Climate Catalyst

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Green steel for growth: The economic case for steel decarbonisation in Indonesia

Climate Catalyst in partnership with Pusat Studi Energi Universitas Gadjah Mada (PSE-UGM)

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This report was commissioned by Climate Catalyst and researched and written in partnership with Pusat Studi Energi-Universitas Gadjah Mada (PSE-UGM).

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The views, assumptions, findings and conclusions expressed in this report remain those of the authors and do not necessarily reflect the views or endorsement of the reviewers.

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Introduction

This report was commissioned by Climate Catalyst, in partnership with Pusat Studi Energi Universitas Gadjah Mada (PSE-UGM), to provide the Government of Indonesia with a quantitative economic evidence base for activating decarbonisation policy instruments that already exist in principle but remain largely dormant in practice. These include green public procurement, renewable power purchase agreements, and the Ministry of Industry's Net Zero Emission (NZE) 2050 Industrial Decarbonisation Roadmap.

The report responds to a specific policy question: whether, and on what terms, government support for low-carbon steel production is economically justified for Indonesia, not only on climate grounds but as industrial and trade policy. Indonesia's steel industry is simultaneously a major source of industrial emissions and a sector in genuine financial distress, as described in the Executive Summary below. This report's premise is that these are not two separate problems requiring separate responses. It presents the transition to low-carbon steelmaking as the pathway out of the sector's existing structural difficulties, not as an additional burden placed on top of them.

The quantitative core of the report draws on two complementary models: a Computable General Equilibrium (CGE) model of Indonesia's economy, and an Indonesian Input-Output (IO) multiplier framework developed by PSE-UGM. Chapter 1.1 sets out why these two models were chosen, and the Appendix gives the full technical methodology. Readers who want the policy recommendations without the modelling detail can move directly from this Introduction to the Executive Summary and Chapter 6; those who wish to assess the evidence base itself should read the Appendix alongside the Results in Chapters 2 to 4.

It is worth stating upfront that the scope of this report is bounded in one important respect. The quantitative modelling, and the scenario results that depend on it, were produced by PSE-UGM using the CGE and IO frameworks described in Chapter 1 and the Appendix. Several of the report's other components, including international project benchmarking, and the policy design recommendations in Chapter 6, sit outside that modelling exercise and reflect the work of Climate Catalyst as report authors. Where this distinction matters for how a figure should be read, it is flagged at the relevant point in the text.

Executive summary

Indonesia's iron and steel industry is one of Southeast Asia's most significant industrial achievements, reaching 17.0 million tonnes of crude steel production in 2024[1], US$12.4 billion in export revenues[2], and US$37.7 billion in cumulative investment by 2023[3]. It underpins 78 per cent of Indonesia's construction sector and 8 per cent of automotive manufacturing[4]. This growth has been built on blast furnace–basic oxygen furnace (BF-BOF) technology, which was commercially rational under the conditions in which it developed.

The industry is also in distress. Krakatau Steel has required repeated government financial intervention; several mid-tier producers have cut jobs; and the sector's 62 per cent average capacity utilisation sits well below the 80 per cent threshold for financial health. This distress is structural, not cyclical: Indonesian BF-BOF producers run an import-dependent model in a market flooded by Chinese surplus exports. These pressures predate and are independent of any decarbonisation policy.

This challenging environment is now compounded by tightening carbon-linked trade measures, emissions-conditioned development finance, and buyers in the EU and across Asia-Pacific Scope 3 commitments beginning to require verified low-carbon credentials. These forces do not create a new problem for the industry; they make it more urgent to resolve the existing one.

	BAU 2050	Gradual 2050	Accelerated 2050
Real Annual GDP Growth	+0.06%	+0.25%	+0.21%
National welfare gain (single year, 2050)	US$335M	US$2,086M	US$1,399M
Cumulative welfare gain (2025–2050)	~US$4B	~US$28B	~US$34B
Steel-sector trade balance	-US$405M	+US$4,360M	+US$8,210M
Steel exports to the EU	2.6Mt	3.7Mt	4Mt
Steel exports to China	3.7Mt	2.6Mt	2.6Mt

*Mt = Million tonnes

This report, prepared by Climate Catalyst in partnership with Pusat Studi Energi Universitas Gadjah Mada (PSE-UGM), offers the Government of Indonesia a quantitative evidence base for activating policy instruments that already exist but remain largely dormant. These include green public procurement, renewable power purchase agreements (PPAs), and the Ministry of Industry's NZE 2050 Industrial Decarbonisation Roadmap. See the Introduction for the report's full background and scope.

The analysis draws on a Computable General Equilibrium (CGE) model and an Indonesian Input-Output (IO) multiplier framework from PSE-UGM, assessed across two transition scenarios against business as usual (BAU).

Under the policy packages modelled, in which decarbonisation and industrial recovery move together rather than compete across GDP, welfare, trade balance and employment, the transition scenarios outperform BAU. This finding depends on the scale of investment and output mobilised under each scenario and should be read as an indicative comparison of investment pathways. Indonesia's steel demand will grow. The real question is which pathway meets that demand competitively. Realising the modelled benefits also depends on credible demand, market access, bankable projects, financing and effective implementation.

The market opportunity

EU first, Asia-Pacific accelerating: Under the EU's Carbon Border Adjustment Mechanism (CBAM), Indonesian BF-BOF crude steel carries an actual emission intensity of roughly 36–92 per cent above the EU's own ETS benchmark of 1.3–1.4 tCO_2/tonne. Verified low-carbon credentials convert CBAM from a liability into a market-access advantage and stimulate import substitution as domestic EAF production displaces high-emission imports.

Asia-Pacific private-sector demand for near-zero emissions steel is projected at 6.1 million tonnes per year by 2030, driven by automotive, machinery and construction, against a verified supply pipeline of only 2.5 million tonnes. Indonesia's construction and automotive sectors, which account for 86 per cent of domestic consumption, are the principal segments generating this demand. Yet 93 per cent of Indonesia's new steel pipeline capacity is BF-BOF. Committing further capital to this route now creates a technology lock-in risk: 20- to 30-year assets built today will carry a structural cost disadvantage from carbon pricing,financing terms and import-dependent inputs, regardless of whether buyers require credentials at the point of sale.

Each Indonesia Rupiah (Rp) invested in electric arc furnace (EAF) technology generates Rp1.77 in total economic output versus Rp1.73 for BF-BOF, and supports 4.25 jobs per Rp1 billion of investment against BF-BOF's 4.15 (see Table 4.1). This shift also lowers the sector's carbon intensity directly, so the economic and climate cases move together. On-site workforce requirements at new EAF facilities are around 25 per cent of comparable BF-BOF plants, so the net employment gain occurs through the broader supply chain rather than at the plant gate, and communities anchored to existing BF-BOF complexes face real near-term adjustment that policy can actively manage.

The cost of delay is cumulative. BF-BOF capacity currently under construction carries an estimated US$17–35 billion stranded-asset risk, the cost of capital for high-emission assets is rising, and development finance institutions (DFIs) will not lend without a credible decarbonisation plan.

Four barriers stand between this opportunity and its realisation: Indonesian producers compete against high-emission imports with no equivalent carbon cost; there is no anchor demand signal large enough to make a direct reduced iron–electric arc furnace (DRI-EAF) project bankable; domestic scrap supply falls four to five million tonnes short of what EAF expansion requires; and the terms for securing bankable, long-term renewable electricity are not yet standardised. The four policy recommendations below address these barriers in phases.

Policy opportunities

Trade defence based on Indonesian National Standards (SNIs), local content requirements (Tingkat Komponen Dalam Negeri or TKDN) and anti-dumping measures: Decarbonisation investment will not proceed if high-emission imports keep undercutting the domestic market. Extend mandatory SNI coverage to all structural steel in nationally funded infrastructure, with carbon-intensity disclosure required for import certification from 2027. Introduce a tiered TKDN credit rewarding verified low-carbon domestic steel. Strengthen the anti-dumping investigation capacity of the Indonesian Trade Remedies Committee (KADI) and introduce mandatory import registration declaring origin, production route and carbon intensity.

Green public procurement (GPP): Activating Presidential Regulation 46/2025 to define verified low-carbon steel and set a 5 per cent GPP threshold, escalating to 35 per cent by 2035 and 70 per cent by 2050 under the accelerated transition scenario, is Indonesia's most powerful near-term demand signal for EAF investment and requires no new legislation. Mandating Monitoring, Reporting and Verification (MRV) systems enables CBAM compliance and green financing access.

Formalisation of scrap supply chain: EAF replaces imported coking coal with domestic scrap. A national traceability standard, incentives for certified processors, a monthly reference price, and processing hubs in major clusters by 2027 would close the current four to five million tonne deficit and build a dispersed, labour-intensive employment base.

Establishment of a PPA framework for renewable electricity: EAF already holds a structural energy cost advantage under PLN Indonesia's regulated tariff; renewable electricity deepens it. PLN's existing Dedicated Source mechanism allows direct industrial renewable offtake, but carries a price premium and restrictive terms that make it hard to underwrite at EAF scale. The priority is to simplify Dedicated Source terms and designate industrial estates with cleared Wilayah Usaha permits, the practical precondition for any renewable power arrangement.

Every year of delay narrows viable transition pathways, raises adjustment costs, and cedes first-mover advantage to regional competitors. The recommendations are implementable in sequence: measurement before pricing, demand signals before supply-side mandates, and trade protection before carbon costs.

CHAPTER 01

Technological pathways: Positioning Indonesia for the low-carbon steel transition

Indonesia's iron and steel industry is among the most consequential industrial achievements in the Southeast Asia region's recent economic history, growing over the past decade into the world's 14th-largest steel producer. It is not simply one industry among many, but a foundational input into the broader national economy.
The industry's growth rests on Blast Furnace–Basic Oxygen Furnace (BF-BOF) technology, which is proven, scalable and well understood. With no financial penalty for high emissions and no incentive to explore alternatives, producers rationally invested in defending and expanding existing capacity rather than switching routes.

Today, the industry is in distress due to three structural problems:

First, despite being the world's largest thermal coal exporter, Indonesia's domestic coal is predominantly low-rank and unsuitable for BF-BOF ironmaking. Two imports fill the gap: raw coking coal from Australia, and coke from China, which supplied 90 per cent of Indonesia's 2.47 million tonnes of coke imports in 2023[5]. This leaves BF-BOF producers import-dependent for both inputs, with coke concentrated in a single partner, a structural disadvantage that domestic policy cannot fix and that exposes margins to international price swings.

The second structural issue is import competition. Chinese steel exports reached a record 118 million tonnes in 2024[6]. Indonesia, without a domestic carbon standard that imposes an equivalent cost burden on imported high-emission steel, has absorbed a growing share of this surplus.

Indonesian BF-BOF producers thus compete against these imports while carrying Indonesian National Standards (SNI) compliance costs, increasingly stringent financing conditions and an underlying structural cost disadvantage. The competitive playing field is not level, and this is not due to decarbonisation policy.

Third, there is a misalignment of capacity. Indonesia's total steelmaking capacity is on track to exceed 45 million tonnes per annum by 2035, far above the government's target of 25 million tonnes[7]. Overcapacity at the national level suppresses domestic prices, intensifies inter-producer competition, and prevents any individual producer from achieving the utilisation rates that BF-BOF economics require. This is the structural consequence of investment decisions taken across the sector over the past decade, not of pending environmental regulation.

None of these three structural factors is caused by decarbonisation policy; the transition, properly designed and sequenced, is the pathway out of this structural trap. It moves producers towards lower input costs, greater domestic supply security, and access to the premium market segments that global trade is progressively reserving for verified low-carbon steel. Moreover, the technology choices made in the next two to three years will determine whether Indonesia captures the growing commercial premium for low-carbon steel, or locks itself into assets that global trade will increasingly penalise. This is not primarily an environmental decision. It is a decision about Indonesia's long-term industrial competitiveness.

1.1 Growth assessment based on three analytical scenarios

This report provides a quantitative assessment of the economic consequences of three distinct trajectories for Indonesia's iron and steel industry, drawing on two complementary economic models. A Computable General Equilibrium (CGE) model captures economy-wide interactions, including price adjustments, resource reallocation, and the behavioural responses of producers and consumers to policy change. It accounts for substitution between production inputs and technologies, allowing industries to adapt to decarbonisation policies rather than assuming a fixed production structure. This enables a comprehensive assessment of impacts on GDP, sectoral output, trade, employment and household welfare under different policy and technology transition scenarios. Moreover, the model assesses how Indonesia's transition choices affect international trade flows, bilateral export volumes and the country's overall trade balance in steel. Using the Indonesian Input-Output (IO) table, PSE-UGM estimates the economic multipliers associated with investment in different steelmaking technologies, including their effects on employment and income across the domestic economy. Together, these models provide both the international commercial and domestic economic dimensions of the transition case.

	Business-as-usual (BAU)	**Gradual transition (GRT)**	**Accelerated transition (ACC)**
Carbon price trajectory	No carbon price signal	Carbon price US$25/tCO2	Carbon price US$50/tCO2
Green Procurement	No green procurement policy	35% green procurement by 2050	70% green procurement by 2050
Technology Direction	Continued BF-BOF dominance; efficiency improvements only	Moderate EAF expansion; measured DRI-EAF adoption	Full NZE 2050 roadmap implementation: DRI-EAF mandate from 2027

The scenarios shown in Table 1.1 are built from technical parameters listed in full in the Appendix. New plants gain 20 per cent in energy and material efficiency over the 2025 baseline, old plants 10 per cent[8]. Switching from BF-BOF to direct reduced iron–electric arc furnace (DRI-EAF) cuts coal use by 98 per cent, while gas use rises 350 per cent and electricity use 400 per cent[9]. The 50 per cent green steel price premium used throughout[10] is a cost that government demand-side measures such as Green Public Procurement (GPP) are designed to absorb, not a price private buyers pay unconditionally. The government's share of total steel demand is set at 10 per cent[11]. These are assumptions that define the scenarios, not results the model produced on its own. A sensitivity analysis on several parameters, including the green premium, is provided in the Appendix.

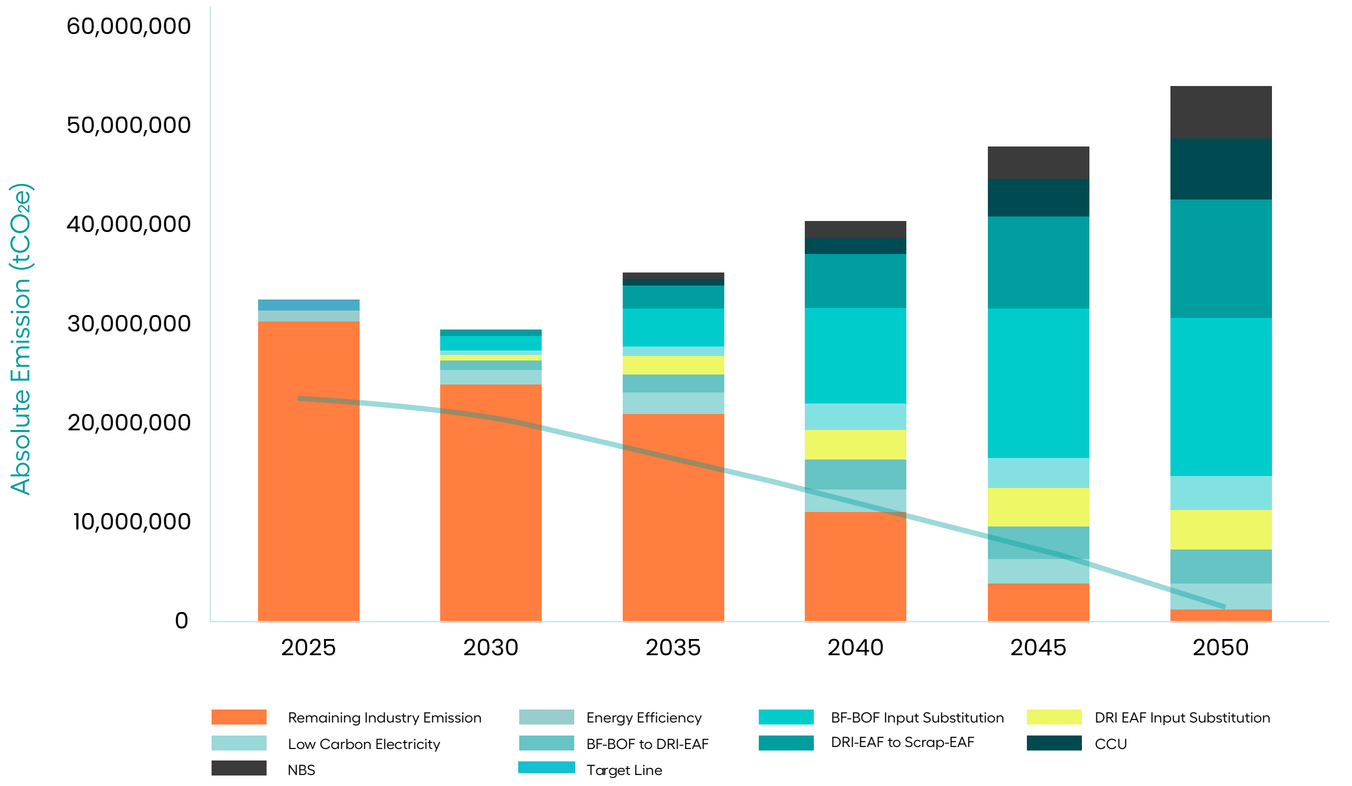
Across every dimension assessed, the more ambitious scenarios outperform BAU under the assumption modelled. Indonesia's steel demand will grow regardless of where the investment in technology is directed. The question this report addresses is how much of the potential benefits of industry growth Indonesia can capture, and under what conditions. This depends on both near-term policy choices and on market-access factors.

1.2 Indonesia's strategic roadmaps for steel decarbonisation

Indonesia's steel decarbonisation strategy, and the analytical foundation of this report, is the Ministry of Industry's Net Zero Emission (NZE) 2050 Industrial Decarbonisation Roadmap (Figure 1.1). All three scenarios are calibrated against its milestones, which prescribe a shift from a 2025 baseline of roughly 70 per cent BF-BOF and 30 per cent Scrap-EAF to a 2050 target of 70 per cent DRI-EAF and 30 per cent Scrap-EAF, effectively eliminating coal-reliant smelting within a generation.

