WORLD TRADE ORGANIZATION

WORLD METEOROLOGICAL ORGANIZATION

Supporting the renewable electricity transition through trade

UNLOCKING RE-GLOBALIZATION OPPORTUNITIES VIA INTERCONNECTION

CONTENTS

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DISCLAIMER

FOREWORD

"By trading energy from sun, wind and water across borders, we can deliver more than enough clean energy to meet the needs of everyone on earth."[1]

One Sun Declaration, COP26

The sun shines, the wind blows, and water flows, but not in the same places or at same times across the globe.

Cross-border trade in renewable electricity can help even out these spatial and temporal mismatches in supply and demand. The energy transition involves a move from fossil fuel-reliant energy generation to abundant, yet intermittent, weather-dependent power production. Cross-border trade has a key role to play in making national power grids operate efficiently while ensuring security of supply.

Advanced weather, water, and climate information and services are essential for a smooth transition to renewable energy. Such information underpins intermittent renewable energy systems, contributing to better operations and maintenance, risk management and investment planning.

Electricity trade represents a trade and development opportunity for many places with comparative advantages in solar, wind and hydropower electricity generation. It offers a path out of the current ironic reality that some of the places with the greatest clean energy potential are also locations with relatively high rates of energy poverty, low levels of economic development and limited integration into the global trading system.

Trade in renewable energy would also help lower the costs of getting to net zero. By unlocking the comparative advantage of renewable power generation hotspots, cross-border renewable electricity trade can reduce the overall cost of the net zero energy transition – by up to USD 3 trillion according to one estimate.[2]

Several least developed countries (LDCs) are already well-established exporters of renewable electricity, generated mainly from hydropower resources. Increased export prospects for renewable electricity promise to help galvanize more investment in generation capacity, grid upgrades, and interconnection, with positive spillovers for domestic electricity access. The latter may in turn incentivize investment in adding value to other goods and services – for instance, abundant renewable energy could be used to make green hydrogen that could in turn be used to process raw commodities.

Cross-border electricity cable interconnections can help reduce greenhouse gas (GHG) emissions and support economies to meet their nationally determined fossil fuel phase-out timelines. By drawing on a greater range of renewable electricity generation sources across a broad geographic area, interconnection and trade can help make power supply more secure through diversification between different sources and locations.

Just as shipping lanes, air corridors, highways and internet cable networks facilitate the movement of goods and services in the global economy, cross-border electricity transmission lines offer a mechanism to get renewable electricity from where it is abundant to where it is needed. The global cross-border network of cables that has been laid to build the World Wide Web underscores what is possible.

Unlocking opportunities in cross-border renewable electricity trade requires action to address the backlog of interconnection projects, as well as delays in the delivery of critical components and long timeframes for project delivery. Action is also needed to upgrade climate services and to relieve supply chain bottlenecks in the goods and services needed to supply grid infrastructure, including transmission lines.

The development of electricity grid connections needs cohesive international policy frameworks and the support of public and private sector capital. These frameworks should derisk capital-intensive interconnection projects and provide transparency and predictability in regulatory approval timeframes.

While there is no World Trade Organization (WTO) agreement that deals specifically with energy trade, various existing WTO rules and bodies can help to address frictions and inefficiencies that delay or stall interconnector projects. And new disciplines or cooperative approaches that WTO Members may wish to pursue could be helpful to attract finance for capital-intensive renewable energy investments and liberalize trade in related environmental goods and services.

The World Meteorological Organization also has a powerful role to play in upgrading the climate services offered by its Members' National Meteorological and Hydrological Services and expand the use of meteorology and hydrology to plan in advance according to where weather-related deficits or surpluses are expected, thus benefitting decision-making in the energy sector.

This report concludes with a simple message for policymakers: the energy transition creates new opportunities to expand trade in renewable electricity and to promote re-globalization. By leveraging renewable energy resource endowments, we can help promote a just transition. Let's work together to seize these opportunities.

Signatures of representatives of the two organizations

WMO

WTO

EXECUTIVE SUMMARY

This co-publication of the World Meteorological Organization (WMO) and the World Trade Organization (WTO) focuses on a core aspect of international trade: ensuring security of supply. This role is increasingly important in the context of the transition to renewable energy, which is central to mitigating the effects of climate change.

