion (US$ 282 million) from Swedish Energy Agency	Majority privately financed
Thyssenkrupp H_2-DRI	Germany	Part of a broader €2 billion investment	Additional funding expected	Not specified	€2 billion+ projected
POSCO HyREX	South Korea	Not specified	Not specified	KRW 26.9 billion (USD 20.4 million) for technology development (2023–2025)	KRW 26.9 billion

7 Action Plan and Recommendations

Decarbonization of Indonesia's steel industry is a complex challenge requiring substantial financial investment, policy coordination, and technological innovation. To avoid long-term lock-in of carbon-intensive assets and align the sector with future climate and market conditions, a clear, phased action plan is essential.

This section outlines strategic recommendations for Indonesia's government and steel companies to unlock the full decarbonization potential of the steel industry. The action plan and recommendations are organized by the decarbonization pillars: (1) material efficiency and demand management, (2) energy efficiency and electrification of heating, (3) fuel switching and cleaner electricity, (4) transitioning to low-carbon iron and steelmaking technologies, and (5) carbon capture, utilization, and storage (CCUS). In addition, one category of actions for steel consumers is listed. The actions are also structured by stakeholder group and organized across the near term (2025–2030), medium term (2030–2040), and long term (2040–2060).

To ensure the viability of policy recommendations, the Indonesian government should strengthen the legal framework for industrial decarbonization by embedding decarbonization targets and standards into binding national laws and sector-specific regulations. This includes updating existing industrial and environmental laws to mandate CO_2 intensity benchmarks, enforce energy performance standards, and require climate risk disclosure for new investments in the steel sector. The government should also clarify the legal authority and coordination mechanisms among relevant agencies to streamline policy implementation and avoid regulatory overlap. Establishing these legal foundations will create accountability, reduce investor uncertainty, and accelerate compliance with decarbonization objectives.

7.1. Recommendations for enhancing material efficiency and demand management

Under the Net Zero scenario, the Material Efficiency and Demand Management pillar contributes about 18% of the total emissions reductions needed to bring Indonesia's steel industry emissions from the BAU level down to Net Zero level in 2060. This means strategies like lightweight design, improved fabrication yields, extending product lifespans, and reusing steel components could avoid approximately 12.4 Mt CO_2 emissions in 2060 compared to the BAU scenario. This contribution underscores that reducing steel demand through material efficiency is not only crucial for limiting new steel production growth but also one of the major levers to achieving deep decarbonization of Indonesia's steel sector. Below are some of the actions that the government and steel companies in Indonesia should take in order to realize this potential.

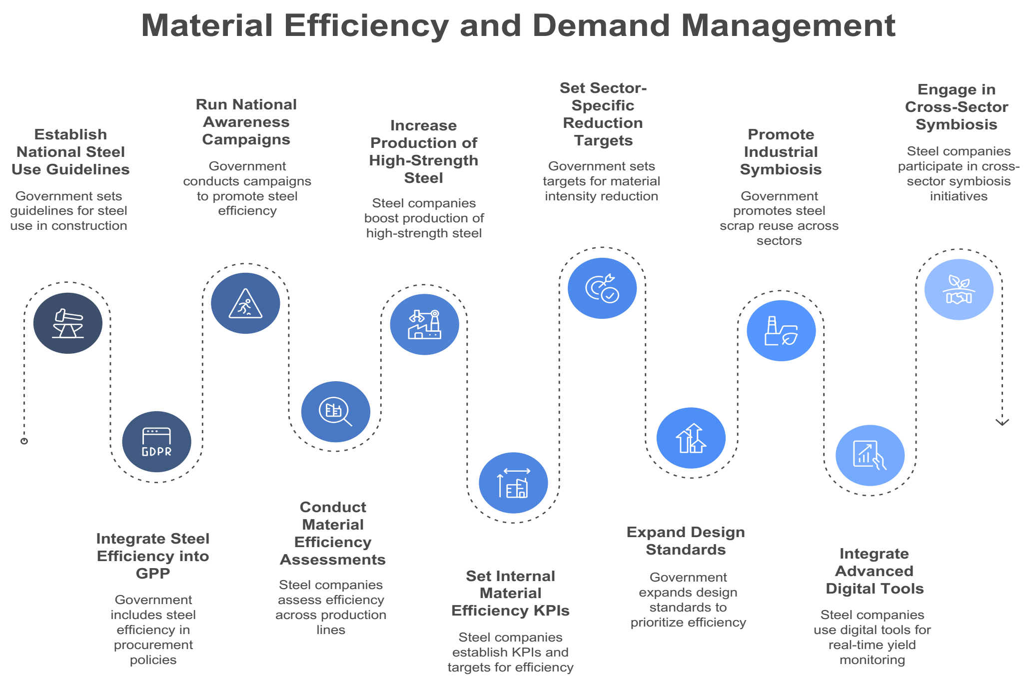


Figure 37: Summary of recommendations for enhancing material efficiency and demand management for steel in Indonesia

Actions for the Government of Indonesia

Near-Term Actions (2025–2030)

1) Establish National Steel Use Optimization Guidelines in Construction
The government should issue detailed technical guidelines for optimizing steel use in building and infrastructure projects. These guidelines should promote lighter design, optimal structural layouts, and alternative materials to reduce steel consumption without compromising safety or quality. By mandating efficient design through updated building codes, Indonesia can avoid excess steel demand in new construction. The Ministry of Public Works and Housing (PUPR) should lead, supported by the Ministry of Industry (The Ministry of Industry) and the National Standardization Agency (BSN) to integrate the guidelines into Indonesian National Standards (SNI).

2) Integrate Steel Material Efficiency into Green Public Procurement (GPP)
Green public procurement criteria for steel in infrastructure projects should include material efficiency performance. By favoring bids demonstrating reduced steel usage through efficient design or high-strength steel, the government can drive early adoption of material-saving approaches. The Ministry of Finance (Kemenkeu) should coordinate with PUPR and the National Public Procurement Agency (LKPP) to incorporate these requirements into procurement rules and project evaluation guidelines.

3) Run National Awareness Campaigns on Steel Material Efficiency
To support rapid adoption of material-efficient practices, the government should launch campaigns targeting architects, engineers, developers, and major manufacturers. These campaigns should highlight design best practices, successful case studies, and potential cost

and emissions savings. The Ministry of Communication and Information Technology (Kominfo) should collaborate with The Ministry of Industry, IISIA, and construction associations to produce and disseminate educational materials nationwide.

Medium-Term Actions (2030–2040)

4) Set Sector-Specific Material Intensity Reduction Targets
Mandatory targets for material intensity reductions should be established for priority steel-consuming sectors such as construction, automotive, and machinery, encouraging smarter material use. Targets should reflect achievable but ambitious reductions from historical baselines. The Ministry of Industry should coordinate target-setting, with the Coordinating Ministry for Economic Affairs and IISIA providing technical support.

