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Stepping Up the Value Chain in Africa

Minerals, materials and manufacturing

International Energy Agency

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Abstract

This report explores key opportunities for African countries to step up the value chain in the growing global market for energy technologies, identifying opportunities beyond a role centred around extraction and mining to one more focused on mineral beneficiation, material production and technology manufacturing. These opportunities would enable Africa to retain a greater share of the economic value generated across energy technology supply chains, and would simultaneously contribute to global efforts to enhance supply chain diversification and resilience.

The economic benefits of the new energy economy are currently distributed very unevenly. Emerging markets and developing economies other than China account for less than 5% of the value generated from producing key energy technologies today. In Africa, there are currently only a small number of facilities dedicated to the beneficiation and processing of critical minerals and resources essential for energy technologies and materials, and only a handful of plants for manufacturing such technologies. In light of this, the government of South Africa requested that the IEA provide insights into potential opportunities for sustainable industrialisation in Africa to inform discussions at the G20 meetings in Johannesburg in 2025. This report explores selected elements of these opportunities and presents strategic considerations for countries seeking to diversify and expand their energy technology manufacturing sectors, which have particular relevance for the G20.

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Executive summary

Africa is endowed with vast energy resources – fossil fuels, but also solar, wind, hydro, and geothermal – and yet energy supply remains limited: Around 600 million people on the continent lack reliable access to electricity. This energy gap constrains economic growth and industrial potential, particularly in rural areas where agriculture remains the dominant sector in the economy. As African economies grow and urbanise, the demand for energy-intensive industries and infrastructure is rising. Strategic investments in sustainable industrialisation can create a virtuous cycle that expands energy access and drives productivity, which in turn can attract more investment.

Market opportunities already exist. Globally, the combined market value of six key clean energy technologies – solar photovoltaics (PV), wind, batteries, electric vehicles (EVs), heat pumps and electrolysers – has more than tripled from less than USD 200 billion in 2015 to more than USD 700 billion in 2023. This growth has rippled through the supply chain, leading to growth in markets for refined critical minerals – notably copper, lithium, nickel, cobalt, graphite, and rare earth elements – the combined market value of which exceeded USD 230 billion in 2024. Nascent markets for low-emissions materials and chemicals like steel, aluminium and ammonia could see steep growth rates in the future, depending on how quickly related technologies and supply chains develop over the coming years.

The economic rewards associated with these supply chains are – as yet – distributed very unevenly between countries. Africa as a whole currently captures less than 1% of the value generated from the manufacturing of clean energy technologies and their components. This is despite supplying large shares of the global demand for key unprocessed critical minerals – around 75% of global manganese, 70% of cobalt, nearly 20% of the world's copper – that are essential inputs to their production. African countries have the potential to change this, tapping into opportunities that can enable economic growth and job creation, as well as supporting domestic efforts to expand access to affordable energy, digitalise, and diversify their economies. This report explores three key elements of these opportunities on the African continent: critical minerals beneficiation; production of low-emissions, energy-intensive commodities; and clean energy technology manufacturing.

From extraction to beneficiation of critical minerals

Africa is already a major supplier to the global market for many minerals such as cobalt, manganese, bauxite and platinum-group metals, but also holds substantial untapped resources such as graphite and lithium. As global demand for critical minerals rises, so will their potential to contribute to the economic growth of African resource holders. Production of mineral resources is already a vital source of income for Africa, representing around 8% of government revenues in resource-rich African countries. The potential economic contribution of mineral production can be increased by moving up the value chain towards processing, smelting and refining.

There are opportunities for mineral beneficiation across the continent. For example, East African countries could develop spherical graphite for battery anodes, while South Africa and Gabon have the potential to expand production of high-purity manganese sulphate, a material poised for high demand. Morocco could scale up its output of purified phosphoric acid, and the Democratic Republic of the Congo and Zambia hold substantial cobalt and copper resources that provide a strong foundation for producing processed materials. Tapping into the associated economic opportunities relies on emerging and developing economies succeeding in overcoming barriers to leverage their existing opportunities for clean industrialisation on the one hand. The High Potential Case in this report shows how this would increase the market value for minerals in Africa by nearly three-quarters compared with today's levels to USD 120 billion by 2040. For comparison, total exports of all goods from African countries were worth around USD 680 billion combined in 2024.

Low-emissions, energy-intensive commodities could provide important economic returns

Several countries in Africa are endowed with low-cost renewable electricity generation potential – and therefore potential to produce electrolytic hydrogen – alongside mineral deposits. Combining the two leads to a potentially competitive proposition for low-emissions, energy-intensive commodity exports, as other countries that are seeking to decarbonise their industries face higher costs for these commodities. In the High Potential Case, low-emissions iron exports to Europe and countries in Asia would be worth more than four times the value of the same tonnage of iron ore exports at today's prices. The markets for these commodities are deep – South Africa alone currently exports around USD 6 billion worth of iron ore per year; global exports are worth around USD 150 billion – which can attract investment and financing for the requisite infrastructure, creating positive spillovers for other areas of development, such as providing energy access.

Low-cost renewable electricity and electrolytic hydrogen can also find an outlet in ammonia production, which is the precursor to all mineral nitrogen fertilisers today, and has significant additional opportunities in new energy applications, including in the shipping and power generation sectors. In the High Potential Case, a surge in ammonia production from around 11 Mt today to 25 Mt in 2035 and 40 Mt in 2050 would enable the African continent to eliminate all ammonia imports for fertiliser production by mid-century. This is a very significant potential knock-on effect for a continent that today derives nearly one-fifth of its GDP from agriculture, despite having some of the lowest rates of agricultural productivity in the world.

An existing industrial base can be foundational for new industries

There are also opportunities in the manufacturing of clean energy technologies themselves. Several countries, particularly in North Africa, have the potential to establish a foothold in the EV and battery manufacturing industries, building on their existing automotive industrial base. In the High Potential Case, Africa's EV production would rise from virtually nil today to nearly 4 million units in 2035 and then on to 5 million in 2050. By mid-century, the continent would become a net exporter of EVs, supplying a domestic market as well as other countries – mostly in the European Union. The competitiveness of this EV export capacity could be bolstered by an integrated battery supply chain, making producers progressively less reliant on component imports.

Africa's mineral resource endowments, while an important asset, do not constitute a guarantee that opportunities to move up the value chain will be realised. Strong market signals – domestically and in potential export markets – for clean energy technologies will be foundational. However, other factors that presently deter investment in emerging economies also require strategic consideration, including political and currency risks, a lack of skilled workers, poor electricity and transport infrastructure and unreliable energy supplies. Fit-for-purpose regulatory environments, co-investment models and international partnerships are key to reducing risk, crowding in private capital and catalysing greater investment.

The continent's industrial success stories – and those elsewhere – show that stepping up the value chain is possible and can yield significant benefits for the local population with respect to local value and job creation, thereby leading to positive spillovers for domestic infrastructure development and countries' innovation ecosystems. The established car industries for internal combustion engine vehicles in South Africa and Morocco; Nigeria's production of cement, fertilisers and petrochemicals; and the electronic and electrical components produced in Tunisia and Egypt are just a few examples from the continent.

Well-designed industrial strategies underpin efforts to take a step up the value chain

The selection and extent of the opportunities identified in this report are not intended as prescriptions – governments will need to balance their own priorities as they design their industrial strategies – but rather to provide a quantitative description of a subset of specific avenues that could be pursued. Robust market analysis, a clear understanding of project economics, as well as targeted strategies to build a skilled workforce and technological expertise – potentially through well-designed strategic partnerships – can help unlock further potential, guided by an approach to industrial strategy that is data-driven, targeted to sectors of advantage, and amenable to course-correction.

Introduction

This report is provided as an input to discussions at the G20 meetings in Johannesburg in 2025, in response to a request from the government of South Africa that the IEA provide insights into the potential for sustainable industrialisation in Africa. The report explores the potential for African countries to develop or expand manufacturing industries across three key areas of opportunity: critical minerals beneficiation; production of low-emissions, energy-intensive commodities; and clean energy technology manufacturing. It concludes with considerations for the design of industrial strategies, including both those concerning domestic actions and measures that will benefit from international collaboration among G20 members and beyond.

Alongside a quantitative assessment of the scale of these opportunities using scenario analysis, the report draws on analysis of enabling conditions that could influence decision making on investment in manufacturing that was first published in Energy Technology Perspectives 2024 (ETP-24). This analysis comprised an assessment of enabling factors in different countries across three key dimensions – the local business environment, energy and transport infrastructure, and resource availability and domestic markets – in order to identify specific opportunities tailored to the potential of different countries. The analysis reflects existing conditions in a country, and not possible future developments, such as those related to policies, costs or demographics. A full list of the enabling factors and the indicators for each factor can be found in ETP-24.

Scenarios used in this report

This report draws on recent scenario analysis prepared for three IEA publications: Energy Technology Perspectives 2024, the World Energy Outlook 2024, and the Global Critical Minerals Outlook 2025. It focuses on one scenario and one case used in these reports:

The **Stated Policies Scenario (STEPS)** is designed to provide a sense of the direction of travel for the global energy sector based on a detailed reading of energy-related policies that have been adopted or indicated. The STEPS takes into account policy intentions that have not been codified into existing laws and regulations. Such targets are not automatically assumed to be met; the prospects and timing for their realisation are subject to an assessment of relevant market, infrastructure and financial constraints. This scenario also takes account of projects that have been announced to build manufacturing capacity for clean energy technologies and associated materials for which funds have been committed, i.e. those that have reached a final investment decision.

The intention of the **High Potential Case (HPC)** is to identify potentially promising economic opportunities for emerging and developing economies in the context of clean energy technology supply chains. For this purpose, the HPC is based on two main assumptions. First, it is assumed that emerging markets succeed in overcoming barriers to exploiting their respective competitive advantages by establishing supportive policy frameworks that can attract investment, further enabled by international support mechanisms. Second, it is assumed that global demand for clean energy technologies and low-emissions materials is large enough to offer a market for their production in emerging markets without relying on lower production volumes in other regions.

Energy technology supply chains in context

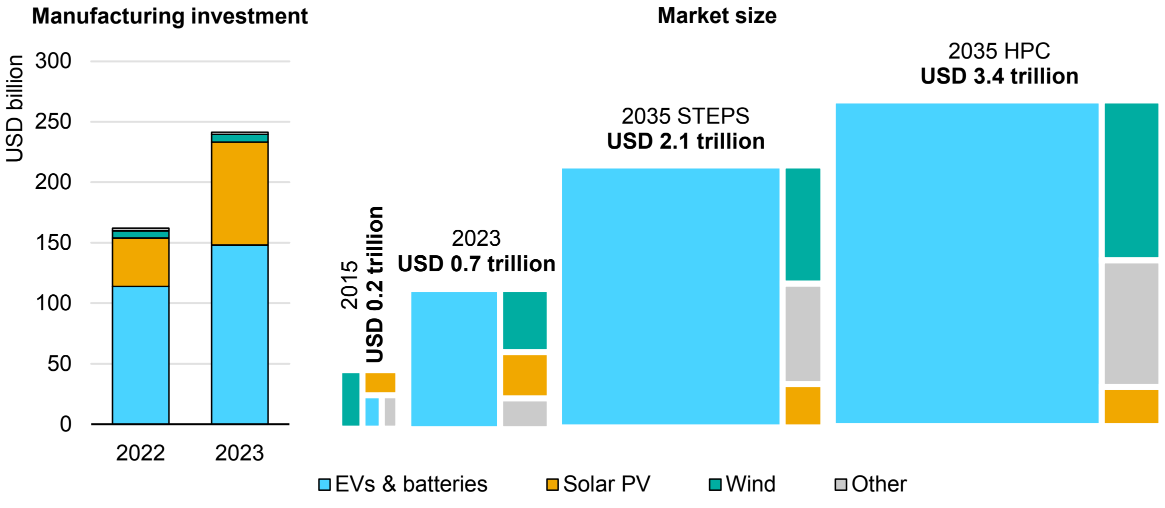
New technology supply chains are being built out

The global combined market for six key clean energy technologies – solar PV, wind, batteries, EVs, heat pumps and electrolysers – amounted to more than USD 700 billion in 2023. The lion's share of this global market is held by the People's Republic of China (hereafter "China"), which accounts for nearly 60%, reflecting the extent of its domestic clean technology deployment. Advanced economies accounted for around one-third, while emerging economies other than China accounted for a much smaller share, at 5% in aggregate. The continent of Africa accounted for less than 1%.

Of all the key technologies listed above, EVs and batteries particularly stand out, accounting for 65% of the total market value in 2023, on the back of significant growth in electric car sales in recent years. EV sales reached almost 14 million units in 2023 globally – 35% more than in 2022. In 2024, global sales went on to set new records, reaching 17 million, or more than one in five cars sold worldwide. Solar PV modules and wind turbines make up most of the rest of the global market. The remarkable growth in global capacity additions for these technologies – nearly fivefold growth between 2015 and 2023 – meant their markets continued to register strong growth, despite the well-publicised cost declines over this period.

The market for clean technologies is set to continue growing in the medium term. On the basis of today's policy settings as reflected in the Stated Policies Scenario (STEPS) (see the box above for a description of the scenarios used in this report), the market nearly triples by 2035, reaching around USD 2 trillion. If more countries were to ramp up clean energy technology manufacturing and clean energy technology market uptake were to move faster – as illustrated by the High Potential Case (HPC) – the market for clean technologies would be larger, offering additional opportunities for emerging and developing economies to play an economic role in related supply chains.

Global manufacturing investments and market sizes for key clean energy technologies, historical and in the Stated Policies Scenario and High Potential Case, 2015-2035



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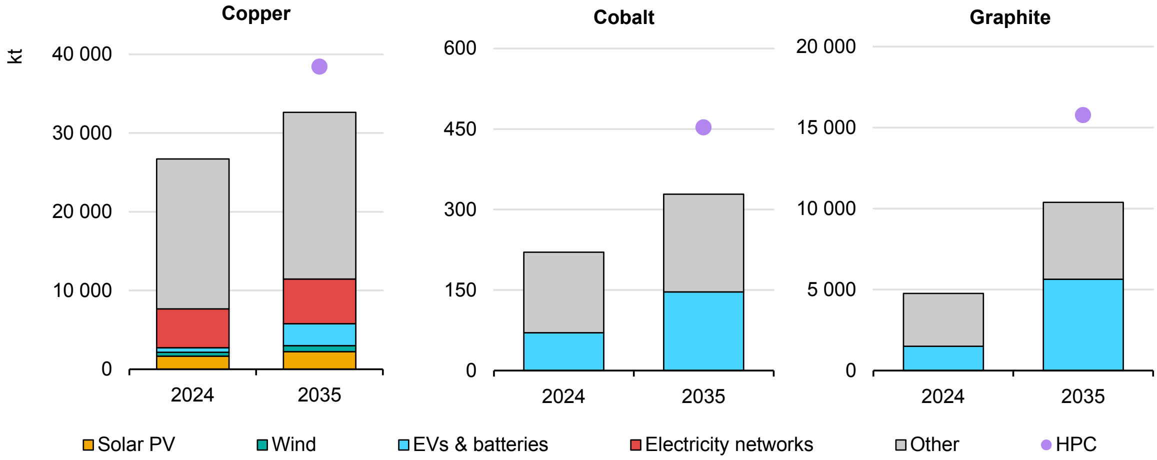
Notes: EVs = electric vehicles; STEPS = Stated Policies Scenario; HPC = High Potential Case.

These growing markets have spurred a wave of manufacturing investments, which jumped 50% to over USD 240 billion in 2023, up from around USD 160 billion in 2022. Investments were led by solar PV and batteries, which together accounted for 80% of the total in 2023. China accounted for nearly three-quarters of total investment in 2023, with the United States and the European Union together accounting for around one-fifth. India, Japan, Korea and Southeast Asia accounted for most of the rest, with virtually no investment taking place in Africa, nor in Central and South America.

Demand for clean energy technologies is boosting demand for critical minerals. Battery deployment in EVs and storage applications drives strong demand growth for copper, graphite, nickel and cobalt. In the Stated Policies Scenario (STEPS), lithium demand grows fivefold from today to 2040, while graphite and nickel demand double. Demand for cobalt and rare earth elements also grows strongly, increasing 50-60% by 2040. Meanwhile, demand for copper – the material with the largest established market today – is projected to grow by 30% over the same period, fuelled by growth in construction and in the electrification of grids and industrial equipment. Growing demand for permanent magnets, particularly for EVs and wind power, boosts the need for magnet rare earths. In the HPC, demand growth would be more rapid, with the demand in 2040 being 15-45% higher than in the STEPS across key critical minerals.

Critical mineral demand and share for key energy applications, historical and in the Stated Policies Scenario and High Potential Case, 2024-2035



Notes: EV = electric vehicle; HPC = High Potential Case.

In the STEPS, the underlying drivers of demand for energy-intensive commodities like steel, aluminium and ammonia remain broadly unchanged by the growing markets for clean energy technologies like solar PV and batteries, relative to today. Demand growth for steel and aluminium in sectors like construction, transportation and packaging, and for ammonia in agriculture and explosives, is incremental in the STEPS. Furthermore, in this scenario, the methods employed to produce these energy-intensive commodities remain largely unaltered.

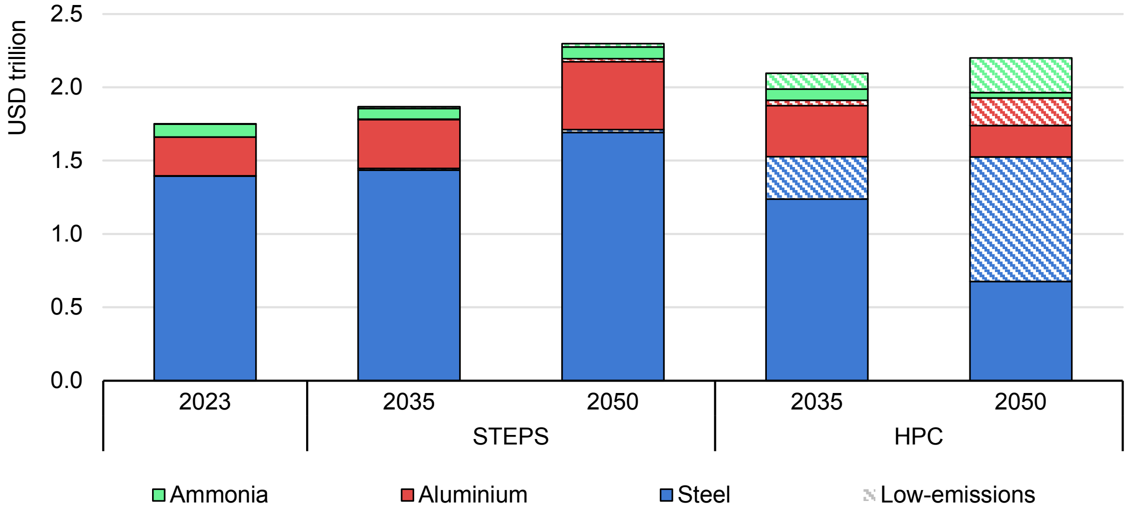
Many countries and regions are, however, looking to transform the manufacturing processes for these energy-intensive commodities. The HPC therefore explores the global implications of an increase in low-emissions[1] production of energy-intensive commodities as a subset of demand for these commodities, much of which will need investment in new manufacturing capacity. Small amounts of these low-emissions materials and chemicals could end up in clean energy technologies, but their manufacturing processes also account for a non-trivial portion of demand growth for clean technologies; solar PV, wind and electrolysers would be used to generate the low-emissions electricity and hydrogen used in several low-emissions production processes for these commodities.

In the STEPS, there is limited uptake of low-emissions technologies in the production of energy-intensive commodities globally. Even by mid-century, the combined market for low-emissions ammonia, aluminium and steel reaches just USD 60 billion, relative to a total market – including materials produced via conventional process routes – of around USD 2.2 trillion. In the HPC, however,

[1] In this report we use "low-emissions" to refer to "near-zero emissions" materials and processes. This does not constitute an adjustment to the definitions associated with these terms used in other IEA reports. See Box 1.1 in ETP-2024 for more details.

markets for low-emissions materials swell to more than USD 435 billion by 2035 and then to USD 1.3 trillion by 2050, reflecting the increasing uptake of low-emissions process routes for these technologies in this projection.