As energy systems transition away from reliance on fossil fuels, the share of electricity in global energy production will grow along with weather-dependent renewable energy. Natural energy sources, notably solar, wind and water – the main focus of this report – are abundant but they are not evenly distributed worldwide. Additionally, many different meteorological factors have an impact on power generation and energy demand.

The transmission of power across borders from renewable electricity sources can help address the mismatches between electricity supply and demand. It can supplement storage solutions, such as batteries, and contribute to security of energy supply. It can also unlock a range of other benefits: better grid utilization of renewable electricity, reduced need for electricity storage and new trade opportunities. Some least developed countries (LDCs) are already realizing these opportunities while others need support to do so.

Moreover, trading renewable energy across borders helps economies meet their decarbonization commitments. Situating renewable energy generation in locations with the most favourable resource endowments and using grid interconnection to benefit from these comparative advantages reduces the overall cost of the global energy transition. Trading renewable electricity across borders can reduce the overall cost of the net zero energy transition – by up to USD 3 trillion according to one estimate.[3] The shared value created by the connection cables is akin to that created by the cable infrastructure underpinning the World Wide Web.

Global electricity trade has grown in nominal terms by USD 99.8 billion since 2003, with 64% of that expansion occurring since 2013. Yet cross-border electricity trade remains low in value (USD 132 billion in 2023, according to UN Comtrade statistics) and far below its potential when compared to the growth of renewable energy needed to meet Paris Agreement climate targets. International electricity trade, measured by gross imports in each country, was 2.8 per cent of the 809 TWh supplied in electricity globally in 2021.[4]

Realizing trade's full potential means addressing the various factors stalling progress in this area. One is to address the bottlenecks in the supply chains of goods and services needed for grid and interconnection expansion. In turn, this would unlock opportunities for developing economies and LDCs to participate more fully in manufacturing value chains. Enabling both the flow of electricity and grid infrastructure goods and services in the most cost-effective manner across borders would help unlock growth opportunities and reduce transition costs.

Several other steps could boost progress. Interconnector projects are capital-intensive and require large up-front investment before revenues start to flow. International investment in renewable energy has nearly tripled since the adoption of the Paris Agreement in 2015. However, much of this growth has been concentrated in developed countries, with most developing economies left behind.[5] Developing economies presently receive less than one-fifth of global clean energy investments. Ensuring that both grid operators and suppliers can reliably access sustainable trade finance and climate finance would help to tackle this critical bottleneck.

Rolling out a new wind or solar project can take between one to five years, but new transmission and distribution networks often take 10 to 15 years to plan, obtain permissions and complete. Improving the predictability of regulatory processes is another important step given the multi-jurisdictional nature of projects – involving approvals, export restrictions, tariffs and transit issues.

This report discusses how WTO rules and bodies dealing with these issues in areas such as telecoms, information technologies and government procurement can be relevant for renewable energy.

ENDNOTES

1 Green Grids Initiative – One Sun One World One Grid (2021), “One Sun Declaration” Glasgow, UN Climate Change Conference (COP26) at the SEC – Glasgow 2021 (nationalarchives.gov.uk).

2 Transition Zero (2023), “*Cables to change the world November 2023 The benefits of transmission to decarbonise global electricity supply*”, London.

3 Aman Majid, Abhishek Shivakumar, Maarten Brinkerink, Thomas Kouroughli, Matt Gray, Isabella Suarez, Trevor Barnes and Handriyanti Diah Puspitarini (2023), “Cables to Change the World”, Transitionzero.org.

4 IEA (2020), Global Overview Trade; Electricity Market Report 2020, IEA, Paris.

5 UNCTAD, World Investment Report 2023. https://unctad.org/system/files/official-document/wir2023_overview_en.pdf.

PLUG INTO THE POWER OF RE-GLOBALIZATION

> The sun shines, the wind blows and water flows, but not in the same places or at the same times across the globe.

PROFESSOR CELESTE SAULO,
SECRETARY-GENERAL, WMO

> Trade in renewable electricity can help even out spatial and temporal mismatches in energy supply and demand - and create new trade opportunities.