5) Expand Design Standards to Prioritize Material Efficiency in National Infrastructure
Indonesia should update infrastructure design standards to explicitly include material efficiency performance, requiring public projects to justify steel quantities and minimize overdesign. PUPR, in coordination with The Ministry of Industry and engineering associations, should lead updates, integrating requirements into official guidelines for roads, bridges, and ports.

6) Promote Industrial Symbiosis for Steel Scrap Reuse Across Sectors
The government should facilitate industrial symbiosis programs connecting steel-consuming sectors with scrap suppliers, reducing virgin steel demand by maximizing high-quality scrap circulation. Industrial estates can act as hubs for these exchanges, with incentives for early participants. The Ministry of Industry and the Ministry of Investment (BKPM) should coordinate implementation, with IISIA and local governments in major industrial zones providing support.

Actions for Steel Companies

Near-Term Actions (2025–2030)

1) Conduct Comprehensive Material Efficiency Assessments Across Production Lines
Steel companies should carry out detailed assessments of their entire manufacturing processes across value chain to identify inefficiencies in material use, sources of excessive offcuts, and opportunities to optimize yields. These assessments should include shop floor observations, process mapping, and data analysis, leading to tailored action plans for each plant. By understanding where steel is wasted, companies can take immediate steps to reduce material losses and improve profitability.

2) Increase Production of High-Strength, Lightweight Steel Grades
Producers should accelerate the development and commercial-scale production of high-strength and advanced steel grades that deliver equivalent or better performance with less material. By offering lightweight options for construction, automotive, and machinery sectors, companies can directly contribute to material efficiency and differentiate themselves in the market. Early investment in this area will also prepare companies for future demand from buyers seeking low-carbon and efficient materials.

3) Set Internal Material Efficiency Key Performance Indicators (KPIs) and Targets
Steel producers should integrate specific KPIs for material efficiency, such as yield rates, scrap generation per ton of steel produced, and offcut reduction percentages, into their management systems. By setting measurable targets and reviewing performance regularly, companies can institutionalize material efficiency and ensure it becomes a core part of their competitiveness strategy.

Medium-Term Actions (2030–2040)

4) Integrate Advanced Digital Tools for Real-Time Yield Monitoring
Steel companies should adopt digital twins, AI-based quality monitoring, and real-time data analytics systems to track yield performance across each production step. These technologies enable fast identification of areas with high material losses, enabling continuous process optimization. Over time, this can significantly reduce steel waste and improve responsiveness to customer requirements for efficient products.

5) Engage in Cross-Sector Industrial Symbiosis Initiatives
Steel producers should participate in or lead industrial symbiosis projects where their by-products or scrap are supplied directly to other industries such as foundries, machinery manufacturers, or smaller steel fabricators to maximize reuse. Working with industrial estate managers, regional governments, and other large manufacturers will strengthen these networks, creating shared economic and environmental benefits while lowering national primary steel demand.

7.2. Recommendations for enhancing energy efficiency and electrification of heating

Under the Net Zero scenario for Indonesia's steel industry, energy efficiency and electrification of heating pillar is projected to deliver significant emissions reductions. In 2060, energy efficiency improvements combined with the electrification of heating are expected to cut CO_2 emissions by approximately 11.7 Mt CO_2 compared to the BAU scenario. This contribution makes energy efficiency and electrification the third largest pillar for emissions reductions, following technology shifts to low-carbon steelmaking and material efficiency pillars. It accounts for about 17% of the total emissions reductions required to meet Net Zero in 2060 relative to BAU emissions. These reductions come from aggressive adoption of commercially available energy-saving technologies, optimization of process heating, and electrification of rolling and finishing. However, the report highlights persistent barriers, including high capital costs, lack of technical skills, and insufficient incentives, which must be overcome to unlock the full potential of this pillar for Indonesia's steel decarbonization. Below are some of the actions that the government and steel companies in Indonesia should take in order to realize this potential.

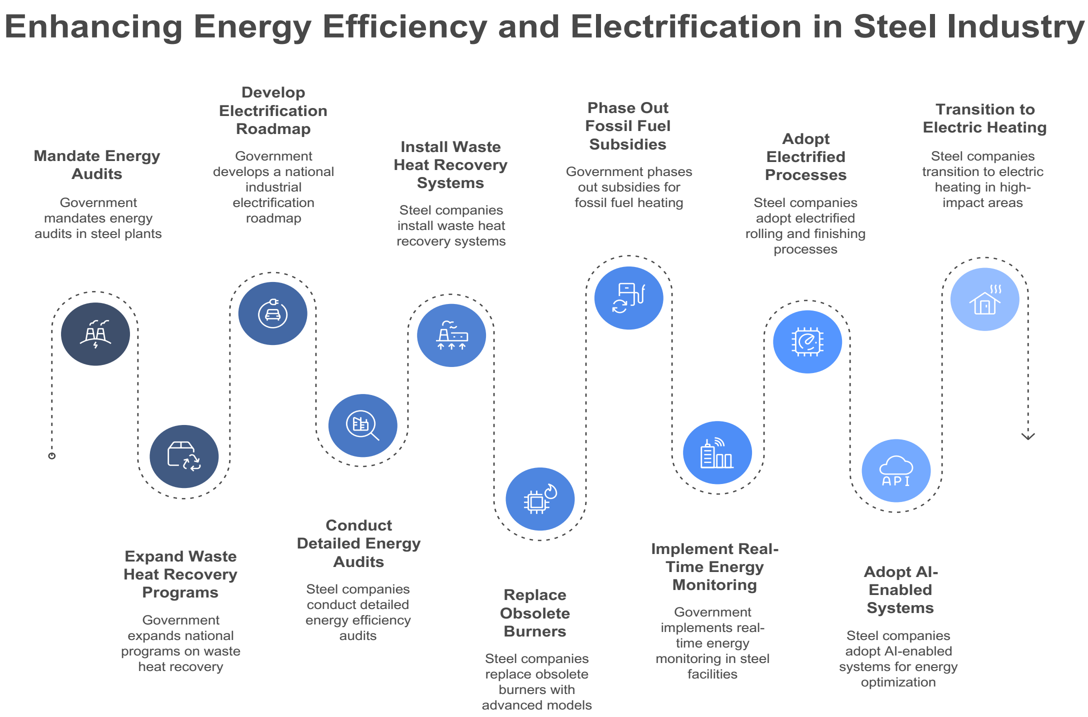


Figure 38: Summary of recommendations for enhancing energy efficiency and electrification of heating in the steel industry in Indonesia

Actions for the Government of Indonesia

Near-Term Actions (2025–2030)

1) Mandate Energy Audits in Steel Plants and Establish Efficiency Baselines
The government should require all steel producers to conduct regular, comprehensive energy audits to identify opportunities for reducing fuel and electricity consumption in different processes. Audits should result in documented energy baselines against which annual improvements can be measured. The Ministry of Energy and Mineral Resources (ESDM) and the Ministry of Industry (Kemenperin) should design regulations and provide technical guidelines for standardized audits.