Global market sizes for key energy-intensive materials and share of low-emissions ammonia, aluminium and steel, historical and in the Stated Policies Scenario and High Potential Case, 2023-2050



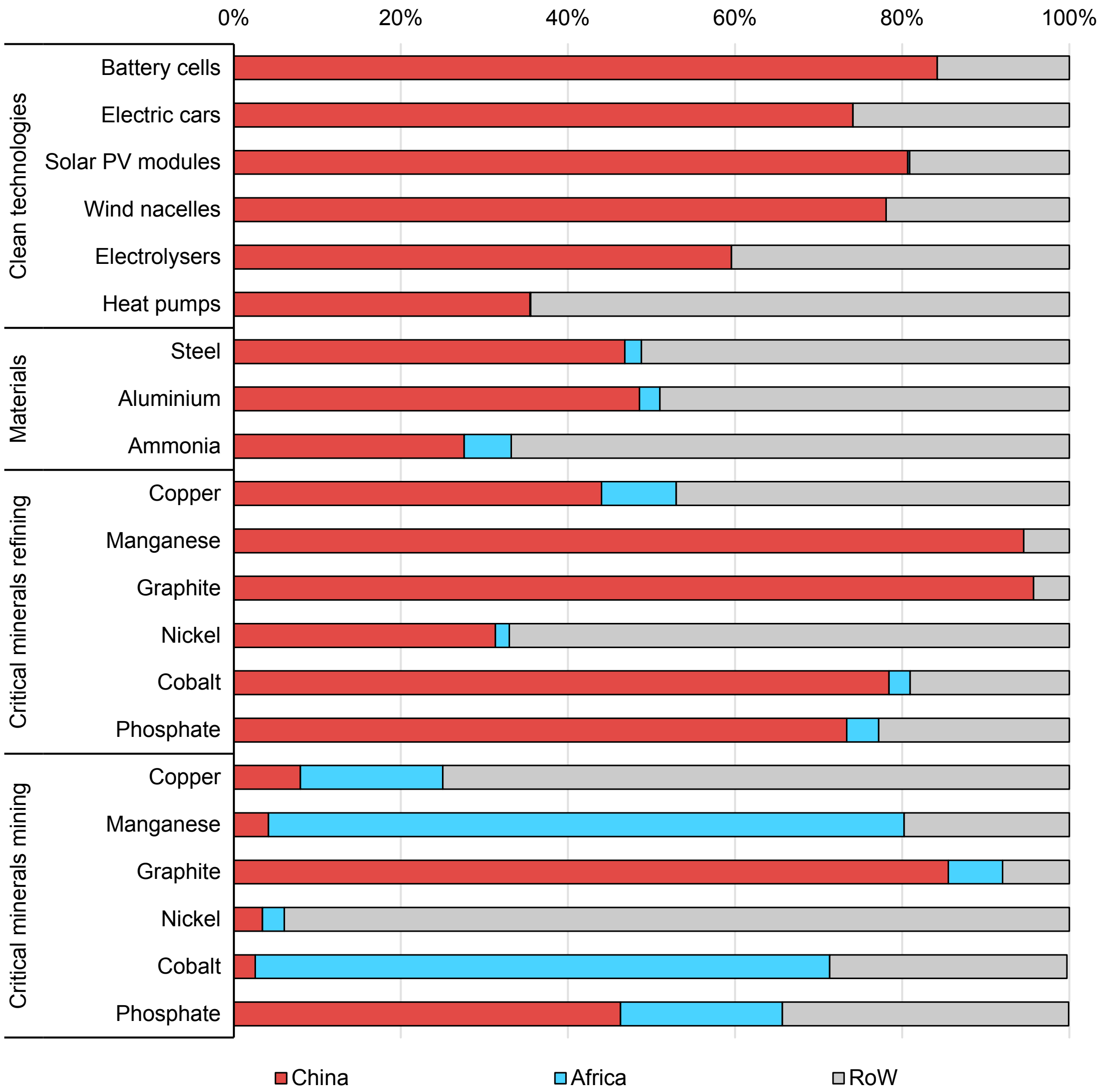
Notes: STEPS = Stated Policies Scenario; HPC = High Potential Case.

Geographic concentration poses risks to security, resilience and equity

Many steps in clean energy technology supply chains are highly geographically concentrated, from the extraction and refining of raw materials to the manufacturing of technologies, their components and the materials required as inputs. This concentration can create supply chain risks and vulnerabilities. In 2024, China held around 80% of battery cell and solar PV module manufacturing capacity, over 70% for wind nacelles, just under 60% for electrolysers and close to 35% for heat pumps. The European Union and the United States generally account for most of the rest, with Japan and India accounting for a significant share of capacity in a few cases. Africa accounts for negligible shares of global manufacturing capacity for these technologies today.

Material production is less concentrated, but China is still often the single largest producer. In 2024, China accounted for around 30% of global production capacity for ammonia and just under 50% of that for crude steel and aluminium. Africa's role in these sectors is more visible, holding 6% of global ammonia capacity and 2% for steel and aluminium. For critical minerals, Africa plays a very important role in the extraction step (76% of global manganese, 69% of cobalt), but a much more limited role in refining (9% for copper, <5% for other key minerals).

Geographical distribution of manufacturing capacity, 2024



Notes: RoW = Rest of World. "Electric cars" values are calculated based on 2024 production numbers, adjusted according to the utilisation rates of car assembly plants in the region.

Geographical concentration is expected to persist despite the growing number of new project announcements for new manufacturing facilities. If all announced capacity additions come to fruition, the three major producing countries and regions are expected to continue to account for 80% or more of global capacity in nearly all cases, with only minor shifts in relative shares. In the case of battery manufacturing, China's share could contract as those of the European Union and the United States increase. The shares of wind manufacturing in China, the

European Union and the United States are set to fall slightly, as there are more announcements in emerging markets. For heat pumps, Europe's share is set to grow the most.

Besides the risks posed to security and resilience, the high geographic concentration in clean energy technology supply chains also threatens the social durability of clean energy transitions. Emerging markets and developing economies other than China account for less than 5% of the value generated from producing clean energy technologies today. In Africa there are just a handful of facilities dedicated to the beneficiation, processing and manufacturing steps in the supply chains for these technologies. While there are some notable exceptions – copper smelting and ammonia production being among them – the role of African countries in clean technology supply chains is primarily limited to the mining of critical minerals. While this is an important role in itself, only a small portion of the value associated with the overall supply chains for final products like solar PV modules and EVs is created at the point of resource extraction. Enabling emerging and developing economies to reap the economic benefits of expanding and strengthening secure and resilient supply chains for clean energy technologies is therefore an important policy consideration.

Sustainable industrialisation opportunities

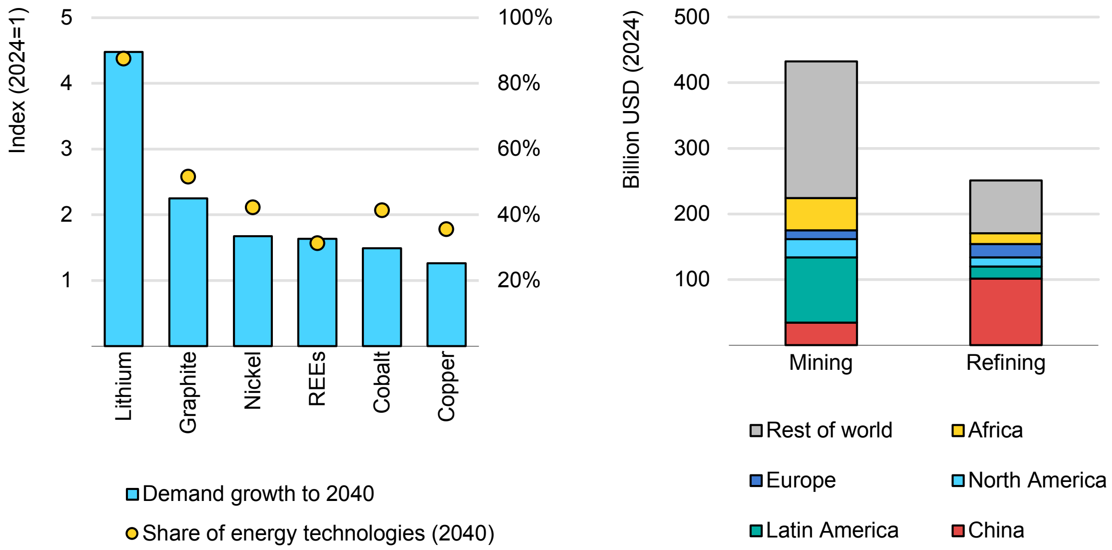
This section examines three key steps in energy technology supply chains in turn – beneficiation of critical minerals, production of low-emissions, energy-intensive commodities, and clean energy technology manufacturing – to identify key opportunities for African countries to retain a larger share of the value generated from these activities.

Critical minerals beneficiation

Critical minerals in Africa today

Increasing global demand for energy technologies is driving a corresponding rise in critical mineral demand. Meeting this rising demand represents a major challenge, but even more crucial is addressing the current high concentration of supply in a small number of countries in order to ensure the rapid deployment of key energy technologies.

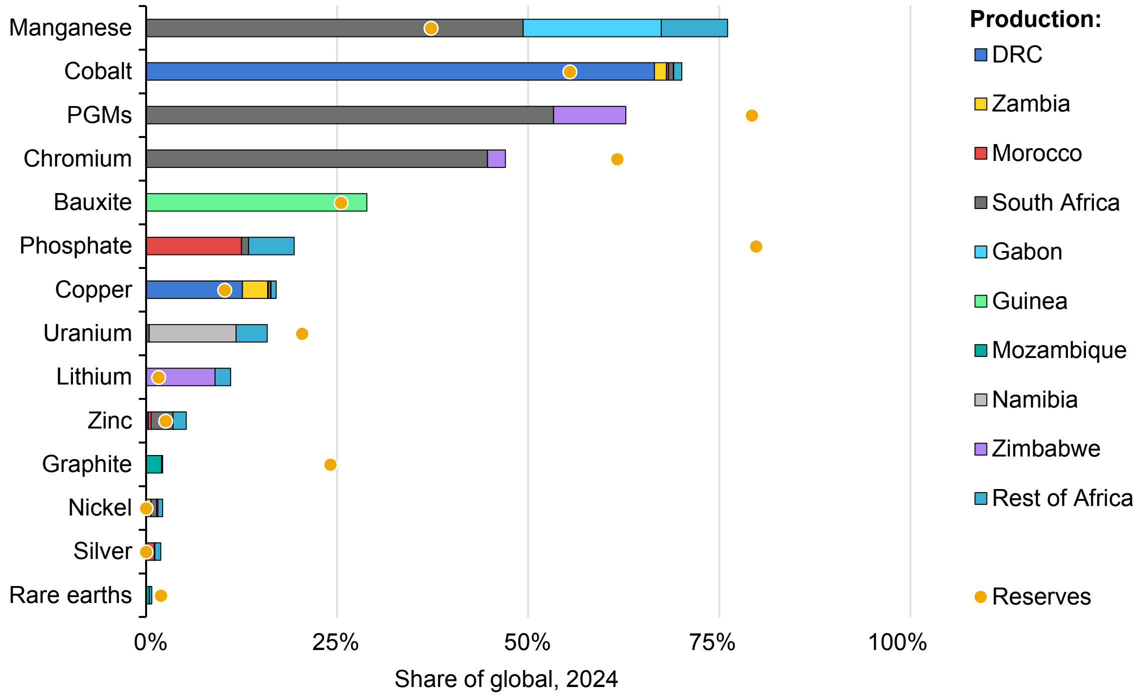
Global demand growth to 2040 in the Stated Policies Scenario and market value of mined and refined materials for selected minerals, 2024



Notes: REEs = rare earth elements. Demand figures for REEs refer to magnet rare earths (neodymium, praseodymium, dysprosium and terbium) only. The minerals included in the market value assessment are lithium, graphite, nickel, REEs and cobalt.
Sources: IEA analysis based on data from S&P Global Capital IQ and company reports.

Current project pipelines suggest that the geographical concentration of both mining and refining is set to remain high for most critical minerals. Despite some diversified projects coming online, China will remain the major supplier for almost all refined minerals. By 2030, China is set to supply over 90% of battery-grade manganese sulphate, over 85% of battery-grade graphite, around 80% of processed cobalt and rare earth elements, 75% of purified phosphoric acid, 60% of refined lithium and 50% of refined copper. Further efforts to diversify the supply of refined minerals are vital to ensure resilient mineral supply chains, and traditional mining regions such as Africa are poised to play a bigger role in local beneficiation of their natural resources.

Africa's share of global mined production and reserves, 2024



Notes: PGMs = platinum-group metals; DRC = Democratic Republic of the Congo. The production figures are for magnet rare earth elements (REEs) only; reserves figures are for all REEs. Graphite refers to natural graphite. Uranium production figures refer to 2022.
Sources: IEA analysis based on US Geological Survey, European Commission, Nuclear Energy Agency and S&P Global Capital IQ.

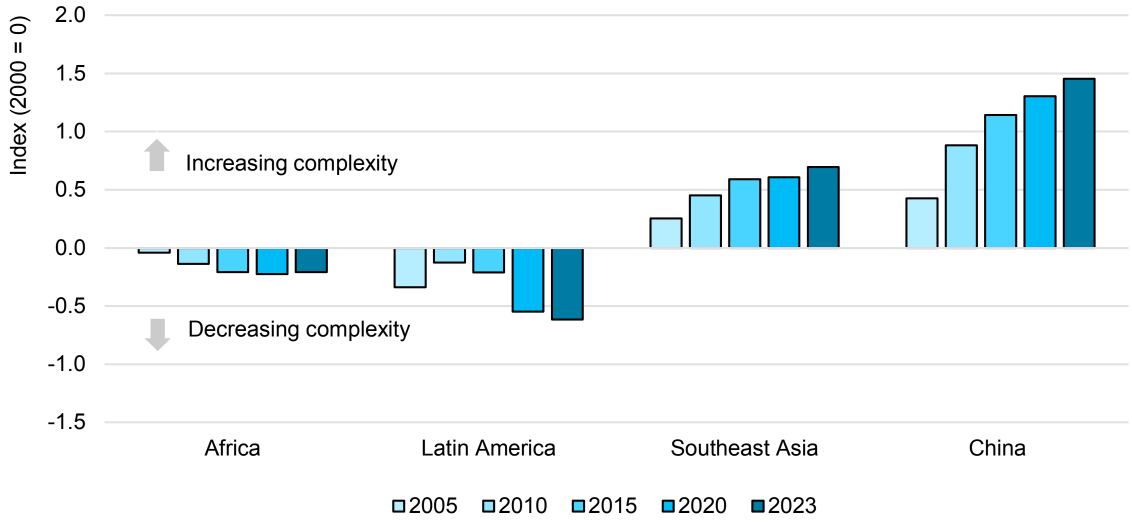
Africa is a key player in the global mined supply of many minerals critical to energy technologies and the broader economy. The continent holds around 80% of global reserves of platinum-group metals (PGM) and phosphate, over 50% of cobalt and chromium, at least 25% of global reserves of manganese, bauxite and graphite, and over 10% of copper and uranium reserves. In terms of mined production, the Democratic Republic of the Congo (DRC) alone accounted for two-thirds of global cobalt production in 2024, while the African continent accounted for 19% of global phosphate production, 17% of mined copper, 16% of mined uranium, and over 11% of mined lithium. South Africa is a major producer of manganese and chromium, and was responsible for over half of the global supply for PGMs in 2024. Furthermore, there is significant untapped potential for graphite production on the continent. This geological wealth presents the opportunity for African countries to move beyond their historical role as exporters of raw materials.

The majority of these mineral resources are currently exported directly as ore or in semi-processed forms to be refined overseas. For instance, despite the DRC accounting for two-thirds of global mined cobalt in 2024, nearly all output is exported with minimal processing, primarily to China, for refining into battery-grade material. This pattern is replicated across other minerals: A substantial portion of Africa's bauxite, lithium and manganese is shipped as raw material, meaning the economic value added during the refining and manufacturing stages is captured outside the continent.

This reliance on raw material exports is a key factor behind a trend of decreasing economic complexity in Africa. The continent's export basket has, on average, become less sophisticated and more concentrated on raw materials and basic commodities over the past two decades. A similar trend is visible in Latin America, another region with abundant mineral resources.

However, by developing local processing and manufacturing capabilities, countries can reverse this trend to capture more economic value from raw materials. Moving up the value chain can be a catalyst for a virtuous cycle of industrialisation, creating higher value exports, skilled employment and lasting economic resilience. A domestic mineral processing industry can also foster domestic energy transitions; mineral processing is a highly energy-intensive industry, and rising demand for power has the potential to catalyse investments in local renewable energy infrastructure.

Change in economic complexity index for selected regions, 2000-2023



Notes: The economic complexity index is an assessment of countries based on the diversification and complexity of their export basket. Each milestone year is depicted as a change relative to the baseline in 2000.
Sources: IEA analysis based on data from the Atlas of Economic Complexity database.

Many African governments are implementing policies to support domestic value addition. Following the example of Indonesia's 2014 ban on the export of unprocessed nickel and bauxite ores, several countries have enacted similar measures to encourage investment in local mineral resource processing facilities. In Zimbabwe, the Base Minerals Export Control Order (2023) introduced tighter controls on lithium extraction and exports to encourage in-country beneficiation. In May 2025, Gabon announced its intention to ban the export of raw manganese ore from January 2029, as a means to prompt the development of downstream processing.

The effectiveness of such export bans is highly contingent on specific national and market conditions. Indonesia was able to significantly increase downstream investment in nickel refining due to its control over laterite reserves used in the nickel pig iron process and fiscal incentives that attracted investment. In contrast, its bauxite export ban primarily served to encourage aluminium producers to shift refining to neighbouring countries. Many African countries, despite being resource-rich, do not hold a similar level of market power for their key commodities. This suggests that increasing domestic value addition requires a sustainable strategy to attract capital, rather than attempts to force it.

This approach is supported by geopolitical tailwinds. As global capital seeks new, stable industrial hubs for mineral processing, African countries are well-positioned to emerge as key investment destinations. This dynamic is already channelling substantial funding into the region's infrastructure and industrial capacity. Flagship projects like the Lobito Corridor can therefore be seen as part of a holistic investment strategy that prioritises foundational infrastructure and African regional development as core components of resilient global energy supply chains.

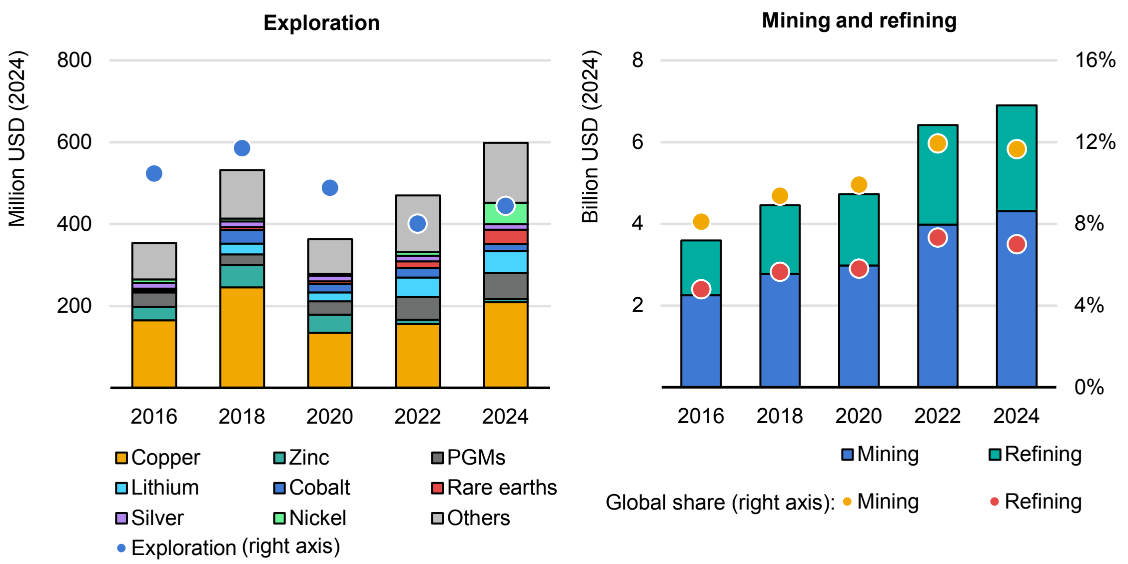
Capitalising on this opportunity is not without significant structural challenges. It would require substantial investment in enabling infrastructure, particularly in reliable energy and transport logistics, as well as in technology transfer and the development of human capital. Robust governance frameworks are also essential: Without transparent revenue management and strong anti-corruption measures, the value generated risks being lost, undermining the goal of equitable and broad-based industrial development.

Investment trends in Africa

Despite Africa’s geological potential, exploration activity has remained relatively modest over the past 10 years. From 2015 to 2024, annual exploration spending in Africa averaged USD 470 million. However, the last 5 years have seen Africa’s share of global exploration budgets fall from 12.6% in 2015 to just under 9% in 2024. This reflects a slowdown in broader exploration spending as prices fell and investment appetite weakened, as well as underinvestment in geoscience and limited access to risk capital. Limited exploration spending constrains future production growth, putting supply diversification at risk.

In spite of this broader slowdown, exploration spending on energy minerals in Africa such as lithium, nickel and rare earth elements has grown over the last 10 years. These minerals accounted for just 3% of Africa's total exploration spending in 2015; in 2024, this was 25%. Although exploration spending on cobalt is relatively small, at only USD 17 million in 2024, Africa attracted one-third of the global total. Copper accounts for the largest share of exploration spending, but this share has declined over the last decade – from nearly half of the total exploration spending from 2015 to 2019 to just one-third in 2024.

Spending on exploration (left), mining and refining investment (right) in Africa, 2016-2024



Notes: PGMs = platinum-group metals. Exploration spending excludes budgets for diamond and gold. The investment figures cover copper, lithium, nickel, cobalt, graphite and rare earth elements and consider only overnight greenfield investment, and are calculated based on capital intensities by region in 2024 USD, applied to production additions.
Sources: IEA analysis based on data from company reports and S&P Global Capital IQ.

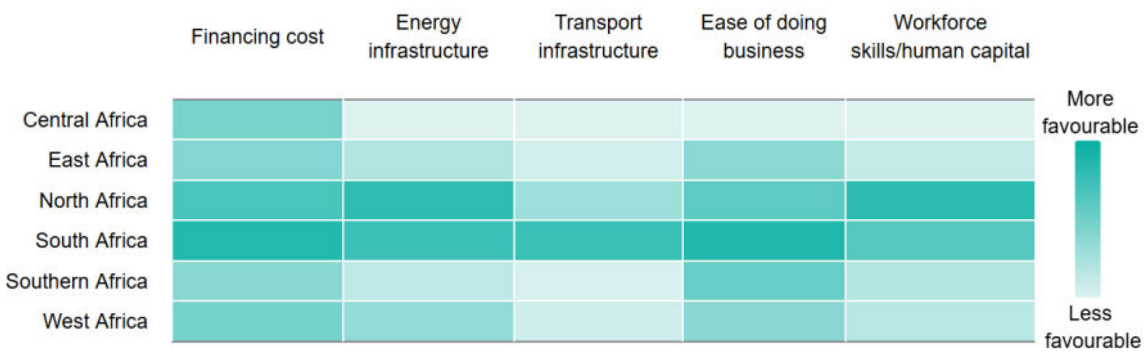
African overnight greenfield mining investment for key energy minerals such as copper, lithium, nickel, cobalt, graphite and rare earths has grown significantly over the last 10 years, rising by nearly 85% from around USD 2 billion in 2015 to just over USD 4 billion in 2024. Its share of global investment also increased from 14% to 19%. However, this growth has stagnated in recent years, with only a marginal increase from 2023 to 2024. Growth has primarily been supported by large investments in copper mining, largely concentrated in the DRC, Zambia and Morocco. Nevertheless, investment in lithium mining has grown rapidly, from under USD 10 million in 2023 to just over USD 28 million in 2024. Investment in refining has not kept pace. While spending on cobalt has risen sharply from under USD 90 million in 2015 to just under USD 200 million in 2024, most of the investment has been directed towards the mining stage of the value chain.

