



03

Opportunities for trade integration in clean energy value chains

Nearly 40 per cent of anthropogenic GHG emissions are caused by burning fossil fuels to produce electricity (IEA, 2022b). Decarbonizing electricity generation is a critical step toward achieving net zero goals. Target 7.2 of the UN Sustainable Development Goals (SDGs) calls for a substantial increase in the share of renewable energy in the global energy mix by 2030 (UN General Assembly, 2015).

According to the International Energy Agency (IEA), renewables¹ accounted for 90 per cent of the global growth in electricity capacity in 2022 (IEA, 2023h). Global solar photovoltaic (PV) capacity increased by around 340 GW, a new annual record.

Renewable energy capacity is expected to grow by 85 per cent over the next four years, at a pace nearly two-thirds faster than that witnessed between 2015 and 2020. Renewables are on track to become the largest source of electricity generation by early 2026, at a pace vastly exceeding that predicted in all major studies (IEA, 2022e), and by 2050, renewables are projected to generate nearly 95 per cent of the global electricity supply (see Figure 3.1).

The pace of deployment of renewable energy is not consistent globally. IRENA estimates that China, the European Union and the United States accounted for 75 per cent of renewable energy capacity additions in 2022 (IRENA, 2023a). In contrast, Africa continues to account for less than 3 per cent of the world's installed renewables-based electricity generation capacity (IRENA and AfDB, 2022). This gap is particularly significant in the context of solar power generation – as reported by the IEA, 60 per cent of the world's best solar resources are in Africa, yet the continent only accounts for 1 per cent of installed solar PV capacity (IEA, 2022j).

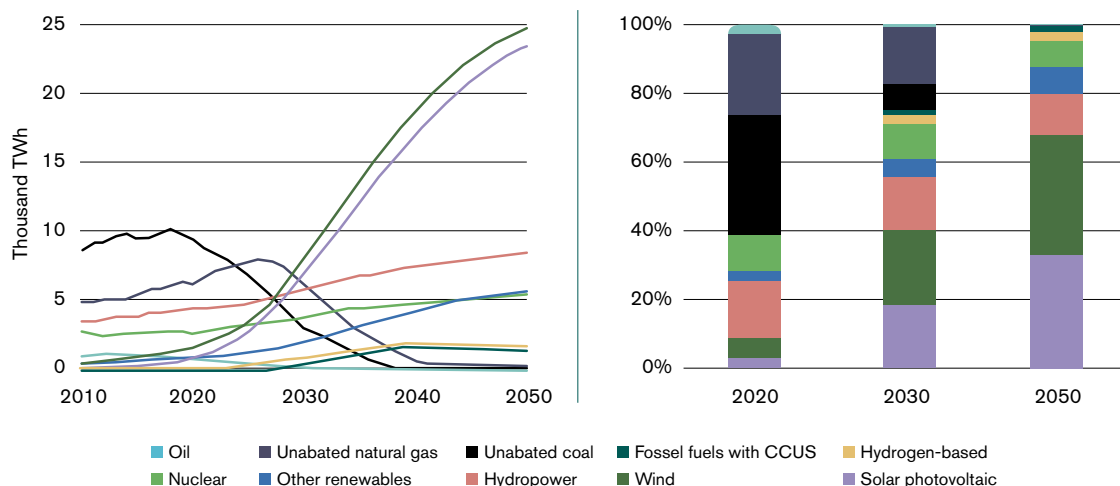
Accelerating the rate of renewable energy diffusion promises economic benefits. One study projects that a 1 per cent increase in renewable energy consumption is expected to generate 0.07 per cent, in the short run, and 1.9 per cent, in the long run, of African economic growth (Qudrat-Ullah and Nevo, 2021). A clean energy transition would help to lower energy costs, increase

energy access, stabilize energy prices, reduce import dependency, create value-added potential and generate additional employment opportunities.

Expanding domestic clean energy infrastructure can offer direct trade benefits. This was one of the key messages of the WTO's 2022 *World Trade Report* (WTO, 2022b). The report noted that international trade in renewable energy and electricity could help to compensate for an uneven geographical distribution of clean energy sources. For example, the report highlighted the potential for solar energy production in many economies in Africa, Asia, Latin America and the Middle East. By using this natural asset as a factor for comparative advantage, these economies could generate and export surplus electricity to regional and international partners in which domestic power generation creates a higher cost burden. These energy exports could take place in different forms, such as through undersea cables, pipelines or in related physical consignments (e.g., transporting hydrogen in the form of ammonia).

Achieving net zero goals will also depend on whether the production and trade of clean energy technologies and services can be expanded rapidly enough to match rising demand. This growth in demand presents new trade integration opportunities for developing economies and LDCs. Seizing these opportunities will require concerted action by developing economies, LDCs and their development finance partners. This action should explore areas beyond technology diffusion, to support the creation and engagement of these economies in clean energy markets.

Aid for Trade is helping developing economies to seize opportunities for trade integration, created in both the domestic and the international space. In particular, Aid for Trade is supporting economies in expanding their productive capacity in sectors that feed into value chains for the production and deployment of clean energy technologies. Sectors broadly fall into three “horizontal” value chain phases that are common to each clean energy technology, i.e.: i) the supply of critical minerals and metals, ii) machinery and equipment manufacturing and iii) services value chains.

FIGURE 3.1 Global electricity generation by source (2010-50)

Source: IEA (2021).

Note: "Unabated natural gas/coal" refers to the production and use of these fossil fuels without interventions that substantially reduce the amount of greenhouse gases emitted throughout the life cycle (IPCC 2023).