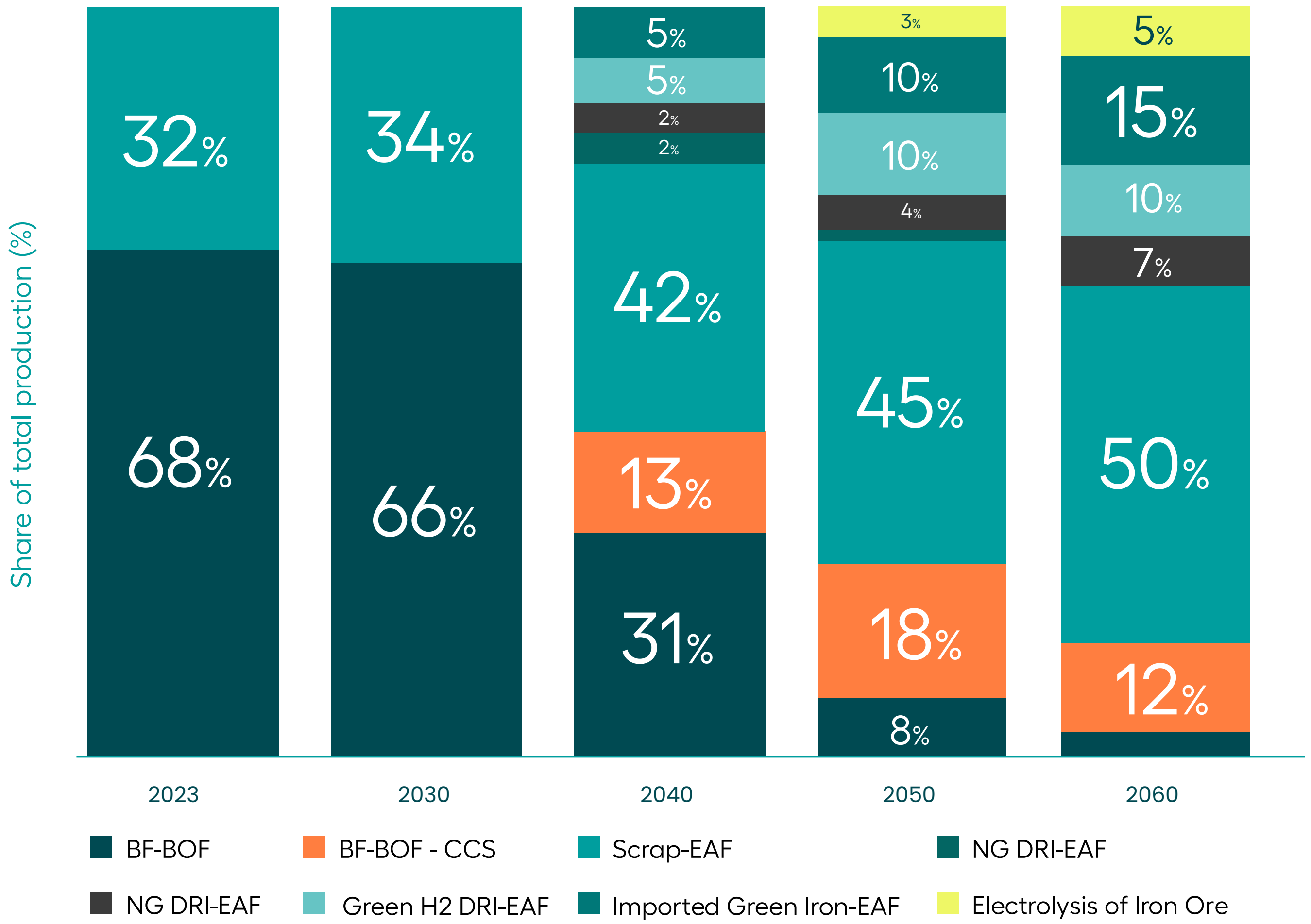
A complementary framework, the NZE 2060 pathway developed jointly by Global Efficiency Intelligence and the ASEAN Centre for Energy, reaches the same structural conclusion: full phase-out of BF-BOF, the dominance of secondary and hydrogen-based steelmaking, and a total investment requirement exceeding US$40 billion, achieved over a longer timeframe (Figure 1.2). Both frameworks require the same enabling conditions, namely: formalisation of the scrap supply chain, development of renewable energy infrastructure, power purchase agreement (PPA) regulatory frameworks, and green hydrogen investment. The critical strategic difference lies in the timing of when those conditions are established. Under NZE 2060 pacing conditions are built later, increasing exposure to the EU's Carbon Border Adjustment Mechanism (CBAM) tariff in the interim. This extends the period of stranded-asset risk on BF-BOF investments and reduces Indonesia's competitiveness for climate-aligned concessional finance, which is itself time-limited resource.

FIGURE 1.1. Absolute emission trajectories for net-zero steel in 2050



Source: Ministry of Industry, 2025[12]

FIGURE 1.2. Share of steel production technologies under the Net Zero scenario up to 2060[2]



Source: ASEAN Centre of Energy & Global Efficiency Intelligence, 2025[13]

The government's NZE 2050 and NZE 2060 roadmaps are not the only published assessments of Indonesia's steel transition. The Lawrence Berkeley National Laboratory and Institute for Essential Services Reform (IESR) joint decarbonisation roadmap for Indonesian industry reaches a broadly similar conclusion for steel: that reducing coal dependence and shifting towards secondary and hydrogen-based steelmaking is the dominant lever for emissions reduction from 2030 onward, with material efficiency and cleaner electricity playing a supporting role earlier in the transition[14]. Across the roadmaps, there is consensus on direction – away from BF-BOF and towards EAF, DRI-EAF and eventually hydrogen-based routes – but the organisations differ on pace, driven mainly by different assumptions about how quickly green hydrogen costs fall and how fast domestic scrap and renewable electricity infrastructure can scale.

On green hydrogen specifically, the NZE 2050 roadmap depends on green hydrogen production costs reaching below US$1.60–1.80/kg commercially by the mid-2030s. Current production costs remain well above this threshold. Globally, hydrogen cost-reduction trajectories have consistently underperformed against optimistic projections, and there is genuine uncertainty about the speed and depth of the cost curve. This is a strong argument for Indonesia to participate in the global pilot investment wave that will determine whether and when the threshold is reached. Producers and policy makers who wait for cost certainty before investing will not be part of the process that creates it. The modelling in this report assumes no hydrogen penetration in the baseline scenarios. This is a conservative assumption. If the cost curve is reached, the gains from hydrogen-based DRI-EAF would be in addition to gains the scenarios already show.

1.3 Technology pathways and readiness for the Indonesian steel context

The transition unfolds across three phases with different cost profiles and requirements. Near-term actions (2026–2030) are low-cost and immediately executable. Mid-term actions (2030–2035) need more capital, but depend on regulatory, financial and logistical conditions being established now. Long-term actions (post-2035), including full commercial hydrogen-based DRI, rest on foundations that will be stronger if building begins today. This makes the next two to three years more consequential than the 2050 targets themselves: a DRI-EAF facility takes four to six years to build, so capacity committed now determines what is possible by 2030.

As shown in Table 1.2, scrap costs make up roughly 75 per cent of EAF's levelised cost, making scrap price and supply stability the single largest lever on EAF competitiveness. Electricity is the second determinant: EAF uses roughly three times the electricity of BF-BOF per tonne, so the contracted price, whether PLN's regulated tariff or a premium renewable rate, has an outsized effect on unit cost. Global green steel capital expenditure (CAPEX) per tonne ranges from €156 for straightforward EAF conversion to over €1,500 for fully integrated hydrogen-based DRI (Table 5.3), so Indonesia's cost position depends heavily on which route it pursues, not a single 'green steel cost' figure. A full levelised cost comparison across routes under Indonesian input prices, benchmarked internationally, is therefore recommended as a priority companion study.

The shift to EAF and DRI-EAF is the sector's most consequential investment decision. Under the NZE 2050 roadmap, new facilities must adopt DRI-EAF from 2027 and existing plants by 2030. BF-BOF capacity committed before then carries an estimated US$17–26 billion stranded-asset risk over a 20- to 30-year asset life. Scrap supply chains, green financing, renewable energy contracts and policy signals need to be secured now to make the 2027 route-shift executable.

A further option is value chain decoupling: rather than building full domestic DRI capacity, EAF producers could import hot briquetted iron (HBI) and melt it domestically, separating capital-intensive ironmaking from the steelmaking step where most of Indonesia's investment benefit is concentrated. This trades one import dependency (coking coal) for another (HBI), so it is not costless, but may be more viable in the near term than full domestic DRI-EAF, particularly where domestic ore quality is uncertain.[i]

TABLE 1.2: Pathways towards low-carbon steel

Category	Enabler	**Phase 1:** Near-term	**Phase 2:** Mid-term: 2030 to 2035	**Phase 3:** Long-term: post-2035
Energy source				
Coal & gas	Natural gas injection to replace coal in BF-BOF	• Commercially proven; no infrastructure change • Immediate CO_2 reduction within existing BF-BOF	• Phased out as the DRI-EAF mandate takes effect from 2027.	• Fully replaced by green hydrogen in both pathways after 2035. No role in long-term production mix.
Biofuel	Biofuel to replace coal injection in BF-BOF	• Deployable within existing BF-BOF combustion systems with moderate emissions reduction • Constrained by domestic feedstock availability	• BF-BOF reduction in relevance as the route transition accelerates	• Phased out in both pathways as green hydrogen and renewable electricity replace fossil and bio-reductants.
Green hydrogen (H2)	H_2 to replace natural gas in DRI and EAF (H_2-DRI route)	• Pilot and infrastructure investment must begin early to compress the cost curve. • Current cost: well above US$1.60–1.80/kg viability threshold • Initiate pilot projects and PPA frameworks	• Partial injection into BF-BOF to replace coke (within-route option) • Infrastructure buildout for full H_2-DRI must be underway • Target green hydrogen price: <US$ 1.60–1.80/kg by mid-2030s	• 1.3 Mt/year green H_2 required • Outcome: 90% emissions reduction potential vs BF-BOF
Renewable electricity	Solar PV and low-carbon electricity purchase	• Corporate renewable PPAs needed from 2026 • Low-carbon electricity purchase reduces EAF emissions by 13.05% • A regulatory framework for PPAs must be established	• Grid infrastructure and storage investment are underway • Powers EAF operations as route transition accelerates	• 9.59 GW solar PV + 28.8 GW Battery Energy Storage System (BESS) • Powers green hydrogen electrolysis at scale • Prerequisite for H_2-DRI-EAF commercial viability
Technology				
Efficiency	Energy & material efficiency in BF-BOF and EAF	• Up to 20% emissions reduction; payback 1-4 years • Waste heat recovery and electrification of auxiliary processes • Highest-certainty, lowest-risk action in the entire portfolio	• Continues as an operational baseline across both pathways. Gains from efficiency compound as production volumes grow during route transition.	• Embedded standard across all technology routes. Ongoing rather than transformative role in later periods.
Scrap use	Increase scrap ratio in BF-BOF and EAF	• Reduces coke consumption without a route change • Domestic scrap supply: 4-5 Mt/year vs 9 Mt/year needed • Formalisation of the scrap value chain must begin immediately • Scrap costs: ~75% of EAF levelised cost, supply stability will be critical	• Scrap infrastructure must be operational to support EAF scale-up • Domestic collection, sorting and processing must be formalised • Contamination and rejection rates must be reduced • Supports route-shift viability in this window	• 15.17 Mt/year scrap required • Scrap-EAF dominant route in both pathways by the end of the period • Global scrap competition intensifies: domestic supply essential
Route shift	Substitute BF-BOF for secondary steelmaking (EAF/DRI-EAF)	• Enabling conditions: scrap supply, finance and policy signals must be put in place now to make the transition commercially executable by 2027	• Most consequential investment decision in the entire timeline • DRI-EAF mandated for new facilities from 2027; existing plants by 2030 • US$17–26 billion stranded asset risk if blast furnace investment continues	• 70% DRI-EAF + 30% Scrap-EAF by2050 • BF-BOF is fully phased out in both pathways • Shared H_2 pipelines + offshore CO_2 storage

Sources: Ministry of Industry NZE 2050 Industrial Decarbonisation Roadmap; ASEAN Centre of Energy & Global Efficiency Intelligence NZE 2060 Roadmap for Indonesia's Steel Industry

[i] A landed-HBI-cost comparison against domestic DRI capacity is recommended as part of the further techno-economic work.

CHAPTER 02

Macroeconomic performance – Output, income and welfare across scenarios

The central finding of this chapter is that policy ambition and economic performance move together. Each step up in policy ambition produces measurably better outcomes in GDP, household welfare and the general price level. The gap between the three scenarios widens over time, making the policy choices of the current period increasingly consequential with each year that passes.

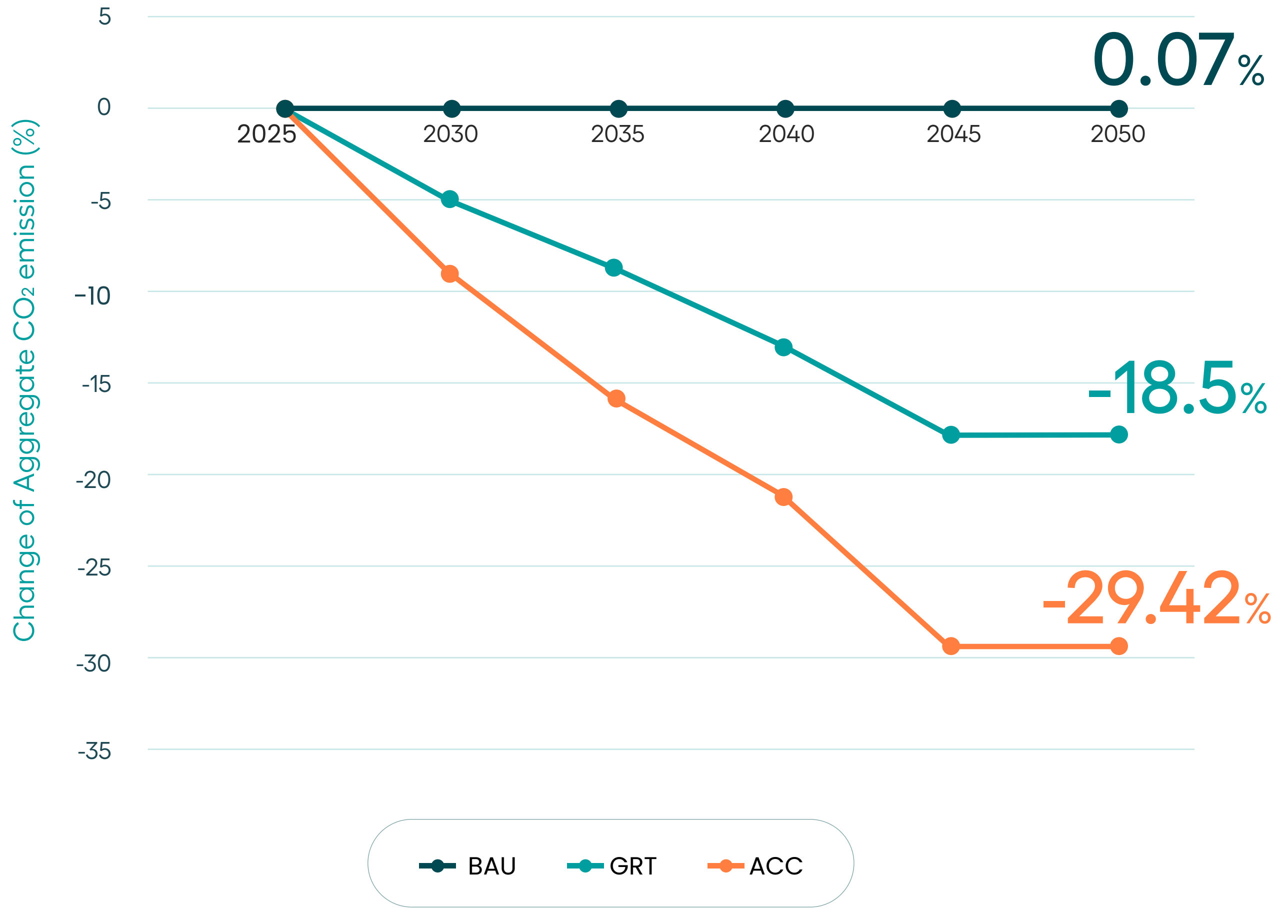
The results in this chapter reflect the bundled policy package modelled under each scenario – carbon pricing, green public procurement and the BF-BOF moratorium applied together – and the difference between BAU and the transition scenarios is driven mainly by the scale of investment and output assumed.

2.1 GDP growth and welfare are highest under the accelerated scenario

The three scenarios produce fundamentally different economic trajectories, and the gap widens over time. Under BAU, aggregate CO_2 emissions from the steel sector are virtually unchanged by 2050, just 0.07 per cent reduction above no-policy counterfactual. This marginal difference reflects existing efficiency policies already in place under BAU, which generate minor gains over a purely unregulated baseline.

The gradual transition scenario reduces emissions 18.55 per cent below the no-policy counterfactual by 2050, while the accelerated scenario achieves a 29.42 per cent reduction, a difference of roughly 11 percentage points that reflects the compounding effect of stronger and earlier policy signals applied consistently over a 25-year horizon.[ii]

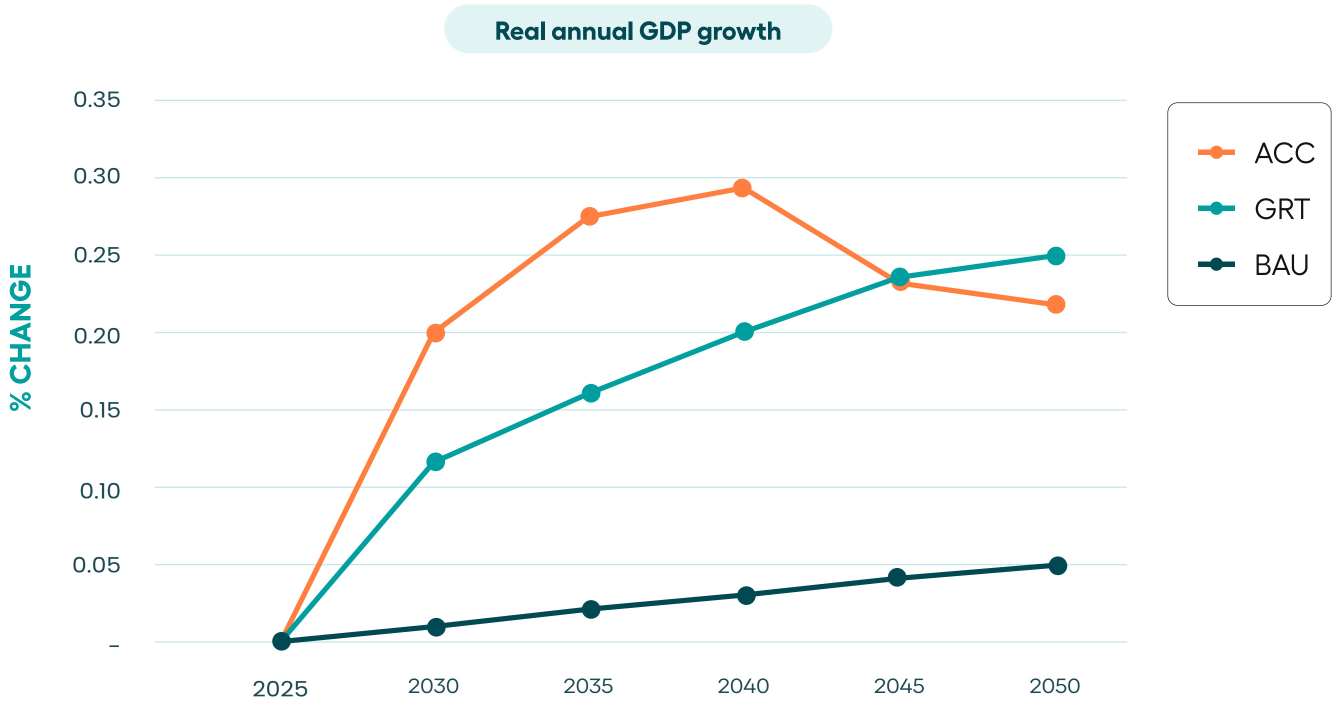
FIGURE 2.1: Aggregate CO_2 emission change (%) relative to 2025 baseline, by scenario



These emissions reductions are not achieved at the expense of economic growth. Real GDP responds proportionately to policy ambition across all three scenarios. The Accelerated scenario generates the strongest early growth premium, driven by the capital mobilisation required to build new EAF and DRI-EAF capacity across Indonesia's steel clusters. This investment surge, concentrated in the 2025–2040 window, flows through the economy via output and employment multipliers, raising incomes and activity above the unregulated baseline.