DR NGOZI OKONJO-IWEALA,
DIRECTOR-GENERAL, WTO

only **2.8%** of electricity generated is traded (IEA)

$132 billion value of electricity trade (UNCTAD)

The energy transition offers scope to grow electricity trade

85% projected share of renewable energy by 2050 (IEA)

PROBLEMS

- On average, each cross-border grid interconnector project takes 10-15 years
- Significant delays arise obtaining regulatory approvals and permits
- Tariffs and non-tariff measures can add to costs and delays
- Limited access to climate and trade finance
- Inadequate quality of climate information services

SOLUTIONS

- More transparency in regulatory practices
- Plugging gaps in grid-related supply chains
- Diversifying related goods and services trade
- Reducing procurement costs
- Better access to climate and trade finance
- Enhanced accuracy and reliability of climate information services

$720 billion to be invested in grid infrastructure by 2030 (IEA)

80 million kilometres of new electricity grid needed by 2040 (IEA)

RE-GLOBALIZATION OPPORTUNITIES

Africa is home to 60% of the best solar resources globally

Offshore wind energy in the Caspian Sea can support Europe's decarbonization

Many LDCs can expand their renewable electricity exports - several are already hydropower exporters

Investing in electricity trade helps manage the intermittancy of renewable energy and can bring down the cost of the energy transition

> Let's work together to seize these opportunities.

PROFESSOR CELESTE SAULO & DR NGOZI OKONJO-IWEALA

INTRODUCTION

This joint WMO-WTO report has been issued in conjunction with the COP29 Presidency Initiatives to Focus Global Attention and Accelerate Climate Action, notably those concerning Pledges on Green Energy Zones and Corridors and Global Energy Storage and Grids.

The report has three main sections:

- Section A, drafted by the WMO, outlines how endowments of solar, water and wind resources differ worldwide. The section examines how this range of endowments underlines the potential for trade to help buttress security of energy supply by matching renewable energy supply with demand. In turn, this can help unlock new export opportunities for developing economies, and in particular LDCs, that have comparative advantage in renewable energy.
- Section B, drafted by the WTO, examines why interconnector projects are difficult to initiate and frequently stall. After surveying electricity trade patterns, the report identifies the factors delaying project implementation and where the multilateral trading system may be able to ease bottlenecks to ensure greater cross-border transmission of renewable electricity.
- Section C, drafted jointly by WMO and the WTO, concludes with a call to work together to ease the transition to weather-dependent electricity generation systems in an efficient and timely manner in line with the Paris Agreement timelines.

The role of trade in renewable electricity

A

1.1 Overview

The transition to renewable energy is central to achieving both the UN 2030 Agenda for Sustainable Development and the Paris Agreement on climate change. Energy accounts for more than three-quarters of total greenhouse gas (GHG) emissions globally.[1]

The global energy system is moving increasingly towards renewable energy sources, but the speed and geographic scope of the transition needs to accelerate and expand. Developing economies presently receive less than one-fifth of global clean energy investments. Concerted action is needed therefore if the world is to stay within Paris Agreement climate targets and reach net zero by 2050, whereby the amount of GHG produced is balanced by the amount removed from the atmosphere.

The COP28 climate change conference in the United Arab Emirates in December 2023 called for a tripling of renewable energy capacity and a doubling of energy efficiency by 2030 to limit global warming to 1.5°C. Energy efficiency and renewable energy are the main pillars of the energy transition. Together, they can provide over 90 per cent of the energy-related CO_2 emission reductions that are required, using technologies that are safe, reliable, affordable and widely available, to meet Paris Agreement targets.[2]

A decarbonized power sector, with renewable sources at its core, is central to the transition to a sustainable energy future. To achieve net zero, the share of renewable energy in the power sector has the potential to reach 85 per cent by 2050, mostly through growth in solar and wind power generation.[3]

However, wind, water and solar resources, the focus of this report, are not equally distributed worldwide. National endowments differ considerably in terms of renewable energy sources and vary by season and by the day. Energy demand is similarly prone to fluctuations.

Trading renewable electricity across borders can support the transition to weather-dependent power generation systems, addressing intermittency of renewable energy supply and mismatches between electricity supply and demand. Currently, global cross-border electricity trade is valued at USD 132 billion in 2023 by UN Comtrade statistics, but has the potential to grow much higher.

Expanding interconnections would improve grid renewable energy usage, complement storage options and offer new trade opportunities, including for LDCs.

Trading renewable energy across borders also helps importing economies meet their decarbonization commitments and lessens the overall cost of the global energy transition. Furthermore, since electricity can flow in both directions, the shared value created could eventually lead to the establishment of a global green grid akin to the World Wide Web.

