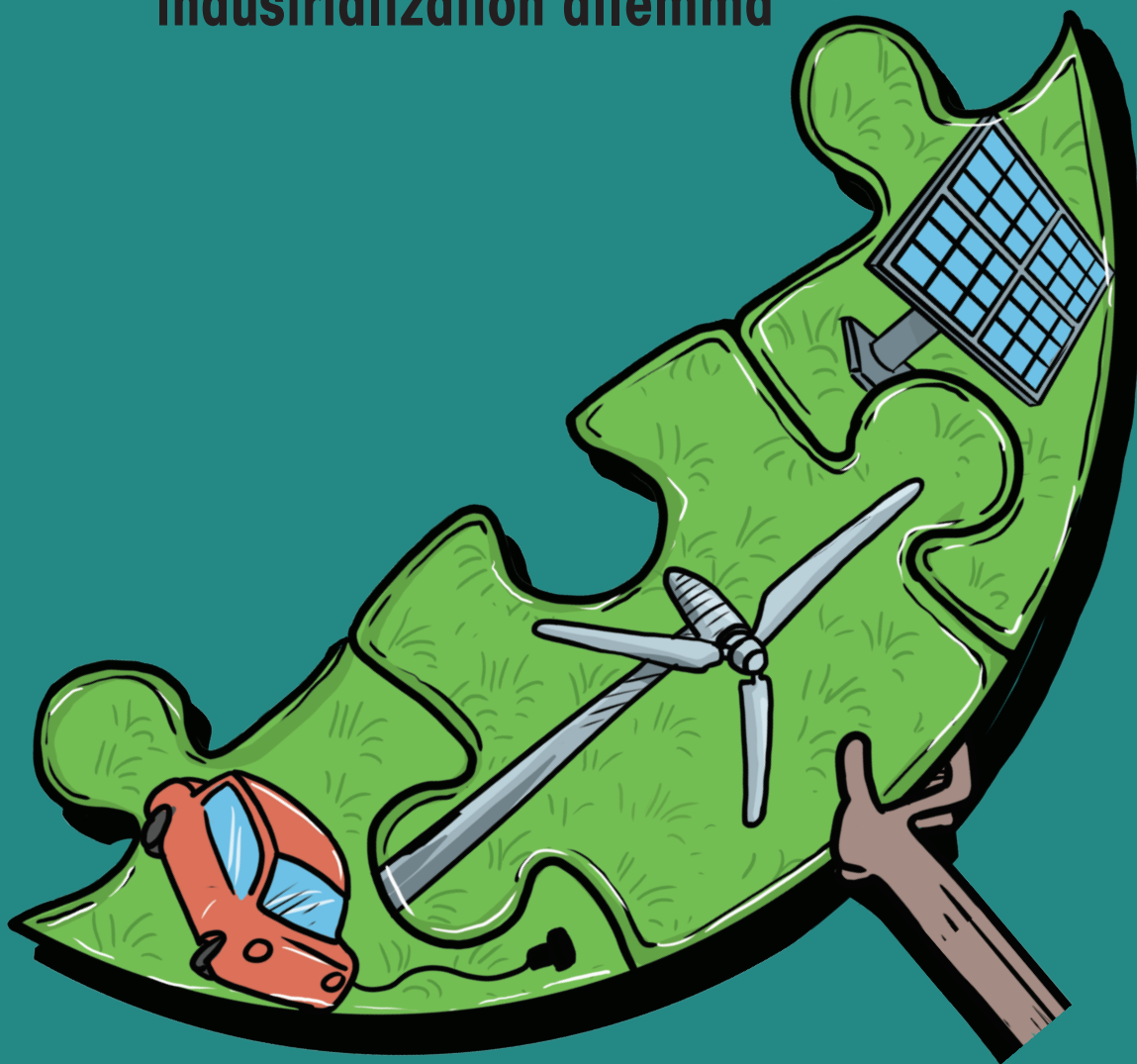




TOWARDS A NEW GREEN WORLD

CLEAN TECHNOLOGY MANUFACTURING

**Navigating the green
industrialization dilemma**





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Executive summary

The fundamental challenge for the Global South is the “double-barrelled challenge” of achieving decarbonization while simultaneously undergoing structural industrialization. The high-carbon industrial pathways previously used by the Global North are no longer viable. The solution lies in green industrialization, specifically by building domestic manufacturing capacity for the clean technologies (clean tech) central to the energy transition, such as solar panels, batteries, and electric vehicles (EVs). This paper examines the pathways taken by dominant economies and the formidable barriers and opportunities facing developing countries in this new, green economy.

The challenge is steep, as clean-tech manufacturing—a global market estimated at US \$700 billion in 2023—is already a story of dominance. China commands the sector, accounting for roughly 75 per cent of all new clean-tech manufacturing investment and 84.6 per cent of global solar PV production. Emerging and developing countries (excluding China) account for less than 5 per cent of production value.

This dominance was not accidental. China and advanced economies used a suite of deliberate industrial policy tools—including massive subsidies, public procurement, tax cuts and R&D funding—to build their strategic sectors. Recent additional efforts by the US and EU to launch their own subsidy-driven policies (e.g., the US Inflation Reduction Act), have potentially created a global subsidy race that most developing countries cannot afford to join.

Key findings

This paper identifies four core structural barriers that create a policy paradox for the Global South: they are tasked with solving a climate crisis they did not cause, using a new industrial sector where they are fundamentally uncompetitive.

1. **Prohibitive finance and subsidy asymmetries:** Green industrialization is capital-intensive. Developing countries face a weighted average cost of capital (WACC) that is two to three times higher than in advanced economies. Furthermore, they lack the fiscal space to compete with the hundreds of billions of dollars in subsidies being deployed by the US, EU, and China.

2. **Subordinate position in global value chains (GVCs):** Most developing nations are trapped in low-value assembly roles, a “low-end lock-in.” This is evident even in ambitious countries like India, which has built 118 GW of solar module assembly capacity but only 2.2 GW of high-value upstream wafer capacity, remaining dependent on imports for critical components. Similarly, resource-rich countries (e.g., DRC, Indonesia) export raw minerals while China captures the vast majority of value in processing and battery manufacturing.
3. **Restrictive global trade and technology regimes:** The Global South is blocked from using the very industrial policy tools (like local content requirements) that the North and China used. WTO rules (like ASCM and TRIMS) have been used to strike down such policies (e.g., the 2014 dispute against India’s National Solar Mission). Concurrently, technology and intellectual property are highly concentrated; the Global South (ex-China) holds less than 2 per cent of all green patents, while China dominates new filings in solar and wind.
4. **Divergent national strategies illustrate the trade-offs:**
 - o China (electric vehicles): Demonstrates the success of large-scale, persistent state intervention (over US \$230.9 billion in subsidies 2009–2023) combined with a massive domestic market. This strategy fostered vertical integration and allowed domestic firms to achieve global scale and technological leadership, making China the world’s largest car exporter.
 - o Indonesia (nickel nationalism): An example of resource nationalism leveraging the 2020 raw nickel ore export ban to force downstream processing. This resulted in nickel-related exports soaring from US \$6 billion (2013) to US \$30 billion (2022). However, the high price was deep reliance on Chinese investment, which now controls 75 per cent of refining capacity, raising concerns over profit repatriation and environmental costs.
 - o India (solar manufacturing): Illustrates an Import Substitution approach using the Production Linked Incentive (PLI) scheme to build domestic capacity (100 GW in modules reached). Despite scaling production, the case highlights persistent challenges with upstream import dependency (up to 81 per cent of solar PV imports come from China) and high vulnerability due to reliance on a single export market (97 per cent of PV exports go to the US).
 - o Mexico (auto assembly): Shows the opportunity of export-oriented integration into regional value chains (USMCA) but also the risk of low value capture. Despite being a leading auto producer, its model relies heavily on assembling imported parts, leading to weak technology transfer and limited domestic industrial linkages.

The way forward

The Global South cannot simply replicate China and the advanced economies' path in today's fragmented and protectionist world; the way forward must be focused on building resilient and autonomous capabilities.

- First, **proactive domestic efforts** are essential, requiring states to experiment with hybrid “insertion-oriented” and “autonomy-oriented” pathways, create domestic demand and build state capacity.
- Second, developing countries must **confront dependencies**, particularly on China's outsized power, by exercising agency to negotiate mutually beneficial terms for technology transfer and localization.
- Finally, these efforts must be supported by a **collective push to overhaul global systems** to create policy and fiscal space for their own green industrial development. This should be aimed at leveling the playing field by demanding reforms to restrictive trade rules—such as a WTO climate waiver and the international financial architecture—including scaling up public climate finance and large-scale debt cancellation to invest in clean technologies domestically.

1 INDUSTRIALIZING WHILST DECARBONIZING: TWIN IMPERATIVES FOR THE GLOBAL SOUTH

The Global South faces a dual challenge: achieving industrial growth while cutting emissions to meet the Paris Agreement targets.

Manufacturing is central to both decarbonization and economic development, enabling structural transformation and job creation.

Green industrialization offers a pathway to balance growth and climate goals by building domestic capacity in clean technologies.

The color of the economy of the future is green. The climate crisis has created an urgency for decarbonization through the rapid scaling of emissions-cutting measures across whole economies. To meet the 1.5 °C target of the Paris Agreement, the IPCC states in its Sixth Assessment Report (AR6) that global GHG emissions must fall by 43 per cent by 2030 compared to 2019 levels. Widespread ‘system transformations’ are required for this, across the energy, buildings, transport, land and other sectors, and this will involve adopting low-emission or zero-carbon pathways of development in each sector.

At the primary fuel level, this involves swapping coal, oil and gas with renewable power and electrification. This requires the deployment of clean technologies to replace incumbent technologies that harness fossil fuels, alongside non-technological measures like afforestation and avoiding deforestation. To achieve net zero emissions for the energy sector by 2050, the IEA states that 60 per cent of global car sales must be electric by 2030, electricity must account for 40 per cent of industrial energy consumption by 2040, and nearly 90 per cent of electricity must come from renewables by 2050. Technologies will include, but are not limited to, solar panels and wind turbines to replace coal and gas power plants, electric cars and batteries to replace internal combustion engines, and electric arc furnaces to replace blast furnaces in steel-making. Demand for products traded globally will also shift towards ‘greener’ goods produced with low-carbon methods.

The manufacturing sector is at the center of this challenge, to churn out the clean technologies of the future at scale and at low enough costs.

For countries of the Global South, there is an added imperative—development. A core aspect of this is industrialization and the growth of manufacturing, the ‘second stage’ of development following the agriculture-dominated stage and preceding a services-oriented economy. One prominent view is that developing economies need to industrialize to achieve economic development and ‘structural transformation’, i.e., a shift in the share of output from low to high productivity sectors.^{1,2} Evidence has shown that a structural transformation towards manufacturing “has been accompanied by considerable advancements in social and human development, with decreasing fertility rates, increasing life expectancy, and reductions in poverty and inequality”.³ UNCTAD’s 2016 Trade and Development Report states that “a broad and robust domestic manufacturing base has been the key to successful economic development, since it helps generate virtuous and cumulative linkages with other sectors of the economy, drives technological progress, and has the strongest potential for productivity gains”.⁴

Developing countries cannot follow the same high-carbon industrialization pathways of developed countries, as the risks of exacerbating climate impacts threaten to erode the very gains of such development. Moreover, they cannot be left behind in the clean technology race to then become buyers of clean-tech from the Global North and China, while themselves being saddled with high-carbon stranded assets.⁵

Decarbonization and industrialization are the double-barrelled challenge for the Global South. The pathway forward, therefore, is through green industrialization, which should ideally then precipitate *green structural transformation* for the Global South. Oxford economist Amir Lebdioui argues that the “challenge of ecological sustainability goes beyond consuming less or differently, as it also involves an ancillary shift towards low-carbon manufacturing, given the important potential that new technologies and manufacturing transitions have in drastically reducing the material and energy content of consumption patterns”.⁶

Clean technology manufacturing is therefore central to the effort for green industrialization in developing countries. By aiming to manufacture some of these technologies domestically, developing countries could secure a supply of affordable, clean power for decarbonization, while establishing new, high-value industrial sectors, generating skilled employment, reducing reliance on global supply chains and protecting themselves from volatile fossil fuel prices.

This discussion paper examines the pathways that China and developed countries, and select developing countries have taken to grow clean technology manufacturing. It then raises questions about the future of the Global South’s participation in this new, green economy, reflecting on the barriers and opportunities that lie ahead.

MANUFACTURING'S ROLE FOR A GROWING ECONOMY

Manufacturing remains central to the development challenge facing large emerging economies, particularly as demographic and economic pressures intensify. It provides the scale of employment, productivity growth, and formal jobs that services alone cannot meet for a more broad-based development.⁷ For economies such as India, with a labour force participation rate of 59.6 per cent and only a fraction in formal work, industrialization is essential to absorb a growing workforce. India will need to create around 115 million jobs by 2030,⁸ yet its share in global manufacturing output is only 2.9 per cent, far behind economies with comparable labour surpluses.⁹

At a broader level, manufacturing drives structural transformation, shifting workers from low-productivity to higher-value activities.

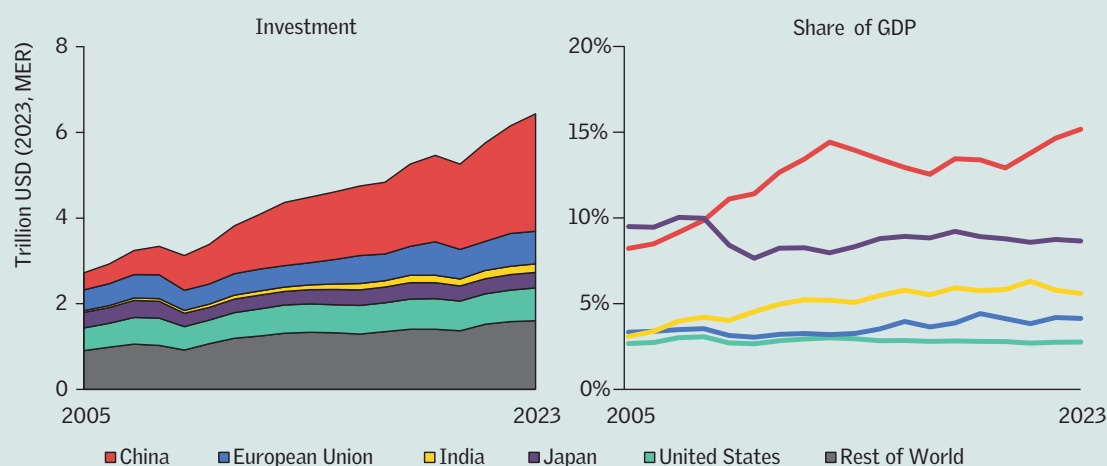
Countries at different levels of depth in manufacturing

The structure and sophistication of manufacturing vary widely across emerging economies. Countries also differ in the depth of their industrial bases, which shape their readiness for green industrialization. Among them, China and Vietnam have a significantly higher share of manufacturing value added in GDP, whereas India and Brazil operate at roughly half those levels (see *Graph 2*).

Beyond just scale, manufacturing also needs depth. A more meaningful indicator is manufacturing value-added (MVA) per worker, which could be a proxy for technological sophistication. On this measure, China and Mexico outperform, indicating stronger technological capabilities, while India and Vietnam rely on labour-intensive, low-technology production. This distinction matters because economies with deeper manufacturing ecosystems, such as skilled labour, supply-chain linkages and capital goods capacity are better positioned to diversify into clean technologies.^{10,11} Shallow industrial bases, by contrast, trap countries in low-value assembly roles.

Graph 1: Global manufacturing investment trends, 2005–2023 (IEA, 2024)

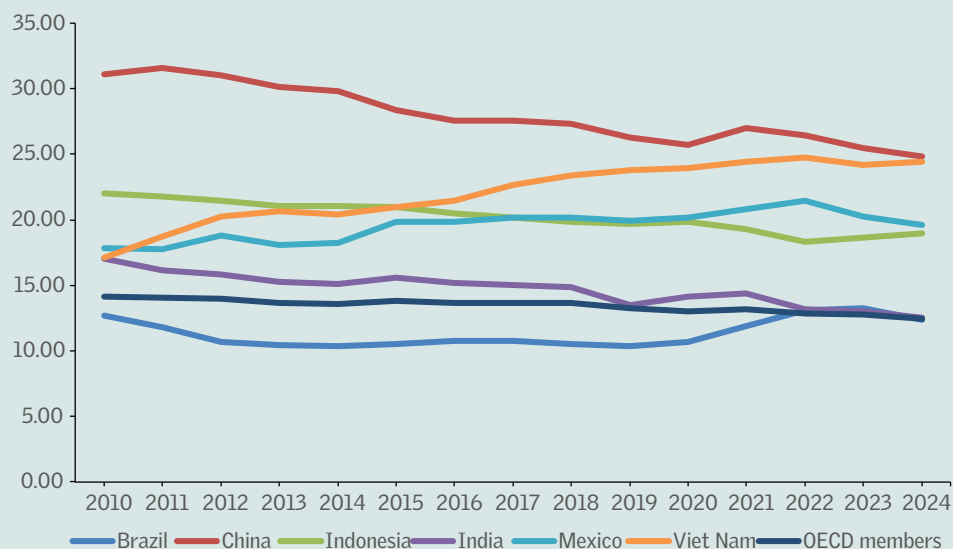
China dominates global manufacturing investment, accounting for the largest and fastest-growing share, rising to nearly 15 per cent of GDP by 2023. The European Union, the United States and Japan maintain relatively stable investment levels, while India shows gradual growth from a low base.



Source: IEA analysis based on Oxford Economics Limited (2024a)

IEA. CC BY 4.0.

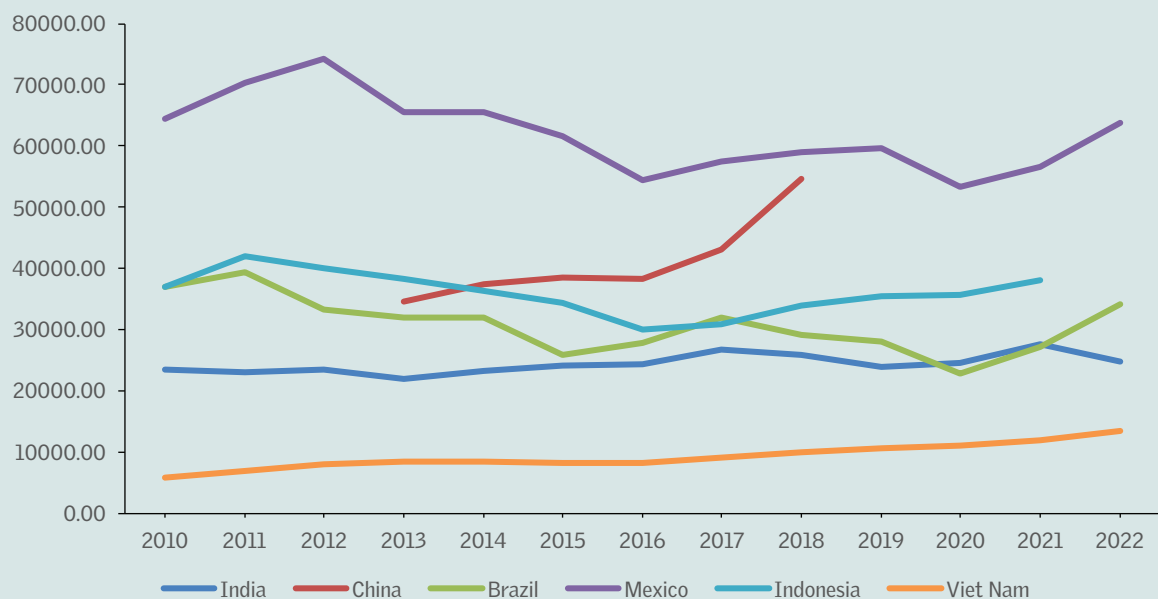
Graph 2: Trends in manufacturing value-added as a percentage of GDP



Source: World Bank, Graph: CSE

Graph 3: Trends in manufacturing value-added per worker (2010–2022) across major emerging economies (US\$/worker)

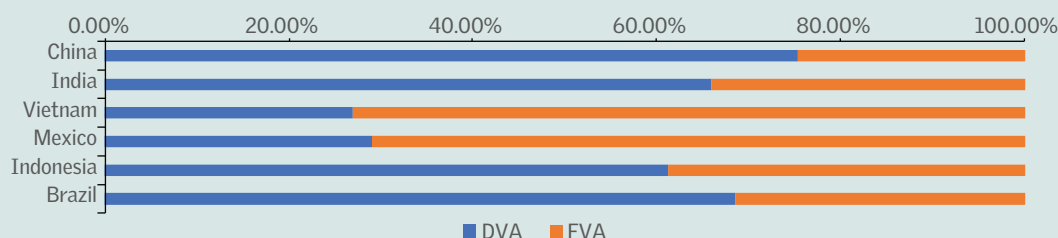
Mexico and China have higher productivity levels, reflecting higher technological intensity and capital investment in manufacturing. India and Vietnam, in comparison, have lower MVA per worker.



Source: UNIDO, Graph: CSE

Graph 4: Share of the domestic and foreign value-added content in high-tech (computers, electronics and electrical equipment) exports, 2022

Countries with a higher degree of foreign value-added content in their exports participate in the global value chain mainly through assembly and processing.



Source: WTO, Graph: CSE

Most developing economies have yet to build resilient local manufacturing ecosystems. They assemble goods but import much of the value. For green industrialization, this creates a dual vulnerability—to external shocks in global supply chains and to the rising cost of clean technology inputs.

Domestic linkages and import dependence in manufacturing

Another dimension of manufacturing depth lies in the strength of domestic linkages and the degree of import dependence. This reflects how much of a country's manufacturing inputs are sourced locally versus imported. A higher domestic share indicates stronger internal industrial connections and greater self-reliance, while a higher foreign share suggests dependence on external suppliers. A higher domestic share suggests that a country relies more on its internal industries for production inputs. In contrast, a higher foreign share could mean the country is more dependent on international suppliers.

India sources about three-fourths of its manufacturing inputs domestically. Its main import partners for intermediate goods are China (10.7 per cent of imported intermediate goods), Saudi Arabia (8.8 per cent), UAE (8.3 per cent), US (7.9 per cent) and Russia (5.0 per cent).

China relies very little on imports of intermediate goods for its manufacturing sector, with its foreign sourcing spread across Taiwan (7 per cent), Australia (6.9 per cent), South Korea (6.8 per cent) and Japan (6.6 per cent)—showing its tight regional backward supply chain links.

Mexico is highly dependent on the US (41.4 per cent of imported intermediate goods) for manufacturing inputs, reflecting its deep integration into North American production networks. China (21.9 per cent) is its second-largest source.

Vietnam imports heavily from China (36.2 per cent), Korea (19.9 per cent) and Taiwan (7.1 per cent), reflecting strong regional supply chain connections in manufacturing.

Indonesia imports about 15 per cent of its intermediates, mainly from within ASEAN and East Asia.

Brazil imports roughly 13 per cent of its inputs, mostly from China (22.8 per cent) and the US (16.3 per cent).

The structure of existing manufacturing provides an important baseline—while many countries have integrated into global value chains, few have built the technological and institutional depth needed for green industrialization. This fragmentation of capabilities in the global south foreshadows a similar picture in clean tech manufacturing.