The market value of Africa's key energy minerals production stood at approximately USD 50 billion for mining and USD 16 billion for refining in 2024, accounting for 15% and 7% of the global total, respectively. Announced projects suggest that market value for refining is likely to fall to 2040, representing only 5% of the global total, with growth driven largely by copper refining in the DRC and by nickel refining in South Africa and Madagascar. In addition, in March 2025, a new lithium processing plant that will process around 500 tonnes of ore per day was nearing completion in Zimbabwe.

Although Africa's mineral resources represent a critical enabling factor for economic and industrial development, unlocking their full potential through domestic beneficiation depends on a range of interconnected enabling factors. These can be broadly classified into two categories: the direct economic inputs required for processing operations, and the foundational environment that makes such investment viable and sustainable.

The first category comprises the core elements of production: labour, capital and technology. Mineral processing facilities, such as smelters and refineries, are highly capital-intensive, and the ability to attract this level of private and public investment is therefore critical. To keep plants running efficiently, a skilled workforce is required, encompassing engineers, metallurgists and workers with other specialised skillsets. In addition, access to appropriate and efficient technology is essential in ensuring competitiveness and adherence to environmental standards.

State of selected enabling factors for the beneficiation of critical minerals



IEA. CC BY 4.0

However, the successful deployment of these inputs is fundamentally contingent on the broader foundational environment. Foremost among enabling factors is a stable and transparent policy and governance framework. Predictable regulatory regimes, clear fiscal terms, and the consistent application of the rule of law are essential for the long-term confidence required to attract capital. This policy framework must be supported by adequate physical infrastructure. In particular, reliable and competitively priced energy is a critical determinant of operational viability for energy-intensive refining processes, alongside efficient transport logistics to connect facilities to raw material sources and global markets.

It is the integration of these foundational enablers with economic inputs that creates a viable ecosystem for mineral value addition. Sustained underinvestment therefore holds the risk of missing vital opportunities to develop the resources needed for energy technologies, and for broader economic development on the continent and global diversification efforts.

Policy overview for beneficiation in Africa

Despite growing policy ambitions that aim to capture greater economic value from mineral wealth, implementation varies widely across Africa. Although the majority of the 24 countries analysed have announced plans for mineral resource beneficiation, only half have enacted supporting legislation. A further nine have released strategies, but many remain high-level and lack the mineral-specific considerations, infrastructure planning, or action on enabling conditions necessary to translate regulatory requirements and fiscal incentives into actual investment and industrial capacity.

Key policy levers employed include:

- **Fiscal incentives.** Some countries have introduced economic incentives to encourage mineral processing activities, including tax incentives, differentiated royalties for processed versus raw exports, export processing zones or duty exemptions for value-added products. However, fiscal incentives alone are insufficient without corresponding industrial capacity and infrastructure. Countries need the institutional mechanisms to effectively monitor and evaluate the impact of these incentives on actual beneficiation outcomes.
- **Beneficiation strategies.** As part of broader economic development plans, such strategies focus on identifying priority value chains and proposing comprehensive approaches to domestic processing. To translate policy aspirations into outcomes, these strategies require legislation implementation, detailed regulatory frameworks and sufficient funding mechanisms. Yet many remain at the strategic level without the legal instruments or sector-specific implementation plans necessary for meaningful industrial transformation.
- **Local content targets.** Some countries have announced targets for local processing that cover raw materials and the workforce, including requirements that a certain percentage of the final product is value-added locally and employs local

workers. These targets necessitate enforcement mechanisms and specific timelines for compliance, along with technical support for capacity-building.

- **Export restrictions on raw materials.** Several African governments have implemented restrictions on raw mineral exports. However, export bans alone do not guarantee domestic processing capacity and may lead to reduced production rather than drive beneficiation, highlighting the need for comprehensive industrial policies that go beyond trade restrictions.

Selected African policy instruments supporting domestic minerals beneficiation

Policy instrument	Examples
Fiscal incentives Governmental financial benefits to promote mineral beneficiation, including tax holidays, reduced corporate tax rates, import-duty exemptions and industrial park benefits.	South Africa: Companies may offset the value of qualifying beneficiation investments against equity ownership obligations; discounted electricity rates granted to smelters. Zambia: Preferential tax treatment, deductible mineral royalties and 100% capital allowances for downstream copper processors; incentives for registered value-added copper activities. Zimbabwe: Duty-free importation of capital equipment; Special mining leaseholders may access reduced corporate income tax rates and exemptions from withholding taxes.
Beneficiation strategies Comprehensive policy frameworks that mandate or promote local mineral processing and value addition, either embedded within national development plans, or established through specific legislation that aims to build local processing.	Kenya: Promotion of local processing clusters and value chain development in the 2023-27 Strategic Plan. Morocco: Tailored incentives for domestic beneficiation of key minerals, including tax relief and reduced duties. Namibia: Increased beneficiation targets for copper and zinc; allowances and incentives for domestic processing. Nigeria: Fiscal incentives to expand domestic processing industries and reduce raw mineral exports in the Mining Roadmap. South Africa: Identification of five priority value chains (e.g. PGMs and energy minerals); policy focus on developmental pricing, infrastructure expansion, R&D support, tax incentives and differentiated royalties for processed versus raw exports.
Local content requirements Requirements for the use of local goods, services, labour and equity participation in mineral beneficiation projects, aimed at maximising domestic beneficiation and economic impact.	Burkina Faso: State authority to mandate domestic processing and enforce local content. Ghana: Minimum local equity participation and procurement thresholds in mineral processing projects. Namibia: Standard licence conditions require local value addition of final mined products; at least 15% local ownership in new mining ventures and mining companies to source up to 80% of procurement from local businesses. South Africa: Minimum procurement of 70% goods and 80% services from local Black Economic Empowerment (BEE)-certified firms, especially in smelting/refining.

Policy instrument	Examples
Export controls Restrictions on the export of raw or unprocessed minerals, designed to encourage domestic value addition by limiting or prohibiting the shipment of unprocessed ores and concentrates.	DRC: Strategic mineral classification for cobalt, allowing for state control on ore export; 2025 short-term export suspension of copper and cobalt, largely with intent to correct low prices. Namibia: Cabinet ban on the export of lithium ore, cobalt, manganese, graphite and rare earth elements. South Africa: Export controls on chrome ore through export permits and export tax. Tanzania: Ban on the export of unprocessed copper and nickel ores in 2017 followed by announced ban of lithium exports in 2023, tied to domestic value addition requirements. Zimbabwe: Ban on lithium ore exports since 2022; ban on concentrate exports from 2027.

Indonesia and Chile offer examples of local value-addition strategies through their respective approaches to mineral beneficiation. Indonesia's downstream strategy began with a policy mandating domestic processing of raw minerals, and was later reinforced through regulations such as the Regulation on Domestic Market Obligation, which prioritises local supply, and the Regulation on Benchmark Pricing, which ensures the accuracy of benchmarks used in financial instruments and contracts. Indonesia's model is state-led, in contrast with fiscal incentive-based approaches in countries like Zimbabwe and Zambia, where tax holidays and economic zones are used to encourage domestic processing. In Chile, the government promoted local value addition in the lithium sector through the National Lithium Strategy and the Mining Royalty Bill, which introduced local content requirements to ensure domestic participation in lithium beneficiation projects. This aligns with policies in Ghana and South Africa that promote domestic participation in mineral value chains. These examples reflect a broader trend also seen across African countries — including Namibia, Nigeria and the DRC — where beneficiation policies are increasingly used to stimulate local industrial development and reduce dependence on raw mineral exports.

Opportunities for beneficiation of critical minerals in Africa

There are three broad models to increase the economic value of mineral resource endowments: export diversification into other sectors like agriculture or manufacturing; producing domestic inputs for the primary commodity sector (e.g. mining services); or moving into downstream activities that utilise the raw materials. This third path, moving from raw ore to processed metals through beneficiation, represents a large portion of the value-add in the mineral supply chain. This can be broadly divided into two major segments, each with distinct processes, requirements, and value-addition potentials.

The first segment involves preparing the extracted ore for further processing. This involves two primary unit operations: comminution, where ore is crushed and ground to liberate minerals from the surrounding waste rock (gangue), followed by concentration, which separates the liberated particles through physical or chemical methods.

This stage requires large-scale material handling and significant capital investment, as well as significant energy inputs: comminution is the most energy-intensive process in the entire mining value chain, accounting for a substantial portion of a mine's total electricity use. The concentration stage requires large volumes of water, reagents and other consumable media, as well as skilled labour.

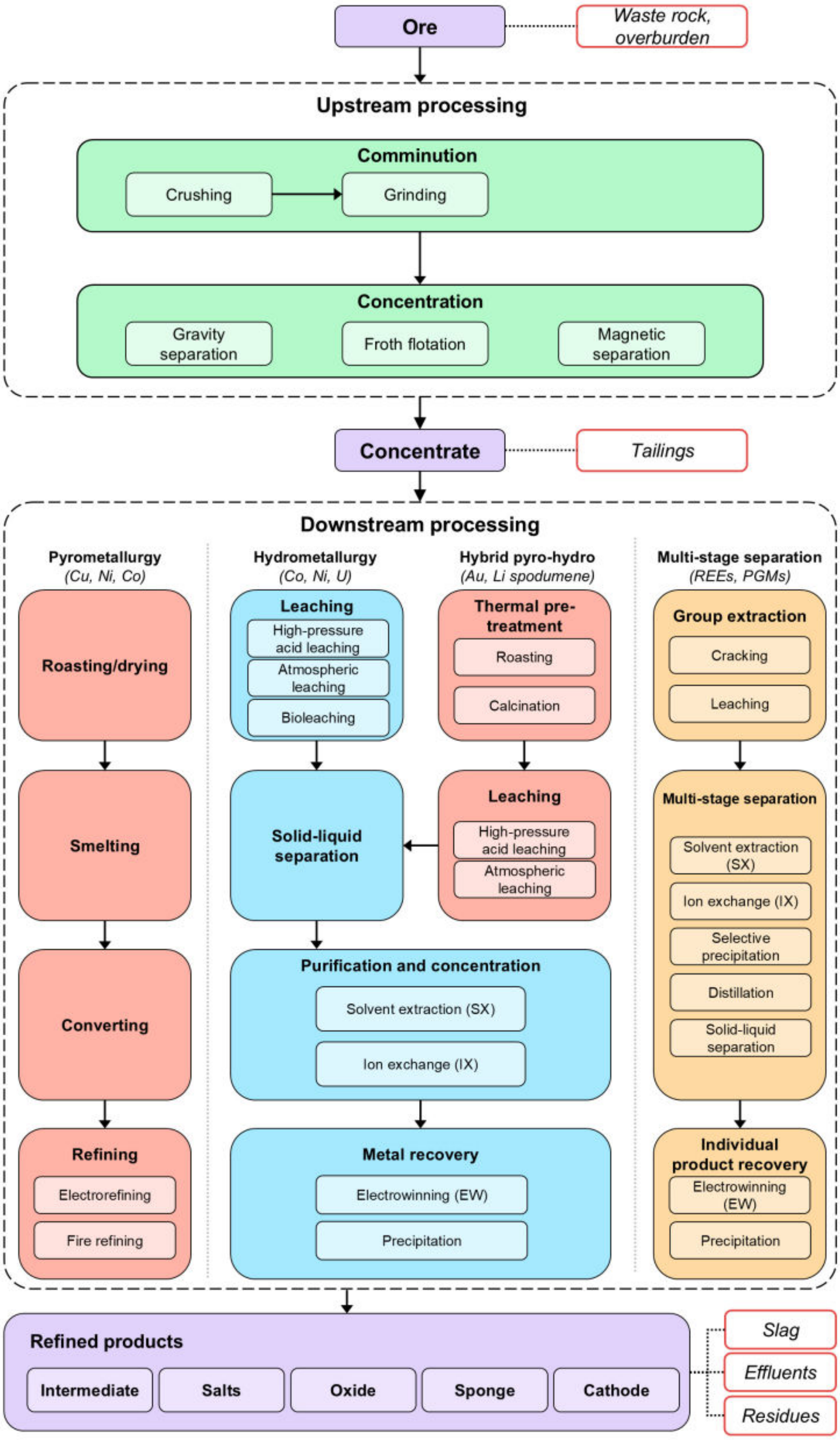
Processing is where the first significant leap in value occurs. For example, a typical copper ore deposit has a grade of less than 1%. Through crushing, grinding and flotation, this is upgraded to a copper concentrate with a metal content of between 25% and 30%. Converting a low-value, high-volume raw material into a standardised, tradable commodity means it can command a higher price on the international market. The degree to which minerals are processed in Africa varies drastically by commodity: nearly all PGM production is refined domestically, but 97% of mined cobalt is exported unprocessed.

Concentrating the ore also drastically reduces the volume of material that needs to be transported for further processing. In the case of copper, upgrading the ore from 1% to 30% concentration means that for every 100 tonnes of raw ore mined, only about 3 tonnes of concentrate need to be shipped. This yields significant savings in transportation and handling costs, making the entire supply chain more economically viable.

This upstream beneficiation is the pre-requisite for the next phase of value addition, refining, where the final market value of the resource can be realised. Metallurgical processes refine concentrates into high-purity metals and chemical products, with the processing route dictated by the ore mineralogy, grade, and project economics.

The pyrometallurgical route is typically used for high-grade sulphide concentrates like those of copper and nickel. Its core stages involve smelting in large furnaces (e.g. electric arc or flash furnaces) followed by conversion to a crude metal. Subsequent refining, typically via electrolysis, yields the final high-purity product. This pathway is defined by its high-temperature equipment and extreme energy consumption, relying heavily on fossil fuels like metallurgical coke as well as electricity. It also requires inputs of fluxes, such as silica and limestone.

Illustrative processing pathway for mineral processing and beneficiation



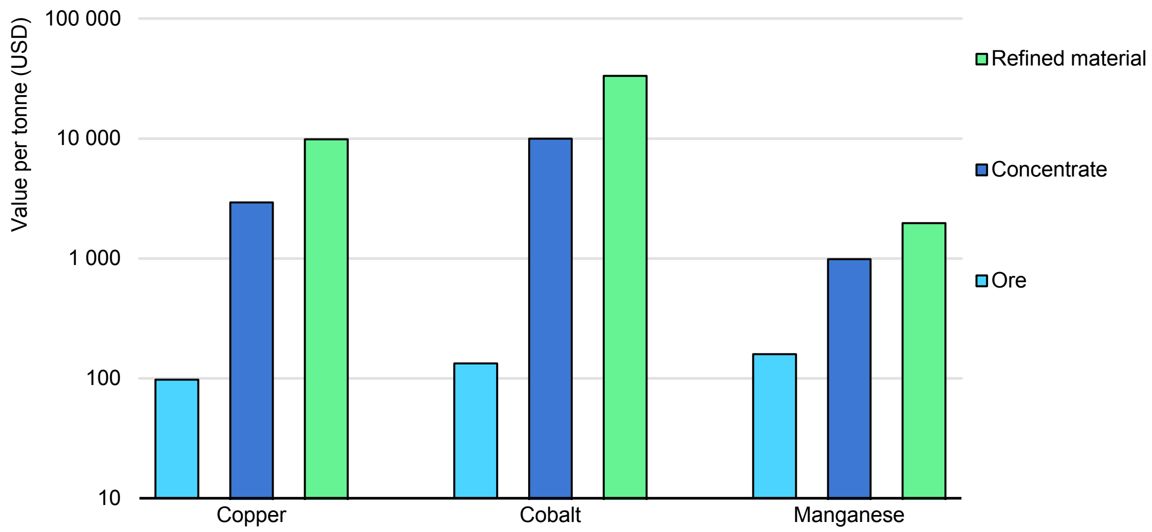
Notes: Au = gold; Co = cobalt; Cu = copper; Li = lithium; Ni = nickel; PGMs = platinum-group metals; REEs = rare earth elements; U = uranium. This figure illustrates generalised flowsheets and does not reflect the complexity of real-world circuits that are customised for specific ores. Phosphate and graphite are not covered by the processes outlined here.

In contrast, hydrometallurgical routes are a versatile, lower-temperature alternative often applied to lower-grade or complex oxide ores where pyrometallurgy is unviable. This pathway uses aqueous chemistry to leach target metals into a solution. While less heat-intensive than pyrometallurgy, this route has significant energy demands for pumping, agitation and electrowinning, and is highly dependent on chemical inputs for the solvent extraction circuit.

Hybrid processes employ parts of the pyrometallurgical and hydrometallurgical pathways. Complex multi-element ores, such as PGMs and rare earth elements, require sophisticated recovery circuits with multi-stage separation techniques to isolate each metal from a group of chemically similar elements before their individual recovery.

The refining stage delivers additional value-add and provides access to the most liquid end-user markets. For instance, refining crude blister copper into 99.99% pure London Metal Exchange (LME)-grade cathodes increases its value to about USD 10 000 per tonne. For battery metals, this stage is even more important: refining intermediates into high-purity chemical precursors can add a further 15-30% premium. While the largest relative value increases often occur in initial upstream processing, the highest absolute value and direct access to end-user markets are unlocked through final, high-purity refining.

Value per tonne of material at different processing stages, 2024



Notes: 2024 average values expressed on a logarithmic scale. Market prices for refined copper and cobalt were obtained from LME. Market prices for African manganese ore, medium-carbon ferromanganese, and electrolytic manganese were obtained from Shanghai Metals Market. Values for copper and cobalt concentrate and ore were derived using representative figures for treatment and refining charges, ore grades, and processing efficiency.
Sources: IEA analysis based on data from London Metals Exchange and Shanghai Metals Market.

Crucially, the development of mineral processing facilities necessitates investment in enabling infrastructure that can catalyse broader regional growth. High-capacity transportation, power and water systems, even if built for the purpose of primary industry, function as quasi-public goods by systematically lowering operational costs and reducing barriers to entry for other economic sectors such as agriculture.

Local processing can also support human capital development and economic diversification. Refining operations require a skilled workforce of engineers, metallurgists and technicians, necessitating investment in local education and training. In turn, plants can anchor demand for a local network of suppliers for services, maintenance and logistics.

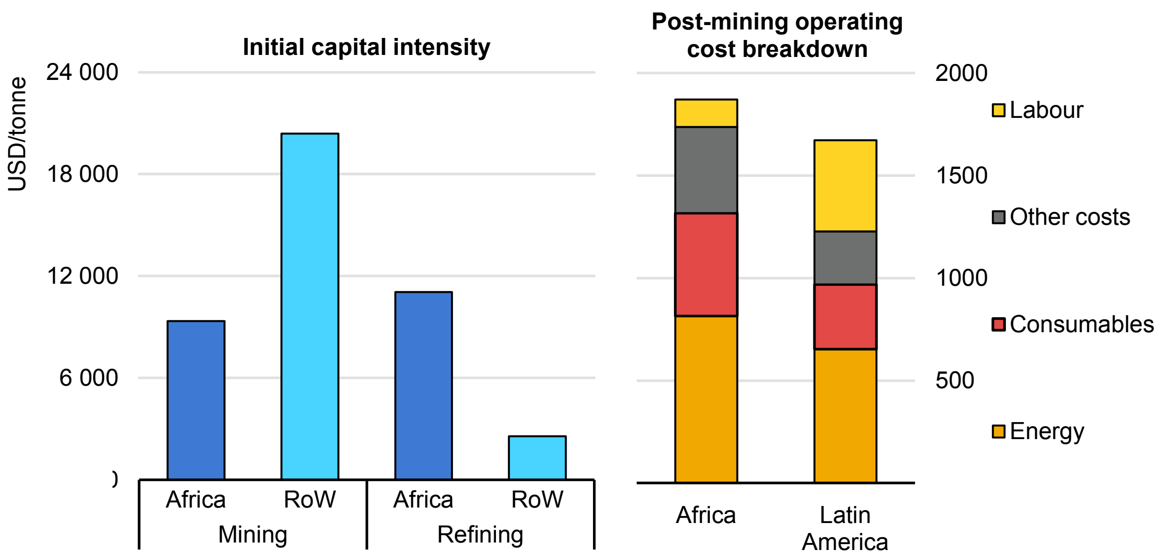
Despite substantial reserves and ongoing mining development across Africa, structural cost challenges continue to constrain the scalability and bankability of processing infrastructure. Refining requires far more capital-intensive infrastructure, including energy-intensive processes that depend on reliable power access, advanced technology, and skilled labour, all of which drive up costs.

These factors have historically limited the pace and scale of downstream industrial development in Africa. Copper offers a clear example: initial capital costs for upstream mining production, at around USD 9 000 per tonne, are nearly 50% lower than in the rest of the world. This reflects cost advantages in Africa such as abundant and higher-grade ore deposits, and relatively low labour and regulatory costs. Initial capital costs further up the value chain, however, show opposing trends, with African copper refining costing over four times more than projects in the rest of the world.

Higher initial capital costs in Africa are compounded by higher operating costs in key areas, which further constrain competitiveness. For refined copper, Africa's operating costs are 12% higher than in Latin America. This is primarily due to higher consumable costs, which cost nearly twice as much as in Latin America. This reflects the high cost of importing specialised reagents and input materials. Energy costs in Africa are also 25% higher than those in Latin America and represent 44% of total production costs, driven by high energy prices, unreliable grids and frequent reliance on off-grid diesel generation. Although labour costs in Africa are significantly lower, this is insufficient to counterbalance these broader cost pressures.

These dynamics place constraints on refining margins and limit the ability of African producers to attract investment, remain profitable, and retain value through local beneficiation. Addressing these barriers will require a combination of reliable and affordable energy, improved logistical and transportation infrastructure, long-term offtake agreements, and mineral-specific industrial strategies to support value-added production for both downstream domestic and export markets. This will require targeted investment in industrial energy infrastructure and material inputs to lower capital and operating costs.