[ii] The emission reduction figure measure emissions avoided relative to the no-policy counterfactual under the model's assumptions where there is no hydrogen penetration and using current grid intensity (see Appendix).

FIGURE 2.2: Annualised incremental GDP growth rate, percentage change, by scenario and endpoint year



The accelerated scenario's GDP premium peaks around 2040, then narrows toward 2050. The carbon price, reaching US$50/t$CO_2$ under ACC and US$25/t$CO_2$ under GRT by 2050, combined with the progressive BF-BOF phase-out. The gradual transition premium, by contrast, continues rising through 2045 and remains marginally above the accelerated scenario's premium by 2050. In other words, ACC's premium appears smaller at 2050 simply because its transition is largely complete by then, while GRT is still in the active investment phase, continuing to generate economic activity from ongoing capacity expansion.

Three dynamics drive this pattern.

- First, the investment surge under ACC generates its largest multiplier gains in the early transition period and decelerates once structural transformation is largely complete by 2045.
- Second, ACC's carbon price of US$50/t$CO_2$ imposes a heavier cumulative cost burden than GRT's US$25/t$CO_2$ in the post-2040 phase, compressing the net premium in the later years.
- Third, GRT's transition remains actively underway through 2045–2050, continuing to generate above-BAU investment multiplier effects precisely when ACC's have plateaued.

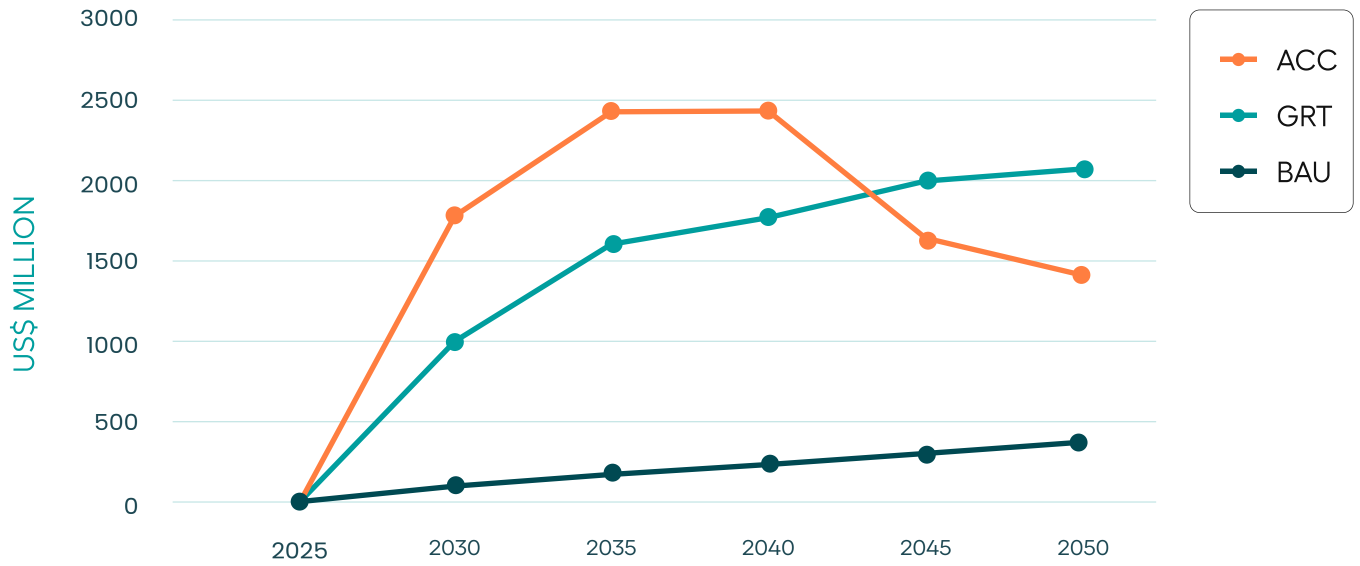
Taken together, ACC delivers substantially larger cumulative economic gains across the full 2025–2050 horizon.

The post-2040 narrowing of ACC's premium shows what happens when carbon pricing runs ahead of supply-side readiness. A carbon tax alone does not fully capture the efficiency gains that justify it unless complementary supply-side conditions are in place. When the carbon price escalates without a corresponding acceleration in DRI-EAF deployment capacity, renewable electricity procurement and green hydrogen availability, the net benefit of higher ambition compresses in the later periods.

alone does not fully capture the efficiency gains that justify it unless complementary supply-side conditions are in place. When the carbon price escalates without a corresponding acceleration in DRI-EAF deployment capacity, renewable electricity procurement and green hydrogen availability, the net benefit of higher ambition compresses in the later periods.

This means pairing the carbon price with active supply-side policy, namely: technology procurement frameworks that de-risk early DRI-EAF adoption; bankability standards that make green steel facilities financeable; and concessional financing through development finance institutions (DFIs) and green bonds that reduce the cost of capital for transition investments. The carbon price creates the incentive; supply-side policy determines whether that incentive translates into investable projects at the scale and speed the transition requires.

FIGURE 2.3: National welfare – equivalent variation, US$ million, by scenario, 2030–2050



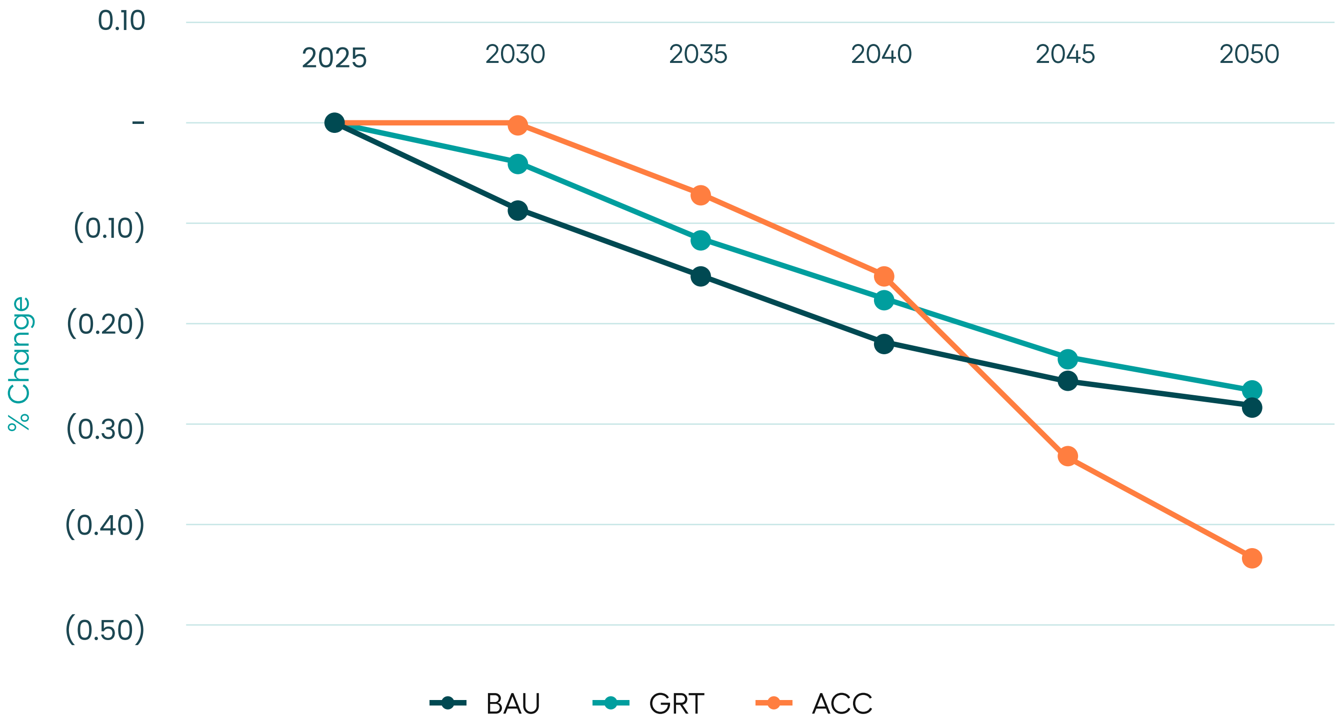
Welfare gains follow the same pattern as GDP (Figure 2.3). On a cumulative basis across the full 2025–2050 horizon, the accelerated scenario delivers approximately US$34 billion in aggregate welfare gains, compared with US$28 billion under the gradual transition. The 2050 single-year endpoint figure, where ACC shows US$1,399 million against GRT's US$2,086 million, is misleading as a basis for comparison. By 2050, ACC's transition is largely complete and its investment multiplier effects have run their course. GRT, still in the active investment phase, continues generating above-baseline economic activity in those final years. The decisive gains under ACC occur in the 2030–2040 window, when Indonesia's long-term industrial position is actually being determined.

The comparison between ACC and GRT scenarios should not rest on the economic figures alone. Where the GDP and single-year welfare premium of ACC over GRT narrows toward 2050, as each scenario's investment phase matures at a different point, the emissions outcome does not narrow in the same way. ACC delivers a 29.4 per cent reduction in steel sector emissions relative to the no-policy counterfactual by 2050, against 18.6 per cent under GRT. That is a substantially larger climate benefit for a broadly comparable, or in some years smaller, economic cost. On climate grounds alone, the case for ACC over GRT is stronger than the later-year GDP and welfare numbers on their own suggest.

2.2 The inflation risk is limited and transient, the long-run price effect is deflationary

A common concern among industry stakeholders and policy makers is that decarbonisation policies will push up costs and generate persistent inflation. The modelling results suggest otherwise (Figure 2.4). Under the accelerated scenario, a marginal positive price impulse of 0.007 per cent is recorded in 2030; this is the only scenario and the only period across the entire modelling horizon in which prices rise above the baseline. This reflects the green steel price premium associated with early-stage EAF investment and large-scale capital mobilisation. It is transient and self-correcting as capacity scales and unit costs fall.

FIGURE 2.4: Inflation (% change) by scenario, 2030–2050



As EAF scales, unit steel production costs fall with rising capacity utilisation, improving input efficiencies and declining renewable electricity costs. These cost reductions flow through construction, automotive and fabricated metal products, where together they account for a substantial share of Indonesia's industrial value added, moderating input costs and reducing producer prices economy-wide. The green steel price premium in 2030 is a short-term cost of early investment, not a permanent feature. From 2035 onwards, falling EAF production costs push steel prices down across the economy, reducing input costs for construction, automotive and manufacturing industries.

This finding is consistent with international evidence on 'greenflation' – the hypothesis that decarbonisation systematically elevates the general price level. Chung and Kim (2024), in a panel study of 26 OECD countries, found no evidence of persistent greenflation: any inflationary effects of the energy transition were transient, not structural. The implication for Indonesian policy makers is clear: the inflation risk from steel decarbonisation is not a reason to delay. It is a reason to build supply-side infrastructure such as DRI-EAF capacity, renewable energy procurement and scrap logistics ahead of demand, so that the transient price premium compresses as rapidly as possible.

2.3 The structural mechanism: EAF expansion as the engine of macroeconomic gains

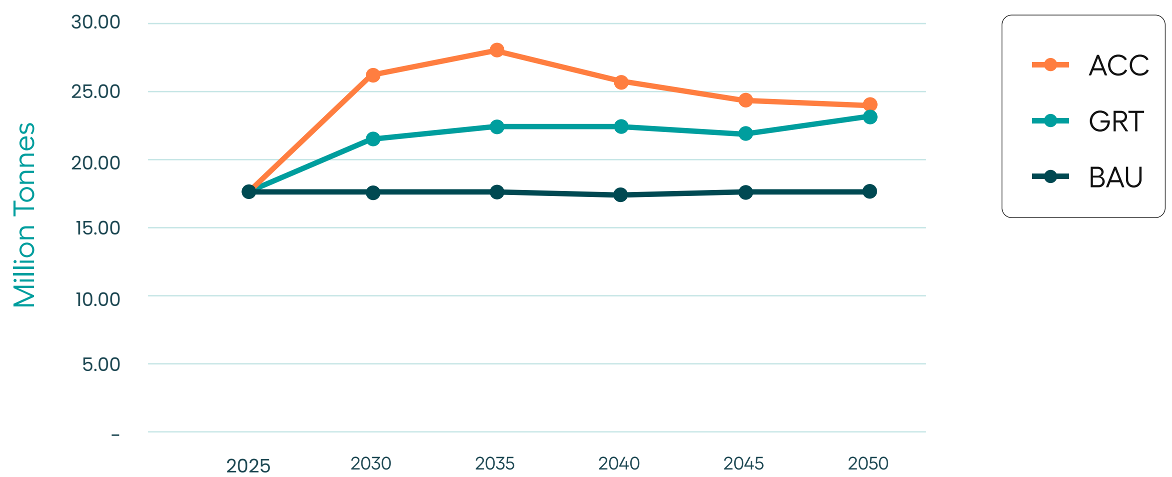
The macroeconomic improvements presented in this chapter stem from a specific structural shift: the progressive replacement of BF-BOF, which is high-cost, exposed to commodity price swings and subject to carbon penalties, with EAF and DRI-EAF, which is lower-cost, domestically grounded and carbon-credentialled. This shift is the primary driver of the GDP and welfare gains across both transition scenarios.

Under BAU, total steel output stays flat at approximately 18 million tonnes per annum (Figure 2.5). Under GRT it rises to approximately 23 million tonnes by 2050. Under ACC it peaks at approximately 27.5 million tonnes in 2035 before moderating to approximately 24 million tonnes by 2050 as BF-BOF retirement reduces primary production; this is not a weakness but the signature of a sector completing its shift to leaner, lower-emission steelmaking. Within that total, EAF output under ACC rises to 91.7 per cent above the no-policy counterfactual by 2050, nearly double what it would have been without policy intervention. EAF's output decisively exceeds BF-BOF's above the counterfactual around 2040, the same year the GDP premium peaks.

It is worth showing how much of the gain comes from the multiplier versus investment scale. Table 4.1 shows EAF generating Rp1.77 per rupiah invested, against Rp1.73 for BF-BOF; this is only a 2.3 per cent difference, and employment multipliers differ by a similar 2.4 per cent. Equal investment in both technologies would produce a gap this small, not the much larger gap between BAU and the transition scenarios, which comes mainly from investment volume, not a better return per rupiah for EAF.

Emissions tell a related but separate story. After 2045, the ACC trajectory flattens once BF-BOF phase-out is complete, and further cuts depend on replacing fossil inputs in DRI-EAF with green hydrogen. Total output also levels off after 2035, for the same reason. Investing in green hydrogen infrastructure now is the way to unlock further gains beyond those already captured by these scenarios.

FIGURE 2.5: Steelmaking output (% above/below the no-policy counterfactual) by scenario



These macroeconomic gains are generated under conservative modelling assumptions, and still deliver positive, substantial GDP, welfare and trade balance gains above BAU. A carbon price alone will not deliver this shift at the required pace: the transition also needs concessional financing and capital cost guarantees for DRI-EAF adoption, domestic scrap supply chain development, government green steel procurement mandates to anchor early demand, and technology partnerships to accelerate DRI-EAF deployment ahead of BF-BOF retirements.

CHAPTER 03

Trade competitiveness: Decarbonisation as a condition of market access

Decarbonisation is not a constraint on Indonesia's participation in global steel trade; it is increasingly the condition on which continued and expanded participation depends. Under the accelerated scenario, Indonesia's steel-sector trade balance improves by over US$8.2 billion relative to BAU in a single year. The mechanism operates through two reinforcing channels: export volumes rise in regulated markets that reward verified low-carbon credentials, while import penetration from high-emission suppliers falls as domestic EAF expansion drives import substitution[iii].

Without domestic carbon standards and EAF capacity, Indonesian steel producers stay locked in high-volume, low-margin, carbon-intensive trade segments as global procurement shifts toward verified low-carbon steel. Producers without a carbon pricing framework are increasingly assigned conservative default emission values by border mechanisms, generating tariff exposure that penalises even efficient producers. Indonesia's absence of verified Monitoring, Reporting and Verification (MRV) infrastructure compounds this exposure. A carbon price signals long-run policy commitment, not just domestically but also to CBAM authorities, sustainability-linked finance providers and Scope 3-committed procurement chains.

