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Net-Zero Roadmap for Vietnam's Steel Industry

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ACE

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Disclaimer

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Executive Summary

Key Takeaways

- The main decarbonization lever to get to Net Zero by 2060 in Vietnam'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 Vietnam may carry a large cost premium per ton of steel, the impact on end products is modest, adding about $285 per passenger car or $790 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.
- CCS is not a major driver of the Net Zero pathway and contributes relatively little to total emissions reductions in Vietnam's steel industry by 2060.

Vietnam has committed to achieving net-zero greenhouse gas (GHG) emissions by 2050. As the country advances toward its climate targets, emissions from the steel sector will need to peak and decline. Steel production in Vietnam is highly carbon-intensive due to the large share of primary blast furnace-basic oxygen furnace (BF-BOF) steelmaking. With continued investment in new BF-BOF capacity, Vietnam will face challenges in decarbonization of the steel sector. This report provides an overview of steel production, energy use, and emissions trends in Vietnam 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 Vietnam's government, steel producers, consumers, and other relevant stakeholders.

While Vietnam produces a smaller share of the world's steel than some major producers, it is one of the fastest-growing steel-producing countries in Southeast Asia. In 2023, Vietnam produced approximately 19 million tons (Mt) of crude steel and was the 12th largest steel-producing country. The steel production is expected to grow to up to 55 Mt per year in 2060. The steel industry is an important pillar of Vietnam's economic development, underpinning the country's rapid infrastructure expansion, supporting key manufacturing sectors such as construction and shipbuilding, and contributing to export revenues and industrial employment.

The Net-Zero Roadmap for Vietnam's Steel Industry ('Roadmap') describes the current status of Vietnam'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. Although Vietnam's net zero commitment is for 2050, the relatively young fleet of BF-BOF plants in Vietnam will make this challenging, and hence our study timeline goes through 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).

We estimated the total final energy use and CO_2 emissions of the steel industry in Vietnam through 2060 under four scenarios: Business-as-Usual (BAU), Moderate, Advanced, and Net-Zero, with the scenarios varying in their degree of adoption of technologies under each decarbonization pillar. Figure ES1 shows the projected emissions trajectory for Vietnam's steel industry under each scenario. In the BAU scenario, emissions from the steel industry are projected to grow through 2060, driven by significant growth in crude steel production with only moderate levels of energy efficiency improvement and shifting to low-carbon technologies. The Net Zero scenario has the greatest reduction in emissions for Vietnam's steel industry, based on slower growth in crude steel production resulting from material efficiency and steel demand management in the economy, aggressive energy efficiency measures, the highest adoption of transformative low-carbon iron and steelmaking technologies like scrap-EAF, natural gas-based direct reduced iron (NG-DRI) or green hydrogen-based DRI (H_2-DRI), and more CCUS. Under the Net Zero scenario, the total CO_2 emissions of Vietnam's steel industry would be lower by 89% relative to 2023 emissions, and by 95% relative to the BAU scenario's emissions in 2060.

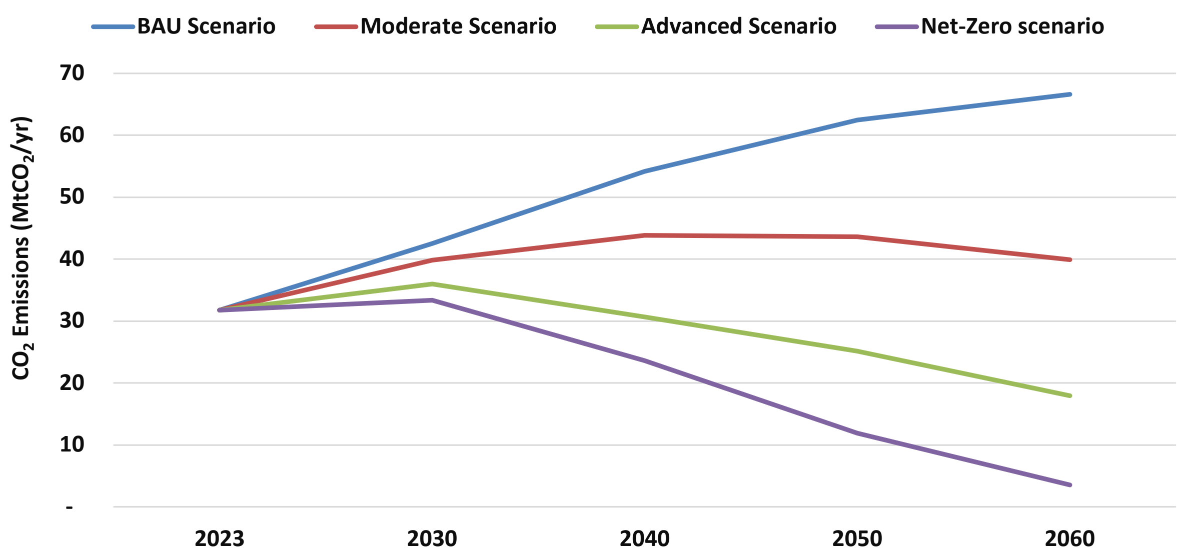

Figure ES1: Total annual CO_2 emissions in the steel industry in Vietnam under four decarbonization scenarios, 2023-2060 (Source: this study)

The Roadmap shows how much each decarbonization pillar contributes to total decarbonization. Figure ES2 below breaks down the emissions reduction contribution of each pillar for the Net Zero scenario in 2060 relative to the BAU scenario's emissions in 2060. The technology shift to low-carbon iron and steelmaking pillar is projected to have the greatest amount of emissions reduction potential, and it combines multiple lower-carbon steelmaking technologies like scrap-based EAF, NG-DRI-EAF, and green H_2-DRI-EAF, and electrolysis of iron ore. Material efficiency and demand management has the second largest emissions reduction potential. The energy efficiency and electrification of heating, and fuel switching and cleaner electricity contribute roughly the same amount to emissions reductions. Our analysis shows that the impact of CCUS will be lower than other decarbonization pillars. We have also assumed a small amount of green iron produced by green H_2-DRI is imported (10% in of total steelmaking in 2050 and 15% in 2060 under the Net Zero scenario) and then used in EAFs in Vietnam to produce steel. Figure ES2 below shows the contribution of this imported green iron in decarbonization of steel production in Vietnam.

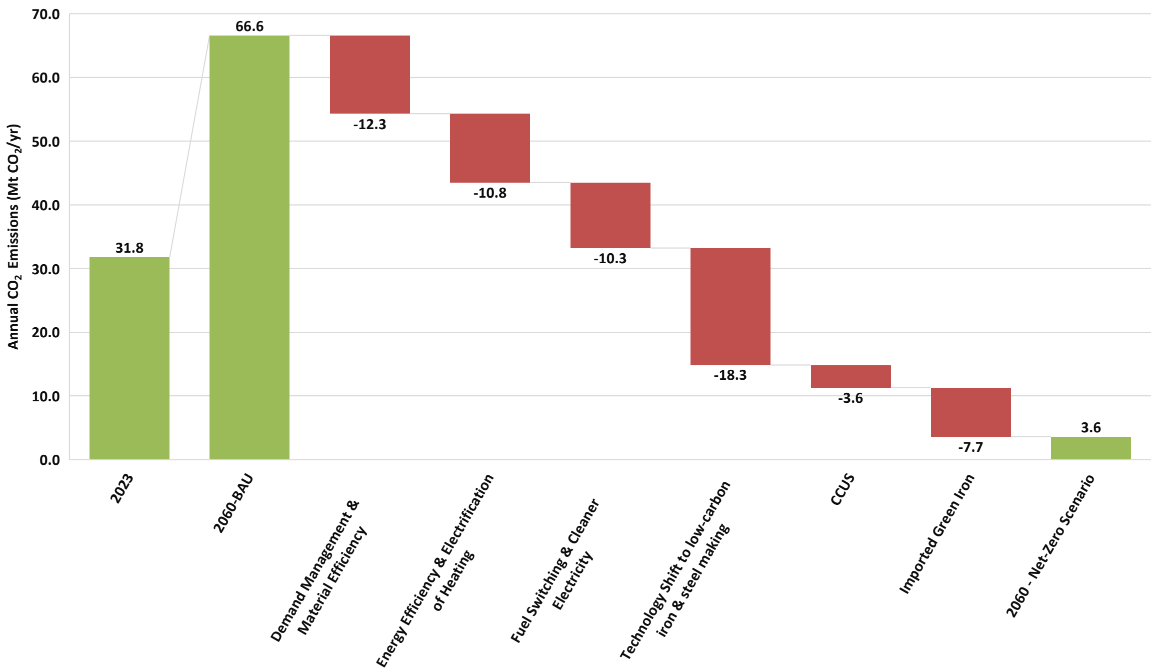

Figure ES2. Impact of each decarbonization pillar on CO_2 emissions of Vietnam's steel industry, Net Zero scenario relative to BAU (Source: this study)

The Roadmap also shows the contribution of each pillar over time in terms of bringing 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 Vietnam 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 also expected to play a small role with adoption starting in 2030s.

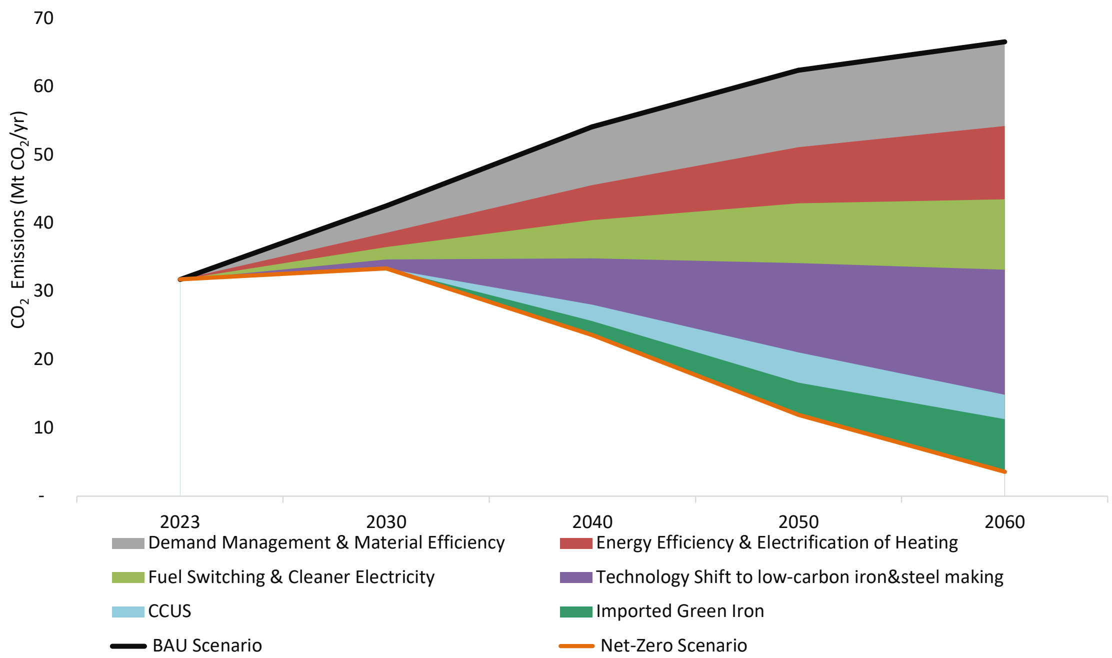

Figure ES3. Impact of decarbonization pillars on CO_2 emissions of Vietnam's steel industry to bring BAU emissions down to the Net Zero scenario's level (Source: this study)

The Roadmap also evaluates the economic feasibility of three lower-carbon steel production routes, scrap-EAF, green H_2-DRI-EAF, and NG-DRI-EAF steelmaking, relative to BF-BOF. Our analysis shows that scrap-based EAF steelmaking in Vietnam has similar costs as BF-BOF at current scrap prices, and could be competitive if scrap prices remain stable or decline. The cost structure for EAF is heavily dominated by scrap costs (around 75%), highlighting the importance of stable and reliable scrap supply to sustain 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. This is primarily because of the lower price for both coking coal and thermal coal and especially a substantial drop in price in the past two years making BF-BOF production more cost-competitive. However, the green steel premium is expected to narrow as hydrogen costs fall due to technological improvements and stronger policy support (Figure ES4). Our analysis finds that while Vietnam currently faces a higher green steel premium per ton of steel due to the early stage of its hydrogen infrastructure development, the green steel premium per unit of the final product remains relatively small: around $285 per passenger car and $790 per residential building unit (50 m^2), indicating that green steel adoption would have minimal impact on end-user affordability. Moreover, the introduction of carbon pricing and ongoing declines in hydrogen production will make green H_2-DRI-EAF increasingly competitive.

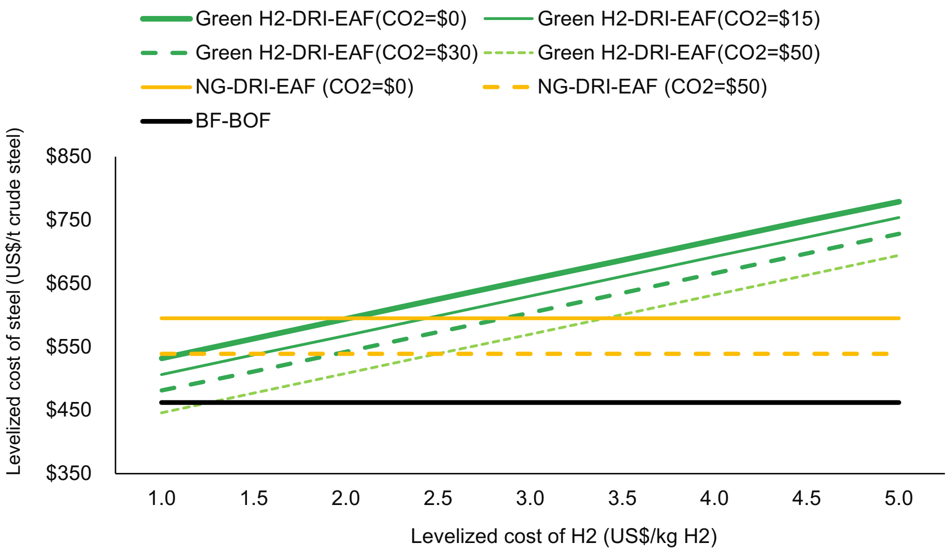

Figure ES4. Levelized Cost of Steel ($/t crude steel) with varied levelized costs of green H_2 at different carbon prices in Vietnam (Source: this study)

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.

This Roadmap shows that achieving Net Zero emissions for Vietnam's iron and steel sector will require unprecedented uptake of low-carbon technologies. The roadmap lays out an action plan for Vietnam's government, steel companies, steel consumers, and other stakeholders to enable this transition.

Summary of recommendations

Enhancing Material Efficiency and Demand Management:
In the near term (2025–2030), the Government of Vietnam should focus on issuing national guidelines to optimize steel use in construction, embedding material efficiency criteria into public procurement processes to reward reduced steel consumption, and launching large-scale awareness campaigns to spread efficient design practices among architects, engineers, and developers. Vietnamese steel producers should carry out detailed assessments of their production lines to identify sources of material waste and improve yields, accelerate the production of high-strength, lightweight steel grades to cut steel use in end applications, and set internal targets for material efficiency to ensure these practices are institutionalized throughout their operations.

For the medium term (2030–2040), the Government of Vietnam should introduce mandatory material intensity reduction targets for key steel-consuming sectors such as construction and automotive, update infrastructure design standards to require efficient use of steel in public projects, and promote industrial symbiosis programs to increase scrap reuse across sectors. Steelmakers should deploy advanced digital tools for real-time yield monitoring to continually reduce scrap and offcuts, and participate in cross-sector networks to exchange scrap and by-products, maximizing resource efficiency and cutting the demand for primary steel.

Enhancing Energy Efficiency and Electrification of Heating:
In the near term, the government should require steel plants to conduct comprehensive energy audits to set efficiency baselines, expand support for waste heat recovery installations to reuse heat from steel processes, and develop guidelines for electrifying low- and medium-temperature heating systems. Steel producers should prioritize quick-win improvements like sealing furnace leaks, enhancing combustion control systems, investing in waste heat recovery, and replacing outdated burners with modern, efficient ones to cut energy consumption and emissions.

By the medium term, steel producers should implement real-time energy monitoring systems in large facilities to ensure continuous efficiency improvements. Companies should electrify rolling mills and finishing lines with clean electricity sources, integrate AI-powered energy management systems to dynamically optimize furnace operations, and shift high-impact processes like ladle preheating to electric heating, further reducing dependence on fossil fuels.

Enhancing Fuel Switching and Cleaner Electricity:
In the near term, policies must guarantee that the steel sector's renewable electricity needs are considered in Vietnam's power sector expansion plans. The government should establish a clear legal framework for corporate renewable PPAs and simplify processes for businesses to procure renewable electricity. Steel companies should carry out detailed feasibility studies on switching from coal to cleaner fuels like natural gas as a transitional step, sign long-term renewable PPAs to secure clean power, and retrofit existing combustion systems to prepare for future fuel transitions.

For the medium term, Vietnam should require major industrial consumers, including steel plants, to progressively increase the share of renewables in their electricity consumption. Reforms to industrial electricity tariffs should encourage steelmakers to shift loads to off-peak times when renewable power is more abundant, and the national grid should be modernized and expanded to ensure steel producers can access low-carbon electricity. Establishing a national task force on industrial fuel switching and investing in on-site hydrogen storage and distribution infrastructure will be key, alongside steelmakers committing to science-based emission targets that include concrete timelines 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 and redirect incentives toward electric arc furnace (EAF) and direct reduced iron (DRI) technologies, strengthen scrap collection networks and enforce quality standards for scrap used in EAFs, and offer financial incentives for upgrading existing facilities or building new EAF and DRI plants. Additionally, Vietnam should plan the development of green hydrogen production hubs near major steel regions, publish national guidelines for hydrogen-ready DRI plants, and launch pilot programs to demonstrate low-carbon steelmaking technologies like hydrogen-based DRI.

For the medium term, Vietnam should set a clear schedule for phasing out high-emission blast furnace-basic oxygen furnace (BF-BOF) lines beyond specified CO_2 benchmarks, support pilot-scale hydrogen DRI plants, facilitate green iron imports as part of a diversified low-carbon supply strategy, and integrate renewable electricity directly into EAF operations by upgrading power infrastructure and reforming electricity markets. Creating certification systems for green steel products and carbon credits will also be essential to incentivize low-carbon production and ensure competitiveness in future markets.

Adopting Carbon Capture, Utilization, and Storage (CCUS):
In the near term, the government should release a comprehensive CCUS roadmap highlighting steel-sector priorities, create clear legal and regulatory frameworks for CO_2 capture, ownership, liability, and storage permitting, and conduct geological studies to identify and evaluate potential storage sites. Providing funding for early pilot CCUS projects at steel plants and encouraging companies to conduct feasibility studies for implementing capture systems will help build local expertise and reduce technology risk. Steelmakers should collaborate with technology providers to tailor solutions for their specific processes.

In the medium term, the focus should shift to building shared CO_2 transport and storage infrastructure to lower costs and enable smaller steelmakers to access CCUS solutions. The government should create incentives for industries to use captured CO_2 in commercial applications like construction materials or fuels, while pursuing international cooperation with experienced countries to gain technical knowledge and secure concessional financing. Steel companies should progress from pilots to full-scale CCUS installations, partner with other industries on shared infrastructure, and pilot innovative uses of captured CO_2 to create valuable products.

Recommendations for Steel Buyers:
In the near term, government procurement processes should mandate the inclusion of Environmental Product Declarations (EPDs) or verified carbon footprints in tenders to favor low-carbon steel suppliers. Large private sector buyers, including developers and manufacturers, should adopt green procurement standards that reward suppliers providing verified low-emission products. Key steel consumers should issue forward-looking commitments to purchase green steel, sending clear demand signals that will encourage steelmakers to invest in cleaner technologies.

In the medium term, Vietnam should expand green public procurement to all major infrastructure projects to create stable demand for low-carbon steel. Procurement guidelines should include incentives for suppliers who exceed sustainability standards, while industry groups and NGOs can coordinate buyer alliances to combine demand and accelerate investments in clean steel. Promoting indirect demand signals such as including green steel requirements in building codes or investor reporting frameworks will help mainstream low-carbon steel and drive the market towards more sustainable production.

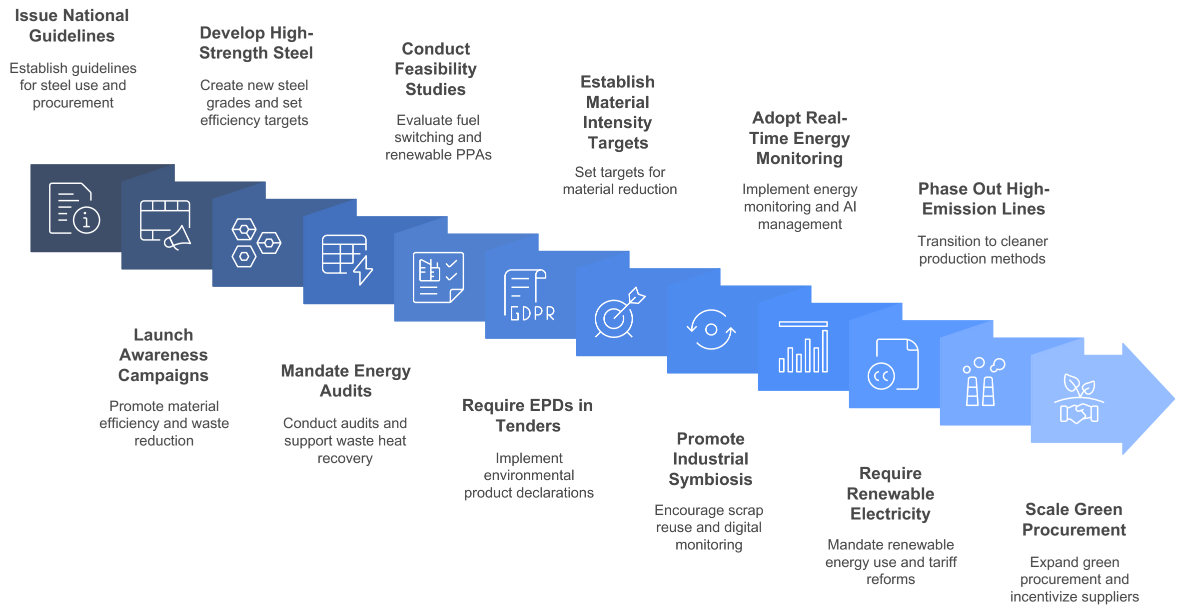

Figure ES5. Examples of recommendations for decarbonizing the steel industry in Vietnam

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1 Introduction

Iron and steel manufacturing is one of the most energy- and carbon-intensive industries globally. The heavy reliance on coal and other fossil fuels in steel production makes it one of the highest-emitting sectors in terms of CO_2 emissions. Globally, the iron and steel industry accounts for roughly a quarter of greenhouse gas (GHG) emissions from the manufacturing sector (IEA 2025) and over 11% of total global CO_2 emissions (Hasanbeigi 2022).

Global steel demand is projected to rise from 1,884 Mt in 2024 to as much as 2,500 Mt by 2050 (IEA 2020), driving significant increases in energy use and emissions if the sector does not undergo deep decarbonization. Vietnam's steel industry, while smaller in global terms, is expanding rapidly. Since 2014, crude steel production in Vietnam quadrupled and is now currently around 20 Mt per year. Vietnam is now the largest steel producer in Southeast Asia and 12th largest steel-producing country globally. and the country continues to invest in both BF-BOF and EAF routes.

Steel can be produced through three main routes: the BF-BOF route, the direct reduced iron–electric arc furnace (DRI-EAF) route, and the scrap-based EAF (scrap-EAF) route. In both the BF-BOF and DRI-EAF routes, iron ore is first chemically reduced to produce iron, which is then refined into steel. Alternatively, the scrap-EAF route produces steel by directly melting recycled scrap in an EAF, bypassing the need for iron ore reduction. Today, the BF-BOF and EAF routes dominate global steel production. As of 2023, approximately 70% of the world's crude steel was produced via the BF-BOF route, while about 30% came from EAF-based production (worldsteel 2024a).

The share of EAF-based production in Vietnam's steel industry is slightly higher than the global average, at around 35% in 2023, but remains lower than leading industrialized countries like the U.S. and EU. Additional unabated BF capacity is under planning or construction in Vietnam, and these new high-capital BFs investments are expected to operate at least four decades (40+ years), presenting challenges to achieving net zero emissions by 2050 or even 2060.

Vietnam has made national-level commitments to climate action, including a pledge to achieve net-zero GHG emissions by 2050. In line with this target, government agencies and industry stakeholders have begun exploring low-carbon steelmaking technologies, including increased scrap recycling, energy efficiency upgrades, and emerging technologies such as H_2-DRI EAF steelmaking. Green hydrogen-based steelmaking, in which hydrogen is produced through electrolysis using renewable electricity and used as an energy source and reductant for iron production, is a promising deep decarbonization solution and is being deployed internationally.

To highlight the significant emissions benefits of adopting lower-carbon iron and steelmaking routes, Figure 1 shows the CO_2 intensity of a typical new primary steel production plant in Vietnam across key production routes. In Vietnam, 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 powered by conventional grid electricity can reduce emissions to about 1.0 ton of CO_2 per ton of steel, representing a 46% reduction compared to BF-BOF. If the NG-DRI-EAF route is supplied entirely with renewable electricity, emissions can fall further to around 0.66 tons of 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.

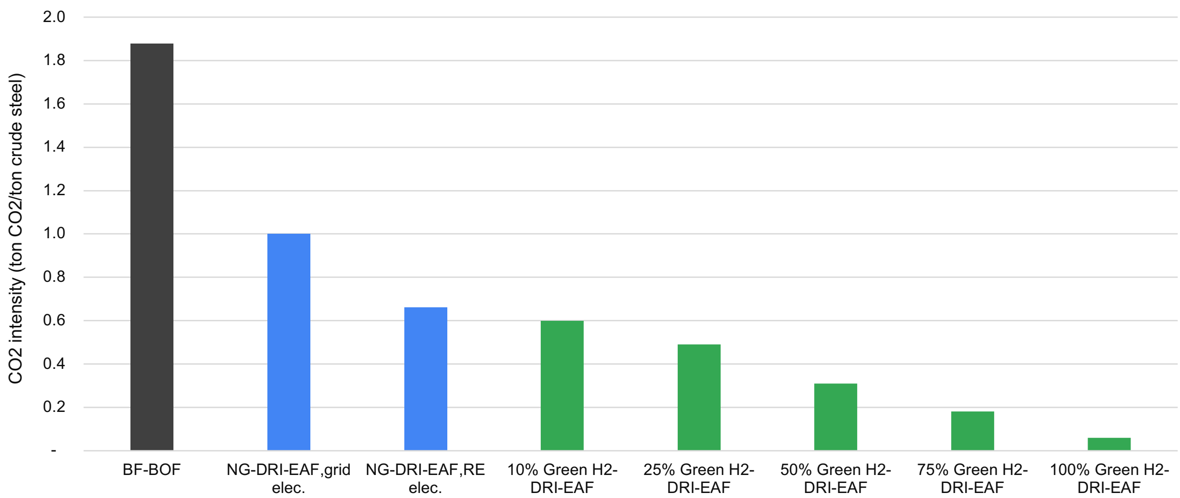
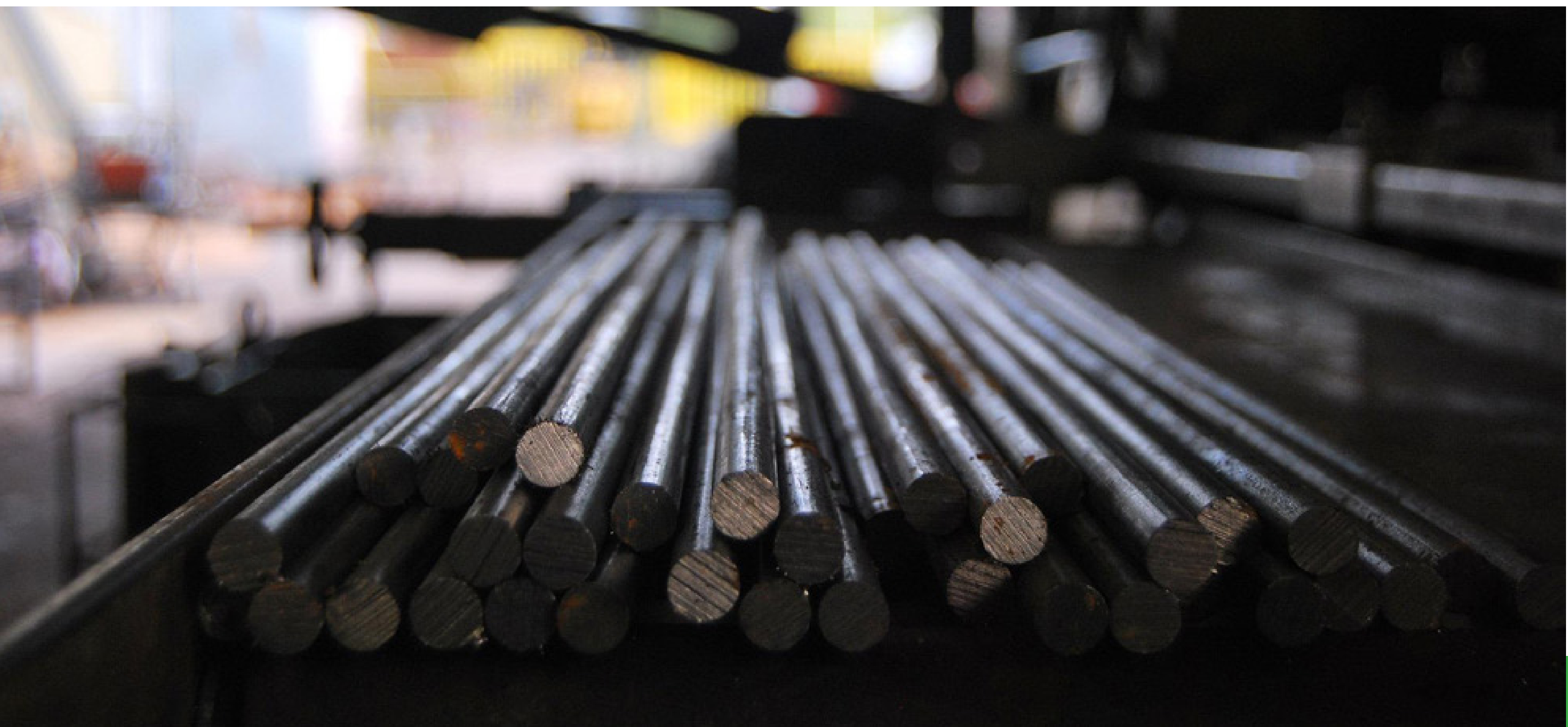


Figure 1. CO_2 intensity of different new primary crude steel production plants in Vietnam (Source: this study)

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

This report presents the current state of steel production, energy use, and emissions in Vietnam and proposes a data-driven, scenario-based roadmap to reduce CO_2 emissions in the sector by 2060. It outlines key milestones for 2030, 2040, 2050, and 2060, and concludes with targeted policy recommendations and action plans for the Vietnamese government, steel producers, steel consumers, and other stakeholders.



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

Steel production and consumption

Vietnam is currently the world's 12th-largest producer of steel (worldsteel 2024b), and the largest steel producer in the Southeast Asia region. Crude steel production in Vietnam has increased significantly over time, more than quadrupling crude steel production between 2014 and 2021, followed by a slight decrease driven by low-cost steel from China. Current steel production levels in Vietnam are around 20 Mt per year. Production of finished steel products has also increased over time, with Vietnam importing crude steel products (billets, blooms, slabs, etc.) to produce finished steel products (Figure 2).