3.1 Supply of critical minerals and metals

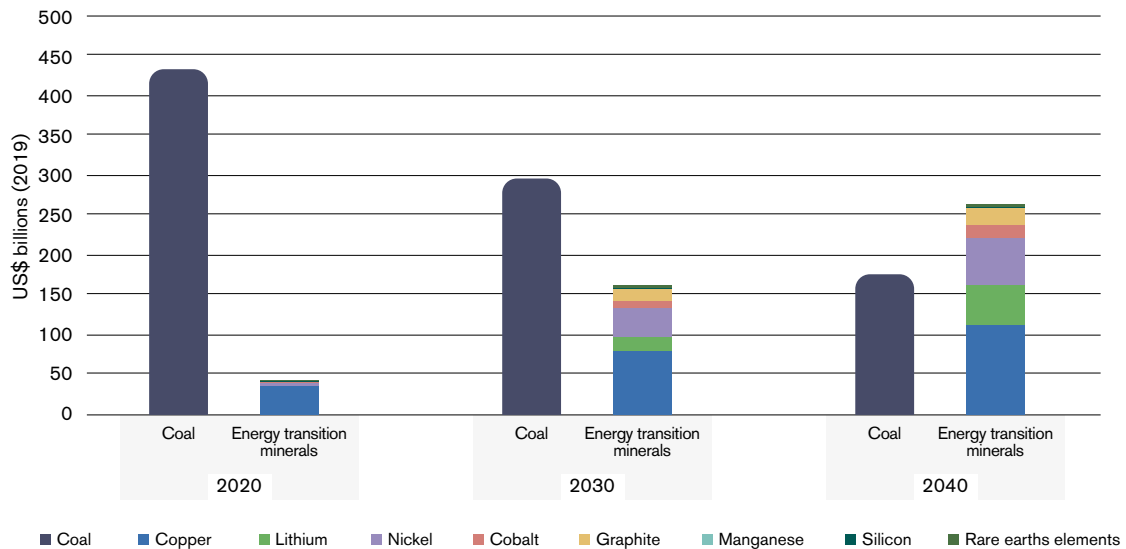
The availability of critical minerals and metals underpins a clean energy transition. The production of clean energy technologies requires larger quantities of these inputs than those necessary for fossil-fuel based power generation. The IEA estimates that the average quantity of minerals needed for power generation has risen by 50 per cent since 2010, in line with the accelerated diffusion of clean energy technologies. As a specific example, an onshore wind plant requires nine times more mineral resources than a gas-fired power plant (IEA, 2022h).

Given their critical role in the clean energy deployment, the demand for minerals and metals is expected to expand over coming decades. For example, the World Bank estimates that over 3 billion tons of minerals and metals will be needed to deploy clean energy for a net zero transition by 2050 (Hund et al., 2020). It is estimated that the aggregate demand for critical materials for

solar PV alone could expand as much as 400 per cent by 2030 (IEA, 2022f). This translates to increased revenue potential from sustainable mineral extraction. As indicated in Figure 3.2, revenues from coal production were approximately 10 times larger than those from producing minerals in clean energy technologies.

Given their critical role in the clean energy deployment, the demand for minerals and metals is expected to expand over coming decades.

FIGURE 3.2 Revenue from select minerals and coal (2020-40)



Source: IEA (2022h).

However, by 2040, the combined revenue from the mining of minerals required for the energy transition is expected to exceed that of coal.

The manufacture of clean energy equipment already accounts for a substantial proportion of global metal demand. Solar PV production accounted for 10 per cent of the global demand for silver and approximately 40 per cent of global tellurium use in 2021. Aluminium, a key metal in the solar PV manufacturing process, is also witnessing a considerable spike in demand; solar panel production will account for more than 40 per cent of the world's aluminium production by 2040 (Lennon et al., 2022). Essential minerals to produce clean energy, such as graphite, cobalt and nickel are also expected to witness accelerated demand gains. The IEA estimates that the demand for these three minerals could increase by up to 25 times within the next 20 years.

The average quantity of minerals needed for power generation has risen by 50 per cent since 2010, in line with the accelerated diffusion of clean energy technologies.

The demand for copper, an essential metal input in wind turbine production and for electrification, is also expected to increase as the scale of grid connectivity and wind energy deployment expands. Currently, onshore wind farms are estimated to use approximately 4 tons of copper per MW, while offshore installations utilize 10.5 tonnes of copper per MW (Copper Development Association Inc., 2022). The accelerated deployment of clean energy is expected to double the demand for copper by 2035, compared to 2021 estimates (see Box 3.1).

BOX 3.1 Copper and a clean energy transition

Copper is often termed the “metal of electrification”. This is due to its extremely high electrical conductivity potential, which allows for an efficient transmission of electricity over long distances. As a result, it is an important raw material in the manufacture of many electrical appliances.

Copper is a crucial input in the manufacturing of renewable energy generation technologies. It is required to produce conductive grid lines, interconnections and busbars for solar technologies. Copper is utilized in the windings of electric generators in wind turbines, enabling the conversion of wind energy into electricity. Copper also is a key component in electric vehicle manufacturing, where it is required in large quantities to produce batteries, motor windings and charging infrastructures.

Demand for copper is expected to increase rapidly as the pace of clean energy adoption accelerates. The scale of copper requirements was highlighted in a report by S&P Global (2022), according to which solar and offshore wind require two to five times more copper per MW of installed capacity than power generated using non-renewable sources. Meanwhile, electric vehicle manufacturing requires 2.5 times as much copper as an internal combustion engine vehicle. As a result, the demand for copper could nearly double to 50 million metric tons by 2035, and could reach 53 million metric tons by 2050. To put this figure in perspective, this is more than all the copper consumed in the world between 1900 and 2021.

Future spikes in copper demand require long-term strategic planning, due to the extensive lead time required to initiate mining projects. The IEA (2022h) estimates that between 2010 and 2019, it took an average of 16 years to develop projects from discovery to first production, more than 12 years to complete exploration and feasibility studies, and four to five years for the construction phase. These long lead times need to be considered if demand were to pick up rapidly and if it becomes necessary to ramp up output.

Several Aid for Trade projects have been initiated to help developing economies reduce production lead times and assess export market needs. For instance, the World Bank's Climate Smart Mining Facility provides technical assistance to accurately assess mineral endowments and construct sustainable extraction methods that help enhance export potential.

Lithium, central to the production of batteries, is another critical metal essential for a clean energy transition (see Box 3.2). Demand for lithium in clean energy production has swelled over recent decades. In a report on lithium mining, McKinsey observed that 30 per cent of the demand for lithium in 2015 was for batteries. The bulk of demand in that year was split between ceramics and glasses (35 per cent) and greases, polymers and other industrial uses (over 35 per cent) (Azevedo et al., 2022). By 2030, however, batteries are expected to account for 95 per cent of lithium demand.

Many developing economies and LDCs are favourably endowed with mineral and metal resources needed

to produce clean energy (e.g., for battery, solar PV, wind turbine and hydrogen production), which offers them opportunities to expand their export potential by catering to the expanding demand for these resources.

For instance, the Democratic Republic of the Congo (DRC) accounts for 74 per cent of global cobalt production; Chile and Peru collectively account for more than 40 per cent of all copper exports; Guinea accounts for approximately 55 per cent of all currently traded aluminium; South Africa produces and exports approximately 70 per cent of all platinum; and nickel and laterite deposits are mainly found in Indonesia, the

BOX 3.2 Minerals in battery production

Minerals are not just vital to produce clean energy. They are essential inputs for the manufacture of energy storage technology as well. International Monetary Fund (IMF) estimates indicate that a typical electric vehicle battery pack requires around 8 kilogrammes of lithium, 35 kilogrammes of nickel, 20 kilogrammes of manganese and 14 kilogrammes of cobalt (Boer, Pescatori and Stuermer 2021). IEA research also indicates that a battery-powered electric vehicle contains five times more copper (60-83kg) than a car fitted with an internal combustion engine.