2) Expand National Programs on Industrial Waste Heat Recovery Systems
The government should roll out national programs providing technical assistance, grants, or tax incentives to support installation of waste heat recovery systems in steel mills, such as recuperators and economizers. These systems capture and reuse heat from exhaust gases, significantly reducing fuel demand. ESDM should lead implementation with support from The Ministry of Industry and local governments in industrial clusters.

3) Develop a National Industrial Electrification Roadmap
A government-led roadmap should outline strategies for electrifying low- and medium-temperature heating processes across industries, including rolling and finishing lines in steel

production. The roadmap should set technology deployment targets, infrastructure plans, and investment needs to guide electrification efforts. ESDM, The Ministry of Industry, and Indonesia's state electricity company (PLN) should jointly develop the roadmap, ensuring alignment with the broader electricity grid expansion plan.

Medium-Term Actions (2030–2040)

4) Phase Out Subsidies for Fossil Fuel Heating in Industrial Processes
To encourage a shift towards more efficient and electric heating technologies, the government should plan a gradual phase-out of subsidies for coal, oil, and gas used in industrial heating, starting with large steelmakers. Reallocating these funds to support efficiency improvements or electrification will accelerate decarbonization. ESDM, Kemenkeu, and the Coordinating Ministry for Economic Affairs should manage subsidy reforms.

5) Real-Time Energy Monitoring in Large Steel Facilities
The government should encourage real-time energy monitoring systems for large steel plants, enabling operators to track consumption, identify anomalies, and improve efficiency over time. These systems should report key performance indicators to a centralized database for benchmarking and improvement. ESDM and The Ministry of Industry can develop standards for monitoring equipment and data reporting.

Actions for Steel Companies

Near-Term Actions (2025–2030)

1) Conduct Plant-Wide Detailed Energy Efficiency Audits and Implement Quick Wins
Steel companies should perform comprehensive energy audits of all heating processes, including reheating furnaces, ladle heating, and rolling mill operations. By implementing "quick win" measures such as sealing furnace leaks, optimizing combustion controls, and improving insulation companies can achieve immediate energy savings of up to 10% with minimal investment. Management should set annual energy-saving targets based on audit findings and review progress quarterly.

2) Install Waste Heat Recovery Systems on Reheating and Annealing Lines
Firms should prioritize investment in waste heat recovery equipment like recuperators, regenerators, and heat exchangers on high-temperature lines. Captured heat can be reused for preheating combustion air or process fluids, significantly reducing fuel consumption and emissions. Steel companies should conduct feasibility studies to identify the most cost-effective recovery opportunities for each plant section.

3) Replace Obsolete Burners with Advanced Low-NOx, High-Efficiency Models
Outdated burners are often highly inefficient and emit excessive pollutants. Companies should replace them with modern, high-efficiency burners that provide better combustion control, fuel-air mixing, and heat transfer, improving energy use by up to 20%. These upgrades also help meet tightening air pollution regulations while cutting operating costs.

Medium-Term Actions (2030–2040)

4) Adopt Electrified Rolling and Finishing Processes Integrated with Clean Power
Companies should start implementing electrification technologies for rolling mills and finishing lines, sourcing electricity from renewable PPAs where possible. Integrating electric induction or resistance heating in these processes can eliminate significant fossil fuel consumption and emissions from the final stages of steel production.

5) Adopt AI-Enabled Systems for Real-Time Energy Optimization
Steelmakers should invest in digital solutions like AI-powered energy management systems that monitor heating operations in real-time, predicting optimal furnace settings and dynamically adjusting parameters to reduce energy use. These technologies can deliver continuous improvements and detect performance issues faster than manual inspections.

6) Transition to Electric Heating in Ladle Preheating and Other High-Impact Areas
Steel companies should develop plans to electrify traditionally fossil-fueled processes with high energy consumption and high emissions, such as ladle preheating, by installing electric arc or induction systems. This step can demonstrate leadership and yield large emissions reductions, while experience gained will support broader electrification efforts across the company.

7.3. Recommendations for enhancing fuel switching and cleaner electricity

Under the Net Zero scenario for Indonesia's steel industry, the decarbonization pillar of fuel switching and cleaner electricity is projected to deliver substantial emissions reductions. In 2060, strategies such as replacing coal and coke with lower-carbon fuels like natural gas and biomass, along with decarbonizing grid electricity to enable low-carbon EAF steel production, are expected to reduce CO_2 emissions by around 11.5 Mt CO_2 compared to the BAU scenario. This contribution represents approximately 17% of the total emissions reductions needed to achieve Net Zero in 2060 relative to BAU emissions. These reductions are primarily driven by the transition to electricity-based steelmaking routes (EAF and hydrogen-based DRI-EAF) and the shift towards a cleaner power sector, which together significantly cut emissions intensity. However, the report emphasizes that realizing these benefits depends on accelerating grid decarbonization, overcoming infrastructure barriers for natural gas, and avoiding lock-in of new coal-based capacity that could undermine long-term emissions goals. Below are some of the actions that the government and steel companies in Indonesia should take in order to realize this potential.