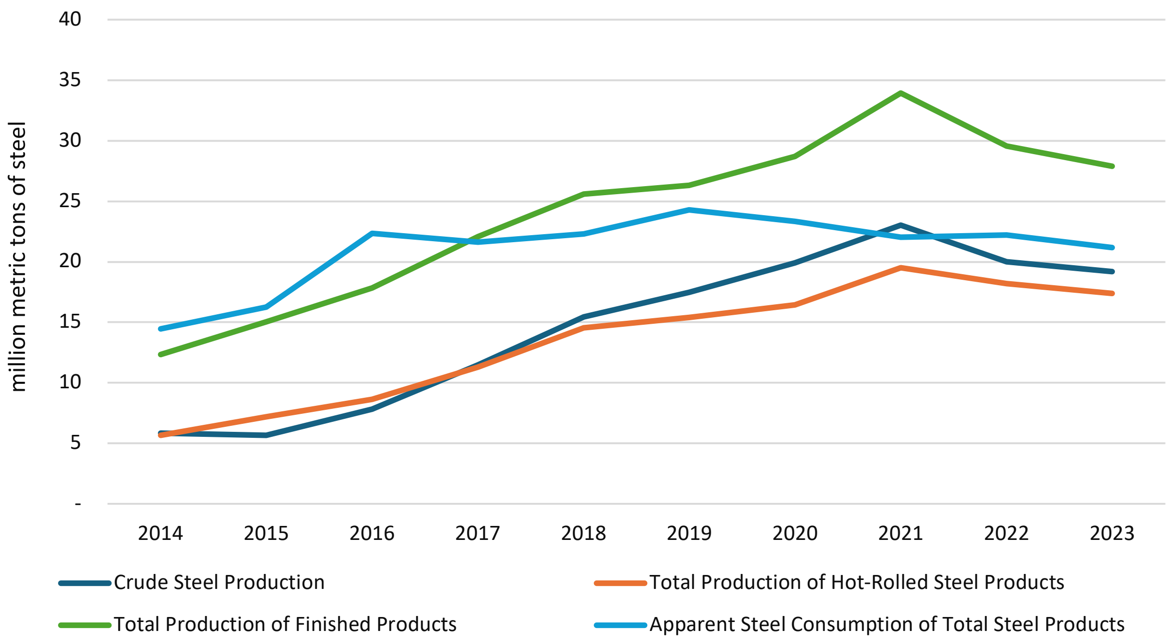


Figure 2: Steel production and consumption in Vietnam, 2014-2023 (Source: SEAISI 2024)

The majority of Vietnam's steel production capacity is through the BF-BOF route, which accounts for approximately 75% of the country's operational capacity and around 65% of actual production as of 2023. Several smaller EAF plants make up 35% of steel production. Table 1 below lists iron and steel plants in Vietnam with available data on production capacity and steelmaking route.

Table 1 below lists Vietnam's operational iron and steel plants. Vietnam's steel industry is dominated by several major companies, especially Hoa Phat Group (HPG) and Formosa Ha Tinh Steel Corporation (FHT), a Taiwanese-Vietnamese joint venture. These companies operate the two largest BF-BOF steel plants in Vietnam. HPG is the largest steel producer in Vietnam, a privately owned company with an annual production capacity of over 14 Mt, including high-quality hot-rolled coil steel, construction steel, and steel pipes. The FHT steel plant is Vietnam's largest foreign direct investment project, with a capacity of 7.5 Mt per year currently and additional expansion plants. VNSTEEL and Hoa Sen Group are other key producers of crude steel and finished products.

Table 1: Currently operating iron and steel plants in Vietnam (Source: GEM 2025)

Plant	Year of Commission	Production Route	Estimated Capacity (Mt per annum)	Location
Formosa Ha Tinh Steel Plant	2008	BF-BOF	7.5 mtpa (crude steel), 7 mtpa (iron)	Ha Tinh
Hoa Phat Dung Quat Steel Plant	2017	BF-BOF	9.8 mtpa (crude steel), 4 million mtpa (iron)	Quang Ngai
Hoa Phat Hai Duong Steel Plant	2007	BF-BOF	2.5 mtpa (crude steel), 3 mtpa (iron)	Hai Duong
Lao Cai Cast Iron and Steel Plant	2014	BF-BOF	0.5 mtpa (crude steel), 0.5 mtpa (iron)	Lao Cai
Pomina Steel Phu My Plant	1999 and 2012 (2 units)	BF, EAF	1.5 mtpa (crude steel), 1 mtpa (iron)	Ba Ria Vung Tau
POSCO Yamato Vina Phu My Steel Plant	2020	EAF	1 mtpa (crude steel)	Ba Ria Vung Tau
Shengli Vietnam Special Steel An Bai Steel Plant	2008	EAF	0.8 mtpa (crude steel)	Thai Binh
Thai Ngyuen Iron and Steel Plant	1963	BF-BOF, EAF	0.3 mtpa (crude steel), 0.3 mtpa (iron)	Thai Nguyen
Tung Ho Steel Phu My Plant	2007	EAF	1 mtpa (crude steel)	Ba Ria Vung Tau
Tuyen Quang Iron and Steel Long Binh Steel Plant	2014	BF-BOF	0.5 mtpa (crude steel), 0.2 mtpa (iron)	Tuyen Quang
VAS An Hung Tuong Steel Binh Duong Plant	1988	EAF	0.5 mtpa (crude steel)	Binh Duong
VAS Nghi Son Cast Iron and Steel Plant	2018	EAF	1 mtpa (crude steel)	Thanh Hoa
VAS Tue Minh Steel Binh Duong Plant	2016	EAF	0.5 mtpa (crude steel)	Binh Duong
Vietnam Italy Steel Pho Noi Steel Plant	2002	EAF	0.5 mtpa (crude steel)	Hung Yen
Vina Kyoei Steel Phu My Plant	1996	EAF	0.5 mtpa (crude steel)	Ba Ria Vung Tau
VNSteel Southern Steel Plant	2005	EAF	0.5 mtpa (crude steel)	Ba Ria Vung Tau

*mtpa: million tons per annum

As Table 1 shows, Vietnam's steel industry is characterized by a number of smaller EAF plants and several very large and relatively new BF-BOF plants. Given that BF-BOF plants typically operate for over 40-50 years, these plants pose a challenge to decarbonization of Vietnam's steel industry toward net zero by 2050, and hence our modeling timeline goes through 2060.

Vietnam's steel trade

In terms of Vietnam's steel trade, Vietnam's imports of semi-finished steel products have declined from a peak in 2016 and remained relatively constant at around 10 Mt per year since 2018, reflecting increasing domestic production capacity. Imports of finished steel products remain low and stable (Figure 3).

Figure 3: Imports of semi-finished and finished steel products in Vietnam, 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.

Vietnam's steel trade profile has transformed in recent years, with the country emerging as a major regional exporter. Steel exports of semi-finished steel surged from less than 2 Mt in 2014 to a peak of 13 Mt by 2021, reflecting the rapid expansion of domestic production capacity. The decline in semi-finished steel exports from 2021 to 2022 shown in Figure 4 was driven by weaker global demand in the wake of the COVID-19 pandemic, rising trade barriers, and high shipping costs.

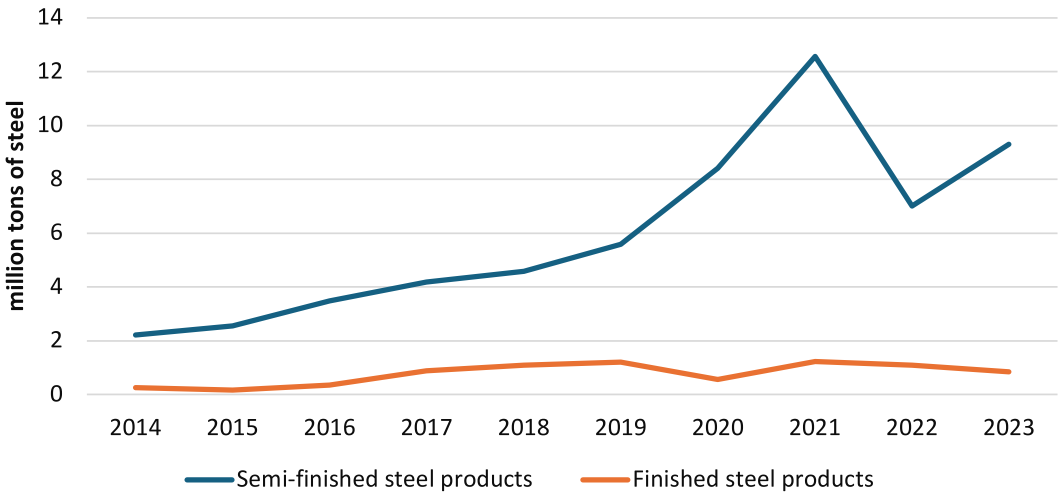


Figure 4: Exports of semi-finished and finished steel products in Vietnam, 2014-2023 (Source: UN Comtrade 2025)

*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.

China was the largest source of imports for both semi-finished and finished steel products, while Japan, Korea, and Taiwan were also significant sources of imports. ASEAN partner Indonesia was a significant source of imports of semi-finished steel, and Thailand was a major source for finished steel products (Figure 5).

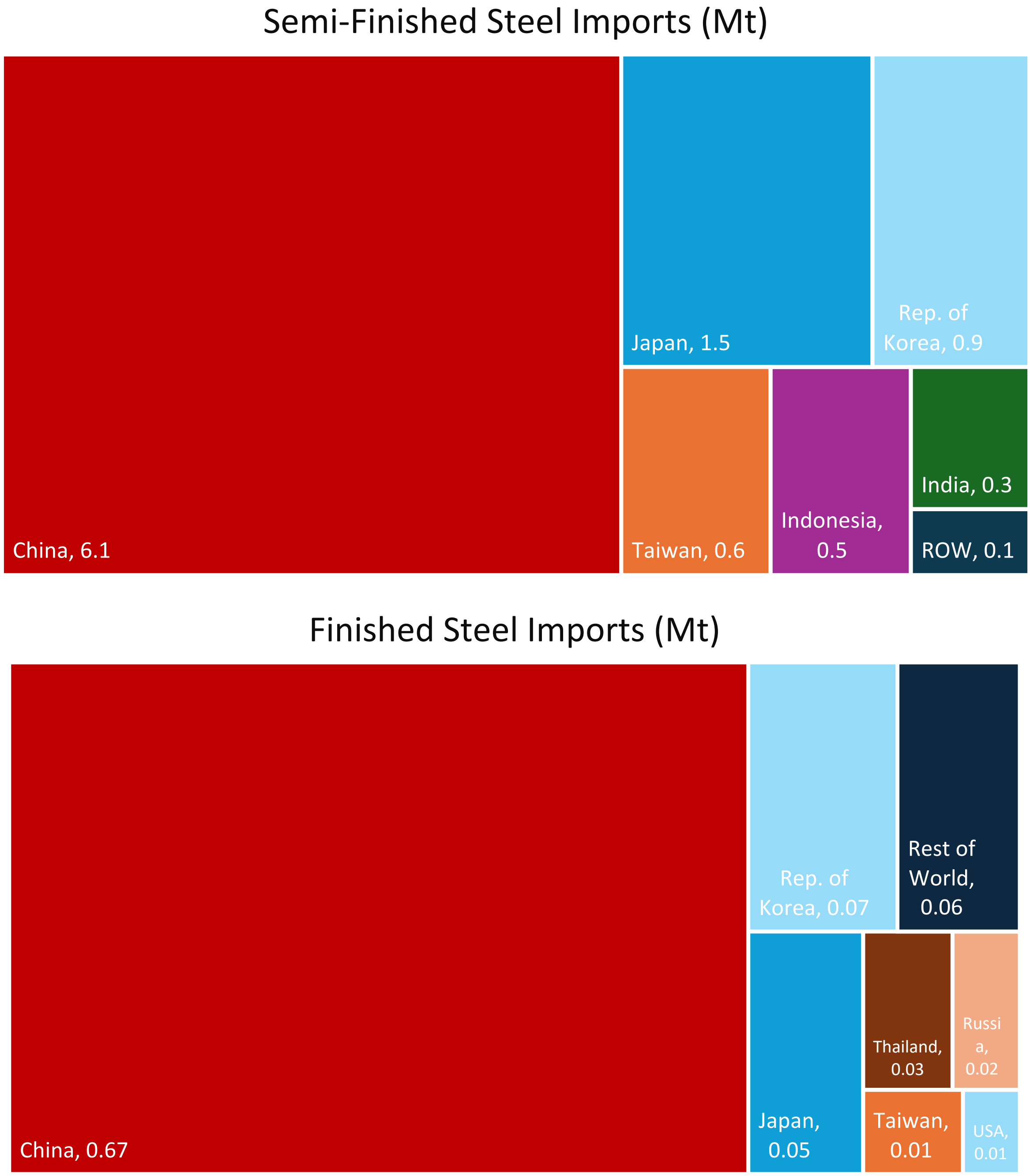
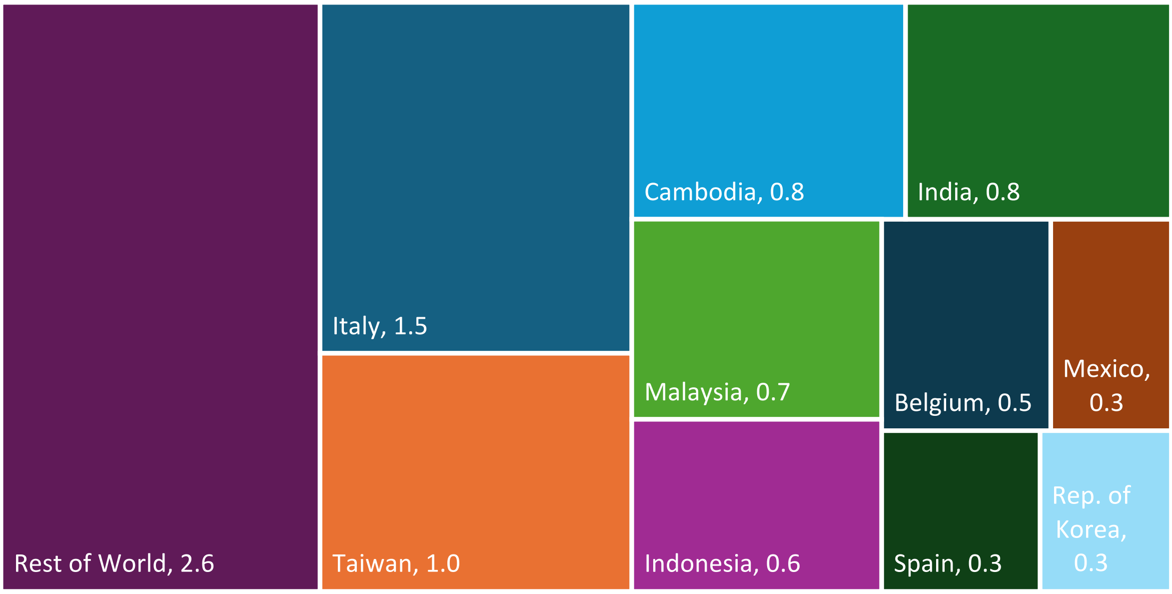


Figure 5: Imports of semi-finished (top) and finished (bottom) steel products in Vietnam in 2023 (Source: UN Comtrade 2025)

*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.

In terms of export destinations, there was more diversity in partner countries. Semi-finished steel products were exported to European partners (Italy, Belgium, and Spain) as well as regional partners and North America (Mexico and the US). Italy was the top destination for finished steel products from Vietnam, followed by the US, Cambodia, and Malaysia. The total volume of semi-finished steel exports to the EU-27 totaled 2.9 Mt in 2023, plus another 0.1 Mt for finished steel products, indicating that Vietnam's steel industry is significantly exposed to the EU CBAM policy that is currently being implemented. The US is also considering similar proposals, and is also a significant export destination for semi-finished (1 Mt) and finished steel products (0.3 Mt) from Vietnam.

Semi-Finished Steel Exports (Mt)



Semi-Finished Steel Exports (Mt)

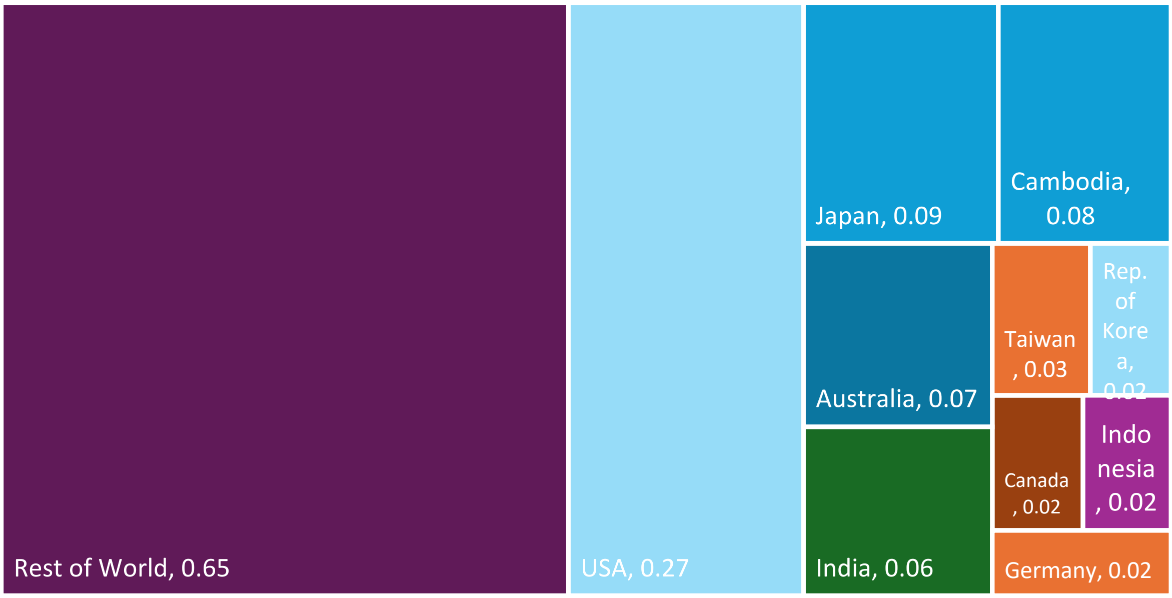


Figure 6: Exports of semi-finished (top) and finished (bottom) steel products in Vietnam in 2023 (Source: UN Comtrade 2025)

*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 Vietnam's Steel Industry

Vietnam's industrial sector accounts for over half of final energy use in the country, and the steel sector is Vietnam's second largest energy-consuming industrial sector (after non-metallic minerals). Vietnam's steel industry used 310 PJ of energy in 2019 (IEA 2022). This amount is poised to substantially increase as steel production increases significantly in the coming decades.

Coal use makes up 78% of energy use in the steel sector, reflecting the high share of BF-BOF steelmaking relative to EAFs. Electricity makes up 14% of energy use in Vietnam's steel industry. Coal is by far the most-used fuel, since coal is used to produce coke for blast furnaces and as a fuel supplement for pulverized coal injection (PCI) in blast furnaces and also fuel for other heating processes. Vietnam's steel industry used around 8.5 Mt of coal (both coking coal and thermal coal combined) in 2023. A small amount of natural gas is also used in Vietnam's steel industry (4% of total energy use), but large-scale scale up of natural gas use is constrained by limited supply, reliance on imports, and high prices in Vietnam (Figure 7).

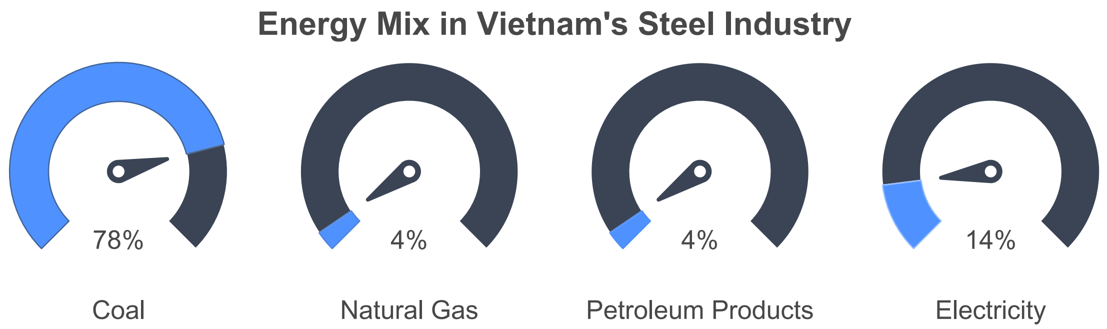


Figure 7. Energy mix in Vietnam's steel industry in 2023 (GEI analysis based on IEA 2025)

In 2023, Vietnam's steel industry emitted approximately 32 Mt of CO_2. Of this, 26 Mt of CO_2 were from fuel-related emissions, primarily from the use of coal and coke in BF-BOF plants. These fossil fuels release significant amounts of CO_2 during combustion and chemical reduction of iron ore. The remaining 6 Mt of CO_2 came from electricity-related emissions, driven by the consumption of grid electricity in electric arc EAFs, and other processing equipment (Figure 8). Since Vietnam's power grid remains heavily reliant on fossil fuels, especially coal, electricity use also contributes an 18% of the industry's carbon footprint.

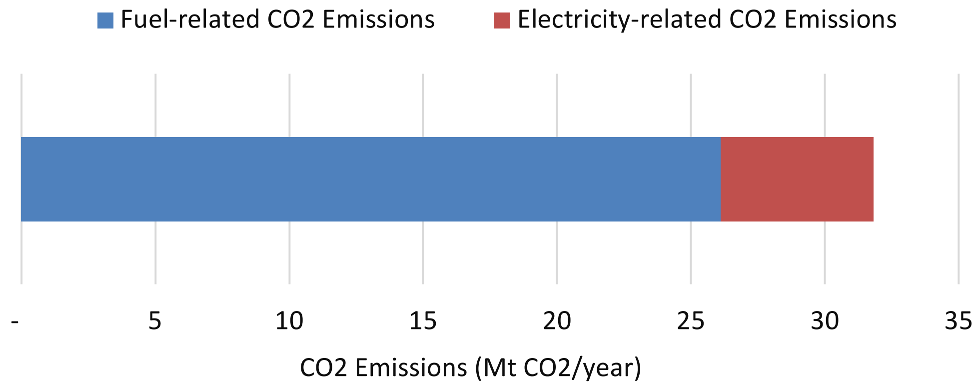


Figure 8. Annual CO_2 emissions in Vietnam's steel industry in 2023 (GEI analysis based on IEA 2025)

4 Net-Zero Roadmap for Vietnam's Steel Industry

4.1. Decarbonization Scenarios

After analyzing the status of Vietnam's steel industry and its energy and CO_2 intensity, we developed a decarbonization roadmap to 2060 using four main scenarios:

1. **Business as Usual (BAU) scenario**: The BAU scenario assumes a slow improvement in energy efficiency and fuel switching, a small amount of imported green iron for EAF steelmaking, and slow adoption of CCUS technologies. These changes are likely to happen based on current business practices, policies, and regulations.
2. **Moderate Technology and Policy (Moderate) scenario**: This scenario assumes higher energy efficiency improvement, more fuel switching, and a slightly higher rate of shifting to EAF steel production and green iron import. It also assumes low adoption of CCUS technologies.
3. **Advanced Technology and Policy (Advanced) scenario**: This scenario assumes significantly higher energy efficiency improvement, more aggressive fuel switching to lower carbon fuels, more switching to scrap-based EAF steelmaking, and low levels of adoption of transformative technologies such as NG-DRI and H_2 DRI-EAF and electrolysis of iron ore (post 2050).
4. **Net-Zero scenario**: This scenario assumes the most aggressive energy efficiency improvement, more aggressive fuel switching, the highest rate of shifting to scrap-based EAF steelmaking, and moderate adoption of transformative iron and steelmaking technologies.

4.2. Decarbonization Pathways for Vietnam'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).

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

In the BAU scenario, emissions from the steel industry are projected to grow through 2060, driven by significant growth in crude steel production with only moderate levels of energy efficiency improvement and technology shifting. Under the BAU scenarios, emissions are projected to reach 67 Mt CO_2/year by 2060, doubling from 2023 levels. Under the other scenarios, emissions peak and then decline, 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 Vietnam'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 Vietnam's steel industry would decrease by 89% relative to the base year, and by 95% relative to the BAU scenario in 2060.[1]

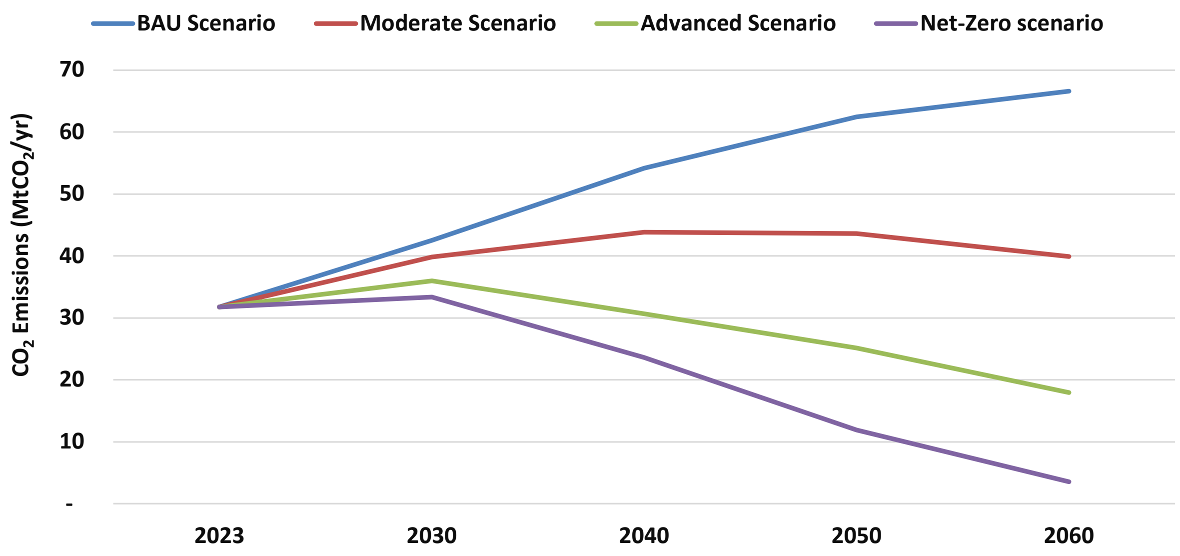


Figure 9: Total annual CO_2 emissions in the steel industry in Vietnam under four decarbonization scenarios, 2023-2060 (Source: this study)

Each decarbonization pillar contributes a different amount to total decarbonization. Figure 10 below breaks down the emissions reduction contribution of each pillar for the Net Zero scenario in 2060 relative to BAU emissions in 2060. The technology shift pillar is projected to have the greatest amount of emissions reduction potential, and it combines multiple lower-carbon steelmaking technologies: NG-DRI-EAF, scrap-based EAF, green H_2-DRI-EAF, and electrolysis of iron ore. Demand management has the second largest contribution, and energy efficiency, and fuel switching/cleaner electricity contribute roughly the same amount of emissions reductions. Our analysis shows that emissions reductions from CCUS will be lower than other decarbonization options. Imported green iron then used in EAFs also contributes 7.7 Mt/year of emissions reductions in 2060 compared to BAU scenario.

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 Vietnam'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.

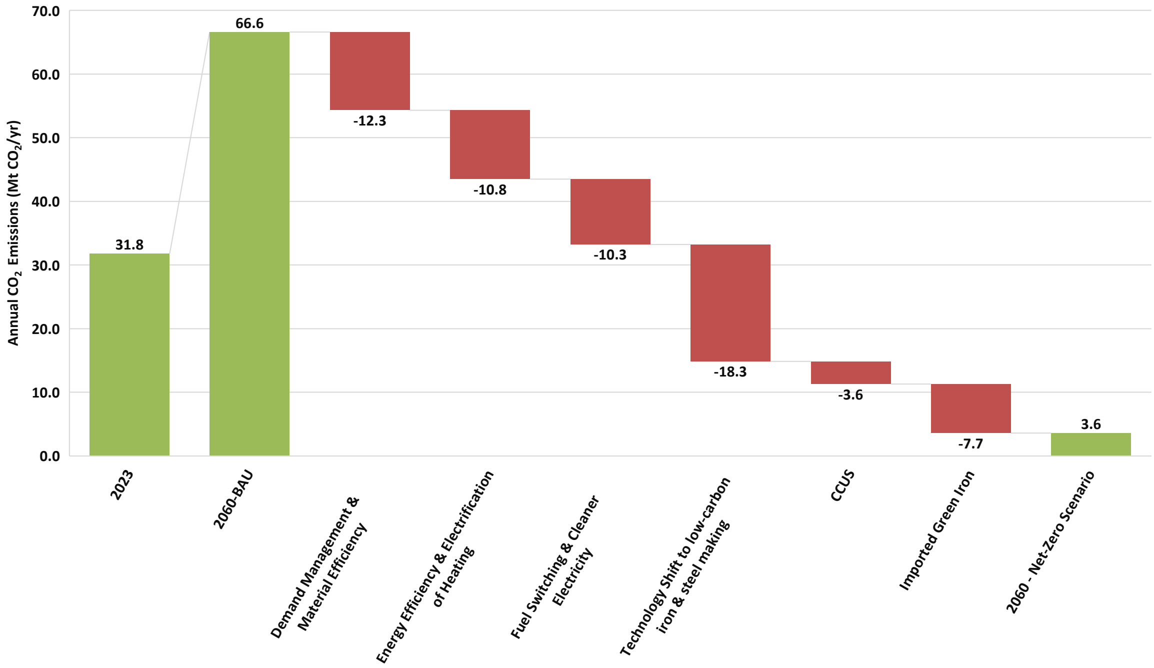


Figure 10. Impact of each decarbonization pillar on CO_2 emissions of Vietnam's steel industry, Net Zero scenario relative to BAU (Source: this study)

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 Vietnam from 2023 to 2060. While demand management, energy efficiency, and fuel switching play a large role 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 in 2030 and onwards.