1.2 Renewable electricity generation potential is unevenly distributed

"More energy from the sun falls on the earth in one hour than is used by everyone in the world in one year."[4]

The potential of renewable electricity is vast, but the uneven distribution of renewable energy resources across the world is an inherent challenge. Renewable energy resources are abundant in some regions but scarcer in others. For example, solar energy is plentiful in desert areas but limited in northern latitudes – see Figure A.1.[5]

Hydropower resources are abundant at the tropics, but wind speeds are lower than at other latitudes – see Figure A.2 and Figure A.3.

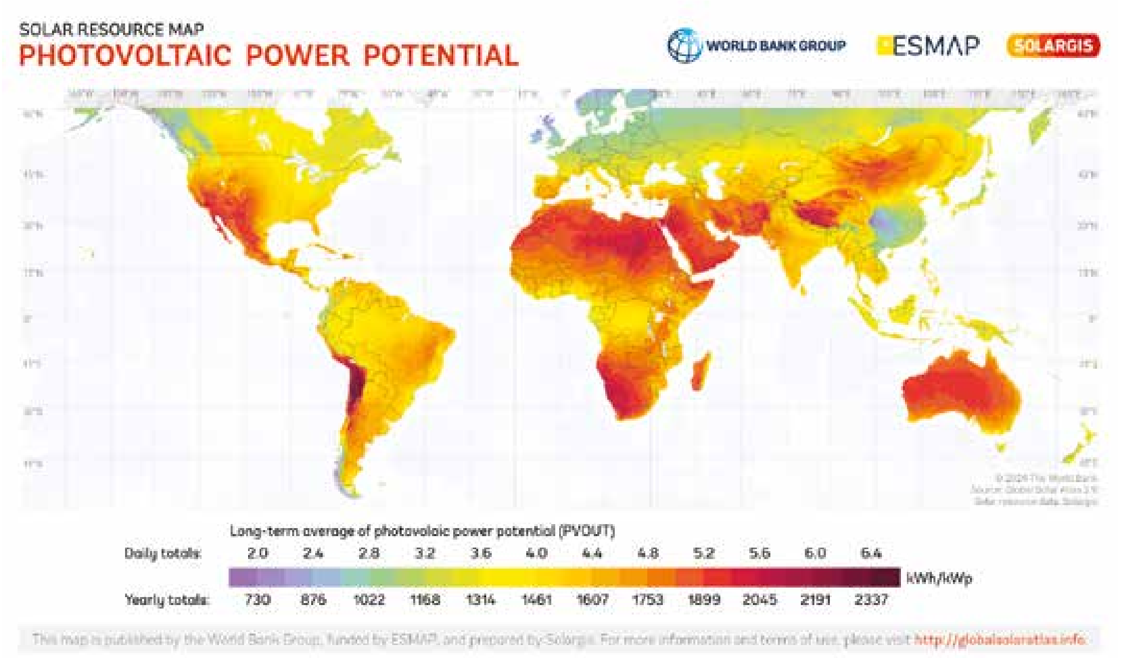
1.3 Renewable electricity supply is intermittent, demand is uneven

Energy generation from water, wind and solar sources is, by its nature, intermittent. This intermittency stems from fluctuations in the natural resources driving power generation, causing variability on a daily and seasonal basis. Factors related to climate change also lead to variability (see Box A.1).

- **Daily fluctuations** are most apparent in solar power, where generation peaks obviously during sunlight hours and drops to zero overnight. Wind power, while less predictable, also experiences daily variations due to changes in wind speeds, influencing output.
- **Seasonal fluctuations** are also evident. Solar generation is typically higher in summer months due to longer days and more direct sunlight. Conversely, wind patterns can shift with the seasons, leading to periods of higher or lower wind resource availability at different times of the year. Hydropower generation is also influenced by seasonal precipitation and snowmelt patterns.