Mineral requirements for battery production are expanding exponentially as demand for electric vehicles grows. The IEA (2023l) expects electric vehicle sales to increase from 30 million in 2022 to 250 million by 2030 under the Announced Pledges Scenario (APS). This can be expected to significantly increase the demand for minerals such as lithium, cobalt and nickel, which are already consumed heavily in the process. In 2022, approximately 60 per cent of lithium, 30 per cent of cobalt and 10 per cent of nickel demand was used for electric vehicle battery production (IEA, 2023m).

Increased material and production requirements for electric vehicle batteries could expand the trade potential of developing economies. Research by the Peterson Institute for International Economics notes that Argentina, Bolivia and Chile collectively hold nearly two-thirds of known lithium reserves (Leruth, Mazarei and Renneboog 2022). Increased demand for nickel will benefit economies such as Indonesia and the Philippines, which hold considerable reserves of this resource.

One example of an Aid for Trade initiative is a regional project developed by the Inter-American Development Bank for Argentina, Chile, Bolivia and Peru.² The project, initiated in 2019 and closed in 2021, seeks to construct a common development agenda for the lithium industry. This will help to help expand extraction in a coordinated and sustainable manner as to support export development opportunities.

Philippines and the Pacific region. In addition, the IEA notes that, collectively, minerals account for over 30 per cent of annual export value in 23 African economies (IEA, 2022h).

One challenge in expanding the extraction of such minerals is the environmental footprint of related operations. Another is in ensuring that the socio-economic benefits of extraction activities are maximized and well-distributed. For instance, assuring labour safety during extraction activity is a key consideration (see Box 3.3).

Developing economies can also generate benefits by integrating into value chains focused on mineral recycling, given that the demand for primary minerals

is likely to be complemented by a strong secondary market for recycled raw materials. Secondary markets are already well established for certain minerals and metals. For example, in 2018, nearly 8.7 million tonnes of copper were recycled from scrap materials, and one-third of nickel supply was sourced from recycled materials (Copper Alliance, 2022).

Many developing economies and LDCs are favourably endowed with mineral and metal resources needed to produce clean energy.

BOX 3.3 Aid for Trade in action: the World Bank's Climate-Smart Mining Facility

Launched in 2019, the World Bank's Climate-Smart Mining Facility³ aims to assist developing economies and LDCs in responding to the growing demand for minerals to manufacture clean energy technologies. By means of technical assistance and investments, the Facility supports the extraction and processing of minerals and metals used for producing solar and wind power. Resource-rich developing economies can therefore benefit from supplying the increasing mineral demand, while creating a minimal environmental and climate footprint.

The Climate-Smart Mining Facility was established as a multi-donor trust fund. Partners include Germany, the Netherlands and several private sector companies. Assistance worth US\$ 50 million is being deployed over a five-year timeframe. The Facility is assisting developing economies build robust policy, regulatory and legal frameworks that promote climate-smart mining and create an enabling environment for private capital.

Projects may include:



Supporting the integration of renewable energy into mining operations, given that the mining sector accounts for up to **11% of global energy use**



Supporting the use of geological data for a better understanding of strategic mineral endowments;



Preventing deforestation and supporting sustainable land-use practices; and



Supporting circular economy approaches to recycle minerals in a sustainable manner.

Currently, up to 70 per cent of aluminium is recycled, with rates as high as 90 per cent in some economies. Production of aluminium from recycled sources delivers a positive environmental impact, as the associated carbon footprint is approximately 5-10 per cent that of primary production (Hund et al, 2020). According to IEA estimates, by 2040 recycled copper, lithium, nickel and cobalt may account for 10 per cent of the global supply of each of these minerals (IEA, 2022h).

Economies also can add value by leveraging circular economy practices that extend mineral and metal life beyond the decommissioning stage. Operations such as material sorting and recycling can create

additional employment and offer opportunities to penetrate international secondary markets for scrap resources. A WEF (2021) study also shows that the high-quality repurposing of lithium-ion batteries can help to create livelihoods and upskilling opportunities for the populations of many low-income economies (see also Box 3.2).

How can Aid for Trade help unlock trade opportunities?

Aid for Trade can help developing economies and LDCs integrate into mineral value chains in several ways.



Aid for Trade can be disbursed with a view to enhancing the sectoral infrastructure of economies, to ensure that they have adequate capacity to partake in safe and sustainable extraction methods. The World Bank's Climate-Smart Mining Facility (see Box 3.3) is an example of this.



Aid for Trade can be used to address technological and regulatory barriers that prevent efficient mineral recycling methods.



Aid for Trade can be used to deliver targeted investment promotion that helps incentivize private sector activity.



Aid for Trade can help trade facilitation and improve the socio-economic footprint of mineral extraction by advancing supply-chain transparency and traceability protocols.

3.2 Machinery and equipment manufacturing

Value chains for solar panels, wind turbines and other clean energy equipment continue to evolve and expand to match growing demand. As a result, market opportunities are expected to increase rapidly over the coming decades. By 2050, the value of manufacturing operations for these products is expected to exceed US\$ 1 trillion (IEA, 2021f). This is comparable to the current size of the international oil market.