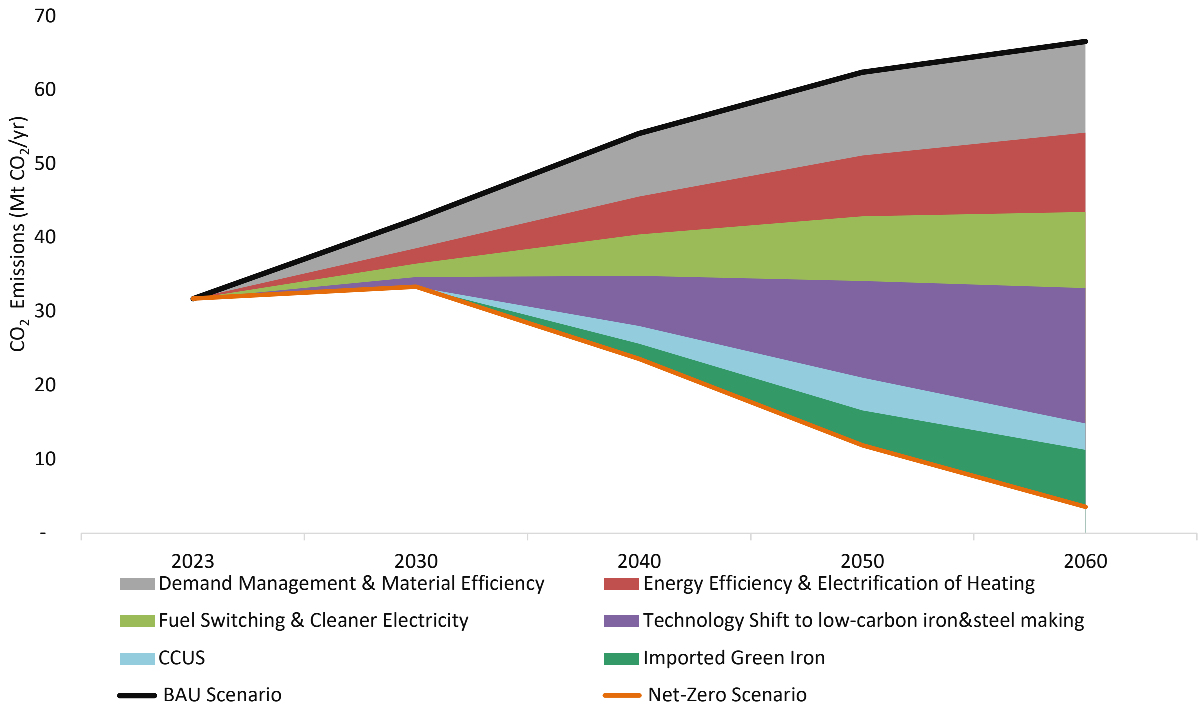


Figure 11: Impact of decarbonization pillars on CO_2 emissions of Vietnam's steel industry to bring BAU emissions down to the Net Zero scenario's level (Source: this study)

5 The Impact of Decarbonization Pillars on Vietnam'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.

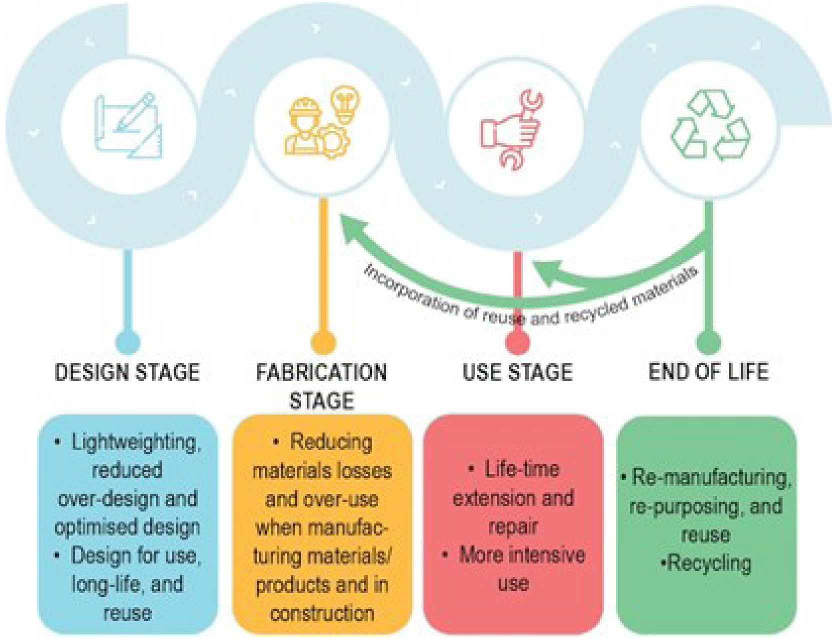


Figure 12: Schematic of material efficiency strategies for industrial supply chains (Source: International Energy Agency 2019)

Material Efficiency and Demand Management in Vietnam's Steel Industry

As Vietnam'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 Vietnam's steel industry. Vietnam added 4 Mt per year of BOF capacity in 2024 (Grigsby-Schulte et al. 2025), and there is an additional 18 Mt per year of announced BOF capacity or BOF capacity under construction. Vietnam also has 17 Mt per year of announced EAF capacity (Figure 13). These additions could double Vietnam's crude steel production, demonstrating the importance of material efficiency and demand management.

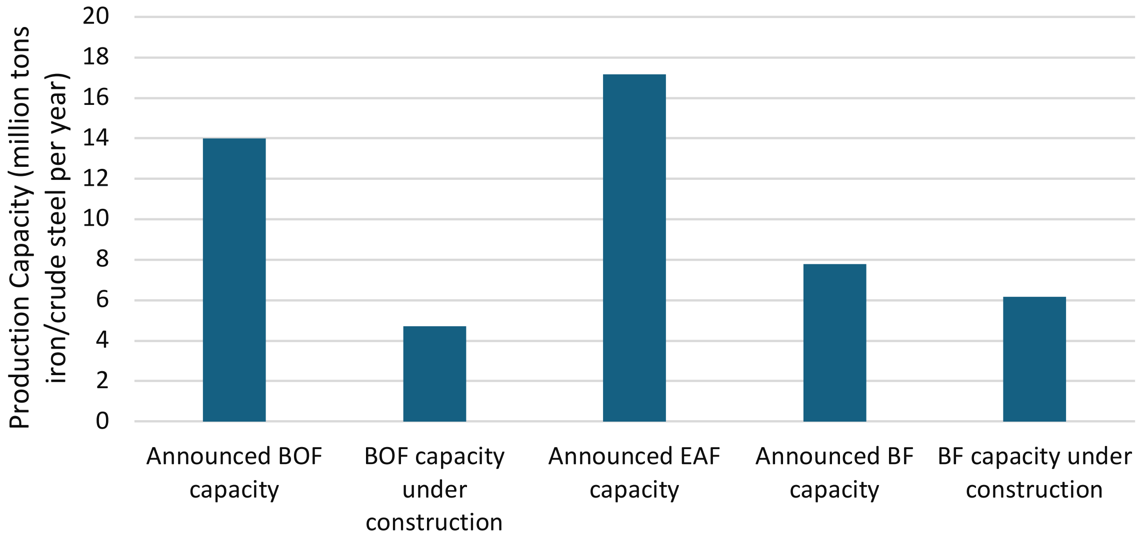


Figure 13: Announced and under-construction iron and steelmaking capacity in Vietnam by production route (Source: Grigsby-Schulte et al. 2025)

Note: It should be noted that some of the announced iron and steel production capacity may not be actually realized in the future.

On the consumption side, Vietnam's apparent steel consumption has remained relatively constant over the past decade, however, consumption is expected to increase as the economy develops, increasing from current levels of around 20 Mt of steel per year to 30-32 Mt per year in the early 2030s, according to the Vietnam Steel Association.

Modeling Inputs

The first step in developing decarbonization pathways for Vietnam's steel industry was to develop projections for steel production over the study period (2023 through 2060). Given the ongoing importance of Vietnam's steel industry to the domestic economy, and stable and increasing demand for steel, we projected Vietnam's steel production through 2060 under the four different scenarios in this study. Material efficiency and demand management in the economy relative to BAU drives the lower production forecasts in the Moderate, Advanced, and Net-Zero scenarios. Under the BAU scenario, we project that Vietnam's annual steel production could nearly triple, from 19.2 Mt in 2023 to 55 Mt by 2060. Production will double under the Net-Zero scenario during the same period. All scenarios have significant growth in production, underscoring the need for decarbonization.

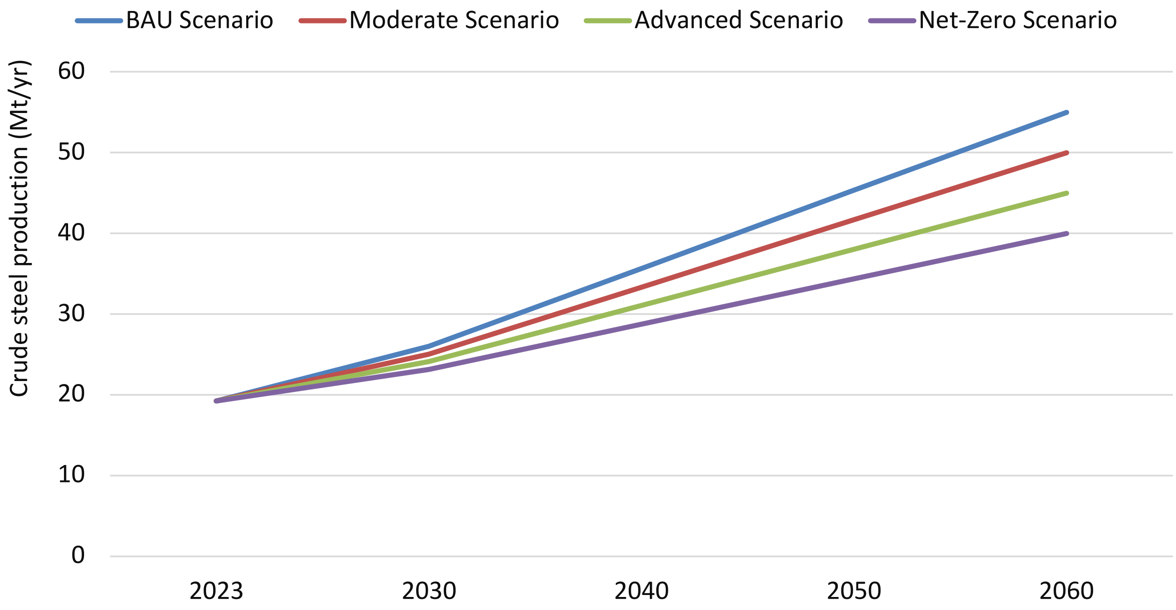


Figure 14: Annual steel production forecasts in Vietnam by scenario for this study, 2023-2060 (Source: this study)

Modeling Results

We find that material efficiency and demand reduction could contribute to 12.3 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.

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

Strategies like lightweighting, optimizing designs, and extending product life can lower steel demand and cut emissions. But these approaches come with trade-offs. For example:

- Improving building energy performance with better insulation or thermal storage can use more materials upfront.
- Keeping buildings in use longer can save materials but might increase energy use over time if they aren't upgraded.
- Replacing steel with alternatives like mass timber can reduce emissions but may cause deforestation and harm biodiversity if forest management is poor.

Because of these complexities, full life-cycle assessments are needed to truly understand the environmental benefits. While data on costs is limited, studies show steel material efficiency measures can range from saving money to costing several hundred dollars per ton of CO_2 avoided, depending on the situation.

In Vietnam, material efficiency in the steel industry remains underdeveloped despite some promising examples. Lightweight steel frame construction is gaining traction, particularly through companies like Phu Nguyen Mechanical & Construction Materials JSC, which produce precision-engineered framing systems that reduce foundation loads and improve structural efficiency (Phu Nguyen Steel 2024). However, widespread adoption of systematic design optimization remains limited and Vietnamese steel structures are often over-engineered. Vietnam has also begun exploring material substitution, particularly through the renewed interest in sustainable timber construction. However, while there is cultural momentum around traditional wooden architecture, the country lacks a robust framework for integrating timber substitution into modern, large-scale construction. Comprehensive strategies to extend the lifetime of steel-intensive assets, such as buildings, infrastructure, and industrial equipment, remain limited. The National Action Plan on Sustainable Consumption and Production targets a 7–10% reduction in resource use across key sectors, including steel, but does not yet translate into specific programs focused on building reuse or life extension (Ministry of Industry and Trade 2020). Similarly, Decree No. 08/2022/ND-CP on the circular economy includes provisions to extend product lifespans and reduce waste but lacks sector-specific guidelines for implementation in steel-intensive industries (Manh and Huyen 2023).

Despite these gaps, Vietnam is positioned to advance material efficiency through targeted policy and industry engagement. A key priority is integrating material efficiency principles into national and municipal building codes and infrastructure standards. This could include updated design criteria to reduce steel overuse, guidance on product life extension, and promotion of lower-carbon construction materials. The government can also support pilot projects that showcase innovative design and substitution approaches, particularly in new urban developments and green building initiatives. Vietnam's expanding green finance framework could provide concessional loans or tax incentives for developers adopting high-efficiency structural design or engaging in component reuse. In manufacturing, policy incentives and technical assistance could help firms adopt digital tools for precision engineering and improve yield in steel fabrication. Government-backed R&D programs, coordinated through the Ministry of Science and Technology, could promote innovations in modular construction, material substitution, and end-of-life recovery.

5.2. Energy Efficiency and Electrification of Heating

A wide range of energy efficiency technologies are already commercially available for deployment in the steel industry. These include solutions such as waste heat recovery across different processes, coke dry quenching (CDQ), and Top-Pressure Recovery Turbine Plants (TRT), among others (JISF 2022). In addition to traditional technologies, advanced tools enabled by smart manufacturing and the Internet of Things such as predictive maintenance systems, machine learning applications, and digital twins can enhance process control and support energy management systems (Hasanbeigi et al. 2013).

Experience from various iron and steel companies shows that modest investments in energy-efficient technologies can yield significant energy and cost savings with favorable payback periods, often under three years. However, some major energy efficiency upgrades require substantial capital investment, which may be difficult to justify based on energy savings alone. However, improving energy efficiency offers benefits beyond energy cost savings. These include reduced exposure to volatile energy prices, improved product quality and access to higher-value market segments, increased productivity, and lower environmental compliance costs due to reductions in GHG emissions and air pollutants.

Table 2 presents a selection of commercialized energy efficiency technologies applicable to the iron and steel industry. However, it is important to note that individual steel plants operate under unique conditions, so identifying and selecting the most suitable energy efficiency measures must be tailored to the specific context and design of the facility.
Table 2. Key commercialized energy efficiency measures and technologies for the iron and

steel industry (JISF 2022, Hasanbeigi 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

Electrification of heating refers to conversion of fuel-based technologies to those powered by electricity. This can include electrifying reheating furnaces, expanding the use of electric induction furnaces, and electrifying ladle and tundish heating using resistance, infrared, or plasma heating technologies. While EAF steel production is a form of electrification, in our analysis it is categorized under the technology shift pillar rather than the electrification pillar. This is because shifting to EAFs represents a fundamental change in the steel production route from primary production using iron ore in blast furnaces to e.g. secondary production using scrap making it more accurately described as a structural or technological transformation rather than a simple energy substitution.

Electrification of heating in steel production, particularly in rolling and finishing processes, can also contribute to energy efficiency and decarbonization. Hot rolling and finishing processes involve reheating steel billets, blooms, or slabs to approximately 1,200°C in order to make the steel malleable for shaping into final products like sheets, bars, and rods. Traditional gas-fired reheating furnaces are a significant source of emissions. In contrast, electric reheating furnaces use resistance heating elements to deliver the same thermal output with greater efficiency. In addition, electric furnaces have no direct emissions, especially when powered by clean electricity.

Energy Efficiency and Electrification of Heating in Vietnam's Steel Industry
Vietnam has demonstrated progress in adoption of energy efficiency technologies for the steel industry. Some steel plants in Vietnam have begun to use the waste heat of the factory to generate electricity (Lee 2023). Hoa Phat Group, Vietnam's largest steel manufacturer, has applied heat recovery technology at its Hai Duong Iron and Steel Complex (Tran 2021). The company has implemented at least 8 emission-reduction actions including recovering waste heat from coke ovens for power generation, generating electricity using heat from the CDQ process, and utilizing heat from the sintering process to produce electricity (Lin 2025). Hoa Phat Group has installed Blast Furnace Power Recovery Turbines (BPRT) equipment as part of its emission-reduction initiatives (Lin 2025). While specific technical details of TRT implementation in other Vietnamese facilities are limited in available documentation, the technology remains relevant for facilities operating blast furnaces, as TRT systems can generate significant power output while controlling blast furnace top pressure. Most of the galvanizing or color coating lines in Vietnam are equipped with gas recovery systems to help manufacturers save energy (Le 2024)most steel was produced through electric arc furnace (EAF.

More broadly than the steel industry, Vietnam has launched comprehensive smart manufacturing initiatives aligned with the National Strategy for Industry 4.0, which promotes the integration of smart technologies including AI, IoT, and robotics into manufacturing (EuroGroup Consulting 2025). Steel industry applications include IoT sensors to monitor various parameters such as temperature, pressure, and vibration in production facilities.

Vietnam has also established frameworks for implementing energy management systems according to ISO 50001. Some large enterprises, including steel companies, have started to recognize and commit to implementing energy management systems according to the ISO 50001 standard (Vets 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 10.8 Mt CO_2 emissions reductions in 2060 under the Net Zero scenario relative to the BAU scenario (Figure 10). This is on par with emissions reductions from material efficiency/demand management and very slightly higher than fuel switching/electricity decarbonization.

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

High capital investment requirements represent the most significant barrier to energy efficiency adoption in Vietnam's steel industry. Limited access to financing compounds this challenge, particularly for smaller enterprises. Vietnam is one of the most energy-intensive countries in East Asia, and only a few local financial institutions have dedicated energy efficiency lending business lines (The World Bank 2018).

Predominance of small mills with outdated technology is a fundamental structural challenge for energy efficiency. With exceptions of only a handful of large steel mills such as Hoa Phat-Dung Quat Iron and Steel Complex and the Formosa Iron and Steel Complex, much of Vietnam's steel industry consists of small mills equipped with outdated machinery and technology (HKBAV 2022).

There are several policies and funding sources to help Vietnam's steel producers overcome barriers to energy efficiency. World Bank and Green Climate Fund financing provides substantial support for energy efficiency investments. The World Bank has signed a US$11.3 million grant with the State Bank of Vietnam to support commercial financing market development for industrial energy efficiency investments, with total financing support including a US$75 million guarantee. This risk sharing facility is expected to mobilize around US$250 million of commercial financing for industrial enterprises and energy service companies at competitive terms with low collateral requirements (The World Bank 2021). The facility will provide enhanced capacity-building programs, including training in energy efficiency project appraisal, technology selection, supplier identification, and energy audits (VNEEP 2025).

Vietnam's National Energy Efficiency Program (VNEEP3) targets reducing average energy consumption rates in industrial sectors, with the goal of 100% of key energy-consuming establishments applying energy management systems (U.S. International Trade Administration 2022). The Steel Industry Development Strategy 2030 is Vietnam's draft strategy on developing the steel industry until 2030, with a vision to 2050, and focuses on developing green and energy-saving steel products while increasing the market share of domestically produced steel to gradually replace imported products (Vietnam+ 2024).

5.3. Fuel Switching and Decarbonization of Electricity Supply

The decarbonization pillar of fuel switching and decarbonization of electricity supply encompasses a suite of measures to decarbonize the energy source used for iron and steel production. In terms of fuel switching, several alternative fuels, such as natural gas, biomass, biogas, and on a longer time horizon, hydrogen, can replace coal or coke as a fuel or reducing agent in the iron and steelmaking processes.

In terms of decarbonization of electricity supply, all processes in steel production that use electricity can be decarbonized by using low-carbon grid electricity, or even directly procured renewable electricity.

Fuel and Electricity Supply in Vietnam

As discussed in Chapter 3, coal is by far the most-used fuel in Vietnam's steel industry, since coal is used to produce coke for blast furnaces and as a fuel supplement for PCI in blast furnaces. A small amount of natural gas is also used in Vietnam's steel industry (4% of total fuel).

Currently, Vietnam's electricity grid has a very high carbon emissions factor, largely due to the dominance of coal-fired power generation, similar to other regional steel producers like Indonesia, China, and India. Vietnam has made rapid progress in integrating RE into its electricity mix, particularly with the boom in solar installations between 2019 and 2021, supported by a government feed-in tariff (FIT) mechanism. Despite this growth, challenges remain. Solar energy curtailment has become a significant issue, and Vietnam's electricity transmission infrastructure has struggled to keep pace with renewable expansion. As a result, the share of solar in total electricity generation has actually declined from its peak of 22% in 2022. Yet, power shortages especially in industrial hubs such as Ho Chi Minh City and the monopoly control over transmission by Vietnam Electricity (EVN) continue to limit grid flexibility and the ability to absorb new renewable capacity.

However, policy support for RE is again increasing. In April 2025, Vietnam released a Revised Power Development Plan VIII (PDP8), updating key targets for domestic power capacity through 2030. A major shift from the original May 2023 PDP8 (Decision 500) is the substantial scaling up of RE ambitions. Under the revised plan, solar power development capacity is now projected at 46,459–73,416 MW by 2030 far higher than the previous target of 12,836 MW with rooftop solar projects now fully counted toward national capacity. Concentrated solar projects must also integrate battery storage equivalent to at least 10% of installed capacity, signaling a stronger emphasis on grid flexibility. For wind energy, the Revised PDP8 increases total wind capacity targets to 26,066–38,029 MW for onshore and nearshore projects and 6,000–17,032 MW for offshore wind by 2035. Offshore wind will initially develop 6,000 MW across 12 projects by 2030, expanding significantly afterward (Tong 2025). These updates highlight Vietnam's efforts to deepen RE integration, especially after earlier challenges with solar curtailment due to grid limitations. The inclusion of storage requirements and the expansion of wind projects, particularly offshore, aim to improve grid stability and reduce future renewable curtailment, although substantial upgrades to Vietnam's transmission system and market reforms are still needed to fully realize these goals. The updates to Vietnam's Revised PDP8, particularly the major increases in RE capacity targets and the new emphasis on storage integration, could create a more supportive environment for electrified steelmaking in the coming years.

Low-carbon electricity can also be obtained by facilities through direct procurement of renewable energy (RE). Corporate RE procurement in Vietnam has been growing steadily, and recent regulatory developments are opening new pathways for industrial users to access cleaner power sources. In July 2024, Vietnam launched its long-awaited Direct Power Purchase Agreement (DPPA) mechanism, allowing eligible large electricity consumers (those using 200 MWh or more per month) to purchase renewable electricity directly from producers, bypassing the traditional EVN utility model. This milestone addresses a long-standing barrier and is expected to significantly boost corporate RE adoption.

Self-generation, particularly through rooftop solar, has been the most common method of corporate RE procurement in Vietnam to date. However, rooftop systems often cannot fully meet the electricity demand of energy-intensive operations like steel production. The introduction of DPPAs, alongside continued onsite solar investments, offers a more scalable solution for the steel industry. Vietnam's DPPA framework offers physical, synthetic, and financial models, though concerns about grid connectivity and incomplete implementation guidelines remain. Over time, successful deployment of DPPAs could help industrial consumers secure long-term renewable electricity contracts at competitive prices.

Vietnam also has a voluntary RE Certificate (REC) market, although its effectiveness has been limited. Most RECs currently originate from older feed-in-tariff (FIT) solar and wind projects, which raises concerns around additionality. Oversupply has kept REC prices low, and the lack of a standardized national REC tracking system creates risks of confusion and double-counting. Nevertheless, as the regulatory environment improves and demand for verified renewable procurement grows, RECs could become a useful complementary mechanism for companies pursuing climate targets. Despite these challenges, Vietnam's corporate RE market shows strong potential for future growth.

Modeling Inputs

In our analysis, we projected the energy mix for Vietnam's steel industry by shifting to cleaner electricity and lower-carbon fuels. Under the Net Zero scenario, we assume that coking coal is substantially displaced by 2060, driven by the higher share of electricity use and natural gas. The share of electricity will increase because of a shift in production process routes towards EAFs, as discussed earlier. We project that the share of electricity in total energy use for steel production would increase from 14% in 2023 to 57% in 2060 under the Net Zero scenario. The share of natural gas is also assumed to increase substantially during this period under the Net-Zero scenario, from 3% to 13%. This is partly driven by steel production via the natural gas-based DRI-EAF route and partly by overall fuel switching from coal to natural gas. In Vietnam, most of this natural gas will need to be imported.

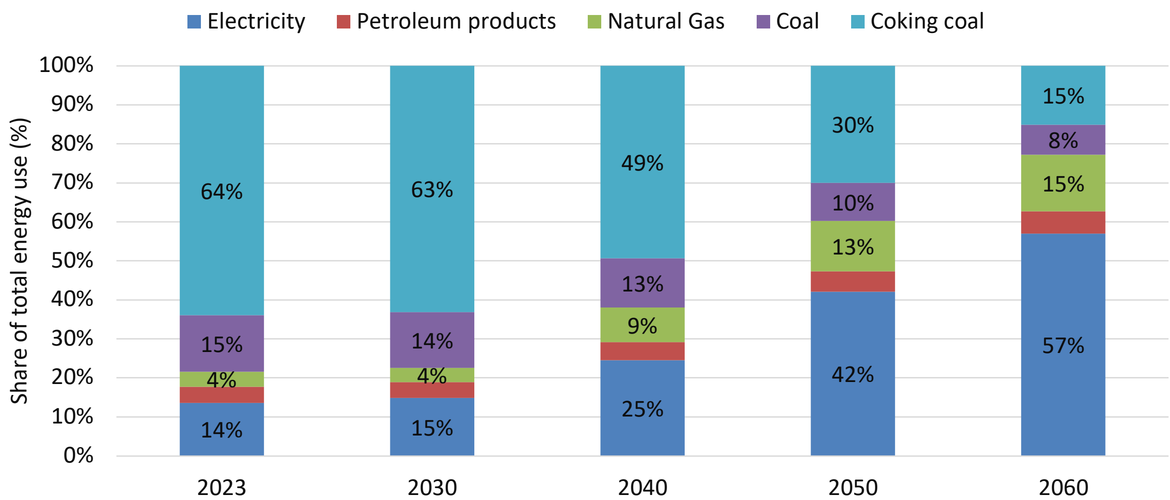


Figure 15. Projected energy mix for Vietnam's steel industry under the Net-Zero scenario, 2023-2060 (Source: this study)

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 Vietnam's steel industry is the carbon intensity of the electricity used in this sector, which was 659 kg CO_2/MWh in 2023 (International Climate Initiative 2024). Vietnam has one of the highest carbon-intensity power sectors in the world because of its heavy reliance on coal for power generation. Of other major steel-producing countries, only India has a higher electricity grid emissions factor.

As Vietnam shifts to more EAF steel production, the role of the power sector's CO_2 emissions intensity will become even more important for the steel industry's overall emissions impacts. Figure 16 shows the electricity grid's CO_2 emissions intensity forecast in Vietnam under the different scenarios used in this study. We assumed that Vietnam's grid will achieve carbon neutrality by 2060 under the Net-Zero scenario (Vietnam has a 2050 net-zero target, but many experts expect this will be challenging and/or would require significant offsets). However, even under the BAU scenario, the grid emissions factor is expected to drop by 71%.

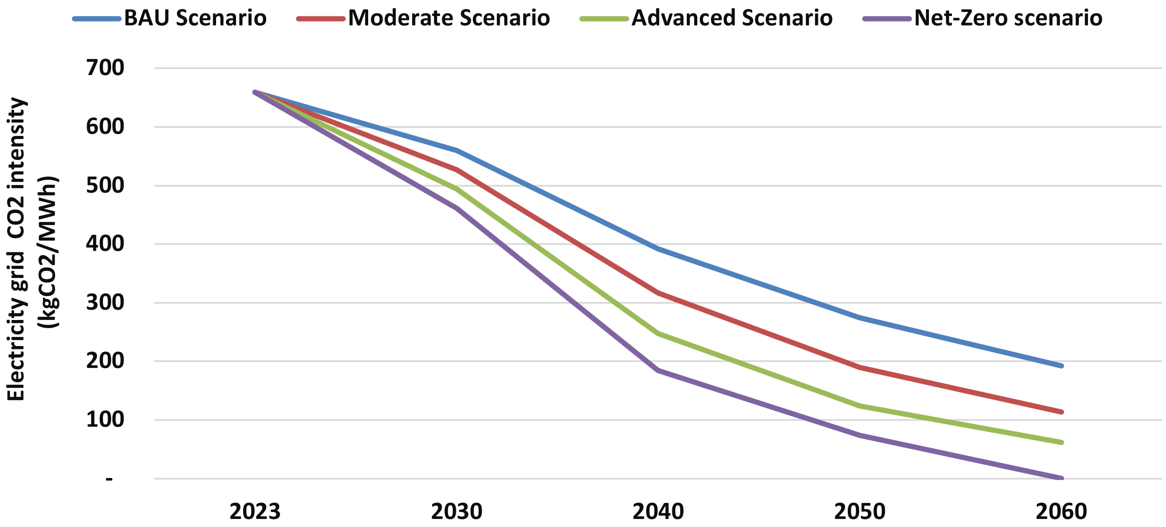


Figure 16. Electricity grid CO_2 emissions intensity forecast in Vietnam under different scenarios (Source: this study)

Modeling Results

Our results show that by 2060, Vietnam'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 the increase in electricity use, the total energy consumption of the steel industry will drop slightly by 2060 compared to 2023, despite steel production more than doubling during this period (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.

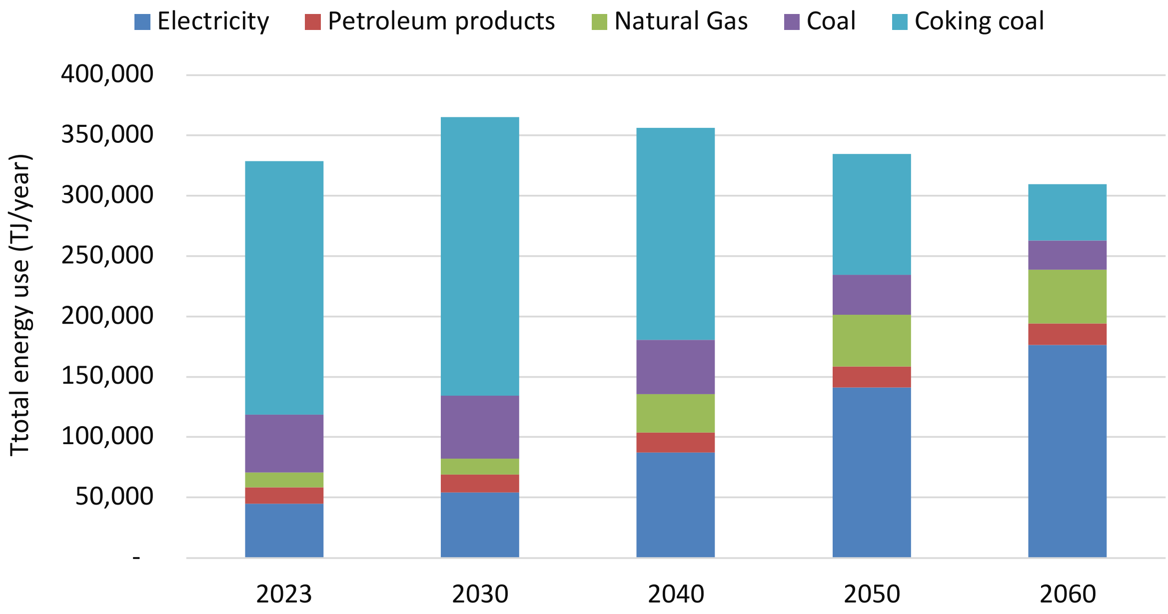


Figure 17. Projected energy use by energy type in Vietnam's steel industry under the Net-Zero scenario, 2023-2060 (Source: this study)

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 10.3 Mt CO_2 emissions reductions in 2060 under the Net Zero scenario relative to the BAU scenario (Figure 10). This is just below estimated emissions reductions from material efficiency and demand management, and energy efficiency and electrification of heating. Still, emissions reductions are greater than from imported green iron or CCS. 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 Fuel Switching and Electricity Decarbonization in Vietnam's Steel Industry

Vietnam's steel sector faces a range of structural, financial, and regulatory barriers that hinder fuel switching and electricity decarbonization. Vietnam's electricity grid is dominated by coal, and there is still a small amount of planned coal capacity expansion under PDP8 (Tong 2025). Without concurrent grid decarbonization, electrification alone offers little benefit.

Vietnam also faces major constraints in expanding the use of natural gas. Limited pipeline infrastructure and declining domestic gas production make fuel switching prohibitively expensive, particularly for plants located far from existing transmission lines. Moreover, competition from other priority sectors like power generation and fertilizer production further restricts industrial access to gas.

While Vietnam's RE procurement market is promising, near-term RE procurement poses another challenge to being able to decarbonized electrified processes in steel production. Despite high interest, corporate access to renewables is blocked by delays in implementing DPPAs, restrictions on private supply within utility zones, and a shortage of scalable, bankable clean energy projects.

From a financial and policy standpoint, the transition is also slowed by prohibitively high capital costs for adopting new technologies, a lack of carbon pricing to create economic incentives, and the absence of a cohesive national strategy to support industrial decarbonization. Addressing these barriers requires targeted strategic solutions. Accelerated deployment of RE is key, including expanding the national grid to link industrial centers with clean power, scaling solar and wind deployment, and investing in battery storage to improve reliability. On the policy front, implementing carbon pricing before 2030 can create a clear business case for low-carbon technologies. Speeding up the DPPA framework will allow companies to directly procure off-site renewables.

5.4. Technology Shift to Low-Carbon Iron and 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), and imported green iron-EAF. 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

Electric arc furnaces are primarily used to produce steel by recycling ferrous scrap, though they can also use DRI, pig iron, or even molten iron (up to about 30 percent) as part of the feed mix. EAFs operate using carbon electrodes, which are inserted through the furnace roof and adjusted to create an electric arc that generates the heat needed to 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 liquid steel is typically transferred to a ladle metallurgy station (LMS) for further refining to achieve the desired quality. Using EAFs to recycle scrap conserves virgin raw materials, lowers energy use, and significantly reduces the CO_2 intensity of steel production.