Steel-sector trade balance by scenario, 2050

BAU
steel-sector trade balance, 2050

- US$405
Million

Gradual Transition
trade balance vs counterfactual, 2050

+ US$4.3
Billion

Accelerated
trade balance vs counterfactual, 2050

+US$8.2
Billion

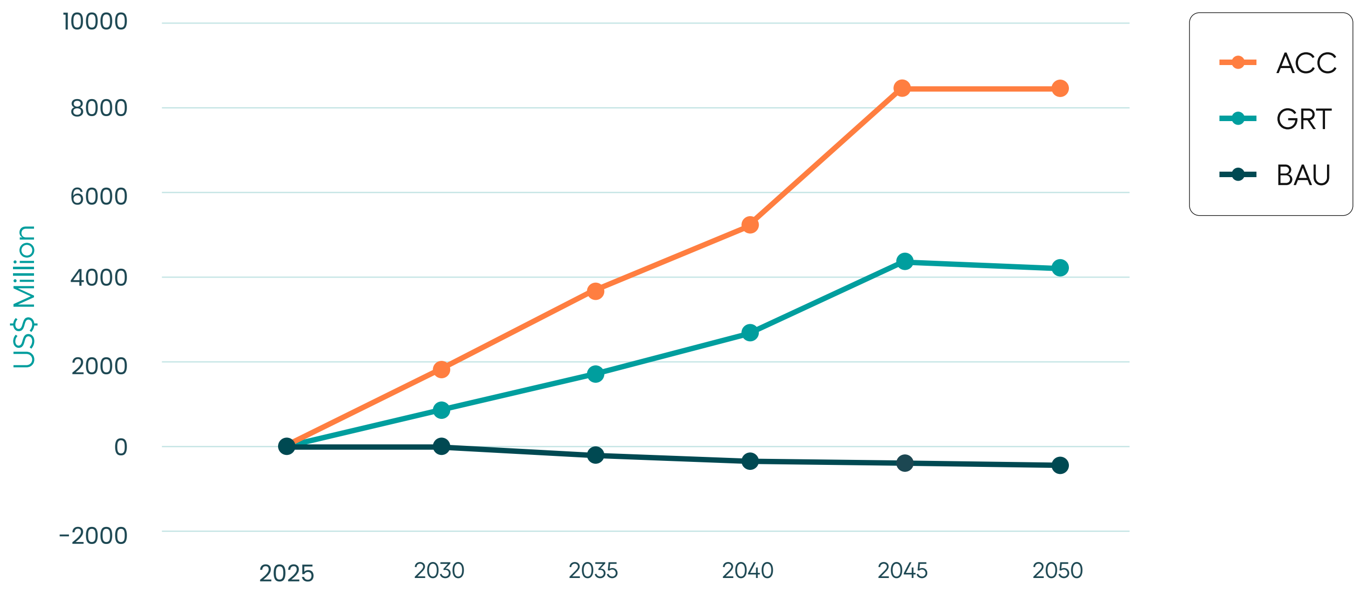
[iii]Export figures in this chapter are aggregate ferrous metals from GTAP-CE and are not split between carbon steel and stainless steel, which have different cost, ownership and trade profiles. EU and China export figures should be treated as aggregate, not carbon-steel-specific, until a product-level breakdown is available.

3.1 Market opportunities arising from green steel demand

Across the broader Asia-Pacific region, a 2026 analysis by Rocky Mountain Institute (RMI) of seven key economies – Japan, South Korea, Vietnam, Indonesia, Malaysia, the Philippines and Thailand – estimates total private-sector demand for near-zero emissions steel at 6.1 million tonnes per year by 2030, driven principally by the automotive, machinery and construction sectors[18]. Approximately 70 per cent of this demand originates from companies with formal Scope 3 emissions-reduction commitments, reflecting the extent to which corporate decarbonisation obligations are reshaping procurement decisions across regional supply chains[19].

The verified clean steel supply pipeline across these economies stands at only 2.5 million tonnes by 2030, far below both the private-sector demand figure and the 17.6 million tonnes that could be required if governments align public procurement with their 2030 climate targets [20]. Indonesia's construction and automotive sectors, which together account for 86 per cent of domestic steel consumption,[iv] are precisely the segments where this supply gap is most acute. For producers capable of delivering verified low-carbon steel, this gap is a direct and quantifiable commercial opportunity, provided enabling conditions are in place within the current investment window.

FIGURE 3.1: Steel-sector trade balance, US$ million, by scenario, 2030–2050



Capturing this demand window (Figure 3.1) requires supply-side conditions that the market will not generate autonomously within the required timeframe. The 2025–2032 first-mover window identified in this report is narrow relative to the capital cycle of a DRI-EAF facility, which typically requires four to six years from investment commitment to operational commissioning. Projects that have not reached financial close by 2027–2028 are unlikely to contribute verified supply by 2030. Closing this gap requires bankable project structures: offtake agreements, concessional first-loss capital and government procurement anchors. The government committing to buy verified green steel for public infrastructure at a carbon-reflective price is the single most direct way to make DRI-EAF projects financeable.

[iv]Figures above on steel supply pipeline are from the (RMI): Asia-Pacific's Green Steel Demand Opportunity analysis, not an Indonesia-specific projection modelled in this report. A segment-level breakdown distinguishing binding offtake from general commitment is recommended before using these as a project planning basis.

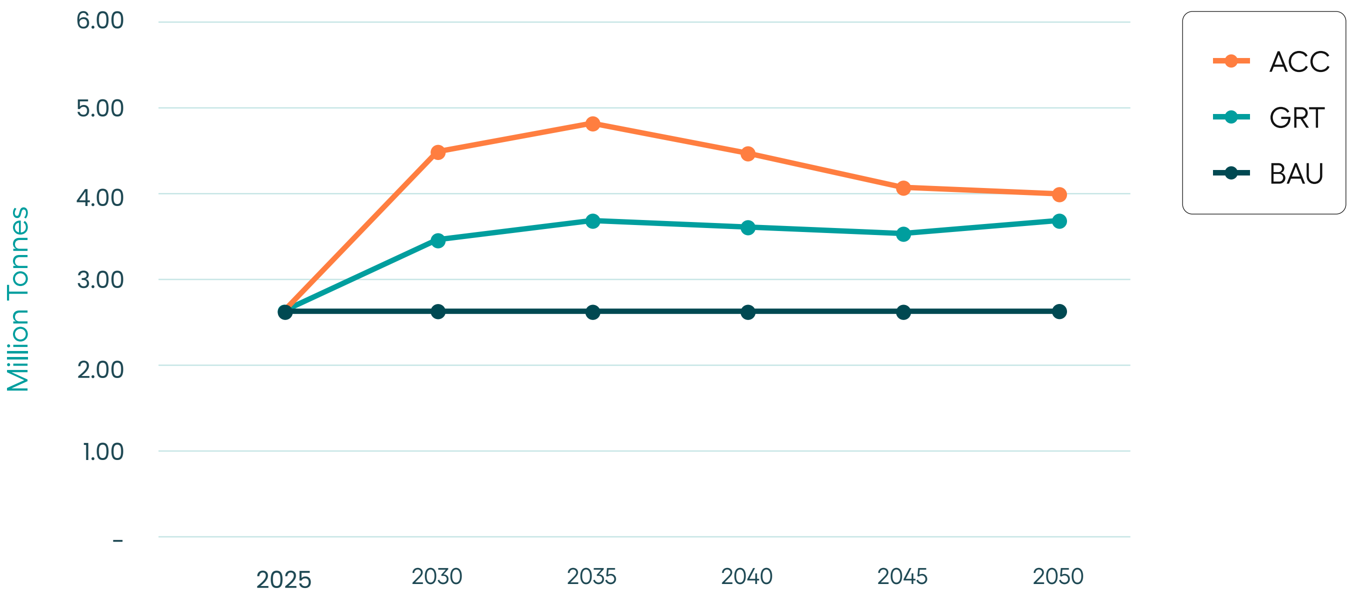
3.2 The EU: A strategically significant market

The EU is the export market where Indonesia's decarbonisation choices carry the most immediate commercial consequence. Two CBAM impacts must be distinguished: the near-term financial exposure, and the strategic market access dimension.

In 2023, about 17 per cent of Indonesia's steel exports (6.3 million tonnes) went to markets with active or proposed carbon border mechanisms.[18] The EU accounts for only three per cent of exports by volume today, but its growth potential makes CBAM a priority disproportionate to that share.[19] Without decarbonisation, CBAM could cut Indonesia's EU trade balance by up to US$35 million a year, with US$6.67–15.01 million of export value at risk annually; this is 2.3 to 4.5 times what Indonesia earned from EU steel exports in 2020.[20]

The strategic dimension is what matters. CBAM is the mechanism that either unlocks or forecloses Indonesia's access to the much larger future EU market opportunity modelled in the transition scenarios. The EU's CBAM prices imported steel against the EU's own domestic emissions benchmark; Indonesian producers' actual emission intensity currently runs well above that benchmark of roughly 36–92 per cent higher for BF-BOF carbon steel which means Indonesian exporters face a substantive carbon cost gap, not a measurement[21]. As shown in Figure 3.2, under the accelerated scenario, steel export volumes to the EU peak at approximately 4.9 million tonnes increase in 2035 before moderating to 4.0 million tonnes increase by 2050, 153.1 per cent above the no-policy counterfactual. BAU stays flat at approximately 2.6 million tonnes. The difference between these trajectories, worth several hundred million dollars annually at mature volumes, is unlocked by establishing verified low-carbon credentials.

FIGURE 3.2: Primary and secondary export volumes to the EU, change above the no-policy counterfactual[v]



The import substitution effect and the export growth effect together constitute the bilateral trade improvement with the EU and represent the commercial case for treating CBAM alignment and MRV infrastructure not as regulatory compliance costs but as market access investments.

[v] This growth is modelled as a combination of overall EU import demand growth and share gains from suppliers without verified low-carbon credentials, rather than displacement of a specific named competitor; a supplier-level breakdown is recommended as a future study (see 'Recommendations for future study' in Chapter 6).

3.3 China: Displacement of imports, significant export gains

China is the world's largest high-emission steel producer, accounting for a record 118 million tonnes of exports in 2024, and Indonesia's largest import source[22]. Without domestic carbon standards, Indonesia is exposed to Chinese steel displacing domestic production in lower-value market segments while remaining unable to compete in the premium segments emerging in response to carbon-linked demand.

Under BAU, Chinese steel imports stay at approximately 5.1 million tonnes throughout the horizon, leaving the domestic market fully exposed to import pressure and carbon dumping (Figure 3.3). Under the transition scenarios imports fall meaningfully, to approximately 4.6 million tonnes under ACC and 4.7 million tonnes under GRT by 2050. This reduction is achieved through domestic EAF capacity-building, not trade protection, making it durable rather than subject to challenge by the World Trade Organization (WTO). On the export side, the transition opens new ground. Indonesian steel exports to China rise from approximately 1.8 million tonnes in 2025, peaking at approximately 3.2 million tonnes in 2035 under ACC before settling at approximately 2.6 million tonnes by 2050, matching GRT's endpoint. China's own

FIGURE 3.3: Primary and secondary steel trade volumes from China, unit trends above/below the no-policy counterfactual[vi]

[vi] This growth is modelled as a combination of overall China import demand growth and share gains from suppliers without verified low-carbon credentials, rather than referencing the China-specific mechanism (domestic EAF capacity displacing imports; export gains driven by China's own carbon-linked feedstock shift) (see Recommendations for future study in Chapter 6).

carbon policy frameworks are increasingly pushing its market toward lower-emission feedstocks, and Indonesian EAF steel is well-positioned to capture that demand.

A further dimension of the China trade relationship is pricing. Under ACC by 2050, Indonesian decarbonisation reduces Chinese secondary steel import prices by approximately 12 per cent below the BAU, as domestic EAF production displaces imports and reduces Indonesian demand pressure on Chinese supply. For Indonesian industries that continue to import some secondary steel, falling Chinese import prices reduce their input costs, partially offsetting transition costs in import-dependent supply chains. The China trade picture shows the transition working on both sides simultaneously: fewer imports displacing domestic producers, and more exports accessing China's premium market segments. Indonesia's decarbonisation does not just defend existing market access – it opens new trade channels.

3.4 The domestic market: Protecting Indonesian producers from carbon dumping

The most immediate domestic market risk under BAU is the displacement of Indonesian producers by imported high-emission steel from jurisdictions that face no equivalent carbon cost burden. As OECD economies tighten their carbon border regimes, surplus high-emission steel is progressively redirected towards markets without equivalent standards. This report uses the term 'carbon dumping' as shorthand for this dynamic; the more precise technical term is carbon leakage through import displacement'. Indonesian producers are competing against imports that carry none of their Indonesian National Standards (SNI) compliance costs, and this disadvantage widens as global carbon regulation tightens.

Indonesia, without a credible domestic decarbonisation and border architecture, is structurally positioned to absorb that surplus. Indonesian steel producers bear SNI compliance costs, increasingly face financing conditions tied to emissions performance, and operate in a market where verified credentials are becoming a procurement requirement. This is not a level playing field, and enhanced trade defence is a legitimate and necessary response.

However, trade protection alone cannot resolve this imbalance. The root cause is a carbon cost differential that will widen as global regulation tightens. Addressing it durably requires three instruments. First, a Monitoring, Reporting and Verification (MRV) mandate to generate verified emissions data. Second, a domestic carbon price to redirect investment towards lower-emission production routes. Third, a border adjustment mechanism to level the playing field against unregulated imports.

These three instruments are mutually reinforcing and constitute the durable solution to the imbalance that import tariffs can only temporarily address.

Import substitution – the replacement of high-emission imported steel with domestically produced low-carbon alternatives – is the outcome through which market protection and industrial development are achieved simultaneously. For the Indonesian steel industry, this is not a regulatory burden. It is the commercial pathway to a defensible and durable domestic market position.

Import substitution is not only constrained by price and availability, but also by contracting structure: end-users, particularly in automotive supply chains, often operate under long-term offtake agreements tied to the country of origin of upstream production. Addressing this may require trade-policy engagement (e.g., sourcing provisions linked to Free Trade Agreements) alongside the domestic measures above, since substitution is unlikely to occur purely organically given persistent Chinese price advantages.

CHAPTER 04

Employment, social impact and the just transition

The transition to low-carbon steel creates more jobs overall than BAU and distributes them more widely across Indonesia than the current BF-BOF-centred model. EAF generates marginally greater economic output per rupiah of investment than BF-BOF and does so through a broader domestic supply chain that extends benefits to communities and sectors beyond established steel production clusters. However, the positive aggregate outcome does not automatically resolve the distributional challenge at the plant, community and regional levels, and that challenge requires deliberate policy response.

4.1 The transition generates more output and employment mainly through scale of investment

Each rupiah invested in BF-BOF generates Rp1.73 in total economic output across the Indonesian economy, comprising Rp0.46 in direct effects and Rp1.27 in indirect effects through the supply chain (Table 4.1). The corresponding figure for EAF is Rp1.77, comprising Rp0.45 in direct effects and Rp1.32 in indirect effects. This higher total is driven by EAF's broader linkages to electricity generation, scrap logistics and professional services, in contrast to BF-BOF's dependence on imported coal and iron ore inputs.

Each rupiah invested in an EAF plant generates economic activity not only within the steel sector but across a wider set of industries: scrap collection and processing, renewable energy services, certification and verification, and green hydrogen production. Employment multipliers reflect the same pattern. BF-BOF generates 4.15 additional jobs per Rp1 billion of investment; EAF generates 4.25 jobs, which are distributed more broadly across sectors and regions. Income multipliers are effectively equivalent, and the transition does not reduce aggregate labour income. It redirects that income through a supply chain with wider geographic reach.

TABLE 4.1: Indonesian steel multiplier outputs [vii]

MULTIPLIER	BF-BOF	EAF
Total output multiplier (per Rp1)	Rp1.73	Rp1.77
Direct output	Rp0.46	Rp0.45
Indirect output	Rp1.27	Rp1.32
Income multiplier (per Rp1)	Rp0.22	Rp0.21
Employment multiplier (per Rp1 bn)	4.15 jobs	4.25 jobs

[vii] The multipliers in Table 4.1 show a modest advantage for EAF over BF-BOF. Most of the transition's reported output and employment gains come from the volume of investment mobilised under the transition scenarios, not from this multiplier difference on its own.

4.2 Labour demand shifts toward secondary steelmaking under the transition scenarios

Under the accelerated scenario, secondary steelmaking labour demand rises continuously to 64.1 per cent above the no-policy baseline by 2050 (Figure 4.1).[viii] The net employment picture across both steelmaking sub-sectors is positive relative to BAU, and that positive picture is the starting point for understanding the transition's labour market effects. The adjustment challenge is real, but it operates within an aggregate trajectory that is growing, not shrinking.

At the plant and community levels, the picture requires a more precise framing. New low-carbon EAF facilities require approximately 25 per cent of the on-site workforce of the integrated BF-BOF plants they replace at comparable output levels. This means a 4,000-worker integrated steel complex is replaced by a facility employing approximately 1,000 workers at the site. The remaining net employment gain occurs through the broader supply chain: scrap collection and processing, renewable energy construction and maintenance, certification services, and green hydrogen infrastructure. These are dispersed jobs created in different locations from those where BF-BOF employment is displaced.

FIGURE 4.1: Labour demand in primary and secondary steelmaking, % above no-policy counterfactual

The skills transition compounds the adjustment challenge. Miles, J. et al. (2025) estimated that approximately 85 per cent of occupations in the steel sector face a skills gap relative to the process requirements of new low-carbon production technology.

This gap is addressable, but not automatically. Illustratively, structured retraining takes time, typically 18 to 36 months for meaningful technical transitions. It also carries cost: international experience suggests US$5,000–15,000 per worker for mid-career retraining. And it requires institutional infrastructure, specifically training partnerships between producers, vocational training centres and technology suppliers. None of this is prohibitive, but all of it has to be actively organised and funded.

[viii] This figure, like other DRI-EAF-linked results in this report, is estimated using the BF-BOF multiplier in the absence of a dedicated DRI-EAF multiplier in the Input-Output framework, and should be read as indicative rather than precise.

4.2.1 Geographic specificity: The communities most exposed to structural change

The geographic mismatch between where employment is displaced and where new employment is created is as important to manage as the sectoral dimension.
Two clusters bear the greatest concentration of existing BF-BOF employment.[23]

Cilegon, Banten is home to Krakatau Steel's integrated complex and a range of downstream fabricators and industrial service providers that depend directly on its operations. The integrated steel industry and its direct supply chain support tens of thousands of workers in the broader Cilegon–Serang corridor, along with significant indirect employment in logistics, utilities and industrial services.

Morowali Industrial Park in Central Sulawesi hosts a newer cluster of nickel-based steelmaking operations, including stainless steel and carbon steel production lines.
The industrial park's workforce, including contractor and indirect employment, is concentrated in a region with limited alternative employment infrastructure.

Not all industrial joint ventures necessarily produce the same domestic employment outcome, and this distinction matters for how transition-linked facilities are structured going forward. PT Krakatau POSCO, the BF-BOF joint venture between PT Krakatau Steel and South Korea's POSCO, operating in Cilegon since 2014, is a relevant precedent for how international technology partnerships translate into domestic employment capture. A comparative assessment of its outcomes against the Morowali model would help inform how future DRI-EAF joint ventures are structured, and is recommended as a discrete piece of further study.

The scrap logistics jobs, renewable energy construction roles and certification services that the transition generates are not naturally concentrated in Cilegon or Morowali. However, some geographic overlap is achievable. Morowali in particular has the infrastructure and energy context to host DRI pilot facilities, and Cilegon's industrial base and port access support the development of a scrap processing hub. But proactive policy is required to create these opportunities in the locations where displacement occurs, rather than leaving them to emerge organically in locations of economic convenience.