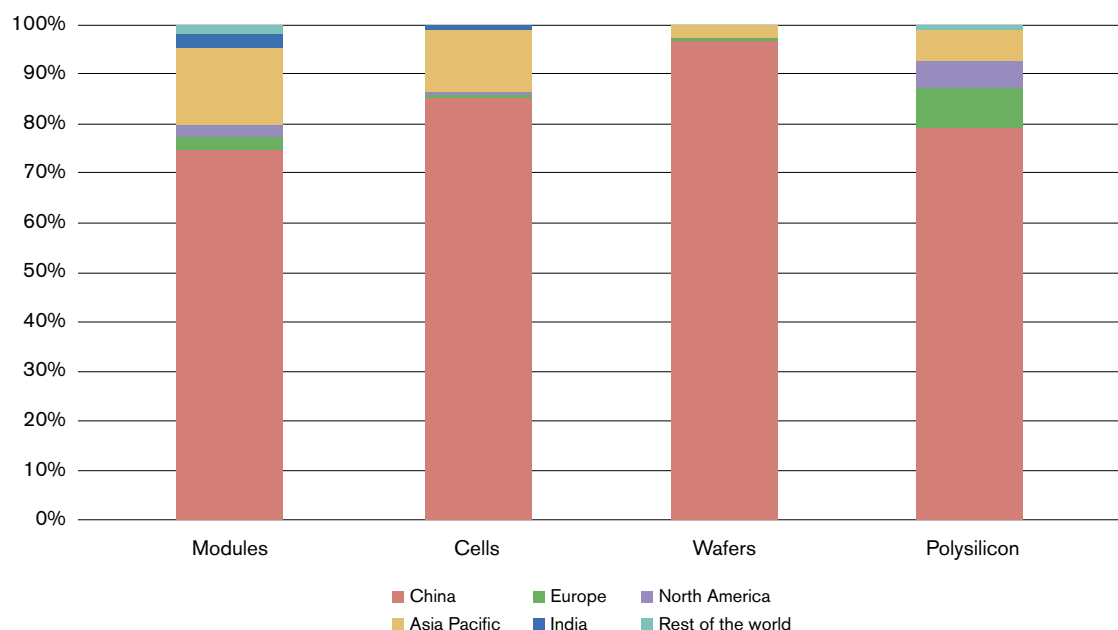
Expanding clean energy markets presents trade opportunities for developing economies and LDCs. Many possess competitive advantages that favour their participation in manufacturing value chains, such as raw materials (e.g., metals and minerals, as detailed in Section 3.1) and large domestic market and/or locational advantages that could position them as vital sustainable energy value chain nodes. By embedding into these value chains, these economies could expand their export potential, increase employment prospects, enhance foreign direct investment flows, and accelerate the diffusion of technology necessary for efficient local clean energy adoption.

As is clear from Figure 3.3, China has emerged as the key manufacturing hub for clean energy technologies. Some other developing economies have experienced a degree of success in integrating into these value chains. For instance, Malaysia and Viet Nam have positioned themselves as important nodes in the solar

PV value chain, and since 2017, components such as solar wafers, cells and chips account for around 10 per cent and 5 per cent respectively of their trade surpluses (IEA, 2022g). India, Thailand, Mexico and Philippines have also carved out niche spaces for themselves in solar and wind turbine manufacturing.

African economies also have the potential to participate in the manufacturing value chains for renewable energy technologies. Examples of firms actively involved in domestic and regional value chains already exist. For instance, Solar Power Solutions (SPS) is a Ghanaian firm that manufactures, supplies and installs off-grid and grid systems, photovoltaic systems and PV streetlights.⁴ Established at a cost of US\$ 50 million in 2016, the firm has the capacity to produce 30 MW of solar modules a year with plans to expand production in the future.

Expanding clean energy markets presents trade opportunities for developing economies and LDCs; many possess competitive advantages that favour their participation in manufacturing value chains.

FIGURE 3.3 Solar PV manufacturing capacity by economy and region, 2021

Source: IEA (2022e)

How can Aid for Trade help unlock trade opportunities?

Aid for Trade projects are encouraging developing economies to enter the manufacturing space in clean energy supply chains. One example cited in the 2022 Aid for Trade M&E questionnaire was the partnership between Australia and Indonesia to produce grid-scale batteries (see Box 3.5). Initial scoping for the project is currently underway under the “Katalis” programme backed by Australia to promote the bilateral partnership.

Another example of multilevel coordination is the “Africa-EU Green Energy Initiative”, which is a forum for political dialogue, knowledge sharing and peer connection between EU and African stakeholders

in renewable energies.⁵ Leveraging private sector investment to support the deployment of clean energy technologies is a priority of this initiative.

The “China-Africa Cooperation on Climate Change” seeks to enhance South-South cooperation to facilitate the delivery of climate technologies and services in Africa.⁶ And the Africa Renewable Energy Manufacturing Initiative (AREMI), launched in 2023, aims to drive investment and mobilize action to scale up renewable energy manufacturing capacity. A significant action priority of the initiative is to partner with government officials to create a facilitatory policy environment for clean energy investment. The initiative will also seek to improve supply-side capacity by training engineers and technicians to support manufacturing operations.

BOX 3.4 Renewable energy manufacturing in Africa

Africa's clean energy manufacturing potential was highlighted in a recent study by Sustainable Energy for All (SEAL) (2023). The study analysed continental manufacturing prospects by considering key factors such as domestic demand, infrastructure, manufacturing scale, policies, trade relations, infrastructure and the ability to export.

Economies identified as viable manufacturing hubs for renewable energy, particularly solar PV manufacturing, included:

EGYPT

Egypt's large domestic market and export base, as well as its specific domestic laws promoting renewable energy and manufacturing make it ideal for renewable energy manufacturing. Its close trade ties with the Middle Eastern region lends for a favourable regional export strategy.

MOROCCO

A strong manufacturing track record, reliable infrastructure and institutional support for clean energy production make Morocco well-suited for renewable energy manufacturing and exporting. Morocco's strong trade ties with the European Union and China provide a conducive environment for strong export and inward investment potential.

NAMIBIA

Namibia offers strong projected demand for renewable energy by 2030. It also possesses high-quality infrastructure and mineral resources, and it has prioritized the development of clean energy, particular hydrogen, for export markets.

SOUTH AFRICA

South Africa's projected solar energy demand is expected to increase exponentially over the next few years. Its strong manufacturing base, coupled with an enabling policy space, means that a domestic industry could be established to cater to this spike in domestic consumption.

Ways in which Aid for Trade can help developing economies and LDCs to integrate into manufacturing value chains include:



Financing the development of infrastructure projects critical for clean energy technology manufacturing to improve trade competitiveness. Activities include establishing renewable energy generation facilities, scaling domestic grid infrastructure and modernizing transportation networks (e.g., port and roadway infrastructure).



firms establish and implement operations that comply with international standards, making it easier to trade these products globally.

Helping regulators streamline trade procedures to minimize trade-related costs. Aid for Trade can also be used to encourage regional cooperation and integration between neighbouring economies. This allows economies to pool resources and build a stronger collective presence in the global clean energy technology market.



Connecting developing-economy and LDC manufacturers with potential buyers, distributors, and partners in other economies. Aid for Trade can also be leveraged to help



Providing financial assistance in the form of grants, loans, or guarantees to attract private sector investment to clean energy technology manufacturing.

BOX 3.5 Grid scale battery production in Indonesia

IA-CEPA ECP Katalis (Katalis)⁷ is a five-year (2020-25) development programme backed by Australia that looks to unlock the economic potential arising from the partnership established under the Indonesia-Australia Comprehensive Economic Partnership Agreement Economic Cooperation Program (IA-CEPA ECP).⁸

Katalis seeks to maximize the benefits from the bilateral partnership in three ways:



improve
bilateral market
access,



increase bilateral
trade and
investment, and



help achieve
inclusive economic
growth in Indonesia.