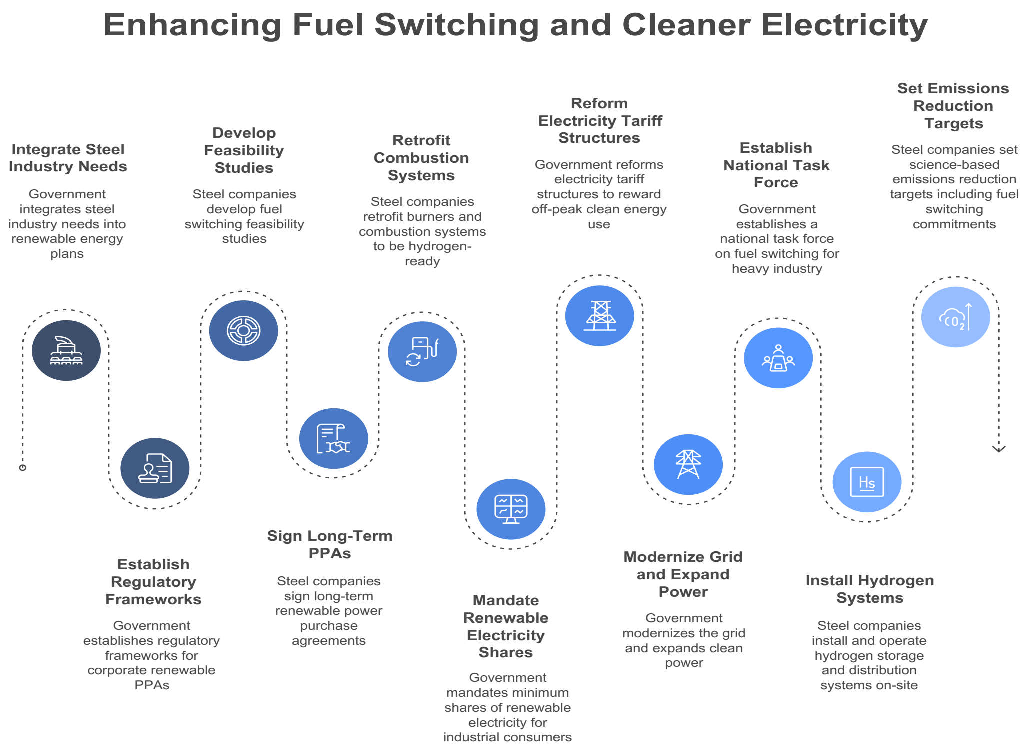


Figure 39: Summary of recommendations for enhancing fuel switching and cleaner electricity for the steel industry in Indonesia

Actions for the Government of Indonesia

Near-Term Actions (2025–2030)

1) Integrate Steel Industry Needs into PLN's RE Expansion Plans
The government should require PLN to explicitly consider the steel industry's future demand for renewable electricity when planning new solar, wind, geothermal, and hydro projects. Prioritizing clean electricity availability in steel-producing regions like Banten and Sulawesi will enable faster fuel switching and electrification. ESDM, The Ministry of Industry, and PLN should jointly lead planning efforts.

2) Establish Regulatory Frameworks for Corporate Renewable PPAs: Given that Indonesia's PPA market is still at a relatively early stage, significant upfront work is needed to create a viable ecosystem. The government, working with PLN and RE developers, should prioritize establishing a clear regulatory framework for corporate PPAs, including transparent guidelines on grid access, contract structures, pricing mechanisms, and legal protections for buyers and sellers. Streamlining permitting processes for renewable projects and simplifying procedures for companies to engage in corporate procurement are essential to build market confidence. Expanding eligibility beyond the largest consumers and piloting flexible models such as virtual or synthetic PPAs could open participation to a broader range of industrial users, including steel producers. RECs, which face challenges in their emissions reduction claims, should have a clear legal framework in Indonesia. Specific policy measures could include embedding RECs into export compliance for energy-intensive sectors, mandating RE shares for the steel industry, and expanding the number of renewable facilities able to issue RECs, particularly in underrepresented regions. Making REC access simpler for SMEs, expanding diversification across technologies (solar, hydro, geothermal), and linking RECs directly to national decarbonization targets would help scale adoption. ESDM, PLN, and the Financial Services Authority (OJK) should work together to finalize regulations.

Medium-Term Actions (2030–2040)

1) Mandate Minimum Shares of Renewable Electricity for Industrial Consumers
The government should introduce regulations requiring large industrial consumers, including steel plants, to source an increasing minimum percentage of their electricity from renewable sources over time (e.g., 30% by 2035). This will create predictable demand for renewables and accelerate the grid's decarbonization. ESDM and The Ministry of Industry should oversee implementation.

2) Reform Electricity Tariff Structures to Reward Off-Peak Clean Energy Use
PLN, under guidance from ESDM, should reform industrial electricity tariffs to incentivize steelmakers to shift electricity consumption to off-peak periods when renewable generation is abundant. This policy will maximize clean energy integration and reduce curtailment of solar and wind resources, making fuel switching to electricity more attractive.

3) Modernize the Grid and Expand Clean Power: PLN and related agencies must scale up investments in renewable generation and transmission to ensure the steel industry has access to low-carbon electricity. This includes expanding solar, wind, and hydro projects, and upgrading substations and transmission lines near industrial hubs such as Java and Sulawesi. RE development should be integrated with the needs of the steel sector through demand-side management, storage deployment, and smart grid coordination.

4) Establish a National Task Force on Fuel Switching for Heavy Industry
The government should create an inter-ministerial task force specifically focused on accelerating fuel switching from coal to gas and renewables in industries like steel. This task force should coordinate policies, resolve regulatory barriers, and engage private stakeholders. Members should include ESDM, The Ministry of Industry, KLHK, and PLN, reporting directly to the Coordinating Ministry for Economic Affairs.

Actions for Steel Companies

Near-Term Actions (2025–2030)

1) Develop Fuel Switching Feasibility Studies for Individual Plants
Steel companies should conduct detailed technical and economic feasibility studies for switching from coal or heavy oil to cleaner fuels such as natural gas or biomass in existing heating and melting equipment. These studies should consider equipment retrofits, local fuel availability, logistics, and CO_2 reduction potential, laying the groundwork for investment decisions. By understanding site-specific pathways, firms can plan realistic short- and long-term fuel transitions.

2) Sign Long-Term Renewable Power Purchase Agreements (PPAs)
Producers should pursue long-term PPAs with RE developers or PLN to secure stable, clean electricity supplies for their steelmaking operations. Such agreements will reduce exposure to fossil energy price volatility, cut emissions, and build credibility with customers demanding low-carbon steel. Early movers will gain competitive advantages as global markets shift toward green materials.

3) Retrofit Burners and Combustion Systems to Be Hydrogen-Ready
Steelmakers planning to adopt hydrogen should start retrofitting existing combustion systems such as those in reheating furnaces to be compatible with high hydrogen blends. Hydrogen-ready equipment allows gradual fuel switching as hydrogen availability ramps up, avoiding the need for expensive replacements later. Firms can work with technology vendors to source certified hydrogen-compatible components.

Medium-Term Actions (2030–2040)

4) Install and Operate Hydrogen Storage and Distribution Systems On-Site
Firms planning to adopt hydrogen should design and build storage tanks, pipelines, and safety systems at their plants, allowing efficient delivery of hydrogen to production lines. Early investments in storage infrastructure will reduce future bottlenecks as hydrogen supply becomes more consistent.

5) Set Science-Based Emissions Reduction Targets Including Fuel Switching Commitments
Steel companies should publicly commit to science-based emissions targets that include concrete milestones for reducing fossil fuel use and switching to cleaner energy sources. Transparent commitments demonstrate leadership, attract sustainability-focused customers, and align corporate strategies with Indonesia's climate goals.