As of 2023, EAFs accounted for about 35% steel production in Vietnam, which is higher than the world average of 28% and but below the level in some industrialized countries (U.S.: 70%; EU: 42%) (Hasanbeigi et al. 2023). Vietnam has a relatively large number of small- and medium-sized steel producers that rely on EAF technology due to its lower capital cost, quicker construction timeline, and suitability for flexible, regional production using scrap. However, the share of EAF production remains lower than in countries like the U.S. because Vietnam's steel industry has rapidly expanded in recent years through large-scale, integrated BF-BOF plants. Once built, these plants represent significant sunk costs. As a result, steel producers have strong financial incentives to maximize the use of existing BF-BOF capacity to ensure economic returns on those investments. Additionally, BF-BOF plants are typically optimized for large-scale production and are integrated with upstream facilities such as sinter plants, coke ovens, and captive power plants, making it operationally and economically difficult to shift away from their use in the short to medium term.

Steel Scrap Supply and Demand in Vietnam

Scrap is used in two ways in Vietnam's steel industry: 1) melted in BOFs along with molten iron and 2) melted directly in EAFs. Vietnam is primarily reliant on imported scrap due to the country's relatively young steel stock and still-developing recycling infrastructure. Domestic scrap collection meets only 20–30% of demand. Japan is the largest scrap exporter to Vietnam, with 2.6 million ton of scrap exported in 2024, followed by Hong Kong, the U.S., and Australia (Argus 2025). Total scrap imports peaked at 6.3 Mt in 2020 (Reintjes 2021), and have since decreased to about 5 Mt in 2024. Scrap demand will rise as overall steel production and the share of EAF production increases.

As infrastructure in Vietnam ages, it presents a growing opportunity to expand the domestic steel scrap supply. Much of Vietnam's built environment including roads, bridges, ports, industrial zones, and urban buildings experienced rapid development starting in the late 1990s and 2000s during the country's industrialization and modernization boom. These assets are now beginning to approach mid-life, and over the next two to three decades, an increasing share will reach the stage where decommissioning, refurbishment, or replacement becomes necessary. This aging infrastructure will gradually generate more recyclable steel, creating an important secondary resource for Vietnam's growing EAF steel sector. However, given that typical infrastructure lifespans range from 40 to 100 years, the increase in scrap supply will be gradual rather than immediate.

Modeling Inputs

Based on the penetration rate of EAFs in Vietnam's steel industry and the rate of scrap used in EAFs and BOFs under different scenarios, we have estimated scrap consumption in Vietnam's steel industry from 2023-2060 for each scenario. The scrap demand in 2060 under the Net-Zero scenario is around 20 Mt. The Moderate scenario has the highest demand for scrap, based on its higher production forecast and higher 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.

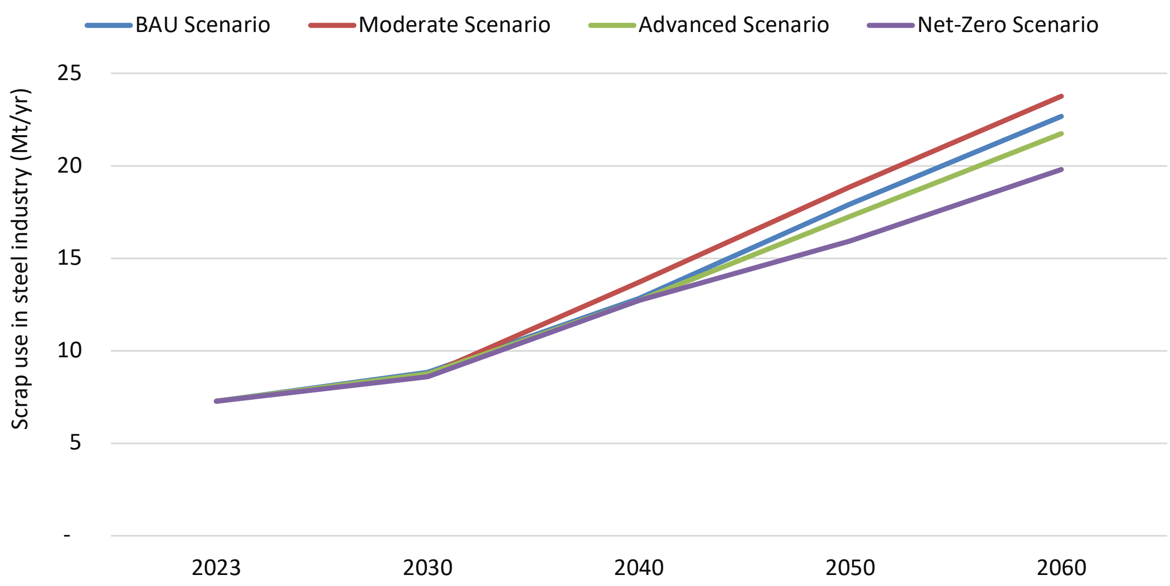


Figure 18. Scrap consumption forecast for Vietnam's steel industry, 2023-2060

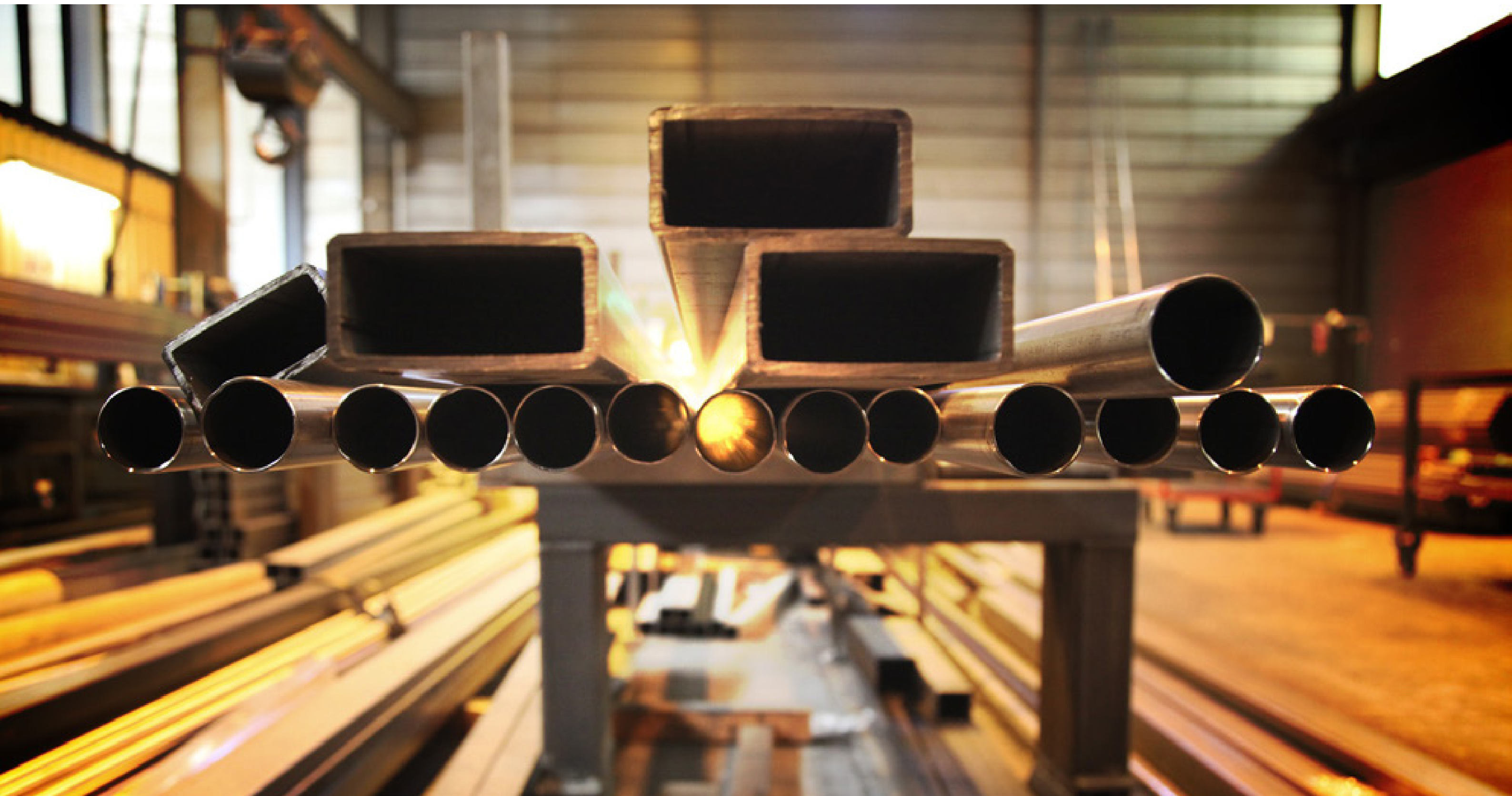
Barriers and Solutions for Scrap-EAF Adoption in Vietnam's Steel Industry

The economic viability of scrap-based EAF production in Vietnam is closely linked to the availability, quality, and price of scrap. While EAF steelmaking can be highly competitive under the right conditions, it remains very sensitive to fluctuations in scrap prices. In the near term, domestic scrap supply in Vietnam faces constraints due to the relatively young age of much of its infrastructure and industrial stock, limiting the volume of scrap available for recycling. Although scrap imports, primarily from Japan, have increased steadily, they expose Vietnam's steelmakers to international price volatility. 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. Regulatory controls on scrap imports, aimed at environmental protection, have come into effect to address quality control issues (Rodl and Partner 2023), further limiting scrap supply. Geographic disparities also affect EAF deployment. While southern Vietnam, particularly around Ho Chi Minh City and Ba Ria–Vung Tau, benefits from better scrap logistics and lower scrap costs, facilities in the north face higher scrap prices and competition for limited domestic supply.

In addition, while Vietnam has strengthened environmental and quality standards for imported scrap, enforcement remains inconsistent. The scrap supply chain includes both formal businesses and informal small-scale collectors, with informal operations sometimes failing to meet safety and quality standards. This fragmented collection system complicates efforts to secure reliable, high-quality scrap supply for industrial-scale EAF operations, highlighting the need for further investment in scrap processing infrastructure and regulatory oversight.

Vietnam's steel industry also faces structural challenges that could limit new EAF adoption. The industry is relatively fragmented, with a large number of small and medium-sized producers operating alongside a few major players like Hoa Phat Group and Formosa Ha Tinh. Overcapacity and market competition, including rising imports of cheap steel products from China and other countries, have put pressure on domestic producers' profit margins.

To fully realize the potential of infrastructure-derived scrap, Vietnam will need to modernize scrap recovery systems, strengthen regulations, and develop formal supply chains that can support the quality and volume needs of large-scale EAF production.



5.4.2. Direct Reduced Iron (DRI) Production

Currently, the MIDREX and HYL/Energiron processes are the two most commercially mature and widely deployed direct reduction (DR) technologies used as alternatives to traditional BF iron production. Both technologies produce DRI by chemically reducing iron ore in the solid state, avoiding the need for coke and the associated carbon-intensive steps of BF-BOF steelmaking.

The MIDREX process uses a vertical shaft furnace where iron ore pellets or lump ore are fed from the top and come into contact with a hot reducing gas, typically a mixture of H_2 and carbon monoxide (CO) derived from natural gas, introduced from the bottom. The iron ore is reduced to solid metallic iron at temperatures below its melting point, typically around 800–1,050°C. The HYL process (also known as Energiron) also uses a shaft furnace but differs slightly in gas management. It allows more flexible operation with a broader range of feedstocks and gas compositions. When DRI from either MIDREX or HYL is fed into an EAF, the overall CO_2 emissions are significantly lower than in the BF-BOF route, especially when the EAF is powered by low-carbon electricity.

If the energy source and reducing agent for iron ore is green hydrogen (i.e. hydrogen generated via electrolysis using renewable electricity), the emissions from the ironmaking stage can potentially approach near-zero levels. The hydrogen demand for producing steel via the H_2-DRI process is typically estimated in the range of 50 to 70 kilograms of hydrogen per ton of steel (Vogl et al. 2018). However, producing this amount of hydrogen via the green production route remains a challenge. Currently, the vast majority of global hydrogen production relies on fossil fuel-based methods, including natural gas reforming (steam methane reforming), partial oxidation of methane, autothermal reforming, and coal gasification, all of which are highly carbon-intensive processes. In contrast, green hydrogen accounts for only a small fraction of total hydrogen production worldwide (Wang et al., 2021). This limited availability of low-carbon hydrogen presents a major barrier to scaling up H_2-DRI steelmaking as a near-zero emissions 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. 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 underway around the world. In Sweden, SSAB, LKAB, and Vattenfall have partnered to launch the HYBRIT initiative, which began pilot operations in Luleå in 2021 and plans to expand to a full-scale demonstration plant in Gällivare by 2026. In Spain, ArcelorMittal is developing a full-scale H_2-DRI facility in Gijon, expected online in 2025, while the company also has large hydrogen steel projects in France (using blue hydrogen) and Germany (pilot scale, green hydrogen). Fortescue Metals in Australia and POSCO in South Korea are also advancing a small pilot H_2-DRI project. In China, HBIS Group, one of the largest steelmakers in the country, is developing a two-stage DRI plant that will initially use coke oven gas rich in hydrogen, with plans to switch to green hydrogen in the second stage. Meanwhile, Baowu Steel, the world's largest steel producer, is constructing a 1 Mt/year green H_2-DRI facility at its Zhanjiang site. Other notable projects include Rizhao Steel, which uses byproduct syngas for DRI production, and Jianlong Steel, which has piloted a coke oven gas–based H_2-DRI plant and aims for 0.3 Mt/year capacity (Hasanbeigi et al. 2023).

The Hydrogen Landscape in Vietnam

Vietnam's hydrogen production is currently modest but poised for significant growth. The country primarily produces industrial-grade hydrogen through biomass gasification, steam methane reformation, refining process byproduct, and limited water electrolysis. Grey hydrogen produced via biomass gasification is particularly significant due to Vietnam's agricultural economy centered in the Mekong Delta region, which has current biomass output of about 13 Mt per year (Hung et al. 2016). Current technology produces 50 kg of hydrogen per ton of biomass, supporting industries such as oil refining and fertilizer manufacturing (Vietnam Petroleum Institute 2020). Primary industrial consumers and producers of hydrogen are largely in the chemicals and petrochemicals sectors, including the Dung Quat and Nghi Son oil refineries, as well as nitrogen fertilizer plants such as Phu My and Ca Mau (VAHC 2025). Annually, the grey hydrogen production rate for these industries is approximately 500,000 tons, generated via steam methane reforming, which is highly carbon intensive. Production of green hydrogen is still in its nascent stages.

Water electrolysis powered by wind and solar is emerging as the most promising method for green hydrogen production, especially in southern Vietnam with ample RE availability. Factories near rivers, such as the Phu My Nitrogen Plant by the Thi Vai River in Vietnam, are exploring river water as a resource for electrolysis (Vietnam Petroleum Institute 2020). Additionally, industrial zones within Can Tho, Quang Nam, and Binh Thuan provinces have been studied as suitable regions to integrate photovoltaic systems into hydrogen production processes due to their solar energy potential. If implemented in these zones, annual production of green hydrogen using hybrid power systems could reach 17 tons (Phap et al. 2022).

Pilot projects are underway with significant investments proposed for green hydrogen facilities combining solar and wind energy with electrolyzers. The construction of the first large-scale green hydrogen production project in the Tra Vinh Province of Vietnam was initiated in February 2025 by a partnership between The Green Solutions Group (TGS) and the Vietnam-Germany Energy Partnership Project at GIZ. The project aims to achieve commercial operation in late 2026 and is slated to produce 575 tons of green ammonia per day (The Green Solutions Group 2025). Six additional projects led by The Green Solutions are in the planning stages, with aims to produce 500 kt green hydrogen annually by 2030 (OECD 2024). Vietnam's additional emerging hydrogen projects include planned facilities in regions rich in RE resources such as Binh Dinh, Ninh Thuan, and Quang Tri provinces. Various existing coal, fertilizer, refinery, and petrochemical plants in the country are being explored for their potential to produce green hydrogen feedstock using existing infrastructure, and the steel industry could also be a user of green hydrogen in the future.

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

Province/Region	Project Name/ Details	Timeline	Associated Entities	Announced Hydrogen Production Capacity
Mekong Delta Region, Trà Vinh Province	Trà Vinh Green Hydrogen/Ammonia Manufacturing Plant	Commercial Operation Date: Est. Q4 2026	The Green Solutions Group Corp. (TGS) Honeywell Vietnam-Germany Energy Partnership Project	48,000 cubic meters/hour
Bình Định	Offshore wind-powered electrolysis	2024-2026	Phy My Group Siemens Energy	20,000-160,000 tons/year
Quảng Trị	N/A	Announced March 2024 Operational 2028-2030	Chian Huadian Engineering Co. Ltd. Minh Quang JSC	100-200 kt/year
Binh Thuan	Coastal hybrid systems: Solar PV + battery	2024-2025		17 tons/year
Ninh Thuan	Solar/wind hybrid projects	First phase of operation by 2030	Trungnam Group Siemens Energy Group Envision Group	250,000 tons/year
Ben Tre	N/A	2023	The Green Solutions Group Corp. (TGS)	24,000-60,000 tons/year
Pha Lai Ward, Chi Linh Town, Hai Duong	Transition Pha Lai 1 coal plant to 100% green hydrogen (2x100 MW)	2023-2045	UNDP-Institute of Energy CN	N/A
Ca Mau	Pilot green hydrogen production at fertilizer producer	2024-2025	UNDP	N/A
Quang Ngai	Renewstable and HyPower hydrogen power plants	Announced 2024	HDF Energy Company Quang Ngai Department of Industry and Trade	N/A

Sources: Yep 2024; Tri 2024; Vietnam Economy News 2024; Socialist Republic of Vietnam 2023; OECD 2024; The Green Solutions Group 2024

Vietnam's green hydrogen strategy aims to transform the country into a regional hub for renewable hydrogen by leveraging its vast wind and solar resources. By 2030, the government has set production targets to produce 100,000 to 500,000 tons of hydrogen annually, scaling to 10 to 20 Mt by 2050. These targets are meant to align with Vietnam's 2050 net-zero emissions goal and include plans for green hydrogen integration into various sectors, including steel (Yep 2024).

Vietnam's hydrogen development roadmap sets goals for the industrial sector to pilot tests replacing grey hydrogen used in fertilizer production and petrochemical refining with green hydrogen. Specifically, the country aims to transition gas power plants, with a projected capacity of 32.4 GW by 2050, to green hydrogen usage as technology becomes commercially viable and economically competitive (PwC Vietnam 2023). For the iron and steelmaking sector, manufacturers in Vietnam are expected to trial hydrogen as a replacement for carbon-intensive coke inputs in the BF-BOF process to innovate towards a greener, lower-carbon steel. However, challenges such as high costs, insufficient infrastructure, and limited legal frameworks remain barriers to widespread adoption.

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 Vietnam

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. High-quality, consistent iron ore input is essential for both process efficiency and the production of high-grade steel in EAFs. DR-grade iron ore, with an average iron content of around 67%, is the preferred input for H_2-DRI processes. However, it currently makes up only about 4% of global iron ore shipments (IEEFA 2022), and the overall quality of available iron ore has declined in many regions. This presents a key bottleneck, as lower-grade ores with higher impurity levels not only reduce DRI plant productivity but also lead to increased slag volumes and steel defects during EAF production.

To address these challenges, several strategies are emerging. When DR-grade iron ore is limited, alternatives such as BF-grade pellets or fines can be considered, though these require additional processing to manage issues like impurity removal and sticking behavior in shaft furnaces. Process modifications such as using fluidized bed reactors or operating DRI plants at adjusted temperatures can help adapt to lower-grade inputs. Additionally, beneficiation and blending techniques offer pathways to upgrade or mix lower-grade ores to meet quality thresholds. Beneficiation processes like magnetic separation, flotation, and gravity separation are effective in removing gangue materials and improving ore quality.

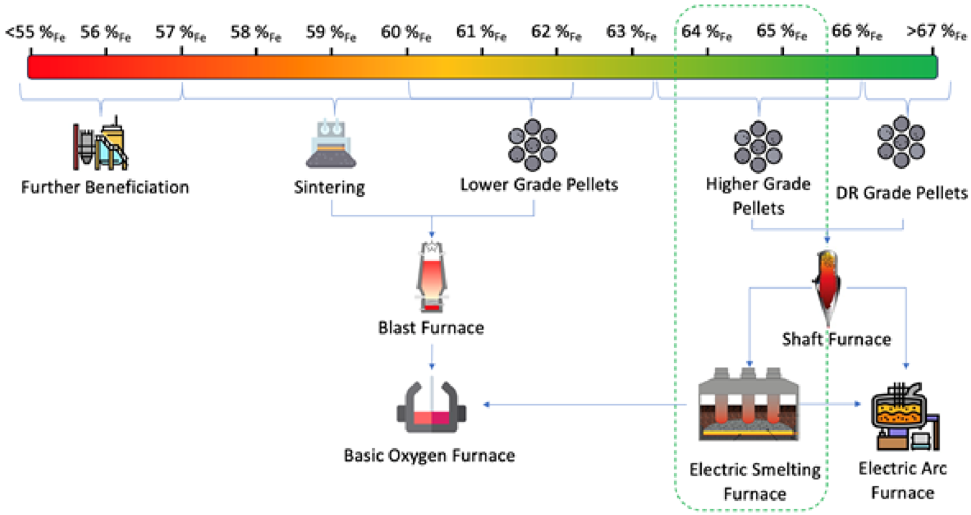


Figure 19. Iron ore grade and steel production routes (Stewart 2023)

Maintaining product quality in H_2-DRI also requires real-time monitoring and advanced process control. Effective screening systems upstream of the shaft furnace, rigorous material analysis throughout the process, and automation systems for adjusting parameters in real time are all needed to ensure stable operation. These tools help manage issues like nitrogen absorption, slag foaming, and bath-mixing, which are more pronounced with variable ore quality and lower-grade feedstocks.

To mitigate some of the metallurgical challenges in EAFs, particularly slag formation and bath instability, several solutions are being explored. These include adding small amounts of biocarbon or carbon-based additives, using oxygen top lances and bottom stirring systems for improved mixing, and deploying slag modifiers to control slag properties. Maintaining sufficient slag in the furnace using techniques like hot heel operation can also protect the arc and improve melting stability.

Moving forward, optimizing process flexibility, improving ore preparation, and enhancing control systems will be critical to overcoming the limitations of iron ore availability and quality in H_2-DRI steelmaking. Vietnam could partner with countries such as India and Australia, which also deal with low-quality iron ores, to conduct joint research on improving ore beneficiation and agglomeration techniques. They could launch pilot projects to trial refining and DRI processes using local low-grade ores with hydrogen.

Other Challenges and Solutions

Scaling up green hydrogen and H_2-DRI steelmaking in Vietnam faces a number of interrelated challenges. The primary barrier to adopting green H_2-DRI in Vietnam is cost, which is discussed further in the next section. Hydrogen production from renewable electricity remains expensive, and hydrogen can represent nearly half of the total production cost for H_2-DRI steel (Hasanbeigi et al. 2024). Although Vietnam has made rapid progress in deploying solar and wind power, the current electricity grid faces curtailment issues, and large-scale RE integration remains limited by infrastructure bottlenecks. Additionally, Vietnam's carbon market is still in a pilot phase and has not yet established pricing strong enough to drive major industrial transitions. Without a sufficiently high and stable carbon price, or robust green incentives, green H_2-DRI remains at a competitive disadvantage relative to traditional BF-BOF steelmaking. Estimates suggest that for green hydrogen to become cost-competitive, renewable electricity prices will need to fall below $0.02/kWh, while building out transmission and storage capacity.

Moreover, green hydrogen production depends on reliable access to large volumes of low-carbon electricity and water. Vietnam's RE resources are promising but unevenly distributed, and the grid currently struggles with congestion and curtailment in high-generation regions like the South-Central provinces. Building green hydrogen hubs and integrating renewable generation, electrolysis, and steel production facilities will require major investments in grid infrastructure, energy storage, and water management systems.

Vietnam also lacks a comprehensive regulatory framework to support green hydrogen development. Vietnam's national hydrogen strategy, expected in the coming years, along with expanded corporate demand for low-carbon materials, could help accelerate cost reductions for green hydrogen and overall feasibility of green H_2-DRI-EAF steelmaking. Technical and metallurgical challenges also complicate the shift to H_2-DRI in Vietnam. The country's steel sector is currently dominated by conventional BF-BOF technology, with limited operational experience in DRI-EAF pathways. Scaling up H_2-DRI would require major investments in new reduction plants, EAF capacity, and improved raw material preparation, especially given that Vietnam's domestic iron ore resources are typically of lower quality. As discussed above, DRI production demands high-grade iron ore pellets, requiring beneficiation, blending, or increased reliance on imports. Adapting operational practices to manage differences in slag foaming, DRI melting behavior, and hydrogen safety will be necessary to ensure successful technology integration.

Finally, capacity building across the workforce and industry stakeholders is another challenge. Expanding green H_2-DRI steelmaking in Vietnam will require targeted technical training in hydrogen handling, electrolyzer operation, EAF optimization, and process safety. Managers and executives will also need education on green steel technologies, financing models, and the long-term strategic advantages of early adoption. Figure 20 below summarizes the main challenges and opportunities for enabling green H_2-DRI development in Vietnam. Further solutions and recommendations are discussed in Chapter 7.

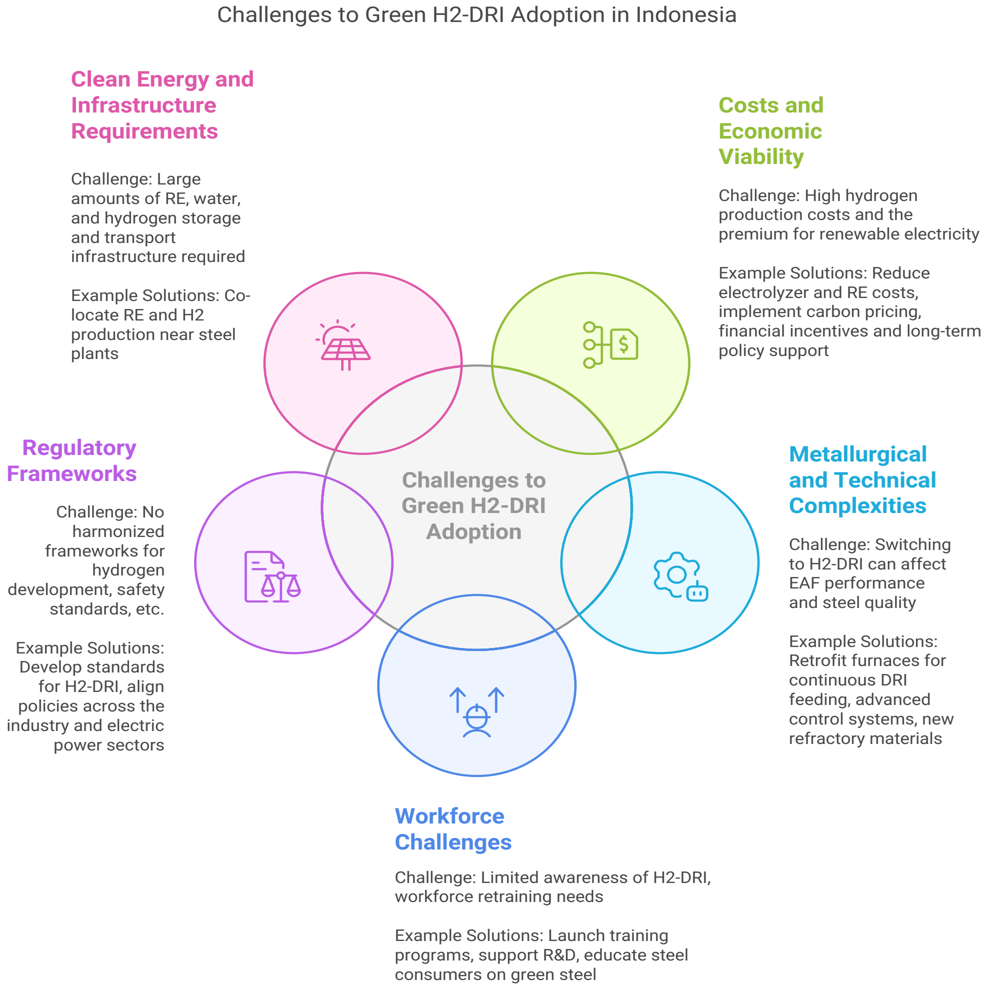


Figure 20: Summary of challenges to green H_2-DRI adoption (Hasanbeigi et al. 2024)

5.4.3. Green Iron Trade

Importing green iron, or iron produced via the green H_2-DRI route, can be a key lever for the decarbonization of Vietnam's steel industry. Accessing low-carbon iron inputs can enable a faster and more cost-effective transition to low-carbon steelmaking. By substituting carbon-intensive domestic iron production with imported green HBI or DRI, Vietnam can avoid the immediate technical and infrastructure challenges associated with scaling up domestic green hydrogen and iron ore production, while still achieving significant 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.

Internationally traded forms of iron include iron ore, pelletized iron ore, DRI, and HBI. HBI is particularly attractive for Vietnam because it is denser, safer to transport over long distances, and can be directly 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 is making major investments 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, with plans to export 100 Mt of green iron per year to China (Fortescue Metals 2025). The NeoSmelt project is another Australian initiative aiming to produce low-emissions green iron by transforming Pilbara iron ore with an electric smelting furnace (ESF) at Kwinana Industrial Area. Developed by BlueScope, Rio Tinto, BHP, and Woodside, NeoSmelt will initially use natural gas, with plans to transition to green hydrogen over time (SEAISI 2025).

Brazil's Vale is also establishing a network of "mega hubs" in Saudi Arabia, Oman, and the UAE to produce low-carbon briquetted iron for regional and international markets. These hubs are designed to leverage abundant RE resources, concentrating iron ore processing near low-carbon energy sources, producing briquetted green iron, and exporting it to steelmakers for EAF production (Vale 2024). Although some hubs will initially use natural gas, they aim to transition to green hydrogen as technology and infrastructure mature.

Modeling Inputs

For the scenarios in this model, we assume a small share of imported green iron from 2040 onwards, 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 Vietnam's Steel Industry

Despite the potential benefits of green iron imports for decarbonizing Vietnam's steel industry, several challenges could hinder uptake. First, Vietnam 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 Vietnam's shift toward lower-emission steel production. Trade and industrial policies should facilitate green iron imports through tariff adjustments and incentives for the use of certified low-carbon inputs. Clear regulations will also be needed for the safe handling, transportation, and storage of green iron to protect environmental and operational integrity. Lastly, early engagement with major exporting countries and project developers will be critical to securing reliable, sustainable supply arrangements and technical collaboration, supporting Vietnam's broader transition to a low-carbon steel industry.

5.4.4. Electrolysis of Iron Ore

Electrolytic processes produce metallic iron by using electricity to break the chemical bonds between iron and oxygen in iron ore, releasing oxygen gas as the only byproduct. When powered by renewable energy, these processes can eliminate CO_2 emissions entirely, offering a zero-emissions alternative to traditional BF-BOF steelmaking.