4.3 Emerging sectors and new employment opportunities

Beyond the steel sector itself, Indonesia's decarbonisation transition creates substantial new demand in enabling industries that do not yet exist at scale domestically.
These industries represent both a significant economic development opportunity and a material pathway for employment diversification in the communities most exposed to structural change.

Green hydrogen and industrial renewables
DRI-EAF adoption generates large-scale demand for two inputs. Green hydrogen must be priced below US$1.60–1.80 per kilogram to be commercially competitive[24]. Renewable electricity is required at scale, with EAF consuming approximately 600 kWh per tonne of steel produced, compared with BF-BOF's 200 kWh equivalent[25]. The geographic concentration of Indonesia's steel production in industrial clusters creates a structural advantage for shared renewable energy procurement frameworks, enabling economies of scale in generation and storage that reduce per-facility capital costs. The employment generated by the construction, operation and maintenance of this renewable energy infrastructure, including solar generation, battery storage, transmission connections and electrolyser facilities, represents a direct economic offset to employment displaced from coal and BF-BOF supply chains in the same regions.

Domestic scrap supply chain
EAF requires approximately 1.04 tonnes of scrap per tonne of steel produced, compared with BF-BOF's 0.13 tonnes, which is a sevenfold increase in scrap intensity. Indonesia's current annual scrap deficit of four to five million tonnes, relative to the nine million tonnes required to support EAF scale-up, must be addressed through domestic infrastructure development rather than increased import dependence. Scrap collection, sorting, grading and processing represent a geographically dispersed, labour-intensive value chain with meaningful employment potential in logistics, materials processing and certification services across a broad range of Indonesian regions beyond the established industrial centres.

Direct-reduced iron and hot briquetted iron as premium-value feedstock
The production of direct-reduced iron (DRI) and hot briquetted iron (HBI), initially utilising natural gas as a reductant and transitioning progressively to green hydrogen, adds premium downstream value to Indonesia's iron ore resources in a form directly aligned with both the decarbonisation transition and regional demand for lower-emission primary iron feedstock.

DRI-EAF's input requirements go beyond gas or hydrogen and low-carbon electricity. The process requires higher-grade iron ore or pellets than BF-BOF typically uses, with tighter chemical specifications. Whether Indonesia's domestic iron ore resource can supply this at scale, or whether beneficiation and pelletising investment is needed, or whether DRI-EAF would in practice create a new dependence on imported high-grade ore, pellets, DRI or HBI, would need to be assessed further. This is directly relevant to the resilience case made elsewhere in this report for moving away from BF-BOF's import-dependent coking coal supply chain: if DRI-EAF simply substitutes one imported input for another, the resilience gain is smaller than the headline technology shift suggests[ix].

Industrial facilities in Morowali, where energy and logistics infrastructure are already established and existing nickel-steel industrial relationships create natural synergies, are well positioned as early candidates for DRI and HBI development, once this feedstock question has been assessed. Should domestic beneficiation and pelletising investment proceed, this would generate skilled roles in ore processing, plant operation and quality assurance, distinct from the scrap-logistics and EAF-operator roles described above and requiring different training.

Certification and carbon market services

Verified credentials are the commercial foundation of green steel market access. MRV systems, environmental product declarations, life-cycle assessment and carbon registry management collectively represent a growing professional services sector. In comparable industrial transitions internationally, certification and verification services have generated hundreds of skilled professional roles per major production cluster, roles that require technical understanding of industrial processes and are therefore well-suited to workers transitioning from operational positions in conventional steel production. This sector retains its value within the domestic economy and grows as the transition deepens, providing a durable employment pathway rather than a transitional one.

[ix]Importing HBI is an alternative to building domestic DRI capacity. Whether securing domestic ore or importing HBI is more commercially sound is unresolved and should be settled before any site is treated as a candidate for domestic DRI and HBI production.

4.4 Just transition policy requirements

The positive aggregate employment trajectory does not automatically resolve the distributional challenge at the level of specific plants, communities and regions. Communities anchored economically to coal-based steelmaking, such as in Cilegon and Morowali, face the potential loss not only of direct industrial employment but also of the broader upstream and downstream economic activity that integrated steel complexes generate within their regional economies. The spatial dimension of the transition, meaning the geographic mismatch between where employment is displaced and where new employment is created, is as important to manage as its sectoral dimension.

The commercial case for transition and the employment and social case are not in tension. They are, in structural terms, the same case. Green public procurement creates the guaranteed demand that makes EAF investment financially viable and generates employment in scrap logistics and certification services across a broader value chain. Scrap supply chain formalisation is simultaneously an import substitution programme, an input resilience measure and a national employment generator. The Power Purchase Agreement (PPA) framework serves not only the EAF producers who require renewable electricity contracts but also the construction, installation and maintenance workforce required to build the renewable infrastructure those contracts underpin.

CHAPTER 05

The risk of continuing to do business as usual

The macroeconomic gains of transition compound with early action and erode with delay. Each year that capital continues to flow into BF-BOF extends the period of carbon lock-in, increases the volume of assets at risk of becoming stranded, narrows the range of viable transition options, and reduces access to the concessional finance that makes the transition affordable. This chapter sets out the commercial and financial risks of the BAU trajectory across four dimensions: market and regulatory exposure, technology lock-in, input cost vulnerability, and financial misalignment. Several of these risks have already begun to materialise.

5.1 Market and regulatory exposure: CBAM is generating additional cost

The window for establishing verified low-carbon credentials is closing faster than a new blast furnace can be built and commissioned. This is a present commercial cost, and one that is not incurred by producers operating in jurisdictions with established MRV infrastructure. Establishing that infrastructure converts the CBAM mechanism from a financial liability into a competitive market-access asset.

The absence of trade-aligned decarbonisation simultaneously exposes Indonesia's domestic market to structural import penetration risk. Chinese steel exports more than doubled since 2020, reaching a record 118 million tonnes in 2024,[26] and have driven a fivefold increase in anti-dumping measures across OECD economies. Without a domestic carbon standard, Indonesia faces a double exposure: losing access to premium export markets as those markets raise their carbon requirements, while simultaneously absorbing the surplus high-emission steel being redirected away from those same markets. Trade protection instruments are necessary as an immediate response, but they address the symptom rather than the structural cause. The durable solution is downstreaming: developing higher-value, lower-emission production capacity that competes on credentials, not just price.

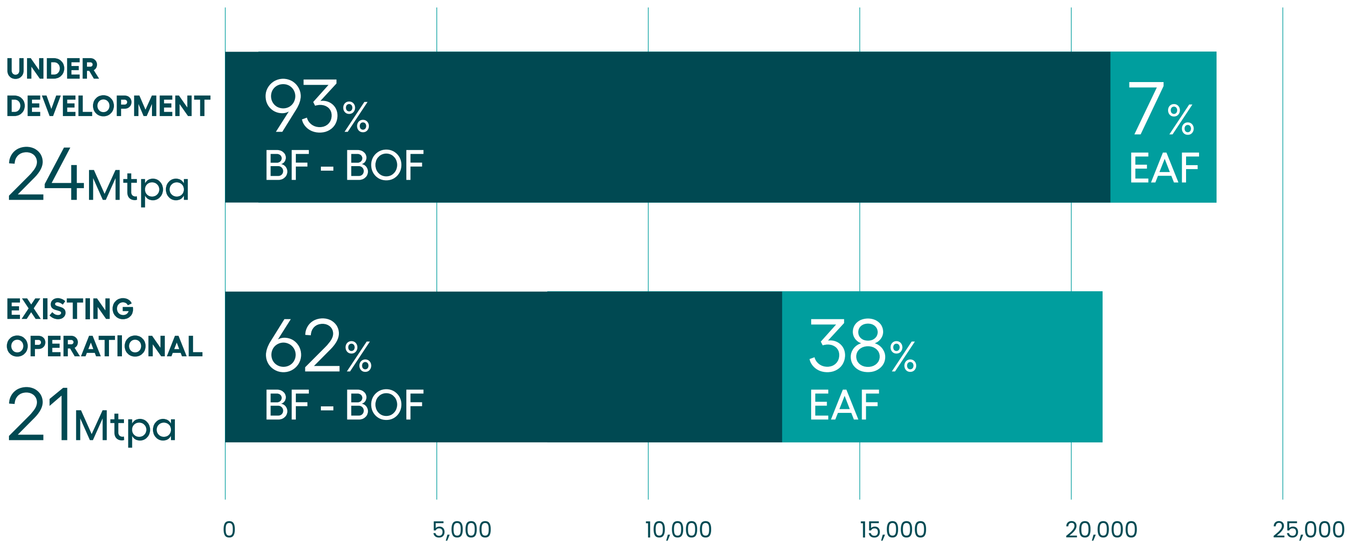
5.2 Technology lock-in: The stranded-asset risk of continued BF-BOF investment

The BF-BOF capacity currently under construction in Indonesia carries an estimated US$17–35 billion stranded-asset risk.[27] Three factors drive this range: a higher carbon price pushes the figure towards the upper bound; a lower discount rate extends the effective asset life and raises the value at risk; and facilities with a 25-year design life may be written down at year 15–20 if conditions deteriorate faster than expected. The midpoint, approximately US$26 billion, corresponds to a US$25–30/t$CO_2$ carbon price by 2035 at an eight per cent cost of capital.

Indonesia's steel sector has prior experience of this dynamic: Krakatau Steel and Gunung Raja Paksi (GRP) both illustrate the financial consequences of capacity commissioned at a scale that market conditions subsequently rendered uncompetitive. The current investment pipeline risks repeating this pattern at a considerably greater scale, in an external environment that is actively and progressively reducing the commercial viability of high-emission steel assets.

Each new blast furnace commissioned represents a 20- to 30-year capital commitment. That time horizon extends past the point at which international lenders are expected to exit high-emission asset financing, and into a period when market access will depend on verified carbon performance. Of the approximately 24 million tonnes per annum of new crude steel capacity in the pipeline, 93 per cent uses BOF technology. Only 1.2 million tonnes per annum uses EAF.

FIGURE 5.1. Indonesia steel capacity pipeline



Source: Global Energy Monitor, 2026.[39]

Combined with 21 million tonnes per annum of existing capacity, total steelmaking will exceed 45 million tonnes per annum, far above the government's 2035 target of 25 million tonnes. Yet existing plants ran at only 62 per cent utilisation in 2023, well below the 80 per cent threshold for a financially healthy operation.[37]

The structural misalignment is stark in both the existing fleet and the pipeline (Figure 5.1). Of the 21 million tonnes per annum currently operating, 38 per cent uses EAF. However, 100 per cent of the 11 million tonnes per annum of operating ironmaking capacity uses coal-based blast furnaces, with no operating DRI facility in the country today. A further six million tonnes per annum of new ironmaking capacity is in development, and every unit uses coal-based blast furnaces.[38]

Without a strategic recalibration of investment toward low-carbon technologies, Indonesia could be left with underutilised, high-emission industrial assets that weaken both its long-term competitiveness and its ability to integrate into the emerging global market for green steel.

5.3 Input cost vulnerability: BF-BOF's import dependence is a structural liability

BF-BOF production is structurally dependent on premium-grade coking coal that Indonesia cannot supply domestically. Despite being the world's largest thermal coal exporter, Indonesia's domestic coal resource is predominantly low-rank thermal and semi-soft coking material, technically unsuitable for BF-BOF ironmaking.

This import dependence runs through two distinct inputs with different supplier profiles. Raw coking coal comes predominantly from Australia, with the US and Canada emerging as diversification sources; China supplies only occasional spot shipments and is not a routine source.[40] Processed coke, by contrast, is overwhelmingly China-sourced; Indonesia imported 2.47 million tonnes of coke and semi-coke in 2023, of which China supplied 90 per cent[41]. Both inputs expose steelmakers to international commodity price volatility that cannot be managed through domestic policy measures, and the coke supply chain in particular concentrates that exposure in a single trading partner.

Under CBAM, BF-BOF-based steel could face added costs of €40–90 per tonne, compounding regulatory exposure with a structurally unavoidable input cost disadvantage.[42]

EAF, by contrast, runs on electricity at PLN's regulated industrial tariff of approximately Rp 1,114.74/kWh (the I-3 tariff category, applicable to industrial customers above 200 kVA). This rate is held stable by government policy, giving EAF operators a predictable energy cost that is insulated from the international commodity price swings that BF-BOF operators cannot avoid.[43] The commercial case for EAF transition rests not on carbon pricing alone, but on a structural input cost advantage that already exists today. This comprises domestic, policy-stable electricity on one side, and volatile, import-dependent coking coal on the other. Owning a steel plant does not mean controlling its costs. Genuine resilience against input price shocks comes from controlling the inputs themselves, and EAF runs on domestic electricity rather than imported coking coal.

5.4 Financial misalignment: international capital is moving away from BF-BOF

Global financial institutions increasingly treat supply chain emissions as a material credit risk, embedded in lending standards, concessional finance eligibility, and sustainability-linked bonds. For Indonesia's almost entirely BF-BOF-dependent sector, this means rising capital costs, a shrinking pool of transition finance relative to demand, and lending terms increasingly set by climate-alignment frameworks.

Table 5.3 illustrates both the scale of the global capital reallocation already underway and how uneven its progress has been. Of the eight projects listed, three are operating or completed on schedule, several are under construction but running behind their original timelines or facing input-supply complications of their own and one has needed emergency financing to avoid collapse.

TABLE 5.3 Announced full-scale green steel projects globally

Company	Country	Technology	Year	Capacity (Mt/yr)	CAPEX (EUR/tonne)	Status
Algoma Steel	Canada	EAF	2024	3.7	EUR 156	First EAF unit operating and ramping up since July 2025; second unit under con-struction, on track for H2 2026.
Arcelo Mittal	Spain	DRI + EAF	2025	1.1	EUR 1,572	EAF under construction targeting early 2026 first heat, but the accompanying DRI unit is delayed.
H2 Green Steel (Stegra)	Sweden	DRI + EAF	2024	5.0	EUR 580	Under construction since 2022; the com-pletion timeline nzow under review.
British Steel	UK	EAF	2026	1.5	EUR 962	Under UK government special measures since April 2025; formally nationalised on 16 July 2026 after the Steel Industry Act received Royal Assent. The original blast-furnace-toEAF plan continues under state ownership
Thyssenk-rupp	Germany	DRI	2026	2.5	EUR 800	Under construction toward end-2026 completion, but will run initially on natural gas after the green hydrogen tender was paused, pushing the hydrogen ramp-up to 2028–2029.
POSCO	South Korea	EAF	2026	2.5	EUR 170	Construction completed and the Gwang-yang furnace became fully operational in June 2026, on schedule.
Tata Steel (Port Talbot)	UK	EAF	2027	3.0	EUR 481	Under construction; 6–12 month delay past end-2027 target disclosed mid-2026 due to National Grid connection issues.
Salzgitter	Germany	DRI + EAF	2033	1.9	EUR 907	First phase underway, but the next-stage investment decision has slipped from 2026 to 2028–2029.

Note: Selected announced full-scale green steel projects globally | Source: A. Huettel, J. Lehner, 2024[44]

This variance is a useful corrective to any assumption that green steel technology, once announced, proceeds smoothly to commercial operation. It is also a live risk factor for Indonesia's own timeline: several of these projects compete for the same regulated and voluntary premium markets that Indonesia's export strategy in Chapter 3 is targeting, and delays elsewhere may either ease near-term competition for that demand or signal that the underlying commercial conditions, hydrogen cost and availability in particular, are harder to achieve on schedule than early announcements suggested.

It is worth noting more broadly that the direction of decarbonisation policy is not uniform across the countries in Table 5.3, or globally. Some jurisdictions are tightening carbon pricing, carbon border measures, and green procurement requirements, while others are delaying, scaling back, or reconsidering similar commitments. This affects the size of the addressable premium market, the availability of concessional finance, and the pace at which green steel projects elsewhere reach commercial operation, and should be read as a live risk factor rather than a settled trend when assessing Indonesia's own transition timeline.

Multilateral and bilateral development finance institutions have begun directing targeted financing toward low-carbon steel in Indonesia. IFC, for example, has entered an advisory engagement with one of Indonesia's leading steel producers to develop and implement a decarbonisation strategy, including assessment of financing options for the transition.
The emerging standard across DFIs is consistent: companies seeking concessional or development finance must demonstrate a credible decarbonisation pathway. Those without one are progressively excluded from the financing instruments that make large-scale industrial investment commercially viable.

CHAPTER 06

Policy opportunities for low-carbon steel

Under the accelerated scenario, Indonesia's steel-sector trade balance improves by US$8.2 billion above the no-policy baseline by 2050. This depends on domestic EAF producers building at commercial scale within a supportive policy framework. If Indonesia's energy transition and hydrogen programmes advance alongside steel decarbonisation, the gains, emissions cuts and competitive advantage will all be larger.

The policy recommendations below draw on the scenario modelling, but not every figure that follows is a direct model output. Some numbers, such as the modelled carbon price and the 35 and 70 per cent green procurement endpoints, come straight from the scenarios. Others, including the intermediate procurement milestones and technical thresholds set out in this chapter, are policy design choices intended to move the sector toward those modelled endpoints in a sensible order. Both types of number matter but they carry different weight, and this chapter tries to be clear about which is which.

Implementation follows one sequencing principle: within each policy stream, measurement comes before penalties, demand signals before mandates, trade protection before carbon costs. These rules apply within each stream, not between them; policies such as trade defence and demand activation, need to start simultaneously. The carbon price trajectory would ideally be announced early, even before it takes effect, since the trajectory itself, not the starting price, is what redirects 20- to 30-year capital decisions. This will enable producers and investors to see, years ahead, the rising cost of staying in BF-BOF against the falling cost of moving to DRI-EAF.

6.1 Trade defence: National standards, local content requirements and anti-dumping

In this report, industrial resilience refers to Indonesia's ability to set and enforce its own trade terms, and to reduce its exposure to a single volatile input — imported coking coal — rather than to a claim that the country will produce all the steel it needs domestically. The trade protection measures below are about levelling the playing field and protecting the domestic market, which is a narrower and more achievable goal.

It is recommended that the Indonesian Government advances three immediate trade defence priorities in parallel with the decarbonisation programme. These measures are not alternatives to decarbonisation. They are the protective architecture within which the decarbonisation investment casecan be built.