7.4. Recommendations for transitioning to low-carbon iron and steelmaking technologies

Under the Net Zero scenario for Indonesia's steel industry, transitioning to low-carbon iron and steelmaking technologies is the single largest driver of emissions reductions. In 2060, this pillar is expected to reduce CO_2 emissions by around 20 Mt compared to the BAU scenario, accounting for nearly 29% of the total emissions reductions needed to achieve Net Zero in Indonesia's steel sector. This impact comes from a significant shift toward scrap-based EAF production, adoption of green hydrogen-based DRI-EAF, natural gas DRI-EAF with CCUS, and small amount adoption of electrolysis of iron ore in 2050 and onward. These technologies dramatically cut emissions compared to the traditional BF-BOF route, enabling deep decarbonization of primary steelmaking. The report highlights that to realize these benefits, Indonesia must overcome challenges including the high initial capital cost of new technologies, uncertain hydrogen availability, and the need for infrastructure investment in hydrogen and renewable electricity supply. Below are some of the actions that the government and steel companies in Indonesia should take in order to realize this potential.

Actions for the Government of Indonesia

Near-Term Actions (2025–2030)

1) Restrict Approval of New Blast Furnace Projects and Direct Investment Toward EAF and DRI
To avoid locking in high-emissions technologies, the government should tighten permitting rules to discourage new BF capacity and redirect incentives toward low-carbon routes like EAF using scrap or DRI. This policy will set a clear signal to investors and developers about Indonesia's commitment to modern, low-carbon steelmaking. The Ministry of Industry and the Ministry of Investment (BKPM) should coordinate permit revisions.

2) Strengthen Scrap Collection and Quality Standards: The government should launch a national strategy to modernize scrap collection and sorting by designating scrap steel as a strategic resource, building centralized collection points in key regions, and enforcing strict scrap quality standards to ensure low-impurity feedstock for EAF steelmaking. These efforts will secure supply, improve steel quality, and reduce emissions from remelting scrap.

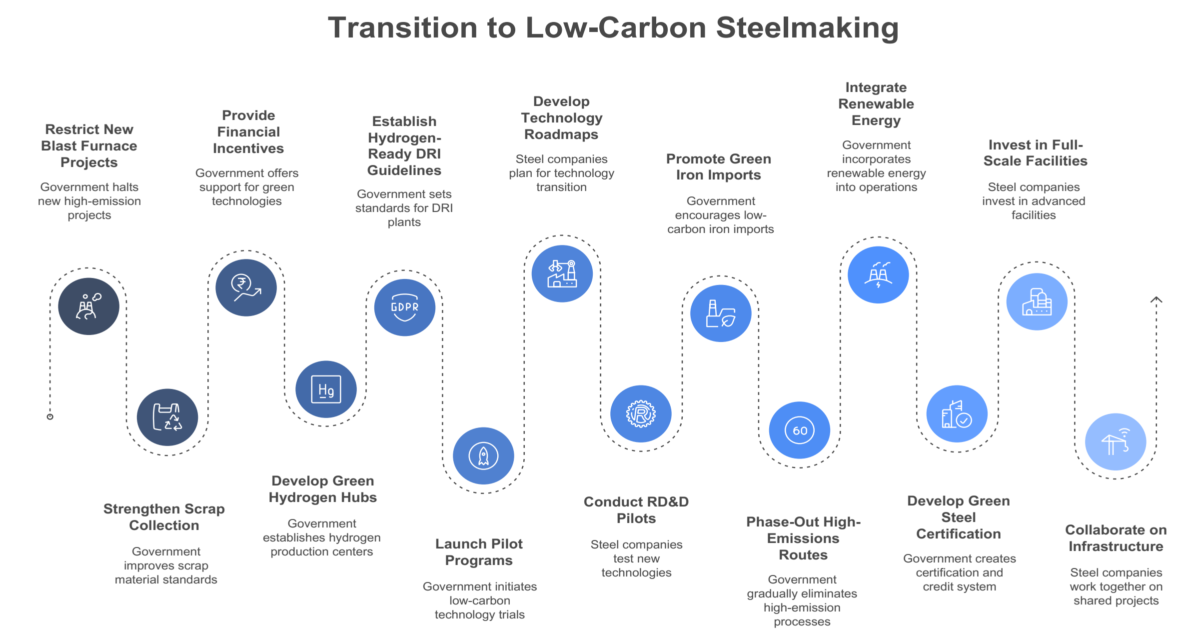


Figure 40: Summary of recommendations for transitioning to low-carbon iron and steelmaking technologies in Indonesia

3) Provide Financial Incentives for EAF Adoption and Upgrades: To accelerate the transition to scrap-based EAF steelmaking, Indonesia should introduce tax incentives and grants for companies upgrading existing facilities or building new EAF plants using low-impurity scrap. These incentives will lower upfront costs and encourage industry-wide investment in clean steel production.

4) Develop National Green Hydrogen Production Hubs Linked to Industrial Zones
To enable large-scale hydrogen use in steelmaking, the government should support the establishment of green hydrogen hubs near major steel production regions. These hubs should co-locate renewable generation, electrolyzers, and pipelines or trucking logistics for hydrogen supply. ESDM, PLN, and the Ministry of Investment (BKPM) should coordinate infrastructure planning and permitting.

5) Establish National Guidelines for Hydrogen-Ready DRI Plant Development
The government should publish comprehensive guidelines covering technical specifications, safety standards, and permitting processes for hydrogen-ready direct reduced iron (DRI) plants. These guidelines will give steelmakers confidence to invest in modern DRI facilities compatible with future green hydrogen supply, reducing the risk of stranded assets. The Ministry of Industry, ESDM, and the National Standardization Agency (BSN) should collaborate on drafting and disseminating these guidelines.

6) Launch Pilot Programs for Low-Carbon Steelmaking Technologies
The government should fund and support pilot-scale projects demonstrating emerging low-carbon steel technologies, such as hydrogen-based DRI, molten oxide electrolysis, or electrochemical ironmaking. This can be done though international collaborations. Successful pilots can de-risk large-scale adoption and attract private investment. The Ministry of Industry, ESDM, and research agencies like BRIN should provide grants or co-financing for these programs.

Medium-Term Actions (2030–2040)

7) Promote Green Iron Imports: The Ministry of Industry and ESDM should integrate green iron imports into Indonesia's national steel decarbonization roadmap. The Ministry of Trade (Kemendag) should review and adjust tariff structures to facilitate green iron imports and develop incentive schemes. To ensure environmental and operational safety, the Ministry of Transportation and the KLHK should establish clear regulations for the handling, transportation, and storage of green iron products. Finally, the Ministry of Foreign Affairs, in collaboration with The Ministry of Industry, should proactively engage with major green iron exporters such as Australia, Brazil, and Saudi Arabia to negotiate long-term supply partnerships and foster technical cooperation. As green iron imports increase, the government should anticipate concerns about job displacement and ensure that safeguards, such as investment in retraining programs and local DRI production, are in place to support a just transition for Indonesia's steel workforce.