Among high-temperature electrolytic technologies, molten oxide electrolysis (MOE) is currently the most advanced. This method involves dissolving iron ore in a molten electrolyte at approximately 1,600°C and applying an electric current. Iron ions migrate to the cathode and are reduced to molten metallic iron, while oxygen ions travel to the anode and are released as oxygen gas. Boston Metal is a leader in MOE development, having designed modular cells capable of processing a wide range of iron ore grades directly into high-purity liquid iron (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 Vietnam 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 main technical challenges for electrolytic ironmaking revolve around issues of scale, production throughput, and energy efficiency. A key bottleneck is the iron production rate, which is constrained by the current density that can be applied across the 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 a country like Vietnam, scaling up electrolytic ironmaking presents additional challenges beyond the core technical issues. Reliable access to low-cost and preferably renewable electricity may be limited, especially if competing with other uses for the steel industry like for scrap-EAFs or green hydrogen production. Building and operating high-temperature facilities capable of sustaining molten oxide conditions requires substantial capital and industrial infrastructure. Moreover, Vietnam lacks a domestic manufacturing base for critical components such as inert anodes and corrosion-resistant equipment, increasing reliance on imports and raising overall project costs. Given these barriers, widespread deployment of electrolytic ironmaking in Vietnam is unlikely to occur for several decades.

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

Technology shifting to lower-carbon steel production routes drives the greatest overall emissions reductions under the Net Zero scenario, as discussed in Section 4.2. This technology shift is represented by the share of each steel production route in total steel production in Vietnam through 2060. Figure 21 shows the contribution of each production route to total steel production in Vietnam under all scenarios up to 2060. Under the BAU scenario, the BF-BOF route continues to grow in terms of overall crude steel production, while under the Advanced and Net Zero scenarios, BF-BOF production grows through the 2030s, based on existing plans, but decreases afterwards. In all scenarios, the scrap-EAF production route grows significantly by 2060 because of more domestic steel scrap availability in the coming decades.

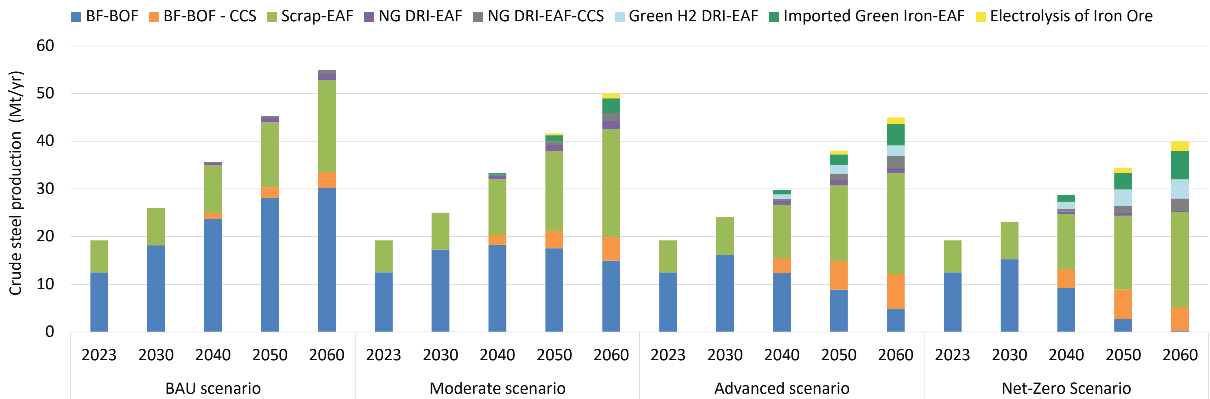


Figure 21. Crude steel production by technology type under each scenario in Vietnam, 2023-2060 (Source: this study).

Figure 22 presents the share of each steelmaking technology in total steel production under the Net-Zero scenario. Under the Net Zero scenario, the scrap-based EAF production route will account for 50% of total steel production in Vietnam by 2060. 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 will make up 37% of steel production combined. These technologies include NG-DRI-EAF with CCS (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 Vietnam.

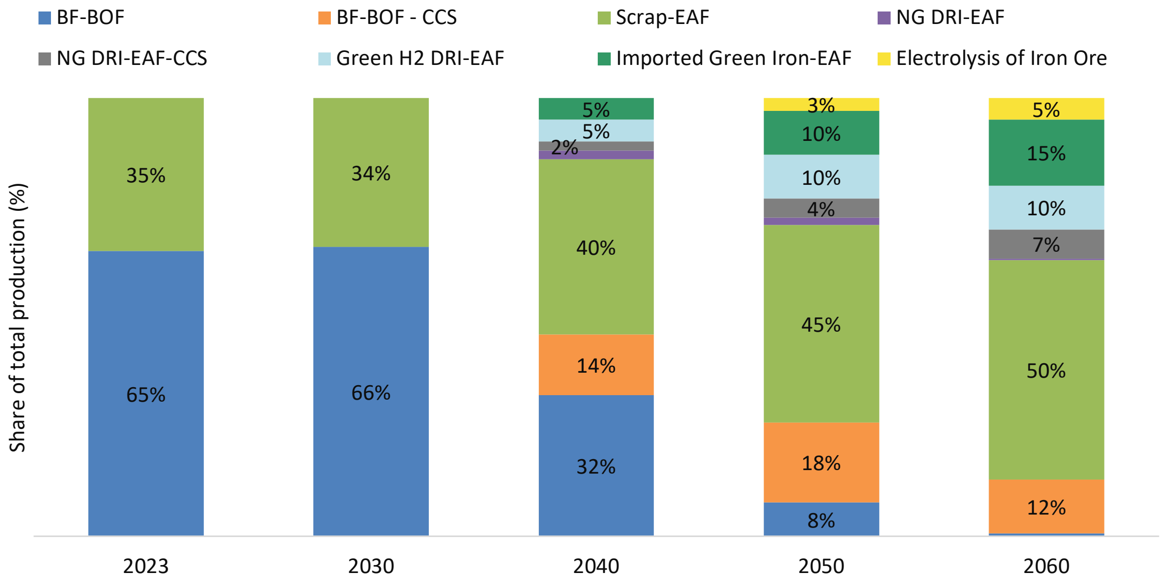


Figure 22. Share of steel production technologies under Net-Zero scenario up to 2060 in Vietnam (Source: this study).

Modeling Results

Technology shifting toward lower-carbon steel production routes is the largest driver of emissions reductions in the Net Zero scenario, as detailed in Section 4.2, accounting for 18.3 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 substantially higher than 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 in Section 4.2 show that green iron imports in Vietnam could reduce 2060 emissions by about 7 Mt CO_2 per year under the Net Zero scenario compared to BAU, an emissions reduction that is greater than what is projected for CCUS deployment.

The two low-carbon steelmaking technologies that are quite impactful in our roadmap to reduce GHG emissions in Vietnam'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 Vietnam'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 Vietnam's steel industry under the different scenarios. In the Net Zero scenario, we project that hydrogen demand could start at 86 kilotons (ktons) in 2040 and increase to 240 ktons by 2060. Note that the BAU and Moderate scenarios assume no H_2-DRI steel production. Other literature estimates expect that Vietnam's total hydrogen demand could reach 2 Mt annually by 2050 (2,000 ktons), with the steel industry accounting for approximately 4.5% of demand, or 90 ktons of H_2 per year (Hoang et al. 2023).

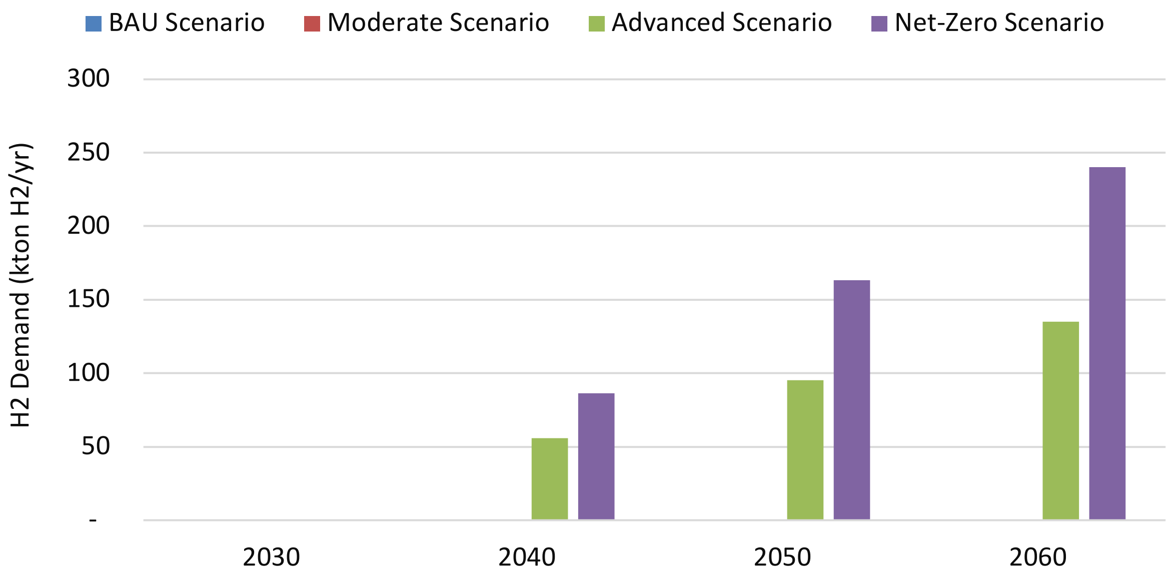


Figure 23. Total additional hydrogen demand for Vietnam's steel industry under different scenarios (Source: this study)

For our analysis, we assumed that the hydrogen used in Vietnam'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 Vietnam's steel industry under the different scenarios. Green hydrogen production to meet the steel industry's demand in Vietnam increases annual electricity consumption by 5, 9, and 14 TWh/year in 2040, 2050, and 2060, respectively, under the Net-Zero scenario. For comparison, Vietnam generated 276 TWh of electricity in 2022, indicating that future green hydrogen production would only make up a very small share of demand for growing electricity production.

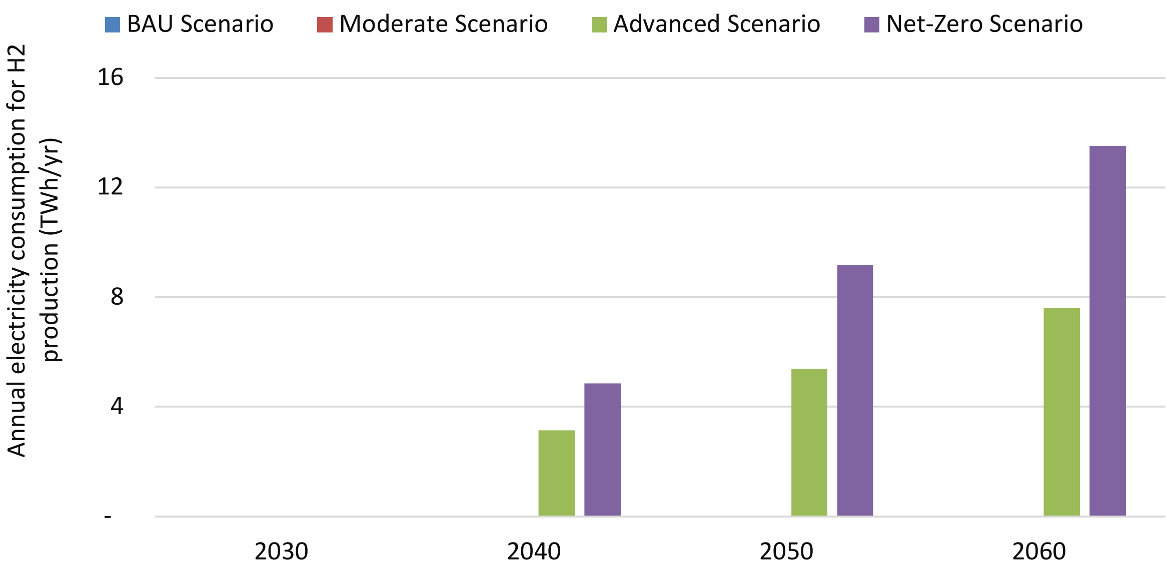


Figure 24. Additional annual electricity consumption for green hydrogen production for Vietnam's steel industry under different scenarios (Source: this study)

Note that the BAU and Moderate scenarios assume no H_2-DRI steel production.

To maximize the decarbonization benefits of H_2-DRI, Vietnam will need to invest more in renewable power generation, power distribution, and green hydrogen production capacity. Figure 25 shows our estimate of the total electrolyzer capacity needed for green hydrogen production for Vietnam's steel industry under different scenarios. For example, under the Net Zero scenario, about 3.9 GW of electrolyzer capacity equal to over 390 units of 10 MW electrolyzers if current 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 calculating the required capacity.

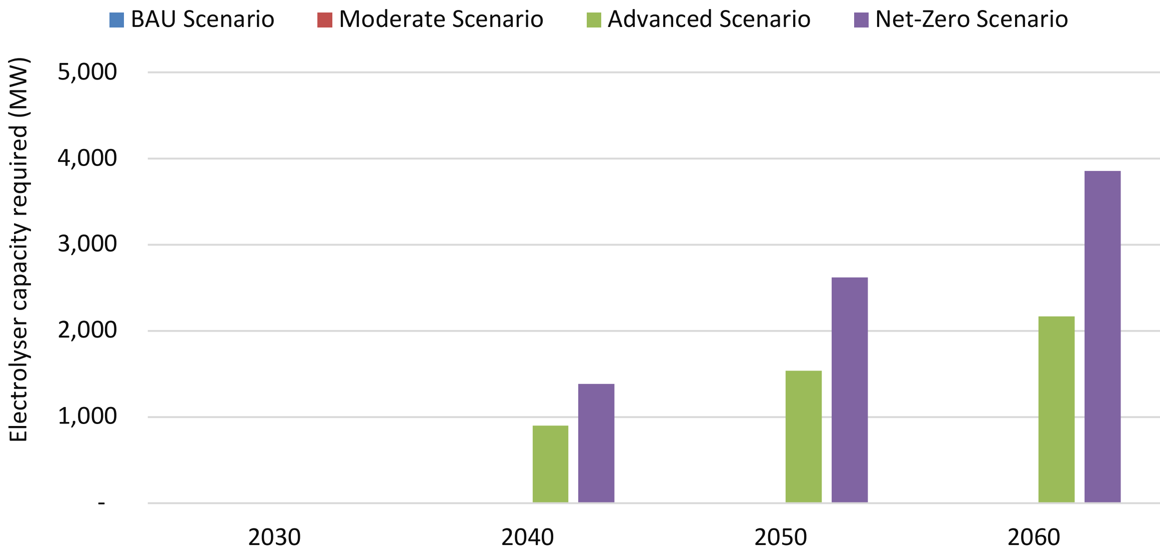


Figure 25. Electrolyzers capacity required for hydrogen production for Vietnam's steel industry under different scenarios (assuming 40% capacity factor for electrolyzers) (Source: this study)
Note that the BAU and Moderate scenarios assume no H_2-DRI steel production.

Optimal Siting of EAFs in Vietnam

In Vietnam, the optimal siting of new EAF facilities should prioritize locations that offer strong access to scrap supply, reliable electricity infrastructure, and proximity to major steel demand centers. Coastal areas like Phu My in Ba Ria–Vung Tau Province stand out due to their established scrap steel unloading facilities, dedicated docks for bulk shipments, and port access for scrap imports. Major steel producers like Thep Viet have already capitalized on these advantages by building their own unloading infrastructure at their Phu My EAF facility (Minter 2014). Similarly, the Ho Chi Minh City region offers cost advantages through lower domestic scrap prices compared to the north, a large concentration of steel enterprises, and efficient port logistics to handle growing scrap imports. Northern and central Vietnam also present promising opportunities for EAF development. The Hanoi region benefits from a dense concentration of steel enterprises and future railway connectivity through the planned Thuong Tin cargo station. Meanwhile, Vung Ang in Ha Tinh Province is emerging as a major industrial growth center, anchored by the Formosa Ha Tinh Steel complex and the Vung Ang Economic Zone.

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

The implementation of CCUS systems can help 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 technologies vary significantly in their commercialization status, with most still at the pilot stage. Captured CO_2 emissions from iron and steel production can either be permanently stored underground (storage) or utilized to produce chemicals, fuels, construction materials, and other products (utilization).

CCUS applications in the steel sector remain almost entirely at the pilot or early development stage. As of late 2024, only one commercial-scale CCUS facility (Al Reyadah in the UAE) is operational in connection with a steel plant, capturing just 26.6% of that plant's total emissions. No commercial CCUS facilities yet exist for blast furnace-based steelmaking, which remains the most carbon-intensive steel production route. Of the six steel-related CCUS projects currently in the global pipeline, nearly all lack firm timelines, specified capture capacities, or clearly defined storage solutions.

Carbon utilization provides a complementary pathway to CCUS for decarbonizing the steel industry by converting CO_2 emissions into valuable products rather than treating them solely as waste. In the context of steel production, captured CO_2 can be used to create chemicals, fuels such as ethanol, and construction materials like carbonated slag for use in cement and concrete. Initiatives like ArcelorMittal's collaboration with LanzaTech, where carbon monoxide from blast furnace waste gases is transformed by microbes into ethanol, highlight the potential for industrial-scale carbon utilization. While some applications, such as slag carbonation, have already been commercialized, most carbon utilization technologies remain in early stages of development and continue to face significant technical, economic, and scalability hurdles. Advancing this pathway will require substantial research, development, and demonstration (RD&D) efforts to reduce costs, enhance material performance, establish standards, and better integrate carbon utilization technologies into industrial operations (U.S. Department of Energy 2022).

A major barrier to scaling CCUS is the high cost and complexity of infrastructure. Retrofitting a BF-BOF facility to capture emissions from multiple point sources is technically demanding, and the need for CO_2 transport and long-term storage adds further costs and uncertainty. Even where capture is technically achievable, such as in gas-based DRI plants, the net emissions reductions can be modest once upstream methane leakage and energy demands are considered. Pilot project results from the U.S. and China have also shown that real-world capture rates often fall short of design targets. Additionally, many CCUS projects depend on enhanced oil recovery (EOR) to justify investment economics, which undermines their net climate benefit.

Despite these challenges, major steelmakers such as Nippon Steel, ArcelorMittal, and BHP continue to advocate for CCUS development. However, the trajectory of new low-carbon steelmaking capacity is clearly shifting toward hydrogen-based DRI rather than CCUS. Globally, the project pipeline for green DRI stands at around 96 Mt/year, compared to just 1 Mt/year for steel-related CCUS initiatives (Nicholas and Basirat 2024).

A useful way to evaluate CCUS prospects across industries is the "CCUS Ladder" (Figure 26). This framework ranks sectors by factors such as technical feasibility, mitigation potential, availability of alternative technologies, risk of fossil fuel lock-in, and emissions concentration. Steelmaking consistently ranks low on this ladder due to its dispersed emissions profile, the availability of cleaner alternatives like hydrogen-based DRI, and the challenges of retrofitting existing facilities. Reflecting these limitations, even organizations like the International Energy Agency (IEA) have scaled back their expectations for CCUS in the steel sector.

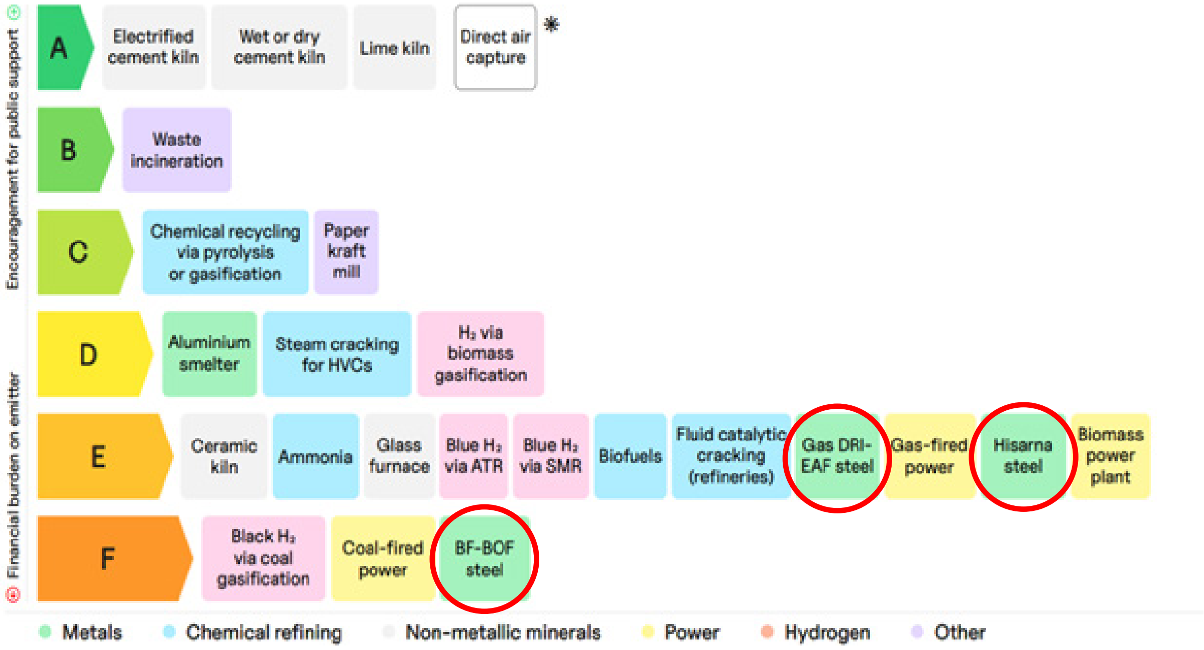


Figure 26: CCUS Ladder for long-term viability of CCUS technologies (Source: E3G and Bellona via Nicholas and Basirat 2024); steel production processes circled.

While niche opportunities for CCUS may emerge, particularly in gas-based DRI plants co-located with storage sites, its broader role in steel decarbonization appears increasingly constrained. High costs, limited emissions reductions, infrastructure bottlenecks, and weak technology learning effects make it a comparatively risky investment. In light of these realities, steelmakers and policymakers should prioritize scaling more promising pathways like green hydrogen-based DRI and scrap-based EAF production powered by renewables, while reserving CCUS for highly specialized, hard-to-abate contexts.

CCUS in Vietnam

Vietnam's CCUS landscape as of 2025 lacks steel sector pilots, but Vietnam's steel industry is prioritizing launch of a CCUS model between 2025 and 2030 (Vietnam Steel Association 2023).

Vietnam has an estimated total of 186 gigatons of subsurface carbon storage capacity. Feasibility of implementing a CCUS pipeline for the steel industry hinges on geologic stability and proximity to emissions sources (Harsha et al. 2023). Deep saline reservoirs in Vietnam have a storage potential of 10.4 gigatons, and depleted oil and gas fields have an estimated 1.4 gigatons of storage capacity (IEA 2021). Steel plants in Nghi Son and Formosa Ha Tinh would require dedicated CO_2 transport networks to connect with nearby depleted gas field storage sites of Hac Long and Ken Bai respectively. Proposed offshore pipelines in north Vietnam could allow these plants to capitalize on the significant storage capacity in the Song Hong aquifer basin (Harsha et al. 2023).

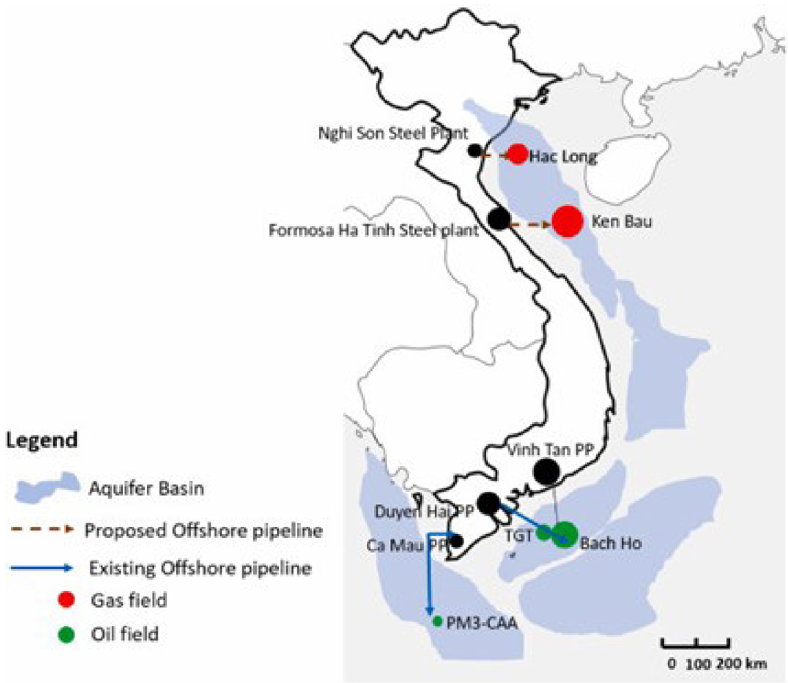


Figure 27. Matching of CO_2 sources (including two steel plants) to oil and gas reservoirs within Vietnam (Harsha et al. 2023).

Cross-sector coordination and international financing is required to ensure long-term sustainability of proposed steel sector CCUS operations due to high capture, transport, and storage costs. A study by Nguyen and Ha (2017) estimated that even at moderate carbon price scenarios, rising from $25 per ton of CO_2 in 2030 to $35 per ton of CO_2 in 2040, CCUS-integrated capacity steelmaking capacity in Vietnam would represent just 1.4% of total projected capacity (Nguyen and Ha 2017).

The regulatory landscape in Vietnam could accelerate CCUS adoption feasibility, with Vietnam's carbon market pilot planned in 2025 with an expected launch in 2028. Steel producers are included in a proposed emission quota decree for the 150 largest emitting actors in emission-intensive sectors, exemplifying how government ministries in Vietnam are looking to create a suite of financial mechanisms for carbon management (Duong 2025). International mechanisms like the European Union's Carbon Border Adjustment Mechanism (CBAM) could also incentivize CCUS adoption (Long Chu et al. 2024).

Modeling Inputs

In our analysis, we assumed different adoption rates of CCUS technologies in Vietnam's steel industry across scenarios for BF-BOF steelmaking and conventional DRI plants. Under the Net-Zero scenario, it is assumed that 95% of BFs and conventional DRI plants would adopt CCUS by 2060. Capture efficiency is expected to improve over time, reaching 70% for blast furnaces and 80% for DRI plants by 2060, as newer and more efficient technologies are deployed. 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 3.6 Mt in 2060 under the Net Zero scenario relative to the BAU scenario. Figure 28 illustrates the CO_2 emissions captured through the adoption of CCUS in Vietnam's steel industry.

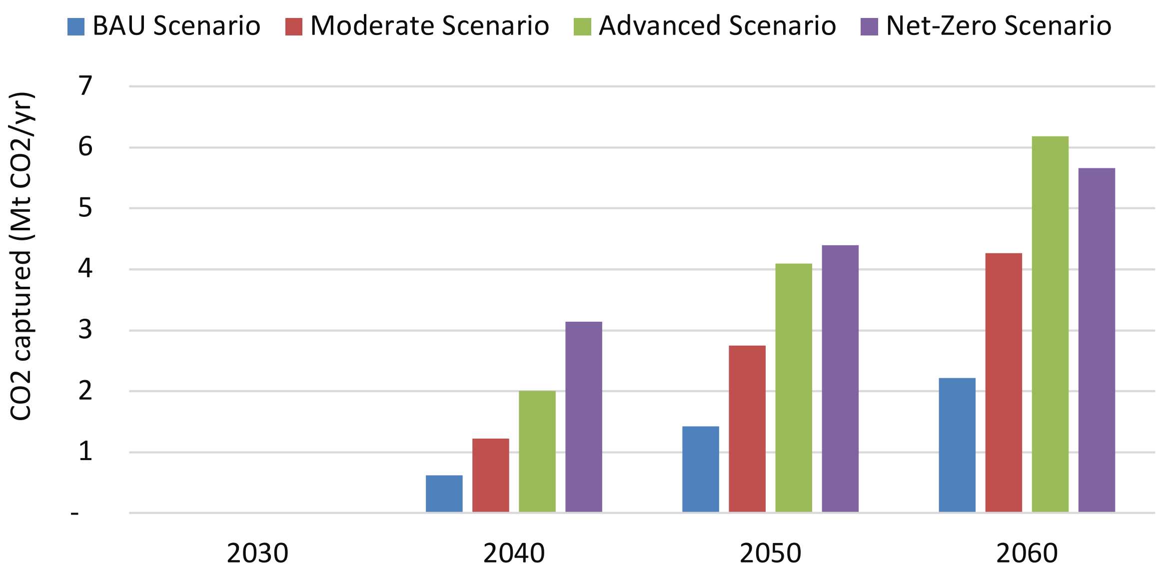


Figure 28. CO_2 emissions captured by the adoption of CCUS in Vietnam's steel industry (CCUS is applied after the adoption of other decarbonization technologies) (Source: this study).

However, low-carbon production routes such as scrap-based EAF and green H_2-DRI steelmaking offer greater overall decarbonization potential for Vietnam's steel sector, and thus the role of CCUS may be relatively limited. Another constraint is that CCUS technologies do not achieve 100% capture rates. Although post-combustion capture systems can theoretically reach efficiencies of up to 95%, practical factors, such as the dispersed nature of emissions sources across a steel plant and leakage during the capture process, mean that maximum capture efficiency is rarely achieved in practice.

Barriers and Solutions to CCUS in Vietnam's Steel Industry

The most significant challenges facing the implementation of CCUS in Vietnam are costs and domestic policy frameworks lacking incentives for private-sector CCUS options (Nguyen and Minh 2017). Decarbonizing Vietnam's steel sector required an estimated $0.6-1.4 billion in investments by 2050, with CCUS alone demanding $75-189 million by 2030 (United Nations Industrial Development Organization 2024). These costs risk being transferred to steel prices, raising costs of production and potentially hindering competitiveness in a market already pressured by low-priced Chinese imports and rising energy expenses (Vietnam+ 2025). Additionally, many small to medium sized steelmaking enterprises lack access to capital for retrofitting older BF-BOF infrastructure. Revenue from carbon credit sales post-2028 derived from emissions reductions through CCUS could partially offset these costs (Nguyen-Trinh et al. 2015). However, the industry's capacity to adopt CCUS will depend on the carbon market's ability to deliver viable financing mechanisms.

Additional technical requirements of increased energy use for the operation of CCUS systems pose an obstacle to steelmaking CCUS implementation. Plants that integrate CCUS technology have higher energy demand to produce the same amount of steel than a plant without CCUS technology (Nguyen-Trinh et al. 2015). This can in turn affect the production capacity and emission reduction potential of the system if RE is not readily available to meet this marginal increase in energy use. Storage site locations that are offshore and distant from steel plants pose technical connection challenges and require additional costs for pipeline construction. Lack of a unified CCUS regulatory system in Vietnam further complicates site permitting and liability management. Solutions to these challenges require long-term financial frameworks and appropriate policies to improve knowledge and awareness of CCUS for steel industry stakeholders.

6 Economic Feasibility of Low-Carbon Steelmaking in Vietnam

6.1. Economic Feasibility of EAF Steel Production in Vietnam

We also examined the levelized cost of steel (LCOS) production for a typical scrap-based EAF steelmaking facility in Vietnam, assuming an annual steel output of one Mt. This analysis compares the scrap-EAF route to the BF-BOF route. A detailed financial model was developed to evaluate these production 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, along with other necessary inputs like oxygen, alloys, and lime. The model is designed to adjust for varying scrap prices and includes projections through 2050.

The LCOS calculation distributes CAPEX across the plant's economic lifespan and uses net present value (NPV) accounting to discount future costs to their present value. Operating costs are projected annually over a 20-year analysis horizon, incorporating expected price changes for major inputs. This methodology allows for the assessment of the low-carbon steel premium by comparing the levelized costs of scrap-EAF steelmaking to primary steelmaking routes.

We find that the LCOS of BF-BOF steel and scrap-EAF steel is slightly higher than BF-BOF steelmaking in Vietnam. However, a breakdown of production costs across the BF-BOF and scrap-EAF routes reveals important differences in dominant cost drivers. For a BF-BOF plant in Vietnam, fuel and fossil reductants (primarily coal and coke) account for 31% of total LCOS, and iron ore makes up the largest share of costs (34%).