Katalis was flagged as a flagship Aid for Trade partnership by Australia in its response to the 2022 Aid for Trade M&E exercise.

One strategy employed by Katalis to achieve these objectives is to leverage breakthrough investment from advanced manufacturing firms based in Australia into Indonesia. As part of this strategy, Katalis is funding a market entry study⁹ to identify the next steps to establish manufacturing plants for grid-scale long-duration batteries in Indonesia by 2026. The demand for such batteries is expected to grow in the medium to long term, as economies increasingly look for ways to store surplus energy created through clean energy sources.

The establishment of such a battery plant offers trade and economic benefits for Indonesia. It would help to supply local needs and to scale up domestic manufacturing capacity, as well as providing trickle-down benefits to local MSMEs, who now have an opportunity to integrate into the services or manufacturing battery value chain as product and service providers. The plant would also help expand export potential, as Indonesia could develop into a source for battery production for regional neighbours in Southeast Asia.

3.3 Services value chains

Services activities play a vital role in every stage of the clean energy generation cycle. They are essential from the planning of clean energy production sites down to the eventual decommissioning of capital equipment. LDCs and developing economies could enhance growth prospects and generate additional employment by prioritizing value-added services as they build domestic clean energy capacity.

The importance of services operations in clean energy deployment has been recognized in several studies. For

instance, an IRENA study on wind energy reveals that nearly 75 per cent of the labour involved in deploying a 50 MW wind farm was comprised of services sector activities, such as grid installation, operation and maintenance (IRENA, 2017a). Another study, focused on solar PV plants, indicated that nearly 56 per cent of labour was involved in services such as operations and maintenance (IRENA, 2017b).

Estimates by IRENA and the AfDB (IRENA and AfDB, 2022) project that the energy transition has the potential

to boost employment in the renewable energy sector in Africa substantially. The number of jobs in the renewable energy sector is expected to increase from around 0.35 million 2020 to over 4 million by 2030.

Clean energy services spanning the entire value chain were identified by IRENA and the WTO in a study analysing solar PV trade (WTO and IRENA, 2021). Highlighted services in each value chain node include:



Project planning: Includes service activities such as site surveying, drafting technical and financial feasibility reports, engineering design and project development.



Manufacturing services: Involves services such as the cutting, welding, washing, bending, melting and joining of clean energy equipment.



Transport: Delivering supplies and/or finished equipment by truck, plane, train or boat.



Installation and grid connection: Encompasses site preparation activities involving staff operating loaders, cranes, trucks and excavators.



Operation and maintenance: Activities that take place during the entire expected lifetime of clean energy equipment. Key activities in this phase focus on preventive and corrective maintenance.



Decommissioning: Involves products dismantling and activities involved in clearing sites.

Operation and maintenance services, in particular, are essential roles in the life cycle of clean energy plants. These include activities such as ensuring smooth turbine or solar PV operations, handling equipment failure and coordinating with utility services to ensure streamlined energy transmission to the national grid.

Efficient clean energy production also requires inputs from external service operators providing essential support for daily operations. Box 3.6 focuses on the World Meteorological Organization's Systematic Observations Financing Facility (SOFF),¹⁰ which provides institutional support to LDCs and small-island developing states to develop advanced weather forecasting systems. This is an important activity, given that only 10 per cent of required basic weather and climate forecasting systems are available in this economy group (WMO, 2022).

Services activities are essential from the planning of clean energy production sites down to the eventual decommissioning of capital equipment.

Adopting circular economy mechanisms can also enhance the value of service sector operations. For instance, product-service systems, which provide access to a service for a certain period, could operate as a model to stimulate resource efficiency and reduce waste.¹¹ The European Commission's "Circular Business Models for the Solar Power Industry" ("CIRCUSOL")¹² is an example of such an initiative. The initiative seeks to develop and promote solar product management, both through the re-use, refurbishment and remanufacturing of these products, and by developing value-added new product-services for residential, commercial and utility end-users.¹³

Governments are already investing in reskilling workers in the energy sector. For example, the United States Agency for International Development (USAID) is supporting Egypt in introducing new renewable specializations through its Workforce Improvement and Skills Enhancement (WISE) project. To date, 75 new occupational standards have been defined under WISE (Bouchene et al., 2021).

BOX 3.6 The Systematic Observations Financing Facility (SOFF)

Accurate weather forecasts and climate data are key to optimize the productivity of clean energy. This is because the operation of clean energy technologies, such as solar PV and wind turbines, is influenced by fluctuations in local weather systems. In this context, weather forecasting systems can considerably increase the resilience of energy systems, provide economies with the ability to locate the best regions for weather-dependent energy systems, and identify when to switch energy sources to ensure stable power supply.

According to the WMO (WMO, 2022a; 2022b), historical climatological data does not offer sufficient granularity for power generation purposes. Hence, in many developed economies, the energy sector is increasingly reliant on sophisticated climate services applications for weather forecasting capacity. Ensuring that these technologies are available to developing economies and LDCs is critical to ensure optimal use of clean energy assets. LDCs and small-island developing states face particularly significant weather data gaps because less than 10 per cent of required basic weather and climate forecasting systems are available domestically. Expanding domestic meteorological infrastructure would help to improve clean energy output and, at the same time, ensure timely weather services for other tradable activities that depend on timely weather forecasting. This includes activities in the agriculture sector, a significant export earner for many LDCs.

Launched in 2021, the Systematic Observations Financing Facility (SOFF) is a financing mechanism that aims to address this measurement deficit.¹⁴ Created as a partnership between the World Meteorological Organization (WMO), the United Nations Development Programme (UNDP) and the UN Environment Programme (UNEP), the Facility provides grant financing and technical assistance for the collection and international exchange of surface-based weather and climate observations for economies lacking infrastructure for accurate data collection.

SOFF works with economies with the most severe shortfalls in observations, prioritizing LDCs and small-island developing states.

In its initial phase, SOFF will support 55 economies improve their weather forecasting services. Activities that are supported include the rehabilitation or establishment of up to 400 data-gathering stations. Initial financial support has been provided by donors, including Austria, Denmark, the Nordic Development Fund, Norway and Portugal.

How can Aid for Trade help unlock trade opportunities?

Aid for Trade can support developing economies and LDCs to capture market share in the services value chains for clean energy by:



Channelling capacity-building and training programmes for local service providers in

areas such as project planning, management, deployment, maintenance and operation of renewable energy systems. Aid for Trade can also be used to support the dismantling and recycling of clean energy technology, in line with circular economy principles. Upskilling service providers in this manner will help to attract more projects and investments, facilitating the expansion of trade in clean energy services.