SNI National Standards: establishing a level playing field	Inconsistent enforcement of Indonesian National Standards (SNIs) can generate a structural cost asymmetry: domestic producers bear compliance costs that import competitors are not required to meet. This asymmetry distorts competition in the domestic market and needs to be addressed if carbon-transition incentives are to functionas intended.	→ Extend mandatory SNI coverage to all structural steel categories used in nationally funded infrastructure, with strengthened import inspection protocols and systematic product sampling at major entry ports. → From 2027, introduce mandatory carbon-intensity disclosure as a condition of SNI certification for steel imports. This builds the import-side data infrastructure required for a future border adjustment mechanism while immediately creating a market distinction between low-emission and high-emission imported steel.
TKDN: Local content requirements as an instrument of industrial sovereignty	Local content requirements (Tingkat Komponen Dalam Negeri or TKDN) have the capacity to convert Indonesia's substantial public infrastructure investment programme into a demand signal for domestic steel production and a driver of downstreaming across the value chain. Calibrating TKDN to reward low-carbon domestic production makes EAF investment more commercially attractive by guaranteeing a procurement advantage for verified green steel producers without requiring new legislation.	→ Extend mandatory SNI coverage to all structural steel categories used in nationally funded infrastructure, with strengthened import inspection protocols and systematic product sampling at major entry ports. → From 2027, introduce mandatory carbon-intensity disclosure as a condition of SNI certification for steel imports. This builds the import-side data infrastructure required for a future border adjustment mechanism while immediately creating a market distinction between low-emission and high-emission imported steel.
Anti-dumping: Building proactive border architecture	Global steel overcapacity reached 551 million tonnes in 2023 and is projected to reach 745 million tonnes by 2028[36]. Without a domestic carbon standard, Indonesia is structurally positioned to absorb the surplus that regulated markets are redirecting, at the expense of domestic producers who bear compliance and quality costs that import competitors do not.	→ Strengthen the anti-dumping investigation capacity of the Indonesian Trade Remedies Committee (KADI) through dedicated steel sector expertise and accelerated investigation timelines. The current average timeline of 14–18 months can be improved to protect the domestic market against rapid import surges in commodity markets. → Initiate a formal review of anti-dumping duty rates on steel product categories currently under import pressure. Update assessments to reflect current cost-of-production differentials and the embedded carbon cost advantage held by unregulated foreign producers relative to Indonesian domestic producers subject to SNI compliance requirements. → Introduce a mandatory import registration system for steel products, requiring importers to declare product specifications, country of origin, production route, and estimated carbon intensity at the point of entry. This registration system creates the import-side evidentiary base that a WTO-defensible border adjustment mechanism will require, building data capacity before rather than after the legal instrument is needed.

6.2 Demand activation: Government actions to activate the transition

Indonesia does not enter this transition from a standing start. A range of policy instruments, regulatory frameworks and institutional capabilities are already in place that can be activated or extended to support the four policy streams set out in this chapter: trade protection, demand activation, supply chain formalisation, and energy and renewable PPA frameworks, summarised in Table 6.1. No single ministry or agency holds sufficient authority to deliver any of these four streams in isolation The MRV registry, led by the Ministry of Industry, is a prerequisite for the GPP threshold administered by the National Public Procurement Agency (LKPP). The PPA template developed by the Ministry of Energy and Mineral Resource (MEMR) and PLN needs to be recognised by the Ministry of Industry for MRV accreditation purposes, and by LKPP for GPP eligibility, before it can serve as the bankable long-term contract that EAF investors require. Effective delivery requires coordination across institutions.

The three policy opportunities set out below the table describe practical implementation entry points. These milestones represent the on-ramp toward the full modelled scenario parameters: a five per cent GPP threshold commencing in the immediate term to build ahead of the modelled 2030 baseline; and a carbon price introduced by 2035 at US$25 per tonne of CO2 (gradual scenario), increasing to US$50 by 2050. GPP escalates in step with EAF capacity additions through the intermediate milestones in the model: 15 per cent by 2035, 25 per cent by 2040, 50 per cent by 2045, and 70 per cent by 2050 under the accelerated scenario.

TABLE 6.1: Government actions to activate the transition: Existing policy instruments, opportunities for advancement, and lead institutions

Policy instrument	What is in place	Opportunity to advance	Lead institution(s)	Basis for key figures
Carbon pricing (ETS + Carbon Levy) — Presidential Regulation (PR) 110/2025 (amending PR 98/2021)	Indonesia's consolidated carbon pricing framework: a mandatory cap-and-trade Emissions Trading System (ETS), a carbon levy, and offsetting, with IDX Carbon (IDXCarbon) operating as the trading and settlement platform. An ETS has been piloted for the power sector.	Extend the ETS to steel with a sector-specific cap, verified emissions baseline and price floor; set an inclusion timeline and escalating price trajectory to give investors long-term cost certainty and support CBAM compliance. Begin sectoral ETS design and stakeholder consultation for steel in the near term, ahead of full inclusion.	Ministry of Industry (lead), as per the sectoral decentralisation mandate under PR 110/2025, Ministry of Finance, Ministry of Environment and Forestry, OJK (Financial Services Authority)	US$25/tCO2 (gradual scenario) and US$50/tCO2 (accelerated scenario) are modelled parameters; early trajectory announcement is a policy recommendation.
NZE 2050 Industrial Decarbonisation Roadmap	Prescribes a restructuring of production mix: 70% BF-BOF → 70% DRI-EAF + 30% Scrap-EAF by 2050. Underpins all three scenarios.	Embed the 2027 DRI-EAF mandate into investment approval, guidance for state-owned enterprises (SOEs), and financing eligibility to unlock DFI engagement.	Ministry of Industry (lead), Ministry of SOEs, Ministry of Finance, Coordinating Ministry of Economic Affairs	70% DRI-EAF is a modelled parameter.
Renewable Energy Regulation, Government Regulation (GR) 112/2022 on Electricity Supply	Legal basis for renewable energy, including PLN's Dedicated Source mechanism for direct industrial renewable contracting.	Simplify Dedicated Source's price premium and grid resale terms; designate industrial estates with cleared Wilayah Usaha permits.	MEMR (lead), PLN, Ministry of Industry, LKPP	Existing regulation and mechanism; simplification and estate designation are policy recommendations.
National Hydrogen and Ammonia Roadmap	Projects steel-sector hydrogen demand of 850,000 tonnes by 2030, rising to 6.5 Mt by 2060; electrolyser capacity to 55 GW by 2060.	Launch a steel-sector hydrogen offtake framework (volumes, pricing, quality) to support financial close ahead of 2032.	MEMR (lead), Ministry of Industry, BAPPENAS, Ministry of Finance, PLN	Hydrogen penetration is recommended to be modelled for future analysis.
Green Public Procurement (GPP) Framework — Presidential Regulation 46/2025	Legal basis for environmental criteria in government procurement.	Define verified low-carbon steel and set a 5% GPP threshold, with a published reference price and audit mechanism to prevent premium mark-up; Indonesia's strongest near-term demand signal, no new legislation needed	LKPP (lead), Ministry of Industry, Ministry of Finance	35% and 70% 2050 endpoints are modelled parameters; the 5% start and interim milestones (15/25/50%) are policy recommendations.
JETP — Just Energy Transition Partnership (Power Sector Focus)	Framework for concessional climate finance, including blended finance and DFI co-financing.	Formalise a JETP extension to steel, reusing power-sector finance channels and mechanisms.	Ministry of Industry (lead), Ministry of Finance, Coordinating Ministry of Economic Affairs	Existing power-sector arrangement; extension to steel is a policy recommendation.
GISCO — Green Industry Service Company (Perusahaan Jasa Industri Hijau)	State-backed body linking producers, technology providers and green financiers.	Make GISCO the channel for a carbon-revenue-funded Transition Finance Facility, co-financing scrap hubs, renewable infrastructure, and a contract-for-difference or first-mover fund to de-risk early DRI-EAF investment.	Ministry of Industry (lead), Ministry of Finance, Coordinating Ministry of Economic Affairs	Existing institution; facility design is a policy recommendation, financing scale is to be estimated for future analysis.
RUKN — National Electricity General Plan	Long-term electricity planning: generation, grid, renewables to 2060.	Add an industrial cluster annex aligning grid/renewable investment with EAF demand.	MEMR (lead), PLN, Ministry of Industry, BAPPENAS	Existing plan; alignment with EAF demand is a policy recommendation.

Policy opportunity 1:
Define Green Public Procurement (GPP) thresholds and mandate Monitoring, Reporting and Verification (MRV) systems

IMMEDIATE **Establish the measurement foundation**

- It is recommended that the Ministry of Industry mandates investment-grade MRV systems for all steel producers above 500,000 tonnes per year of output, with verified data feeding into a central national steel emissions registry. This infrastructure simultaneously enables CBAM compliance, unlocks access to international green financing, and makes GPP eligibility credible.
- LKPP can exercise the authority provided under PR 46/2025 to define verified low-carbon steel at or below 1.2 tCO_2/tonne, declining to 0.4 tCO_2/tonne by 2035, and introduce a five per cent GPP threshold for nationally funded infrastructure contracts. LKPP can then publish an indicative reference price for verified low-carbon steel, updated annually, alongside an audit requirement for GPP-eligible contracts to guard against premium mark-up beyond the certified green cost differential.

This action represents the most powerful domestic demand signal for EAF investment available within the existing legislative framework. It functions as a technology procurement instrument: by engaging the government as an anchor offtaker for verified green steel, it reduces the revenue uncertainty that is currently the primary barrier to commercial financing of DRI-EAF projects.

GPP raises the cost of public procurement wherever green steel carries a premium. As the threshold rises, the government needs to be realistic about the scale of the resulting budget impact. Using the model's own parameters,[x] an illustrative estimate can be built. At current output (~18 Mt) and a 10 per cent public share, a 5 per cent GPP threshold requires ~90,000 tonnes of verified low-carbon steel, an indicative annual premium cost of ~Rp0.6 trillion. At the ACC scenario's 2050 output (~24 Mt) and a 70 per cent threshold, this rises to ~Rp11 trillion a year. These are illustrative, not budgeted figures, and should be refined into a proper fiscal costing before the higher thresholds are locked in as commitments.

NEAR TERM **Scale government demand alongside growing supply**

- It is recommended that LKPP escalates the GPP threshold to 15 per cent by 2035 and extend its application to subnational projects receiving above 40 per cent central government co-financing. The modelled trajectory continues to 25 per cent by 2040 and 50 per cent by 2045. These intermediate milestones are a policy design recommendation intended to keep government demand in step with EAF capacity additions, rather than a set of figures produced directly by the model. Throughout, the GPP threshold should rise in line with EAF capacity additions, not ahead of them, so that government demand encourages new investment rather than creating procurement obligations that cannot yet be met.
- The Ministry of Finance can require SOE construction companies to publish annual steel procurement carbon-intensity reports commencing in 2028, with a five per cent annual improvement target, creating a parallel demand channel across the broader public enterprise sector.

ONGOING **Sustain and lock in the competitive position**

In 2030, the MRV registry and import registration system will have generated two years of verified baseline data sufficient to support a WTO-defensible adjustment. At this point, it is recommended that The Ministry of Industry and LKPP introduce a carbon border safeguard on imported steel. LKPP can escalate GPP progressively, calibrated to EAF capacity additions and BF-BOF retirements, targeting 70 per cent of total publicly funded steel procurement by 2050, the modelled accelerated scenario endpoint.

[x]A government share of total steel demand of 10 per cent, and a green steel price premium of 50 per cent over the weighted average domestic steel price of roughly Rp 12.9 million per tonne

Policy opportunity 2:
Formalise the domestic scrap supply chain

The transition from BF-BOF to EAF is, above all, a decision about the resilience of Indonesia's input supply. BF-BOF depends on imported premium coking coal, a commodity whose price is set by international markets and whose supply is beyond domestic policy control. EAF depends on domestically available scrap steel generated by Indonesia's own industrial and construction activity, a material whose supply, price and quality are directly within reach of domestic policy. Formalising the domestic scrap supply chain turns this into an operational reality rather than a theoretical advantage, and it does so regardless of how far EAF's overall share of national output ultimately grows, generating geographically dispersed employment across the national economy along the way.

IMMEDIATE **Develop a national scrap traceability standard**

- The Ministry of Industry can develop and mandate a national scrap steel traceability standard covering product grades, contamination thresholds and chain-of-custody documentation requirements, developed in consultation with EAF producers and Indonesian scrap metal recycling industry associations.
- The Ministry of Finance can introduce financial incentives for processors certified by the National Standardisation Agency (BSN), including export levy exemption, accelerated depreciation on processing equipment, and preferential access to business lending.
- A monthly domestic scrap steel reference price published by the Ministry to Trade would provide price transparency that reduces the asymmetry currently exploited by informal intermediaries and improves supply chain visibility for green financing institutions.

NEAR TERM **Establish processing hubs and digital traceability**

- The Ministry of Industry could establish at least one certified scrap processing hub in each major steel cluster, co-located with EAF operations, to anchor regional scrap collection networks, and provide the sorting, testing and certification services that raise domestic scrap to MRV-eligible quality standards.
- Development of a national scrap supply-chain mapping programme, comprising a registry of certified collectors, processors and processing hubs, would provide the verifiable supply chain documentation that concessional financiers require before committing capital to EAF expansion.

ONGOING **Tie the scrap export levy to domestic content requirement**

- It is recommended that the Ministry of Trade replaces the current flat-rate scrap export levy with a sliding-scale mechanism linked to domestic EAF capacity utilisation rates, rising when mills are operating at high utilisation and competing for scrap supply, and declining when domestic demand is lower.
- LKPP and the Ministry of Finance could require verified domestic scrap to constitute a rising share of EAF charge materials, reaching defined thresholds by 2035, as a condition of GPP eligibility and access to concessional finance.

Policy opportunity 3: Establish a PPA framework for EAF renewable electricity

EAF already holds a structural energy cost advantage over BF-BOF under PLN's regulated tariff. Renewable electricity deepens this: it lowers the unit energy cost, generates the verified low-carbon credentials that CBAM, green financing and GPP require, and turns Indonesia's renewable resource into a lasting export advantage. As renewable penetration rises alongside EAF scale-up, costs fall faster, emissions intensity drops and export competitiveness improves further. GR 112/2022 already provides the legal basis for this. What activates it is not a new instrument, but making PLN's existing Dedicated Source mechanism bankable at EAF scale and clearing the site permitting that sits ahead of it.

IMMEDIATE **Provide a standard PPA template and regulatory clarity**

- MEMR and PLN could simplify PLN's Dedicated Source mechanism,[xi] which already lets industrial users contract directly for renewable power and has been used by at least one major offtaker. This could aim to address two problems: it costs a premium over the standard I-3 tariff[xii] (7–9 US cents/kWh versus approximately 6 US cents), and its terms for selling back excess generation are restrictive. Both need to be resolved before the mechanism is bankable at EAF scale.

[xi]PLN's Dedicated Source mechanism lets an industrial customer contract directly with a specific renewable power generator for supply, rather than draw from the standard grid mix.
[xii]I-3 is PLN's medium-voltage industrial electricity tariff category, covering customers with connected power above 200 kVA, the tier most EAF facilities would fall under.

- The Ministry of Industry, with regional governments, can identify industrial estates suited to EAF facilities and clear their Wilayah Usaha (electricity business area) permits. This permit is the precondition for any direct power arrangement; without it, even a well-designed PPA framework has nothing to attach to.
- Since electricity is EAF's second-largest cost after scrap, the Ministry of Industry can stress-test EAF viability across the real tariff range, 5–6 US cents (standard) to 7–9 US cents (Dedicated Source), to find the ceiling tariff at which investment stays financeable. This would tell the government how much effort to spend lowering Dedicated Source tariffs versus just using the standard rate for early projects.
- It is recommended that MEMR confirms that direct corporate PPAs, Dedicated Source, virtual PPAs, and PLN's green tariff programme all produce renewable energy certificates valid for MRV reporting and GPP eligibility. Removing this ambiguity is a precondition for unlocking private investment.

NEAR TERM **Cluster renewable energy and green hydrogen pilots**

- By developing collective renewable energy procurement frameworks for major steel industrial clusters, MEMR could enable pooled procurement that reduces per-facility capital costs, achieves generation and storage economies of scale, and creates a viable commercial model for co-located dedicated renewable energy providers.
- It is recommended that MEMR supports a pre-feasibility study for green hydrogen infrastructure at both major steel clusters and commits to a 5 to 10 MW demonstration electrolyser at one of them. This would generate the cost and logistics data DFIs require before committing capital, and brings down green hydrogen costs ahead of the 2032 DRI-EAF adoption window. The current modelling assumes no hydrogen penetration; investing in this infrastructure now is what unlocks the deeper emissions reductions and cost advantages that hydrogen-based DRI-EAF can deliver beyond what the scenarios already show.

ONGOING **Introduce carbon pricing as a transition accelerator[xiii]**

- By introducing a carbon price reaching US$25/tCO2 by 2050 under the gradual scenario and US$50/tCO2 under the accelerated scenario, with a pre-announced escalation schedule published at the point of introduction, the Ministry of Finance can provide the long-term investment certainty that changes 20- to 30-year capital allocation decisions. The trajectory, not the initial price level, is what redirects investment away from high-emission assets.
- The Ministry of Finance could direct carbon revenue to a dedicated Transition Finance Facility, channelled through GISCO, co-financing scrap hubs, renewable infrastructure and transition planning support for producers. Within this facility, GISCO can scope a carbon contract-for-difference or first-mover innovation fund to directly de-risk early DRI-EAF investment ahead of carbon pricing and GPP demand reaching scale, piloted with one or two anchor projects before wider rollout. This would ensure that producers see the carbon price as a source of transition funding, with a clear, government-backed route to support that doesn't rely on procurement demand alone.

[xiii]A project-level assessment of financing capacity, covering capital expenditure, operating expenditure, expected margins, and debt service capacity under each scenario, is recommended as a companion study before major capital commitments are made on the strength of this report alone.

Conclusion

Under the accelerated scenario, Indonesia's steel-sector trade balance improves by US$8.2 billion above the no-policy baseline by 2050. This depends on domestic EAF producers building at commercial scale within a supportive policy framework, which in turn depends on two conditions holding simultaneously.

First, the domestic market must not be continuously disrupted by underpriced imports, principally the Chinese steel exports that reached 118 million tonnes in 2024 and have already triggered a fivefold rise in OECD anti-dumping measures; this is addressed below by trade defence, carbon pricing, and continued export-side engagement in the EU and China, not import protection alone, and is deliberately time-bound rather than a permanent feature.

Second, the policy environment needs to give EAF and DRI-EAF investment the long-term certainty it requires. This is addressed jointly by the demand-signal, energy and carbon-pricing streams set out in the table below, and by direct instruments that reduce the green premium's cost for early movers rather than leaving that to procurement policy alone. If Indonesia's energy transition and hydrogen programmes advance alongside steel decarbonisation, the gains, emissions cuts and competitive advantage will all be larger.

The policy framework in Chapter 6 is calibrated to Indonesia's institutional and regulatory architecture, activating instruments that already exist: PR 46/2025 for green procurement, GR 112/2022 for renewable PPAs, PR 110/2025 for carbon pricing, and the existing Ministry of Industry mandate for MRV.