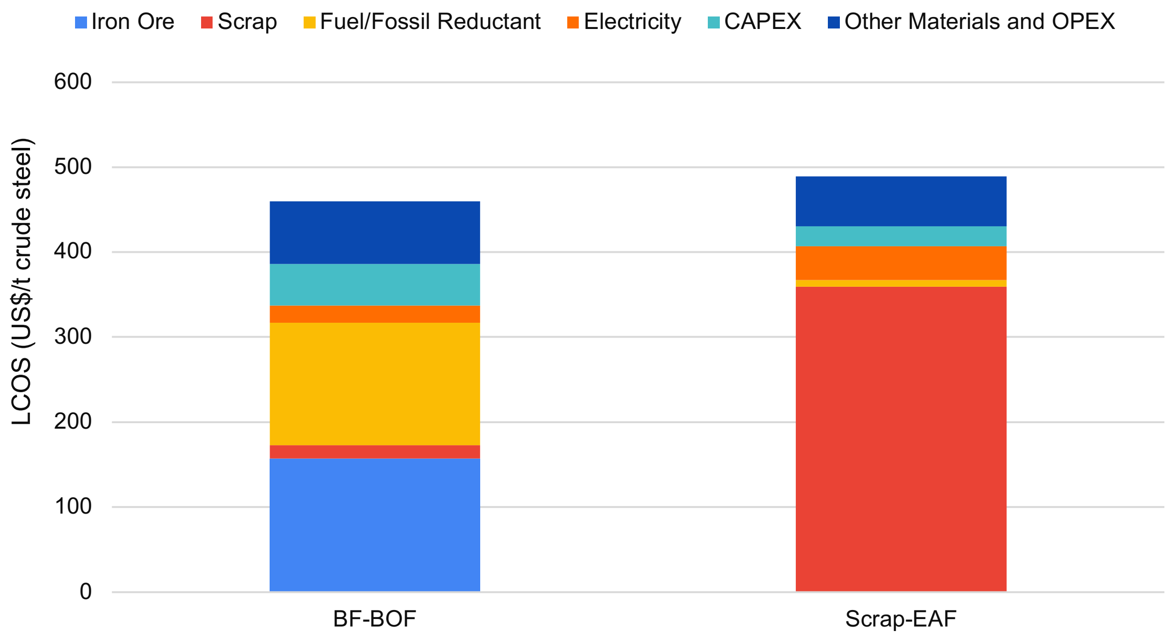
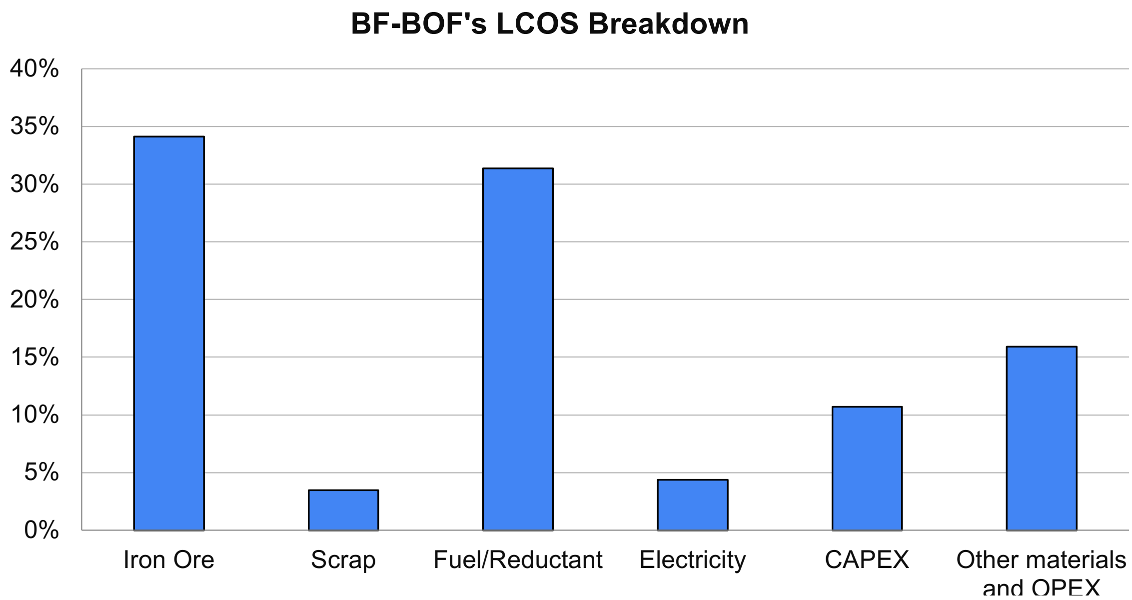


Figure 29. Breakdown of LCOS components for the BF-BOF and scrap-EAF steelmaking routes in Vietnam (Source: this study)

By contrast, for a scrap-EAF plant, scrap costs dominate, making up 73% of total LCOS, while electricity contributes just 8%. CAPEX and other materials/O&M account for 5% and 12%, respectively. This fundamental shift from coal and iron ore dependency in BF-BOF steelmaking to scrap dependency in EAF operations underscores the critical importance of ensuring a stable and high-quality scrap supply to sustain competitiveness.



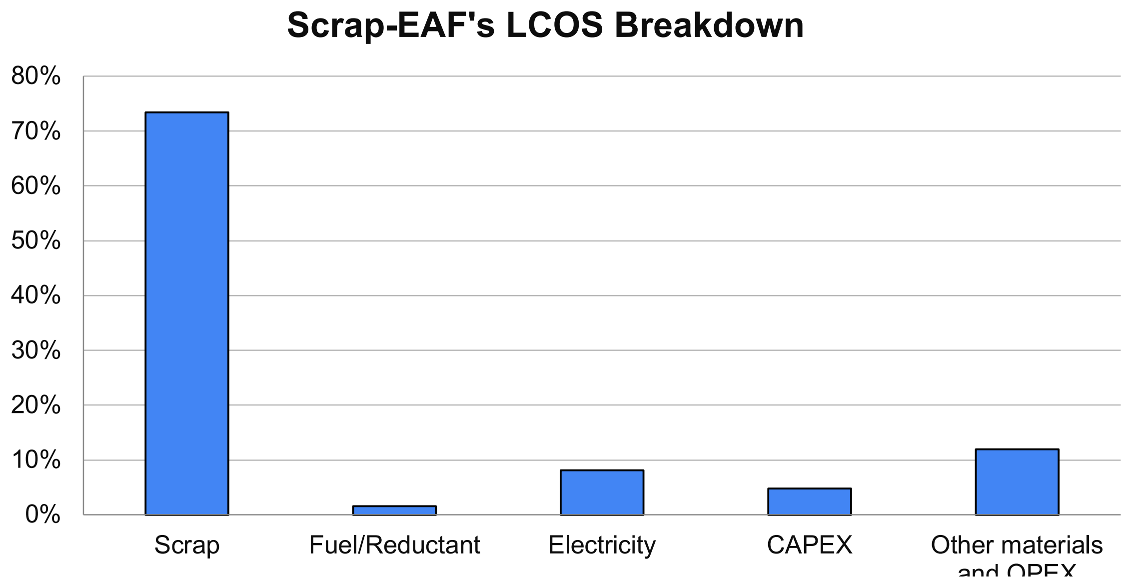


Figure 30. Share of cost components in BF-BOF and scrap-EAF LCOS in Vietnam (Source: this study)

6.2. Economic Feasibility of NG-DRI-EAF and Green H_2-DRI-EAF Steel Production in Vietnam

This section compares the LCOS for green hydrogen-based steelmaking in Vietnam with BF-BOF and NG-DRI-EAF methods. Our LCOS analysis follows the same methodology applied to scrap-EAFs in Section 5.4.1., using a standardized plant design with an annual output of one Mt. The model allows for varying degrees of hydrogen substitution in DRI production and includes sensitivity analysis based on hydrogen costs. In this study, the levelized cost of hydrogen represents the full delivered cost to the steel plant, covering production, transport, and storage.

Forecasts indicate that hydrogen prices will need to fall below $2/kg for green H_2-DRI-EAF to effectively compete with NG-DRI-EAF, a goal dependent on reducing electrolyzer capital costs below $400/kW and securing electricity prices at or under $0.02/kWh (Bataille et al., 2021). Widespread competitiveness is expected by 2035, driven by advances in technology, economies of scale, and supportive public policies. Policy initiatives such as the U.S. Hydrogen Hubs and the European Union's Hydrogen Bank are already working to accelerate the commercial deployment of green hydrogen through subsidies and financial incentives. These programs aim to lower green hydrogen costs to the $1–$2/kg range during the 2030s, making it a viable alternative to fossil fuel-based hydrogen.

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 Vietnam to scale up investment in green H_2-DRI steelmaking and align with long-term decarbonization goals.

The Vietnam Petroleum Institute reports the cost of green H_2 at 85,000 VND/kg (approximately 3.34 USD/kg), notably higher than the price of H_2 from industry byproduct, which is estimated at 30,000 VND/kg (approximately 1.18 USD/kg). To be competitive in the market for industrial applications, green H_2 prices will need to steadily decline over the coming decades. VPI estimates that a carbon tax could be highly effective at lowering green H_2 prices - at a tax rate of 1.275 to 2.55 million VND/t CO_2 (approximately 50 to 100 USD/t CO_2), the price of green H_2 is estimated to reach 17,830 to 25,500 VND/kg (approximately 0.70 to 1.00 USD/kg) (Hoang et al. 2023).

Our analysis indicates that green H_2 integration into steelmaking in Vietnam would still be more expensive than BF-BOF production even at the lowest H_2 price points, though at some lower price levels, green H_2 steelmaking could be cheaper relative to NG-DRI-EAF. For Vietnam, our analysis shows that although green H_2-DRI-EAF steelmaking offers emissions reductions of up to 97% compared to BF-BOF production, it is initially more costly than both BF-BOF and NG-DRI-EAF at current hydrogen prices. A hydrogen price of $2/kg would be required to achieve parity with NG-DRI-EAF, and reaching cost parity with BF-BOF would likely require carbon pricing. Only with a carbon price of $50 per ton of CO_2 and $1/kg H_2 does H_2-DRI-EAF become cost-competitive with BF-BOF in Vietnam, based on our analysis.

This is primarily because of the lower price for both coking coal and thermal coal and especially a substantial drop in price in the past two years making BF-BOF production more cost-competitive. However, the green premium embedded in final products is relatively low, as discussed in the following section. These findings underscore the critical need for policy support and investment in Vietnam's green hydrogen infrastructure.

As shown in Figure 32, carbon pricing could also play a key role in improving the economics of green steel in Vietnam. For this analysis, it is assumed that carbon pricing would take the form of tradable credits or allowances based on emissions reductions relative to a BF-BOF benchmark, with producers able to monetize these credits through carbon markets.

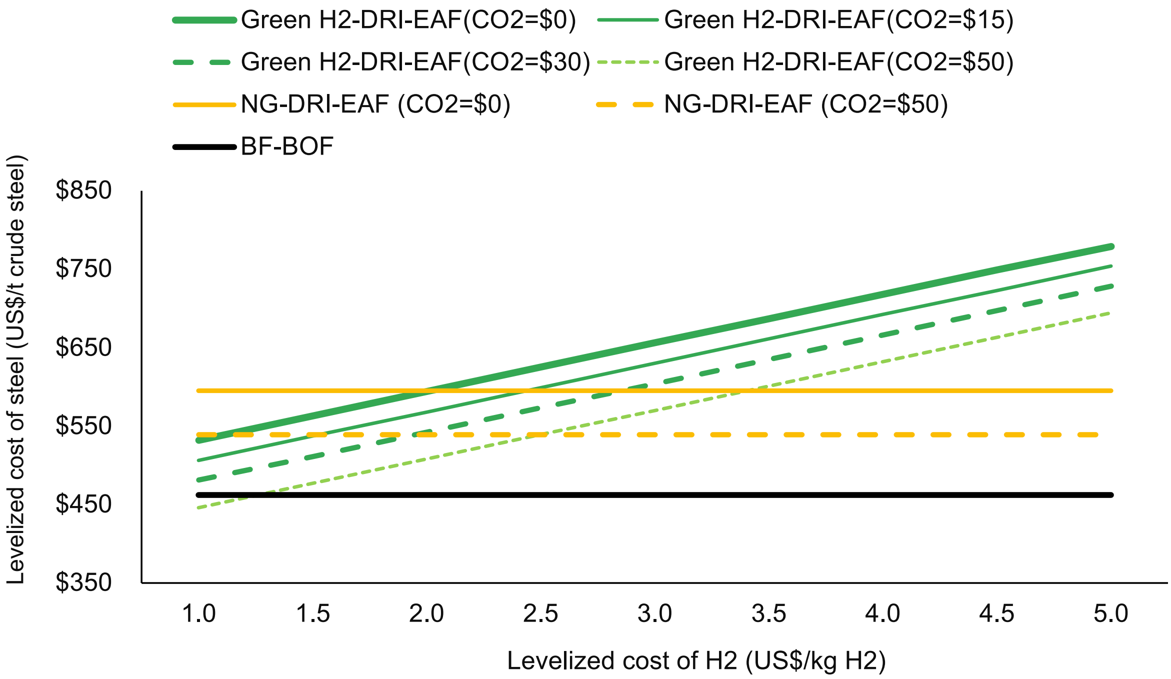


Figure 32. Levelized Cost of Steel ($/t crude steel) with varied levelized costs of H_2 at different carbon prices in Vietnam (Source: this study)

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 cost structure of green H_2-DRI-EAF steelmaking represents a shift from BF-BOF steelmaking, where coal and coke are the dominant inputs (in addition to iron ore), to hydrogen as the key input besides iron ore. The cost drivers for NG-DRI-EAF steelmaking remain heavily influenced by fuel inputs alongside iron ore costs (Figure 33).

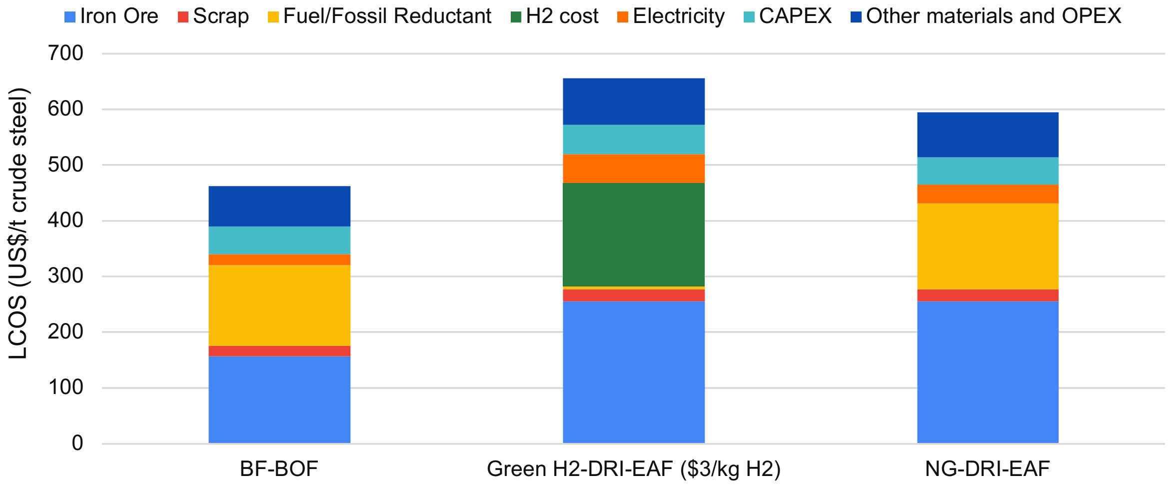


Figure 33: Breakdown of LCOS components by steelmaking route (Vietnam) (Source: this study)

The cost of green hydrogen production remains the single most important factor influencing the economic feasibility of green H_2-DRI steelmaking in Vietnam, alongside the cost of iron ore (Figure 34). Together, these two inputs account for around two thirds of production costs, with electricity and CAPEX each contributing 4% and 11%, respectively, and other materials and operational expenses (OPEX) accounting for about 16%. 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.

Overall, this analysis shows that even at $1/kg hydrogen, green H_2-DRI-EAF steelmaking remains more expensive than traditional BF-BOF in Vietnam under current conditions (i.e. no carbon pricing). Although other studies have indicated that H_2-DRI-EAF could become competitive at higher hydrogen prices, and that hydrogen prices in Vietnam could reach feasible levels, more recent market conditions, particularly the relatively low cost of coal, underscore the current challenge for green hydrogen steelmaking economics.

Nonetheless, green H_2-DRI remains an essential technology for decarbonizing the steel industry. The relatively small green premium at the product level suggests that the cost could be absorbed without major impacts on end-user affordability or competitiveness.

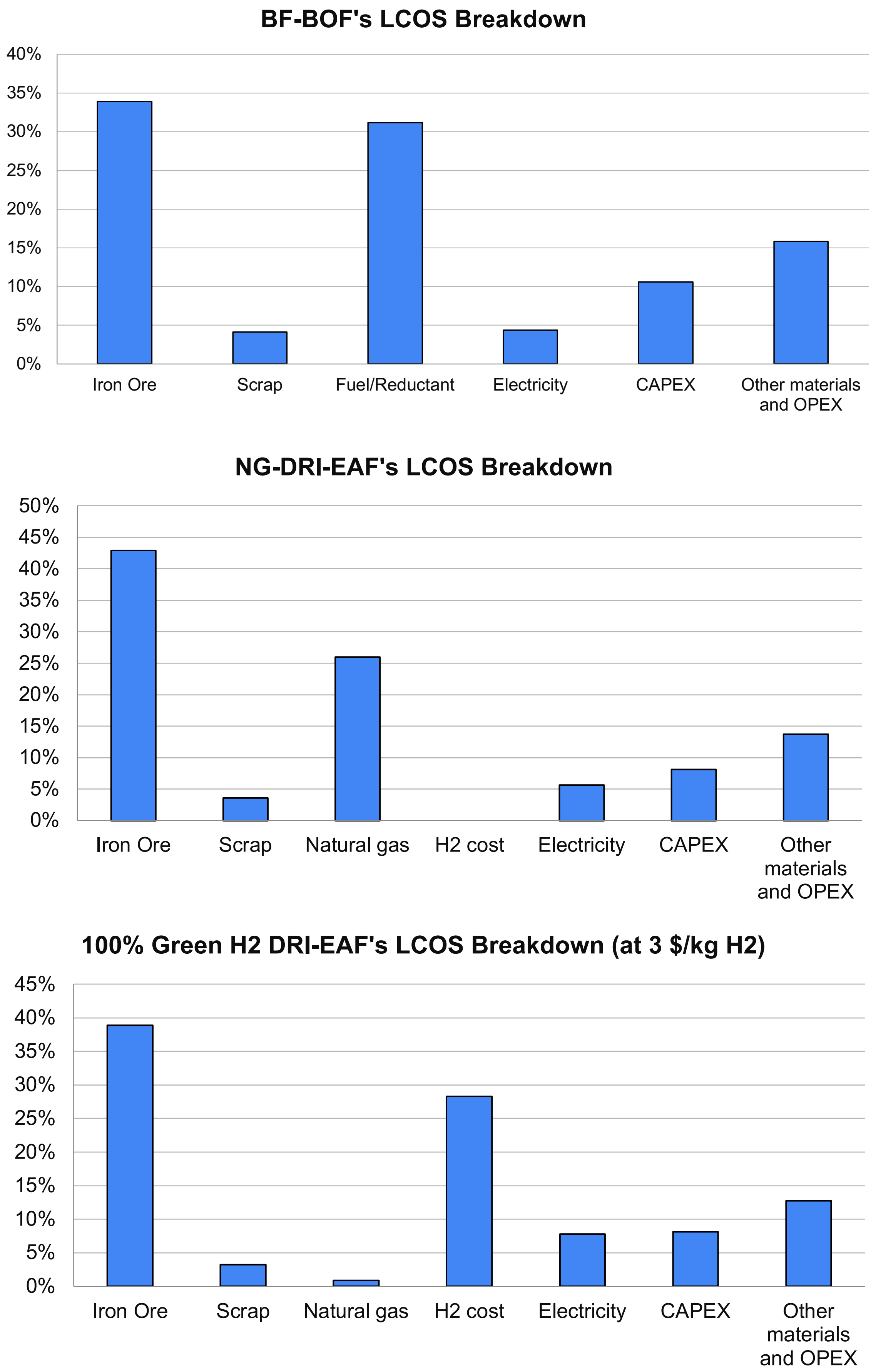


Figure 34. Share of each cost component in the LCOS of a BF-BOF, NG-DRI-EAF, and green H_2-DRI-EAF plant in Vietnam at $3/kg H_2 (100% green hydrogen) (Source: this study)

Moreover, fossil fuel prices are historically volatile, while the cost trajectory for green hydrogen is expected to continue declining through technological advancements, scaling of electrolyzer manufacturing, and growing RE deployment. As hydrogen production costs drop, potentially reaching $1.5/kg or lower by 2030, the competitiveness of green H_2-DRI is likely to strengthen considerably. Early investment in H_2-DRI positions Vietnam's steel industry to minimize future exposure to fossil fuel price volatility and carbon-related regulatory risks.

The environmental benefits of green H_2-DRI are substantial: CO_2 emissions from steelmaking could be reduced by up to 97% compared to the BF-BOF route. In policy terms, this represents one of the most cost-effective emissions reductions available, especially when measured in cost per ton of CO_2 abated. In addition, green H_2-DRI results in much lower air pollution, translating into health and societal benefits that extend beyond immediate financial metrics. Even with today's green premiums, the implied cost of carbon abatement through green steel remains well within acceptable ranges under many carbon pricing schemes and social cost of carbon estimates.

Finally, early adoption of green H_2-DRI technologies offers major strategic advantages. It positions Vietnam's steelmakers to become leaders in the emerging green steel market, helps secure long-term supply contracts with sustainability-driven customers, and strengthens energy security by shifting toward domestically sourced renewables rather than imported fossil fuels. Despite current cost barriers, green H_2-DRI remains the most scalable, credible pathway to achieving net-zero steel production by 2050. Thus, investments made today are not only about chasing short-term cost parity; they are about future-proofing Vietnam's steel industry, maximizing environmental value, and maintaining global competitiveness in a rapidly decarbonizing world.

The Green Steel Premium

The "green premium" for green H_2-DRI steel is reflected in 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 best to support the transition. To address this, we analyzed the impact of the green steel premium from H_2-DRI-EAF steelmaking on passenger car pricing and building construction cost in Vietnam.

The automotive sector accounts for approximately 12% of global steel demand (worldsteel 2023) and is expected to be an early adopter of green steel due to growing climate commitments. The additional cost from using green H_2-DRI-EAF steel in passenger vehicles remains modest and is consistent with recent studies suggesting minimal consumer impact. For example, in Vietnam, at a hydrogen price of $5/kg, the green premium for green steel is approximately $317 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 $317 higher than that of BF-BOF steel per ton). Assuming an average car uses about 0.9 tons of steel, this would translate to a cost increase of around $285 per vehicle. With an average passenger car price of about $25,000 in Vietnam, this results in roughly a 1% price increase, a small margin unlikely to affect overall affordability compared to typical market fluctuations. Future declines in hydrogen prices, potentially down to $1/kg, could substantially lower this premium. In addition, the introduction of carbon pricing or carbon credit mechanisms could further reduce the green premium, accelerating the adoption of low-emission materials in the automotive sector.

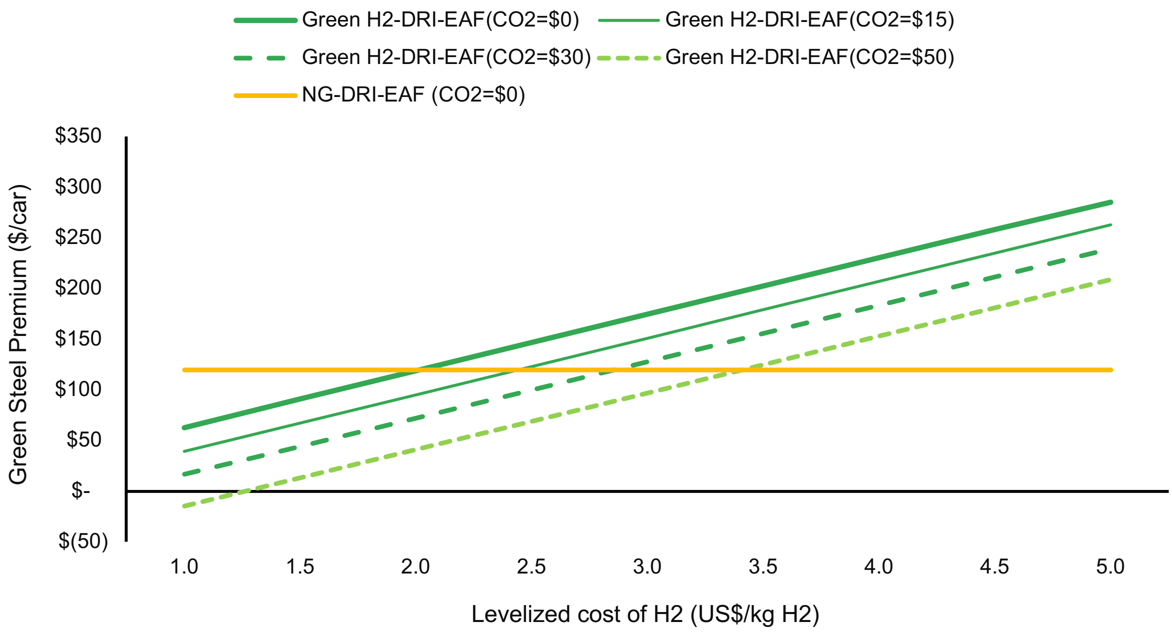


Figure 35. Impact of green steel premium on passenger car prices in Vietnam under different H_2 and carbon prices

The construction sector, including both buildings and infrastructure, accounts for more than half of global steel demand (worldsteel 2023). In the context of low- to mid-rise residential buildings in Vietnam, using green H_2-DRI-EAF steel adds a relatively modest cost compared to conventional BF-BOF steel. At a hydrogen price of $5/kg and with a green steel premium of $318 per ton, this translates to about an $793 increase in the cost of constructing a 50 m^2 residential unit. This added cost is minor relative to the total construction budget and could be further reduced, or even eliminated, with future declines in hydrogen prices or through the introduction of carbon pricing mechanisms.

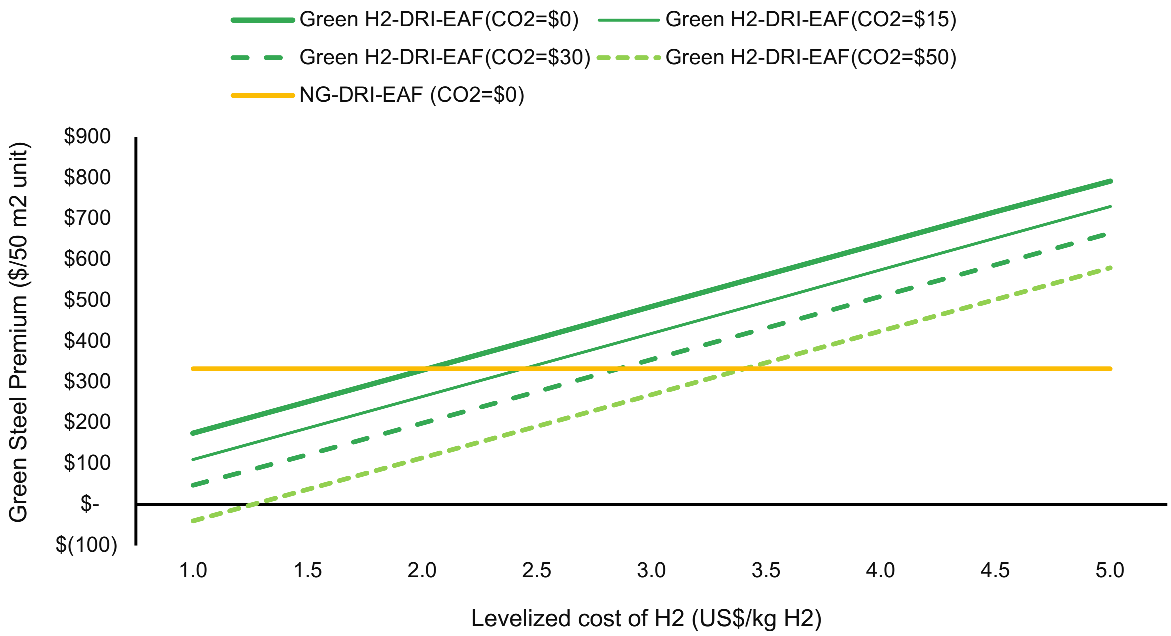


Figure 36. Impact of green steel premium on residential building (50 m^2 unit) construction cost in Vietnam under different H_2 and carbon prices

Note: Based on a 50 m^2 residential building unit assuming 50 kg of steel per m^2 used for low- to mid-rise construction.

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

Given the higher costs of green H_2-DRI-EAF steel under current conditions, the financing of green H_2-DRI technology will be central to the steel sector's ability to shift toward low-carbon production. Innovative financing strategies are key to making these large-scale, capital-intensive projects viable, with companies drawing from a mix of public grants, private capital, and strategic partnerships. Governments are playing a pivotal role by offering subsidies and tax incentives, as demonstrated in several major initiatives across Europe and the United States. These forms of support not only provide early-stage capital but also reduce the financial risk of adopting first-of-a-kind green steel technologies.

On the private side, investment flows through both direct equity and long-term offtake agreements that help secure stable income streams. For example, Stegra has signed multi-year supply agreements with major automakers, ensuring a reliable customer base for its green steel. The following section outlines the diverse financing approaches taken by various H_2-DRI projects around the world.

In 2023, Stegra successfully raised €1.5 billion in equity for its green steel plant in Sweden, and in early 2024, it secured an additional €4 billion in debt financing. The company also received a €250 million grant from the EU Innovation Fund. These funds, along with long-term supply deals with firms like Volvo, Scania, Mercedes-Benz, and KIRCHHOFF Automotive (the latter worth €130 million), position Stegra with both financial strength and market demand. The company's agreement with Rio Tinto for DR-grade iron ore pellets adds supply chain stability. The plant in Boden is expected to begin operations with a capacity of 2.5 Mt per year, later scaling to 5 Mt (Stegra 2024).

Salzgitter AG's SALCOS® program has secured over €1 billion in government support from the German federal and Lower Saxony governments. This is matched by more than €1 billion in internal funding to build a H_2-DRI plant using Energiron ZR® technology (Salzgitter AG 2023).