Indicative copper capital intensity for mining and refining (left), and post-mining operating cost breakdown (right) in Africa and Latin America



Notes: RoW = Rest of the world. Capital intensity data collected through company announcements and financial reports. Companies selected based on sample of the largest completed and planned projects across the world for each mineral. Capital intensities are estimated based on historical investment data. They do not account for declining ore grades, which may affect future capital intensities, particularly in established markets such as copper. Post-mining cost breakdown analysis does not include the smelting phase.

Sources: IEA analysis based on data from company reports and S&P Global Capital IQ.

Creating the right investment environment for refining and processing will be essential for Africa to play a larger role in global critical mineral supply chains. Targeted interventions can bridge structural cost gaps, unlock downstream investment, and advance objectives around supply chain resilience, economic development and sustainability.

Several African governments are now seeking to use regulatory tools, including local processing requirements, beneficiation quotas and export controls, to drive value addition in their mineral sectors. However, without clear implementation plans and supportive commercial frameworks, there is a risk that these measures may deter investment by creating uncertainty about compliance requirements and policy consistency. Key to driving value creation is building robust investment cases by enforcing domestic value retention through beneficiation requirements, supported by coherent policy frameworks that prioritise beneficiation within the mining sector.

Moving from policy intent to tangible impact requires long-term purchase agreements, adequate energy infrastructure, access to patient capital, clarity on the intended use of refined outputs, whether for domestic industry development or value-added exports, and comprehensive traceability systems to monitor compliance and measure progress. While governments can already track overall production and export volumes, verifying compliance with beneficiation requirements demands more sophisticated traceability systems that can monitor the value-addition process itself, distinguishing between raw material exports, semi-processed goods and fully beneficiated products. Such systems would also enable African producers to demonstrate responsible sourcing credentials that increasingly influence global supply chain decisions.

Tapping into the opportunities for beneficiation – trends in the High Potential Case

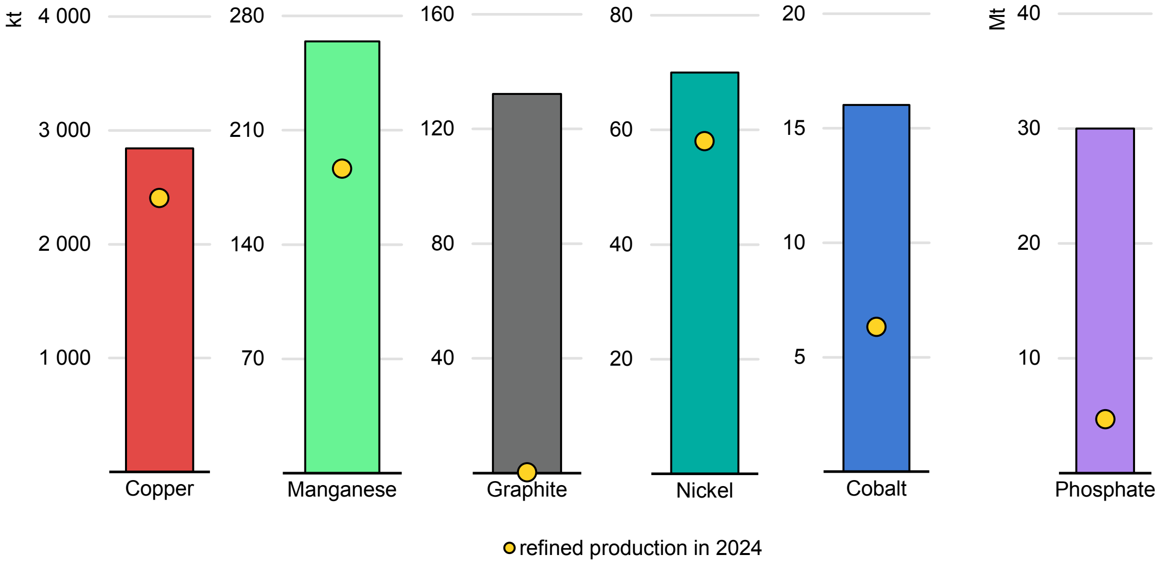
If the enabling factors for mineral beneficiation are favourable, and targeted policy and investment frameworks are put in place, as reflected in the High Potential Case (HPC), Africa could play a key role in the global supply of concentrates and refined minerals. This would both benefit local economies and help diversify global sources of supply.

For the HPC, a set of six minerals has been selected to create a representative portfolio of Africa's resource endowments: copper, cobalt, graphite, nickel, manganese and phosphate. The minerals were selected based on their relevance to energy technology or wider industrial supply chains, as well as Africa's share of mineral production or reserves.

There are ample opportunities for beneficiation of these minerals across the continent. The DRC and Zambia hold substantial cobalt and copper resources that provide a strong foundation for producing processed materials. This dual opportunity would allow them to capture significantly more value by supplying the refined copper that is essential for all energy technologies, including motors, power transmission and industrial machinery, as well as battery-grade cobalt used in the cathodes of nickel manganese cobalt oxide (NMC) lithium-ion batteries.

NMC batteries also require refined manganese and nickel, metals that are produced in South Africa, Gabon and Madagascar. Beyond the NMC chemistry, Morocco could leverage its vast phosphate reserves to expand production of purified phosphoric acid – a key input for lithium iron phosphate (LFP) batteries, for which demand is growing rapidly. Similarly, the graphite mined in east African countries like Mozambique and Madagascar could be upgraded into spherical graphite, the processed anode material required for nearly all types of lithium-ion batteries.

Refined production for selected minerals in Africa in the High Potential Case, 2040



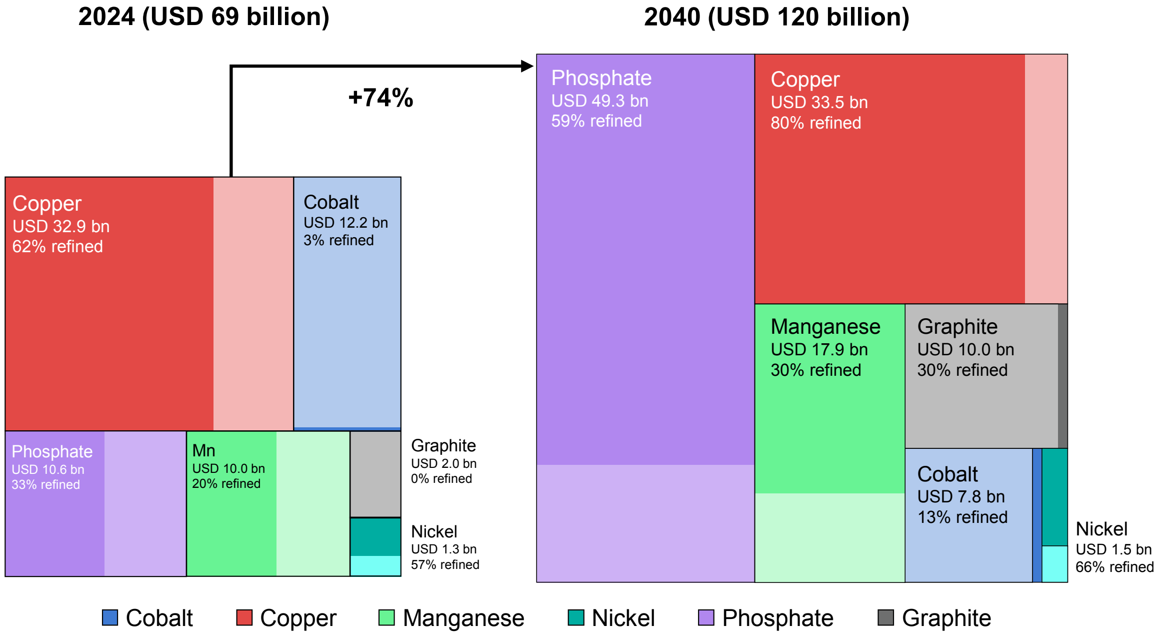
Notes: Refined phosphate expressed in phosphorus pentoxide (P_2O_5) content. Graphite refers to battery-grade spherical graphite.
Sources: IEA analysis based on Wood Mackenzie; Shanghai Metals Market; company reports.

Today, domestic refining of copper is far more advanced than refining of most other minerals, with over 60% of African mined copper being refined domestically. Africa represented 9% of global refined copper output in 2024. In the HPC, Africa refines 80% of its mined copper production locally by 2040, increasing total refined output by almost 20% and maintaining its current market share. Similarly, about 55% of African nickel production is refined domestically today, though the overall volume remains small. This rises to over 65% in 2040, boosting the market value by over 10% even as mine output remains stable.

In the case of cobalt, Africa's refining increases from 3% of mined output today to 13% in 2040, increasing refined output by 2.5 times to 16 kt, even as mine production decreases by a third from 2024 levels. From today's very low levels, battery-grade graphite production in Africa surpasses 130 kt in 2040, accounting for 25% of the growth in global mined supply over this period.

At today's price levels, the total market value of these minerals would increase from about USD 70 billion today to USD 120 billion in 2040 in the HPC, driven by two key variables: changes in mined output and proportion of ore that is refined domestically. For comparison, total exports of all goods from African countries were worth around USD 680 billion combined in 2024.

Market value of refined minerals in 2024 and in the High Potential Case, 2040



Notes: Values in 2024 USD. % refined indicates volume share of mine output that is refined. 2024 values determined using methodologies described in the figure above titled "Value per tonne of material at different processing stages, 2024''.

Sources: IEA analysis based on data from London Metals Exchange; Shanghai Metals Market; Wood Mackenzie; and S&P Global Capital IQ.

In aggregate, the total value of ore sales would increase by more than USD 5 billion. The increase in the HPC is driven by increases in manganese, graphite and phosphate production, which more than offset declines in copper, cobalt and nickel ore sales. These declines are a result of overall decreases in mine output, as well as increases in foregone ore sales as more production is processed domestically.

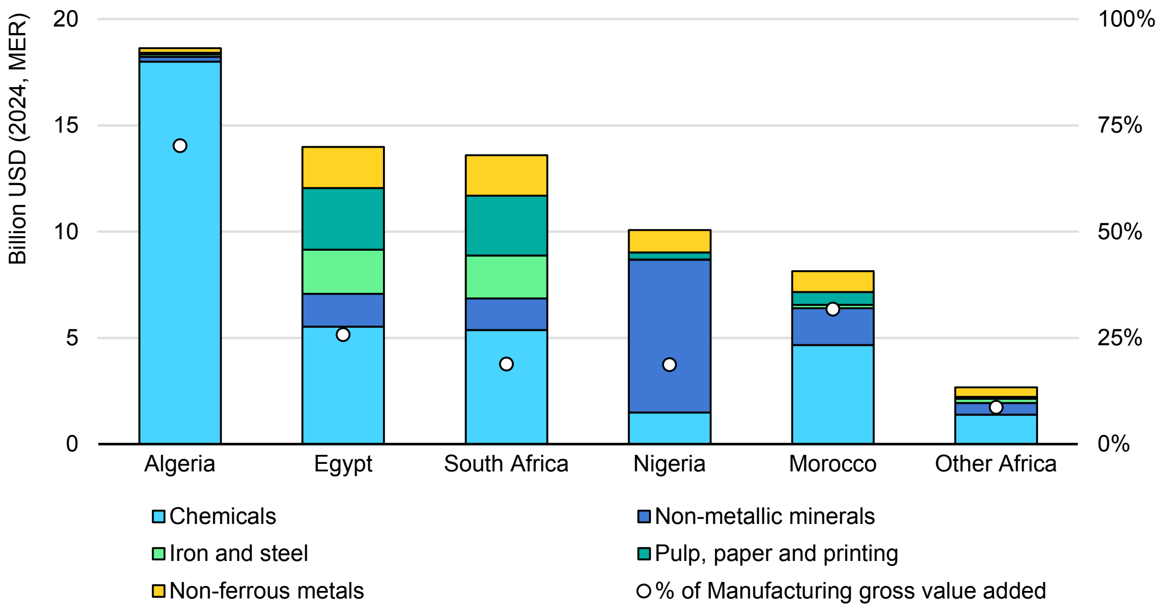
In the HPC, the value of refined material would increase for all minerals considered, with the combined value increasing by two-thirds between today and 2040. Refined phosphate would account for an additional USD 39 billion of value in 2040 compared to 2024, followed by manganese and graphite at USD 8 billion. Refined cobalt would increase in value by around USD 340 million, but this would not offset the decrease in mine production, which is estimated to lead to a USD 5 billion drop in the value of ore sales.

Production of low-emissions, energy-intensive commodities

Energy-intensive manufacturing in Africa today

Energy-intensive commodities – such as iron and steel; non-metallic minerals (including cement); chemicals (including fertilisers); pulp, paper and printing; and non-ferrous metals – are essential to the construction of critical infrastructure and buildings, and to the production of vehicles and countless other goods that can support socio-economic development. Africa's population, currently around 1.5 billion, is projected to grow by around 25% by 2035, compared to an average of less than 2% across the world's advanced economies. Most of this population growth will take place in Africa's rapidly expanding urban areas, driving up demand for energy-intensive commodities to support infrastructure development.

Gross value added by energy-intensive manufacturing industries in Africa, 2024

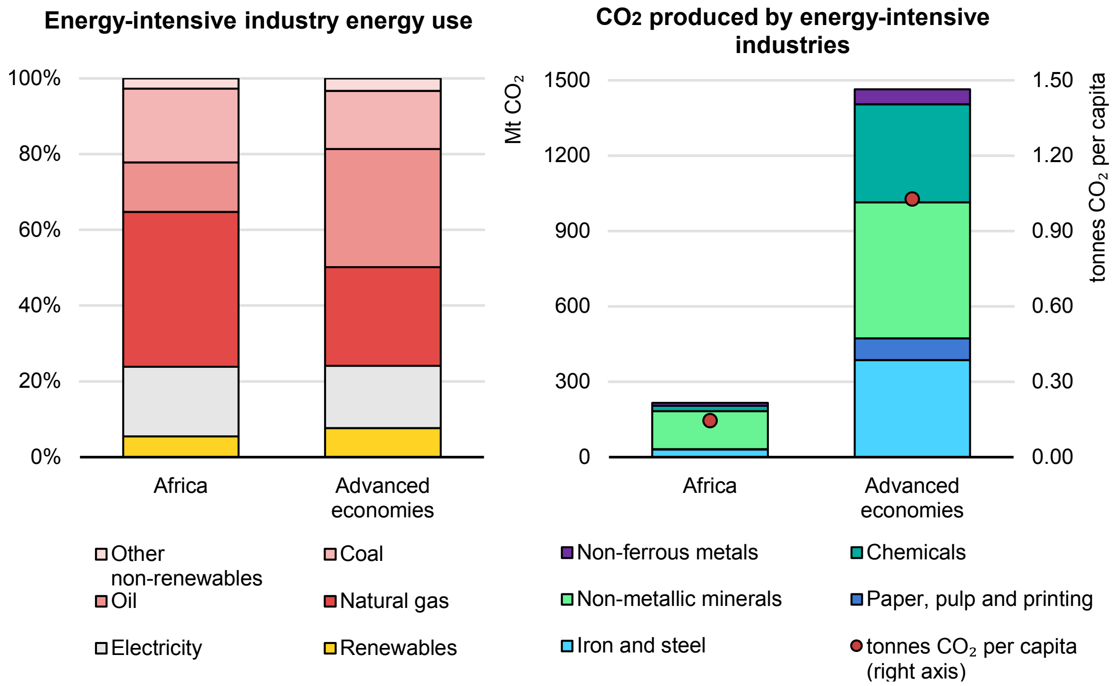


Note: Industry names refer to manufacturing industries under the NACE Rev. 2 classification.
Source: IEA analysis based on Oxford Economics Global Industry Service.

Energy-intensive industries currently account for around 2.5% of Africa's GDP, and contribute more than USD 65 billion to the economic value added by manufacturing – about 25% of the total. The continent's largest energy-intensive manufacturing sectors are the chemicals and fertiliser industries, primarily concentrated in Algeria, South Africa, Egypt and Morocco. In Algeria, chemicals and fertilisers account for over 65% of manufacturing value added, highlighting their strategic importance. In Nigeria, non-metallic minerals is the leading energy-intensive manufacturing sector, driven by high levels of cement production. As economic development continues, these industries have significant potential to further contribute to local value creation; historical evidence shows that as countries industrialise, there is a positive relationship between manufacturing output share and real GDP per capita.

Across the world, energy-intensive manufacturing industries are also emissions-intensive. Energy-intensive sectors are responsible for almost 75% of emissions produced by the industrial sector in Africa, just slightly lower than the average of over 75% in advanced economies on other continents. Despite this, African countries produce and consume far less of the outputs from these sectors today than the advanced economy average, which explains why the emissions associated with energy-intensive industries in Africa represent only around 15% of those of the world's advanced economies, both in absolute terms and per capita.

Energy use and CO_2 emissions by industry sector in Africa and in advanced economies, 2024



Note: Industry names refer to manufacturing industries under the NACE Rev. 2 classification.
Source: IEA analysis based on Oxford Economics Global Industry Service.

The industrial sector's energy mix in Africa differs from that of advanced economies due to variations in the size and energy use of their energy-intensive industries. In Africa, the non-metallic minerals industry (with cement being its single largest component) is the largest energy consumer, accounting for just over one-third of total energy-intensive industrial energy demand. This industry relies more heavily on coal and uses less oil compared to in advanced economies. In contrast, the chemicals industry dominates energy use in advanced economies, accounting for almost 50% of energy-intensive industrial energy demand. This is primarily due to the use of oil as a feedstock, rather than for combustion. In Africa, the chemicals industry represents a smaller share of energy-intensive activity and relies more on natural gas.

Low-emissions industrial processes

New low-emissions industrial processes and commodities – many of which enable direct use of electricity, or its indirect use through electrolytic hydrogen – are essential for decarbonising industry. Some energy-intensive industrial processes are already largely electrified using commercially available technologies, such as aluminium smelting and steel production from scrap in electric furnaces, but many others, like blast furnaces and steam crackers, rely on fossil fuels as the main sources of process energy and feedstock. African countries are leveraging domestic fossil fuel discoveries to power domestic industries, and will continue to do so, but other regions with comparative advantages on production cost (e.g. oil and gas in the Middle East) or an already dominant position in these sectors (e.g. China) may make for tough competition in energy-intensive industries operating with conventional technology. Differentiated markets for low-emissions material production, by contrast, are still nascent, with no established players operating at scale as yet.

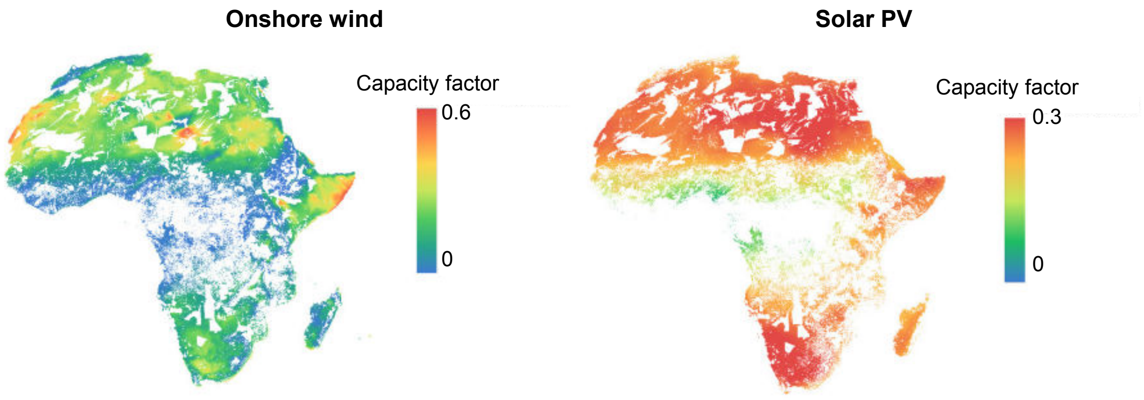
A transition to net zero energy-intensive industries could have implications for the competitive landscape, and open up new opportunities for countries with competitive low-emissions energy resources to step up the value chain in these industries. Several advanced economies, including in Europe and East Asia, are pursuing a transition to net zero heavy industries in what is today a high-price environment for energy, with limited prospects for an abundant domestic supply of low-cost, low-emissions electricity in the future. At the same time, many countries want to retain their heavy industries, and in particular the final steps in these processes (such as casting, rolling and forming in the steel supply chain) in order to preserve industrial clusters that support higher-value-added downstream sectors (such as the automotive, defence and pharmaceutical industries).

One option to reconcile these competing priorities could be for these advanced economies to import selected energy-intensive, low-emissions inputs to upstream supply chain steps from countries where they could be produced more competitively. This could provide a mutually beneficial opportunity for advanced economies with high energy costs to maintain downstream manufacturing industries, while developing economies with abundant, cost-competitive renewable energy could export products higher up the value chain than they do in most cases today (see box below).

Mineral deposits and high capacity factors for solar PV and wind as enablers

Many African countries have abundant, low-cost renewable energy resources that remain largely untapped. While the share of renewables in Africa's grid electricity mix is today relatively low, the continent holds some of the world's best physical potential for expanding solar PV and wind generation. Average capacity factors for solar PV can reach up to 30% in parts of Africa, compared to just 15-25% in Europe and Japan. For onshore wind, western and eastern Africa offer good resource conditions, with capacity factors in some regions approaching 45%, which is similar to the best resources in Europe.

Potential electricity generation for onshore wind and solar PV in Africa



Note: The capacity factor is a ratio between 0 and 1, representing the actual annual energy output of a power source compared to the maximum possible output if it operated at full capacity all year.

Sources: Based on hourly wind data from Copernicus Climate Change Service and hourly solar data from Renewables.ninja, and land-use data from UN Environment Programme World Conservation Monitoring Centre; US Geological Survey; European Space Agency.

Low-emissions production of iron – the most energy-intensive step in steel production – and ammonia production using low-emissions hydrogen are two examples of energy-intensive industrial processes that could leverage this renewable energy potential. This could provide opportunities for many African countries to move up the value chain in energy-intensive industries. The indicator analysis developed for ETP-2024 (see the Introduction) can be used to assess the enabling factors for these two opportunities in more detail.