2

CLEAN TECHNOLOGY IS THE SOLUTION; MANUFACTURING THEM IS A STORY OF DOMINANCE

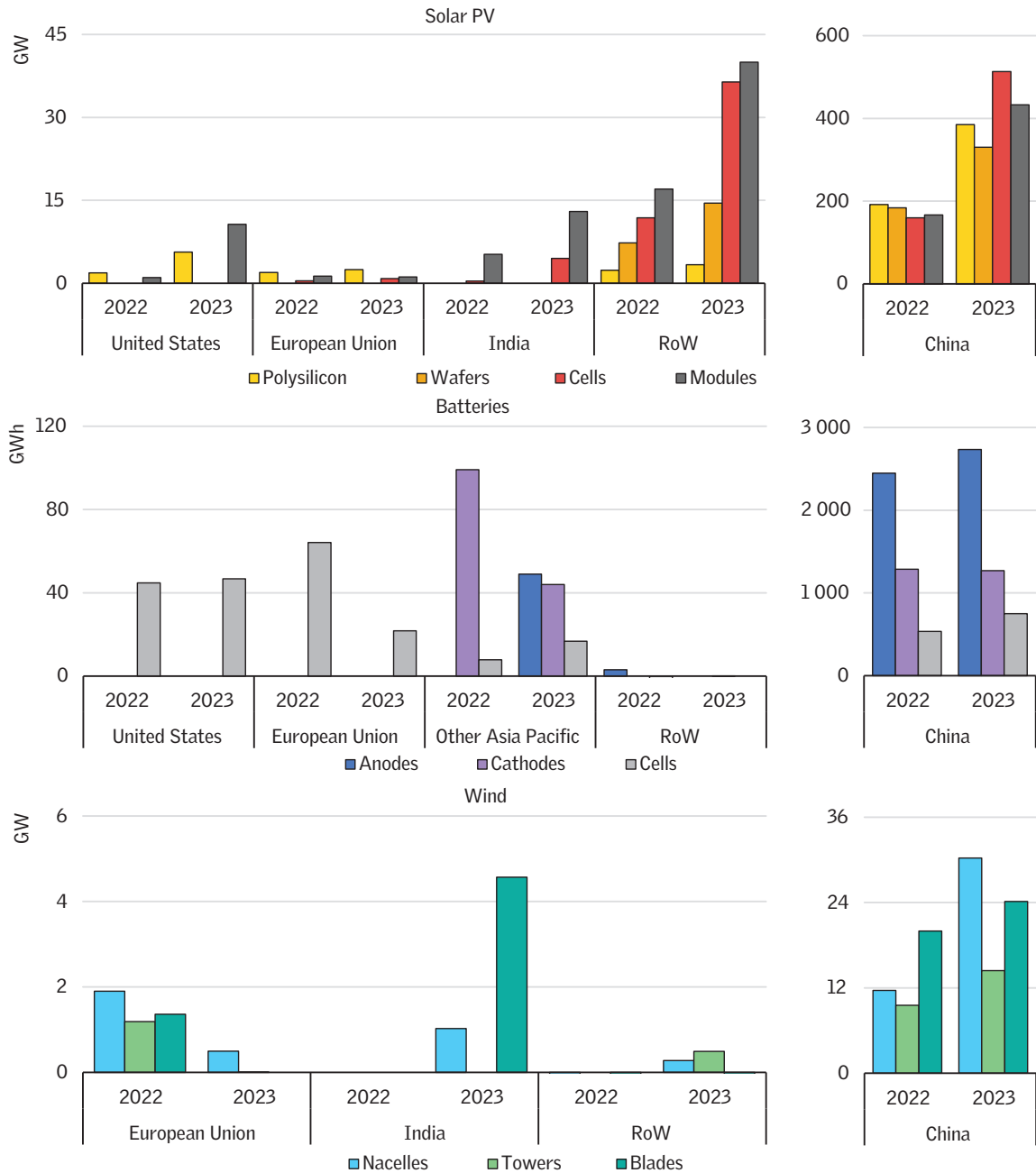
Clean-tech manufacturing has become a key industrial sector, with global investment reaching US \$235 billion in 2023, dominated by China.

China accounts for nearly 85 per cent of global solar PV output, underscoring its overwhelming lead in clean technology production.

According to the IEA, emerging and developing countries in Latin America, Africa and Southeast Asia together account for less than 5 per cent of total clean technology manufacturing value.

Graph 5: Global clean energy manufacturing capacity additions by technology and region (2022–2023)

China overwhelmingly leads new manufacturing capacity.

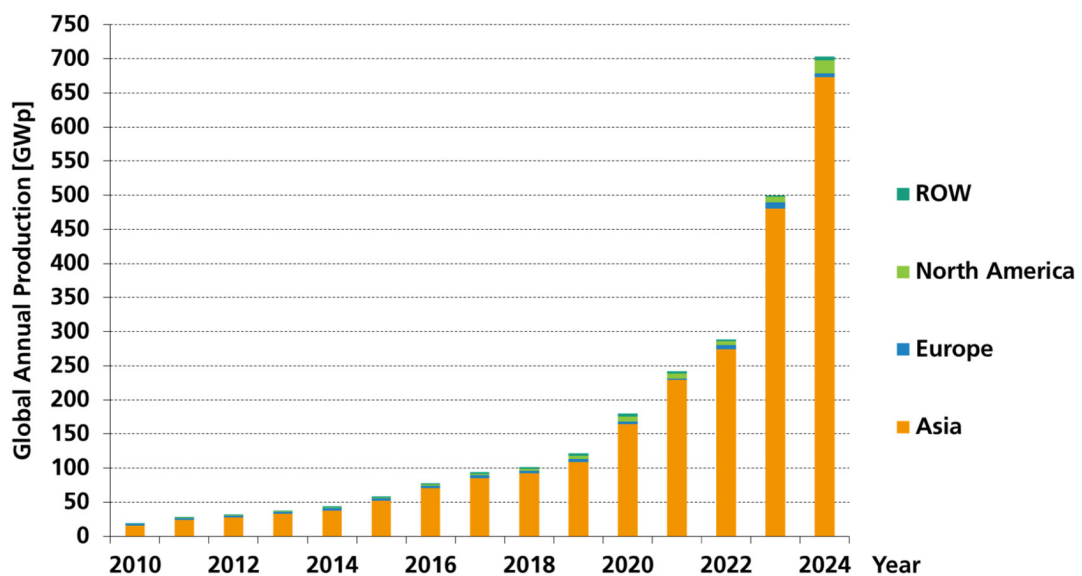


Source: IEA

A global wave of clean technology manufacturing is transforming clean technology into a major industrial sector in its own right. In 2023, global investment in clean-tech manufacturing was estimated at US \$235 billion, according to the IEA. Nearly 80 per cent of this investment went into solar photovoltaic (PV) manufacturing. Yet, much like the broader manufacturing landscape, the centre of gravity remains overwhelmingly in China, which accounted for roughly three-quarters of all new clean-tech manufacturing investment that year. IEA estimates that emerging and developing countries in Latin America, Africa, and Southeast Asia account for less than 5 per cent of the value of total clean technology production.¹² China, the EU and the US accounted for 70 per cent, 13 per cent and 8 per cent of growth in global clean-tech manufacturing, respectively, in 2023.

In the photovoltaic sector, 84.6 per cent of global output came from China, followed by 3.4 per cent in Vietnam and 2.7 per cent in India.¹³

Graph 6: Global Annual Photovoltaic Production¹⁴



Source: Fraunhofer Institute

3

CHINA AND ADVANCED ECONOMIES USED A SUITE OF INDUSTRIAL POLICY TOOLS TO ACHIEVE DOMINANCE

China and the Global North achieved clean-tech leadership through state-supported industrial policy: subsidies, R&D investments, public procurement and tax incentives.

These interventions built technological learning, economies of scale and export competitiveness.

The resurgence of industrial policy globally has triggered a subsidy race that most developing countries cannot match.

As a relatively ‘new’ sector with important and ever-increasing strategic value, clean technology manufacturing has seen deliberate interventions by governments of advanced economies and China to nurture and create strategic new sectors. Many of the policy tools deployed fall within the gamut of “industrial policy”, which refers to intentional government intervention in strategic economic sectors. Tools have included subsidies, public procurement to create a market to absorb output from a sector, product-specific research and development (R&D), and feed-in tariffs. Advocates suggest that industrial policy can create jobs, and in the context of decarbonization, can create political support for the further growth of green industry, from economic winners that outweigh the opposition from economic losers.¹⁵

Industrial policy has produced vital wins in the past century. The IPCC AR6 report of 2022 highlights the “government R&D and public procurement effort in the 1970s in the USA, that enlisted skilled scientists and engineers into the effort and stimulated the first commercial production lines” for solar photovoltaics, which contributed to its eventual cost reduction and widespread deployment.

Industrial policy is also credited for the East Asian Miracle—the rapid growth of the mobile phone and car industries in South Korea, Japan, and Taiwan.¹⁶ Other examples include India’s public procurement of energy-efficient LED bulbs, the Chinese government’s tax reduction, preferential pricing and credit guarantees given to the wind, solar and biomass sectors in the 1990s,¹⁷ and Germany’s feed-in tariffs that are said to have transformed the country into a renewable energy leader by guaranteeing a fixed, above-market price for electricity generated from renewable sources, encouraging investment.

Table 1: Snapshot of industrial policy toolbox

Exports barriers	Export ban, export licensing requirement, export quota
Import barriers	Anti-dumping, anti-subsidy, import ban, import licensing requirement
Domestic subsidies	Capital injection and equity stakes (including bailouts), financial grant, in-kind grant, tax or social insurance relief, production subsidy
Export incentives	Trade finance, export subsidy, tax-based export incentive
Public procurement measures	Public procurement access
Foreign Direct Investment measures	FDI: Entry and ownership rule, FDI: Financial incentive
Localization content measures	Local content incentive, local content requirement, local operations incentive, local operations requirement

Source: Adapted from Simon Evenett, Adam Jakubik, Fernando Martín, and Michele Ruta. “The Return of Industrial Policy in Data”, IMF Working Papers 2024, 001 (2024)

SEE CASE STUDY: CHINA'S EV EXPERT BOOM IN SECTION 5.1

It is estimated that the Chinese government invested around US \$230.9 billion in developing the country's electric vehicle (EV) ecosystem. In 2015, China accounted for more than half of global EV sales, and by 2024, EVs made up 47.9 per cent of all automobile sales domestically in China.

China's decades-long consistent strategy to grow solar, wind, and EV sectors through R&D funding, tax cuts, cheap land, and low-interest loans has allowed Chinese companies to achieve unprecedented economies of scale. Through domestic procurement policies, it also created robust domestic demand.

Advanced economies—UK, USA, Germany, France, and Japan—have pursued state-driven industrial policy for decades in their early stages of development to protect “infant industries” from foreign competition.^{18,19} In recent years they have additionally developed new programmes of state interventionism on green technologies, largely in response to China's dominance. The US launched the Inflation Reduction Act (IRA) in 2022—a programme of about US \$370 billion in subsidies over ten years, mainly through tax credits, for renewable energy, electric vehicles, energy-efficient appliances, carbon capture and storage and clean hydrogen.²⁰ The European Union's Green Deal Industrial Plan and Net Zero Industry Act attempted to simplify regulations, allow faster access to state funding, and boost domestic clean tech manufacturing.²¹ Data for 2023 shows that 48 per cent of all industrial policy efforts were concentrated in the US, China and EU. Climate change was stated as a reason for 28 per cent of all initiatives. And while advanced economies and China primarily used corporate subsidies as an instrument, emerging markets focused more on import barriers and localization policies, while low income developing countries focused on import barriers.²²

Experts have stated that the push for green industrial policy is a global phenomenon in which governments of some of the world's most affluent countries too are embracing bold policies to address the climate crisis and economic growth simultaneously.²³ For the US, this was, however, only until the re-election of Donald Trump as US President, who rolled back the IRA and continues to pressure global partners to roll back all climate-related interventions as well.

4

THE GLOBAL SOUTH CANNOT BE LEFT BEHIND

Developing nations must industrialize cleanly under inequitable global conditions of finance, technology and trade.

China's dominance creates both opportunity and dependency; its lead offers affordable clean tech but deepens supply-chain reliance.

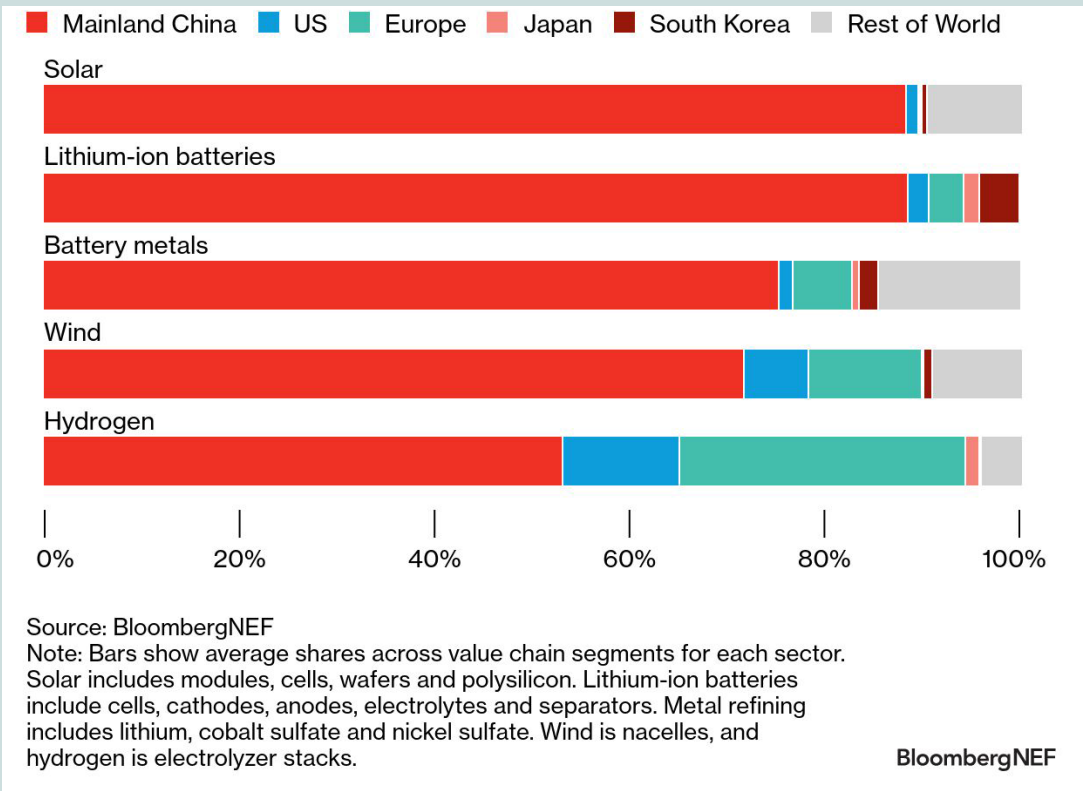
The key challenge for the Global South is to engage strategically with this new landscape while building its own industrial capabilities and policy autonomy.

Developing countries are forced to solve a global problem (decarbonization) that they largely did not cause, using a new industrial sector (clean technology) where they are fundamentally uncompetitive due to capital and technological asymmetry. This situation creates a policy paradox—they must industrialize through clean-tech, but the economic conditions for success are dictated by the heavily subsidized, technologically superior Global North and China.

THE DRAGON IN THE ROOM: HOW SHOULD THE GLOBAL SOUTH RECKON WITH CHINA'S CLEAN ENERGY DOMINANCE?

The global clean energy transition, once a vision defined by Western technology and climate policy, is now overwhelmingly a story written in Chinese factories. China's strategic, decades-long industrial policy has resulted in a staggering dominance over the manufacturing of critical clean technologies—solar, batteries, and electric vehicles (EVs)—that is reshaping geopolitics, trade and the pace of the global energy transition. This dominance is a double-edged sword—it offers the cheapest path to global decarbonization while simultaneously creating a new, deeply concentrated supply chain dependency.

Graph 7: Mainland China dominates global clean-tech manufacturing capacity across solar, batteries, and critical materials, accounting for the majority of global production in 2024



Source: BloombergNEF, 2024

China controls overwhelming shares of the global manufacturing capacity for key components—over 80 per cent of solar module production and significant portions of battery and wind turbine manufacturing, as well as upstream processing of minerals deemed “critical” for the clean energy transition.

It has achieved this through decades of consistent government policy encompassing, but not limited to, direct grants to companies, tax incentives and below-market access to finance, equity, land and subsidized energy.²⁴

Individual estimates have been tabled for sectoral subsidies, such as CSIS’s estimate of US \$231 billion provided by China for EVs between 2009 and 2023. On a larger scale, an IMF working paper published in 2025 estimates that China’s subsidies for industrial policy across all manufacturing sectors, covering four instruments, cash subsidies, tax benefits, subsidized credit, and subsidized land for favored sectors, amount to 4.4 per cent of its GDP. The equivalent for the European Union was 1.5 per cent in 2022.

The results are evident both domestically and globally. Domestically, it has increased its share of primary energy consumption from renewables and hydropower from 5 per cent in 2000 to 18 per cent in 2024.²⁵ Its cumulative domestic installed solar capacity for 2024 stands at 47 per cent of the world total, and wind at 46 per cent. Its clean energy penetration may be causing a gradual peak and plateau in its greenhouse gas emissions²⁶, of which it currently contributes one-third of the world’s total annually. Clean energy is also a growth driver, contributing more than 10 per cent of China’s economic growth in 2024.²⁷ Globally, it is rapidly powering the clean energy transition with its exports of solar, wind, EVs and batteries²⁸—estimates suggest it may have cut overseas emissions by 1 per cent as a result.²⁹

The question for the Global South is no longer how to slow China’s lead, but how to leverage it without succumbing to the economic and strategic vulnerabilities of relying on a single clean energy colossus. For some developing countries, China is both a formidable giant that has outpaced all others in growth and a power whose economic and trade leverage must not be over-relied upon lest it be turned into a weapon; others are eager to engage.³⁰

4.1 The South’s goals are unique, and the pathway is riddled with obstacles

Unlike advanced economies that grew rich using carbon-intensive models, developing nations must now industrialize cleanly, reducing emissions and broader environmental impacts while delivering economic growth, jobs and foundational infrastructure to vast populations. We explore the core aims driving this green industrialization push and the formidable structural and institutional barriers that restrict its success.

4.1.1 Aims of the Global South

Decarbonization

For the Global South, beyond just cutting emissions, energy transition is also about doing so while still building economies, industries and basic infrastructure.

Graph 8: Structural asymmetries shape green industrialization prospects



Energy demand continues to rise as economies industrialize, and most affordable power still comes from fossil fuels.

Growth in countries like China and India has remained energy-intensive, and coal continues to do the heavy lifting. In 2023 alone, China added 47 gigawatts of new coal power, accounting for almost 95 per cent of global additions that year.³¹ In India and Indonesia, more than 70 per cent of electricity still comes from coal. Moreover, the pace of industrialization is pushing electricity demand sharply upward. Vietnam's electricity demand grew over 10 per cent and India's by 5.8 per cent in 2024.^{32,33} Meeting this kind of growth means countries have to do three things at once—build massive new power capacity, clean up the energy mix and keep electricity affordable and reliable for hundreds of millions of people.

It can be argued that a stronger domestic supply of clean-tech goods could aid in the energy transition by helping the expansion of renewable energy that is more stable and cost-effective. Yet the import dependence of developing countries is huge for clean energy components. Relying on imports for solar modules, turbines or batteries exposes economies to supply-chain shocks, geopolitical risks and trade deficits.

This makes decarbonization a much more layered challenge for the South than for industrialized economies. The real test for policy is also to find ways to connect renewable expansion to industrial goals so that new clean energy industries don't just replace coal but also create jobs, build supply chains, and deepen domestic capabilities.

Manufacturing: Structural transformation and value addition

Economic resilience is crucial for developing nations to sustain growth and manage shocks like the 2018 U.S.-China trade war, the COVID-19 pandemic, or the 2022 global food price surge, which highlighted their extreme vulnerability to external volatility.^{34,35} Unlike advanced economies, which can deploy large fiscal stimuli and subsidies, most developing nations lack this financial buffer, often struggling with high sovereign debt and steep international borrowing costs.³⁶

SEE CASE STUDY: MEXICO'S AUTO ASSEMBLY ECOSYSTEM IN SECTION 5.1

Mexico is one of the world's leading automotive producers, with an export-oriented automobile market—about 87 per cent of vehicles manufactured are exported, two-thirds of which go to the United States.

Local production strengthens supply chains, lowers expensive import bills and keeps value and jobs in the country. For instance, for resource-dependent countries like Chile, localizing the processing and manufacturing of critical minerals is key to moving beyond raw commodity exports. For Brazil, domestic manufacturing of biofuels equipment and wind turbines reduced reliance on foreign energy tech and is also helping establish new industrial clusters, skilled jobs and technology ecosystems.

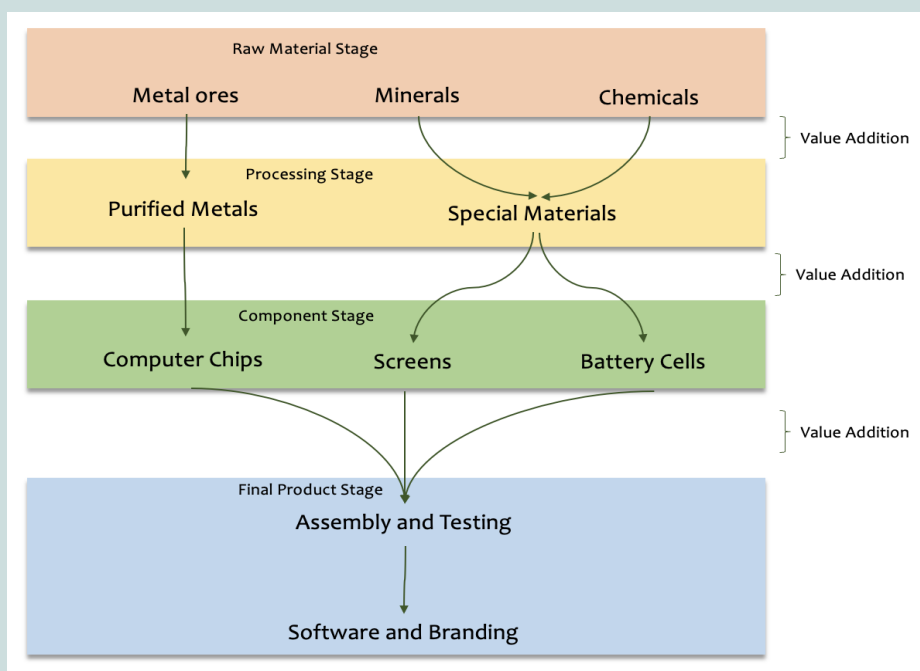
The economic incentive is huge—the IEA projects that the global clean-tech market will more than double, growing from around US \$700 billion in 2023 to over US \$2 trillion by 2035. Trade in these technologies is expected to triple to US \$575

VALUE ADDITION

Value addition in manufacturing is the process of increasing the economic value of a product at each stage of its production. It is the difference between the cost of the raw materials and components that go into making a product and the final selling price of the finished product.

It is an important parameter as it is the primary source of profit and wages for manufacturers. An example is the production of a smartphone. The raw materials like glass, metals and silicon may be of low value. However, through manufacturing, these are transformed into a high-resolution screen, a powerful processor, and a complex device. This process, combined with design and software, adds immense value, turning cheap minerals into a product that can sell for hundreds of dollars.

Figure 1: Example of value addition in mobile manufacturing



Source: CSE

billion, surpassing the current value of global natural gas trade.³⁷ Capturing even a fraction of this growth could strengthen a country's finances. China's experience with clean-tech manufacturing has yielded direct economic gains among other advantages—in 2024, clean-energy industries contributed 10 per cent of its GDP, generating US \$1.9 trillion in sales and investments, surpassing the real estate sector in value in the country.³⁸

The success of industrialization cannot be measured only by the size of manufacturing output or export volumes. Many developing countries have expanded exports by assembling imported parts, but this model often leads to what scholars describe as a 'low-end lock-in', where countries remain stuck in low-value segments of global value chains.³⁹ The 'Smiling Curve' hypothesis illustrates this imbalance—the highest value and profit accrue in upstream activities like research, design and core component manufacturing, and in downstream functions such as branding and distribution, while assembly and fabrication capture the least value.⁴⁰ For example, in electronics and solar manufacturing, most developing countries produce modules or devices but rely on imported semiconductors, wafers or inverters that embody most of the intellectual property and value.

The solar PV supply chain heavily concentrates value in upstream stages—wafers and cells are the high-value, capital-intensive segments. Module Assembly, often the entry point for developing economies, is the lowest-value segment of the process. Globally, capacity is heavily concentrated, with one geography controlling 97 per cent of Wafers and 81 per cent of Cells. This forces module-assembling countries into a low Domestic Value Added (DVA) trap, relying on imports for most of the product's value.^{41,42}

Building robust domestic supply chains from basic materials and small components to specialized areas like rare-earth processing and semiconductor manufacturing is therefore essential for genuine industrial deepening.⁴³ Without promoting these backward linkages and substituting imported intermediate inputs with domestic ones, clean manufacturing risks reproducing a structural vulnerability that restricts job creation to low-skill roles and curtails the long-term technological upgrading.

Global trade competitiveness

Trade competitiveness is yet another important aspect of a growing economy. It is important to absorb growing labor forces, earn foreign exchange, and integrate into global technology and production systems. Industrial take-offs from East Asia's electronics boom to China's clean-energy expansion have been built on export strength, not domestic demand alone.

SEE CASE STUDY: INDIA'S SOLAR MANUFACTURING EXPERIMENT IN SECTION 5.3

India's Production Linked Incentive Scheme (PLI) is reported to have created 30.4 GW of Solar PV manufacturing capacity in the country, along with 38,500 jobs, a decline in module imports, and greater vertical integration across the solar value chain.