STREAM	IMMEDIATE	NEAR-TERM	ONGOING
Measurement (MRV)	Mandate MRV for producers >500kt; establish emissions registry	Extend to full supply chain; link to import registration	Underpins border adjustment and GPP eligibility
Demand signals (GPP)	Define low-carbon steel (explicit emissions-intensity threshold) and set 5% GPP threshold under PR 46/2025; publish reference price and audit mechanism to prevent premium mark-up	Escalate to 15% by 2035; extend to subnational co-financed projects	Escalate to 70% by 2050 in step with EAF capacity additions
Trade defence	Strengthen SNI enforcement; initiate import registration; build KADI capacity; set a defined grace period and performance standards for protection measures	Carbon-intensity disclosure as SNI condition; tiered TKDN multiplier	WTO-defensible border adjustment from 2030 on verified MRV data; protection measures loosen progressively as domestic MRV/GPP infrastructure matures
Market access (export-side)	Formalise MRV data-sharing to support CBAM alignment; continue engagement with EU and China on verified low-carbon credential recognition	Pursue trade arrangements (e.g., FTA-linked sourcing provisions) supporting import substitution in contract-bound segments (e.g., automotive)	Sustained EU and Asia-Pacific market positioning as a verified low-carbon supplier
Supply chain (scrap)	Set national scrap traceability standard and incentives; monthly reference price	Processing hubs in industrial precinct, digital traceability registry	Export levy tied to domestic EAF utilisation
Energy (PPA/H_2)	Simplify Dedicated Source terms; designate EAF-ready industrial estates and clear Wilayah Usaha permits	Cluster renewable procurement frameworks; green hydrogen pre-feasibility study	Full renewable integration for EAF; H_2-DRI commercial deployment
Carbon price (ETS + levy)	Announce trajectory and escalation schedule; begin sectoral ETS design and consultation for steel	Begin at low initial level as MRV data matures	US$25/t$CO_2$ or US$50/t$CO_2$ by 2050; revenues to Transition Finance Facility
Direct investment support	Scope a carbon contract-for-difference or first-mover innovation fund via GISCO to de-risk early DRI-EAF investment directly	Pilot the facility with one to two anchor projects, co-financing scrap hubs and shared renewable infrastructure	Transition Finance Facility fully operational, funded by carbon price revenues
Just transition	Identify and map affected workers in industrial precinct	Workforce transition plans as condition of transition finance; retraining partnerships	Community Transition Fund; siting of scrap hubs favours affected areas

Crucially, it begins with the industry's present crisis. The transition is not an additional burden on a struggling sector. It is the pathway through which the sector exits the structural trap that is causing it to struggle.

That framework depends on the two conditions set out in Chapter 6: durable protection against underpriced imports, achieved through trade defence, carbon pricing and market access rather than import protection alone; and long-term investment certainty for EAF and DRI-EAF, delivered jointly by the demand-signal, energy, carbon-pricing and direct investment-support streams below.

The numbers make the economic case plainly. The accelerated scenario delivers approximately US$34 billion in cumulative welfare gains, an annual improvement of US$8.2 billion in the steel-sector trade balance, and secondary steelmaking labour demand 64 per cent above the no-policy baseline by 2050. These are not environmental outcomes dressed in economic language: they follow directly from moving to a production model that runs on domestic inputs, competes on verified credentials, and attracts financing from institutions reshaping global industrial capital.

For individual producers, those investing in DRI-EAF and EAF capacity today are building assets that will be more cost-competitive, more financeable, and more accessible to premium market segments as global trade conditions evolve. By contrast, those continuing to invest in BF-BOF face a 20- to 30-year time horizon that increasingly conflicts with the direction of international trade, finance and regulation.

Indonesia's steel demand will grow whether or not this transition happens. Policy decisions taken now will determine whether that growth goes to high-emission or low-carbon capacity, on Indonesia's own terms and timing, or reactively, at higher cost and with fewer options. Confirming the scale of the economic case at the confidence needed for major investment decisions requires the demand-led and project-level work set out above.

Recommendations for future study

Consolidating the limitations noted throughout this report, the following extensions would most strengthen the evidence base made on this study alone:

- An independently derived national steel demand projection, with a full production, import and export balance by scenario.
- A dedicated Input-Output disaggregation of DRI-EAF, replacing the BF-BOF proxy currently used.
- A project-level techno-economic and financing-capacity study, covering capital expenditure, operating expenditure, margins, return on investment, and debt-service capacity for domestic producers under each technology route.
- A carbon steel/stainless steel disaggregation of the trade model, and a landed-cost comparison of imported HBI against domestic DRI capacity.
- A supplier- and mechanism-level analysis of Indonesia's projected EU and China export gains, distinguishing growth in destination-market demand from displacement of specific competing suppliers.
- A review of contract-structure barriers to import substitution in captive supply chains (e.g., long-term offtake or local-content arrangements in automotive steel procurement), and the trade-policy instruments, such as FTA-linked sourcing provisions, that might address them.

Appendix

Literature Review

Decarbonisation and macroeconomic growth

A growing body of empirical and modelling literature examines the relationship between decarbonisation trajectories and macroeconomic performance, though findings vary considerably depending on context, technology assumptions and policy design. Chen et al. (2025) investigate decarbonisation pathways across G7 economies, finding that integrating renewable energy with globalisation and coherent policy frameworks is essential to sustain economic growth during the low-carbon transition. Their cross-country analysis underscores that decarbonisation is not inherently growth-reducing but is highly sensitive to how transition policies are sequenced and calibrated. A similar conclusion emerges from Khadka et al. (2025), who document the nexus between carbon emissions, economic growth and energy transition in Nepal, finding that decarbonisation pathways can yield growth co-benefits when supported by appropriate institutional frameworks. For advanced economies, Chung and Kim (2024) address the 'greenflation' hypothesis – the concern that decarbonisation policies systematically raise the general price level – using panel data from 26 OECD countries. Their empirical evidence finds little support for persistent greenflation, suggesting that the inflationary effects of the energy transition are transient rather than structural, a finding that bears directly on the inflation dynamics modelled in the present study.

These cross-country findings establish that decarbonisation and growth are compatible under well-designed policy. Still, they cannot be directly applied to an industrial transition in a developing economy without sector-specific modelling. The present study addresses this by focusing on Indonesia's iron and steel sector through a CGE and IO framework calibrated to national conditions.

CGE modelling of industrial decarbonisation

Computable General Equilibrium (CGE) modelling is the established methodology for assessing the economy-wide effects of industrial decarbonisation, because it captures simultaneous adjustments in prices, factor markets and trade flows across sectors and regions. Huang et al. (2020) apply a CGE framework to analyse the role of bioenergy with carbon capture and storage (BECCS) in deep decarbonisation of the Chinese economy, demonstrating that CGE models can incorporate complex technology substitutions and their knock-on macroeconomic effects within a consistent general equilibrium structure. Their work establishes important methodological precedents for modelling transitions in carbon-intensive sectors in the context of a large emerging economy. Zhou et al. (2025) advance this methodology further by combining deep learning with a dynamic CGE model to analyse multi-energy synergy and deep carbon emission reduction mechanisms specifically for steel enterprises, demonstrating how process-level technical detail can be integrated into macro-level economic simulation; a modelling ambition that shares common ground with the Global Trade Analysis Project (GTAP) Circular Economy (GTAP-CE) disaggregation approach adopted in this study.

For the steel sector specifically, Vercoulen et al. (2023) simulate carbon-neutral steel production pathways and their macroeconomic impacts across China, Japan and Korea using the E3ME-FTT: Steel model. Their results show that deep decarbonisation exceeding 80 per cent emission cuts, when supported by both incentive and penalty policies, is compatible with modest GDP gains of 0.8 per cent (China), 1.3 per cent (Japan), and 0.1 per cent (Korea) by mid-century – a finding that supports the hypothesis, tested in the present study, that steel decarbonisation can be macroeconomically positive under the right policy conditions.

Macroeconomic and trade implications of steel decarbonisation

The macroeconomic implications of switching from carbon-intensive to low-carbon steelmaking have been most extensively studied in European contexts. Mayer et al. (2019) examine the macroeconomic consequences of transitioning to process-emission-free iron and steel production in Europe, finding that the timing and cost of low-carbon technology deployment is the decisive variable. Under scenarios where low-carbon technologies remain costly, early adoption reduces long-run GDP in EU steel-producing regions by up to 2.3 per cent by 2050. It widens the range of adverse outcomes compared with a delayed transition. However, if low-cost technologies become available, the 2050 GDP impact narrows substantially to between −0.3 and 0.9 per cent, with much lower sensitivity to the timing of adoption. This finding – that technology cost trajectories, not transition timing per se, are the central determinant of macroeconomic outcomes – is directly relevant to Indonesia's scenario design, particularly regarding the trajectory of green hydrogen and renewable electricity costs.

Mayer et al. (2019) also highlight that welfare losses from steel decarbonisation are front-loaded: the heavy investment required to build new low-carbon assets crowds out other consumption during the build-up phase, creating short-term to medium-term wellbeing costs even when long-run GDP effects are modest. Furthermore, the long investment horizon – extending beyond a human generation – raises intergenerational equity concerns, since the cohort bearing the bulk of transition costs may not fully realise the long-term benefits. The present study's finding that the accelerated scenario's incremental GDP premium above the no-policy counterfactual peaks around 2040 before narrowing is consistent with this front-loading dynamic: the initial investment surge generates the largest above-counterfactual gains in the near term, while the rising carbon price burden in the post-2040 phase compresses the net premium. Rinaldi et al. (2024) complement the macroeconomic perspective through a hybrid Input-Output model of the EU steel sector, finding that decarbonisation strategies have heterogeneous environmental and market impacts depending on the technology mix chosen, with 25 to 56 per cent increases in steel prices by 2050 that could reshape global competitiveness and trade flows. This price trajectory underlines the commercial importance of CBAM alignment and MRV verification systems for market access, themes central to Chapter 3 of the present report.

Labour market transitions and spatial restructuring

The employment consequences of steel decarbonisation are characterised in the literature by a consistent pattern: aggregate employment may be maintained or even rise across the broader economy, but significant local and sectoral dislocation occurs at the plant and community levels. Miles et al. (2025) simulate the regional workforce impacts of decarbonising integrated steelmaking in the US, finding that the transition from BF-BOF to DRI-EAF and scrap-EAF can sharply reduce on-site steel employment at existing plants, with new low-carbon facilities requiring only approximately 25 per cent of the workforce of the integrated plants they replace. Critically, the main barrier to redeployment is not workers' fundamental capability but skills alignment: approximately 85 per cent of occupations in the steel sector are constrained by skills gaps relative to the requirements of new low-carbon processes, rather than by any lack of basic ability. This finding has direct implications for workforce transition policy in Indonesia's steel clusters, where Cilegon and Morowali host large BF-BOF workforces whose retraining needs should be planned in advance of capacity shifts.

While and Eadson (2022) situate steel decarbonisation within a broader framework of spatial economic restructuring, arguing that zero-carbon transitions redistribute industrial activity across regions, creating both winners and losers at the subnational scale. Communities anchored to coal-based steelmaking lose not only direct employment but also the upstream and downstream economic activity generated by integrated steel complexes, while new low-carbon industrial hubs and supply-chain clusters emerge elsewhere. In economies with high coal dependency – a category that includes Indonesia – job losses in coal mining compound the displacement effects in primary steelmaking, creating concentrated regional vulnerabilities that aggregate national employment statistics conceal. The present study's IO multiplier analysis, which traces employment effects through both the BF-BOF and EAF sub-sectors and their respective supply chains, is designed to surface precisely these distributional dimensions that headline employment figures would otherwise obscure.

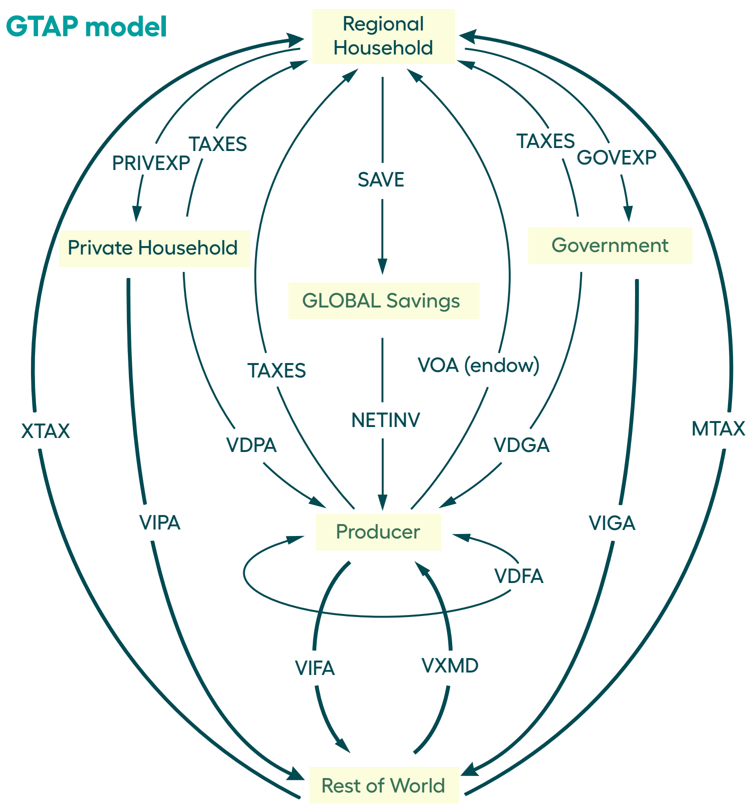
Taken together, the literature establishes three propositions that frame this study. First, steel decarbonisation is macroeconomically feasible – GDP and welfare outcomes are positive under favourable technology cost and policy conditions, but distributional and timing dimensions are critical. Second, CGE and IO modelling provide complementary validated tools for quantifying economy-wide effects, provided the model is disaggregated to capture sub-sectoral technology shifts. Third, the labour market transition requires active policy management, particularly regarding skills gaps and regional restructuring. No previous study applies this integrated framework to Indonesia's steel sector across multiple scenarios calibrated to national roadmap targets, the gap this study fills.

Methodology

Model framework: Global Trade Analysis Project (GTAP)
To analyse the impact of iron and steel decarbonisation, this study employs the Global Trade Analysis Project (GTAP) Circular Economy Model (GTAP-CE) as the primary analytical framework. GTAP is a multi-regional Applied General Equilibrium (AGE) model designed to capture world economic activity across all major industries and regions simultaneously. The model is grounded in neoclassical economic theory; it assumes that producers and consumers optimise subject to resource and budget constraints, with markets clearing through price adjustments.

Standard GTAP architeacture
The standard GTAP database comprises 65 sectors and 163 regions (145 individual countries and 18 composite regions), providing a comprehensive representation of global trade and production linkages.

FIGURE A.1: GTAP model



Source: Brockmeier (2001)

As illustrated in Figure A.1, the circular flow of the GTAP model connects four primary agents:

- Regional household: aggregates income from factor endowments, taxes, and transfers, allocating expenditure to private households, government, and global savings.
- Private household: maximises utility subject to a budget constraint, with private expenditure financed by the regional household.
- Government: receives government expenditure from the regional household, purchasing domestically produced and imported commodities.
- Producer: combines primary factors (land, labour, capital, natural resources) with intermediate inputs from domestic and foreign sources to produce output

Trade flows are represented by import and export variables (VXMD, VIFA) with associated taxes (XTAX, MTAX), while value-added components (VDPA, VDGA, VDFA, VIGA, VIPA) [50] capture the distribution of production value across agents. Global savings are intermediated through the GLOBAL Savings bank, which finances net investment (NETINV) across regions.

GTAP Circular Economy Model (GTAP-CE)
Building on the standard GTAP database, GTAP-Power disaggregates the electricity sector into energy-source-based categories, expanding the sector count to 76. This extension enables more granular analysis of electricity-generation technologies and their cost structures, which is particularly relevant for modelling energy transition pathways in energy-intensive industries such as iron and steel production. The GTAP-CE further extends GTAP-Power to 95 sectors by disaggregating metal ore mining, rubber and plastic products, ferrous metals and non-ferrous metals into 23 new sub-sectors. This disaggregation is critical for capturing the distinct production technologies, input structures and emissions profiles within the iron and steel industry. The ferrous metals sector is split into four sub-sectors:

- Iron and Steel Primary, representing blast furnace–basic oxygen furnace (BF-BOF) production from virgin iron ore inputs.
- Iron and Steel Secondary, representing electric arc furnace (EAF) production from scrap-based inputs.
- Recycling Iron and Steel, capturing end-of-life scrap collection and processing activities.
- Iron and Steel Casting, representing downstream forming and casting operations.

This sectoral disaggregation allows the model to simulate policy-driven shifts between production technologies (e.g., from BF-BOF to DRI-EAF) with full representation of their differential input requirements in coal, natural gas and electricity.

[50] VXMD is the value of exports at market prices by destination. VIFA is the value of import purchases by firms, at agents' prices. XTAX and MTAX are export tax and import tax revenue, respectively. VDPA, VDGA, and VDFA are the values of domestic purchases at agents' prices by private households, government, and firms respectively; VIGA and VIPA are the corresponding values of import purchases at agents' prices by government and private households

Decarbonisation scenarios

Three policy scenarios are constructed to represent alternative trajectories for the decarbonisation of Indonesia's iron and steel sector over the period 2025–2050. The scenarios are calibrated in five-year intervals (2030, 2035, 2040, 2045, 2050) and differ in the pace and stringency of policy implementation.

TABLE A.1: Summary of decarbonisation scenarios

	BAU – Business as usual	GRT – Gradual transition	ACC – Accelerated transition
Carbon price trajectory	No new policy beyond the existing baseline; BF-BOF remains dominant.	Implementation at 50% of the accelerated rates; incremental EAF adoption with partial natural gas shift.	Full strategy implementation with rapid EAF scale-up and higher-value carbon pricing enforced.
Process share (BF-BOF)	~53% throughout	Partial phase-down	Full phase-out by 2045
Carbon pricing (2050)	None	US$25/tonne CO_2	US$50/tonne CO_2
Green procurement (2050)	None	35%	70%
EAF scale-up	None	Partial	Full by 2045+

Business as usual (BAU)

The BAU scenario represents a counterfactual baseline in which no new decarbonisation policies are introduced. The iron and steel sector continues to rely on BF-BOF technology, which accounts for approximately 53 per cent of total production. There is no carbon pricing signal, no moratorium on new BF-BOF investments, and no green procurement mandate. Only autonomous efficiency improvements consistent with the existing trajectory are incorporated.

Gradual transition (GRT)

The GRT scenario implements all decarbonisation strategies at 50% of the rates specified in the ACC strategy matrix (Table A.2). Carbon pricing is introduced by 2035, reaching US$25 per tonne of CO_2 by 2050. EAF adoption increases incrementally, accompanied by partial natural gas substitution. Green procurement policy supports 35% green steel demand from the government by 2050.