BOX 3.7 Aid for Trade in Action: USAID capacity-building assistance in Guajira, Colombia

In recent years, Colombia has enacted a series of regulatory initiatives to promote domestic wind energy potential. These commitments are centred around the Guajira region, located in Colombia's north-eastern peninsula. Over the next three years, 16 wind park projects, representing around 70 per cent of the newly installed capacity in Colombia, will be situated in the region.

Although it is rich in wind energy resources, Guajira is one of the most impoverished parts of Colombia. Approximately 20 per cent of its urban residents lack electricity services, and this number rises to 60 per cent in the region's rural areas. Ensuring that the local community benefits from electricity access and the economic opportunities arising from clean energy investments have emerged as key policy priorities.

With support from USAID, Colombia has created a sustainable local workforce training programme for Guajira¹⁵ that will meet the needs of both the indigenous communities and the renewable energy companies situated working in the province. The project will be spearheaded by SENA ("Servicio Nacional de Aprendizaje"), a government initiative that develops vocational training programmes to increase employment and strengthen Colombian competitiveness. Assistance from USAID will be delivered under its flagship "Scaling Up Renewable Energy" (SURE) initiative.¹⁶

Upon completion of the training, participants are certified as competent in the knowledge and skills necessary to work in areas related to renewable energy. Through this initiative, Colombia is helping to build regional capacity with a view to enabling the younger generation to service and manage a future fleet of renewable energy projects on a national and regional scale.



Leveraging finance to expand aggregate investments in renewable energy services. Aid for Trade can be used to catalyse financial support, by reducing investment risks for service providers, and to encourage private sector participation.



Assisting MSMEs in developing economies and LDCs in their efforts to comply with international standards and quality requirements for renewable energy services. Providing firms with the support to understand and comply with quality assurance frameworks, certifications and conformity assessment measures can enhance the credibility and marketability of services. This allows for better access to global markets.



Supporting trade facilitation measures, simplifying customs procedures, and reducing trade barriers for renewable energy services. This includes streamlining import and export processes, reducing tariffs and addressing non-tariff barriers.



Facilitating technology transfer and innovation partnerships to promote the adoption of advanced technologies in renewable energy services.

3.4 Development opportunities through carbon credits and carbon capture utilization and storage

One emerging market opportunity that can help to improve sustainable growth prospects is related to carbon credits. In essence, carbon credits refer to tradable permits that represent that value of emissions that have been reduced, avoided or captured in projects verified through credible standards (UNFCCC, 2021). Each carbon credit constitutes the right to emit one metric ton of CO₂ or an equivalent greenhouse gas (GHG) emission. The price of each carbon credit is determined by the interaction between demand and supply in local, regional or international carbon markets (WTO, 2022b).

The use of carbon credits as a form of carbon pricing has received significant attention over recent years. It is estimated that more than two-thirds of economies are planning to use carbon markets to meet their nationally determined contributions (NDCs) to the Paris Agreement (World Bank, 2022a). The focus on carbon markets has gained considerable traction since COP26, at which delegates approved Article 6 of the Paris Agreement. This article creates the basis for trading in GHG emission reductions across economies and establishes a mechanism for trading GHG emission reductions between economies (World Bank, 2022b).

Carbon credits are generated in markets when a project reduces or avoids greenhouse gas emissions beyond what is required by law or regulation. For example, each ton of CO₂ that is avoided by energy generation through a clean source such as solar PV (in comparison to a fossil fuel plant) can be sold as a carbon credit to companies or governments that need to offset their emissions. This market structure creates an incentive for all stakeholders to reduce their carbon footprint, either to reduce existing costs or to benefit from a potential income-generating mechanism.

For developing economies, carbon credits can be an important source of revenue and can help finance clean energy projects. The proceeds from the sale

of voluntary carbon credits enable the development of carbon-reduction projects across a wide array of project types. For instance, part of the proceeds from carbon credits can be reinvested into renewable energy and energy efficiency to increase credit returns in consecutive cycles. Financial incentives offered through carbon credits therefore contribute to an overall reduction of GHG emissions by the domestic economy. The World Bank notes that carbon credit markets could help developing economies by reducing the cost of implementing NDCs by as much as US\$ 250 billion by 2030. Developing economies such as Chile, Ghana, Jordan and Vanuatu are building end-to-end digital infrastructures to support their participation in international carbon markets (World Bank, 2022a).

In the context of an energy transition, one particular renewable source that can benefit from carbon market integration is bioenergy. Currently accounting for 6 per cent of global energy supply, bioenergy can be either derived through biomass fuels (such as charcoal, wood, industrial residues and agriculture by-products) or biofuels (such as bioethanol, biodiesel and methanol) (IEA, 2023l). Approximately 80 per cent of bioenergy is used for cooking and heating in buildings and industry.

Biomass and biofuels are considered renewable because they can be produced using fast-growing organic matter. However, unlike other forms of renewable energy, they are pollutive and generate negative environmental and health consequences. Traditional forms of biomass carry particular risk, but they remain a primary energy source in many developing economies and LDCs. Nearly 2.4 billion people, mostly in developing regions of sub-Saharan Africa and South Asia, continue to rely on inefficient biomass sources to generate energy for cooking and other household needs (IRENA, 2022b). The combustion of wood fuels for cooking is estimated to generate up to 1 gigaton of carbon dioxide equivalent (Clean Cooking Alliance, 2020). This equates to about 2 per cent of global CO₂ emissions.

BOX 3.8 Powerstove – digitalized clean cooking solutions for development

Nearly 70 per cent of all Nigerian households continue to use solid biomass, such as firewood and charcoal, for cooking. In their raw forms, these energy sources are highly pollutive and burning them can cause respiratory problems.¹⁷ Increasing access to alternative and cleaner energy sources for cooking has proven difficult due to limited grid accessibility: the World Bank estimates that nearly 50 per cent of Nigerian households lack access to electricity access.¹⁸

Founded in 2018, Powerstove is a Nigerian company that manufactures cookstoves using wood bio-pellets to produce reliable energy. Cookstoves produced by Powerstove are smokeless and burn 70 per cent less biomass than traditionally used cooking solutions. This represents a significant, locally created step toward improving access to clean cooking in Nigeria.¹⁹

Powerstove is in the process of incorporating innovative technology that improves the efficiency and revenue-generating capacity of manufactured cookstoves. For instance, cookstoves will be integrated with self-powered devices that help to monitor user behaviour and generate carbon credits in a transparent and traceable channel. Each device will be geo-tagged to help pay a share of the carbon credits through digital identities. These gains are delivered directly to households through registered mobile money accounts.