8) Gradual Phase-Out of High-Emissions BF-BOF Routes Beyond Set CO_2 Benchmarks
The government should set clear timelines and emissions intensity thresholds for phasing out existing BF-BOF steelmaking lines exceeding set CO_2 benchmarks. Plants failing to meet future standards should face mandatory upgrades or retirement. The Ministry of Industry, KLHK, and regional authorities in steelmaking regions should oversee compliance.

9) Integrate RE Directly into EAF Operations: The government should support dedicated renewable electricity supply to EAF facilities by expanding grid infrastructure, reforming power markets, and enabling scrap-EAF operators to sign long-term green power purchase agreements. Simplifying access to green power markets for SMEs will broaden participation and ensure EAF steel's emissions stay low.

10) Develop a National Green Steel Certification and Carbon Credit System: Indonesia should establish a certification program for low-emission steel, enabling verified green steel products to earn carbon credits or benefit from emissions trading schemes. A robust certification and carbon credit system will make green steel more competitive, and align industry efforts with national climate targets. Such certification scheme should be aligned with reputable international standards and protocols such as Responsible Steel standard.

Actions for Steel Companies

Near-Term Actions (2025–2030)

1) Develop Technology Roadmaps for Shifting to DRI and EAF Production
Steel companies should create clear, company-specific technology roadmaps laying out steps, timelines, and investment requirements for transitioning from blast furnace-basic oxygen furnace (BF-BOF) to direct reduced iron (DRI) and electric arc furnace (EAF) routes. These roadmaps should identify technology partners, necessary workforce training, and infrastructure upgrades to ensure realistic and financially sound transition plans.

2) Conduct RD&D Pilots and Trials: Indonesian steel companies should invest in research, development, and demonstration (RD&D) projects to test low-carbon steel technologies under local conditions. This includes piloting hydrogen-based DRI, advanced energy efficiency measures, waste heat recovery, electrification of rolling and finishing processes, etc. Collaborating with universities, research institutes, and technology providers can help lower technical and financial risks while building local expertise. These pilots will provide practical data on performance, costs, and integration challenges, informing future scale-up and policy design.

3) Conduct Feasibility Studies on Retrofitting Existing Facilities
Steelmakers should undertake detailed technical and economic feasibility assessments for retrofitting existing blast furnaces or EAFs to integrate low-carbon technologies, such as hydrogen injection systems, carbon capture readiness, or hybrid EAF-DRI setups. These studies should inform investment decisions and help companies plan for a phased, cost-effective transformation.

4) Commit to Green Steel Production Targets: Steel companies in Indonesia should publicly commit to green steel production targets. This includes setting clear timelines and goals for reducing emissions from steelmaking and aligning future investments with the national net-zero target by adopting low-carbon technologies such as scrap-based EAF and hydrogen-based DRI. Companies can use international initiatives like SteelZero as a guide, which calls for full adoption of net-zero steel by 2050 with interim milestones for 2030. Joining such efforts can showcase climate leadership, improve access to green financing, and help Indonesian steel producers stay competitive as global demand for low-emissions steel continues to grow.

Medium-Term Actions (2030–2040)

5) Invest in Full-Scale Hydrogen-DRI and Scrap-Based EAF Facilities
Steel companies should move beyond pilots to construct and operate large-scale hydrogen-based DRI or scrap-EAF plants, replacing high-emissions BF-BOF lines. These investments will drastically cut direct CO_2 emissions and align production capacity with global demand for green steel. Firms should secure long-term hydrogen or scrap supply contracts to support plant operations.

6) Collaborate on Shared Hydrogen and Infrastructure Projects
Steelmakers should work together, including with competitors, to co-invest in shared infrastructure for hydrogen production, storage, and distribution around steel clusters. Collaborative approaches can reduce capital costs, ensure reliable supply, and accelerate hydrogen adoption for DRI processes across multiple producers.

7.5. Recommendations for adopting carbon capture, utilization, and storage (CCUS)

Under the Net Zero scenario for Indonesia's steel industry, CCUS is projected to play a small but still important role in cutting emissions. In 2060, CCUS adoption BF-BOF and NG-DRI processes could reduce CO_2 emissions by about 4.1 Mt CO_2 compared to the BAU scenario. This represents roughly 6% of the total emissions reductions needed to reach Net Zero in 2060 relative to BAU emissions. While CCUS can capture residual emissions after other decarbonization measures are deployed, its overall contribution is limited by high capture costs, technical challenges in integrating capture systems at steel plants, and uncertainties around long-term CO_2 storage. The roadmap shows that CCUS can complement other pillars, but significant progress on technology readiness, cost reductions, and deployment of CO_2 transport and storage infrastructure will be necessary for CCUS to achieve its projected impact and contribute meaningfully to Indonesia's steel decarbonization strategy. Below are some of the actions that the government and steel companies in Indonesia should take in order to realize this potential.

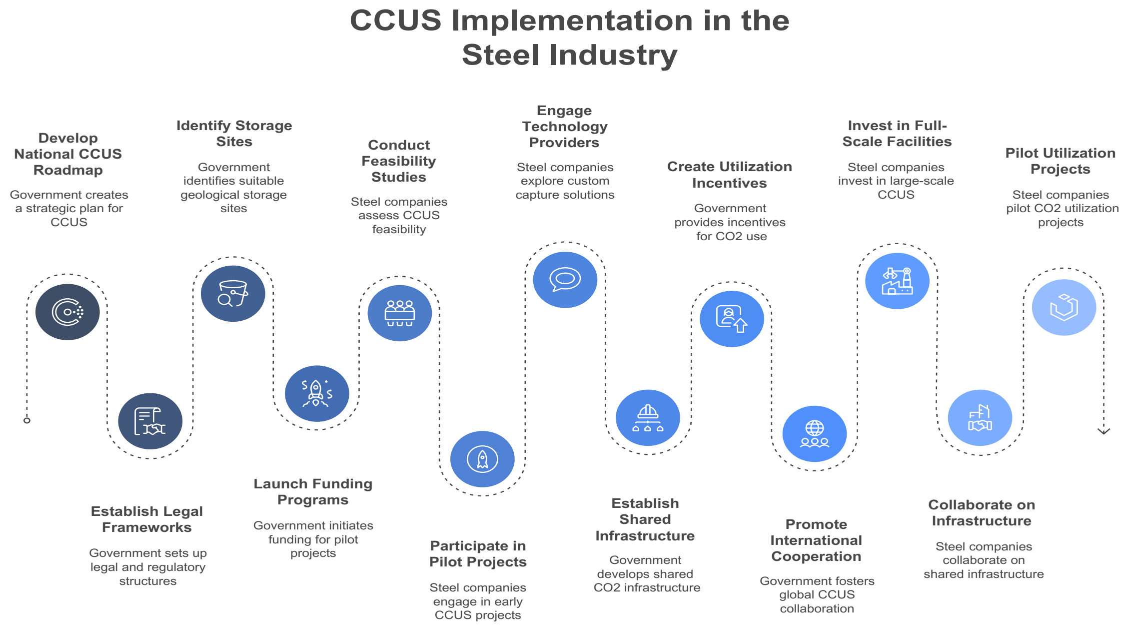


Figure 41: Summary of recommendations for adopting CCUS in the steel industry in Indonesia