Developing countries now need to secure positions in emerging green trade flows in electric vehicles, solar, and batteries before supply chains, trade rules and technical standards harden.

China's dominance in clean-tech manufacturing has translated into its trade leadership. Its clean-tech exports were US \$20 billion in August 2025 alone.⁴⁴ The country accounts for 19 per cent of the global low-carbon technology export. These exports are still concentrated in developed markets such as the EU and the US⁴⁵, while sales to developing economies like India or Brazil are limited and largely confined to intermediate components, reflecting that end-consumption remains concentrated in the North.

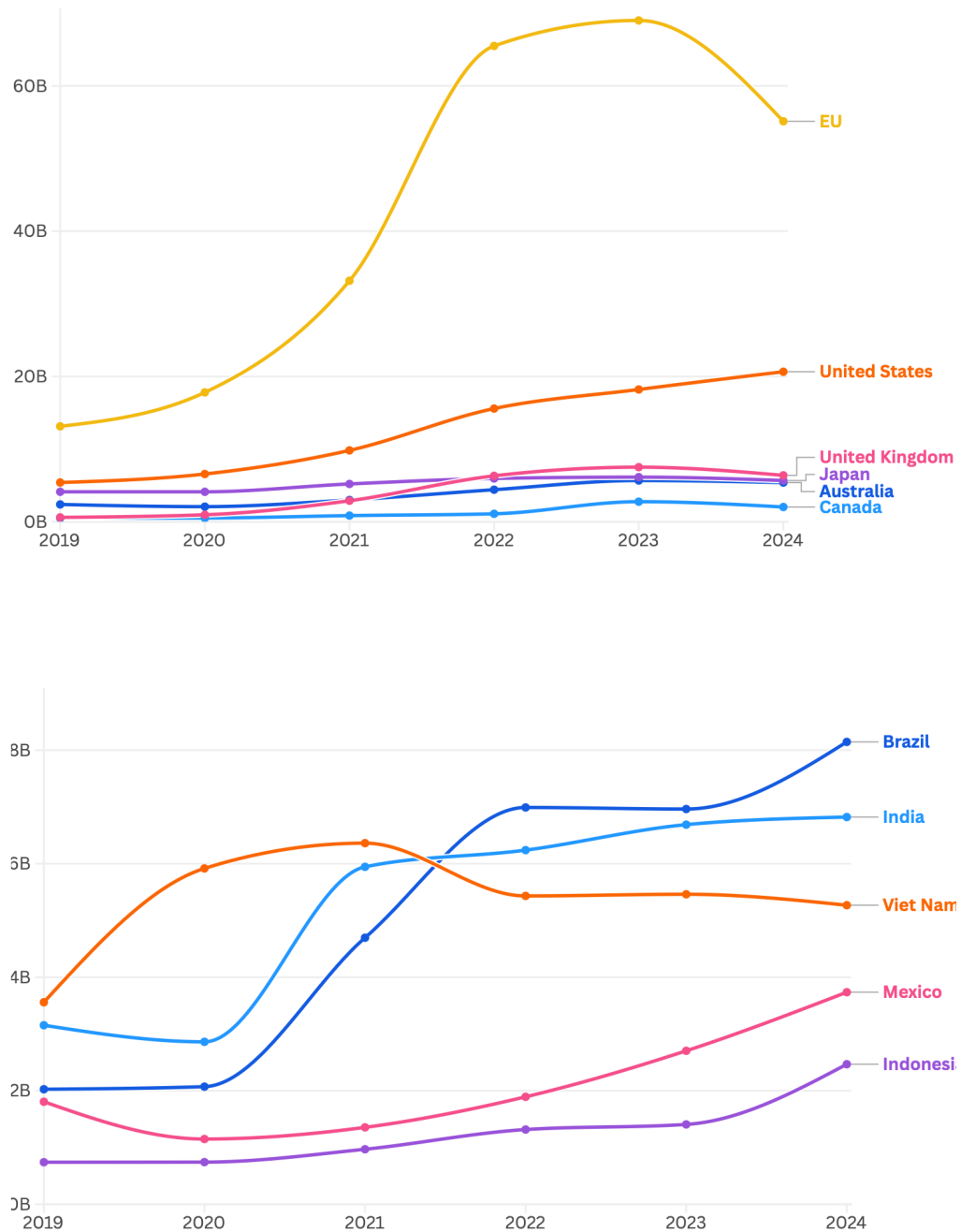
As protectionism expands and climate-linked trade measures increase, competitiveness is no longer defined by price alone but by origin of materials, carbon intensity and geopolitical alignments. This new 'green mercantilism', the strategic use of industrial policy and subsidies to secure market share in low-carbon goods, has made trade integration more complex and selective.

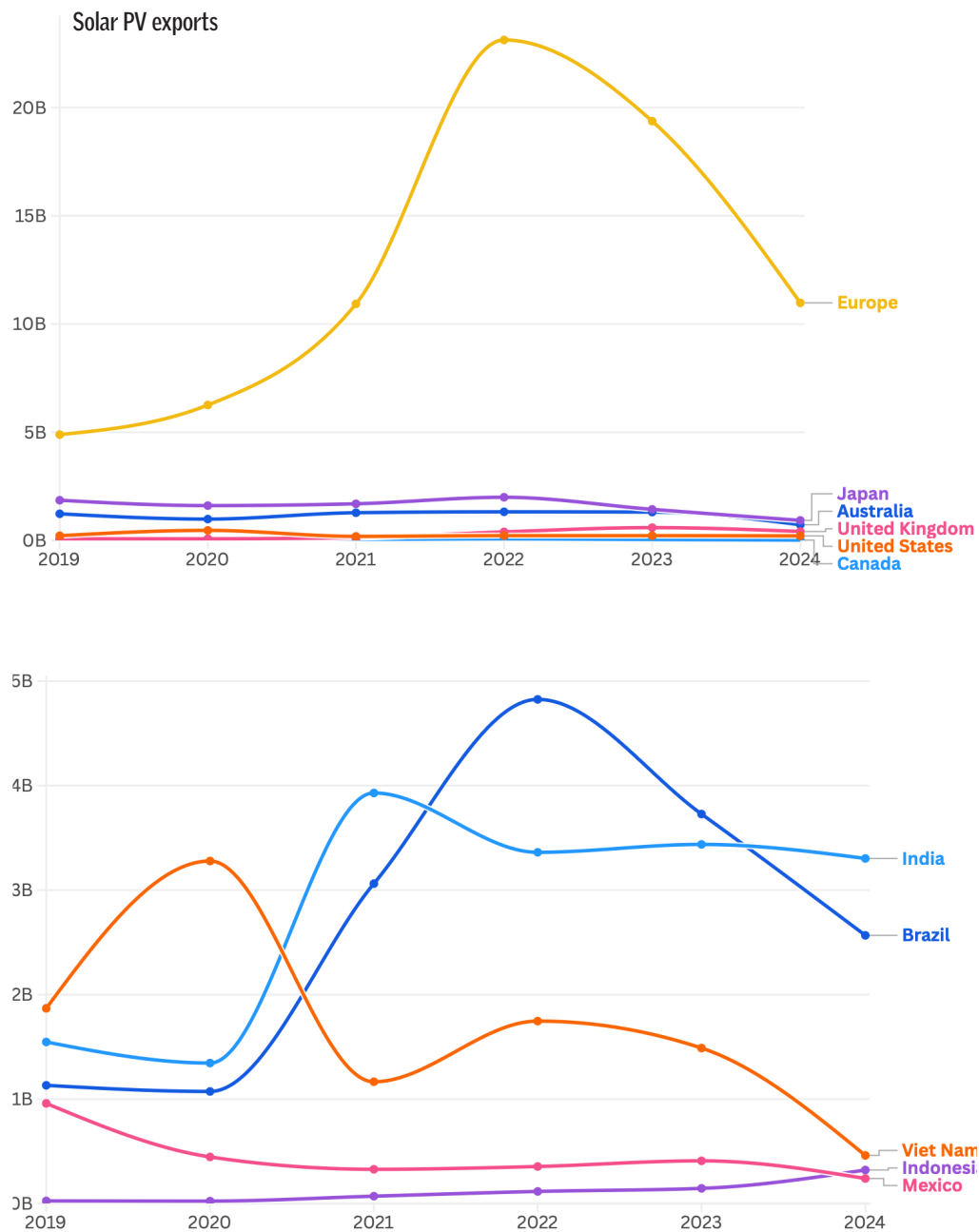
For the Global South, achieving trade competitiveness is therefore a necessity. Many developing economies face chronic trade deficits driven by energy imports and low-value exports. Expanding participation in clean-tech trade offers a pathway to reverse that imbalance by shifting from import dependence to exporting value-added green goods.

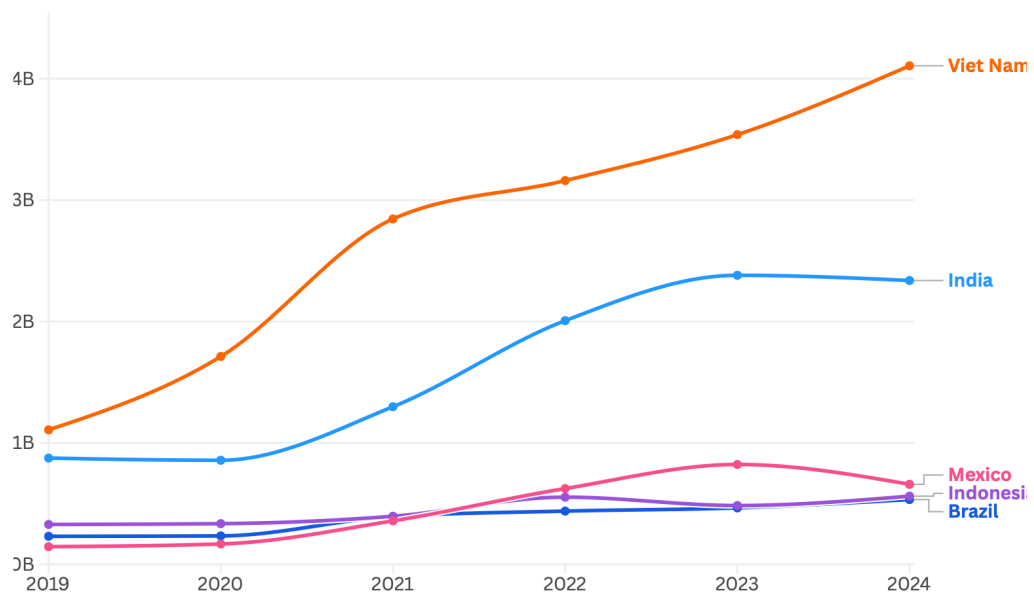
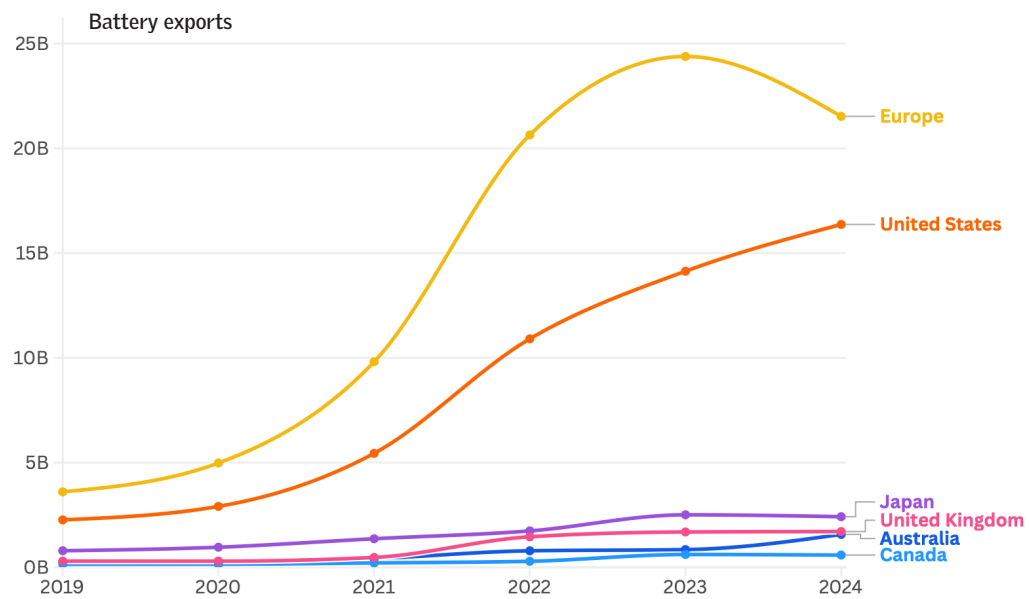
Graph 9: China's clean technology exports, 2019–2024 (US\$)

China's clean tech exports remain overwhelmingly oriented toward developed markets.

All clean-technology exports







Source: Ember, Graph: CSE

Just transition

As fossil-fuel industries decline, millions of workers will need new sources of employment. For coal-dependent countries, this makes employment absorption a central aim of green industrial policy. Clean technology manufacturing must become an avenue not only for decarbonization but for large-scale job creation and social stability.

Sectors such as solar, wind and electric vehicles are labor-intensive in their installation, assembly and operation phases. Yet current patterns are worrying. In many Global South economies, clean-tech production remains assembly-oriented, with unstable, low-skilled jobs and limited upward mobility.⁴⁶ Without deliberate policy design, incentives for skill development, local supplier linkages and new sectors could replicate the precarity of informal work.

The stakes are particularly high for coal-dependent regions such as East Kalimantan in Indonesia, Mpumalanga in South Africa, and Jharkhand and Chhattisgarh in India, where economic dependence on fossil industries coincides with low human development levels. For these regions, green industrial policy must drive diversification and regional industrialization, locating new manufacturing clusters.

4.1.2 Barriers to achieving these aims

The ambitious dual agenda of the Global South is constrained by deep-seated economic, institutional and geopolitical asymmetries inherited from the past.

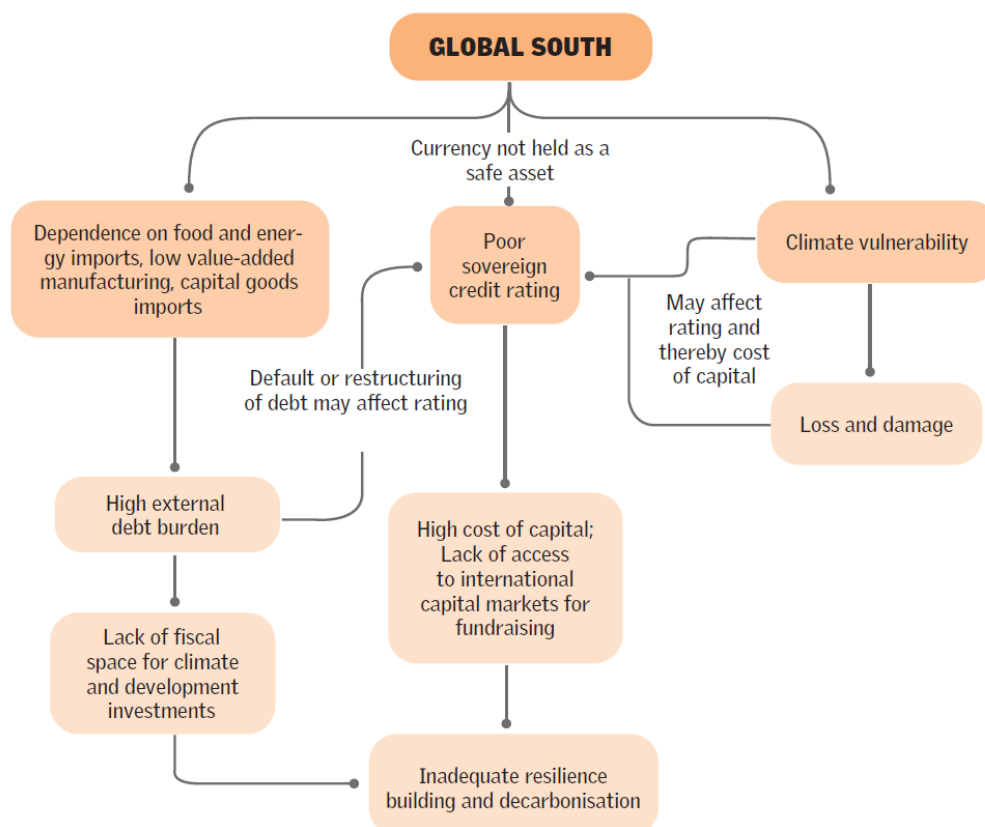
Finance

Clean manufacturing is capital-intensive and long-gestation, but financing terms for developing countries are prohibitive. Of the US \$1.3 trillion in global climate investment, only 19 per cent flowed to developing countries, and less than 4 per cent to Africa.⁴⁷

The weighted average cost of capital (WACC) for renewable and industrial projects is typically two to three times higher than in advanced economies.⁴⁸ According to IEA estimates, the WACC for solar PV projects in India, Brazil and Indonesia was 9.5 per cent, 11.25 per cent and 8.25 per cent, respectively, compared with 4.7–6.4 per cent in advanced economies in 2022.⁴⁹

Green industrialization today unfolds in a global subsidy race that most developing countries cannot afford to join. UNIDO estimated that between 2009–2019, high-income countries implemented five times more industrial policies than low- and

Figure 2: Financial barriers faced by the Global South



Source: Beyond Climate Finance, CSE, 2023

middle-income economies.⁵⁰ The U.S. Inflation Reduction Act (2022) committed over US \$369 billion in clean-tech investments, including subsidies and tax credits⁵¹, the EU's Net-Zero Industry Act (2023) estimates investments of EUR 92 billion by 2030, and the Clean Industrial Deal plans to mobilize over EUR 100 billion.^{52,53} China's fiscal effort is on another scale altogether—the pipeline of announced investment in the green industry exceeded US \$280 billion in 2023, including credit lines from state banks and local-government incentives.⁵⁴ By contrast, developing countries lack the fiscal space to spend on industrial support on a comparable scale.

This asymmetry leaves developing countries competing on a tilted field; their fiscal hands are tied just as green manufacturing becomes subsidy-driven in the North.

Subordinate position in global value chains

Even as developing countries have become more integrated into global value chains over the past few decades, these chains remain largely governed and coordinated by firms based in advanced economies. Control over design, technology and market access continues to rest with lead companies in the developed world, while developing countries are often confined to low-margin, assembly-oriented roles within these networks.⁵⁵

Further, the value is concentrated in design, technology and branding, and not in raw materials and basic processing, which are a feature of developing countries. For instance, although the DRC (over 70 per cent of cobalt's supply), Indonesia (over 40 per cent of Nickel's supply), and other resource-rich countries supply large shares of battery minerals, most of the value in batteries accrues downstream in material processing, cell components manufacture, battery and EV production, which are heavily geographically concentrated in China.⁵⁶

This is evident in the lithium-ion battery value chain. By 2030, global revenues from battery production are projected to exceed US \$400 billion, yet nearly half of this is expected to accrue to China alone. The highest-value activities, such as refining, active materials, and cell manufacturing, are concentrated in a few advanced and emerging industrial economies, while resource-rich developing countries remain confined to low-value mining and raw material exports.⁵⁷

Even in sectors where developing countries have expanded production capacity, participation often remains confined to the lower end of the value chain. The solar industry provides a clear example. In India, for instance, module manufacturing capacity has reached around 118 GW, but domestic capacity for solar cells is only about 27 GW, and for ingots and wafers, the upstream, technology-intensive stages, only 2.2 GW.⁵⁸

In capital and technology-intensive sectors, such as automobiles and wind power, the barriers to upgrading are steep. Countries like Brazil in wind energy or Mexico in automotive manufacturing have entered global chains, but typically through joint ventures or contract assembly plants, where key technologies and product design remain externally controlled.

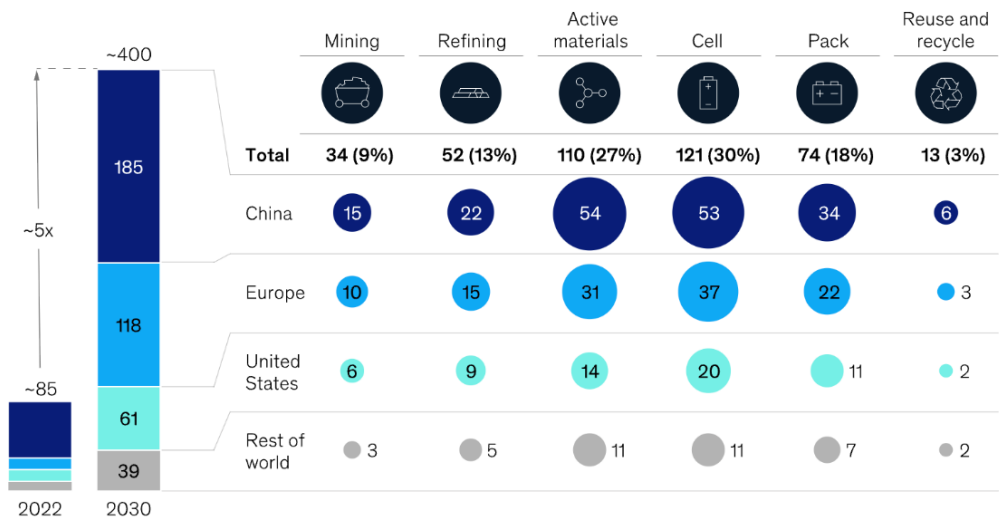
Restrictive trade regime and emerging protectionism

Over the years, the international trade architecture has systematically eroded the policy space of developing countries to pursue manufacturing-led development. As an IIFT Working Paper⁵⁹ notes, WTO agreements such as the Agreement on

Graph 10: Projected distribution of revenues along the global lithium-ion battery value chain by 2030

China is expected to capture nearly half of the industry's US \$400 billion market, dominating high-value segments such as active materials and cell manufacturing, while most developing economies remain limited to low-value extraction and refining.

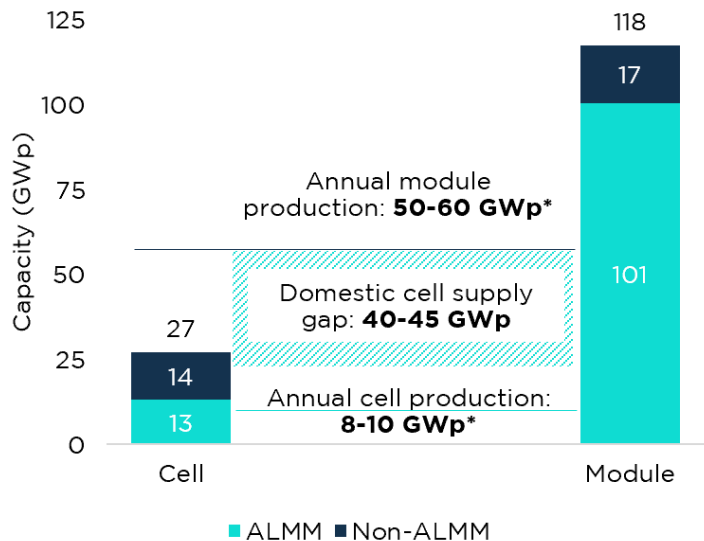
Revenues, base case 2030, \$ billion



Source: McKinsey Battery Insights, 2022

Graph 11: India's solar manufacturing capacity

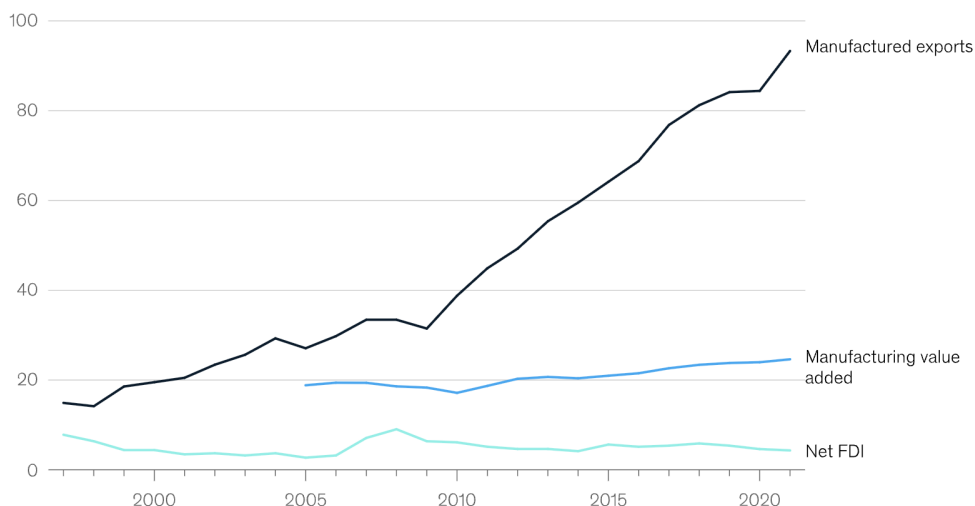
India's solar manufacturing capacity is concentrated in module assembly, with around 118 GW of module capacity but only 27 GW of cell capacity by July 2025, leaving a domestic cell supply gap of 40-45 GW



Source: CareEdge Ratings

Graph 12: Manufactured exports, manufacturing value added, and foreign direct investment (FDI) in Vietnam as a share of GDP from 1997–2021

Vietnam's manufactured exports have surged since the 2000s, rising far faster than manufacturing value added or FDI inflows, indicating strong export growth but limited deepening of domestic industrial capacity.