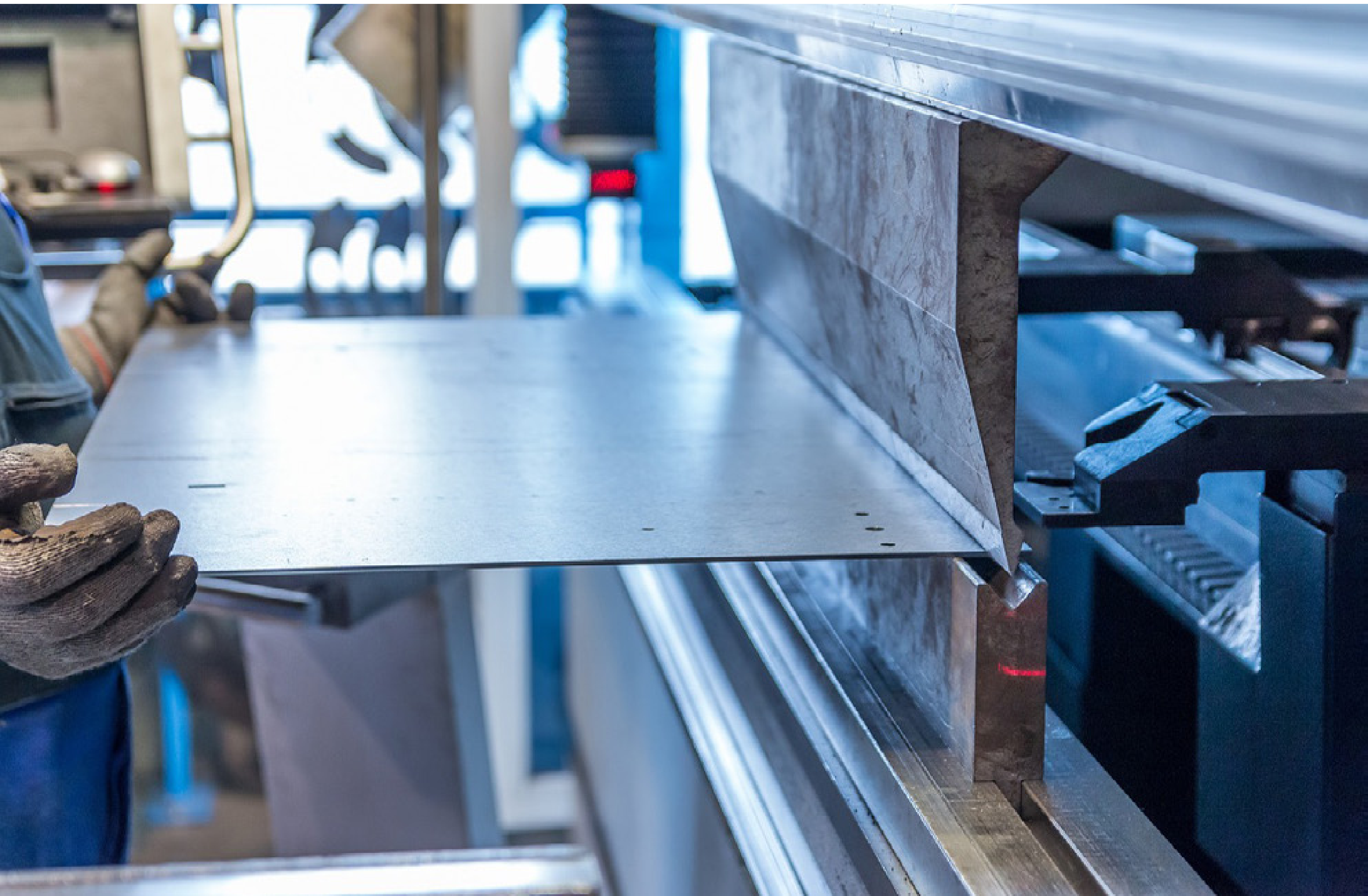
The HYBRIT project, led by SSAB, LKAB, and Vattenfall in Sweden, benefits from a SEK 3.1 billion (US$ 282 million) grant via the Swedish Energy Agency's Industrial Leap initiative. Around 75% of its development funding is being contributed by the project's owner companies (Hybrit 2023).

Thyssenkrupp has committed €2 billion to decarbonize its steel operations by replacing conventional BF-BOF systems with a H_2-DRI plant capable of producing 2.5 Mt per year. Additional funding from both public and private sources is anticipated to support the rollout (thyssenkrupp 2022).

POSCO in South Korea is advancing its HyREX project, a hydrogen-based fluidized bed reduction process, with government support of KRW 26.9 billion (about USD 20.4 million) between 2023 and 2025 (Kweon 2024).

Table 4. 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

Decarbonizing Vietnam's steel industry is a complex but necessary challenge that will require substantial financial investment, strong policy alignment, and technology deployment. Without clear direction, there is a risk of locking in high-emissions assets that could undermine Vietnam's climate commitments and competitiveness. A phased and coordinated action plan is essential to guide the sector toward a low-carbon future while meeting domestic and international market expectations.

This section presents strategic recommendations for the Government of Vietnam, steel companies, and steel consumers to unlock the full potential for deep decarbonization of the steel industry. Recommendations are organized by 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). An additional set of recommendations targets actions by steel consumers to accelerate market transformation. Actions are structured by stakeholder group and divided into near-term (2025–2030), medium-term (2030–2040), and long-term (2040–2060) timelines.

To make these recommendations effective, the Government of Vietnam should establish a robust legal and regulatory framework embedding clear decarbonization targets and performance standards into national and sectoral policies. This includes updating existing industry and environmental regulations to set CO_2 intensity benchmarks, enforce strict energy efficiency standards, and require climate risk disclosures for new steel sector investments. The government should also clarify roles and coordination mechanisms among ministries and agencies to ensure smooth implementation and prevent regulatory overlaps. Creating these legal foundations will build investor confidence, improve accountability, and accelerate progress toward Vietnam's net-zero goals.

7.1. Recommendations for enhancing material efficiency and demand management

Under Vietnam's Net Zero scenario, the Material Efficiency and Demand Management pillar is expected to deliver around 20% of the total CO_2 reductions needed to bring the steel industry's emissions down from BAU levels to net zero in 2060. This means strategies such as lightweight design, improving fabrication yields, extending the lifespan of steel products, and promoting reuse of steel components and other material efficiency measures could help avoid 12.3 million tons of CO_2 emissions in 2060 compared to the BAU. This contribution highlights that reducing steel demand through material efficiency is not only critical for limiting the growth of new steel production but also one of the most important levers to achieve deep decarbonization of Vietnam's steel sector. Below are specific actions that the Government of Vietnam and steel companies should take to realize this potential.

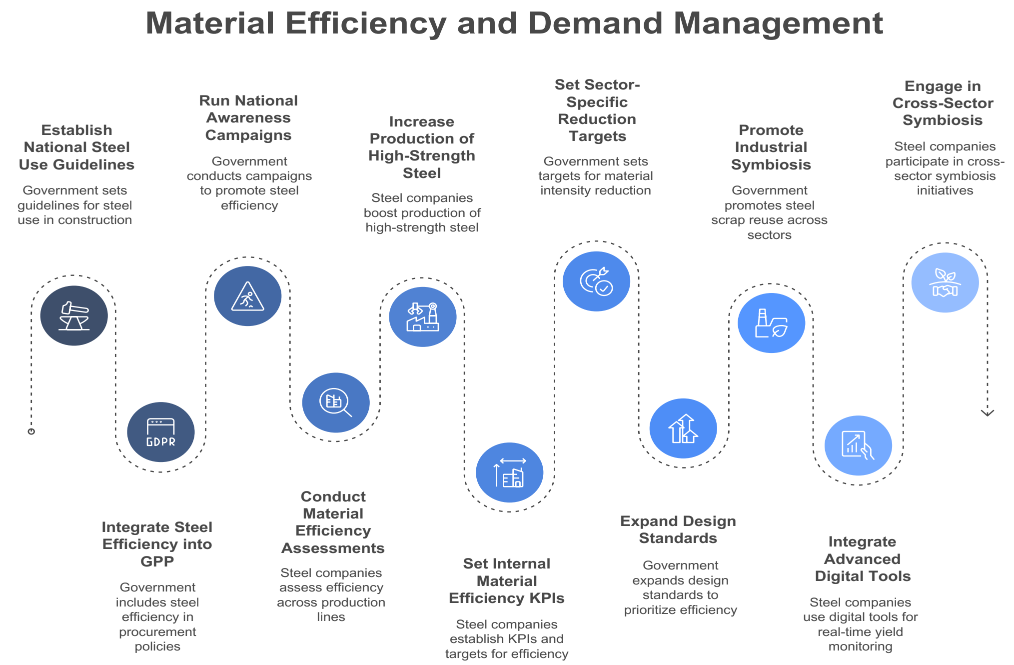


Figure 37: Summary of recommendations for enhancing energy efficiency and electrification of heating in the steel industry in Vietnam

Actions for the Government of Vietnam

Near-Term Actions (2025–2030)

1. **Establish National Steel Use Optimization Guidelines in Construction**
   The government should develop and issue comprehensive technical guidelines to optimize steel consumption in building and infrastructure projects. These guidelines should promote lighter structural designs, improved layouts, and alternative materials to reduce steel usage without compromising safety or structural integrity. By embedding these guidelines into updated national building codes, Vietnam can prevent unnecessary steel demand in new construction. The Ministry of Construction (MOC) should lead this work, supported by the Ministry of Industry and Trade (MOIT) and the Directorate for Standards, Metrology, and Quality (STAMEQ) to integrate them into Vietnamese Standards (TCVN).

2. **Integrate Steel Material Efficiency into Green Public Procurement (GPP)**
   Green public procurement requirements for infrastructure projects should include clear criteria for steel efficiency performance. By prioritizing bids that demonstrate minimized steel use through efficient design or adoption of high-strength steel, the government can drive early adoption of material-saving practices. The Ministry of Finance (MOF) should work with the Government Procurement Agency to embed these requirements into procurement regulations and project evaluation guidelines.

3. **Run National Awareness Campaigns on Steel Material Efficiency**
   To accelerate widespread uptake of material-efficient practices, the government should launch nationwide campaigns aimed at architects, structural engineers, developers, and large manufacturers. These campaigns should highlight best practices in steel design, real-world case studies of successful applications, and the financial and emissions savings achievable through material efficiency. The Ministry of Information and Communications (MIC) should coordinate with MOIT, the Vietnam Steel Association (VSA), and industry associations to develop and disseminate materials to reach a broad audience.

Medium-Term Actions (2030–2040)

4) **Set Sector-Specific Material Intensity Reduction Targets**
Mandatory targets should be established for reducing material intensity in key steel-consuming sectors such as construction, automotive, and machinery, to encourage smarter use of steel. These targets should set realistic but ambitious reductions from current baselines and reflect sector-specific opportunities for efficiency improvements. MOIT should oversee target-setting, with technical input from the Ministry of Planning and Investment (MPI) and VSA.

5. **Expand Design Standards to Prioritize Material Efficiency in National Infrastructure**
   Vietnam should revise national design standards for infrastructure to explicitly incorporate requirements for material-efficient performance, obligating public projects to justify steel quantities and minimize overdesign. MOC, in collaboration with MOIT and relevant engineering and construction associations, should lead the process of updating these standards to apply to roads, bridges, ports, and other critical infrastructure.

6. **Promote Industrial Symbiosis for Steel Scrap Reuse Across Sectors**
   The government should support the development of industrial symbiosis programs that connect steel-consuming sectors with scrap processors and suppliers, maximizing the use of high-quality scrap to lower the demand for virgin steel. Industrial parks can serve as hubs for these exchanges, with incentives offered to early adopters. MOIT and MPI should coordinate implementation efforts, with provincial authorities in major industrial zones providing on-the-ground support.

Actions for Steel Companies

Near-Term Actions (2025–2030)

1. **Conduct Comprehensive Material Efficiency Assessments Across Production Lines**
   Steel manufacturers should perform detailed audits of all production processes to identify inefficiencies in steel use, excessive scrap generation, and opportunities to increase fabrication yields. These assessments should involve direct observations, detailed process mapping, and data analysis, leading to specific action plans tailored to each plant. By understanding where material losses occur, companies can quickly implement changes to reduce waste and improve cost efficiency.

2. **Increase Production of High-Strength, Lightweight Steel Grades**
   Producers should accelerate the development and commercial production of high-strength and advanced steel grades that can deliver equivalent or superior performance using less material. By offering lightweight steel products to customers in construction, automotive, and machinery sectors, steel companies can directly contribute to improved material efficiency and gain a competitive edge in markets increasingly seeking low-carbon solutions.

3. **Set Internal Material Efficiency Key Performance Indicators (KPIs) and Targets**
   Steel producers should integrate clear KPIs into their operational management systems, such as overall material yield rates, scrap generated per ton of steel produced, and rates of offcut reduction. By setting specific targets and regularly reviewing performance, steelmakers can institutionalize material efficiency practices across their businesses, ensuring it becomes a core part of their strategy for competitiveness and sustainability.

Medium-Term Actions (2030–2040)

4. **Integrate Advanced Digital Tools for Real-Time Yield Monitoring**
   Steel producers should deploy advanced technologies such as digital twins, AI-driven quality monitoring, and real-time data analytics systems to continuously monitor yield and identify areas of high material loss throughout the production process. These tools enable rapid identification of inefficiencies, allowing ongoing process optimization that significantly reduces steel waste over time.

5. **Engage in Cross-Sector Industrial Symbiosis Initiatives**
   Steelmakers should actively participate in or lead cross-sector industrial symbiosis initiatives, sharing their by-products or scrap directly with other industries like foundries, machinery manufacturers, or smaller steel processors. Coordinating with managers of industrial parks, local governments, and major manufacturers can strengthen these networks, delivering shared economic benefits while helping reduce national demand for primary steel.

7.2. Recommendations for enhancing energy efficiency and electrification of heating

Under Vietnam's Net Zero scenario, the energy efficiency and electrification of heating pillar is expected to deliver major reductions in CO_2 emissions. In 2060, improvements in energy efficiency combined with the electrification of heating processes are projected to cut emissions by 11 Mt CO_2 compared to the BAU. It accounts for about 17% of the total emissions reductions required to meet Net Zero in 2060 relative to BAU emissions. This makes energy efficiency and electrification the second most important pillar for decarbonizing Vietnam's steel sector, after shifting to low-carbon steelmaking technologies. These emissions reductions will largely come from the aggressive deployment of existing energy-saving technologies, optimization of thermal processes, and electrifying rolling and finishing operations. However, persistent obstacles—including high investment costs, limited technical capacity, and insufficient policy incentives—must be addressed to fully unlock the potential of this pillar for Vietnam's steel decarbonization. Below are recommended actions for the government and steel companies in Vietnam to achieve these outcomes.

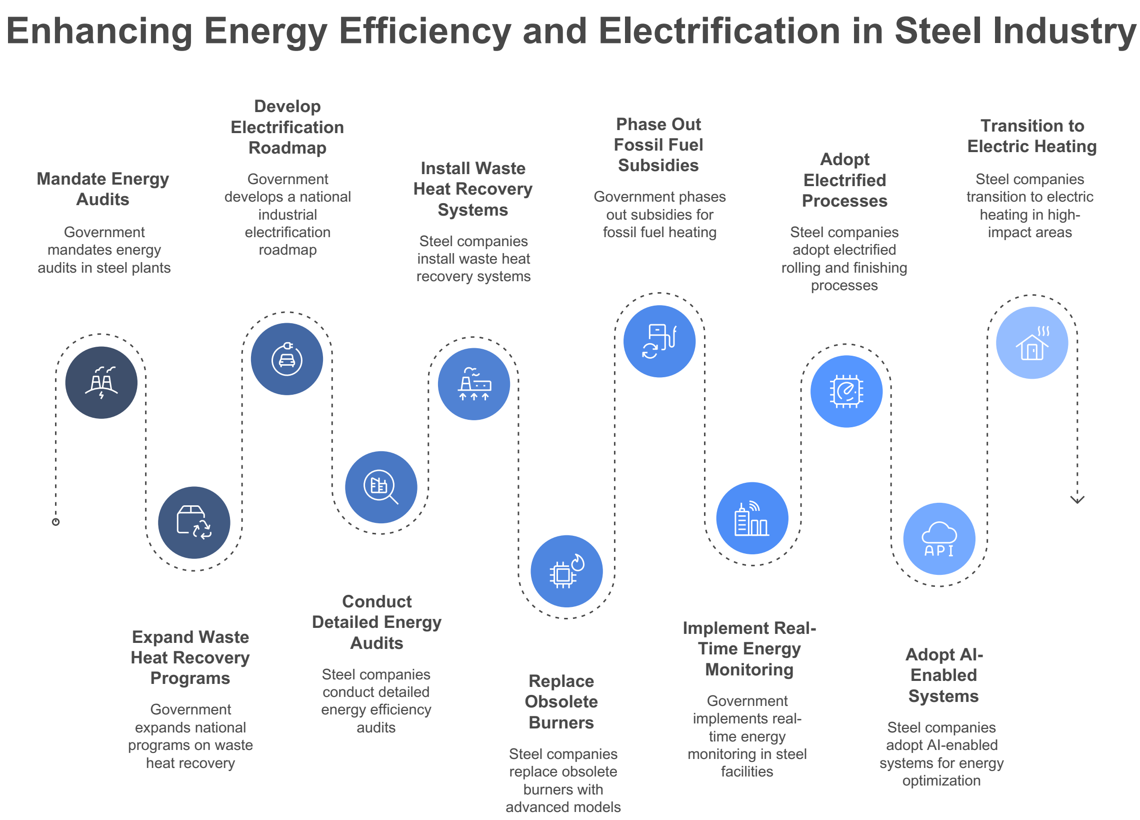


Figure 38: Summary of recommendations for enhancing energy efficiency and electrification of heating in the steel industry in Vietnam

Actions for the Government of Vietnam

Near-Term Actions (2025–2030)

1. **Mandate Energy Audits in Steel Plants and Establish Efficiency Baselines**
   The government should require all steel producers to carry out comprehensive, regular energy audits to pinpoint opportunities to reduce fuel and electricity use across various processes. Audits should result in detailed, documented energy baselines that can serve as reference points for annual improvement assessments. The Ministry of Industry and Trade (MOIT) together with the Ministry of Natural Resources and Environment (MONRE) should issue regulations and develop standardized technical guidelines for conducting these audits.

2. **Expand National Programs on Industrial Waste Heat Recovery Systems**
   National programs should be launched to provide technical support, grants, or tax incentives for the installation of waste heat recovery systems in steel plants—such as recuperators and economizers—that capture and reuse heat from exhaust gases, thereby cutting fuel consumption. MOIT should lead the development of these programs, in coordination with local Departments of Industry and Trade in industrial hubs.

3. **Develop a National Industrial Electrification Roadmap**
   Vietnam should create a government-led roadmap that defines strategies for electrifying low- and medium-temperature heating processes across industries, including steel rolling and finishing lines. This roadmap should establish technology deployment goals, infrastructure development needs, and investment priorities to guide the shift to electrification. MOIT, in cooperation with the Ministry of Construction (MOC) and Vietnam Electricity (EVN), should spearhead the roadmap, ensuring it aligns with the national grid expansion and RE targets.

Medium-Term Actions (2030–2040)

4. **Phase Out Subsidies for Fossil Fuel Heating in Industrial Processes**
   To encourage the adoption of energy-efficient and electric heating technologies, the government should progressively phase out subsidies for fossil fuels—coal, oil, and gas—used in industrial heating, starting with large steel producers. Redirecting these subsidies to support efficiency measures or electrification will accelerate emissions reductions. The Ministry of Finance (MOF), together with MOIT and MONRE, should oversee subsidy reform and reallocation.

5. **Implement Real-Time Energy Monitoring in Large Steel Facilities**
   The government should promote the adoption of real-time energy monitoring systems in large steel plants, enabling operators to continuously track energy consumption, identify inefficiencies, and improve performance. Data from these systems should feed into centralized platforms for benchmarking and continuous improvement. MOIT should work with STAMEQ to develop standards for monitoring equipment and data reporting protocols.

Actions for Steel Companies

Near-Term Actions (2025–2030)

1. **Conduct Plant-Wide Detailed Energy Efficiency Audits and Implement Quick Wins**
   Steel companies should carry out thorough energy audits covering all heating processes, such as reheating furnaces, ladle preheating, and rolling mills. They should implement immediate "quick win" actions like repairing furnace leaks, fine-tuning combustion controls, and improving insulation, which can yield up to 10% energy savings with minimal cost. Management should establish annual energy reduction targets based on audit results and review progress regularly.

2. **Install Waste Heat Recovery Systems on Reheating and Annealing Lines**
   Steel producers should prioritize investments in equipment like recuperators, regenerators, or heat exchangers on high-temperature lines to capture and reuse waste heat for preheating combustion air or other process needs, reducing fuel consumption and CO_2 emissions. Feasibility studies should be conducted at each plant to identify the most effective opportunities.

3. **Replace Outdated Burners with Modern Low-NOx, High-Efficiency Models**
   Companies should upgrade obsolete, inefficient burners with advanced models that ensure better combustion control, improved fuel-air mixing, and more efficient heat transfer—reducing energy use by up to 20% and helping meet stricter air quality standards while lowering operational costs.

Medium-Term Actions (2030–2040)

4. **Adopt Electrified Rolling and Finishing Processes Integrated with Clean Power**
Steelmakers should begin deploying electrification technologies in rolling and finishing lines, using electricity sourced from renewable power purchase agreements wherever possible. By integrating electric induction or resistance heating, steel plants can substantially cut fossil fuel consumption and emissions from these final production stages.

5. **Adopt AI-Enabled Systems for Real-Time Energy Optimization**
   Companies should invest in advanced AI-based energy management systems capable of continuously monitoring furnace operations, predicting optimal settings, and dynamically adjusting parameters to optimize energy efficiency. These digital tools can deliver sustained performance improvements and allow faster detection of process inefficiencies compared to manual oversight.

6. **Transition to Electric Heating in Ladle Preheating and Other High-Impact Areas**
   Steel producers should plan for the electrification of high-consumption, high-emission processes like ladle preheating by installing electric arc or induction heating systems. This shift will significantly reduce reliance on fossil fuels and demonstrate leadership, while the knowledge gained will facilitate broader adoption of electrification technologies throughout the company.

7.3. Recommendations for enhancing fuel switching and cleaner electricity

Under Vietnam's Net Zero pathway, the pillar of fuel switching and cleaner electricity is expected to contribute significantly to emissions reductions in the steel sector. In 2060, shifting from coal to lower-carbon fuels such as natural gas, combined with decarbonizing the national grid to enable low-carbon EAF steel production, could cut 10 Mt CO_2 compared to BAU scenarios. This pillar is expected to deliver roughly 15% of the total emissions reductions needed for Net Zero in Vietnam's steel industry in 2060 in Net Zero scenario compared to BAU in 2060. However, realizing this potential will require accelerating grid decarbonization, overcoming infrastructure limitations for natural gas, and avoiding investments in new coal-based assets that would lock in future emissions. Below are actions the Vietnamese government and steel companies should take to achieve these goals.

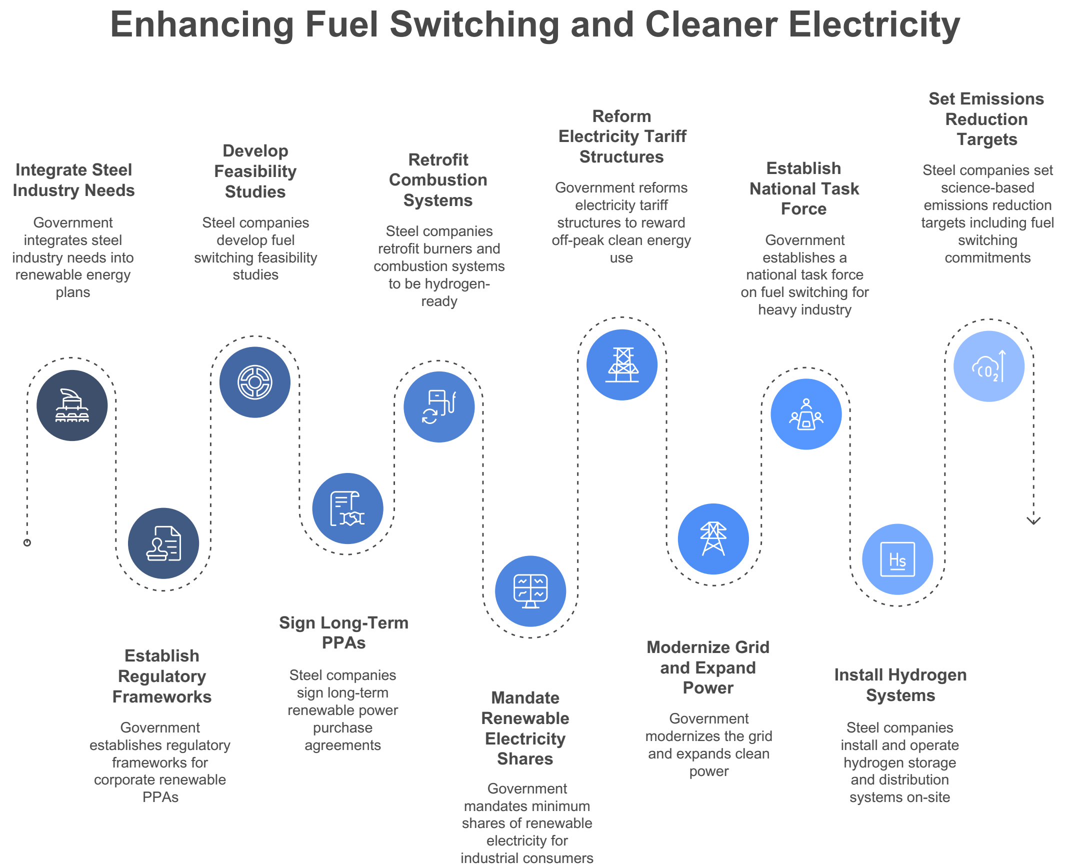


Figure 39: Summary of recommendations for enhancing fuel switching and cleaner electricity for the steel industry in Vietnam

Actions for the Government of Vietnam

Near-Term Actions (2025–2030)

1. **Integrate Steel Industry Needs into EVN's RE Expansion Plans**
   The government should require Vietnam Electricity (EVN) to explicitly account for the steel sector's future renewable electricity needs when planning new solar, wind, and hydropower projects. Prioritizing renewable electricity supply in major steel-producing regions like Hai Phong, Ba Ria-Vung Tau, and Ninh Binh will enable faster electrification and fuel switching. The Ministry of Industry and Trade (MOIT), Ministry of Planning and Investment (MPI), and EVN should jointly coordinate this planning effort.

2. **Establish Regulatory Frameworks for Corporate Renewable PPAs**
   Given that Vietnam's PPA market is still developing, the government should prioritize setting clear rules for corporate renewable power purchase agreements (PPAs). This includes detailed guidelines on grid access, contract terms, pricing structures, and legal protections for buyers and sellers. Streamlining permitting processes for renewable projects and simplifying corporate procurement procedures will build investor confidence. Extending eligibility to medium-sized industrial consumers, introducing flexible models such as virtual or synthetic PPAs, and embedding RE certificates (RECs) into compliance requirements can further boost market participation. MOIT, EVN, and the Ministry of Finance (MOF) should collaborate to finalize these regulations.

Medium-Term Actions (2030–2040)

3. **Mandate Minimum Shares of Renewable Electricity for Industrial Consumers**
   The government should introduce policies requiring large energy-consuming industries, including steel plants, to source an increasing share of their electricity from renewables—e.g., setting a target of 30% renewable use by 2035. This will create stable demand for clean electricity and accelerate the decarbonization of Vietnam's power system. MOIT should oversee implementation of these regulations.

4. **Reform Electricity Tariff Structures to Encourage Off-Peak Clean Energy Use**
   EVN, under guidance from MOIT, should update industrial electricity pricing to incentivize steelmakers to shift their power consumption to periods when renewable generation is abundant—typically midday for solar and nighttime for wind. This reform would maximize RE integration, reduce curtailment of clean power, and make electricity-based steel production more attractive.

5. **Modernize the Power Grid and Expand Renewable Capacity**
   EVN and related government bodies should invest significantly in expanding RE generation, upgrading substations, and building new transmission lines to supply low-carbon electricity to industrial centers. These infrastructure improvements should align with the steel sector's decarbonization needs, incorporating energy storage systems and smart grid technologies to enhance flexibility and reliability.

6. **Establish a National Task Force on Fuel Switching for Heavy Industry**
   Vietnam should create an inter-ministerial task force dedicated to accelerating fuel switching in industries like steel, transitioning from coal to cleaner alternatives such as natural gas, biomass, or hydrogen. This task force should coordinate policy development, address regulatory challenges, and engage industry stakeholders. It should include MOIT, the Ministry of Natural Resources and Environment (MONRE), and the Ministry of Construction (MOC), reporting to the Prime Minister's Office for high-level oversight.

Actions for Steel Companies

Near-Term Actions (2025–2030)

1. **Conduct Fuel Switching Feasibility Studies for Individual Steel Plants**
   Steel companies should conduct detailed technical and economic assessments of switching from coal or oil to cleaner fuels like natural gas or biomass for heating and melting operations. These studies should evaluate retrofit needs, local fuel availability, logistics, and emissions reduction potential to guide realistic investment planning for both immediate and long-term transitions.

2. **Sign Long-Term Renewable Power Purchase Agreements (PPAs)**
   Steel producers should secure long-term contracts with RE suppliers or EVN to guarantee access to stable, low-carbon electricity for steel production. These PPAs will help manage price volatility, reduce emissions, and meet customer expectations for green steel. Early adopters of PPAs will be well-positioned to gain competitive advantages as global buyers increasingly demand low-carbon materials.

3. **Retrofit Combustion Systems to Be Hydrogen-Ready**
   Steelmakers preparing for hydrogen use should begin retrofitting existing combustion equipment—especially reheating furnaces and ladle preheaters—to handle high hydrogen fuel blends safely and efficiently. This future-proofs assets, allowing gradual fuel transitions as hydrogen availability increases, without requiring full replacement of costly infrastructure.

Medium-Term Actions (2030–2040)

4. **Install and Operate On-Site Hydrogen Storage and Distribution Systems**
   Firms intending to adopt hydrogen in steelmaking should invest in constructing hydrogen storage tanks, pipelines, and safety systems at their facilities to enable reliable, efficient delivery of hydrogen to production lines. Early investment will ensure readiness and minimize delays as hydrogen supply becomes commercially viable.

5. **Set Science-Based Emissions Reduction Targets Including Fuel Switching Milestones**
   Steel companies should publicly commit to science-based climate targets with clear timelines for reducing fossil fuel use and increasing reliance on low-carbon energy sources. Transparent goals will demonstrate climate leadership, attract sustainability-minded customers and investors, and align corporate strategies with Vietnam's national decarbonization objectives.

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

In Vietnam's Net Zero roadmap, transitioning to low-carbon iron and steelmaking technologies will be the single largest driver of emissions reductions. In 2060, this pillar could slash CO_2 emissions by 21 Mt CO_2 compared to BAU projections, accounting for over 33% of the total reductions needed to achieve Net Zero in Vietnam's steel sector. This will come from a shift toward scrap-based EAF production, green hydrogen-based direct reduced iron (DRI)-EAF, natural gas DRI-EAF, and gradual adoption of breakthrough technologies like iron ore electrolysis from 2050 onward. Small-scale imports of green iron produced abroad using green hydrogen could also supplement domestic efforts. However, realizing these reductions will require overcoming major challenges such as high capital costs for new technologies, uncertain hydrogen availability, and the need for investments in hydrogen production, storage, and renewable electricity infrastructure. The following actions outline what the government and steelmakers in Vietnam should do to enable this transition.

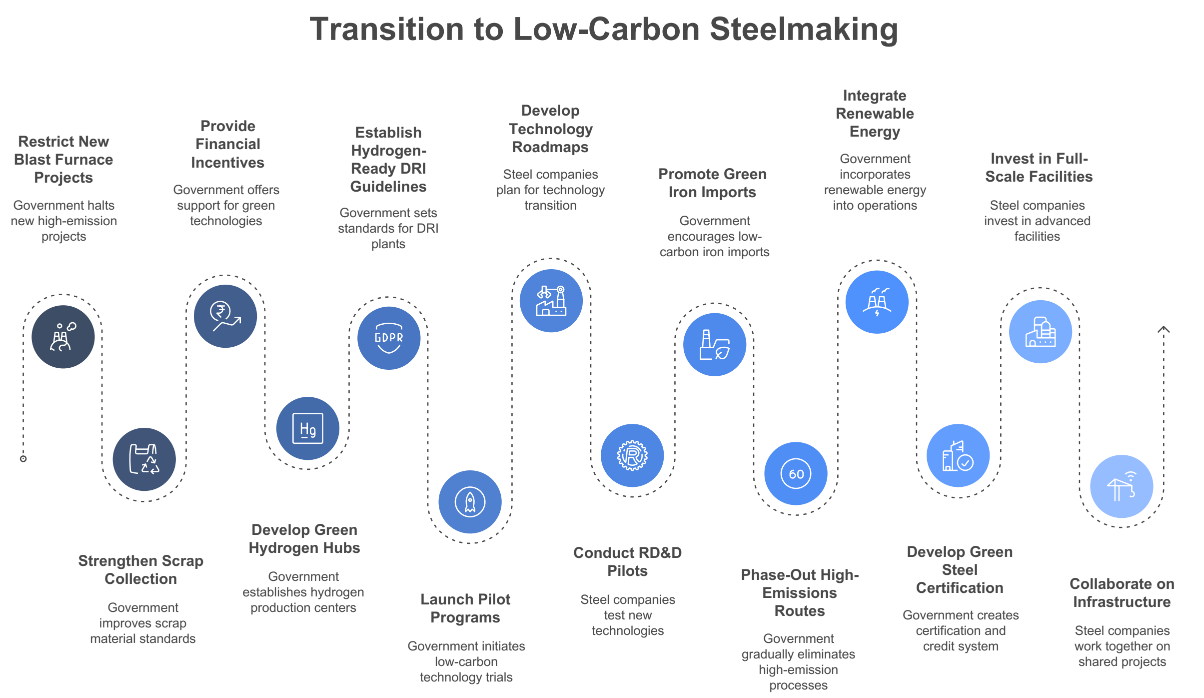


Figure 40: Summary of recommendations for transitioning to low-carbon iron and steelmaking technologies in Vietnam

Actions for the Government of Vietnam

Near-Term Actions (2025–2030)

1. **Restrict New Blast Furnace Approvals and Redirect Investments to EAF and DRI**
   The government should update permitting rules to discourage new blast furnace-basic oxygen furnace (BF-BOF) capacity, steering investment instead to low-carbon options like EAF using scrap or hydrogen/natural gas-based DRI. This will send a clear market signal about Vietnam's commitment to modern, climate-aligned steelmaking. The Ministry of Industry and Trade (MOIT) and Ministry of Planning and Investment (MPI) should coordinate updates to permitting processes.