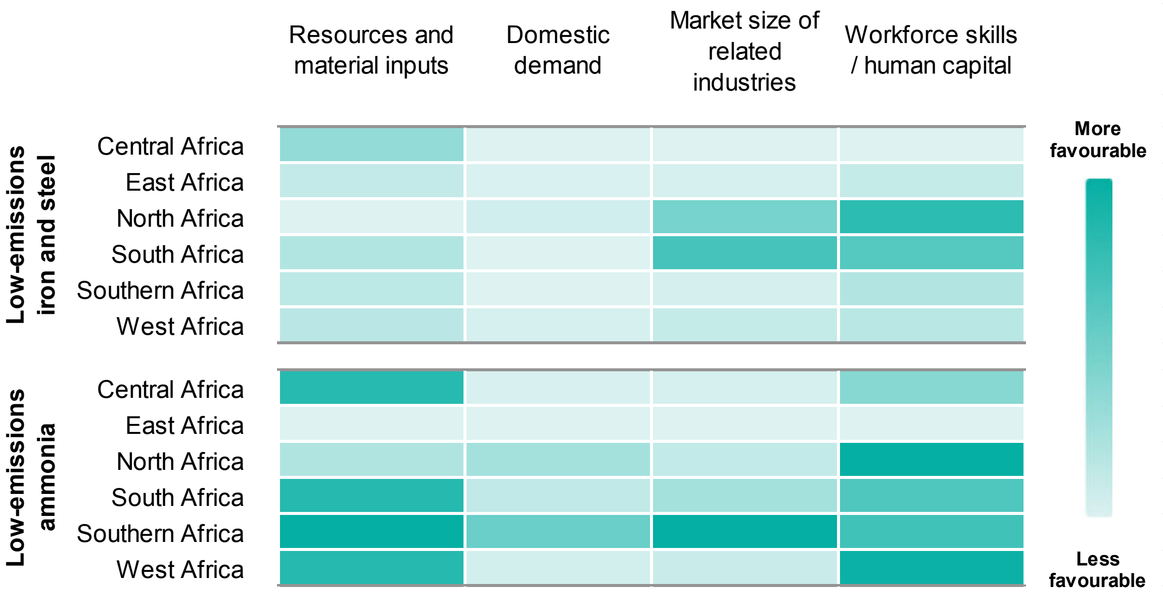
With regards to low-emissions iron, the presence of iron ore reserves across Africa is a crucial enabling factor. Guinea, for example, has the largest reserves of any African country, with 20 Gt (nearly 9 years' worth of global demand). However, the areas with the greatest reserves often have poor energy and transport infrastructure. North Africa has limited iron ore reserves, but benefits from well-developed energy and transport systems, as well as proximity to export markets such as Europe. An established manufacturing sector and active mineral extraction mean there is an existing workforce with complementary skills. South Africa, the world's fourth-largest exporter by value of iron ore, benefits from a well-established steel industry that would allow new production facilities to make use of existing infrastructure and logistics.

For low-emissions ammonia production, the key enabling factors are access to low-emissions electricity, existing domestic demand and production capacity, and the presence of a skilled workforce. Low-emissions ammonia production requires only two material inputs: nitrogen – produced from air – and hydrogen, produced from water. Water stress could therefore be a limiting factor in some countries, as freshwater is particularly scarce across much of Africa. Since ammonia production uses similar processes to other basic chemicals, countries with a strong chemical industry and well-developed science and technical education are better prepared to operate these facilities.

Ammonia production is currently concentrated in a handful of countries, with Egypt, Algeria and Nigeria accounting for more than 90% of production in Africa. As a result, there is existing experience within incumbent manufacturing processes. In addition, there is already a large market opportunity. Morocco, for example, is a major exporter of compound fertilisers, harnessing its abundant phosphate reserves. Yet it relies entirely on imports to meet its ammonia needs, primarily sourcing from countries outside Africa, such as Saudi Arabia and Trinidad and Tobago.

Enabling low-cost renewables in Africa at a scale sufficient to support this kind of industrial development would require strong policy support to reduce costs and accelerate deployment. Access to affordable financing and action to reduce the cost of capital will also be crucial. The cost of capital for solar projects currently varies greatly across African countries, from a required rate of equity return of 16% in Morocco to as much as 51% in Zambia, for example. This compares to 8-9% for Australia, Germany and Sweden. Grid integration and storage also have a critical role to play. Africa is about three times larger than Europe in terms of land area, but Europe's transmission and distribution lines are more than three times longer in aggregate. The lack of transmission network infrastructure limits further grid development across the continent, as well as limiting energy access. As a result, while producing electricity using hydropower is cheaper in Africa than in Europe, both solar PV and wind are often more expensive. However, Africa's vast renewable potential provides a significant opportunity to reduce electricity costs. If African countries are able to capitalise on this opportunity, low-cost renewable electricity could provide a strong foundation to enable the development of low-emissions industrial processes and commodities.

State of enabling factors for selected low-emissions, energy-intensive commodities



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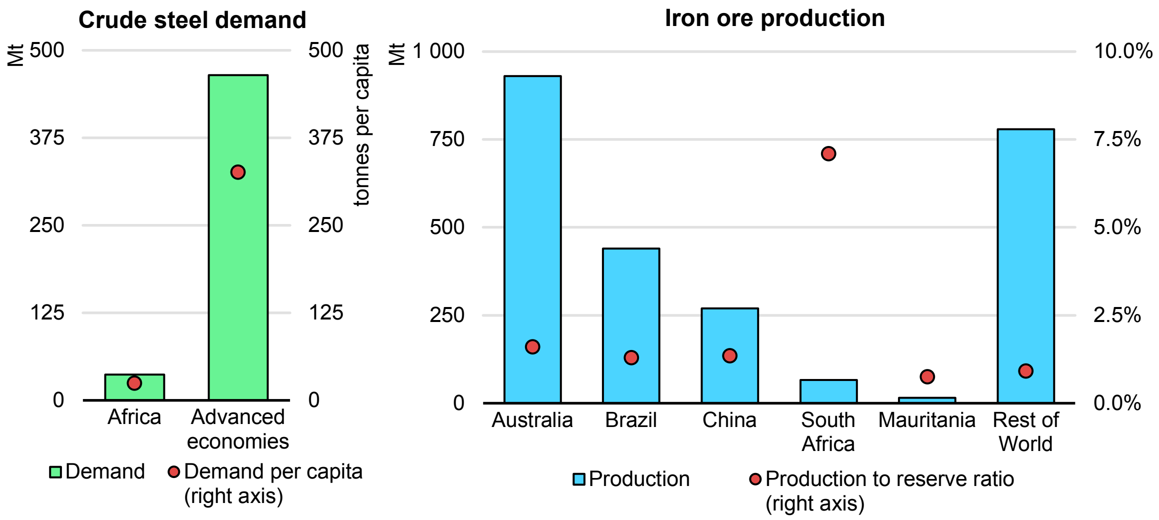
Opportunities for low-emissions iron production in Africa

As economic development continues in Africa, demand for steel is expected to grow significantly to support the construction of vital infrastructure, including transportation networks (such as bridges, ports and harbours), energy systems (power grids and renewable installations), and residential and commercial buildings. Demand for crude steel per capita in North Africa and South Africa today is just over 25% of the average across advanced economies; demand in other parts of Africa is significantly lower. The primary metallic input in steelmaking is iron, which is also the most energy-intensive. While advanced economies often supplement iron in steelmaking with scrap steel that comes from their mature stocks of vehicles, buildings and infrastructure, in many developing economies, scrap steel is far less available. As a result, expanding steel production in Africa can be expected to require greater use of iron and thus to increase domestic demand for iron ore.

Africa has very large iron ore reserves, spread across the continent. West and Central Africa alone have a total of about 22 billion tonnes of proven iron ore deposits, compared to 34 billion in Brazil and 58 billion in Australia, the world's biggest iron ore producers. Both South Africa and Mauritania have room to expand iron ore production given their large reserves. At current levels of production and without any additional exploration, South Africa could continue producing for around 15 years, while Mauritania could continue producing for over 100 years. Today, most of the iron ore produced from these reserves is exported in raw form (i.e. not beneficiated), with South Africa being the fourth-largest exporter by value globally, after Australia, Brazil and Canada. Iron production is therefore relatively modest today and primarily situated in Egypt, Algeria and South Africa.

Crude steel demand and iron ore production in selected countries, 2024



Sources: IEA analysis based on data from the US Geological Survey, S&P Global and World Steel Association.

Whether Africa's iron ore is exported or locally beneficiated, the processes used to turn it into iron and then into steel are broadly the same across the world today. Blast furnaces, fuelled by a mixture of coke and pulverised coal, produce pig iron, which is typically converted to steel while still in the liquid phase after exiting the furnace. Direct reduced iron (DRI) furnaces use natural gas or coal to produce hot briquetted iron in shaft furnaces, in the solid phase. These processes are highly emissions-intensive.

Several innovative technologies are being developed to reduce emissions from ironmaking.[2] One key approach involves adapting DRI furnaces to use low-emissions hydrogen as the reducing agent, replacing the gases derived from natural gas and coal used in conventional DRI processes. When the hydrogen is produced using renewable or other low-emissions electricity, hydrogen-based DRI furnaces can significantly lower the CO_2 emissions intensity of iron production.

Countries with access to iron ore (beneficiated where necessary), low-cost renewable electricity and the necessary rail and port infrastructure to connect these resources to domestic markets and export terminals are well-positioned to transition to hydrogen-based DRI. Today, there are a range of investments and

[2] See the IEA's Clean Energy Technology Guide for more details.

supportive government policies in Namibia, Mauritania and South Africa which aim to capitalise on this potential (see table below).

Projects and government policy supporting low-emissions steel manufacturing in Africa

Country	Project	Focus	Output
Announced projects			
Namibia	HyIron Project, HyIron (2024)	DRI with renewable hydrogen	15 ktpa of DRI
Mauritania	ArcelorMittal + SNIM collaboration (2022)	Pelletisation and DRI production	Exploring new DRI and pelletisation facility
South Africa	Freeport Saldanha Industrial Development Zone hub, Sasol, ArcelorMittal (2022)	Hydrogen-based DRI production	Exploring hydrogen-based DRI hub
Government policies/initiatives			
EU-Mauritania partnership	EU strategic interest in Mauritania's low-emissions steel, European Commission (2024)	Low-emissions hydrogen and near-zero emissions steel export	Mauritania positioned as a low-emissions steel supplier to Europe
Mauritania	Nationally Determined Contribution (2021-2030), Ministry of Environment and Sustainable Development (2021)	Reshape energy mix; enable hydrogen development	Increase renewables to 50% of electricity mix by 2030
South Africa	Just Energy Transition Investment Plan, Presidential Climate Commission (2022)	Low-emissions iron and steel as part of inclusive development	Address poverty, inequality, and unemployment through green steel
Kenya	Vision 2030, Government of Kenya (n.d.)	Development of integrated iron and mini steel mills	Develop domestic capacity in steel and iron
African Union	African Union Agenda 2063 (n.d.)	Move up the value chain in commodity production	Support sustainable growth by capturing more value from mineral exports

Tapping into the opportunities for low-emissions iron production – trends in the High Potential Case

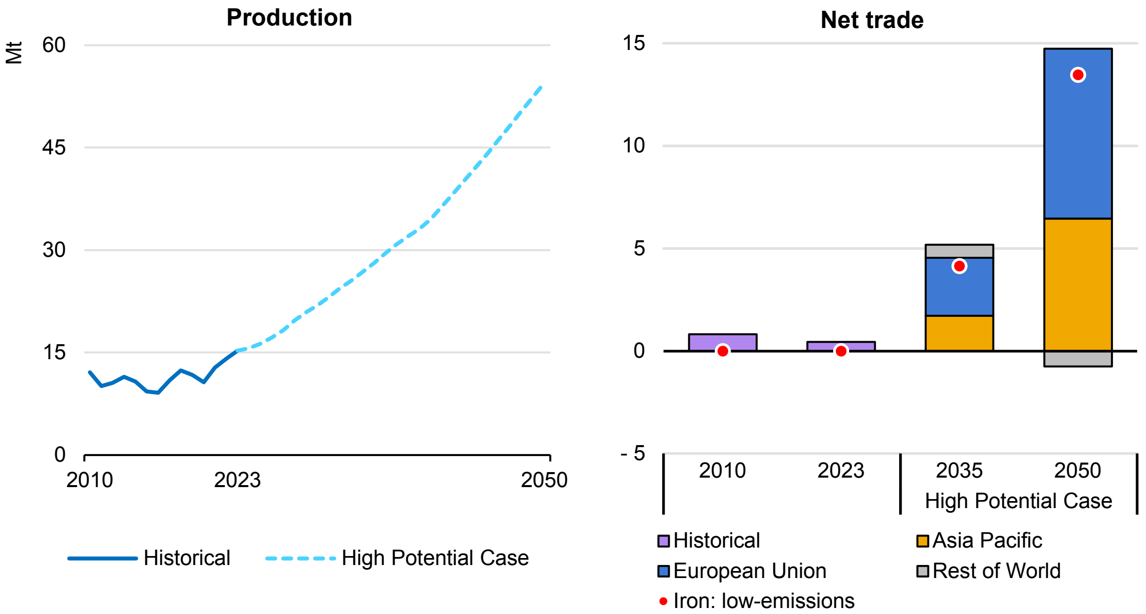
Iron production was 15 Mt in 2023 and is set to grow to over 40 Mt in 2050 in the Stated Policies Scenario (STEPS). In this scenario, global iron production continues to be primarily based on fossil fuels, and so Africa's relative opportunities in the steel supply chain remain largely unchanged. With the continued use of fossil fuels, relocating production to regions with both iron ore deposits and low-cost renewable electricity offers limited economic benefit for steel producers from advanced economies.

In the High Potential Case (HPC), the higher global deployment of clean energy technologies and low-emissions materials would enable iron production in Africa to double to 30 Mt in 2035, and reach 55 Mt by 2050. This would push up exports to 5 Mt in 2035 and 15 Mt in 2050. Demand for exports is mostly driven by the cost-competitiveness of production, and the majority of the exports land in Europe (around 60%) and Japan (around 35%). In the HPC, markets succeed in overcoming barriers to exploiting all of their competitive advantages.

Europe and major material producers in Asia do not have the same potential for renewable energy as many African countries, but they do have established steel industries. Today, they face relatively high costs for producing steel, due to increasingly expensive energy costs. In the HPC, these regions would remain at a competitive disadvantage relative to many countries in Africa for the most energy-intensive steps in the process. Nonetheless, they would require cost-effective domestic low-emissions steel production to support downstream industries such as car manufacturing, and could ensure adequate supplies by importing a portion of their low-emissions iron needs from cost-competitive sources of production in Africa (see box below). This is an important feature of their strategy to improve competitiveness in the context of the HPC.

For African countries, the low-emissions iron exports seen in the HPC would constitute a significant step up the value chain relative to exporting iron ore. This means that far more value added is retained in Africa, as well as jobs in the industry. While it is difficult to accurately quantify the economic benefit, it is estimated that by 2050, the 15 Mt of low-emissions iron exports would be worth more than four times the value of the same tonnage of iron ore exports at today's prices, or around USD 6 billion, based on the estimated costs of producing this iron in Europe.

Iron production and net trade in Africa, historical and in the High Potential Case, 2010-2050



Can African countries benefit from helping to bridge competitiveness gaps in advanced economies' net zero heavy industries?

One option for advanced economies that are pursuing the decarbonisation of heavy industries at lower cost could be to import selected energy-intensive, low-emissions inputs to upstream supply chain steps from countries where they can be produced more competitively. The European steel industry in the HPC can be used as an illustrative case study. In the HPC, carbon prices in the European Union rise to around USD 250/t of CO_2 by 2050, and the planned implementation of a Carbon Border Adjustment Mechanism (CBAM) is successful in ensuring that both domestic production and foreign imports face equal costs per tonne of CO_2 emitted.

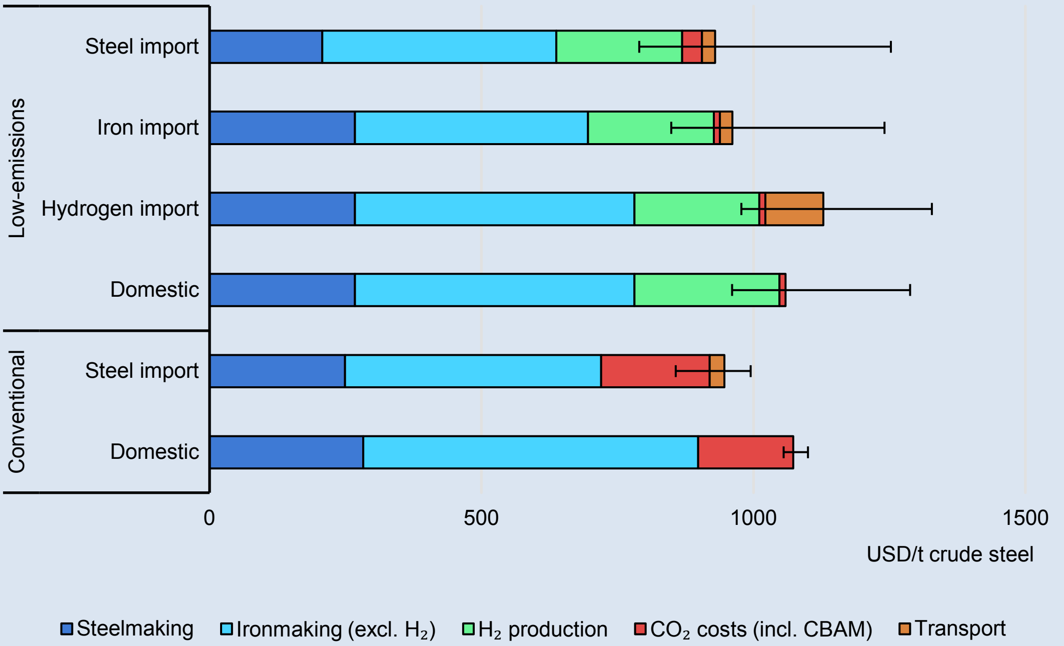
A conventional natural gas-based DRI steelmaking facility using best available technology directly emits around 0.6 t CO_2 per tonne of crude steel. In 2050 in the HPC, such a plant in western Europe* is estimated to have a production cost of around USD 1 070/t crude steel, with around 16% of this attributable to CO_2 costs. Steel produced in the same way in Africa and exported to the European Union would cost around USD 945/t, including CO_2 (levied via the CBAM) and transport costs.

The most cost-competitive option for Europe would be to import low-emissions steel produced in Africa via hydrogen-based direct reduced iron (H_2-DRI) at USD 930/t. The lower cost of production in Africa is mainly due to its strong potential in renewable electricity generation, which can be used to produce low-emissions hydrogen at a competitive price, at just over USD 3.5/kg on average, compared to over USD 4/kg in western Europe. Under the best conditions, the delivered cost falls to USD 790/t, reflecting hydrogen prices under USD 3/kg.

By 2050, the delivered cost to Europe of importing DRI and completing the steelmaking step within the European Union could be as low as USD 850/t. Retaining the steelmaking step offers producers greater flexibility, particularly for serving end-users like EV manufacturers, which may justify the small cost difference. Alternatively, importing hydrogen from Africa – at USD 1 130/t – represents the most expensive of the low-emissions import options assessed.

This analysis reflects opportunities for Africa to establish strategic partnerships across different parts of the iron and steel supply chain that hold competitive advantages in specific supply chain segments. If African countries are able to overcome current barriers to production and harness their renewable energy potential, they could increase the economic value added domestically and lead to employment growth in these sectors.

Indicative range of the levelised cost of production of steel in the European Union and cost of imports from Africa



Notes: H_2 = hydrogen; CBAM = Carbon Border Adjustment Mechanism. Values in 2024 USD (MER). Domestic refers to production in western Europe. Import is from Africa to western Europe. Low-emissions corresponds to H_2-DRI technology, while conventional refers to a natural gas-based furnace, both of which are equipped with an electric arc furnace. In all cases, a 9% scrap share of metallics in the steelmaking furnace is assumed. Best available technology energy performance is assumed for all units. Error bars show the impact of variation in H_2 costs for different locations in each region for the low-zero emissions route (USD 2.8-7.9/kg for the European Union and 2.2-7.3/kg for Africa), and ranges of natural gas and electricity prices over the period 2015-2019 (natural gas: USD 11.3-13.9/GJ the European Union and 2.7-12.1/GJ for Africa; electricity: USD 156-175/MWh the European Union and 24-182/MWh for Africa).

*Western Europe refers here to France, Germany and Italy.

Opportunities for low-emissions ammonia production in Africa

Ammonia plays a vital role in agriculture worldwide. About 70% of ammonia demand is for use in fertiliser production, and the rest is for industrial applications. It is the starting point for all mineral nitrogen fertilisers, such as urea, ammonium nitrate and ammonium sulphate. Demand for ammonia is expected to grow significantly as it becomes increasingly important in the energy transition – not only for fertilisers, but also for power generation, hydrogen-based fuels, and as a direct fuel in heavy transport.