Accelerated transition (ACC)

The ACC scenario reflects full implementation of all strategies in the strategy matrix. Carbon pricing rises progressively to US$50 per tonne of CO_2 by 2050. A moratorium on new BF-BOF plants is enforced from 2030, and existing capacity is phased down toward DRI-EAF by 2040–2045. Government green procurement reaches 70 per cent of total steel demand by 2050. This scenario represents the most ambitious feasible decarbonisation trajectory consistent with Indonesia's long-term climate commitments.

Decarbonisation strategies and implementation rates

Five categories of decarbonisation strategies are modelled, each operationalised through technology-specific parameters applied to the GTAP-CE production structure. The full implementation rates under the accelerated scenario are presented in Table A.2.

TABLE A.2: Full implementation rates under the accelerated (ACC) scenario

CATEGORY	STRATEGY	2025	2030	2035	2040	2045	2050
Energy & material efficiency	New plant	0%	100%	100%	100%	100%	100%
	Old plant	0%	80%	100%	100%	100%	100%
Fuel & material substitution	Partial biofuel/H_2in BF-BOF & EAF	0%	0%	4%	4%	15%	72%
Process improvement	Moratorium on new BF-BOF	0%	100%	100%	100%	100%	100%
	BF-BOF phase down → DRI-EAF & scrap-EAF	0%	0%	10%	60%	100%	100%
Green procurement	Government green steel policy	0%	5%	15%	30%	50%	70%
Carbon pricing	Carbon price in Indonesia (US$/tonne CO_2	0	10	20	30	50	50

Energy and material efficiency

Efficiency improvements are applied differentially to new and existing (old) plants. For new plants, a 20 per cent efficiency gain (relative to the 2025 baseline) is assumed, consistent with best-available technology benchmarks from IEA (2020). Old plants are assigned a 10 per cent efficiency gain to reflect retrofit constraints. Under the ACC scenario, new plants achieve full efficiency adoption from 2030 onward, while old plants reach 100 per cent adoption by 2035, with an 80 per cent rate assumed at 2030 to reflect staggered retrofitting.

Fuel and material substitution

Partial substitution of coal with biofuels and green hydrogen (H_2) in BF-BOF and EAF processes is modelled. A 10 per cent coal penalty is applied to reflect the energy content disadvantage of biofuel blending, while a 10 per cent biofuel substitution rate is assumed as per Fan & Friedmann (2021). Under ACC, the substitution share rises to 72 per cent by 2050, reflecting accelerated hydrogen deployment consistent with a net-zero pathway.

Process improvement: BF-BOF phase-down
A moratorium on new BF-BOF capacity investments takes effect from 2030 in both GRT and ACC scenarios. Concurrently, existing BF-BOF capacity is progressively converted to DRI-EAF and scrap-EAF routes. The conversion schedule follows the new plant capacity share schedule (Table A.4) and the sub-sector production shares. This shift entails substantial changes in input coefficients: coal usage falls by 98 per cent, natural gas usage increases by 350 per cent, and electricity consumption rises by 400 per cent relative to the BF-BOF baseline (Zang et al., 2023).

Green procurement
A government green steel procurement mandate is simulated by adjusting the government agent's import demand to favour green steel products (iron and steel secondary and recycled categories). The government's share of total steel demand is calibrated at 10 per cent from the GTAP database. A 50 per cent green steel price premium is applied, consistent with Rahbari et al. (2025), representing the additional cost of low-carbon steelmaking that the procurement policy is designed to absorb.

Carbon pricing
An economy-wide carbon price on iron and steel production is introduced as a production tax shock in GTAP-CE, applied to CO_2-equivalent emissions from fossil fuel combustion in primary steelmaking. The tax rate rises progressively from US$10/tonne in 2030 to US$50/tonne by 2050 under ACC, and to US$25/tonne by 2050 under GRT. The carbon price signal induces substitution away from coal-intensive BF-BOF production and incentivises investment in EAF and DRI technologies.

Key assumptions and parameters
The quantitative implementation of the scenarios relies on a set of technology and behavioural parameters drawn from the peer-reviewed literature and industry sources. Table A.3 summarises the core parameter values.

TABLE A.3: Model parameters

PARAMETER	VALUE	SOURCE
Energy & material efficiency gain – new plant	20%	IEA (2020)
Energy & material efficiency gain – old plant	10%	IEA (2020)
Fuel substitution – coal penalty	10%	Fan & Friedmann(2021)
Fuel substitution – biofuel	10%	Fan & Friedmann(2021)
EAF efficiency gain (scaling effect)	15%	Prime Metals (2026)
Coal usage reduction (BF-BOF → DRI-EAF)	98%	Zang et al. (2023)
Gas usage increase (BF-BOF → DRI-EAF)	350%	Zang et al. (2023)
Electricity increase (BF-BOF → DRI-EAF)	400%	Zang et al. (2023)
Government share of total steel demand	10%	GTAP database
Green steel price premium	50%	Rahbari et al. (2025)

New plant capacity share schedule
The share of total sectoral capacity attributed to new plants increases progressively from 5 per cent in 2025 to 100 per cent by 2050 for both primary and secondary steelmaking, as shown in Table A.4. This schedule determines the weighted average application rate of efficiency parameters: new plant parameters apply to the new-plant share, and old plant parameters apply to the residual share.

TABLE A.4: New plant capacity share schedule

SECTOR	2025	2030	2035	2040	2045	2050
Primary steelmaking (% of total)	5%	20%	35%	55%	80%	100%
Secondary steelmaking (% of total)	5%	20%	35%	55%	80%	100%

BF-BOF to DRI-EAF transition schedule
Within primary steelmaking, the sub-sector shares of BF-BOF and DRI-EAF production evolve according to the phase-down schedule in Table A.5, reflecting the process improvement strategy outlined in the previous section. Under ACC, DRI-EAF reaches 100 per cent of primary steelmaking output by 2045.

TABLE A.5 BF-BOF to DRI-EAF transition schedule

SUB-SECTOR	2025	2030	2035	2040	2045	2050
Primary steelmaking (% of total)	100%	80%	65%	45%	0%	0%
Secondary steelmaking (% of total)	0%	20%	35%	55%	100%	100%

Demand projections are scaled by population growth estimates drawn from Badan Pusat Statistik (2023), Indonesia's national statistics agency. Population is accumulated from the base year of 2025, with projected growth rates of 4.58 per cent by 2030, 8.51 per cent by 2035, 11.58 per cent by 2040, 14.06 per cent by 2045, and 15.78 per cent by 2050. These figures enter the model as exogenous demand shifters for steel-consuming sectors.

Simulation design and shock implementation
The model is calibrated to the 2025 benchmark year and solved recursively across five projection years (2030, 2035, 2040, 2045, 2050). At each projection year, scenario-specific policy shocks are introduced as deviations from the BAU baseline. All shocks are applied simultaneously within each projection year simulation, and results are reported as percentage deviations from the BAU scenario for key macroeconomic aggregates including real GDP, household welfare (equivalent variation), sectoral output, trade flows and factor returns.

Scope and limitations
Several limitations of this analytical framework should be noted. GTAP is a comparative-static model solved at discrete benchmark years, so it does not capture dynamic adjustment costs or investment lags between periods. The model assumes that markets clear instantaneously at each benchmark year, which may overstate the speed of structural adjustment in practice. The Input-Output coefficients used to parameterise technology transitions are drawn from engineering studies that may not fully reflect Indonesia-specific conditions. And the model does not endogenise innovation or learning-by-doing effects that could lower the cost of green technologies over time, so decarbonisation costs in later periods may be somewhat overstated.

Four further limitations, already flagged at the relevant points in the main text, are consolidated here:

- First, on demand: the scenarios model differences in technology route, trade flows and domestic supply mix against population growth as the demand driver, not an independently derived projection of Indonesia's total long-run steel requirement from construction, infrastructure, manufacturing, and per-capita consumption growth. A dedicated demand projection of this kind, together with a full domestic production, import and export balance by scenario, is recommended for future study.

- Second, on the source of the modelled gains: the BF-BOF and EAF output multipliers differ by only 2.3 per cent, and the employment multipliers by a similar 2.4 per cent (see Chapter 2.3). Most of the reported GDP, welfare and employment gaps between BAU and the transition scenarios therefore reflect the scale of investment and output assumed under each scenario, not a large multiplier advantage for EAF.

- Third, on DRI-EAF: the national Input-Output table identifies two ferrous metal routes, BF-BOF and EAF, with no separate DRI-EAF sector. Since DRI-EAF becomes the dominant route in the 2050 target mix under both transition scenarios, its output, income and employment effects are approximated using the BF-BOF multiplier, consistent with GTAP-CE's classification of DRI-EAF within Primary Steel (see Chapter 4.2). Results built on this proxy should be read as indicative rather than precise. A dedicated Input-Output disaggregation of DRI-EAF, replacing this proxy, is a priority for future research.

- Fourth, on policy design: BAU, GRT and ACC each combine carbon pricing, green public procurement and the BF-BOF moratorium simultaneously; the scenarios were not run with each instrument isolated. GRT and ACC results should be read as the effect of this policy package as a whole, not as evidence that EAF or DRI-EAF is commercially superior to BF-BOF without policy support. Isolating each instrument's individual contribution through additional model runs is a further priority for future research.

Not withstanding these limitations, the GTAP-CE framework provides a rigorous and internally consistent basis for evaluating the economy-wide impacts of iron and steel decarbonisation policies in Indonesia.

Model framework: Input-output analysis of steel decarbonisation
This appendix explains the methodology used to estimate how steel decarbonisation affects the economy (output and income) and employment in Indonesia. The analysis uses the national Input-Output table 2020 from Badan Pusat Statistik (BPS) and follows three main steps. First, the BPS IO table treats iron and steel as one sector; hence, the disaggregation procedure is applied to split it into two production routes, namely BF-BOF and EAF. Second, the disaggregated table is used to calculate output, income and employment multipliers for each route. Third, demand shocks (percentage output change) from GTAP simulations are converted into Rupiah values and applied to the multiplier framework to estimate the economy-wide impact. The analysis covers three scenarios across 2030 to 2050: business as usual, gradual decarbonisation, and accelerated decarbonisation.

1. Input-Output table disaggregation

In the original IO table, the iron and steel sector is identified under sector number 114, Iron and Steel (Besi dan Baja Dasar). Sector 114 also includes scrap, as well as remelting scrap from iron or steel. Input-Output table disaggregation will be done to the row (output distribution) and column (input distribution) of sector 114.

1. 1 Row disaggregation (output distribution)
Row disaggregation determines how the output of each sub-sector (BF-BOF and EAF) is distributed across all purchasing sectors in the economy. This is done by applying the output share of each technology route as the allocation weight, derived from GTAP. BF-BOF accounts for 52.57 per cent of total steel output, while EAF accounts for the remaining 47.43 per cent. This approach rests on the assumption that the steel consumed by each purchasing sector is sourced proportionally from BF-BOF and EAF in line with their respective shares in national steel output. Under this assumption, the aggregate steel row in the IO table is disaggregated into two rows by applying these shares uniformly across all purchasing sectors.

1. 2 Column disaggregation (input distribution)
Column disaggregation determines how much of each selling sector's output is purchased by each steel sub-sector. Unlike row disaggregation, the allocation across columns follows three distinct rules depending on the type of input.

- First, inputs exclusive to BF-BOF, which are coal and iron ore, are assigned entirely to BF-BOF at 100 per cent.

- Second, inputs shared by both technology routes, i.e. scrap and electricity, are allocated based on technology-specific input intensity ratios derived from the literature. The intensity values are as follows. For scrap, BF-BOF requires 0.13 tonnes/tonne steel (World Steel, 2023) and EAF requires 1.04 tonnes/tonne steel (LBNL, 2024). For electricity, BF-BOF requires 200 kWh/tonne steel (Tian et.al, 2025) and EAF requires 600 kWh/tonne steel (Cappel, 2021).

  To convert these intensity ratios into national-level allocation shares, the values are weighted by total domestic production volume for each route, using total steel produced from CREA (2024) and Global Trade Analysis Project - Social Accounting Matrix (GTAP SAM) share of steel technology, which resulted in 10.4 million tonnes for BF-BOF and 9.3 million tonnes for EAF. This yields allocation shares of 11.76 per cent for BF-BOF and 88.24 per cent for EAF for scrap, and 26.98 per cent for BF-BOF and 73.02 per cent for EAF for electricity.

- Third, all remaining input sectors are split using the same output shares applied in the row disaggregation, that is 52.57 per cent for BF-BOF and 47.43 per cent for EAF.

2. Input-Output table multiplier calculation

The multiplier analysis in this study follows the standard Input-Output framework to estimate the economy-wide effects of changes in steel sector output under each decarbonisation scenario. Three types of multipliers are calculated.

2.1 Output multiplier

The output multiplier measures the total increase in production across all sectors of the economy resulting from a one-unit increase in final demand for a given sector. It is derived by summing the column elements of the Leontief inverse matrix corresponding to that sector. The output multiplier for sector j is formally expressed as:

$$O_j = \sum_{i=1}^{n} \alpha_{ij}$$

where α_{ij} is (i, j) element of the Leontief inverse matrix $(I - A)^{-1}$.

2.2 Income multiplier

The income multiplier captures the effect of a change in final demand on household income. When final demand increases, output across related sectors rises, which in turn increases demand for labour and therefore wages. The income multiplier is calculated by multiplying the wage coefficient of each sector (the ratio of wages and salaries to total input) by the corresponding output multiplier. If the household income multiplier for sector j is denoted as H_j, it can be expressed as:

2. Input-Output table multiplier calculation

$$H_j = \sum_{i=1}^{n} \alpha_{n+1,j} \times \alpha_{ij}$$

where $\alpha_{n+1,j}$ is the coefficient of labour income of sector i.

2.3 Employment multiplier

The employment multiplier, also referred to as the employment effect, estimates the total change in employment across the economy resulting from a one-unit increase in final demand in a given sector. It is calculated by multiplying each sector's labour coefficient, defined as the number of workers required per unit of output, by the corresponding element of the Leontief inverse and summing across all sectors. The employment effect for sector j is expressed as follows:

$$E_j = \sum_{i=1}^{n} l_i \alpha_{ij}$$

where $l_i = L_i / X_i$ is the labour coefficient of sector i, and α_{ij} is (i, j) element of the Leontief inverse matrix $(I - A)^{-1}$.

In the context of this analysis, these three multipliers are applied to the monetary shock derived from GTAP output changes to estimate the direct and indirect impacts of steel decarbonisation on national output, household income, and employment across the three scenarios and time periods examined.

3. Shock calculation using GTAP output change

The demand shock applied in the Input-Output analysis is derived from GTAP CGE model simulations, which report the percentage change in sectoral output (qo) under each decarbonisation scenario relative to the business-as-usual (BAU) baseline. The following steps describe how the monetary shock value is calculated.

3.1 Calculating the baseline output in 2025

The baseline output for each technology route in 2025 is projected using historical production data from the Steel Statistical Yearbook (World Steel, 2021–2022). Historical output data for OBC (Oxygen Blown Converter/BF-BOF) and EF (Electric Furnace/EAF) are recorded from 2017 to 2022 due to data limitations. The observed values for the two latest years are as follows:

	2021	2022
BF-BOF/OBC (Oxygen Blown Converter)	10,400	10,910
EAF	4,440	4,660
Total	14,840	15,570

The year-on-year growth rates derived from this historical data are 4.90 per cent per year for BF-BOF/OBC and 4.95 per cent per year for EAF. Applying these growth rates to project output forward to 2025 yields the baseline values. BF-BOF projected output in 2025 is 12,595 thousand tonnes and EAF projected output is 5,388 thousand tonnes, which resulted in total steel output of 17,983 thousand tonnes.

3.2. Converting GTAP percentage output change to physical output

GTAP simulations produce percentage output changes (qo) for primary steel and secondary steel under three scenarios – business as usual, gradual transition, and accelerated transition – across 2030–2050. The percentage changes are as follows:

SECTOR	2025	2030	2035	2040	2045	2050
Business as usual						
Primary steel output		0.53	0.98	1.32	1.60	1.79
Secondary steel output		0.47	0.87	1.17	1.42	1.59
Gradual transition						
Primary steel output		21.50	25.84	23.73	18.55	20.09
Secondary steel output		19.34	25.83	30.68	35.98	43.54
Accelerated transition						
Primary steel output		44.45	52.02	36.79	14.31	3.67
Secondary steel output		41.33	56.38	68.34	82.36	102.34

The output change in physical terms (thousand tonnes) is calculated using the formula:

$$Output = Baseline \times (1 + \frac{qo}{100})$$

Note on sectoral classification between GTAP and the Indonesian IO table
It should be noted that the sectoral classification used in GTAP differs from that applied in the Indonesian Input-Output table. In GTAP, the iron and steel industry is divided into Primary Steel and Secondary Steel. Primary Steel in GTAP encompasses both BF-BOF and DRI-EAF (direct reduced iron–electric arc furnace) production routes, as both involve primary iron-making from ore. Secondary Steel in GTAP refers exclusively to full-scrap EAF operations. By contrast, the disaggregated Indonesian IO table in this study only distinguishes between BF-BOF and EAF, and does not separately identify DRI-EAF as a distinct production route. As a result, the GTAP shock for Primary Steel (which implicitly includes DRI-EAF) is mapped entirely to the BF-BOF sector in the IO model, while the GTAP shock for Secondary Steel is mapped to the EAF sector. This mapping introduces a degree of approximation, given that the output and input structure of DRI-EAF differs from that of conventional BF-BOF. This limitation should be taken into account when interpreting the multiplier and employment impact results.

3.3. Output valuation (converting physical output to monetary value)
The physical output change (thousand tonnes) is converted to monetary values (Indonesian Rupiah/IDR) using domestic steel prices derived from three major Indonesian steel producers as study cases:

	Total sales volume (TONNE)	Total sales value (IDR)
GRP (Gunung Raja Paksi)	3,115,48	38,531,141,764,400
KS (Krakatau Steel)	7,420,530	97,588,323,950,000
GDS (Gunawan Dianjaya Steel)	888,411	11,728,826,000,000

The output volumes used in the weighting are sourced from annual reports and production data covering the period 2021 to 2025. A national average price is then computed as a weighted average based on each producer's output volume, yielding a weighted average domestic steel price of Rp12,941,422/tonne.

Note on price currency and exchange rate assumption
The steel prices reported by GRP and KS are originally denominated in US Dollars (USD), as these companies publish their financial data in USD. For the purpose of this analysis, these prices are converted into Indonesian Rupiah (IDR) using the official exchange rate assumption set out in the Macroeconomic Assumptions of the State Budget (Asumsi Dasar Ekonomi Makro APBN) for the relevant year. The GDS price is reported directly in IDR. This approach ensures consistency with the policy-relevant macroeconomic framework and avoids reliance on spot market exchange rates that may introduce short-term volatility.

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