Powerstove products are exported across the continent. It is an example of a developing-economy MSME that has used digitalization to gain from a trade opportunity during a clean energy transition.

This new digitalization initiative is being conducted in coordination with the Agence Française de Développement (AFD).²⁰ With AFD assistance, the project will include the development of the Powerstove Academy, a training platform for the company's employees in Nigeria, Kenya and Zimbabwe. Funds provided by AFD will also be used to help Powerstove acquire mobile kiosks to sell its products in new areas of Nigeria.

A transition to refined bioenergy sources (such as compressed wood pellets) could help to reduce health and environmental impacts (see Box 3.8 for an example of a project integrating this technique). It could also offer financial opportunities, as the act of replacing pollutive bioenergy sources with a cleaner alternative with fewer CO₂ emissions can generate carbon credits. The financial benefits gained through leveraging carbon credits in recognized markets can offer an additional incentive to participate in a transition. This is an opportunity that has been increasingly exploited over recent years. Revenue from carbon credits rose to more than US\$ 11 million in 2020, a 22-fold increase over the US\$ 500,000 tracked in 2017 (Galt et al., 2023).

How can Aid for Trade help unlock trade opportunities?

Aid for Trade can help developing economies and LDCs benefit from the opportunities presented by carbon markets by:



Helping MSMEs in developing economies navigate the complex requirements to enter international carbon markets. Activities with which firms may face difficulties in complying include project registration and the valuation of credits gained through renewable energy initiatives and energy efficiency programmes.

These are important steps to enter recognized carbon markets such as the Clean Development Mechanism (CDM).²¹



Assisting economies in developing legal and regulatory frameworks to participate in carbon markets, including establishing transparent reporting mechanisms, standards for carbon accounting and rules for the verification of emissions reductions.



Supporting the development of market intelligence and information-sharing portals to share carbon market opportunities with stakeholders in developing economies. This information can help businesses and governments make informed decisions about participating in carbon markets.



Mobilizing development and climate finance sources to support businesses interested in investing in clean energy and emissions reduction projects. The case study in Box 3.8 is one example of such a partnership in action.

Recent development in the carbon, capture, use and storage (CCUS) sphere may also help developing economies and LDCs in the clean energy transition. CCUS refers to a range of technologies and equipment that can help to capture and store or utilize CO₂ emitted by fossil fuel combustion,²² with a view to permanently removing carbon emissions from the atmosphere.

By implementing CCUS technologies, companies can offset additional carbon, thus creating an additional revenue generating mechanism by earning carbon credits. Carbon credits can also help boost firm-level clean energy deployment by offering firms an added monetary incentive to reduce their carbon footprint. The various means to achieve CCUS are represented in Figure 3.4.

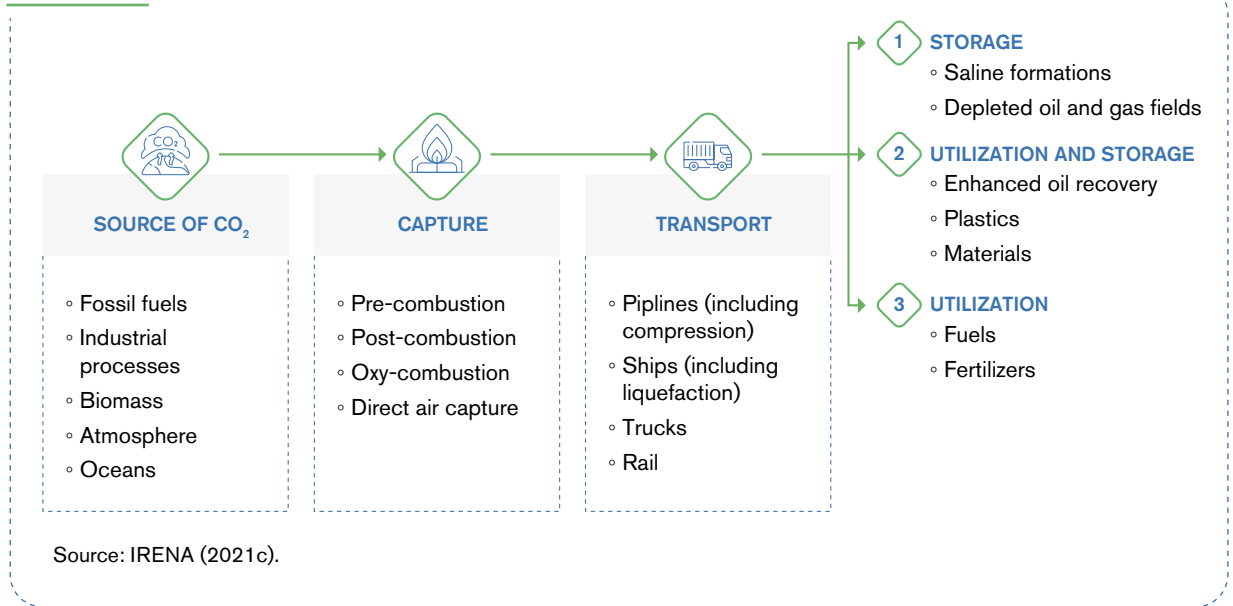
CCUS technologies can also be used to cater to market opportunities by serving the demand for goods with embedded carbon. Examples of activities that

benefit from CCUS expansion include the production of fertilizers, industrial chemicals, building materials, food and beverages. Reframing CCUS technologies as investments that complement the returns from carbon markets may help to increase adoption rates, as they serve as a strong monetary incentive to reduce energy emissions. Box 3.9 offers an example of this strategy in action.

CCUS technologies can also play a crucial role in smoothing the energy transition challenge for many economies. The IEA forecasts that fossil fuels will continue to play a role in the global economy, and estimates that approximately 10 per cent of global electricity in 2050 will be generated from fossil fuels using existing coal, oil or natural gas plants (IEA, 2021c). Several developing economies and LDCs will remain particularly sensitive to trends in this industry. Fuels currently account for approximately 25 per cent of total LDC exports and dominate the export baskets of several economies – for example, fuels accounted for 92 per cent, 77 per cent and 88 per cent of all merchandize exports for Angola, Chad and South Sudan, respectively, in 2020.²³

Retrofitting fossil fuel plants with CCUS technologies contributes to achieving net zero goals by reducing the emission intensity of fossil-fuel based power systems, as reducing and then removing carbon emissions in this manner could help to bridge the emissions gap until innovative technologies are commercialized. As a result, hard-to-abate sectors can continue their operations with reduced or no GHG emissions.