2. **Strengthen Scrap Collection Systems and Quality Standards**
   Vietnam should launch a national program to modernize scrap collection, sorting, and transportation by designating scrap steel as a strategic material, creating centralized collection points in steel-consuming regions, and enforcing strict standards for scrap purity. These measures will secure a reliable supply of high-quality scrap for EAF operations, enhance steel quality, and cut emissions from remelting processes.

3. **Provide Financial Incentives for EAF Investments and Upgrades**
   To accelerate adoption of scrap-based EAF steelmaking, the government should introduce targeted tax breaks, low-interest loans, or grants for steelmakers upgrading existing plants or building new EAF facilities. These incentives will lower the barrier to entry and stimulate broad investment in low-carbon steelmaking technologies.

4. **Develop National Green Hydrogen Production Hubs Near Steel Clusters**
   To enable widespread hydrogen use in steelmaking, the government should support green hydrogen production hubs colocated with steel industry zones such as those in Hai Phong, Ba Ria-Vung Tau, or Quang Ninh. These hubs should integrate RE sources, electrolyzers, hydrogen storage, and transportation infrastructure. MOIT, Vietnam Electricity (EVN), and MPI should coordinate these efforts.

5. **Issue Guidelines for Hydrogen-Ready DRI Facilities**
   Vietnam should publish clear technical standards and permitting guidelines for hydrogen-ready DRI plants, specifying safety requirements, emissions benchmarks, and best practices. These guidelines will give investors confidence that new facilities are compatible with future hydrogen supplies, minimizing the risk of stranded assets. MOIT, Ministry of Natural Resources and Environment (MONRE), and the Directorate for Standards, Metrology and Quality (STAMEQ) should lead guideline development.

6. **Launch Pilot Projects to Demonstrate Low-Carbon Steel Technologies**
   The government should provide grants or cost-sharing support for pilot-scale demonstration of advanced steelmaking technologies, such as hydrogen-based DRI, molten oxide electrolysis, or hybrid EAF systems. This can be done though international collaborations. Successful pilot projects can reduce technology risks, attract private investors, and build technical capacity. MOIT, MONRE, and the Ministry of Science and Technology (MOST) should lead these programs.

Medium-Term Actions (2030–2040)

7. **Promote Green Iron Imports as Part of a Diversified Low-Carbon Supply Strategy**
   Vietnam should include green iron imports in its steel decarbonization plans, adjusting tar iffs and developing policies to facilitate such imports. The government should also nego-tiate long-term supply agreements with potential suppliers in countries like Australia or Brazil, while implementing environmental and safety regulations for green iron transpor-tation and storage. MOIT, Ministry of Finance (MOF), and Ministry of Foreign Affairs (MOFA) should coordinate this strategy, ensuring fair treatment of local workers through retraining programs.

8. **Phase Out High-Emissions BF-BOF Operations with Emissions Benchmarks**
   The government should establish clear emissions intensity thresholds and phase-out schedules for existing BF-BOF production lines that fail to meet future CO_2 standards. Facilities exceeding these limits should be required to upgrade or retire. Compliance monitoring should be managed by MOIT and local People's Committees in steel-producing provinces.

9. **Facilitate Direct RE Integration into EAF Plants**
   Vietnam should support dedicated renewable electricity supply for EAF steelmakers by expanding grid connections, creating policies for direct power purchase agreements (DPPA) for green electricity, and ensuring grid stability with demand-side management and storage solutions. Simplifying DPPA access for small and medium-sized enterprises (SMEs) will broaden participation in green steel production.

10. **Create a National Green Steel Certification and Carbon Credit Framework**
Vietnam should create a certification system for low-emission steel so that verified green steel products can qualify for carbon credits or take part in emissions trading programs. A strong certification and credit framework will boost the competitiveness of green steel and help the industry meet national climate goals. This certification should match well-known international standards and guidelines, like the ResponsibleSteel standard.

Actions for Steel Companies

Near-Term Actions (2025–2030)

1. **Develop Company-Specific Technology Roadmaps for Transitioning to EAF and DRI**
Steel producers should establish detailed roadmaps outlining milestones, investment needs, and infrastructure upgrades required to shift from BF-BOF to EAF or DRI-based production. Roadmaps should include timelines, technology partner identification, and workforce training plans to ensure an organized and financially sustainable transition.

2. **Conduct Research, Development, and Demonstration (RD&D) Pilots for Low-Carbon Steelmaking**

   Steelmakers should invest in RD&D projects testing hydrogen-based DRI, waste heat recovery, electrification of rolling processes, and other innovative technologies suited to Vietnam's conditions. Collaboration with local universities, research institutes, and equipment suppliers will help reduce technical risks and inform future investments.

3. **Perform Feasibility Studies on Retrofitting Existing Facilities**
Steel companies should carry out technical and economic assessments for retrofitting existing blast furnaces or EAFs with low-carbon upgrades, such as hydrogen injection systems or carbon capture readiness, to evaluate the best pathways for gradual, cost-effective decarbonization.

4. **Commit to Green Steel Production Targets Aligned with National Climate Goals**
Steelmakers should publicly announce emissions reduction targets that include milestones for shifting to scrap-based EAF and hydrogen-DRI production, aligning company plans with Vietnam's net-zero commitments. Joining international initiatives such as SteelZero can also demonstrate leadership, enhance reputation, and improve access to sustainable financing.

Medium-Term Actions (2030–2040)

5. **Invest in Full-Scale Hydrogen-DRI and Scrap-EAF Plants**
Steel companies should move beyond pilot projects to build and operate large-scale facilities that produce steel with hydrogen-based DRI or high-quality scrap in EAFs. This shift will drastically cut direct CO_2 emissions and position Vietnamese steelmakers to compete in global green steel markets. Long-term supply contracts for scrap or hydrogen should be secured to support these facilities.

6. **Collaborate on Shared Hydrogen Infrastructure Projects**
   Steel producers should partner with other heavy industries to develop shared hydrogen production, storage, and distribution networks near major steel clusters. Sharing infrastructure will lower costs, reduce investment risks, and speed up hydrogen adoption for DRI processes across multiple companies.

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

Under Vietnam's Net Zero scenario, CCUS is expected to play a small but still valuable role in cutting residual emissions from steelmaking. IN 2060, deploying CCUS on BF-BOF and NG-DRI processes could reduce CO_2 emissions by 4 Mt CO_2, representing around 6% of the total emissions reductions needed for Vietnam's steel sector to reach Net Zero. While CCUS can capture emissions that remain after adoption of other decarbonization pillars, its contribution will be limited by high capture costs, technical integration challenges at steel plants, and uncertainty around long-term CO_2 storage. Vietnam's roadmap shows that CCUS can complement other decarbonization measures, but unlocking its full potential will require major progress in technology readiness, cost reductions, and building reliable CO_2 transport and storage infrastructure. Below are actions the government and steelmakers in Vietnam should take to enable CCUS deployment.

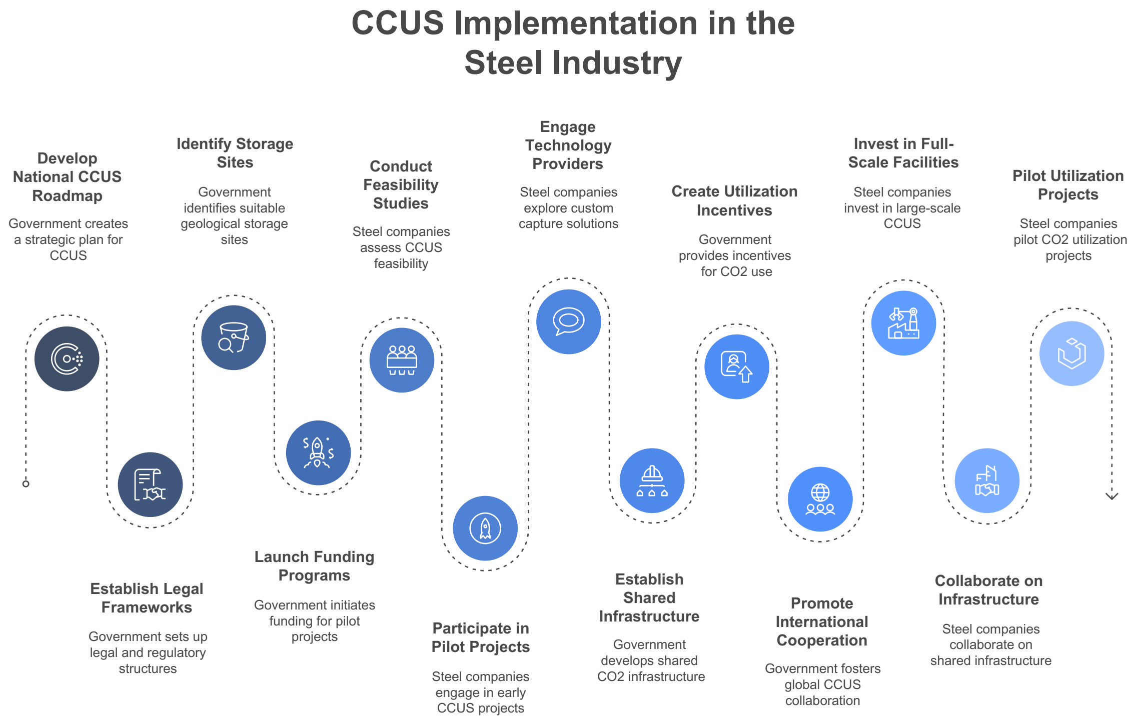


Figure 41: Summary of recommendations for adopting CCUS in the steel industry in Vietnam

Actions for the Government of Vietnam

Near-Term Actions (2025–2030)

1. **Develop a National CCUS Roadmap with Steel Sector Priorities**
   The government should draft and publish a detailed CCUS roadmap that sets timelines, outlines suitable capture technologies, specifies investment needs, and defines regulatory requirements, with special focus on heavy industries like steel. The roadmap should identify and prioritize regions with major steel clusters for early CCUS deployment. The Ministry of Industry and Trade (MOIT) and the Ministry of Natural Resources and Environment (MONRE) should jointly coordinate the development of this roadmap.

2. **Establish Clear Legal and Regulatory Frameworks for CCUS Projects**
   Vietnam should enact laws and regulations to clarify ownership of captured CO_2, define long-term monitoring responsibilities, set liability rules in case of CO_2 leaks, and outline the permitting process for CCUS projects. These legal frameworks will build investor confidence, attract private capital, and ensure the safe and responsible deployment of CCUS. MOIT, MONRE, and the Ministry of Justice should collaborate on drafting these regulations.

3. **Identify and Characterize Geological CO_2 Storage Sites**
   The government should fund geological surveys to map potential CO_2 storage locations in depleted oil and gas reservoirs, deep saline aquifers, or other suitable formations. Thorough characterization of these sites will confirm storage safety, estimate their capacity, and attract investment. MONRE and the Vietnam Petroleum Institute (VPI) should lead exploration and data collection efforts.

4. **Launch Public Funding Programs for Early CCUS Pilots in Steel Plants**
   Vietnam should set up grants or concessional financing schemes to support steelmakers piloting carbon capture technologies, including post-combustion CO_2 capture at BF-BOF lines or hydrogen-DRI facilities. Early pilots will help de-risk future investments, generate valuable data, and build domestic technical know-how. MOIT and the Ministry of Planning and Investment (MPI) should oversee these funding programs.

Medium-Term Actions (2030–2040)

5. **Develop Shared CO_2 Transportation and Storage Infrastructure**
   Vietnam should plan and invest in regional CO_2 pipeline networks and centralized storage hubs that can serve multiple large emitters, including steel plants, cement factories, and power stations. Shared infrastructure will enable economies of scale, lower per-ton capture costs, and make CCUS accessible for smaller steel producers. MOIT, the Ministry of Construction (MOC), and MPI should lead coordination of these projects.

6. **Create Incentives for CO_2 Utilization in Industrial Products**
   The government should introduce tax incentives, subsidies, or preferential purchasing programs for companies that use captured CO_2 in valuable applications such as concrete mineralization, chemical feedstocks, or synthetic fuels. These incentives will reduce net capture costs, generate new revenue streams, and accelerate market adoption of CCUS technologies. MOIT and the Ministry of Finance (MOF) should develop and implement these incentives.

7. **Promote International Cooperation and Financing for CCUS**
   Vietnam should seek technical assistance, technology transfer agreements, and concessional financing from countries experienced in CCUS like Norway, Japan, or Australia. Establishing bilateral or multilateral partnerships and participating in global CCUS alliances will strengthen Vietnam's capacity to deploy CCUS and enable faster adoption of best practices. The Ministry of Foreign Affairs (MOFA), MOIT, and MPI should coordinate international outreach efforts.

Actions for Steel Companies

Near-Term Actions (2025–2030)

1. **Conduct Feasibility Studies for CCUS Implementation at Steel Plants**
   Steelmakers should assess the technical, economic, and logistical feasibility of installing CO_2 capture systems on major emission sources such as BF-BOF or DRI lines. These studies should evaluate technology options, integration costs, storage possibilities, and partnerships with storage providers. The results will guide companies' investment decisions and help align plans with government roadmaps.

2. **Join Early Pilot Projects for CO_2 Capture Technologies**
   Steel companies should actively participate in or co-develop pilot projects testing capture technologies tailored to their production processes. Early involvement will build internal technical capacity, validate performance in real operating conditions, and reduce uncertainties about future scale-up.

3. **Collaborate with Technology Providers to Customize Capture Solutions**
   Steel producers should work with technology vendors and research organizations to adapt capture systems to Vietnam's specific process conditions, including high-temperature exhaust or impurities in steel plant gases. Tailored engineering studies will improve capture performance and cost-efficiency.

Medium-Term Actions (2030–2040)

4. **Invest in Commercial-Scale Carbon Capture Facilities**
   Steel companies should move from pilots to building and operating full-scale CCUS systems at major emission points, capturing significant volumes of CO_2 from BF-BOF, EAF-DRI, or reheat furnaces. Successful projects will demonstrate commercial feasibility and deliver large-scale emissions reductions.

5. **Partner with Other Industries for Shared CCUS Infrastructure**
   Steelmakers should collaborate with nearby emitters like cement plants or power producers to co-develop shared CO_2 pipelines and storage hubs, spreading costs, lowering risks, and accelerating CCUS deployment across multiple sectors.

6. **Pilot CO_2 Utilization Projects for Value-Added Products**
   Companies should launch pilot projects using captured CO_2 in commercial products such as building materials, fuels, or industrial chemicals. Successful pilots will identify profitable utilization routes, offset capture costs, and create additional revenue streams for steelmakers.

7.6. Actions for steel buyers

Steel consumers in Vietnam's public and private sectors can play a critical role in accelerating the decarbonization of the steel industry by integrating green procurement practices that prioritize low-carbon steel. When Vietnamese government agencies include carbon intensity requirements in public tenders for large infrastructure projects like highways, ports, or government buildings, they establish predictable demand for low-emissions steel. This sends a strong market signal to steel producers, encouraging them to invest in cleaner technologies such as scrap-based electric arc furnaces (EAF) or hydrogen-based direct reduced iron (DRI). Meanwhile, private sector buyers—such as real estate developers, car and motorcycle manufacturers, and electronics producers—can adopt procurement policies that favor suppliers providing certified low-carbon steel or Environmental Product Declarations (EPDs). By delivering consistent, forward-looking demand signals through both public green procurement initiatives and private sourcing commitments, Vietnam's steel consumers can create powerful incentives that drive investments in low-carbon production, lower their own supply chain emissions, and align with Vietnam's national net-zero targets.

Figure 42: Summary of recommendations for steel buyers in Vietnam

Actions for the Government of Vietnam

Near-Term Actions (2025–2030)

1. **Mandate EPDs in Public Procurement**
Vietnamese ministries and state-owned enterprises (SOEs) should update tender requirements for infrastructure projects to include EPDs or verified carbon footprints. Requiring carbon data in bids will reward steel producers offering low-carbon products, fostering fair competition based on sustainability performance. This effort should be supported by the Ministry of Natural Resources and Environment (MONRE) and the Vietnam Steel Association (VSA) through training and capacity-building for government buyers and suppliers.

2. **Expand and Refine the National Emissions Trading Scheme (ETS)**
As Vietnam develops its national ETS, it should ensure the steel sector is integrated with fair, sector-specific carbon benchmarks. This means defining emissions allowances, trading mechanisms, and transparent monitoring, reporting, and verification (MRV) systems tailored to steel's unique emissions profile. Close coordination between the Ministry of Finance (MOF), MONRE, and VSA is needed to design an ETS that encourages emissions reductions without undermining the industry's competitiveness.

Medium-Term Actions (2030–2040)

3. **Scale Up Green Public Procurement (GPP) Across Major Projects**
Vietnam's government agencies, including the Ministry of Transport and Ministry of Construction, should rapidly expand GPP requirements in large-scale public infrastructure investments. By setting carbon intensity thresholds for steel used in highways, ports, airports, and new urban developments like those planned in Ho Chi Minh City and Hanoi, GPP can secure stable demand for low-carbon steel and encourage upstream investment in green production.

Actions for Corporate Steel Buyers

Near-Term Actions (2025–2030)

1. **Adopt Corporate Green Procurement Policies**
Major private buyers in Vietnam—including property developers, automotive companies, electronics manufacturers, and large retailers—should establish procurement guidelines favoring steel suppliers who provide verified low-carbon products or EPDs. International voluntary initiatives, such as SteelZero, RE100 or Science Based Targets, can offer frameworks for aligning corporate procurement with climate goals.

2. **Issue Long-Term Demand Commitments for Green Steel**
Leading Vietnamese and multinational companies operating in Vietnam should publicly announce forward-looking purchasing commitments for green steel. By clearly stating long-term demand for low-emission steel products, buyers provide market certainty needed for steelmakers to undertake large-scale investments in technologies like EAF or hydrogen-based DRI.

Medium-Term Actions (2030–2040)

3. **Incentivize High-Performing Green Suppliers**
   Procurement guidelines should include rewards for suppliers exceeding carbon reduction targets—such as preferred contract terms, public endorsements, or tiered supplier rankings within corporate sustainability programs. Ministries and industry groups like VSA can develop templates and certification schemes to streamline this process.

4. **Coordinate Buyer Alliances and Green Steel Clubs**
   Vietnamese industry associations and NGOs should facilitate the creation of alliances of steel buyers—“green steel buyer clubs”—that aggregate demand and issue joint tenders or collective investment signals. Such alliances reduce individual buyer risks, distribute certification costs, and strengthen market pressure for decarbonization.

5. **Promote Indirect Demand Signals for Low-Carbon Steel**
   Beyond procurement contracts, steel buyers can leverage their roles as property developers, investors, or exporters to push low-carbon steel adoption. For example, real estate developers can mandate green steel in design and construction standards, or investor groups can require carbon disclosure on steel sourcing. As carbon border adjustment mechanisms become more common in export markets, these indirect signals will become increasingly important for competitiveness.

References

Argus. 2025. "Vietnam's Scrap Imports Rise in 2024 | Latest Market News." January 16, 2025. https://www.argusmedia.com/en/news-and-insights/latest-market-news/2647765-vietnam-s-scrap-imports-rise-in-2024.

BNEF. 2023. "Green Hydrogen to Undercut Gray Sibling by End of Decade." *BloombergNEF* (blog). August 9, 2023. https://about.bnef.com/blog/green-hydrogen-to-undercut-gray-sibling-by-end-of-decade/.

Chang, Christina M, Patrick D Finch, and Jenifer C Shafer. 2021. "Emerging Technology Concepts to Fully Decarbonize Ironmaking." In .

Chant, Tim De. 2025. "Exclusive: Electra Found a Cheap, Clean Way to Purify Iron, and It's Raising $257M to Make It Happen." *TechCrunch* (blog). January 3, 2025. https://techcrunch.com/2025/01/03/electra-found-a-cheap-clean-way-to-purify-iron-and-its-raising-257m-to-make-it-happen/.

EuroGroup Consulting. 2025. "Vietnam Smart Manufacturing Gains Momentum." Market Research Vietnam Consulting Firm. May 20, 2025. https://marketresearchvietnam.com/insights/articles/vietnam-smart-manufacturing-gains-momentum.

Fortescue Metals. 2025. "Green Iron Metal Project." 2025. https://metals.fortescue.com/en/our-projects/green-metal-project.

Grigsby-Schulte, Astrid, Henna Khadeeja, Caitlin Swalec, Rolando Almada, Ziwei Zhang, and Jessie Zhi. 2025. "Pedal to the Metal: Evaluating Progress Toward 2030 Iron and Steel Decarbonization Goals." Global Energy Monitor. https://globalenergymonitor.org/wp-content/uploads/2025/05/GEM-global-steel-report-May-2025.pdf.

Hasanbeigi, Ali; Morrow, William; Sathaye, Jayant; Masanet, Eric; Xu, Tengfang. (2013). A Bottom-Up Model to Estimate the Energy Efficiency Improvement and CO_2 Emission Reduction Potentials in the Chinese Iron and Steel Industry. Energy, Volume 50, 1 February 2013, Pages 315-325

Hasanbeigi, Ali. 2021. "Global Steel Industry's GHG Emissions." Global Efficiency Intelligence (blog). January 6, 2021. https://www.globalefficiencyintel.com/new-blog/2021/global-steel-industrys-ghg-emissions.

Hasanbeigi, Ali. 2022. Steel Climate Impact - An International Benchmarking of Energy and CO_2 Intensities. Global Efficiency Intelligence.

Hasanbeigi, Ali, Hongyou Lu, and Nan Zhou. 2023. "Net-Zero Roadmap for China's Steel Industry." Global Efficiency Intelligence. https://www.globalefficiencyintel.com/netzero-roadmap-for-china-steel-industry.

Hasanbeigi, Ali, Cecilia Springer, and Dinah Shi. 2024. "Green H_2-DRI Steelmaking: 15 Challenges and Solutions." Global Efficiency Intelligence. https://www.globalefficiencyintel.com/green-h_2-dri-steelmaking-15-challenges-and-solutions.

Hasanbeigi, Ali, Cecilia Springer, Jibran Zuberi, Hongyou Lu, and Nan Zhou. 2024. "Electrifying Industrial Heating in China." Global Efficiency Intelligence. https://www.globalefficiencyintel.com/electrifying-industrial-heating-in-china.

Hasanbeigi, Ali, Bonnie Zuo, Daseul Kim, Cecilia Springer, Alastair Jackson, and Esther Haerim Heo. 2024. "Green Steel Economics: Comparing Economics of Green H_2-DRI and Traditional Steelmaking Around the World." GEI, TransitionAsia, and SFOC. https://www.globalefficiencyintel.com/green-steel-economics.

HKBAV. 2022. "POLICIES NEEDED TO SUPPORT STEEL INDUSTRY DEVELOPMENT." HONG KONG BUSINESS ASSOCIATION VIETNAM. 2022. https://www.hkbav.org/policies-needed-to-support-steel-industry-development_news21922.

International Climate Initiative. 2024. "Viet Nam's 2023 Updated Grid Emission Factor Signifies Lower Electricity Emissions." IKI. 2024. https://www.climatechange.vn/climate_news/viet-nams-2023-updated-grid-emission-factor-signifies-lower-electricity-emissions/.

International Energy Agency. 2019. "Material Efficiency in Clean Energy Transitions – Analysis." https://www.iea.org/reports/material-efficiency-in-clean-energy-transitions.

International Energy Agency (IEA). 2025. World Energy Statistics. https://www.iea.org/data-and-statistics/data-product/world-energy-statistics

Kweon, Yeongmin. 2024. "Enabling the Green Steel Future - Unlocking Government-Led Investment in Core Technology Development for Carbon Neutrality." Solutions for our Climate. https://content.forourclimate.org/files/research/YZkGFUe.pdf.

Le, Ngan. 2024. "Vietnam Steel Quality Overview - Steel Refining Technology and Production Line." MRS STEEL. 2024. https://mrssteel.com.vn/blogs/steel-blog/vietnam-steel-quality-overview.

Lee, Ana. 2023. "Vietnam's Steel Industry Takes Action to Become Carbon Neutral by 2050- Yieh Corp Steel News." Yieh Corp. 2023. https://www.yieh.com/en/News/vietnams-steel-industry-takes-action-to-become-carbon-neutral-by-2050/143777.

Lin, Bo-Yu. 2025. "Decarbonizing Industry: How Vietnam's Steelmakers Respond to EU's CBAM | NEWS." Reccessary. 2025. https://www.reccessary.com/en/news/decarbonizing-industry-hoa-phat-vn-steel.

Manh, Lai Van, and Pham Anh Huyen. 2023. "Viet Nam 2045-Development Issues and Challenges." In *Viet Nam 2045: Development Issues and Challenges.* Jakarta: ERIA. https://www.eria.org/uploads/media/Books/2023-VietNam-2045/21_ch.17-Circular-Economy.pdf.

Ministry of Industry and Trade. 2020. "National Action Plan on Sustainable Consumption and Production (2021-2030)." https://www.switch-asia.eu/site/assets/files/2533/national_action_plan_on_scp_vietnam_pdf_pdf.pdf.

Minter, Adam. 2014. "Vietnam's Search for Scrap." *Recycled Materials Association* (blog). 2014. https://www.isri.org/scrap-articles/vietnam's-search-for-scrap.

Moynihan, Muiris C., and Julian M. Allwood. 2014. "Utilization of Structural Steel in Buildings." *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences* 470 (2168): 20140170. https://doi.org/10.1098/rspa.2014.0170.

Phu Nguyen Steel. 2024. "Light Steel Frame Provider in Vietnam: The Smart Choice for Modern Construction 2025 » PN Steel Frame." December 19, 2024. https://pnsteelframe.com/light-steel-frame-provider-in-vietnam-2025/.

Reintjes, Martijn. 2021. "Growth in Steel Production Capacity Drives Vietnam's Scrap Appetite • Recycling International." *Recycling International* (blog). January 25, 2021. https://recyclinginternational.com/business/growth-in-steel-production-capacity-drives-vietnams-scrap-appetite/32574/.

Rodl and Partner. 2023. "Vietnam Controls Scrap Imports for Production." *Insights* (blog). 2023. https://www.roedl.com/insights/newsflash-asean/2023-02/vietnam-scrap-import-control.

South East Asia Iron & Steel Institute (SEAISI). 2025. "Australia's NeoSmelt Secures Funds to Support Lower-Emissions Steel Project | SEAISI." 2025. https://www.seaisi.org/details/26765.

Stegra, 2025. https://stegra.com/

The World Bank. 2018. "Supporting Energy Efficiency in Vietnam: Designing the Financial Structure of an Energy Efficiency Credit Line." World Bank. https://thedocs.worldbank.org/en/doc/707701522790469337-0340022018/original/casestudyvietnamenergyefficiency.pdf.

The World Bank. 2021. “World Bank, Green Climate Fund Provide Vietnam with US$86.3 Million to Spur Energy Efficiency Investments.” World Bank. 2021. https://www.worldbank.org/en/news/press-release/2021/03/08/wb-gcf-provide-vietnam-with-us863-million-to-spur-energy-efficiency-investments.

Tong, Jerlynn. 2025. “Vietnam Makes Major Updates to Power Development Plan VIII.” Watson Farley & Williams. April 23, 2025. https://www.wfw.com/articles/vietnam-makes-major-updates-to-power-development-plan-viii/.

Tran, Ha. 2021. “Hoa Phat Group Applies Green, Energy-Saving Technology in Steel Production.” VNEEC. 2021. https://vneec.gov.vn/News/Print/28035.

U.S. Department of Energy. 2022. “Industrial Decarbonization Roadmap.” https://www.energy.gov/eere/doe-industrial-decarbonization-roadmap.

U.S. International Trade Administration. 2022. “Vietnam Energy Efficiency.” January 11, 2022. https://www.trade.gov/market-intelligence/vietnam-energy-efficiency.

Vale. 2024. “Vale and Green Energy Park Partner to Develop Green Hydrogen Supply Chain in Brazil for Future Mega Hub.” Vale. 2024. https://vale.com/w/vale-and-green-energy-park-partner-to-develop-green-hydrogen-supply-chain-in-brazil-for-future-mega-hub.

Vets. 2024. “Current Status and Potential for Implementing Energy Management Systems According to ISO 50001.” *Vets | Energy* (blog). August 26, 2024. https://vets.energy/en/current-status-and-potential-for-implementing-energy-management-systems-according-to-iso-50001/.

Vietnam+ (VietnamPlus). 2024. “Vietnam targets developing green steel products.” Vietnam+ (VietnamPlus). September 4, 2024. https://en.vietnamplus.vn/vietnam-targets-developing-green-steel-products-post295941.vnp.

VNEEP. 2025. “Financial Solutions for Energy Efficiency Investment Activities in Vietnam’s Industrial Sectors.” 2025. https://vneec.gov.vn/tin-tuc/news/t42343/financial-solutions-for-energy-efficiency-investment-activities-in-vietnam-s-industrial-sectors.

Winn, Zach. 2024. “Making Steel with Electricity.” *MIT News | Massachusetts Institute of Technology*, May 22, 2024. https://news.mit.edu/2024/mit-spinout-boston-metal-makes-steel-with-electricity-0522.

worldsteel association. 2021. “Fact Sheet: Electrolysis in Ironmaking.” https://worldsteel.org/wp-content/uploads/Fact-sheet-Electrolysis-in-ironmaking.pdf.

List of Abbreviations

ASEAN – Association of Southeast Asian Nations

BAU – Business as Usual

BF – Blast Furnace

BF-BOF – Blast Furnace–Basic Oxygen Furnace

CCS – Carbon Capture and Storage

CCUS – Carbon Capture, Utilization, and Storage

CDQ – Coke Dry Quenching

CO_2 – Carbon Dioxide

DPPA – Direct Power Purchase Agreement

DRI – Direct Reduced Iron

EAF – Electric Arc Furnace

EPD – Environmental Product Declaration

ETS – Emissions Trading System

EVN – Vietnam Electricity (state utility)

FIT – Feed-in Tariff

GHG – Greenhouse Gas

GPP – Green Public Procurement

H_2 – Hydrogen

H_2-DRI – Hydrogen-based Direct Reduced Iron

HPG – Hoa Phat Group

IEA – International Energy Agency

ISO – International Organization for Standardization

MOIT – Ministry of Industry and Trade (Vietnam)

MONRE – Ministry of Natural Resources and Environment

MPI – Ministry of Planning and Investment (Vietnam)

MRV – Monitoring, Reporting, and Verification

Mt – Million Tons

NG – Natural Gas

NG-DRI – Natural Gas-based Direct Reduced Iron

PDP8 – Power Development Plan VIII (Vietnam)

PPA – Power Purchase Agreement

REC – RE Certificate

SME – Small and Medium Enterprises

SOE – State-Owned Enterprise

TRT – Top-Pressure Recovery Turbine

VNEEP – Vietnam National Energy Efficiency Program

VSA – Vietnam Steel Association