Source: UN Comtrade; UNDP Vietnam

Subsidies and Countervailing Measures (ASCM) and the Agreement on Trade Related Investment Measures (TRIMS) imposed disciplines on subsidies, export incentives and domestic content requirements. These disciplines were largely designed by advanced economies to serve multinational interests.

The 2014 WTO dispute initiated by the United States against India's National Solar Mission illustrates the constraint—India's local content rule for solar modules, intended to build a domestic renewable energy industry, was ruled inconsistent with WTO obligations.⁶⁰ Similar rulings against Brazil's Inovar-Auto scheme⁶¹ show how current trade rules penalize green and developmental industrial policies. Meanwhile, advanced economies have introduced subsidy programmes such as the US Inflation Reduction Act and the EU's Green Deal policies that, by the same logic, would also be against the principles of ASCM.⁶² China's complaint at WTO for India's EV subsidies in October 2025 reinforces this pattern.

Moreover, experts have recognized a trend within the WTO to prevent developing countries from deploying industrial policy tools to achieve economic diversification and industrialization. Rob Davies, the former Minister of Trade for South Africa, wrote about various ways in which developed countries are pushing for this⁶³:

- Restricting the application of “Special and Differential Treatment” so that the obligations of developing countries are far less differentiated from those of developed countries;
- Tightening up rules and notifications in relation to the deployment of an increasing range of “behind the border” regulatory and policy issues;
- Seeking recognition for “plurilaterals”, or so-called Joint Statement Initiatives—where selected groups of “like minded” countries make rules without adhering to the principle of consensus decision-making; and,
- Limiting the powers of the Dispute Settlement system so that, say, departures from rules justified on “national security” or strategic withholding of supplies could not be subject to a judicial challenge.

Unilateral measures such as the EU’s Carbon Border Adjustment Mechanism (CBAM) further create barriers for developing countries attempting to expand trade. As a carbon tariff on energy-intensive exports, CBAM penalizes producers in the Global South for structural constraints such as limited access to low-cost green technologies and finance.⁶⁴

Technology and intellectual property barriers

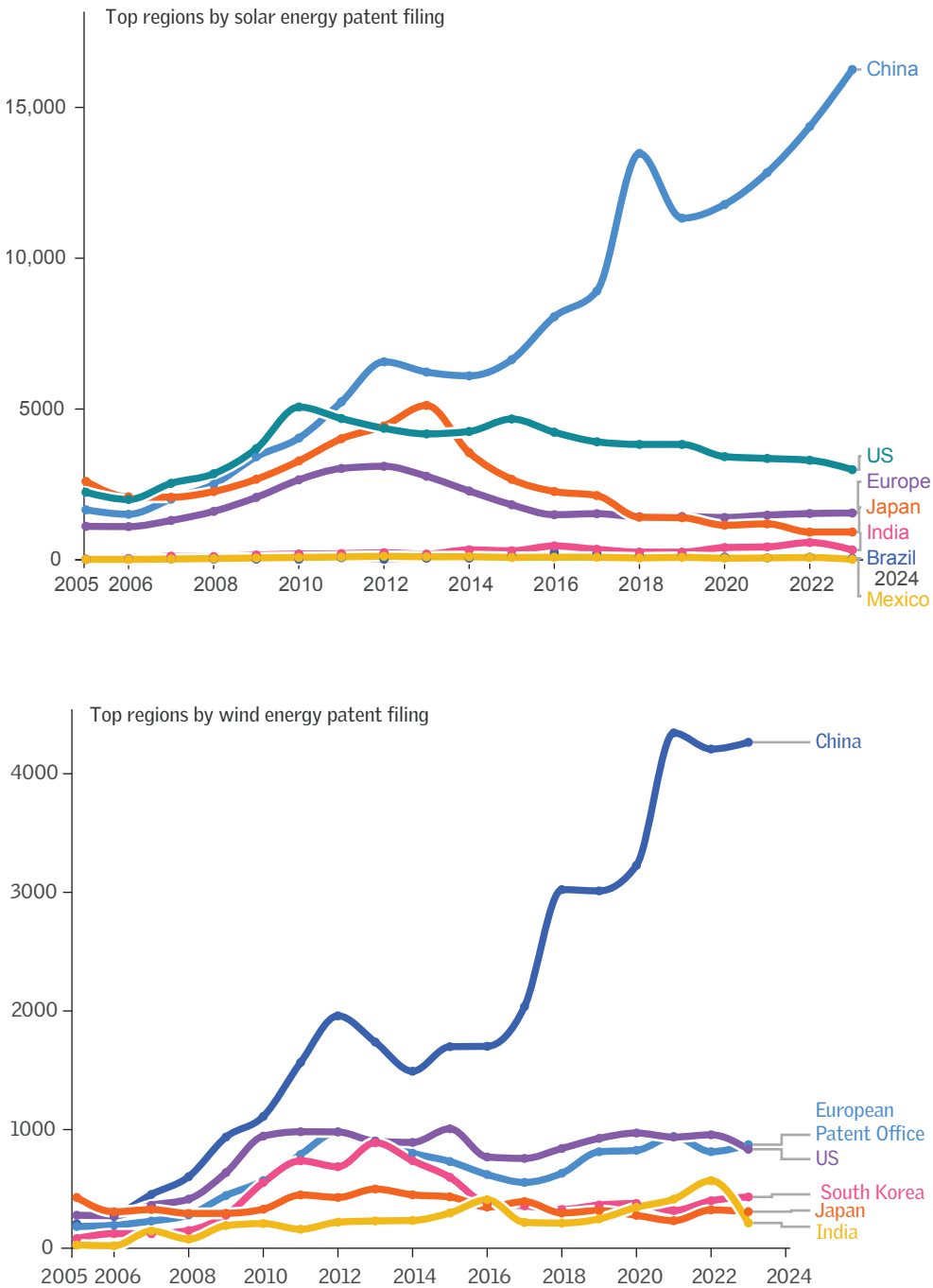
Manufacturing technologies, especially in the clean technology sector, are concentrated in China, the Global North and a few East Asian economies. UNIDO’s analysis finds that 85 per cent of industrial companies involved in green patent activity are concentrated in only five countries, led by Japan (32 per cent), China (19 per cent), the USA (18 per cent) and other high-income industrial countries. Industrial firms from developing countries (excluding China) hold less than 2 per cent of green patents.⁶⁵

Our focused analysis of solar and wind patents shows that between 2018 and 2023, ~55 per cent and ~42 per cent of all patents filed in the solar and wind energy technology sector in the world were filed in China.⁶⁶

While foreign direct investment is often promoted as a vehicle for technology transfer, spillovers are difficult. Moreover, in some developing countries, FDI tends to create enclave-type industries (assembly-based), where multinationals retain control over design, research and critical inputs. Evidence from India has shown that often foreign investment agreements restrict how much knowledge is shared, lock firms into ongoing royalty payments and keep technical know-how within

Graph 13: Total patent filing in solar and wind technology

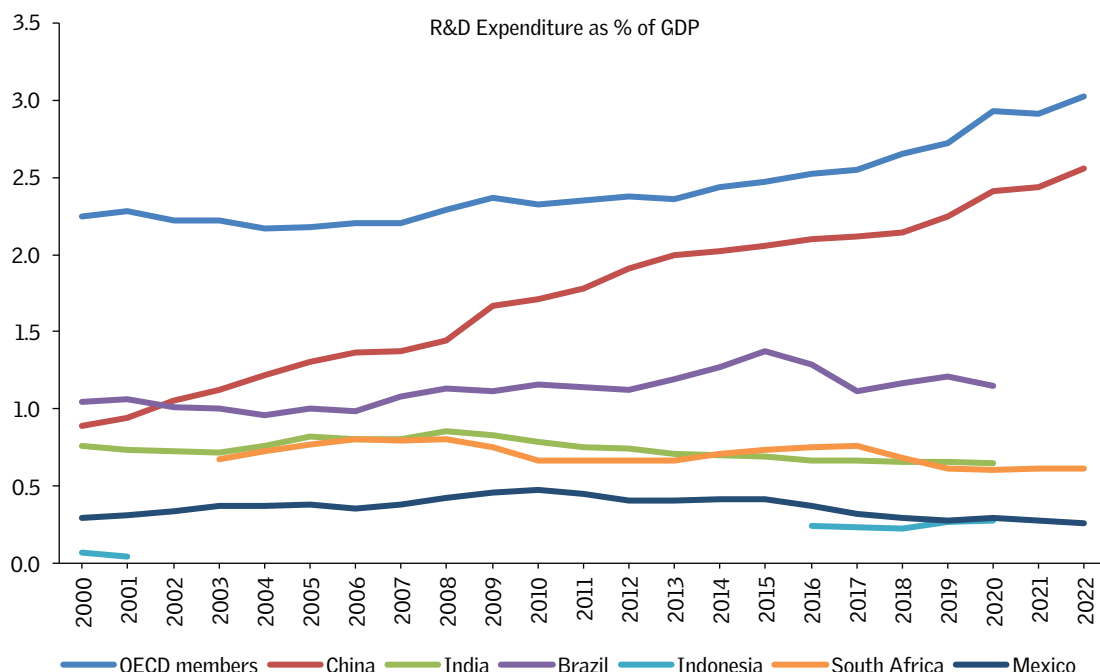
China leads global innovation in solar and wind energy, accounting for the majority of patent filings since 2015, far surpassing the US, Japan, South Korea, and Europe.



Source: WIPO IP Data Center, Graph CSE

Graph 14: R&D expenditure as a percentage of GDP

China's R&D expenditure as a share of GDP has risen steadily since 2000, approaching OECD levels, while most developing economies, including India, Brazil, South Africa, Indonesia, and Mexico, have seen either decline or limited growth, reflecting persistent gaps in innovation investment.



Source: World Bank, Graph: CSE

the foreign company's control.⁶⁷ Beyond these firm-level arrangements, the ability of developing countries to gain technology transfer through industrial policy is further constrained by international trade and investment rules. Agreements such as the United States-Mexico-Canada Agreement (USMCA) explicitly prohibit using tools like public procurement to stimulate technology transfer and local development.⁶⁸

Weak spending on R&D, a shallow industrial ecosystem, and underinvestment in upskilling and capacity building result in low absorptive capacity. This means that even when technology is imported, it is used as-is, without adaptation or upgrading.

Developed countries' green industrial subsidies and export controls, friendshoring production value-chains, risk creating a new technological dependency in clean-tech manufacturing technologies.

MALAYSIA'S EXPERIENCE WITH SOLAR PHOTOVOLTAIC MANUFACTURING

Malaysia's experience with solar photovoltaic manufacturing illustrates how foreign investment can expand industrial output without necessarily deepening local technological capacity. Chinese firms such as Jinko, JA Solar and LONGi established factories in Malaysia, primarily to bypass U.S. and EU antidumping tariffs, creating a large export-oriented manufacturing base. However, a Boston University Global Development Policy Center paper⁶⁹ found that the Malaysian solar market overwhelmingly continued to import panels directly from mainland China rather than sourcing locally manufactured ones. This production model also failed to generate significant spillovers or domestic linkages. The paper concludes, "There is a lesson to be learned regarding the degree to which host countries can capture value and build a solar industry via manufacturing. Beyond employing a few thousand workers, there is limited evidence that multinationals' solar manufacturing production facilities provide additional value added to the local solar industry."

Domestic political economy

Pursuing green industrial policy with a focus on clean technology manufacturing requires decades-long efforts with a push from domestic governments, as demonstrated by China, to ensure that consistent efforts are applied over time, with space for policy experimentation.

Consistent domestic alignment of government and societal goals towards such policy faces headwinds from short-term competing developmental priorities, vested interest from incumbent actors in high-carbon sectors such as coal mining interests in South Africa and agribusiness in Brazil, intra-Ministerial 'turf wars', or shifting priorities in changing electoral cycles as evidenced by the Inflation Reduction Act rollback by the Trump Presidency in its second term.⁷⁰

Moreover, differing national political contexts and available state capacity will determine success or failure of such policy. Of the latter, there is a need for "institutions capable of coordinating multiple agents who hold resources to be mobilized for specific policy objectives like technological learning", such as China's State-Owned Assets Supervision and Administration Commission (SASAC) for public enterprises, a centralised regulatory agency for coordination policies for sectoral investment.⁷¹

4.2 What does the way forward look like for the Global South?

Green industrial policy today almost reads like a footnote to China's industrialization story. China's domestic agency and strategic industrial policy was accompanied by a global landscape characterized by trade openness, large-scale offshoring by OECD countries, cheap finance and expanding demand. While some of these elements

remain, global value chains today have become geopolitically fragmented, subsidy-driven and security-oriented. So, the question is not just how to plug in, but how to build resilient and autonomous capabilities.^{72,73,74}

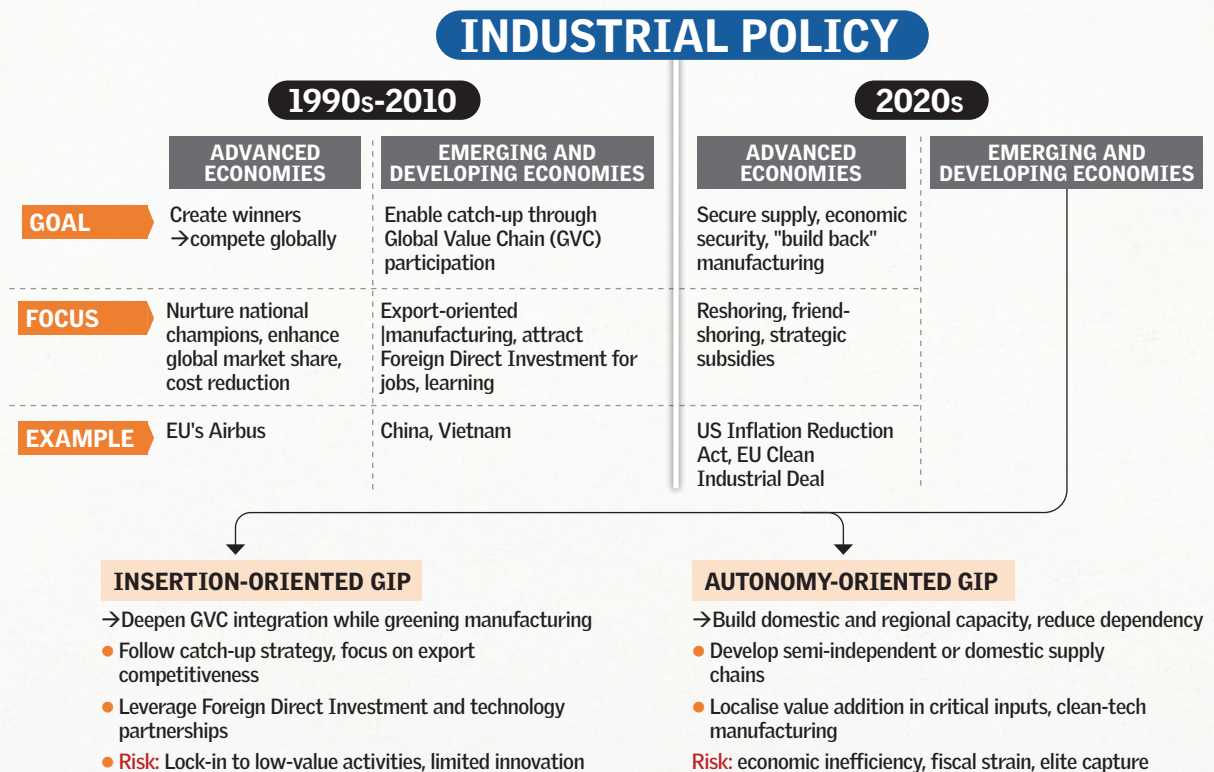
4.2.1 Domestic efforts to enable green industrialization and clean technology manufacturing

Experimenting with pathways

Countries in the Global South now face a new reality—development must go hand in hand with decarbonization; geopolitical fragmentation is intensifying, and global trade has become a hostile space. Within this context, two broad strategic orientations could emerge for green industrial policy:

Figure 3: Industrial policy approaches have evolved over time

In the 2020s, emerging economies have strategic paths to choose: insertion-oriented policies that deepen GVC integration or autonomy-oriented approaches that build domestic capacity and reduce dependency.



Source: CSE, based on various sources

- **Insertion-oriented GIP:** Seeks integration into existing global value chains, as in Vietnam's model. It can deliver rapid export growth and job creation, but often leads to low value capture, exposure to external demand shocks and limited technological upgrading.
- **Autonomy-oriented GIP:** Focuses on building independent or semi-independent supply chains, investing in local R&D, raising standards and developing upstream capabilities. While this approach promises greater resilience and domestic capability, it demands strong institutions, deep capital pools and can produce slower early growth.

This is also reflected in past literature. A 2024 article by Bentley Allan and Jonas Nahm highlights how when governments seek to integrate firms into global supply chains, they delegate investment and technology decisions to firms; but when they seek to build supply chains, they take an active role in coordinating firms and generating investment.⁷⁵

This, however, is not a binary choice. In practice, most countries will pursue hybrid strategies—seeking insertion in some sectors to gain scale and learning-by-doing, while nurturing autonomy in others to secure technological sovereignty and reduce vulnerability. This has to be done whilst avoiding ‘isomorphic mimicry’, i.e., the tendency of governments to mimic other governments’ successes, experts

WHAT CAN THE PROCESS OF GREEN ECONOMIC TRANSFORMATION LOOK LIKE?

Development economist Amir Lebdioui outlines four key processes that characterize green economic transformation⁷⁷:

1. **Production of green technologies:** Technologies central to the transition toward low-carbon energy systems, such as solar and wind technologies, and batteries.
2. **Improving resource efficiency:** Enhancing energy and material use through,
 - a. Adoption of cleaner production processes,
 - b. Design of durable, repairable and reusable products, and
 - c. Integration of circular economy principles to reduce resource needs.
3. **Mitigation of industrial externalities:** Reducing or reversing the environmental harms from existing industrial activities.
4. **Production of low-complexity, eco-friendly goods:** Goods such as bicycles, organic produce and reusable products that deliver both ecological and economic benefits.

suggest, to avoid implementing processes, strategies and systems that may not be suited to a local context.⁷⁶

Proactively building domestic capacity and policies

Domestically, it could be beneficial for developing country governments to develop clear pathways and programmes for green industrialization with the accompanying domestic tools that can support this, within the country's capacity. Creating domestic demand for large-scale deployment of clean technologies can help create a stable and growing market for domestic producers. Examples from India include setting strong renewable energy installation targets in its NDC, public procurement programmes, such as its upcoming green steel mandate for central government projects and local content mandates in its solar manufacturing schemes. Earmarking adequate government budgets to invest in R&D focused on reducing technological dependence, increasing innovation, adapting technologies to local requirements and promoting circularity through recycling and reuse will also be key. Moreover, domestic readiness in the form of state capacity, particularly investing in "organisational design, human resources and information technology infrastructure to enable state action"⁷⁸, and requisite political will is crucial, without which, even well-organized global frameworks would falter.

4.2.2 Confront dependencies and negotiate mutually benefit terms

China's outsized power as a hegemon in the green manufacturing race, is wielded in two primary ways—first is its leverage on material inputs and supply chains, and second is its role as a financier.

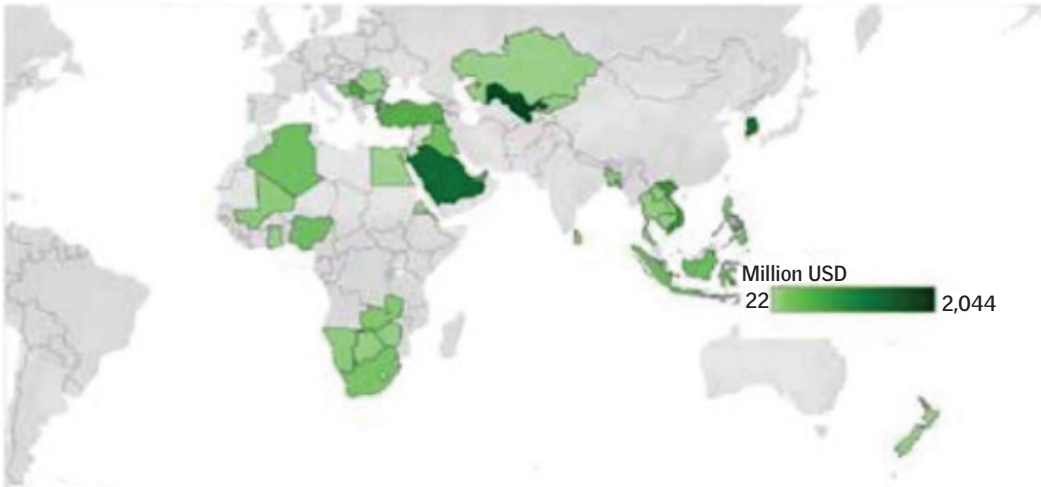
Its control over supply chains results in a risk of it weaponizing its dominance of key technologies and minerals central to the energy transition, as seen in its export controls on materials to India⁷⁹, or retaliation to trade tensions with the US by banning the export of rare earth elements.⁸⁰ China's filing of a complaint at the WTO regarding India's subsidies for EV production reported in October 2025 further complicates its new position as a global hegemon in clean technology manufacturing, with the power to retaliate if it considers its position at the helm of global supply chains threatened.⁸¹

Second, as a financier of infrastructure, both brown and green, China has cumulatively funded US \$1.2 trillion in projects overseas since 2013 through its Belt and Road Initiative (BRI); with construction projects funded by Chinese banks and investments in diverse projects through Chinese public and private entities.⁸² After declining briefly post-2019, BRI investments have soared to US

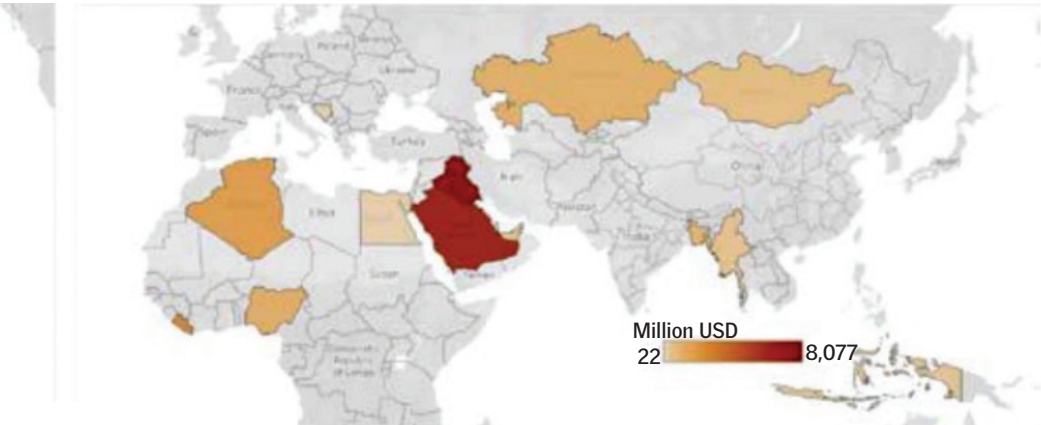
Map 1: Geographic distribution of China's overseas energy engagement

While green energy investments are expanding across parts of Africa, Asia, and Europe, fossil-fuel financing continues to dominate in West Asia and Russia⁸⁴

Green energy engagement



Fossil-fuel energy engagement



Source: Griffith Asia Institute, Green Finance and Development Center, and Fudan International School of Finance 2025

SEE CASE STUDY: INDONESIA'S NICKEL NATIONALISM IN SECTION 5.4

Indonesia's industrial policy aims to capture greater value from its nickel reserves. Export bans on raw ore and incentives for downstream investment have spurred smelting, refining, and value-added manufacturing, driving nickel-related exports from US \$6 billion in 2013 to US \$30 billion in 2022.