Actions for the Government of Indonesia

Near-Term Actions (2025–2030)

1) Develop a National CCUS Roadmap with Sector-Specific Priorities
The government should publish a comprehensive CCUS roadmap detailing timelines, technology pathways, regulatory requirements, and investment needs for industrial sectors like steel. This roadmap should include site identification for potential CO_2 storage, prioritize steel clusters, and coordinate with Indonesia's climate targets. ESDM and Ministry of Industry should co-lead development of the roadmap.

2) Establish Clear Legal and Regulatory Frameworks for CCUS Deployment
Indonesia should draft and enact legislation clarifying the ownership of captured CO_2, responsibilities for long-term storage monitoring, liability in case of leaks, and permitting processes for CCUS projects. Well-defined legal frameworks will attract private investment and ensure safe, responsible deployment. ESDM, the Ministry of Environment and Forestry (KLHK), and the National Development Planning Agency (Bappenas) should coordinate drafting efforts.

3) Identify and Characterize Geological Storage Sites for CO_2
The government should fund detailed geological surveys to map and assess storage potential in depleted oil and gas fields, deep saline aquifers, and other subsurface formations. Accurate site characterization is essential to confirm storage safety, estimate capacity, and build investor confidence. ESDM and the Geological Agency should lead exploration activities.

4) Launch Public Funding Programs for Early CCUS Pilot Projects in Steel
Indonesia should establish grants or low-interest financing facilities to support steel companies piloting CCUS technologies, such as post-combustion CO_2 capture at blast

furnaces or hydrogen-DRI plants. Early pilots will generate operational data, reduce technology risks, and build local expertise. ESDM and The Ministry of Industry should manage funding mechanisms.

Medium-Term Actions (2030–2040)

5) Establish Shared CO_2 Transportation and Storage Infrastructure
Indonesia should invest in CO_2 pipeline networks and regional storage hubs serving multiple emitters, including steel plants, power stations, and cement factories. Shared infrastructure will reduce costs, enable economies of scale, and make CCUS more viable for smaller steel producers. ESDM, the Ministry of Public Works and Housing (PUPR), and BKPM should coordinate planning and investment.

6) Create Incentives for CO_2 Utilization in Industrial Applications
The government should provide tax breaks, subsidies, or preferential procurement policies for businesses using captured CO_2 in commercial products, such as building materials, chemicals, or fuels. Promoting CO_2 utilization can generate revenue streams, reduce net capture costs, and accelerate CCUS deployment. The Ministry of Industry and the Ministry of Finance (Kemenkeu) should develop incentive programs.

7) Promote International Cooperation and Financing for CCUS Projects
The government should actively seek partnerships with countries experienced in CCUS, such as Norway, Australia, and Japan, to secure technical assistance, technology transfer, and concessional financing for Indonesian CCUS initiatives. Establishing bilateral agreements and participating in global CCUS alliances will strengthen Indonesia's capacity and accelerate deployment. The Ministry of Foreign Affairs (Kemenlu), ESDM, and BKPM should coordinate outreach efforts.

Actions for Steel Companies

Near-Term Actions (2025–2030)

1) Conduct Plant-Level Feasibility Studies for CCUS Implementation
Steel companies should evaluate the technical, economic, and logistical feasibility of installing carbon capture systems on key emissions sources such as blast furnaces or direct reduced iron (DRI) plants. Studies should assess capture technology options, integration costs, potential partners, and storage or utilization pathways. Results will provide a foundation for investment decisions and inform discussions with regulators and financiers.

2) Participate in Early Pilot Projects for CO_2 Capture Technologies
Steelmakers should actively join or co-develop pilot projects testing CO_2 capture technologies at their facilities. Early participation will help companies build in-house expertise, gather real-world performance data, and reduce technology risks, positioning them to scale up CCUS once regulations and infrastructure mature.

3) Engage Technology Providers to Explore Custom Capture Solutions
Companies should collaborate with technology vendors to explore solutions tailored to their unique process conditions, such as high-temperature exhausts or specific impurities. Joint engineering studies can identify optimal capture methods, improving performance and cost-effectiveness for steel sector applications.

Medium-Term Actions (2030–2040)

4) Invest in Full-Scale Carbon Capture Facilities at Major Emission Points
Steel companies should move from pilots to building and operating full-scale CCUS installations capturing substantial CO_2 volumes from blast furnaces, EAFs with DRI, or reheat furnaces. Such projects will demonstrate technical viability at commercial scale and significantly reduce their overall emissions footprint.

5) Collaborate with Industrial Peers to Co-Develop Shared CCUS Infrastructure
Steelmakers should partner with other emitters such as power plants or cement factories in their region to jointly plan and invest in shared CO_2 pipelines and storage hubs. This collaborative approach will lower individual costs, spread risk, and accelerate CCUS deployment across sectors.

6) Pilot CO_2 Utilization Projects Creating Value-Added Products
Companies should test commercial uses of captured CO_2, such as mineralization into construction materials, synthetic fuels, or industrial chemicals. Successful pilots will identify profitable utilization pathways, offset capture costs, and generate additional revenue streams.

7.6. Actions for steel buyers

Steel buyers in both the public and private sectors can play a decisive role in driving decarbonization of Indonesia's steel industry by adopting green procurement practices that prioritize low-carbon steel. When government agencies integrate carbon intensity requirements into public tenders for infrastructure projects like roads, ports, or buildings they create predictable demand for low-emissions steel, giving producers the confidence to invest in cleaner technologies such as EAF or hydrogen-based DRI. Meanwhile, private sector buyers including developers, automotive manufacturers, and electronics companies can implement procurement policies that favor suppliers with verified low-carbon products or Environmental Product Declarations (EPDs), setting clear expectations for emissions performance across supply chains. By sending consistent, forward-looking demand signals for green steel through both public green procurement programs and private corporate sourcing commitments, steel consumers create market incentives that accelerate the industry's transition to sustainable production, while also reducing their own carbon footprints and aligning with Indonesia's national net-zero targets.