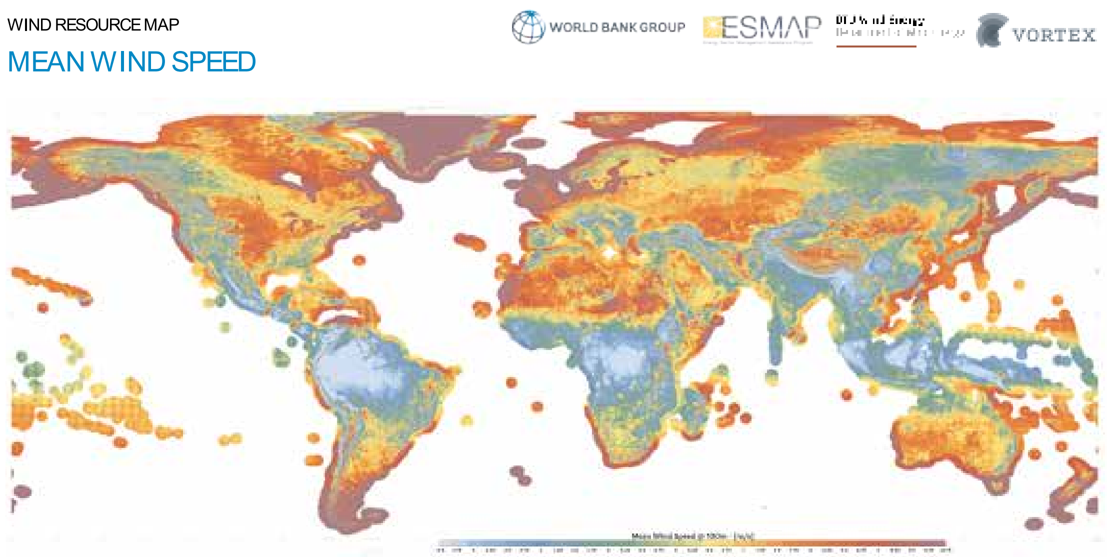
- **Climate change** related factors are also a cause of variability in power generation. Prolonged droughts can affect hydropower generation, while shifts in wind patterns due to climate change can have a major impact on wind energy output.

Figure A.1: Map of global photovoltaic power potential



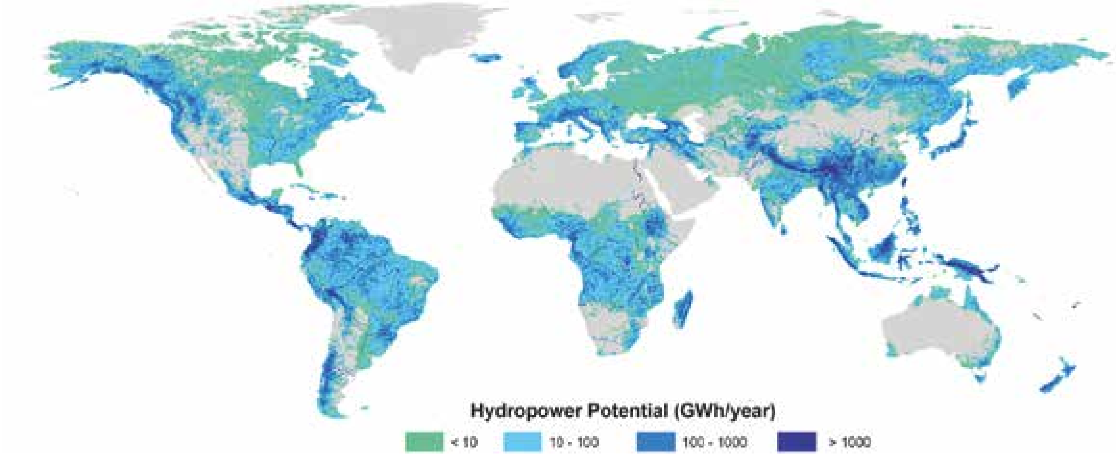
Source: World Bank Group, Energy Sector Management Assistance Program (ESMAP) and Solargis.

Figure A.2: Map of global mean wind speeds[6]



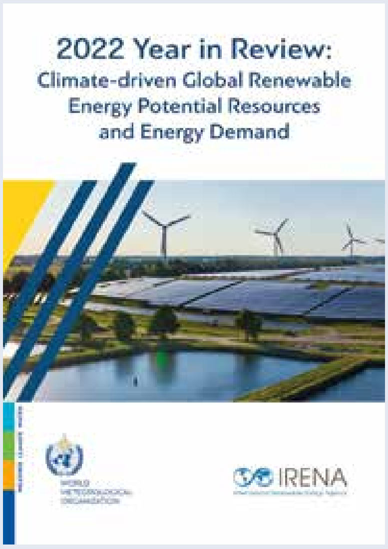
Source: World Bank Group, ESMAP, DTU wind energy and Vortex.