\$122 billion. This has both built vast physical infrastructure, like roads, railways, and ports, but also created economic and geopolitical dependencies for partner countries. BRI financing has been becoming “greener”. For energy in particular, green (solar, wind and hydro) investments and construction financing totaled US \$11.8 billion in 2024, the highest share of total energy engagement in a single year till date. This was still dwarfed by US \$24.3 billion in oil and gas in 2024.⁸³

For green manufacturing in particular, a report by the Net Zero Industrial Policy Lab at Johns Hopkins University finds that Chinese companies have committed over US \$227 billion across 461 green manufacturing projects in 54 countries since 2011—with 88 per cent of investment occurring just since 2022. This has been dubbed as BRI 2.0. For the broader category of “climate finance”, WRI estimates that China provided about US \$45 billion between 2013 and 2022 to developing countries.

Given this outsized power over the enablers for the green transition, it will be essential for developing countries to exercise agency in their partnerships with China and negotiate better terms to reap domestic benefits. Indonesia's requirement for Chinese investors to set up local manufacturing and processing facilities has hugely benefited processed nickel production—although an estimated 73–75 per cent of direct profits accrue to foreign (i.e., mostly Chinese) shareholders.⁸⁵ Brazil, in its discussions for China's BYD to invest in EV production, negotiated for an R&D center and localization targets to ensure that local value-add and know-how are created for domestic firms.⁸⁶ Knowledge and technology transfer have emerged as “one of the central pillars of the bilateral agenda” between Brazil and China, according to experts.⁸⁷ Negotiations on technology transfer, localization and R&D collaboration will be key in the future.

Given China's varying but large estimates of financing firepower, experts have recommended that it should partner with countries in the Global South to accelerate the green transition through increased low-cost lending and foreign direct investment in low-carbon technologies.⁸⁸

4.2.3 A collective push for overhauling global systems that hinder efforts

For the Global South to build its own clean technology industries, the international playing field must be leveled. This requires reforming a system that currently favors wealthy nations, and relegates developing countries to sources of raw materials, assembly hubs and buyers of green goods. On trade, developing countries should advocate for rules that enable—not constrain—green industrial policy, preserving their right to promote localization, secure technology transfer, and prioritize domestic suppliers. This could include establishing explicit green industrial policy exceptions for developing countries within the WTO framework such as a ‘climate waiver’ and the use of special and differential treatment in agreements.⁸⁹

On finance, efforts to reform the international financial architecture must be geared towards scaling up public climate finance to provide patient funding for clean technology investments, lowering the cost of capital and reducing the sovereign debt burden via large-scale debt cancellation. Global coordination is essential; isolated national efforts risk fuelling subsidy races rather than levelling the field. Moreover, in the arena of implementing unilateral trade measures such as the EU CBAM, focus must be on providing specific and additional sectoral financing to developing countries to help decarbonize their manufacturing sectors, rather than shifting the burden of the cost of decarbonization onto them.

Due to a lack of coordination among bodies dealing with these interconnected issues of trade, finance and green industrialization, developing countries must build strong coalitions and engage in strategic collective actions across various fora.⁹⁰

5

CASE STUDIES

China's EV industry demonstrates how persistent state support and industrial coordination can build global competitiveness.

Mexico's auto industry highlights the limits of export-oriented growth, strong output but weak domestic linkages and low value capture.

India's solar experiment shows progress through the PLI scheme but remains constrained by import dependence and narrow export markets.

Indonesia's nickel export ban spurred a downstream boom, increasing export value but deepening dependence on Chinese investment and refining control.

5.1 Case study: China’s EV export boom in less than a decade

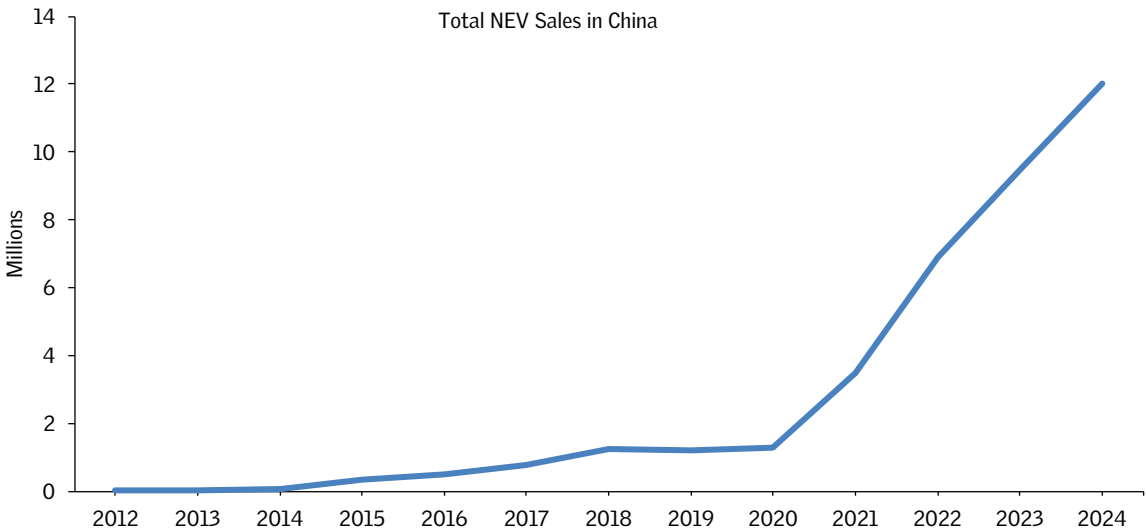
The meteoric rise of China’s manufacturing prowess has resulted from a convergence of diverse factors, making it difficult to isolate clear causal relationships. National and local industrial strategies, global market shifts, technological diffusion and macroeconomic trends have all been at play, interacting in complex and sometimes unpredictable ways. A granular, sector-specific analysis may yield insights into how particular industries evolved and gained a competitive advantage.

One such sector is the electric vehicle (EV) industry in China. The country was already the world’s largest new vehicle market in the first decade of the 21st century, and its motor vehicle production jumped nearly twentyfold during this period. This coincided with rapid economic growth, entry into the WTO, the rise of the private sector, state-owned enterprise reform and an expanding manufacturing base in other sectors. By 2015, more than half of global EV sales were in China, and by 2024, EVs accounted for 47.9 per cent of total auto sales in the country.⁹¹

Although technological advancement is central to the growth of EVs in China and worldwide, it has been supportive policies that both complemented this progress and further stimulated technological innovation. While EVs were not

Graph 15: China’s new energy vehicle (NEV) sales

Sales have grown exponentially since 2020, rising from under 2 million units to over 11 million by 2024, driven by large-scale state support, technological learning, and expanding domestic demand.



Source: China Association of Automobile Manufacturers (CAAM) and China Passenger Car Association (CPCA), 2024

found to significantly reduce CO2 emissions in the early phases due to China's grid intensity, it was hoped that they could offer future benefits in CO2 reduction. Moreover, EVs would improve urban air quality, which had been a problem in large cities in China.⁹² In the first decade, the total investment by the Chinese government and private enterprises in R&D, pilot projects and commercialization amounted to approximately US \$1.79 billion. The 2009 programme to subsidize New Energy Vehicles (NEVs)⁹³ in pilot cities saw some success in terms of vehicle sales and increased production capacity; however, challenges remained, primarily due to inferior technology. This period, followed also by the 12th five-year plan (2011) was marked by economic policies supporting the growth of NEVs in terms of government procurement, subsidy schemes and tax exemptions. In the period between 2013 and 2017, NEV sales jumped 340 per cent and the proportion of NEVs in the total vehicle sales increased from .31 per cent to 2.69 per cent.⁹⁴

These early initiatives gradually evolved into a broader policy ecosystem that combined incentives and regulations to guide the EV sector's growth:

Policy ecosystem

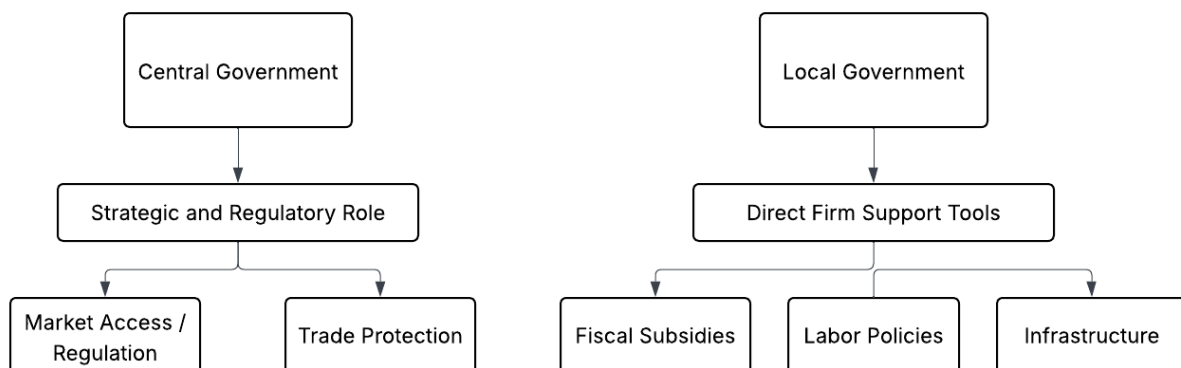
Table 2: Evolution of China's EV policy framework

A sequence of industrial and environmental policies has built a comprehensive ecosystem for EV manufacturing, market expansion and technological upgrading.

Year	Policy instrument		Notes
2009	Ten Cities, Thousand Vehicles Program	Subsidizing NEVs annually across pilot cities	The program began in 2009 and aimed to promote NEV adoption in select cities; by 2012 it had extended to about 25 pilot cities. ^{95,96}
2012-2020	Energy Conservation and New Energy Vehicle Industry Development Plan	Roadmap supporting NEV and energy-saving vehicle industry through 2020	The State Council issued this plan in 2012, establishing electric-oriented strategies, technology roadmap and industrial targets to be met by 2020. ⁹⁷
2015	Made in China 2025		EVs included as one of the strategic sectors
2018	Dual-Credit Policy	Pushed carmakers to make more electric cars as well as improve fuel efficiency	The two types of credits: Fuel-efficiency credits (CAFC): Reward better fuel economy in traditional cars. New Energy Vehicle (NEV) credits: Reward making electric and hybrid vehicles. ⁹⁸
2020	New Energy Vehicle Industry Development Plan (2021–2035)	Long-term NEV strategy from 2021 to 2035	Sets a target of about 20% share for new energy vehicles sales by 2025. Long-term target of making Battery electric vehicles (BEVs) the mainstream of new vehicle sales. ⁹⁹

Source: Compiled by CSE from various sources

Figure 4: Institutional structure for policy implementation in China



Source: Centre on China's economy and institutions, Stanford University¹⁰⁰, Figure: CSE

Subsidies: Fiscal incentives and market shaping

A 2018 study found that every US \$1,000 offered as a rebate or tax credit on EV purchases in the US (approximately 10 per cent of the vehicle's cost) increased average sales by 2.6 per cent.¹⁰¹ Another study in Canada found that a C\$1,000 subsidy (about 1 per cent of an EV's base price) increased sales by 5–8 per cent.¹⁰² On the other hand, the phase-out of the €4,500 subsidy in Germany in 2023 was followed by a decline in the EV market share in the country in 2024.¹⁰³

Of all the policy tools that the government in China has used, subsidies have been proven to be a major contributor to increased EV sales in China.

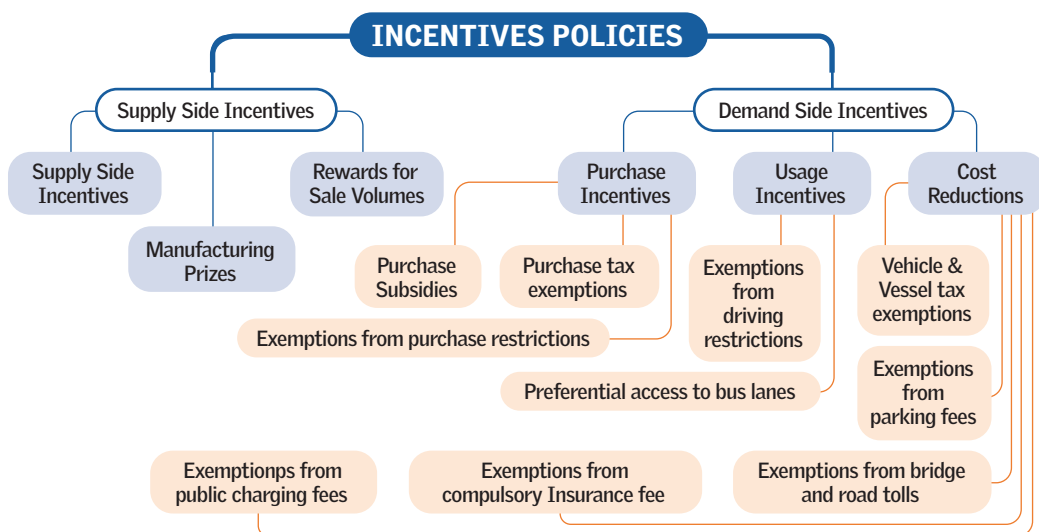
The central government started giving a purchase subsidy per vehicle (buyer rebate) in 2016, reduced over time and finally eliminated it in 2023. Subsidies were also provided by local governments, which was a proportion of the central government's

Table 3: Spending in China on EV Policy Instruments (US\$ billion)¹⁰⁵

Type of support	2009–2017	2018	2019	2020	2021	2022	2023	Total
Rebate	37.8	4.3	3.3	3.5	7.4	9.2	0	65.7
Sales tax exemption	10.8	7.7	6.4	6.6	16.4	30.3	39.6	117.7
Infrastructure subsidies	2.3	0.2	0.2	0.3	0.3	0.6	0.6	4.5
Research and development	2	3.6	3.4	3.5	4.3	3.9	4.3	25
Government procurement	7.8	1.6	1.4	2.9	1.7	1.8	0.8	18
Total	60.7	17.4	14.8	16.8	30.1	45.8	45.3	230.9
Spending as share of total sales	42.40%	22.70%	23.30%	25.40%	18.30%	15.10%	11.40%	18.80%
Subsidy per vehicle (US\$)		13,860	12,311	12,294	8,538	6,656	4,764	

Source: CSIS

Figure 5: Incentive in the Chinese EV ecosystem



Source: CSE

per-vehicle subsidy.¹⁰⁴ Estimates suggest that the Chinese government poured US \$230.9 billion into developing the EV ecosystem in China.

Building a battery manufacturing advantage

Batteries are an important part of EV manufacturing and represent nearly 40 per cent of the cost of the vehicle. The global EV battery market is overwhelmingly led by Chinese firms—in the first half of 2025, CATL and BYD alone accounted for roughly 55–56 per cent of global EV battery market, with several other Chinese companies (including CALB) make the top-ten list, creating an effective oligopoly whose scale and, in cases like BYD, vertical integration have been a core advantage for Chinese EV makers. The concentration of the battery manufacturing ecosystem gives Chinese automakers privileged access to low-cost batteries.

Continuous breakthroughs in battery technology innovation, fast-charging, solid-state batteries, etc., have benefited the EV industry in its own right. This has been underpinned by sustained state support for battery research and development. In the 13th Five-Year Plan (2016–2020), for instance, 27 programmes worth 1.2 billion yuan (US \$168 million) received state support for research and development in vehicle batteries and large-scale industrialization. In addition to the national programme, the National Natural Science Foundation of China (NSFC) and the Chinese Academy of Sciences (CAS) invested another 450 million yuan (US \$63 million) during the same period. In total, roughly 1.844 billion yuan (US \$258

million) was spent on programmes supporting research and development in vehicle battery technology.¹⁰⁶

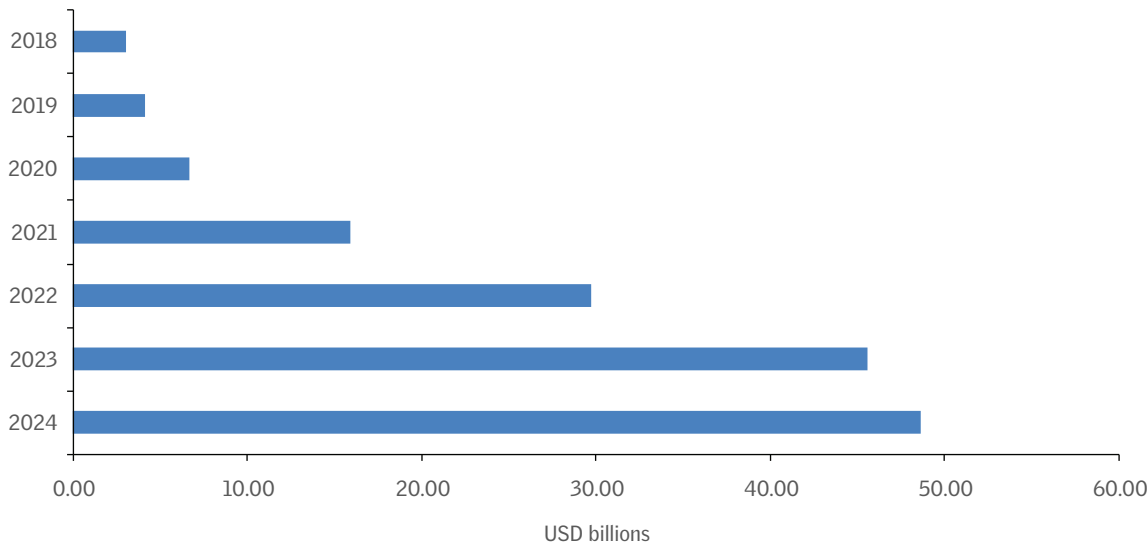
Trade policy: Growth achieved through global expansion

One of the reasons for the early proliferation of Chinese EVs in the European market was the combination of low import tariffs and generous government subsidies on EVs, which did not take the country of origin into consideration.¹⁰⁷ This contrasted with the United States, which had a 27.5 per cent tariff at the time. Subsequently, EU countries introduced tariffs to guard against Chinese EV imports. In 2023, Germany eliminated purchase subsidies for battery EVs, which had previously benefited Chinese imports. By the end of 2024, EU countries were charging tariff rates of over 45 per cent on Chinese EVs.¹⁰⁸

A few key reasons explain China’s expanding EV exports; one of the reasons is Chinese brands becoming major exporters. The vast domestic demand allowed companies to scale production rapidly and test technologies at volumes unmatched elsewhere. For example, BYD sold over 3 million new energy vehicles (NEVs) in 2023¹⁰⁹, a figure larger than the total EV sales in most countries combined. Several automakers have also formed joint ventures with Chinese companies and become successful exporters, such as Mercedes-Benz with Geely, or Renault-Nissan-

Graph 16: China’s electric vehicle exports

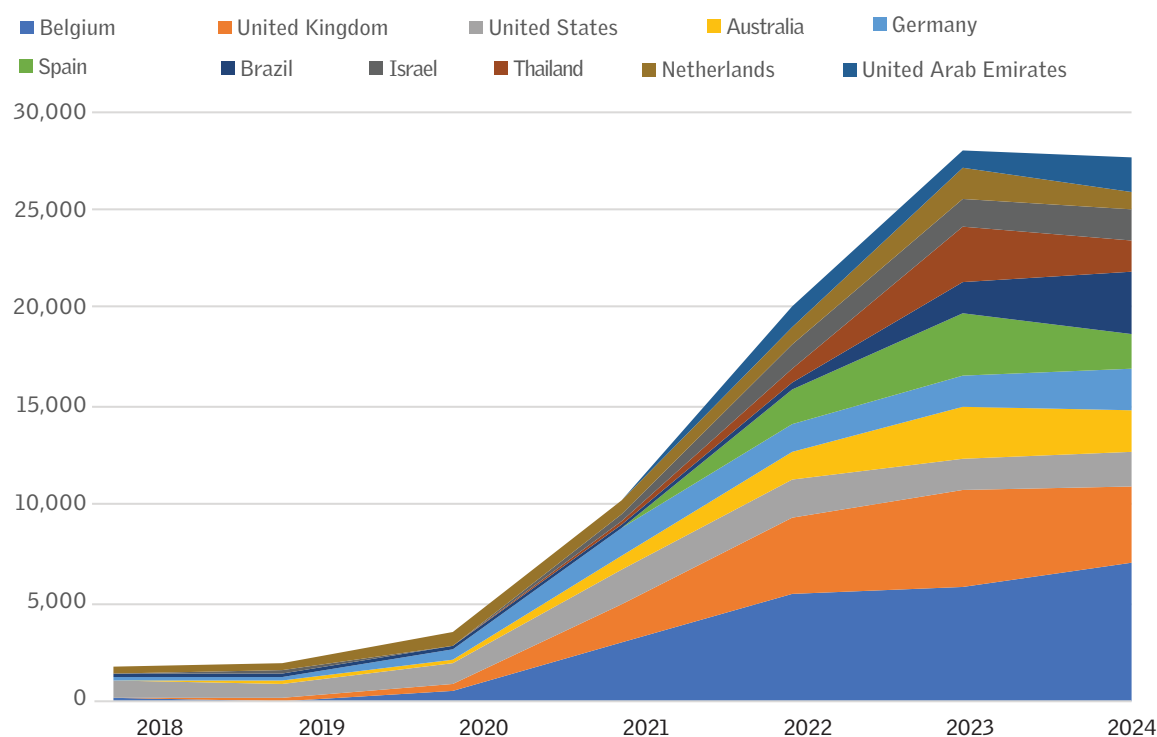
Exports have surged since 2021, rising from under US \$10 billion in 2020 to over US \$48 billion in 2024.



Source: Custom Statistics, Government of China; Graph: CSE

Graph 17: China's electric vehicle exports by destination, 2018–2024 (US\$ million)

EV exports have diversified rapidly since 2022, with strong growth in shipments to Europe.



Source: CSE analysis based on Chinese customs data

Mitsubishi with Dongfeng. Another driver has been the acquisition of foreign brands with strong market recognition abroad, such as MG in the UK, which was acquired by the state-owned SAIC Motors, despite the fact that the vehicles are no longer manufactured in the UK.