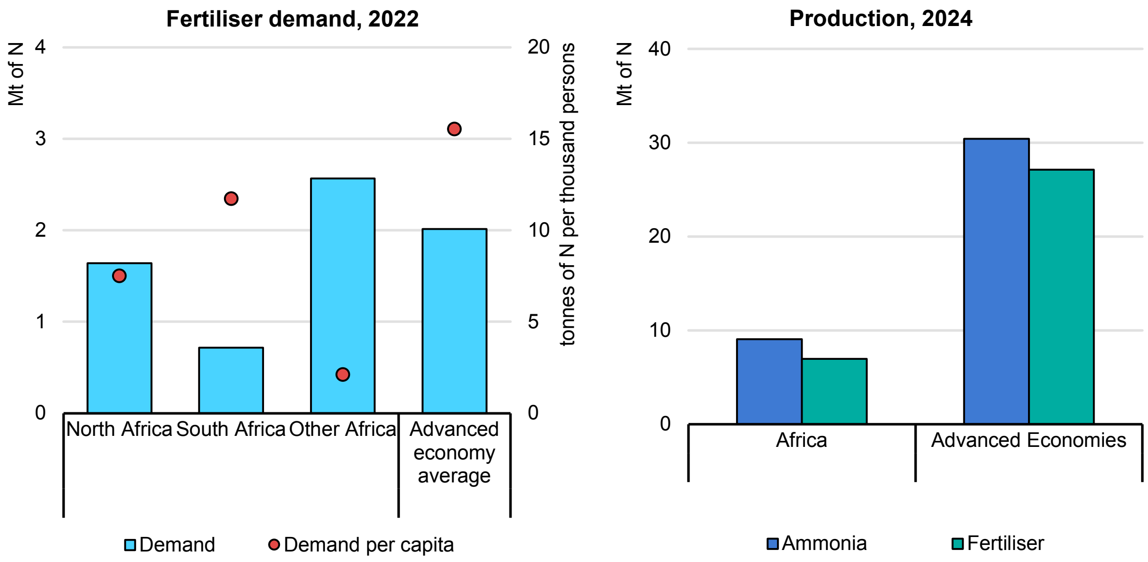
Africa currently derives nearly one-sixth of its GDP from agriculture, compared with an average of less than 2% in advanced economies. This is despite several African countries having some of the lowest rates of agricultural productivity in the world, which is in part caused by underutilisation of mineral fertilisers, due to their high cost. On average, Africa consumes 44 kg of fertiliser per hectare of arable land, compared to a global average of 130 kg.[3] While South Africa sees per capita levels of fertiliser use that are closer to those of advanced economies, the levels in North Africa are around 50% lower than the average across those countries. Elsewhere on the continent, per capita use of fertilisers is around 15% of that in advanced economies. As Africa's population grows and agricultural productivity increases, so too will demand for mineral nitrogen and other fertilisers.

Africa has many of the enabling factors required to develop supply chains for low-emissions ammonia production, and high potential for low-cost renewable energy generation, in particular. Countries in North Africa, such as Algeria, Libya, Egypt and Morocco, have some of the highest solar and wind potential in the world and have already seen some development in their renewable energy production. Combined, these countries have an estimated renewable energy potential of more than 20 000 TWh.

Ammonia production in Africa is already significant, at around 9 Mt of ammonia and 7 Mt of nitrogen fertilisers (both in nitrogen content 'N' terms) per year. Egypt, Algeria and Nigeria account for more than 90% of the continent's ammonia production. These countries are therefore well-placed to benefit from their existing skilled workforce in the sector.

[3] Values from World Bank World Development Indicators (2022).

Fertiliser demand and ammonia and fertiliser production in Africa and in advanced economies, 2022-2024



Note: 'N' = nutrient content, which in this case is nitrogen.
Source: IEA analysis based on data from the International Fertilizer Association.

Ammonia production involves two core steps: first, isolating hydrogen, and second, the Haber-Bosch process, in which hydrogen is reacted with nitrogen from the air to produce ammonia. Globally, almost all ammonia production relies on hydrogen from coal and natural gas feedstocks, along with the process energy required for the production process. Natural gas accounts for around 70% of the ammonia industry's total energy consumption and coal for over 25%. As a result, ammonia production is highly emissions-intensive, but there are two opportunities for emissions reduction: switching to low-emissions hydrogen for feedstock, and decarbonising process energy. Low-emissions ammonia can be produced by using renewable energy to produce hydrogen via water electrolysis and to supply process energy for the Haber-Bosch process.

The strong potential for countries in Africa to develop supply chains for low-emissions ammonia production using renewable energy has already caught the attention of the private and public sector. There are ambitions to reduce reliance on imports and strengthen local value chains, with a particular focus on the agriculture and food processing sectors. The risks of import dependency have recently been seen in Egypt, which had to halt fertiliser production due to a shortage of natural gas supplies. If these ambitions can be realised, there is an opportunity for African countries to increase low-emissions ammonia production and value added in the economy at the same time as creating skilled jobs.

Investment pipeline and government policy supporting low-emissions hydrogen and ammonia production in Africa

Country	Project	Focus	Output
Investments			
Morocco	Green Investment Programme, OCP (2023)	Renewable ammonia production plants	1 Mt of ammonia production by 2027 and up to 3 Mt in 2032
Namibia	Hyphen Hydrogen Energy Project, Hyphen (2025)	Low-emissions hydrogen development	2.4 Mt of annual ammonia production by 2030
Government policies/initiatives			
Tunisia	National strategy for the development of green hydrogen and its derivatives in Tunisia, Ministry of Industry, Energy and Mines, Tunisia (2024)	Making Tunisia a sustainable, carbon neutral and inclusive low-emissions hydrogen economy by 2050	3 Mt of low-emissions hydrogen production by 2050
Kenya	Green Hydrogen Strategy and Roadmap for Kenya, Ministry of Energy and Petroleum of Kenya (2023)	Developing a low-emissions fertiliser industry	300-400 kt of nitrogen fertiliser production by 2032
South Africa	Green Hydrogen Commercialisation Strategy for South Africa, Industrial Development Corporation (2023)	Development of a low-emissions hydrogen economy	Securing long-term global market share of green hydrogen production
Namibia	Green Hydrogen and Derivatives Strategy, Ministry of Mines and Energy, Namibia (2022)	Develop a low-emissions hydrogen industry	Production of 10-12 Mt hydrogen equivalent annually by 2050
Algeria	National Strategy for the Development of Hydrogen in Algeria, Ministry of Energy, Mines and Renewable Energy, Algeria (2023)	Develop a low-emissions hydrogen industry	Supply Europe with 10% of its low-emissions hydrogen needs by 2040

Tapping into the opportunities for low-emissions ammonia production – trends in the High Potential Case

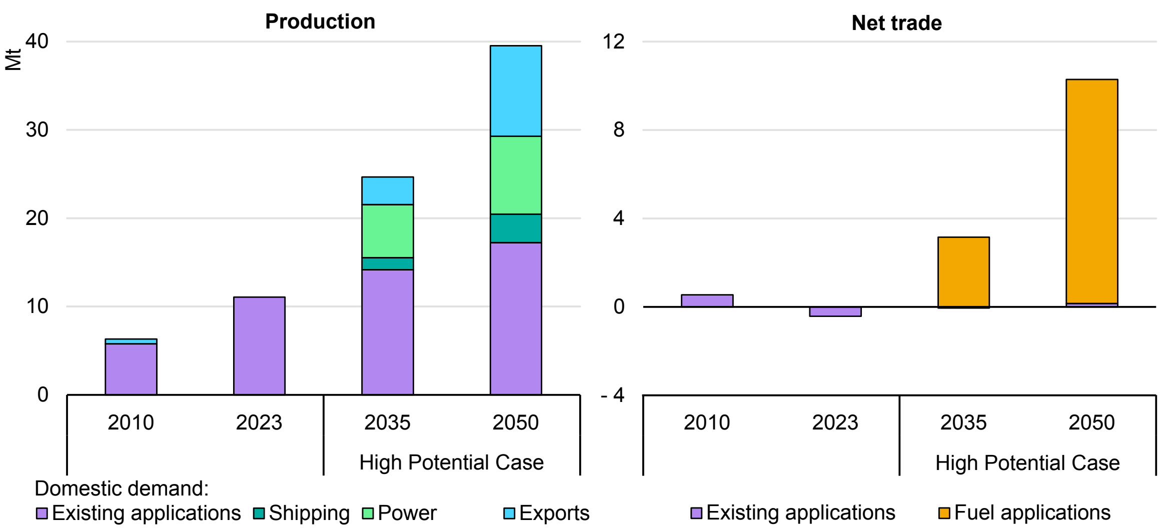
In the STEPS, global ammonia production grows from almost 190 Mt in 2023 to around 280 Mt in 2050, with Africa's share remaining stable at around 6%. Most of this production continues to rely on fossil fuels, with around 20% classified as low-emissions ammonia. In this scenario, it remains difficult for Africa to leverage its comparative advantages to produce cost-competitive low-emissions ammonia.

In the HPC, ammonia production in Africa would reach 25 Mt in 2035 and almost 40 Mt in 2050, driven by an increase in capacity for low-emissions ammonia production. By 2050, low-emissions ammonia production would constitute almost 90% of production, at 35 Mt. In the HPC in 2050, Africa is self-sufficient and does not need to import any ammonia for fertiliser production.

A sizeable share of production would be exported, with demand for low-emissions ammonia from Africa concentrated in Europe, where it would be used for fuel applications for decarbonisation purposes in the HPC. Europe's reliance on imports stems from the region having high ammonia production costs in the HPC. By importing cost-competitive ammonia for fuel applications – while leveraging existing infrastructure, expertise and high transport volumes – Europe's shipping industry would remain competitive throughout the energy transition.

In the HPC, ammonia production in Africa would become more geographically dispersed by 2050. While North Africa would remain the leading producer, its share would fall from 80% today to 50%. South Africa would increase its share to 25%, with a growing focus on power generation. Meanwhile, countries in West and southern Africa would begin to leverage their abundant renewable resources to produce ammonia for export, particularly for use in international shipping. At today's ammonia prices in Europe, the value of Africa's exports to Europe in 2050 would be worth nearly USD 5 billion, stimulating industrial development and creating thousands of skilled jobs across the continent.

Ammonia production and net trade in Africa, historical and in a High Potential Case, 2010-2050



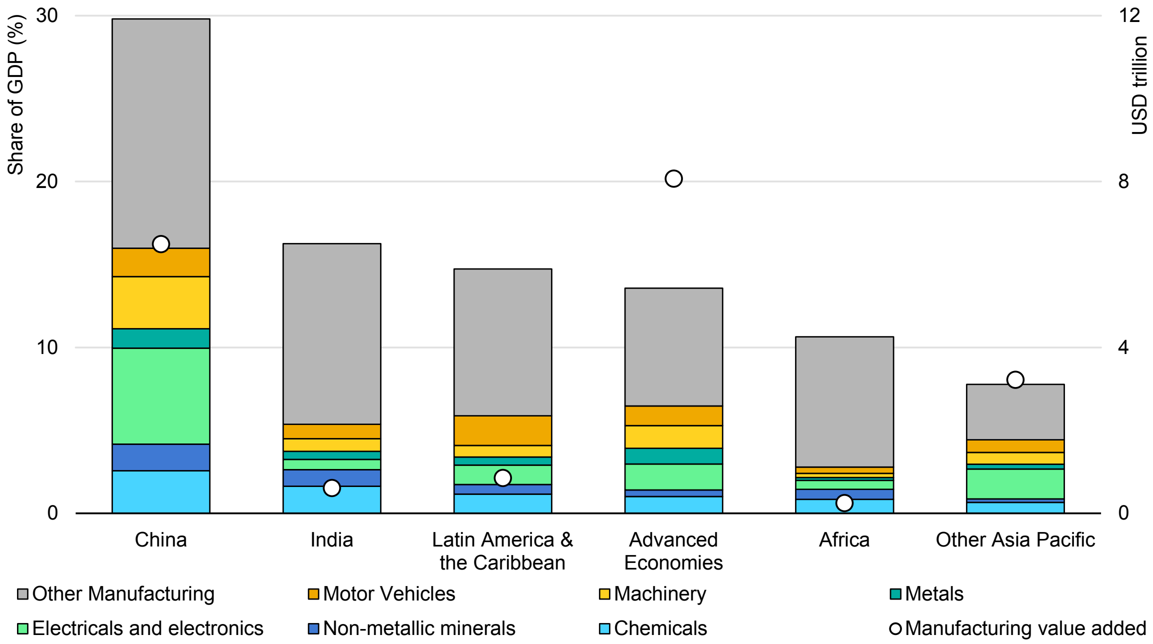
Clean energy technology manufacturing

Clean energy technology manufacturing in Africa today

Africa's share of the global market for key clean energy technologies – solar PV, wind, EVs, batteries, electrolysers and heat pumps – is currently very small, with the continent accounting for less than 0.5% in 2023. Moreover, Africa accounted for less than 0.1% of the value generated by manufacturing these technologies in 2023, meaning that the continent is not reaping the significant economic benefits of this growing sector, nor the opportunities for job creation. However, Africa's growing domestic demand for these technologies, proximity to major international markets, low production costs and existing industrial bases all point to potential opportunities.

At the global level, manufacturing (overall) contributes almost 20% of value added, which is roughly equivalent to USD 19 trillion. Africa contributed just over 1% to global value added by manufacturing in 2023, while it accounted for nearly one-fifth of the world's population. Africa's manufacturing sector has grown more than one-and-a-half times in the past two decades, but its share in the economy has largely remained stable.

Sectoral composition of manufacturing value added as a share of GDP across key regions, 2023

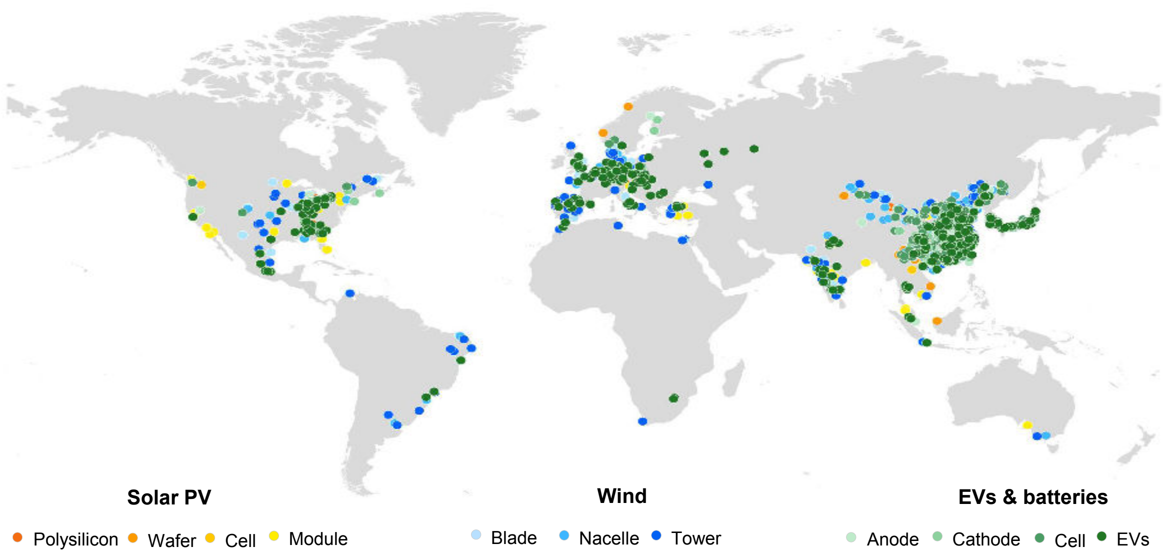


Note: Industry names refer to manufacturing industries under the NACE Rev. 2 classification.
Source: IEA analysis based on Oxford Economics Global Industry Service.

Africa's share of global clean energy technology manufacturing is currently negligible, but the presence of adjacent industries serves as a strong indicator of the potential for expansion. Five manufacturing sub-sectors closely related to clean technology manufacturing – chemicals, electricals and electronics, metals, machinery and motor vehicles – together account for more than 30% of manufacturing sector value-added in Africa. There is a great deal of variation in this aggregate contribution to the manufacturing sector across countries, from as much as 42% in more industrialised countries such as Tunisia, to far lower shares in other countries such as Angola at 8%.

Currently, there are only a handful of clean energy technology manufacturing facilities across the whole continent. In 2023, where were five operating wind tower production facilities spanning across Egypt, Tunisia, South Africa and Morocco. In the car manufacturing industry, there were five facilities capable of producing EVs already in operation across Morocco and South Africa.

Clean technology manufacturing facilities in operation, 2023

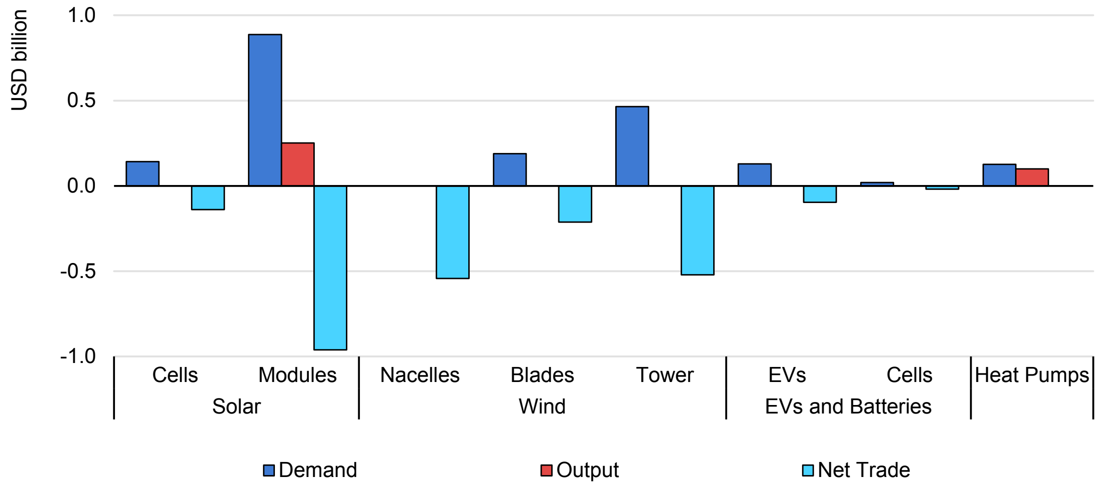


As a result, production to date been limited to relatively small outputs of solar modules (1.4 GW), wind towers (3 GW) and car manufacturing including EVs (1 million units).[4] Domestic demand for the six technologies considered here is nearly seven times larger than current production levels, creating a significant reliance on imports, of which nearly 90% are sourced from Europe and China. Imports are concentrated around the downstream parts of the supply chain, closer to the consumer, as a result of the current absence of capacity to produce these

[4] The 1 million figure refers to total car manufacturing capacity as opposed to that for EVs specifically.

components. The lack of manufacturing capacity for downstream components also means there is virtually no domestic demand for – and therefore no imports of – the upstream components (e.g. electrodes for batteries or polysilicon for solar PV) that are used as inputs.

Manufacturing output, demand and net trade for selected clean energy technologies in Africa, 2023



Notes: The difference between net trade and output, and demand reflects inventory changes. In the case of solar PV modules the positive inventory change is driven by excess output globally in 2023.

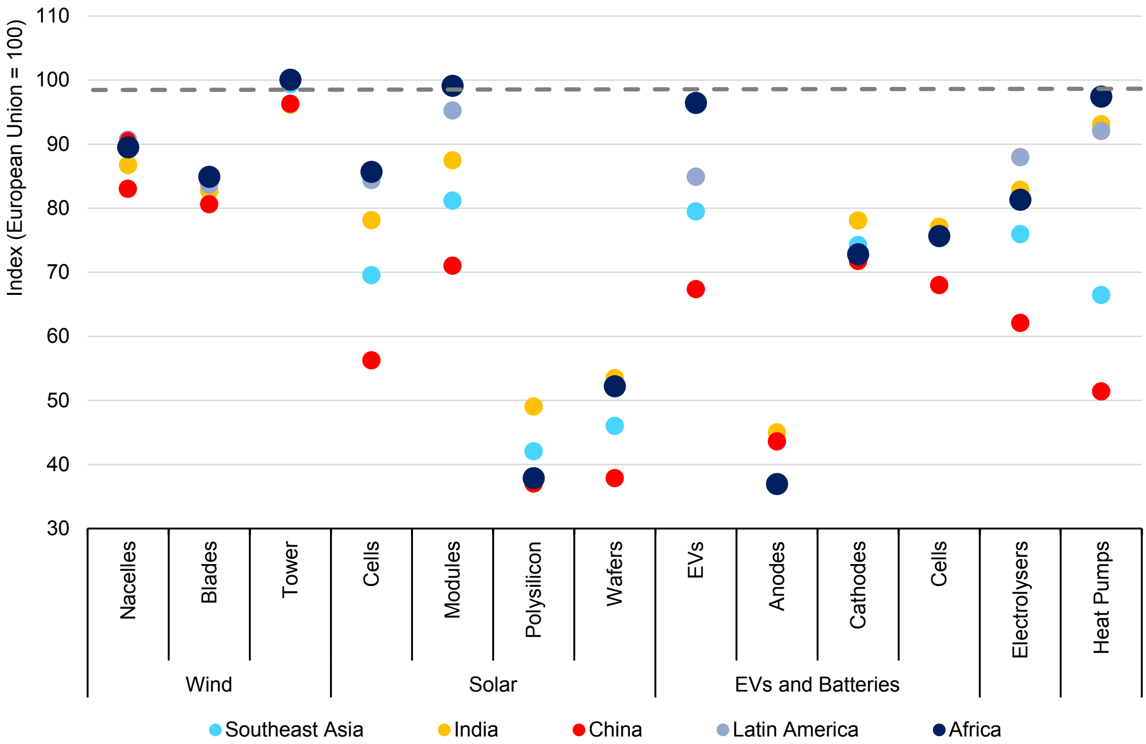
Domestic demand, electricity access and export markets

The gap between domestic demand and supply presents a market opportunity that could attract investment in manufacturing capacity, especially given the prospects for domestic demand growth in the future. Future demand growth for clean energy technologies depends strongly on the policies that are put in place, but the underlying potential in Africa is high, because of the relatively low starting point for many countries on the continent.

The average rate of car ownership in Africa is around 3 vehicles per 100 people, compared to a global average of 16, and nearly 50 in advanced economies. Average electricity consumption on the continent is around 500 kWh per person per year compared to more than 7 000 kWh per person per year on average in advanced economies. While the heating market has much lower growth potential due to higher-than-average temperatures in most African countries, the market for air conditioners – a technology closely related to heat pumps in terms of manufacturing – is currently nascent. Less than 10% of households have air conditioners in Africa compared to about 20% in India or 90% the United States and Japan.