Currently, the high capital costs for CCUS integration act as an impediment for its adoption in developing economies. However, CCUS technologies may become cheaper through technology spillovers and economies of scale. The costs of large-scale CCUS projects have already shown declines; IEA (2021g) research notes that the cost of CCUS capture from large-scale coal power plants has come down by 35 per cent over the period 2014 to 2020. Planned coal plants with carbon capture (commissioned from

FIGURE 3.4 Carbon capture, utilization and storage


2025) are expected to operate at even lower costs, at approximately 35 percent of costs estimated in 2014.

The use of CCUS technologies can be particularly useful in the context of bioenergy with carbon capture and storage (BECCS), which involves capturing and storing CO₂ where biomass is converted into fuels

or directly burned to generate energy.²⁴ BECCS has been identified in consecutive United Nations Climate Change (UNFCCC) Assessment Reports as one of the strategies to enable a net zero transition. According to IRENA estimates, it is the most developed example of carbon removal technology that is currently available (Lyons, Durrant and Kochhar, 2021).

BOX 3.9 Retrofitting thermal infrastructure with CCUS

Founded in 2009 and headquartered in London, Carbon Clean²⁵ delivers cost-effective CCUS solutions to industrial carbon emitters. This includes firms involved in activities such as cement, steel and energy production and waste processing. Its rapid expansion has enabled Carbon Clean to open offices in India, Spain and the United States, as well as 44 facilities across the globe. As of June 2022, Carbon Clean had removed over 1.5 million metric tonnes of carbon by means of these facilities.

In 2022, Carbon Clean partnered with India's largest power station, Vindhyachal Super Thermal Power Station,²⁶ to explore the possibility of capturing CO₂ from plant flue gas to produce 10 tonnes per day of methanol for commercial trade.²⁷ Methanol is used as a starting substrate for the synthesis of various other chemical compounds required for the production of adhesives, foams and paints.

The use of CCUS technologies can also provide an incentive to decarbonize bioenergy production. This can be a particularly effective strategy to curb emissions generated during the use of scaled biomass combustion for industrial processing. In many developing economies and LDCs, agricultural wastes and process residues are used as biomass sources are used to generate such energy. Research by the United Nations Industrial Development Organization (UNIDO) and the Global Environment Facility (GEF) has shown that this has proved to be a viable strategy for economies with a large agricultural production base (UNIDO and GEF, 2021).

Examples provided in this research include:



Waste from avocado cultivation to generate biogas to cover manufacturing electricity needs in Kenya.



Substrate wastes from food processing units (e.g., potato scraps, dairy sludge) to generate electricity in Brazil.



Agricultural residues, such as rice husks, rice straw, cotton seeds and maize cobs, to produce charcoal briquettes in Uganda.

How can Aid for Trade help unlock trade opportunities?

Aid for Trade can play a role in accelerating the diffusion of carbon capture technologies by:



Providing financial and technical support to promote carbon capture technologies. For instance, Aid for Trade can facilitate technology transfer from developed economies to developing nations, helping them access advanced carbon capture solutions.



Enhancing the technical capacity of developing economies and LDCs. This may involve the training of local engineers and technicians in the design, installation and maintenance of CCUS systems.

Endnotes

1. In this context, the term “renewables” refers to electricity generated through solar photovoltaic (PV), wind, hydropower, hydrogen, nuclear and bioenergy sources.
2. See <https://www.iadb.org/en/whats-our-impact/RG-T3340>.
3. See <https://www.worldbank.org/en/news/press-release/2019/05/01/new-world-bank-fund-to-support-climate-smart-mining-for-energy-transition>.
4. See <https://sps.com.gh/>
5. See https://ec.europa.eu/commission/presscorner/detail/en/fs_22_1120.
6. See, for example, the “Declaration on China-Africa Cooperation on Combating Climate Change” issued by the Ministry of Foreign Affairs of People’s Republic of China on 2 December 2021 (https://www.fmprc.gov.cn/eng/wjdt_665385/2649_665393/202112/t20211203_10461772.html).
7. See <https://iacepa-katalis.org/about-katalis/>.
8. See <https://www.dfat.gov.au/sites/default/files/katalis-fact-sheet.pdf>.
9. See at <https://prospera.egnyte.com/dl/glhE6zAMui>.
10. See <https://un-soff.org>.
11. See <https://circulareconomy.earth/publications/how-can-we-create-circular-opportunities-for-energy-access>.
12. See <https://cordis.europa.eu/project/id/776680>.
13. See <https://cordis.europa.eu/project/id/776680/reporting>.
14. See <https://sdg.iisd.org/news/financing-facility-to-support-ldcs-and-sids-on-climate-observations/>.
15. See <https://www.usaid.gov/energy/colombia-clean-energy-future/inclusive-transition/community-buy-in>.
16. See <https://www.usaid.gov/energy/sure>.
17. See <https://energytransition.org/2022/06/enhancing-nigerias-clean-cooking-access-to-reduce-greenhouse-emissions/#:~:text=In%20Nigeria%2C%20about%20174%20million,increase%20access%20to%20the%20commodity>.
18. See <https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=ZG>.
19. See <https://www.gsma.com/mobilefordevelopment/blog/introducing-powerstove-pay-as-you-go-smokeless-biomass-cooking-in-nigeria/>.
20. See <https://www.afd.fr/en/powerstove-factory-inauguration/abuja-nigeria>.
21. See [https://unfccc.int/process-and-meetings/the-kyoto-protocol/mechanisms-under-the-kyoto-protocol/the-clean-development-mechanism#:~:text=UNFCCC%20Nav&text=The%20Clean%20Development%20Mechanism%20\(CDM,reduction%20project%20in%20developing%20countries](https://unfccc.int/process-and-meetings/the-kyoto-protocol/mechanisms-under-the-kyoto-protocol/the-clean-development-mechanism#:~:text=UNFCCC%20Nav&text=The%20Clean%20Development%20Mechanism%20(CDM,reduction%20project%20in%20developing%20countries).
22. See <https://www.iea.org/fuels-and-technologies/carbon-capture-utilisation-and-storage>.
23. See WTO official document number WT/COMTD/LDC/W/71 (available via <https://docs.wto.org/>).
24. See <https://www.iea.org/energy-system/carbon-capture-utilisation-and-storage/bioenergy-with-carbon-capture-and-storage>.
25. See <https://www.carbonclean.com/about-us>.
26. See <https://www.world-energy.org/article/26923.html>.
27. See <https://www.carbonclean.com/news/ntpc-power-plant-india>.