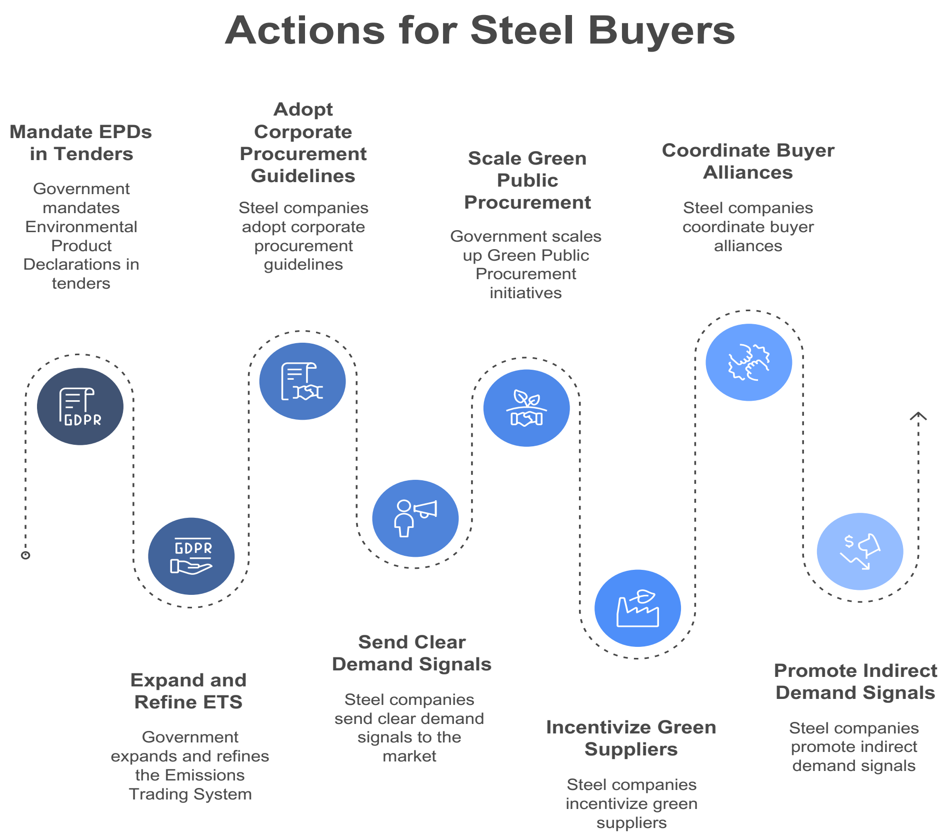


Figure 42: Summary of recommendations for steel buyers in Indonesia

Actions for the Government of Indonesia

Near-Term Actions (2025–2030)

Mandate EPDs in Tenders: Ministries and SOEs involved in procurement should revise bidding requirements to include EPDs or verified carbon footprints. Requiring lifecycle carbon data in public tenders will reward low-carbon producers and foster competition around sustainability. This could be supported by KLHK and IISIA through capacity-building programs for both buyers and suppliers.

Expand and Refine the Emissions Trading System (ETS): As Indonesia pilots its national ETS, steel must be integrated with fair and sector-specific benchmarks. This includes defining allowances, trading mechanisms, and transparent monitoring, reporting, and verification (MRV) systems. Coordination among the Ministry of Finance, KLHK, and IISIA is crucial to ensure that steel producers are fairly incentivized to reduce emissions without losing competitiveness.

Medium-Term Actions (2030–2040)

Scale Green Public Procurement (GPP): The government, through agencies like the Ministry of Public Works (PUPR), should rapidly expand the use of green public procurement in infrastructure projects. By setting carbon intensity thresholds for steel used in roads, ports, and housing projects for major construction projects, such as the new Nusantara capital, GPP can create guaranteed demand for low-carbon products and drive upstream decarbonization.

Actions for Corporate Steel Buyers

Near-Term Actions (2025–2030)

Adopt Corporate Procurement Guidelines: Large-scale private buyers, including developers, automobile manufacturers, and electronics firms, should adopt green procurement policies that favor suppliers with verified emissions data and low-carbon products. Voluntary programs like the SteelZero, RE100 or the Science Based Targets initiative can provide frameworks for aligning procurement with climate goals.

Send Clear Demand Signals: Key consumers, including multinational firms operating in Indonesia, should issue forward-looking purchasing commitments for green steel. By articulating long-term demand for low-carbon materials, companies like Toyota Astra can provide the market certainty needed for steel producers to make capital-intensive decarbonization investments.

Medium-Term Actions (2030–2040)

Incentivize Green Suppliers: Procurement guidelines should be designed to reward suppliers that meet or exceed sustainability criteria. This could include preferential contract terms, public recognition, or tiered supplier status within corporate ESG programs. Ministries and trade associations can provide templates and certification pathways to simplify this process.

Coordinate Buyer Alliances: Industry groups and NGOs should help aggregate demand from multiple buyers into “green steel buyer clubs” that issue collective tenders or investment signals. These alliances can help lower the risk for producers investing in new technologies and spread the cost of verification and certification systems.

Promote Indirect Demand Signals: Beyond direct procurement, steel consumers can use their influence as investors, developers, or exporters to drive low-carbon material adoption. For example, property developers can specify green steel in building codes or investor disclosure frameworks. As carbon border taxes become more prevalent, these indirect signals will grow in importance.

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List of Abbreviations

BAU – Business As Usual

BF – Blast Furnace

BF-BOF – Blast Furnace–Basic Oxygen Furnace

BOF – Basic Oxygen Furnace

CCUS – Carbon Capture, Utilization, and Storage

CDQ – Coke Dry Quenching

CO_2 – Carbon Dioxide

CREA – Center for Research on Energy and Clean Air

DRI – Direct Reduced Iron

EAF – Electric Arc Furnace

EE – Energy Efficiency

EPD – Environmental Product Declaration

ESDM – Ministry of Energy and Mineral Resources (Indonesia)

ETS – Emissions Trading System

GHG – Greenhouse Gas

GPP – Green Public Procurement

H_2-DRI – Hydrogen-based Direct Reduced Iron

IBAI – Indonesian Business Association of Iron and Steel

IEA – International Energy Agency

IISIA – Indonesian Iron and Steel Industry Association

JETP – Just Energy Transition Partnership

KPI – Key Performance Indicator

MRV – Monitoring, Reporting, and Verification

NG-DRI – Natural Gas-based Direct Reduced Iron

NOx – Nitrogen Oxides

PPA – Power Purchase Agreement

PLN – Perusahaan Listrik Negara (Indonesia's State Electricity Company)

RE – Renewable Energy

REC – RE Certificate

SNI – Indonesian National Standard

TRT – Top Pressure Recovery Turbine