Some clean energy technologies – particularly solar PV and wind – can also help African countries make progress towards the goal of universal electricity access. An estimated 750 million people globally lack access to electricity in 2024, with four out of five of them residing in sub-Saharan African countries. Clean energy technologies can enable electricity access directly (e.g. via solar home systems), but also via the grid, alongside fossil fuels like natural gas and other electricity generation technologies. Solar home systems accounted for just under 10% of the population with access to electricity in sub-Saharan Africa in 2023, with the annual number of new connections via these systems rising from 1.4 million in 2019 to 2.2 million in 2023. Solar PV and wind installations are also playing an increasingly important role in electricity access via the grid: these two technologies accounted for 11% of electricity generation capacity in 2023, up from 5% in 2019. Since half of the population in sub-Saharan Africa (around 600 million people) still lacks access to electricity, there is significant potential for demand growth in this segment.

Theoretical cost of manufacturing clean energy technologies and components in selected regions and countries, relative to the European Union, 2023



Beyond satisfying its growing domestic demand, Africa's proximity to other clean energy technology markets, such as Europe, could open up export opportunities. For export markets, competitiveness on production cost is particularly important.

Africa is currently among the cheapest places to produce technologies including EVs and wind nacelles and blades. Importantly, it can compete with the European Union – one of its key import partners – on production costs for these technologies. Compared to the European Union, Africa is around 10% cheaper for the production of wind nacelles, 15% cheaper for blades, and 4% cheaper for EVs,[5] largely due to the lower costs of labour and energy. Production costs are set to fall even further as component costs decline, especially for EVs and batteries.

While market demand and cost-competitiveness are key drivers of investment in manufacturing, a supportive policy environment can be fundamental to attracting investors. This can take many forms, including direct financial incentives for production and trade policy settings. There has been a recent uptick in the adoption of industrial policies across various countries in Africa, which demonstrates a growing recognition that industrialisation is essential for driving economic development. The emphasis on clean technology manufacturing in these policies also speaks to its potential to address other policy priorities, such as emissions reduction targets or energy access. Industrial policies in Africa operate at various levels – subnational, national, regional and continental.

Selected industrial and trade policies relevant to clean energy technology and materials manufacturing in Africa

Country	Policy	Description
Key industrial policies and measures to reduce production costs		
Morocco	Industrial action plan (PAI) (2014)	Aims to boost industrial output, diversify exports, create jobs and increase the industrial sector's share of GDP. Supports these goals through policy tools like the development of Integrated Industrial Zones and Free Zones, which offer infrastructure, land and fiscal incentives to attract investment and drive industrial growth.
Morocco	Investment charter (2022)	A national framework to attract and scale private investment across all sectors. The Charter complements the PAI by providing a nationwide incentive system, clearly defined investment support mechanisms and institutional reforms that enhance transparency, efficiency and regional equity.
South Africa	Industrial Policy Action Plan (IPAP) (2007)	A rolling multi-year plan to build domestic value chains and support manufacturing competitiveness. The Special Economic Zones (SEZs) Act (2014) complements IPAP by offering reduced corporate tax (15%), customs and VAT exemptions, and government infrastructure support in designated industrial zones.

[5] This includes the levelised cost of production for Battery Electric Vehicles (BEVs) only, and not Plug-in Hybrid Electric Vehicles (PHEVs)

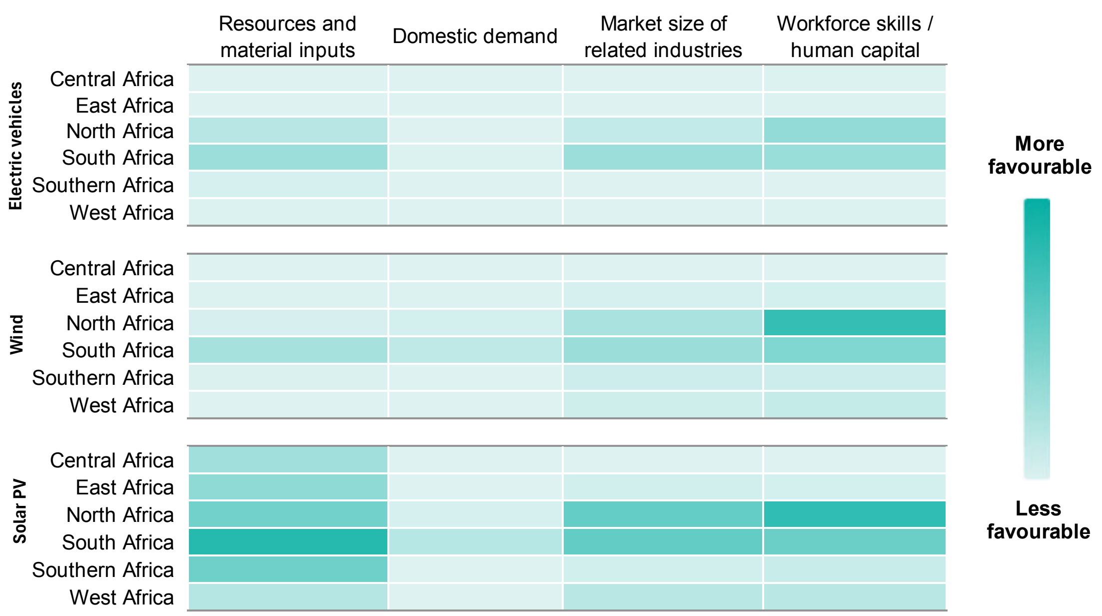
Country	Policy	Description
Key industrial policies and measures to reduce production costs (continued)		
Ghana	One District One Factory (1D1F) & Ghana Investment Promotion Centre (GIPC) Act (2017)	Promotes decentralised industrialisation by establishing a factory in each district. It offers access to land, infrastructure, and concessional loans, while the GIPC Act provides tax holidays for strategic sectors.
Trade policy measures		
African Union member states that have ratified the AfCFTA Agreement	African Continental Free Trade Area (AfCFTA) Clean Tech Rules	Aims to reduce tariffs and harmonise trade rules to boost intra-African trade and regional industrialisation, including in clean energy technologies. Member states have committed to gradually eliminating tariffs on 90% of goods, enabling more competitive trade in products like solar panels, EVs and batteries. Flexible, product-specific Rules of Origin are key to ensuring these goods qualify for tariff-free trade while supporting local manufacturing.
Morocco	FTAs & Export Zones	Morocco aims to position itself as a strategic hub for EV and battery manufacturing by making use of Free Trade Agreements with the European Union and United States, enabling duty-free access to major markets. Industrial Acceleration Zones offer tax and customs incentives, attracting global firms.
South Africa	EV/Battery Tariff Reform	South Africa is advancing its EV and battery manufacturing sector through targeted reforms, including a 150% tax deduction for qualifying EV and hydrogen vehicle investments. The updated Automotive Production and Development Programme (APDP) offers customs duty rebates via the Production Rebate Certificate, tied to local value-added thresholds.
Ghana	Duty-Free Solar/Battery Imports	Ghana supports domestic manufacturing by offering import-duty and VAT exemptions on solar panels, batteries and renewable energy equipment under the Renewable Energy Act. These incentives, extended through the National Energy Fund and Renewable Energy Master Plan, apply to solar home systems, mini-grid components, and machinery used in assembly, especially for firms registered with the GIPC.

Local mineral resources and growing manufacturing expertise are key enablers

For certain clean energy technology industries, such as for EVs and batteries, the availability of key resources such as critical minerals is an important enabling factor. Minerals like lithium, nickel and cobalt, which are vital for battery production, are found and mined in a limited number of countries today. These raw materials are typically exported for refining and transformation into precursors for battery components. As outlined in the section on Critical minerals beneficiation earlier in this report, China is currently the major supplier of refined minerals. However, Africa's abundant mineral resources present an opportunity for African countries to develop their own refining and processing industries, which could eventually support the local manufacturing of battery components such as cathodes and anodes. Similarly, Africa's vast iron ore reserves (see Opportunities for low-emissions iron production in Africa) could support scaling up production of steel, which is a key input for wind towers and countless other products.

With regards to developing EV supply chains, interest is likely to be strongest in countries that either have large domestic markets or are close to other such markets. In the African context, Morocco is a prime example. While Morocco's domestic EV market is still emerging, it is rated favourably for ease of doing business, and its proximity to the European Union – a major and rapidly growing EV market – means the country is well-positioned to develop its supply chain. The presence of an existing internal combustion engine (ICE) vehicle industry in several African countries also provides a competitive advantage for EV manufacturing. Many components and materials, such as car bodies, chassis, electronics, steel and aluminium, are common to both ICE and electric car manufacturing, and existing assembly plants can often be repurposed.

Current status of enabling factors for clean energy technology manufacturing across Africa



With regards to batteries, Tunisia stands out due to its strength in related industries, with a notable share of its manufacturing activities (around 20%) derived from the electricals sector This could serve as a foundation for scaling up battery manufacturing. Egypt, which has relatively low electricity prices, also presents an attractive environment for investment in the battery sector. Morocco benefits from a favourable business climate and rich phosphate resources, which are important for certain battery technologies.

African countries with existing industrial bases in the chemical industry are also well-positioned to lead production of polysilicon and wafers for solar PV in Africa. Co-locating facilities for these components with existing chemical, semiconductor and high-tech industries could reduce costs, and would mean infrastructure can be shared. Polysilicon production, in particular, is a complex process based on heavy industrial chemical processes, meaning that countries with an established industrial capacity and skilled workforce in the chemical sector are at an advantage.

Despite these opportunities, many African countries face challenges such as less favourable business environments and comparatively small domestic markets for technologies such as EVs. Some countries, such as South Africa and Egypt, possess relatively strong energy and transport infrastructure, which gives them an advantage over many others in the region.

The importance of clusters and network effects for clean technology manufacturing

A strong foundation in related manufacturing sectors can provide a strategic advantage when investing in clean technologies. Businesses often choose to locate operations where there is strong market demand or where established industries offer a supportive ecosystem that can boost confidence for new entrants. Policy design increasingly emphasises that countries seeking to develop their clean energy technology manufacturing sectors do not need to build industrial capacity from scratch. Instead, they can transform existing factories and skilled labour pools into manufacturing hubs through targeted investments, innovation partnerships and supportive policies. There are two main strategies for leveraging existing industries to unlock clean energy technology opportunities:

- **Pivoting within the same industry.** Countries can transition from producing traditional to low-emissions technologies within the same sector by utilising existing capabilities, market networks, and industrial expertise. This approach allows for a relatively short step to the production of low-emissions goods, maintaining high-productivity jobs. For example, countries like Morocco and South Africa, with established ICE vehicle manufacturing or assembly hubs, are well-placed to transition to EV production. This can be achieved by upgrading workforce skills and retrofitting plants. They may also be able to tap into strong renewable resources to integrate renewable energy systems. Experience with similar technologies can significantly reduce the time and cost required to train workers for clean energy manufacturing. Often, the companies producing ICE vehicles also manufacture EVs, enabling a smoother transition.

- **Integrating and consolidating supply chains.** Another strategy involves leveraging existing supply chains that provide key inputs for clean technologies and expanding into downstream user industries to form industrial clusters. This model has already proven successful in several clean energy technology growth regions, such as in China, and even more so in Korea, where the strengths of the electronics industry have provided a basis for expanding into clean energy technology production. Similarly, the chemical industry, which supplies a wide range of inputs for clean technologies, plays a vital economic role in countries including China, Korea, Japan, India and Germany. This strategy also includes moving up the value chain from producing low-value inputs to engaging in higher value activities. Africa, with its abundant critical minerals and growing manufacturing expertise, is well-positioned to develop battery value chains, solar component assembly, and wind turbine parts. Achieving this potential will require co-ordinated public-private efforts, strategic financing, and robust skills development.

Opportunities for EV and battery production in Africa

At the global level, a mix of energy and industrial policies, as well as the increasing affordability of electric cars and their batteries, are fuelling a strong increase in demand. As EV and battery industries continue their growth, Africa benefits from several opportunities that could position it as a global player.

As noted above, Africa has vast reserves of critical minerals, many of which are essential for EV batteries, such as lithium, cobalt, manganese and graphite. Africa possesses over 50% of the world's cobalt, and 40% of manganese reserves. Extraction of these minerals is expected to grow substantially in the coming years, particularly for cobalt, led by the Democratic Republic of the Congo (DRC) and Zambia. Revenues from copper and key battery metals already exceed USD 20 billion annually, and based on projects currently in the pipeline, the market value could increase 65% by 2030. Africa is also a major player in phosphate production and holds 80% of global reserves, with Morocco ranking as the world's second-largest producer. Phosphates are a key input in lithium iron phosphate (LFP) batteries, which have seen rapid adoption and now power nearly half of all electric cars sold globally – up from less than 10% in 2020.

Morocco, in particular, is attracting interest from investors in EV and battery manufacturing, due to its geographical proximity to the large EU market, low labour costs, and potential access to low-cost renewable electricity with its abundant solar resources. Morocco also benefits from free trade agreements with more than 60 countries, which could open the door to exports of EVs and batteries, including to the European Union and United States (where EVs manufactured with minerals from Morocco remain eligible for tax rebates). In 2023, Morocco's automotive exports, largely to the European Union, overtook those of the phosphate mining sector in monetary value. The country's phosphate resources are proving to be a draw for overseas battery-related companies, with investments to establish LFP battery manufacturing facilities reaching USD 15.3 billion in 2022 – equal to that of the previous 5 years combined.

Tunisia also benefits from experience in manufacturing automotive supplies, with more than 260 automotive component companies, accounting for about 90 000 direct jobs. The Tunisian government recently introduced policy support to kickstart the local EV market, with purchase incentives of up to USD 3 200 per car. The country also benefits from phosphate resources suited to the production of LFP batteries.

The Egyptian automotive industry, with an annual production capacity of more than 200 000 vehicles, is starting to attract Chinese investment in EV manufacturing. The emergence of a wide network of battery and battery components suppliers in Egypt is helping to build a skilled workforce, which should make it easier to scale up EV manufacturing capacity in the future.

These developments are laying the groundwork for an EV manufacturing industry on the continent, just as global demand for EVs and batteries is set to rise. The prospects for manufacturing EVs and batteries in Africa – and for trading into high-growth markets – will depend on the extent to which policy settings incentivise uptake of EVs and encourage expansion of existing industrial capacity by leveraging the continent's low production costs. Efforts towards this end are already underway through a number of national policies that aim to drive up domestic demand and investment.

In South Africa, for example, the EV Transition White Paper, Renewable Energy Independent Power Producer Procurement Programme (REIPPPP), and the 2024 Public Procurement Act collectively promote early EV uptake, renewable energy investment, and local manufacturing through procurement mandates. Kenya's procurement laws and Access to Government Procurement Opportunities (AGPO) programme support local assembly of clean energy technologies, especially for EV fleets. Rwanda's E-Mobility Policy offers tax incentives to boost EV adoption, and both Tunisia and Egypt have introduced incentives for foreign investors in EV manufacturing, as well as to spark demand for EVs.

In reflection of expected EV demand growth globally, and Africa's enabling factors such as resource availability, industrial capabilities and infrastructure, there has already been wave of announcements aimed at expanding EV and battery production across Africa.

Selected investments and project announcements for EVs and batteries

Company and project location	Estimated capacity & focus	Status / Timeline
EV production		
Stellantis Kenitra Plant (Morocco)	Scaling up to 400 000 vehicles per year, with 50 000 EVs per year by 2030 (Citroën Ami, Opel Rocks-e)	Scale-up underway; EVs in production
Renault (Morocco)	100 000 EVs by 2025; 600 000 by 2030 to support domestic targets	Active hybrid/EV production; scaling EV output
BAIC (Egypt)	20 000 EVs/yr, increasing to 50 000/yr	MoU signed Oct. 2024; production by late 2025
Battery production		
Gotion High-Tech Gigafactory (Morocco)	20 GWh initial battery production capacity; plans to scale to 100 GWh	Set to begin production Q4 2026
LG Chem + Youshan (Huayou) (Morocco)	50 000 t/yr of battery cathode materials	Mass production by 2026
BTR New Material Group (Morocco)	Large-scale cathode facility	First 25 000 t by Sept 2026
CNGR Advanced Material (Morocco)	Anode precursor component production with 60 kt capacity	Inaugurated in June 2025
Shinzoom Anode Plant (Morocco)	Anode precursor material	Announced in May 2024

Tapping into the opportunities for EV and battery manufacturing – trends in the High Potential Case

In the Stated Policies Scenario (STEPS), EV demand in Africa begins to grow over the next decade, reaching 0.2 million cars sold in 2035. The High Potential Case (HPC) would see demand grow more strongly – from just 4 000 electric car sales in 2023 to 5 million by 2035, and then almost doubling to 9 million by 2050. In 2024 alone, demand for EVs more than doubled to 9 000 units in Africa. While global demand would also increase significantly, the pace of growth in Africa would be far steeper.

Battery cell demand in Africa would follow a similar trajectory in the HPC, increasing to over 300 GWh by 2035 and exceeding 400 GWh by 2050. The slower growth in battery demand relative to EVs by 2050 reflects a growing reliance on imports to meet rising needs. Globally, EV and battery cell demand would be expected to increase fourteen-fold, driven primarily by China and Other

Asia Pacific region, with strong growth also seen in Europe and the Middle East – regions of strategic interest to Africa due to their proximity and competitive advantage. Africa's share of global EV demand would rise from less than 0.05% today to nearly 10% by 2050, with its share of battery cell demand reaching a more modest 3.5%.

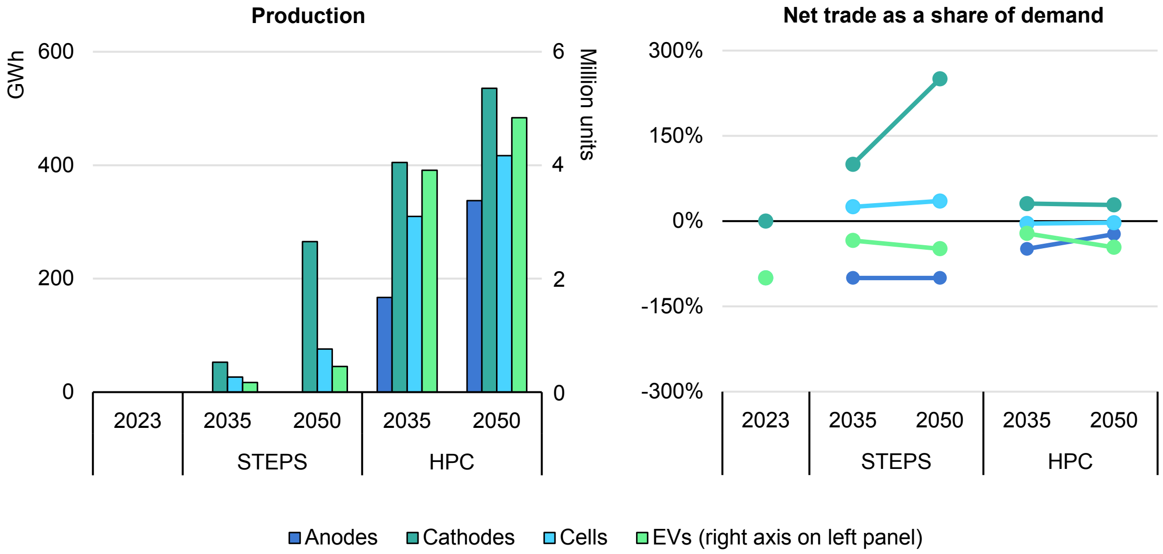
In the STEPS, EV production in Africa reaches 0.5 million units per year in 2050. Investments in battery and cathode active material manufacturing mean that the continent, and specifically North Africa, becomes a net exporter of batteries and cathode active materials, primarily to the European Union, the United States and other parts of Europe. Most of these investments come from Chinese producers, particularly in Morocco. These new manufacturing facilities will therefore benefit from the extensive technical experience that Chinese companies have acquired in low-cost manufacturing of battery cells and components.

Over the longer term, EV and battery manufacturing could become key pillars of economic development in North Africa. In the HPC, EV production would reach nearly 4 million vehicles per year by 2035, up from negligible levels today, and nearly 5 million in 2050, more than ten times the level of production in the STEPS. However, despite the projected increase in EV production, demand is expected to outpace supply, leading to continued reliance on imports, primarily from China and the Other Asia Pacific region. Import dependency is projected to decline from 70% in 2023 to 22% in 2035, before rising again to 46% by 2050 – still far below current levels.

In this case, North Africa becomes a large production centre for battery materials and cells, which are used to supply domestic EV manufacturers. North Africa also becomes a strategic supplier of batteries and cathodes for Europe, with exports meeting 4% of Europe's battery demand and nearly 17% of its cathode demand in 2050. This reflects Africa's increasing price competitiveness in cathode manufacturing. However, the continent continues to rely on imports for battery anodes, sourcing nearly half from India and other global suppliers.

To fully tap into its potential, Morocco would need to continue to attract investments from original equipment manufacturers in a broad range of countries in order to diversify its production base. The surge of investments in recent years should also create an opportunity to build a skilled local workforce, which could benefit other countries in North Africa that are well-positioned to develop EV and battery supply chains, such as Egypt and Tunisia.

Manufacturing opportunities for electric vehicles and batteries in Africa, historical and in the Stated Policies Scenario and High Potential Case, 2023-2050



Note: EVs = electric vehicles

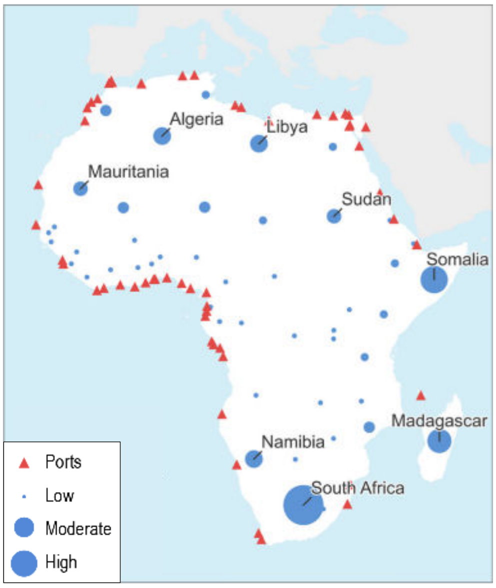
Opportunities for other clean energy technologies

As global demand for clean energy technologies grows, Africa has opportunities to tap into its potential to manufacture and export key technologies and components, such as wind turbine parts, solar PV cells and modules, and electrolysers. Key enabling conditions include its abundant natural resources, proximity to major markets and emerging industrial capabilities. Africa is well-placed to ramp up its activity in global clean energy technology supply chains.