Chinese EVs are also gaining ground in emerging markets across the Global South. Ethiopia's ban on the import of internal combustion engine (ICE) vehicles, for instance, has created strong incentives for EV imports from China and for joint-venture assembly operations.¹¹⁰ Similarly, Nepal's electric vehicle transition, driven by favorable import duty structures, has opened new export opportunities for Chinese manufacturers. Over 76 per cent of cars sold in Nepal in 2024 were EVs, while more than 100,000 EVs were on Ethiopian roads by mid-2025.^{111,112}

5.2 Case study: Mexico's auto assembly ecosystem

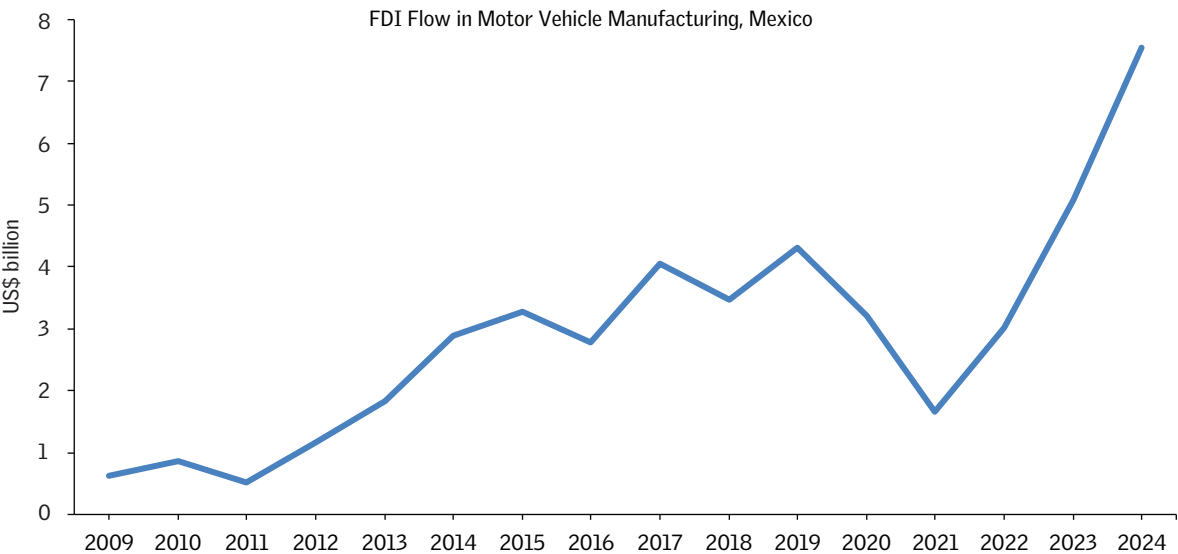
Mexico is one of the world's leading automotive producers, with an export-oriented automobile market; about 87 per cent of vehicles manufactured are exported, two-thirds of which go to the United States. The sector directly contributes ~4.7 per

cent of national GDP and ~21.7 per cent of manufacturing GDP and supports around one million direct jobs in the country.^{113,114}

Mexico’s automotive industry has a presence of major global automakers such as GM, Ford, Volkswagen, Nissan, BMW and Toyota, which operate large assembly plants across key industrial states including Puebla, Guanajuato, San Luis Potosí, Coahuila and Nuevo León. This strong base is tied to the regional trade dynamics under the United States–Mexico–Canada Agreement (USMCA), 75 per cent of auto content (70 per cent for trucks) must originate within North America to qualify for duty-free access, a rule that has encouraged greater vertical integration across the continent.¹¹⁵

In recent times, electric vehicle production in Mexico has also been expanding, although the base is still relatively small. In the first quarter of 2025, sales of plug-in hybrids and battery electric vehicles reached 20,560 units, almost quadruple the figure from the same period in 2024, with pure EV sales alone growing by over 70 per cent year-on-year. EVs still, however, represent 1.3 per cent of the vehicle market, with hybrids continuing to dominate. On the production side, the EV output of Mexico rose 70 per cent in early 2025, compared to 2024.¹¹⁶

Graph 18: Foreign direct investment (FDI) in Mexico’s motor vehicle manufacturing sector¹¹⁹



Source: Government of Mexico

A combination of factors has been found to promote the expansion of the EV sector in Mexico. Notably, studies show that the nearshoring trend, spurred by U.S. policy (such as higher automobile tariffs and stricter rules of origin under United States-Mexico-Canada Agreement), is channeling new investment into Mexico's EV sector, as firms expand assembly capacity and integrate more local suppliers.¹¹⁷

In addition, an established industrial infrastructure, a network of suppliers and low labor costs are also contributing to Mexico being chosen as a base for EV manufacturing.¹¹⁸

Mexico's automotive FDI reached US \$7.5 billion, with a shift in several investments toward electrification. For instance, GM committed US \$1 billion to convert its Ramos Arizpe plant to EV production, BMW pledged US \$872 million for EV manufacturing in San Luis Potosí, and Volkswagen earmarked US \$764 million for upgrades at its Puebla plant.¹²⁰ In the second quarter of 2025, Mexico received US \$2.2 billion in automotive investment. Out of this, US \$473.8 million went to electromobility projects and about US \$737.3 million in auto parts manufacturing. Investment was led by China, followed by the US, South Korea, Japan, Germany and the UK.¹²¹

The expansion, however, comes with several constraints that limit Mexico's potential to capture higher value. Mexico's automotive manufacturing and export model since the 1980s has been built largely on assembling imported parts, with limited use of local suppliers.^{122,123} This has meant weak technology transfer and little value capture within the domestic economy—high exports, but few deeper industrial or innovation linkages at home.¹²⁴ For the electric vehicle industry, the poor domestic uptake of EVs, coupled with weak charging infrastructure, compounds this challenge.

Beyond vehicle assembly, Mexico could also have a role in the upstream EV value chain. The country holds significant lithium reserves, particularly the La Ventana deposit in Sonora, estimated at around 243 million tonne. In 2022, the government nationalized lithium and created a state-owned company, LitioMX, to oversee exploration and development.¹²⁵ These reserves could enable Mexico to move into lithium refinement and battery production. However, governance and regulatory challenges have slowed progress, leaving the country's potential in this upstream segment still largely unrealized.¹²⁶

Together, these cases illustrate the diversity of pathways available to developing countries. China shows the power of scale, long-term planning and upstream

integration; Mexico highlights both the opportunities of export-oriented integration and the risks of low value capture.

5.3 Case study: India’s solar manufacturing experiment

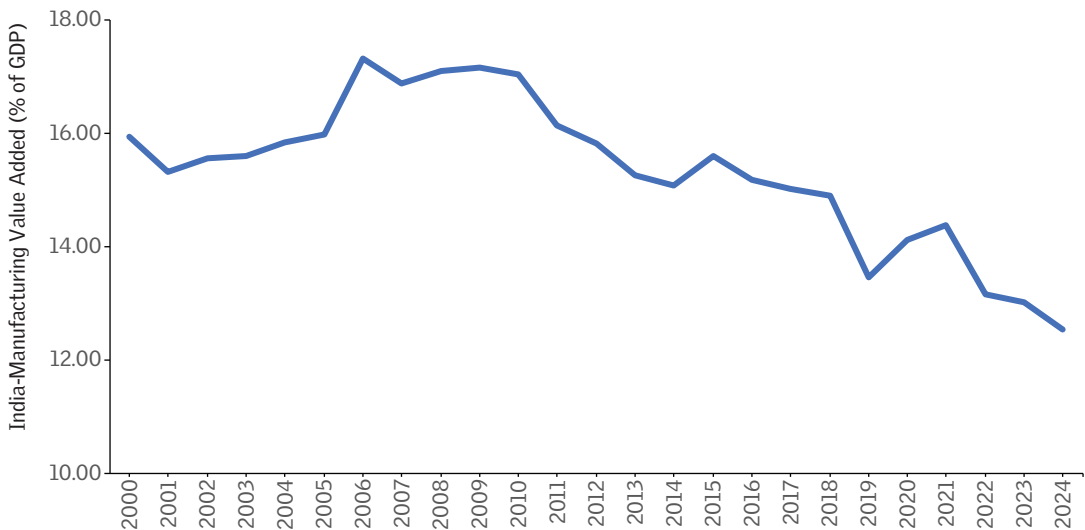
India’s clean technology manufacturing aspirations are nested within its goal of growing manufacturing as a sector, most recently through the ‘Make in India’ scheme of 2014, which aimed to increase the share of the manufacturing sector in GDP to 25 per cent by 2025. However, from hovering around 16 per cent in the 2010s, the share of manufacturing declined to 13 per cent in 2024.

Within this ongoing challenge, the goal of manufacturing clean technologies of the future was taken on, covering solar photovoltaics (PV), electric vehicles (EVs), batteries and a recent push to build a green hydrogen ecosystem. For solar in particular, the country has seen some success—but headwinds remain numerous, including an export dependence on the US for 97 per cent of solar panel exports¹²⁷ that may be a challenge, given US protectionism and anti-climate government sentiment, and a reliance on imported components to produce modules.

India’s efforts to produce solar panels date back to the 1980s with the establishment of Central Electronics Limited (CEL), a public sector company, which yielded

Graph 19: India’s manufacturing value added (MVA) as a share of GDP

India’s manufacturing value added (MVA) as a share of GDP has stagnated around 15–17 per cent since the early 2000s and declined to about 13 per cent by 2024.



Source: World Bank

Table 4: Key policy instruments supporting India's solar photovoltaic (PV) manufacturing sector

Scheme	Details	Nature
PLI Scheme for High Efficiency Solar PV Modules	(Tranche I & II) with a financial outlay of Rs 24,000 Crore / US \$2.9 billion to set up a cumulative manufacturing capacity of over 48 GW of integrated, high-efficiency Solar PV modules	Subsidies to national champions
Duties and Cess	20% Basic Customs Duty (BCD) plus 20% Agriculture Infrastructure and Development Cess (AIDC) on solar PV modules and a 20 per cent BCD plus 7.5 per cent AIDC on solar PV cells ¹²⁹	Import barrier
Approved List of Models and Manufacturers (ALMM)	Mandates domestic procurement, with List-I for solar PV modules already active, List-II for solar PV cells effective from June 2026, and a proposed List-III for wafers and ingots targeted for 2028—contingent on 15 GW of domestic manufacturing capacity.	Localisation, import substitution
CPSU, PM-KUSUM	Public procurement via certain government schemes now requires the use of domestically sourced solar PV cells and modules. This includes the CPSU Scheme Phase-II which creates a government-backed demand for solar power and the PM-KUSUM Scheme which provides financial assistance to promote solar energy in agriculture by installing solar pumps and solar power plants	Public procurement, demand stimulation, localisation
Renewable Purchase Obligations (RPO)	Mandates power procurers to purchase a certain percentage of their electricity from renewable sources—help create a guaranteed market for domestic solar PV manufacturers	Demand stimulation

Source: Compiled by CSE from various sources

modest efforts.¹²⁸ Large flagship programmes like the Jawaharlal Nehru National Solar Mission (JNNSM) of 2010 and the most recent Production Linked Incentive (PLI) scheme for high-efficiency solar PV modules are a series of experiments intended to build both domestic demand and deployment of solar, as well as create a manufacturing ecosystem.

The PLI scheme offers a subsidy to large firms with conditions attached for localisation to boost manufacturing competitiveness. It could be compared to the 'sectoral champions' approach of South Korea and Japan that produced the 'East Asian Miracles' in the 1980s.

The PLI Scheme has been complemented with a range of other measures combining import substitution and localization, with demand stimulation. A national-level NDC aiming for 50 per cent non-fossil power capacity by 2030 provides a banner target to direct these efforts.

As per a government press release, India reached 100 GW of solar module manufacturing capacity in August 2025.¹³⁰ The PLI scheme—awarded to 14 firms—itself has been cited to have created 18.5 GW of module manufacturing capacity, 9.7 GW of solar cell, and 2.2 GW of ingot-wafer capacity as of June 30,

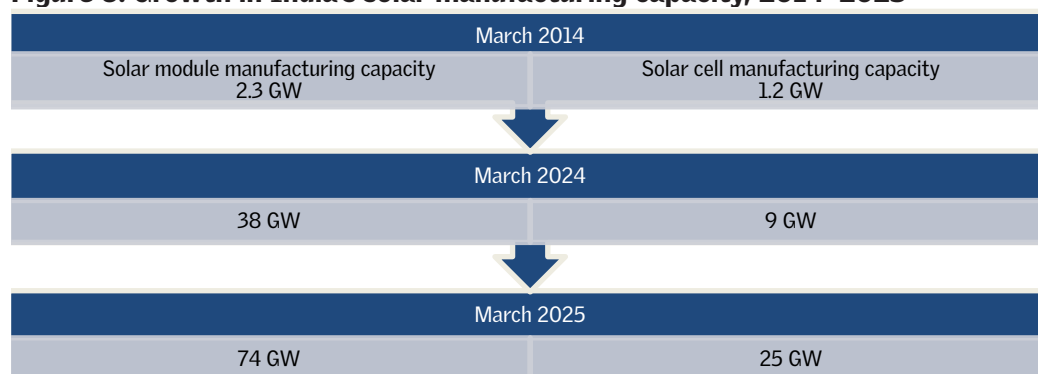
2025,¹³¹ as well as 38,500 jobs.¹³² A decline in module imports to India from US \$3,363.21 million in FY 2021–22 to US \$2,151.75 million in FY 2024–25 is also attributed to this initiative.¹³³ It is also said to be spurring vertical integration (polysilicon > wafer > cell > module), with companies like Reliance and Adani committing to building multi-stage integrated facilities, in a bid to promote localisation and not just final assembly.¹³⁴

However, challenges remain in the form of upstream import dependency, slow disbursement, and constraints in critical mineral supplies.

Under the wider PLI Scheme that covers many sectors, “application clearances” for solar PV has been among the lowest since 2021—14 for solar and four for batteries, compared with “traditionally strong” sectors like food products (182), and specialty steel (109)¹³⁵. Reasons cited have been inability of companies to meet the targets and “pricing pressure” from China.

Moreover, two-thirds of PV cells and 100 per cent of wafers (essential components for these cells) are imported. China supplies India with between 57 and 100 per cent of the components it needs for its solar panels.¹³⁶ Import of components from Vietnam, Thailand and Malaysia has increased—which happen to be intermediary countries where Chinese firms dominate production—thereby complicating reports of India’s reduced import dependence on China.¹³⁷

Figure 6: Growth in India’s solar manufacturing capacity, 2014–2025



Source: Press Information Bureau, Government of India

Table 5: Share of India’s Solar PV imports from China, 2019–2025

Year	2019-20	2020-21	2021-22	2022-23	2023-24	2024-25
Solar PV	78%	87%	92%	65%	63%	81%

Source: Directorate General of Commercial Intelligence and Statistics, Government of India

This raises questions about whether or not the PLI scheme provided sufficient incentives for R&D and innovation, and led to improved net value addition. Former RBI Governor Raghuram Rajan critiqued a similar PLI scheme for electronics for encouraging imports of hardware from other countries, and questioning whether India was genuinely manufacturing finished products in its factories or merely assembling them.¹³⁸ A wider analysis of India's trade with China in particular reveals an increase in intermediate and production goods, which accounted for 70.9 per cent and 22.3 per cent, respectively, of total industrial imports from China in 2023–24, compared with 64.8 per cent and 24.3 per cent, respectively, in 2020–21.¹³⁹

Unrelated to the PLI, the export of solar modules from India has risen exponentially in the past five years, due to factors varying from subdued domestic demand to achievement of 40–60 per cent higher profit margins in developed countries.¹⁴⁰ This has led to leading Indian manufacturers such as Waaree Energies, Adani Solar and Vikram Solar targeting export markets for more than half of their annual production in FY 2024. However, the destination for exports is predominantly the US, which accounted for 97 per cent and 99 per cent of India's PV exports in FY 2023 and FY 2024, respectively. The rest goes to South Africa, Somalia, Kenya, the UAE, Afghanistan, Nepal and Bangladesh.¹⁴¹ India's share of the US' module imports rose from 2.5 per cent in 2022 to 10.7 per cent in 2024, amounting to approximately US \$2 billion in 2023–24.¹⁴² In an atmosphere of high protectionism in the form of tariffs and other barriers from the current US administration, as well as a crackdown on climate-related investments and technologies, this exposes a vulnerability for India's solar manufacturers.

India's green industrial strategy, while demonstrating successes in scaling production, continues to face the core challenges of deepening domestic value addition and mitigating external supply chain vulnerabilities. The application of tariffs, subsidies and procurement mandates is systematically building a domestic green manufacturing base. However, progressing from import-dependent assembly towards integrated and competitive value chains remains a work in progress. The success of India's green industrial policy will, therefore, hinge on its ability to overcome the hurdles in upstream integration and critical mineral security.

5.4 Case study: Indonesia's nickel nationalism

Indonesia leveraged a developed-oriented trade policy to promote its industrial goals. As a holder of 42 per cent of the world's known nickel ores¹⁴³, concentrated in Sulawesi, Halmahera, etc. Indonesia has found itself central to the manufacturing of key technologies for the clean energy transition—batteries and electric vehicles

(EVs), as well as other industrial applications such as stainless steel, for which nickel is a key input.

Indonesia's industrial policy has been centered on moving from exporting raw nickel ores to processing (smelting, refining), as well as the manufacturing of value-added goods. One of its primary policy tools leveraged has been the export ban on raw nickel—first on nickel ore in 2014, and then on all unprocessed nickel in 2020—coupled with attracting foreign investment.

As a result, the country's nickel-related exports grew from US \$6 billion in value in 2013 to US \$30 billion in 2022¹⁴⁵, propelled by the processing and production of derivatives like ferronickel, nickel matte and mixed hydroxide precipitate (used in EVs), as well as the exports of higher value-added products such as stainless steel.

Table 6: Key policy measures shaping Indonesia's nickel and EV industrial strategy, 2009–2021

A combination of export bans, local content requirements, and state-led coordination has driven domestic value addition.

Year/instrument	Detail
2009: Mining Law	New licensing system introduced. Foreign-owned mining firms required to progressively divest up to 51 per cent of ownership to domestic firms. Export bans, tariffs and quotas floated for ores and refined metals.
2010: Master Plan for the Acceleration and Expansion of Indonesian Economic Development, 2011-2025 (MP3EI)	Identifies 6 economic corridors and US \$20 billion in required investment, including smelters and industrial parks.
2012: De facto commodity and ban announced	Unprocessed nickel ore export ban enforced 2014; concentrate exports permitted until 2017.
2019: Ministry of Energy and Resources Regulation No. 11/2019	Banned exports of ore with nickel content <1.7 per cent from January 2020.
2019: Presidential Regulation 55/2019	Sets 80 per cent local content requirement for electric vehicles by 2026 for bicycles and 2030 for cars. Ministry of Industry guidelines limit government procurement to compliant vehicles.
2020: Omnibus Law on Job Creation	Promotes investment by streamlining land acquisition and licensing and reducing labour and environmental regulation.
2020: Law 3/2020	Amended 2009 Mining Law, centralising authority and tightening foreign investor's divestment obligations.
2020: Ministry of Energy and Mineral Resources Decree 154/2019	Implements ban on low-grade nickel ore exports from January.
2021: New investment list	Further liberalized foreign investment in energy and natural resources, including smelting.
2021: Indonesia Battery Corporation (IBC) created	A joint venture of four major state-owned enterprises (SOEs), IBC set out plans to foster a whole supply chain to EVs.

Source: Wijaya & Jones (2025), Third World Quarterly¹⁴⁴

Supply chain for stainless steel and nickel-based alloy

Legend:
 Key: Available in Indonesia? Yes No In Development
 Dashed line = broken supply chain.

Process Flow:

- ORE:** Saprolite, Sulphide, Limonite.
- SMELTING/ PROCESSING:**
 - Saprolite → RKEF/BF → Nickel Pig Iron (4-15% Ni) [Yes]
 - Sulphide → Nickel Matte (40-75% Ni) [Yes]
 - Sulphide → Mixed Sulphide Precipitate [In Development]
 - Limonite → HPA → Mixed Hydroxide Precipitate [In Development]
 - Nickel Matte (40-75% Ni) → Converter → Ferronickel (16-30% Ni) [Yes]
 - Nickel Matte (40-75% Ni) → Pure Nickel (99.9% Ni) [Yes]
 - Mixed Sulphide Precipitate → Pure Nickel (99.9% Ni) [Yes]
 - Mixed Hydroxide Precipitate → Nickel Sulphate [In Development]
- FORMING/ REFINING:**
 - Nickel Pig Iron (4-15% Ni) → Stainless Steel (SS) slab [Yes]
 - Ferronickel (16-30% Ni) → SS billet [Yes]
 - Pure Nickel (99.9% Ni) → Nickel-based alloy [Yes]
 - Nickel Sulphate → Battery precursors (NMC, NCA) [In Development]
- FINISHED GOODS:**
 - Stainless Steel (SS) slab → SS slab → SS cold rolled coil → SS cold rolled coil → SS welded pipe [Yes]
 - SS billet → SS rod/ bar → SS seamless pipes; SS nuts and bolts [Yes]
 - Nickel-based alloy → Nickel-based alloy; plating [Yes]
 - Battery precursors (NMC, NCA) → Batteries [In Development]

Table 7: Primary nickel products and average unit values of exports from Indonesia in 2022

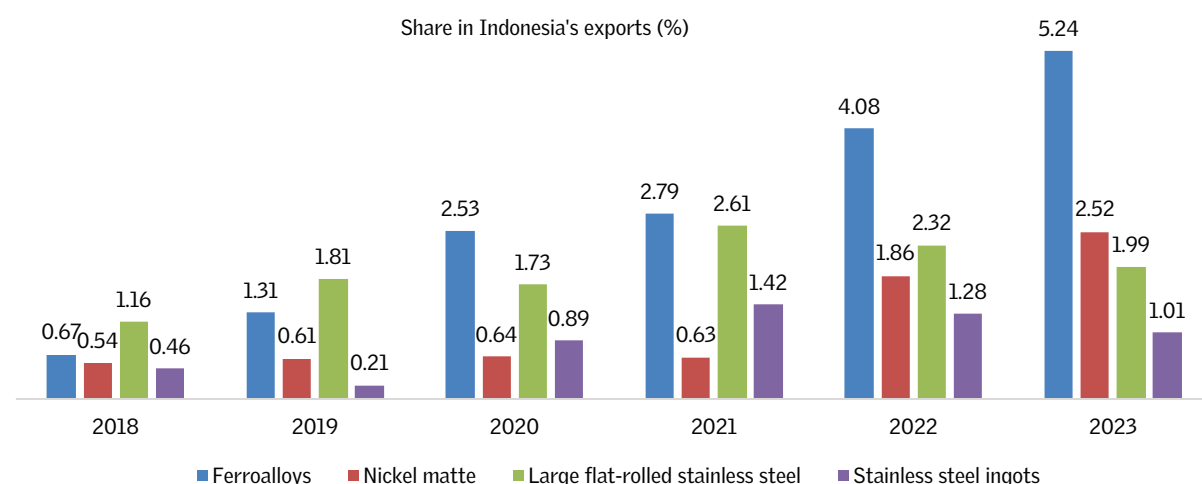
HS Subheading	Title	Category	Average unit value of exports (\$/metric ton)
2604	Nickel ores and concentrates	Raw material	60
7202.6	Ferronickel (includes nickel pig iron)	Processed (Class 2)	2,357
7501.2	Nickel oxide sinter and other intermediate products	Intermediate	3,784
7501.1	Nickel matte	Intermediate	14,834

According to the US International Trade Commission's Office of Industry and Competitiveness Analysis, the value of nickel products increases depending on the amount of processing involved in production and the nickel contained in the product. At the lowest end, raw, unprocessed nickel ores and concentrates were exported from Indonesia at an average of US \$60 per tonne in 2022.¹⁴⁷ However, moving further down the value chain to processed ferronickel and different intermediate nickel products boosts the unit values of the products that are exported.

67

Graph 20: Composition of Indonesia's nickel-related exports, 2018–2023

The share of ferroalloys and nickel matte in total exports has risen sharply.



Source: The Observatory of Economic Complexity (OEC)

In addition to a sharp rise in nickel's value-added exports, the number of smelters grew from zero in 2014 to 36 by 2023¹⁴⁹, and foreign investment surged as high as US \$30 billion in 2023—primarily Chinese. In fact, the primary players investing in nickel's downstream activities in Indonesia have been Chinese companies, bolstered by Indonesia's seeming geopolitical 'polyalignment'. However, this has resulted in deep embeddedness of Chinese interests in Indonesia's nickel-based industrial policy outcomes. Chinese technological prowess supported innovations in nickel matte production and high-pressure acid leaching (HPAL) methods, which have greatly aided Indonesia.¹⁵⁰ 75 per cent of refining capacity is controlled by Chinese entities¹⁵¹, and an estimated 73–75 per cent of direct profits accrue to foreign—mostly Chinese—shareholders.¹⁵² China is the biggest buyer of Indonesian nickel too.

There has also been a surge in jobs created. However, the distributional impact on jobs and poverty reduction remains a question mark, as poverty reduction in key districts of nickel processing has been modest—a meagre reduction in Morowali⁸⁶, while other districts like Konawe have seen economic growth, but a rise in poverty levels as well.¹⁵⁴

Environmental costs have been high with reports of improper tail waste disposal, contamination of fresh water¹⁵⁵, and deforestation linked with nickel processing

activities rising exponentially, as well as the addition of captive coal power plants to power the smelting process, which adds to pollution and emissions.¹⁵⁶

Indonesia's efforts nevertheless remain an aspirational case study for a developing country deploying resource nationalism and attempting to move up the value chain and deepen its standing in the industrial and clean tech ecosystem—although the sustainability of these efforts will hinge heavily on stronger environmental oversight, and clear positive spillover effects on the local economy. The IEA projects that the share of batteries in nickel consumption will rise from 6 per cent in 2020 to 36 per cent in 2040. In the long term, the use of nickel-free lithium iron phosphate (LFP) and alternate battery chemistries may pose threats to the vast demand projected¹⁵⁷, but in the near future, nickel's centrality to the energy transition remains unchallenged. Announcements by Hyundai Motor, LG, CATL, and Wuling to build battery plants in Indonesia further cement the economic potential of the sector^{158,159,160}, as well as VinFast and BYD building EV assembly plants.¹⁶¹

Annexure

Import Substitution Industrialization (ISI) and Export-Oriented Industrialization (EOI)

Import Substitution Industrialization (ISI) refers to an economic and trade strategy aimed at reducing a country's dependence on imports by developing domestic industries. The core idea is to replace imported goods with locally produced ones, allowing economies to build internal industrial capacity and conserve foreign exchange. Governments pursuing ISI typically protect “infant industries” from international competition through measures such as high tariffs on imports, quantitative import restrictions and subsidies or preferential credit for local firms.¹⁶²

In practice, ISI has had a mixed impact. While it initially nurtured industries, created jobs, and insulated economies from global volatility, long-term protection often encouraged inefficiency, rent-seeking and technological stagnation. In countries such as Brazil, Argentina and India, ISI regimes became characterized by overprotected markets and limited export dynamism, leading to pressures for liberalization.¹⁶³ In some advanced countries and many developing countries, it remains synonymous with ‘white elephants’.¹⁶⁴

Yet, this experience does not fully capture the diversity of ISI outcomes. Recent scholarship shows that strategic protectionism also played a role in the early industrialization of many advanced economies.¹⁶⁵ In these cases, protection was typically strategic, helping firms build competitiveness before gradual exposure to global markets.