Demand for wind energy is expected to continue to rise worldwide, including in Africa. This builds a stronger case for developing wind turbine manufacturing on the continent, particularly in countries like South Africa, which also has some of the continent's best wind resources. While the continent as a whole currently accounts for 1% of global tower manufacturing capacity (and negligible capacity in other wind components), several African countries have multiple enabling factors that could support scale-up.

Port infrastructure is particularly critical for enabling wind manufacturing that could cater for global markets. Wind turbine components, especially blades and towers, are large and heavy, making overland transport costly and logistically complex. However, several African countries already have deep-water ports capable of handling medium to large vessels that could transport large components, including Algeria, Libya, Mauritania, Morocco and Somalia. Several of these ports are located near zones with strong wind resources, particularly in North and southern Africa, and could serve both domestic deployment and exports to Europe and beyond. South Africa's ports, such as Cape Town and Durban, are already integrated into global shipping networks and could support regional manufacturing and distribution. The availability of low-cost raw materials in South Africa – thanks to its large iron ore reserves – could also make manufacturing of towers and other components cost-competitive.

Existing port infrastructure and wind resources in Africa



Notes: The circles represent the level of wind resources. Triangles indicate ports from the World Port Index Maritime Safety Office with a cargo depth of over 11 metres (category J) and where the maximum vessel size is medium or larger (category M or L). This document, as well as any data and map included herein, are without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area.
Source: Reproduced from IEA (2024), Energy Technology Perspectives 2024.

With regards to solar PV manufacturing, Africa's potential is anchored in its abundant solar resources and growing interest in domestic module assembly. While the continent currently plays a limited role in upstream manufacturing of components such as polysilicon and wafers, there are early signs of progress. Nigeria, for instance, has begun developing a vertically integrated solar manufacturing facility. Countries like Algeria, Angola, Ethiopia and Nigeria benefit from relatively low industrial electricity prices, which is a critical factor for energy-intensive processes like polysilicon production. Moreover, 24 African countries have grid carbon intensities below the global average, which could become a competitive advantage as global buyers increasingly consider the carbon footprint of solar components. Morocco, with its strong base in chemicals and electronics, is also well-positioned to co-locate solar PV and related manufacturing. Electrolyser manufacturing in Africa is still nascent but holds promise due to the continent's vast renewable energy potential and growing interest in low-emissions hydrogen.

As a reflection of the expected growth in demand, a range of projects have been announced in different African countries.

Selected project announcements for clean energy technology and component manufacturing

Company	Estimated capacity & focus	Status / Timeline
Solar		
Toyo Solar (Ethiopia)	2 GW solar cell and panel factory, set to double to 4 GW	To begin operating in 2025
Oando Clean Energy / DARES (Nigeria)	1.2 GW solar module assembly + recycling (Phase I: 600 MW)	Launch expected by 2026
Seraphim Solar (South Africa)	500 MW solar module + 200 MW panel expansion	Operational since 2019
CMG Cleantech JV (North Africa)	Joint venture for solar cell manufacturing	Announced in 2023
Wind		
Aeolon Technology (Morocco)	Up to 600 wind turbine blades per year, supporting approximately 3 900 MW of onshore wind capacity	Construction began in late 2023, operations expected to start by 2025
Electrolysers		
sub-Saharan Electrolyser Pipeline (Mauritania, Namibia, South Africa)	70 GW total electrolyser capacity across pipeline Africa)	Highly tentative; only 13 MW reached final investment decision

Tapping into the opportunities for clean technology manufacturing – trends in the High Potential Case

Africa's domestic demand for wind components is projected to grow from just over 1 GW in 2023 to 4 GW by 2035 in the STEPS, before plateauing to 2050. In contrast, in the High Potential Case (HPC), demand would more than triple in both 2035 and 2050 compared to in the STEPS. Despite this growth, Africa's share of global wind component demand would remain modest, but would nonetheless rise from 1% today to less than 5% by 2050. Demand growth globally would be led by Southeast Asia, followed by more evenly distributed growth across North America, Europe, the Middle East and China.

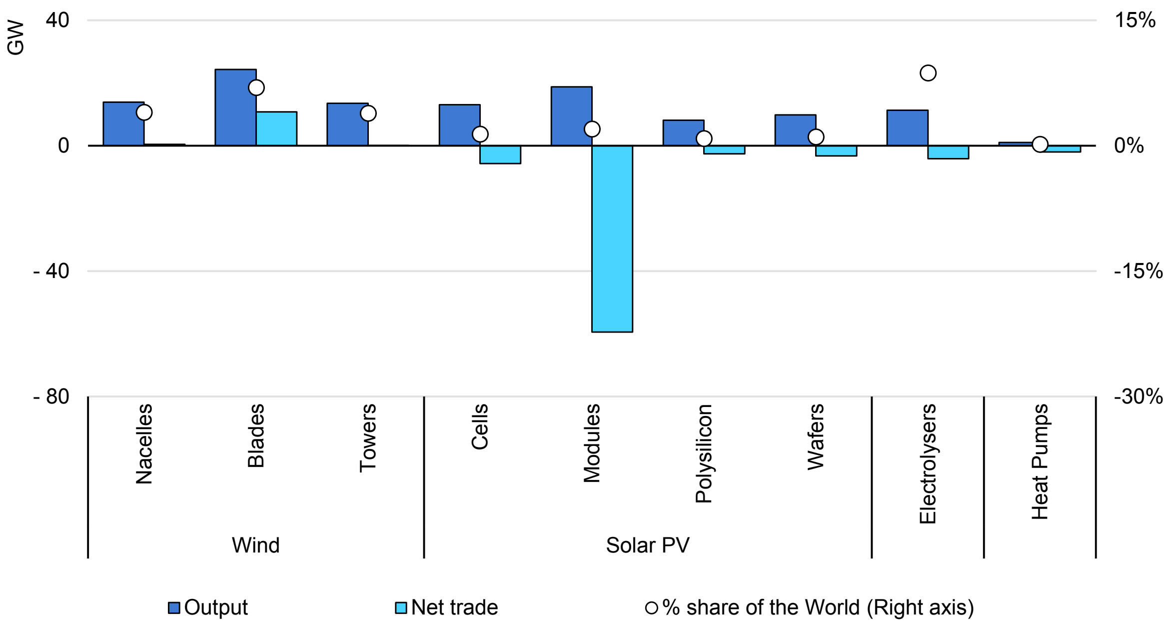
In the solar PV sector, Africa's demand increases more significantly for downstream components, particularly modules and cells, while remaining low for upstream components like polysilicon and wafers. In the STEPS, demand for modules grows threefold by 2050 to 15 GW. This growth is more pronounced in the HPC, rising to nearly 85 GW by 2035 before slightly declining to around 80 GW by 2050. Similarly, demand for solar cells would increase sixfold by 2050 in the

STEPS, whereas in the HPC it would surge 21-fold by 2035 to reach nearly 30 GW before moderating to 20 GW by 2050. As with wind, Africa's share of global solar component demand would rise to around 2% for cells and 8% for modules, starting from a similarly low base.

Demand for electrolysers in Africa starts from a negligible base but grows steadily, reaching 2 GW by 2050 in the STEPS. In the HPC, demand would expand more rapidly, reaching around 10 GW in 2035 and 13 GW in 2050. Africa's share of global electrolyser demand rises to 4% in 2035 and 9% in 2050 in the STEPS, and to 10% in 2050 in the HPC.

In the STEPS, Africa has virtually no domestic production of solar components, resulting in full reliance on imports to meet cell demand and nearly half of all module demand by 2050. In contrast, in the HPC, domestic manufacturing capacity would more than double, enabling Africa to meet around 80% of its polysilicon and wafer demand, 70% of its cell demand, and 30% of its module demand by 2050. The higher import dependence for downstream components reflects the faster growth in demand for these products, which outpaces the ability of local production to scale up at the same rate.

Manufacturing of selected key clean energy technologies and components in Africa in the High Potential Case, 2050



Similarly, in the STEPS, Africa expands its wind energy manufacturing capacity to 3 GW of blades and 6 GW of towers by 2050, largely to meet rising domestic demand. However, over half of demand for blades continues to be met through imports. In the HPC, Africa would capture 4% of global wind nacelles and tower production, and 7% of blade production, and export around 45% of its blade production, primarily to nearby markets like the European Union. While EU manufacturers would remain competitive, North African producers would be well-positioned to supply part of the region's demand. Additionally, Africa would significantly reduce its reliance on imports for nacelles (down to 20%) and achieves full self-sufficiency in tower production.

Electrolyser production in the HPC would reach approximately 10 GW by 2050, with this capacity largely retained for domestic use to support Africa's growing hydrogen sector. By that year, Africa would account for almost 10% of global electrolyser production, reflecting its rising role in the global low-emissions hydrogen economy.

Considerations for industrial strategies

This report has outlined three key areas of sustainable industrialisation opportunities for African countries. These examples are not intended to be prescriptive, but rather instructive as to the scale of opportunity that can be realised and the enabling conditions that would need to be put in place in order to successfully capitalise on those opportunities.

Exactly which opportunities are pursued, and how, is a matter for industrial strategy, the priorities of which are the prerogative of individual governments. To conclude this report, this section presents a series of considerations for governments designing their industrial strategies, divided across two main areas: The first concerns measures that can be taken domestically, whereas the second pertains to measures that will benefit most from international collaboration among G20 members and beyond.

Domestic actions to advance clean technology manufacturing

Strengthen the domestic market

Strong and consistent demand signals for clean energy technologies can help de-risk the investment required both for deployment and manufacturing. Long-term procurement commitments, infrastructure investment plans and regulatory targets are examples of measures that can be used to send these signals, steering capital towards priority sectors identified in countries' industrial strategies. International trade is also crucially important for the proper functioning of today's clean energy technology supply chains. The traded value of key clean energy technologies and their main components amounts to around one-third of their combined market value. Political and economic unions among African nations, notably the African Union and the Economic Community of West African States and initiatives like the African Continental Free Trade Area have a potentially important role to play in facilitating international trade in clean energy technologies and their key inputs.

Prioritise and play to strengths

Governments cannot prioritise everything at once, and industrial strategy must be mindful of the near-term opportunities and existing industrial strengths and weaknesses. For most countries, it is simply not realistic to effectively compete in all supply chain steps, or even in parts of all clean technology supply chains. Not only would the costs of the various support measures be prohibitive for countries with higher-cost production or no legacy of leadership in these sectors, but many individual economies are likely to be too small to accommodate all the requisite investment. Understanding relative strengths and weaknesses, and where it might be better to build complementary strategic partnerships with other countries, should be key considerations of industrial strategies for clean technology manufacturing.

Beyond deciding where to focus, it is also important for governments to define what they wish to achieve. Clearly articulating thresholds for success before making any financial commitments gives a government room to cease or redirect support when things do not turn out as hoped. In this domain, more so than in many other energy policy areas, precise outcomes are often highly uncertain, and unintended consequences may arise. Therefore, the ability to experiment and course-correct should be built in from the start. As industrial policy inevitably involves picking winners at a sectoral level, and often at a company level too, governments need to create the political and economic headroom to identify, monitor and manage any "losers" resulting from the policy measures. Many of the oft-cited examples of industrial policy backfiring stem from a commitment to a specific measure, firm or project without a clear means of determining or monitoring success. In such cases, precise objectives (e.g. "limit single-supplier dependencies for a given product to less than 50% of annual demand") are preferable to broadly defined ones (e.g. "improve national security").

Attract and support innovators

Hosting researchers and other innovators can have multiple benefits for a country. Chief among these is the strong link between innovation and domestic manufacturing that is at the cutting edge of technical advances, able to withstand competition from regions with low-cost inputs and able to command a premium price. Other benefits include the ability to attract highly educated workers and the spillovers that accrue from co-location of innovative firms, raising the combined and individual productivity of clustered firms more quickly. Governments can use a combination of direct and indirect measures to support clean technology manufacturing innovation. Indirect measures, which can be very effective, involve making the market for successful clean technologies larger, more differentiated or more dependable. Support for innovation – including R&D grants, tax incentives, start-up incubation, knowledge sharing and demonstration project finance – can be directed towards important challenges or high-potential domestic capabilities.

Plug cost gaps strategically and for the long term

Governments may deem it appropriate to subsidise or otherwise provide direct financial support to manufacturing operations or investments. The intention is typically to lower the costs faced by manufacturers and thereby raise their competitiveness, usually by redistributing costs from private to public balance sheets. This may well be warranted in certain circumstances, but governments have limited balance sheets, just as private sector actors do, and every subsidy comes with opportunity costs.

Aside from innovation, which is not usually a short-term option, there are some measures that can help fundamentally reduce the total cost for all stakeholders. Reducing lead times through enhanced permitting procedures reduces transaction costs, project risks and, consequently, the interest paid on monies committed during the early stages of a project. While some aspects of upskilling or reskilling workforces are costly outlays, targeted training programmes and certification schemes can increase productivity and alleviate costly skilled labour shortages.

International co-operation to support domestic investment and global progress

Collect data and track progress

It is difficult to manage what is not measured, and the current state of data availability on clean energy technology manufacturing makes accurate measurement challenging. Much of the data used in this report – and in the underlying analysis presented in Energy Technology Perspectives 2024 and the Global Critical Minerals Outlook 2024 – are initially from proprietary sources, which can have gaps in their coverage and require significant post-processing and analysis. Policy makers may often be left with two or more conflicting data points or trends.

Efforts to improve data collection can be advanced to a certain extent by national statistical offices and agencies. But to obtain effective, granular comparisons between technologies and along supply chains, governments could benefit from co-operating on data collection efforts internationally. One specific area that deserves prompt attention are the international systems for collecting production and trade data for clean technologies and their components. Internationally adopted frameworks for collecting statistics on industrial activity currently lack the detail to be able to isolate individual clean technologies and their components. Individual countries' customs authorities and other national bodies already collect data at higher levels of granularity, but often not in a harmonised manner. Tried-and-tested frameworks like the International Standard Industrial Classification of

All Economic Activities (ISIC) and Harmonized System (HS) already exist and should be adapted to incorporate sufficient detail on production activity and products, but further data on clean technology manufacturing (e.g. energy use, physical production quantities, emissions foot-printing, investments, costs, employment) should also be sought and harmonised by governments internationally.

Co-ordinate efforts across supply chains

Much attention is now paid – quite rightly – to the security of supply of critical minerals, but any supply chain is only as strong as its weakest link. Governments should co-ordinate the work they are doing at each stage in the supply chain to increase overall resilience and avoid unwanted duplication, examining remaining gaps that may lead to bottlenecks. Wherever possible, governments should co-ordinate efforts to enhance the resilience of supply chains.

This collaboration can cover many specific areas and take many forms. Sharing best practice in the appropriate fora – including the IEA's Working Party on Critical Minerals and as part of emergency preparedness exercises under its Critical Minerals Security Programme – at an appropriate level of detail is an important vehicle for collaboration. This could include domestic experience with creating favourable investment conditions at home or abroad, accelerating permitting, designing effective and efficient environmental regulation and stockpiling of input materials and components. "How-to-guides" for developing industrial strategies could be a method of disseminating such efforts and experiences among countries. Beyond sharing experience, governments can also collaborate on the ground. Efforts to reduce the costs of financing for capital-intensive components of supply chains in developing economies, by, for example, pooling investments, is an area where many hands can make for lighter work.

Identify and build strategic partnerships

Mutually beneficial strategic partnerships are a way for countries to increase resilience in areas of manufacturing supply chains where domestic production may otherwise be uncompetitive. At the same time, such partnerships can facilitate investment in African countries. An appropriate balance should be sought between export opportunities and support for in-country clean energy transitions and socio-economic development. Risks can be mitigated by developing a systematic framework for identifying and evaluating potential partnerships, rather than proceeding ad-hoc.

Annex

Regional groupings

Advanced economies: Australia, Chile, Colombia, Costa Rica, countries in the Europe grouping, Japan, Korea, New Zealand and countries in the North America grouping.

Africa: Algeria, Angola, Benin, Botswana, Cameroon, Côte d'Ivoire, Democratic Republic of the Congo, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Kingdom of Eswatini, Libya, Madagascar, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Republic of the Congo (Congo), Rwanda, Senegal, South Africa, South Sudan, Sudan, United Republic of Tanzania (Tanzania), Togo, Tunisia, Uganda, Zambia, Zimbabwe and other African countries and territories.[6]

Asia Pacific: Southeast Asia regional grouping and Australia, Bangladesh, Democratic People's Republic of Korea (North Korea), India, Japan, Korea, Mongolia, Nepal, New Zealand, Pakistan, People's Republic of China (China), Sri Lanka, Chinese Taipei, and other Asia Pacific countries and territories.[7]

Central Africa: Burundi, Chad, Cameroon, Central African Republic, Democratic Republic of the Congo (DRC), Equatorial Guinea, Gabon, Republic of the Congo (Congo), Sao Tome and Principe.

Central and South America: Argentina, Plurinational State of Bolivia (Bolivia), Bolivarian Republic of Venezuela (Venezuela), Brazil, Chile, Colombia, Costa Rica, Cuba, Curaçao, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay and other Central and South American countries and territories.[8]

China: Includes the (People's Republic of) China and Hong Kong, China.

East Africa: Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Rwanda, Seychelles, Somalia, South Sudan, Sudan, United Republic of Tanzania (Tanzania) and Uganda.

Emerging market and developing economies: All other countries not included in the advanced economies regional grouping.

[6] Individual data are not available and are estimated in aggregate for: Burkina Faso, Burundi, Cabo Verde, Central African Republic, Chad, Comoros, Djibouti, Kingdom of Eswatini, Gambia, Guinea, Guinea-Bissau, Lesotho, Liberia, Madagascar, Malawi, Mali, Mauritania, Réunion, Rwanda, São Tomé and Príncipe, Seychelles, Sierra Leone, Somalia and Uganda.
[7] Individual data are not available and are estimated in aggregate for: Afghanistan, Bhutan, Cook Islands, Fiji, French Polynesia, Kiribati, Macau (China), Maldives, New Caledonia, Palau, Papua New Guinea, Samoa, Solomon Islands, Timor Leste, Tonga and Vanuatu.
[8] Individual data are not available and are estimated in aggregate for: Anguilla, Antigua and Barbuda, Aruba, Bahamas, Barbados, Belize, Bermuda, Bonaire, British Virgin Islands, Cayman Islands, Dominica, Falkland Islands (Malvinas), French Guiana, Grenada, Guadeloupe, Guyana, Martinique, Montserrat, Saba, Saint Eustatius, Saint Kitts and Nevis, Saint Lucia, Saint Pierre and Miquelon, Saint Vincent and Grenadines, Saint Maarten, Turks and Caicos Islands.

Eurasia: Armenia, Azerbaijan, Georgia, Kazakhstan, Kyrgyzstan, the Russian Federation (Russia), Tajikistan, Turkmenistan and Uzbekistan.

Europe: European Union regional grouping and Albania, Belarus, Bosnia and Herzegovina, North Macedonia, Gibraltar, Iceland, Israel,[9] Kosovo, Montenegro, Norway, Serbia, Switzerland, Republic of Moldova, Türkiye, Ukraine and United Kingdom.

European Union: Austria, Belgium, Bulgaria, Croatia, Cyprus,[10, 11] Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain and Sweden.

Latin America: Central and South America regional grouping and Mexico.

Middle East: Bahrain, Islamic Republic of Iran (Iran), Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syrian Arab Republic (Syria), United Arab Emirates and Yemen.

North Africa: Algeria, Egypt, Libya, Morocco and Tunisia.

North America: Canada, Mexico and United States.

Southeast Asia: Brunei Darussalam, Cambodia, Indonesia, Lao People's Democratic Republic (Lao PDR), Malaysia, Myanmar, Philippines, Singapore, Thailand and Viet Nam. These countries are all members of the Association of Southeast Asian Nations (ASEAN).

Southern Africa: Angola, Botswana, Kingdom of Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Zambia and Zimbabwe.

West Africa: Benin, Burkina Faso, Cabo Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo.

[9] The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

[10] The information in this document with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the "Cyprus issue".

[11] The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this document relates to the area under the effective control of the Government of the Republic of Cyprus.

Abbreviations and acronyms

AfCFTA	African Continental Free Trade Area
AGPO	Access to Government Procurement Opportunities
APDP	Automotive Production and Development Programme
BEE	Black Economic Empowerment
CBAM	Carbon Border Adjustment Mechanism
DRC	Democratic Republic of the Congo
DRI	Direct reduced iron
ETS	Emissions Trading System
EV	Electric vehicles
GIPC	Ghana Investment Promotion Centre
HPC	High Potential Case
HS	Harmonized System
ICE	Internal combustion engine
IPAP	Industrial Policy Action Plan
ISIC	International Standard Industrial Classification of All Economic Activities
LFP	Lithium iron phosphate
LME	London metal exchange
MoU	Memorandum of understanding
NACE	Statistical Classification of Economic Activities in the European Community
NEV	New-energy vehicles
NMC	Nickel manganese cobalt
PGM	Platinum-group metals
P_2O_5	Phosphorus pentoxide
REE	Rare earth elements
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
SAAM	South African Automotive Masterplan
SEZ	Special Economic Zones
SPII	Support Programme for Industrial

Glossary

GJ	gigajoule
GW	gigawatt
GW/yr	gigawatts per year
GWh	gigawatt hour
kg	kilogramme
kt	kilotonne
ktpa	kilotonnes per annum
kWh	kilowatt hour
Mt	million tonnes
MWh	megawatt hour
t	tonne
t CO_2	tonnes of carbon dioxide
TWh	terawatt hour
USD	United States dollar

See the IEA glossary for a further explanation of many of the terms used in this report.

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