Export-Oriented Industrialization (EOI) promotes producing goods for global markets rather than domestic consumption. Governments adopting EOI focus on industries where the country holds a comparative advantage, such as low-cost labor or abundant natural resources. Policy tools often include export subsidies, currency devaluation to make exports more competitive and the establishment of export processing areas, offering tax breaks and lighter regulations to attract foreign investment.

EOI encourages efficiency, innovation and economies of scale by linking firms to international value chains. However, it can also make economies vulnerable to global downturns and overdependent on a narrow range of exports. The model's most notable successes are the “Asian Tigers”—South Korea, Taiwan, Hong Kong and Singapore, and later China, all of which achieved rapid growth by pursuing export-led industrialization.¹⁶⁶

References

1. Dani Rodrik. 2017. *Growth Without Industrialization?*. Global Policy Journal. Available at <https://www.globalpolicyjournal.com/blog/21/12/2017/growth-without-industrialization>, as accessed on 3 November 2025.
2. Ha-Joon Chang. 2023. *Edible Economics: A Hungry Economist Explains the World*. PublicAffairs. Available at https://books.google.co.in/books/about/Edible_Economics.html?id=tu5tEAAAQBAJ&source=kp_book_description&redir_esc=y, as accessed on 3 November 2025.
3. UNCTAD. 2016. *Virtual Institute Teaching Material on Structural Transformation and Industrial Policy*. United Nations Publication. Available at https://unctad.org/system/files/official-document/gds2016d1_en.pdf, as accessed on 3 November 2025.
4. UNCTAD. 2022. *China's Structural Transformation: What Can Developing Countries Learn?* United Nations Publication. Available at https://unctad.org/system/files/official-document/gds2022d1_en.pdf, as accessed on 3 November 2025.
5. Avantika Goswami. 2023. *A New Order of Trade*. Down To Earth, Centre for Science and Environment. Available at <https://www.cseindia.org/a-new-order-of-trade-11637>, as accessed on 3 November 2025.
6. Amir Lebdioui. 2024. *Survival of the Greenest: Economic Transformation in a Climate-Conscious World*. Cambridge University Press. Available at DOI: <https://doi.org/10.1017/9781009339414>, as accessed on 3 November 2025.
7. Pauline Lectard. 2023. *Manufacturing exports: A virtuous circle of industrialization or a lock-in development pattern? The case of the machinery and textiles sectors*. Structural Change and Economic Dynamics, vol. 65, pp. 319–338. Available at <https://www.sciencedirect.com/science/article/abs/pii/S0954349X23000346>, as accessed on 3 November 2025.

8. Ruchi Bhatia. 2024. *India must create 115 mn jobs by 2030 as more people enter workforce: Study*. Business Standard. Available at https://www.business-standard.com/economy/analysis/india-must-create-115-mn-jobs-by-2030-as-more-people-enter-workforce-study-124052001062_1.html, as accessed on 3 November 2025.
9. World Bank Group. 2025. Manufacturing, value added (current US\$). Available at https://data.worldbank.org/indicator/NV.IND.MANF.CD?most_recent_value_desc=true, as accessed on 3 November 2025.
10. César A. Hidalgo and Ricardo Hausmann. 2009. *The building blocks of economic complexity*. Proceedings of the National Academy of Sciences of the United States of America (PNAS). Available at <https://www.pnas.org/doi/10.1073/pnas.0900943106>, as accessed on 3 November 2025.
11. United Nations Industrial Development Organization. 2021. *Industrial Development Report 2022. The Future of Industrialization in a Post-Pandemic World*. Vienna. Available at <https://www.unido.org/sites/default/files/unido-publications/2023-03/IDR-2022-en.pdf>, as accessed on 3 November 2025.
12. International Energy Agency. 2024. *Energy Technology Perspectives 2024*. International Energy Agency (IEA). Available at <https://iea.blob.core.windows.net/assets/25e2dab4-fe00-4e97-81e8-8f900ad5a0b6/EnergyTechnologyPerspectives2024.pdf>, as accessed on 3 November 2025.
13. Statista. 2025. *Distribution of solar photovoltaic module production worldwide in 2023, by country*. Available at <https://www.statista.com/statistics/668749/regional-distribution-of-solar-pv-module-manufacturing/>, as accessed on 3 November 2025.
14. Fraunhofer Institute for Solar Energy Systems ISE. Available at <https://www.ise.fraunhofer.de/en.html>, as accessed on 3 November 2025.
15. Jonas Meckling, et al. 2015. *Winning Coalitions for Climate Policy: How Industrial Policy Builds Support for Carbon Regulation*. Science, vol. 349, iss. 6253, pp. 1170–1171. Available at <https://brie.berkeley.edu/sites/default/files/winning-coalitions-2015.pdf>, as accessed on 3 November 2025.

16. Ha-Joon Chang. 2006. *Industrial policy in East Asia: Lessons for Europe*, EIB Papers, European Investment Bank (EIB), Luxembourg, vol. 11, iss. 2, pp. 106–132. Available at <https://www.econstor.eu/bitstream/10419/44860/1/515665460.pdf>, as accessed on 3 November 2025.
17. NREL. 2004. *Renewable Energy Policy in China: Financial Incentives; Renewable Energy in China*. National Renewable Energy Laboratory. Available at <https://docs.nrel.gov/docs/fy04osti/36045.pdf>, as accessed on 3 November 2025.
18. Ha-Joon Chang. 2002. *Kicking Away the Ladder: Development Strategy in Historical Perspective*. Anthem Press.
19. Fred Block. 2008. *Swimming Against the Current: The Rise of a Hidden Developmental State in the United States*. Politics & Society, vol. 36, iss. 2, pp. 169–206. Available at <https://doi.org/10.1177/0032329208318731>, as accessed on 3 November 2025.
20. Avantika Goswami. 2022. *US' new climate bill: The good, the bad and the fossil-addicted*. Down To Earth, Centre for Science and Environment, New Delhi. Available at <https://www.downtoearth.org.in/climate-change/us-new-climate-bill-the-good-the-bad-and-the-fossil-addicted-84275>, as accessed on 3 November 2025.
21. Avantika Goswami. 2023. *EU follows US by boosting its domestic green industry support, outcome for Global South uncertain*. Down To Earth, Centre for Science and Environment, New Delhi. Available at <https://www.downtoearth.org.in/climate-change/eu-follows-us-by-boosting-its-domestic-green-industry-support-outcome-for-global-south-uncertain-88323>, as accessed on 3 November 2025.
22. Simon Evenett, et al. 2024. *The Return of Industrial Policy in Data*. IMF Working Papers, vol. 2024, iss. 001. Available at <https://doi.org/10.5089/9798400260964.001>, as accessed on 3 November 2025.
23. Isabel Estevez and Thea Riofrancos. 2025. *Global Green Industrial Policy: Navigating Power Dynamics for a Pro-Working-Class, Pro-Development Green Transformation*. Climate and Community Institute. Available at

- <https://climateandcommunity.org/research/global-green-industrial-policy>, as accessed on 3 November 2025.
24. Camille Boullenois, Agatha Kratz and Daniel H. Rosen. 2025. *Far From Normal: An Augmented Assessment of China's State Support*. Rhodium Group. Available at <https://rhg.com/research/far-from-normal-an-augmented-assessment-of-chinas-state-support/>, as accessed on 3 November 2025.
 25. Hannah Ritchie and Pablo Rosado. 2020. *Energy Mix: Explore global data on where our energy comes from, and how this is changing*. Our World in Data. Available at <https://ourworldindata.org/energy-mix>, as accessed on 3 November 2025.
 26. Lauri Myllyvirta. 2025. *Analysis: Clean energy just put China's CO2 emissions into reverse for first time*. Carbon Brief. Available at <https://www.carbonbrief.org/analysis-clean-energy-just-put-chinas-co2-emissions-into-reverse-for-first-time/>, as accessed on 3 November 2025.
 27. Lauri Myllyvirta, Qi Qin and Chengcheng Qiu. 2025. *Analysis: Clean energy contributed a record 10% of China's GDP in 2024*. Centre for Research on Energy and Clean Air (CREA). Available at <https://energyandcleanair.org/analysis-clean-energy-contributed-a-record-10-of-chinas-gdp-in-2024/>, as accessed on 3 November 2025.
 28. David Fickling. 2025. *China Is Rewiring the Global South With Clean Power*. Bloomberg. Available at <https://www.bloomberg.com/opinion/articles/2025-02-24/china-is-rewiring-the-global-south-with-clean-power>, as accessed on 3 November 2025.
 29. Lauri Myllyvirta. 2025. *Analysis: China's clean-energy exports in 2024 alone will cut overseas CO2 by 1%*. Carbon Brief. Available at <https://www.carbonbrief.org/analysis-chinas-clean-energy-exports-in-2024-alone-will-cut-overseas-co2-by-1/>, as accessed on 3 November 2025.
 30. Dave Jones. 2025. *The first evidence of a take-off in solar in Africa*. Ember. Available at <https://ember-energy.org/latest-insights/the-first-evidence-of-a-take-off-in-solar-in-africa/>, as accessed on 3 November 2025.

31. Molly Lempriere. 2024. *China responsible for 95% of new coal power construction in 2023, report says*. Carbon Brief. Available at <https://www.carbonbrief.org/china-responsible-for-95-of-new-coal-power-construction-in-2023-report-says/>, as accessed on 3 November 2025.
32. IEA. 2025. *Electricity 2025*. International Energy Agency (IEA), Paris. Available at <https://www.iea.org/reports/electricity-2025/demand>, as accessed on 3 November 2025.
33. EVN Vietnam Electricity. 2024. *Operational situation in first 6 months of 2024; objectives and tasks in July and remaining months of 2024*. EVN Vietnam Electricity. Available at <https://en.evn.com.vn/d6/news/Operational-situation-in-first-6-months-of-2024-objectives-and-tasks-in-July-and-remaining-months-of-2024-66-142-4193.aspx>, as accessed on 3 November 2025.
34. IEA. 2023. *Energy Technology Perspectives 2023*. International Energy Agency (IEA), Paris. Available at <https://www.iea.org/reports/energy-technology-perspectives-2023>, as accessed on 3 November 2025.
35. Samba Diop, Simplicie A Asongu and Joseph Nnanna. 2021. *COVID- 19 economic vulnerability and resilience indexes: Global evidence*. PubMed Central. Available at <https://pmc.ncbi.nlm.nih.gov/articles/PMC8447304/>, as accessed on 3 November 2025.
36. Karin Strohecker and Rodrigo Campos. 2025. *Emerging economies face test from tighter funding as growth slows, says IMF*. Reuters. Available at <https://www.reuters.com/business/emerging-economies-face-test-tighter-funding-growth-slows-says-imf-2025-04-22/>, as accessed on 3 November 2025.
37. IEA. 2024. *Global market for key clean technologies set to triple to more than \$2 trillion over the coming decade as energy transitions advance*. International Energy Agency (IEA), Paris. Available at <https://www.iea.org/news/global-market-for-key-clean-technologies-set-to-triple-to-more-than-2-trillion-over-the-coming-decade-as-energy-transitions-advance>, as accessed on 3 November 2025.
38. Lauri Myllyvirta, Qi Qin and Chengcheng Qiu. 2025. *Analysis: Clean energy contributed a record 10% of China's GDP in 2024*. Centre

- for Research on Energy and Clean Air (CREA). Available at <https://energyandcleanair.org/analysis-clean-energy-contributed-a-record-10-of-chinas-gdp-in-2024/>, as accessed on 3 November 2025.
39. Jingquan Chen, et al. 2023. *Global Value Chains Embedding and Carbon Productivity of China's Manufacturing Industry: Direct Influence, Adjustment Effect, and Heterogeneity Analysis*. Sustainability, vol. 15, no. 17: 13272. Available at <https://www.mdpi.com/2071-1050/15/17/13272#:~:text=The%20term%20%22low%2Dend%20lock,firms%20so%20that%20developing%20countries%27>, as accessed on 3 November 2025.
40. Namchul Shin, Kenneth Kraemer and Jason Dedrick. 2012. *Value Capture in the Global Electronics Industry: Empirical Evidence for the "Smiling Curve" Concept*. Industry and Innovation - IND INNOV, vol. 19, pp. 89-107. Available at https://www.researchgate.net/publication/238046291_Value_Capture_in_the_Global_Electronics_Industry_Empirical_Evidence_for_the_Smiling_Curve_Concept, as accessed on 3 November 2025.
41. U.S. Department of Energy. 2022. *Solar Photovoltaics Supply Chain Review Report*. U.S. Department of Energy. Available at <https://www.energy.gov/eere/solar/solar-photovoltaics-supply-chain-review-report>, as accessed on 3 November 2025.
42. Yasmina Abdelilah, et al. 2022. *Special Report on Solar PV Global Supply Chains*. International Energy Agency (IEA). Available at <https://iea.blob.core.windows.net/assets/d2ee601d-6b1a-4cd2-a0e8-db02dc64332c/SpecialReportonSolarPVGlobalSupplyChains.pdf>, as accessed on 3 November 2025.
43. Anjali Tandon. 2020. *Is Domestic Value Addition a Source of Export Sophistication? A Case Study India*. Institute for Studies in Industrial Development, New Delhi. Available at <https://isid.org.in/wp-content/uploads/2022/07/WP223.pdf>, as accessed on 3 November 2025.
44. Ember. *China Cleantech Exports Data Explorer*. Available at <https://ember-energy.org/data/china-cleantech-exports-data-explorer/>, as accessed on 3 November 2025.

45. Praveena Bandara, et al. 2025. *Developing countries locked out of low-carbon technology trade*. Science, vol. 388, iss. 6744, pp. 248–250. Available at <https://www.science.org/stoken/author-tokens/ST-2575/full>, as accessed on 3 November 2025.
46. D'Maris Coffman, et al. 2023. *Global Value Chain Development Report 2023: Resilient and Sustainable GVCs in Turbulent Times*. Asian Development Bank (ADB), Institute of Developing Economies — Japan External Trade Organization (IDE-JETRO), Research Institute for Global Value Chains at the University of International Business and Economics (UIBE) Beijing, and World Trade Organization (WTO). Available at https://www.wto.org/english/res_e/booksp_e/gvc_dev_rep23_e.pdf, as accessed on 3 November 2025.
47. Barbara Buchner, et al. 2023. *Global Landscape of Climate Finance 2023*. Climate Policy Initiative (CPI). Available at <https://www.climatepolicyinitiative.org/publication/global-landscape-of-climate-finance-2023>, as accessed on 3 November 2025.
48. IEA. 2021. *The Cost of Capital in Clean Energy Transitions*. International Energy Agency (IEA), Paris. Available at <https://www.iea.org/articles/the-cost-of-capital-in-clean-energy-transitions>, as accessed on 3 November 2025.
49. IEA. 2023. *Cost of capital by project type in selected countries*. International Energy Agency (IEA), Paris. Available at <https://www.iea.org/data-and-statistics/charts/cost-of-capital-by-project-type-in-selected-countries-2022>, as accessed on 3 November 2025.
50. UNIDO. 2024. *Industrial Development Report 2024. Turning Challenges into Sustainable Solutions. The New Era of Industrial Policy*. United Nations Industrial Development Organization (UNIDO), Vienna. Available at <https://www.unido.org/sites/default/files/unido-publications/2024-06/Industrial%20Development%20Report%202024.pdf>, as accessed on 3 November 2025.
51. UNCTAD. 2022. *United States of America - \$369 billion in investment incentives to address energy security and climate change*. Investment Policy Monitor. UN Trade and Development (UNCTAD). Available at <https://investmentpolicy.unctad.org/investment-policy-monitor/measures/4004/->

- 369-billion-in-investment-incentives-to-address-energy-security-and-climate-change-, as accessed on 3 November 2025.
52. Guillaume Ragonnaud. 2024. *Briefing: EU Legislation in Progress. Net-zero industry act*. European Parliament. Available at [https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/747903/EPRS_BRI\(2023\)747903_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/BRIE/2023/747903/EPRS_BRI(2023)747903_EN.pdf), as accessed on 3 November 2025.
 53. European Commission. 2025. *Clean Industrial Deal*. European Commission. Available at https://commission.europa.eu/topics/eu-competitiveness/clean-industrial-deal_en, as accessed on 3 November 2025.
 54. European Commission. 2023. *Communication From the Commission to the European Parliament, the European Council and the Council: Report on EU policy initiatives for the promotion of investments in clean technologies*. European Commission. Brussels. Available at https://commission.europa.eu/system/files/2023-10/COM_2023_684_1_EN_ACT_part1_v11.pdf, as accessed on 3 November 2025.
 55. Gary Gereffi. 2018. *Global Value Chains and Development: Redefining the Contours of 21st Century Capitalism*. Cambridge University Press. Available at <https://www.cambridge.org/core/books/global-value-chains-and-development/65A6936F4B34FF41B9AEFE65FEF6E0BB>, as accessed on 3 November 2025.
 56. IEA. 2022. *Global Supply Chains of EV Batteries*. International Energy Agency (IEA), Paris. Available at <https://iea.blob.core.windows.net/assets/4eb8c252-76b1-4710-8f5e-867e751c8dda/GlobalSupplyChainsofEVBatteries.pdf>, as accessed on 3 November 2025.
 57. Jakob Fleischmann, et al. 2023. *Battery 2030: Resilient, sustainable, and circular*. McKinsey & Company. Available at <https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/battery-2030-resilient-sustainable-and-circular>, as accessed on 3 November 2025.
 58. CareEdge Ratings. 2025. *Solar Equipment: Localisation at the Forefront*. CareEdge Ratings. Available at <https://www.careratings.com/report/solar-equipment-localisation-at-the-forefront>, as accessed on 3 November 2025.

59. P. Banerjee, Z. Hussain and K. Karwal. 2025. *Navigating the Development Divide: The Case for Policy Space in India's Industrial Policy Strategy Amid Rising Global Protectionism*. Working Paper Series, No: Centre for WTO Studies, Centre for Research in International Trade, Indian Institute of Foreign Trade.
60. World Trade Organization (WTO). DS456: India — Certain Measures Relating to Solar Cells and Solar Modules. Available at https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds456_e.htm, as accessed on 3 November 2025.
61. World Trade Organization (WTO). DS472: Brazil — Certain Measures Concerning Taxation and Charges. Available at https://www.wto.org/english/tratop_e/dispu_e/cases_e/ds472_e.htm, as accessed on 3 November 2025.
62. *ibid.*
63. Rob Davies. 2022. *Davies: An Inclusive, Cooperative and Equitable Multilateralism*. Progressive International. Available at <https://progressive.international/blueprint/38415e77-d888-492f-be26-bd28ee8d6b15-davies-an-inclusive-cooperative-and-equitable-multilateralism/en>, as accessed on 3 November 2025.
64. Trishant Dev and Avantika Goswami. 2024. *Carbon Border Adjustment Mechanism (CBAM): The Global South's response to a changing trade regime in the era of climate change*. Centre for Science and Environment, New Delhi. Available at <https://www.cseindia.org/carbon-border-adjustment-mechanism-cbam--12271>, as accessed on 3 November 2025.
65. UNIDO. *Who is at the forefront of the green technology frontier? Again, it's the manufacturing sector*. UNIDO's Division of Capacity Development, Industrial Policy Advice and Statistics (CPS). Available at <https://www.unido.org/sites/default/files/unido-publications/2023-10/IID%20Policy%20Brief%206.pdf>, as accessed on 3 November 2025.
66. WIPO IP Statistics Data Centre. IP Facts and Figures. Available at <https://www.wipo.int/en/ipfactsandfigures/patents>, as accessed on 3 November 2025.

67. Swati Verma. 2020. *Technology Transfer through FDI in India: Mode, Extent and Prospects*. Institute for Studies in Industrial Development, New Delhi. Available at <https://isid.org.in/wp-content/uploads/2022/07/WP231.pdf>, as accessed on 3 November 2025.
68. Isabel Estevez and Thea Riofrancos. 2025. *Global Green Industrial Policy: Navigating Power Dynamics for a Pro-Working-Class, Pro-Development Green Transformation*. Climate and Community Institute. Available at <https://climateandcommunity.org/research/global-green-industrial-policy>, as accessed on 3 November 2025.
69. Ishana Ratan. 2023. *Does Manufacturing Matter? Forward Linkages and Downstream Growth in the Malaysian Solar Industry*. BU Global Development Policy Center. Available at https://www.bu.edu/gdp/files/2023/07/GCI_WP_032-FIN.pdf, as accessed on 3 November 2025.
70. Rudrath Avinashi. 2025. *Trump slows clean energy manufacturing projects worth \$27.6 billion in US, report finds*. Down To Earth, Centre for Science and Environment. Available at <https://www.downtoearth.org.in/energy/trump-slows-clean-energy-manufacturing-projects-worth-276-billion-in-us-report-finds>, as accessed on 3 November 2025.
71. Jewellord T. Nem Singh. 2023. *Industrial Experiments*. Phenomenal World. Available at <https://www.phenomenalworld.org/analysis/industrial-experiments/>, as accessed on 3 November 2025.
72. Jostein Hauge. 2020. *Industrial policy in the era of global value chains: Towards a developmentalist framework drawing on the industrialisation experiences of South Korea and Taiwan*. *The World Economy*, vol. 43, iss. 8, Wiley. Available at <https://onlinelibrary.wiley.com/doi/10.1111/twec.12922>, as accessed on 3 November 2025.
73. Rasmus Lema, Xiaolan Fu and Roberta Rabellotti. 2020. *Green windows of opportunity: latecomer development in the age of transformation toward sustainability*. *Industrial and Corporate Change*, vol. 29, iss. 5. Pp. 1193–1209. Available at <https://academic.oup.com/icc/article/29/5/1193/6137243>, as accessed on 3 November 2025.
74. Gary Gereffi, et al. 2025. *Navigating industrial policy and global value chains in an era of disruptions*. *J Int Bus Policy*, vol. 8, pp. 207–223.

Available at <https://link.springer.com/article/10.1057/s42214-025-00223-9>, as accessed on 3 November 2025.

75. Bentley B. Allan and Jonas Nahm. 2025. *Strategies of Green Industrial Policy: How States Position Firms in Global Supply Chains*. American Political Science Review, vol. 119, iss. 1, pp. 420-434. Available at doi:10.1017/S0003055424000364, as accessed on 3 November 2025.
76. A. Lebdioui. 2024. *Survival of the Greenest: Economic Transformation in a Climate-Conscious World*. Cambridge University Press. Available at DOI: <https://doi.org/10.1017/9781009339414>, as accessed on 3 November 2025.
77. *ibid.*
78. Tim Sahay, et al. 2025. *Principles for Cooperation and Competition in a World of Industrial Policy*. T20 South Africa. Available at https://t20southafrica.org/wp-content/uploads/2025/10/T20_TF-1_-PB-5_Principles-Cooperation.pdf, as accessed on 3 November 2025.
79. Rohini Mohan and Yew Lun Tian. 2025. *China's export ban on engineers and equipment disrupts manufacturing overseas*. The Straits Times. Available at <https://www.straitstimes.com/world/china-export-ban-on-engineers-and-equipment-disrupts-manufacturing-overseas>, as accessed on 3 November 2025.
80. Keith Bradsher. 2025. *Cars to Fighter Jets: China's New Export Curbs May Level a Heavy Blow Worldwide*. The New York Times. Available at <https://www.nytimes.com/2025/10/12/business/china-rare-earth-export-controls.html>, as accessed on 3 November 2025.
81. The Hindu. *China files complaint against India in World Trade Organisation over EV, battery subsidies*. The Hindu. Available at <https://www.thehindu.com/business/china-files-complaint-against-india-in-world-trade-organisation-over-ev-battery-subsidies/article70168588.ece>, as accessed on 3 November 2025.
82. Christoph Nedopil Wang. 2025. *China Belt and Road Initiative (BRI) Investment Report 2024*. Griffith Asia Institute and Green Finance & Development Center, FISF, Brisbane. Available at <https://greenfdc.org/china-belt-and-road-initiative-bri-investment-report-2024/?cookie-state-change=1760530845396>, as accessed on 3 November 2025.

83. *ibid.*
84. *ibid.*
85. Trissia Wijaya and Lee Jones. 2025. *Indonesia, nickel, and the political economy of polyalignment in the Second Cold War*. Third World Quarterly. Available at <https://doi.org/10.1080/01436597.2025.2465514> <https://www.tandfonline.com/doi/full/10.1080/01436597.2025.2465514#d1e965>, as accessed on 3 November 2025.
86. Tim Sahay and Kate Mackenzie. 2025. *BRICS in 2025*. Phenomenal World. Available at <https://www.phenomenalworld.org/analysis/brics-in-2025/>, as accessed on 3 November 2025.
87. Patrick Moore. 2025. *Can China share its green expertise with the Global South?*. Dialogue Earth. Available at <https://dialogue.earth/en/business/can-china-share-its-green-expertise-with-the-global-south/#:~:text=At%20a%20diplomatic%20level%2C%20China,vocational%20training%20in%20partner%20countries>, as accessed on 3 November 2025.
88. Kevin P. Gallagher. 2025. *The New Protectionism Toward China and Climate Change*. China Global South Project. Available at <https://chinaglobalsouth.com/analysis/china-low-carbon-tech-trade-global-south-strategy/>, as accessed on 3 November 2025.
89. Richard Kozul-Wright, et al. 2025. *Green Developmental Statecraft: The International Dimension of Green Structural Transformation in the Global South*. Boston University Global Development Policy Center. Available at <https://www.bu.edu/gdp/files/2025/09/GEGI-GST-Report-2025-FIN.pdf>, as accessed on 3 November 2025.
90. A. Lebdioui. 2024. *Survival of the Greenest: Economic Transformation in a Climate-Conscious World*. Cambridge University Press. Available at DOI: <https://doi.org/10.1017/9781009339414>, as accessed on 3 November 2025.
91. Jiri Opletal. 2025. *Early data shows record-breaking 11 million NEVs were sold in China in 2024, penetration rate nearly 50%*. CarNewsChina. Available at <https://carnewschina.com/2025/01/08/early-data-shows->

record-breaking-11-million-nevs-were-sold-in-china-in-2024-penetration-rate-nearly-50/, as accessed on 3 November 2025.

92. ResearchGate. *Thousands of Vehicles, Tens of Cities Program in China*. Available at https://www.researchgate.net/figure/Thousands-of-Vehicles-Tens-of-Cities-Program-in-China_fig6_235723652, as accessed on 3 November 2025.
93. NEVs are used to designate a class of electrically powered vehicles in China and include battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs), fuel-cell electric vehicles (FCEVs), and extended-range electric vehicles (EREVs).
94. Peng Yu, et al. 2019. *The Evolution of China's New Energy Vehicle Industry from the Perspective of a Technology-Market-Policy Framework*. Sustainability, vol. 11. Available at https://www.researchgate.net/publication/331942729_The_Evolution_of_China's_New_Energy_Vehicle_Industry_from_the_Perspective_of_a_Technology-Market-Policy_Framework, as accessed on 3 November 2025.
95. ResearchGate. *Thousands of Vehicles, Tens of Cities Program in China*. Available at https://www.researchgate.net/figure/Thousands-of-Vehicles-Tens-of-Cities-Program-in-China_fig6_235723652, as accessed on 3 November 2025.
96. Initial Success of “Ten Cities & Thousand Units” for New Energy Vehicles. 2011. China Buses. Available at https://m.chinabuses.org/news/3760.html?utm_source=chatgpt.com, as accessed on 3 November 2025.
97. Sebastian Ibold, Xia Yun and Xiao Shuyue. 2021. *NEV Development Plan 2035*. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH. Available at https://changing-transport.org/wp-content/uploads/2021_NEV_Development_Plan_2035.pdf?utm_source=chatgpt.com, as accessed on 3 November 2025.
98. 36Kr Global Research. 2022. *Deep Dive | The impact of China's dual credit system on automobile manufacturers*. KrAsia. Available at <https://kr-asia.com/deep-dive-the-impact-of-chinas-dual-credit-system-on-automobile-manufacturers>, as accessed on 3 November 2025.

99. ICCT. 2021. *China's New Energy Vehicle Industrial Development Plan for 2021 to 2035*. International Council on Clean Transportation (ICCT). Available at <https://theicct.org/wp-content/uploads/2021/12/China-new-vehicle-industrial-dev-plan-jun2021.pdf>, as accessed on 3 November 2025.
100. Hanming Fang, Ming Li and Guangli Lu. 2025. "Mapping Two Decades of China's Industrial Policies." *Decoding China's Industrial Policies*. NBER Working Paper. Available at <https://sccei.fsi.stanford.edu/china-briefs/mapping-two-decades-chinas-industrial-policies>, as accessed on 3 November 2025.
101. Alan Jenn, Katalin Springel and Anand R. Gopal. 2018. *Effectiveness of electric vehicle incentives in the United States*. Energy Policy, vol. 119, pp. 349–356. Available at <https://www.sciencedirect.com/science/article/abs/pii/S0301421518302891>, as accessed on 3 November 2025.
102. Roshanak Azarafshar and Wessel N. Vermeulen, 2020. *Electric vehicle incentive policies in Canadian provinces*, Energy Economics, vol. 91. Available at <https://www.sciencedirect.com/science/article/abs/pii/S0140988320302425>, as accessed on 3 November 2025.
103. DTE Staff. 2025. *Over 1 in 4 cars sold this year to be electric: IEA report*. Down To Earth. Available at https://www.downtoearth.org.in/energy/over-1-in-4-cars-sold-this-year-to-be-electric-iea-report?utm_source=chatgpt.com, as accessed on 3 November 2025.
104. Tong Zhang, Paul J. Burke and Qi Wang. 2024. *Effectiveness of electric vehicle subsidies in China: A three-dimensional panel study*. Resource and Energy Economics, vol. 76. Available at <https://www.sciencedirect.com/science/article/pii/S0928765523000799#bib44>, as accessed on 3 November 2025.
105. Scott Kennedy. 2024. *The Chinese EV Dilemma: Subsidized Yet Striking*. Center for Strategic & International Studies (CSIS). Available at <https://www.csis.org/blogs/trustee-china-hand/chinese-ev-dilemma-subsidized-yet-striking>, as accessed on 3 November 2025.
106. Quan Li, Xiqian Yu and Hong Li. 2022. *Batteries: From China's 13th to 14th Five-Year Plan*. eTransportation, vol. 14. Available at <https://www>.

sciencedirect.com/science/article/abs/pii/S2590116822000467, as accessed on 3 November 2025.

107. Ilaria Mazzocco and Gregor Sebastian. 2023. *Electric Shock: Interpreting China's Electric Vehicle Export Boom*. Center for Strategic & International Studies (CSIS). Available at <https://www.csis.org/analysis/electric-shock-interpreting-chinas-electric-vehicle-export-boom>, as accessed on 3 November 2025.
108. Reuters. *EU, China will look into setting minimum prices on electric vehicles, EU says*. Reuters, Berlin. Available at <https://www.reuters.com/business/autos-transportation/eu-china-start-talks-lifting-eu-tariffs-chinese-electric-vehicles-handelsblatt-2025-04-10/>, as accessed on 3 November 2025.
109. BYD. 2024. *BYD Concludes 2023 with Record 3 Million Annual Sales, Leading Global NEV Market*. Retrieved from <https://en.byd.com/news/byd-concludes-2023-with-record-3-million-annual-sales-leading-global-nev-market/>, as accessed on 3 November 2025.
110. The China-Global South Project. 2025. *Ethiopia's Gasoline Vehicle Ban Boosts Chinese EVs, Local Assembly*. Retrieved from <https://chinaglobalsouth.com/podcasts/ethiopias-ice-vehicle-ban-boosts-chinese-evs-local-assembly/>, as accessed on 3 November 2025.
111. The New York Times. 2025. *Nepal's electric-vehicle surge is powered by China*. Retrieved from <https://www.nytimes.com/2025/07/28/business/nepal-electric-vehicles-china.html>, as accessed on 3 November 2025.
112. Ecofin Agency. 2025. *Ethiopia expands vehicle import ban to trucks, pushing electric transport*. Retrieved from <https://www.ecofinagency.com/news-industry/0810-49366-ethiopia-expands-vehicle-import-ban-to-trucks-pushing-electric-transport/>, as accessed on 3 November 2025.
113. FreightWaves. 2024. *Mexico's automotive industry exports 289,309 vehicles in November*. Retrieved from <https://www.freightwaves.com/news/mexicos-automotive-industry-exports-289309-vehicles-in-november>, as accessed on 3 November 2025.

114. Warburton, S. 2024. *Mexico now seventh largest auto producer with 3.8 m vehicles made and exporting 3.3 m units globally*. Automotive Logistics. Retrieved from <https://www.automotivelogistics.media/supply-chain/mexico-now-seventh-largest-auto-producer-with-38m-vehicles-made-and-exporting-33m-units-globally/212488/>, as accessed on 3 November 2025.
115. International Trade Administration. 2023. *Mexico — Automotive industry*. Retrieved from <https://www.trade.gov/country-commercial-guides/mexico-automotive-industry/>, as accessed on 3 November 2025.
116. F. Gallego Llano. 2025. *Mexico's electric vehicle revolution: An update for 2025*. MexicoBusiness.News. Retrieved from <https://mexicobusiness.news/automotive/news/mexicos-electric-vehicle-revolution-update-2025>, as accessed on 3 November 2025.
117. Nain Martinez and Diana Terrazas-Santamaria. 2024. *Beyond nearshoring: The political economy of Mexico's emerging electric vehicle industry*. Energy Policy. Volume 195. Retrieved from <https://doi.org/10.1016/j.enpol.2024.114385>, as accessed on 3 November 2025.
118. Prodensa. (n.d.). *EV automotive OEM assembly in Mexico — report*. Retrieved from <https://www.prodensa.com/insights/blog/ev-automotive-oem-assembly-in-mexico-report>, as accessed on 3 November 2025.
119. Gobierno de México / DataMéxico. (n.d.). *DataMéxico*. Retrieved from <https://www.economia.gob.mx/datamexico/en>, as accessed on 3 November 2025.
120. Mexico Business News. 2024. *Mexico's auto FDI hits US\$6.9 billion in 2024; tariffs persist*. Retrieved from <https://mexicobusiness.news/automotive/news/mexicos-auto-fdi-hits-us69-billion-2024-tariffs-persist>, as accessed on 3 November 2025.
121. Mexico Business News. 2024. *Mexico reports almost US\$3 billion automotive investments*. Retrieved from <https://mexicobusiness.news/trade-and-investment/news/mexico-reports-almost-us3-billion-automotive-investments>, as accessed on 3 November 2025.

122. Inter-American Dialogue. 2025. *What's at stake for Mexico (publication)*. Retrieved from <https://thedialogue.org/wp-content/uploads/2025/08/Whats-at-Stake-for-Mexico-PubVer.pdf>, as accessed on 3 November 2025.
123. Leonardo Iacovone, et al. 2022. *Productivity Growth in Mexico: Understanding Main Dynamics and Key Drivers*. Washington, DC: World Bank. Retrieved from: <https://documents1.worldbank.org/curated/en/099100103252224294/pdf/P17082908942250380867901fba9060dcbc.pdf>, as accessed on 3 November 2025.
124. Mateo Crossa. 2021. *Contorting transformations: Uneven impacts of the U.S.-Mexico automotive industrial complex*. Competition & Change. 26. 102452942110454. 10.1177/10245294211045453. Retrieved from https://www.researchgate.net/profile/Mateo-Crossa/publication/354553355_Contorting_transformations_Uneven_impacts_of_the_US-Mexico_automotive_industrial_complex/links/626bf676dc014b4379728e5d/Contorting-transformations-Uneven-impacts-of-the-US-Mexico-automotive-industrial-complex.pdf, as accessed on 3 November 2025.
125. D. E. Bond, F. de Rosenzweig and S. Scoles. 2022. *Mexico nationalises lithium; sets up state-owned company*. White & Case LLP. Retrieved from <https://www.whitecase.com/insight-alert/mexico-nationalizes-lithium-sets-state-owned-company>, as accessed on 3 November 2025.
126. Council on Strategic Risks. 2024. *LITIO 2040: Sustainably developing Mexico's lithium from ground to grid*. Retrieved from <https://councilonstrategicrisks.org/2024/06/11/litio-2040-sustainably-developing-mexicos-lithium-from-ground-to-grid/>, as accessed on 3 November 2025.
127. Institute for Energy Economics and Financial Analysis (IEEFA). 2024. *Indian Solar PV exports surging*. Retrieved from https://ieefa.org/sites/default/files/2024-11/Indian%20Solar%20PV%20Exports%20Surging_Nov24.pdf, as accessed on 3 November 2025.
128. A. Shankar. 2024. *India's solar journey*. The India Forum. Retrieved from <https://www.theindiaforum.in/environment/indias-solar-journey>, as accessed on 5 November 2025.

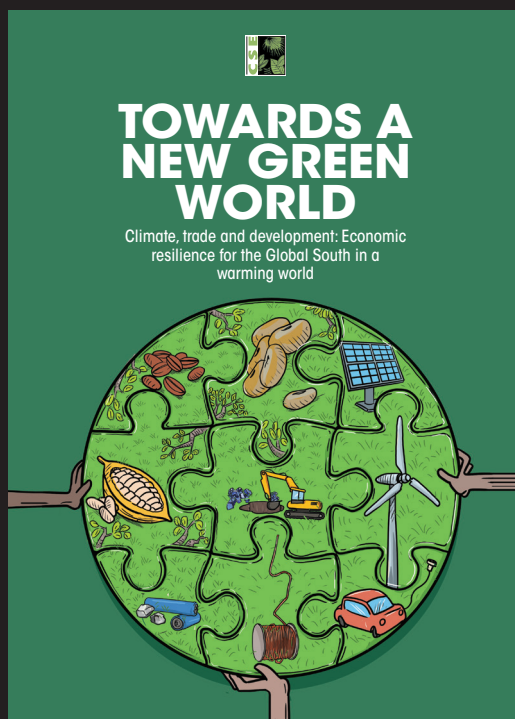
129. V. Srivastava. 2025. *India's solar panel imports face higher costs despite duty cut*. NDTV Profit. Retrieved from <https://www.ndtvprofit.com/business/india-solar-panel-imports-face-higher-costs-despite-duty-cut>, as accessed on 5 November 2025.
130. Press Information Bureau. 2025. *India achieves historic milestone of 100 GW solar PV module manufacturing capacity under ALMM* [Press release]. Ministry of New and Renewable Energy. Retrieved from <https://www.pib.gov.in/PressReleasePage.aspx?PRID=2156173>, as accessed on 5 November 2025.
131. U. Gupta. 2025. *18.5 GW of 48 GW solar module capacity awarded under PLI scheme now operational*. pv magazine India. Retrieved from <https://www.pv-magazine-india.com/2025/08/07/18-5-gw-of-48-gw-solar-module-capacity-awarded-under-pli-scheme-now-operational/>, as accessed on 5 November 2025.
132. S. Anand. 2025. *India secures over - 48,000 crore investment and 38,500 jobs under solar PLI scheme*. Economic Times EnergyWorld. Retrieved from <https://energy.economictimes.indiatimes.com/news/renewable/india-secures-over-48000-crore-investment-and-38500-jobs-under-solar-pli-scheme/122893746>, as accessed on 5 November 2025.
133. U. Gupta. 2025. *18.5 GW of 48 GW solar module capacity awarded under PLI scheme now operational*. pv magazine India. Retrieved from <https://www.pv-magazine-india.com/2025/08/07/18-5-gw-of-48-gw-solar-module-capacity-awarded-under-pli-scheme-now-operational/>, as accessed on 5 November 2025.
134. U. Gupta. 2021. *Adani and Reliance to set up solar gigafabs under PLI scheme*. pv magazine India. Retrieved from <https://www.pv-magazine-india.com/2021/09/25/adani-and-reliance-to-set-up-solar-gigafabs-under-pli-scheme/>, as accessed on 5 November 2025.
135. R. D. Mishra. 2025. *Sunrise sectors battery, solar modules manufacturing lag in PLI application clearance; specialty steel & food products lead*. The Indian Express. Retrieved from <https://indianexpress.com/article/business/sunrise-sectors-battery-solar-modules-manufacturing-lag-in-pli-application-clearance-specialty-steel-food-products-lead-10199430/>, as accessed on 5 November 2025.

136. C. Jaffrelot. (2025). *Scenario India: The Challenges of “Make in India”*. Paris: Institut Montaigne. Retrieved from <https://www.institutmontaigne.org/ressources/pdfs/publications/scenario-india-%20the-challenges-of-make-in-india-note.pdf>, as accessed on 5 November 2025.
137. *ibid.*
138. P. Singh. 2023. *Did Raghuram Rajan’s criticism force the government to introduce PLI 2.0?* Outlook Business. Retrieved from <https://www.outlookbusiness.com/economy-and-policy/did-raghuram-rajans-criticism-force-the-government-to-introduce-pli-20>, as accessed on 5 November 2025.
139. T. V. Kaggundi. 2024. *China’s share in India’s imports: An analysis with focus on intermediates and capital goods*. Indian Westerlies (blog). Retrieved from <https://www.indianwesterlies.com/2024/05/chinas-share-in-indias-imports.html>, as accessed on 5 November 2025.
140. Institute for Energy Economics and Financial Analysis (IEEFA). 2024. *Indian Solar PV exports surging*. Retrieved from https://ieefa.org/sites/default/files/2024-11/Indian%20Solar%20PV%20Exports%20Surging_Nov24.pdf, as accessed on 5 November 2025.
141. Institute for Energy Economics and Financial Analysis (IEEFA). 2024. *Indian Solar PV exports surging*. Retrieved from https://ieefa.org/sites/default/files/2024-11/Indian%20Solar%20PV%20Exports%20Surging_Nov24.pdf, as accessed on 5 November 2025.
142. M. Delgado, et al. 2024. *Transatlantic Clean Investment Monitor: A solar PV snapshot*. Brussels/New York: Bruegel & Rhodium Group. Retrieved from https://www.bruegel.org/sites/default/files/2024-11/transatlantic-clean-investment-monitor%3A-a-solar-pv-snapshot-10412_0.pdf, as accessed on 5 November 2025.
143. T. Wijaya and L. Jones. 2025. *Indonesia, nickel, and the political economy of polyalignment in the Second Cold War*. Third World Quarterly, 1- 20. Retrieved from <https://doi.org/10.1080/01436597.2025.2465514>, as accessed on 5 November 2025.
144. *ibid.*

145. A. Camba. 2023. *Downstream industries: Indonesia's export ban on nickel*. Phenomenal World. Retrieved from <https://www.phenomenalworld.org/analysis/downstream-industries/>, as accessed on 5 November 2025.
146. T. Wijaya and L. Jones. 2025. *Indonesia, nickel, and the political economy of polyalignment in the Second Cold War*. Third World Quarterly, 1-20. Retrieved from <https://doi.org/10.1080/01436597.2025.2465514>, as accessed on 5 November 2025.
147. U.S. International Trade Commission. 2024. *Export restrictions on minerals and metals: Indonesia's export ban of nickel (Working Paper ICA-104)*. Office of Industry and Competitiveness Analysis. Retrieved from https://www.usitc.gov/publications/332/working_papers/ermm_indonesia_export_ban_of_nickel.pdf, as accessed on 5 November 2025.
148. J. Zadeh. 2025. *Nickel surpasses coal as Indonesia's top export commodity*. Discovery Alert. Retrieved from <https://discoveryalert.com.au/news/indonesia-nickel-export-coal-shift-2025/>, as accessed on 5 November 2025.
149. T. Wijaya and L. Jones. 2025. *Indonesia, nickel, and the political economy of polyalignment in the Second Cold War*. Third World Quarterly, 1-20. Retrieved from <https://doi.org/10.1080/01436597.2025.2465514>, as accessed on 5 November 2025.
150. *ibid.*
151. C4ADS. 2025. *Refining Power: Indonesia's nickel refining industry and global implications*. Retrieved from <https://c4ads.org/commentary/refining-power/>, as accessed on 5 November 2025.
152. T. Wijaya and L. Jones. 2024. *Indonesia, nickel, and the political economy of polyalignment in the Second Cold War*. Third World Quarterly, 1-20. Retrieved from <https://doi.org/10.1080/01436597.2025.2465514>, as accessed on 5 November 2025.
153. O. Kim. 2025. *Indonesia climbs the chain: Nickel, industrial policy, and poverty reduction*. Global Developments. Retrieved from <https://www.global-developments.org/p/indonesia-climbs-the-chain>, as accessed on 5 November 2025.

154. R. Walker and H. Palaon. 2024. *A glimpse into Indonesia's nickel policy*. The Interpreter, Lowy Institute. Retrieved from <https://www.lowyinstitute.org/the-interpreter/glimpse-indonesia-s-nickel-policy>, as accessed on 5 November 2025.
155. A. Camba. 2023. *Downstream industries: Indonesia's export ban on nickel*. Phenomenal World. <https://www.phenomenalworld.org/analysis/downstream-industries/>, as accessed on 5 November 2025.
156. L. Myllyvirta, et al. 2024. *Debunking the value-added myth in nickel downstream industry: Economic and health impact of nickel industry in Central Sulawesi, Southeast Sulawesi, and North Maluku* (CREA/CELIOS). The Centre for Research on Energy and Clean Air (CREA) & Centre for Economic and Law Studies (CELIOS). Retrieved from https://energyandcleanair.org/wp/wp-content/uploads/2024/02/CREA_CELIOS-Indonesia-Nickel-Development_EN.pdf, as accessed on 5 November 2025.
157. Mandala. (n.d.). *Downstreaming Industry in Indonesia: Nickel* (41 pp.). Retrieved from <https://www.scribd.com/document/716857774/Downstreaming-Industry-in-Indonesia-Nickel>, as accessed on 5 November 2025.
158. Hyundai Motor Group. (n.d.). *Hyundai Motor Group and LG Energy Solution sign MOU with Indonesian government to establish EV battery cell plant*. Retrieved from <https://www.hyundai.com/worldwide/en/newsroom/detail/hyundai-motor-group-and-lg-energy-solution-sign-mou-with-indonesian-government-to-establish-ev-battery-cell-plant-0000000492>, as accessed on 5 November 2025.
159. Contemporary Amperex Technology Co. Limited (CATL). (n.d.). *[News]*. Retrieved from <https://www.catl.com/en/news/6481.html>, as accessed on 5 November 2025.
160. Wuling Motors. 2024. *Wuling plans to produce electric vehicle battery in Indonesia named MAGIC Battery* [Press release]. Retrieved from <https://wuling.id/en/blog/press-release/wuling-plans-to-produce-electric-vehicle-battery-in-indonesia-named-magic-battery>, as accessed on 5 November 2025.

161. T. Wijaya and L. Jones. 2025. Indonesia, nickel, and the political economy of polyalignment in the Second Cold War. *Third World Quarterly*, 1–20. <https://doi.org/10.1080/01436597.2025.2465514>, as accessed on 5 November 2025.
162. D. A. Irwin. 2021. *The rise and fall of import substitution*. *World Development*, 139, 105306. <https://doi.org/10.1016/j.worlddev.2020.105306>, as accessed on 5 November 2025.
163. H. J. Bruton. 1998. *A reconsideration of import substitution*. *Journal of Economic Literature*, 36(2), 903–936. Retrieved from <https://www.econintel.net/Cl705/BrutonImpSubs.pdf>, as accessed on 5 November 2025.
164. Rodrik, D. 2014. *Green industrial policy*. *Oxford Review of Economic Policy*, 30(3), 469–491. https://scholar.harvard.edu/files/dani-rodrik/files/green_industrial_policy.pdf, as accessed on 5 November 2025.
165. Chang, Ha-Joon. 2002. *Kicking Away the Ladder: Development Strategy in Historical Perspective*. London: Anthem Press.
166. Seric, A., & Tong, Y. S. 2019. *‘East Asian Miracle’ through industrial production and trade lenses*. Industrial Analytics Platform by United Nations Industrial Development Organization. Retrieved from <https://iap.unido.org/articles/east-asian-miracle-through-industrial-production-and-trade-lenses>, as accessed on 5 November 2025.



The Global South faces a dual challenge of decarbonizing while industrializing to meet the demands of a growing economy. With a focus on the clean technology sector, this paper explores how countries can pursue green industrialization amid prohibitive financing costs, limited technology access, and restrictive global trade rules. Using case studies of China, India, Indonesia and Mexico, it outlines key takeaways from country experiences in the clean-technology sector, highlighting both opportunities and structural barriers.

The paper calls for domestic innovation, strategic collaboration and global reforms to enable equitable participation in the new, green economy.

This is the third paper in a series of three by CSE addressing the questions of climate, trade and development, and pathways for economic resilience for the Global South in the new green economy.



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