Figure A.3: Map of global hydropower potential[7]



Source: Hoes OAC, Meijer LJJ, van der Ent RJ, van de Giesen NC (2017).

Box A.1: Impact of climate factors on the energy sector



The first attempt to identify global climatic factors affecting renewable energy potential was published jointly by the WMO and the International Renewable Energy Agency (IRENA) in 2023. It compares data from 2022 to a 30-year average (1991-2020) to assess how climate variability and change have has impacted specific energy technologies and demand.

The report specifically examines wind and solar power efficiency, hydropower and energy demand, focusing on the observed changes between the long-term averages and conditions in 2022.

The results underscore the impact of climate variability and change on various energy technologies. They show significant fluctuations in wind and hydropower usage, while solar photovoltaic (PV) remains relatively stable. The report stresses the need for better understanding and integration of climate factors into energy planning and management, particularly for optimizing renewable energy deployment in developing regions such as Africa.

Source: WMO.[8]

Electricity consumption is also influenced by daily, seasonal and climate-related factors.

- **Daily variations:** in renewable energy demand are linked to typical consumption patterns. Higher demand coincides with peak residential and commercial use.
- **Seasonal** variations: Demand for energy is influenced by cold, heat, precipitation and other factors, such as public holidays or religious festivals.
- **Climate-related** events: Heatwaves can lead to a surge in electricity consumption by cooling systems. During periods of extreme cold, demand for heating can strain energy supplies, particularly in regions dependent on electric-heated systems.

Renewable energy production often does not align with peak demand times. Solar power, for instance, peaks at midday but demand may be highest in the evening. Wind energy, on the other hand, may be more available at night when demand is lower.

1.4 Trading renewable electricity across borders can help balance supply and demand

When one economy has excess wind or solar power, this surplus can be exported to an economy experiencing higher demand or lower generation. Ensuring security of energy supply between surplus and deficit economies is one of the most fundamental roles of trade. Hence, trading renewable electricity across borders can help address intermittency of supply and demand variability.

Integration of renewable energy into existing power systems is a major challenge for electricity grid operators. Networks were typically designed for consistent volumes of electricity based on predictable power generation. These systems were not built to handle new supply connections or variability in energy generation, which requires active management. Increasing the share of intermittent electricity – from solar and wind – into electricity grids requires increases in grid capacity, grid control, flexibility and storage.

One technique used to manage the intermittency of power supply from renewable sources is "curtailment". This refers to the reduction of power production when there is too much electricity in the grid. As the use of renewable energy increases, so the share of curtailed wind and solar generation is also on the rise in many markets.[9]

Curtailing (i.e. reducing or stopping) power provided from renewables is inefficient. Renewable energy generation forgone through curtailment is permanently lost (e.g. a wind turbine's blades are stopped rotating) and may instead be replaced by energy generated from other sources, notably GHG-emitting fossil fuels. Furthermore, curtailment may give rise to compensation payments to the renewable energy generator due to the inability of the network operator to accept this power.

Battery technologies are becoming a key solution to enable the storage of electricity from renewables and release power when it is needed. Some 10 gigawatts of battery storage have been deployed in the US state of California[10] and in Northwest China.[11] Lithium-ion batteries are the dominant storage technology for large-scale plants, allowing electricity grids to ensure a reliable supply of renewable energy.[12]

Lithium-ion batteries are also used in many other applications (e.g. mobile phones and electric cars) so pressure on worldwide lithium resources is increasing. The International Energy Agency (IEA) forecasts that the world may face potential shortages of lithium unless sufficient investments are made to expand global production.[13]

Trade in renewable energy also offers a solution to the problem of market balancing. In Europe, for instance, interconnection has been shown to halve the curtailment of low cost, renewable power and reduce price volatility by giving consumers access to lower-cost electricity from other economies.[14]

The development of interconnectors, including high-voltage direct current (HVDC) transmission lines, enables rapid electricity exchange across borders. An interconnector is any grid infrastructure that connects two or more power systems operating under different legislative regulators and/or operation regimes.[15] Interconnectors are physical cable infrastructure that links the power grids of different economies, running under the sea, underground or via overhead cabling. Interconnectors help to stabilize prices and enhance the reliability of the global power system.

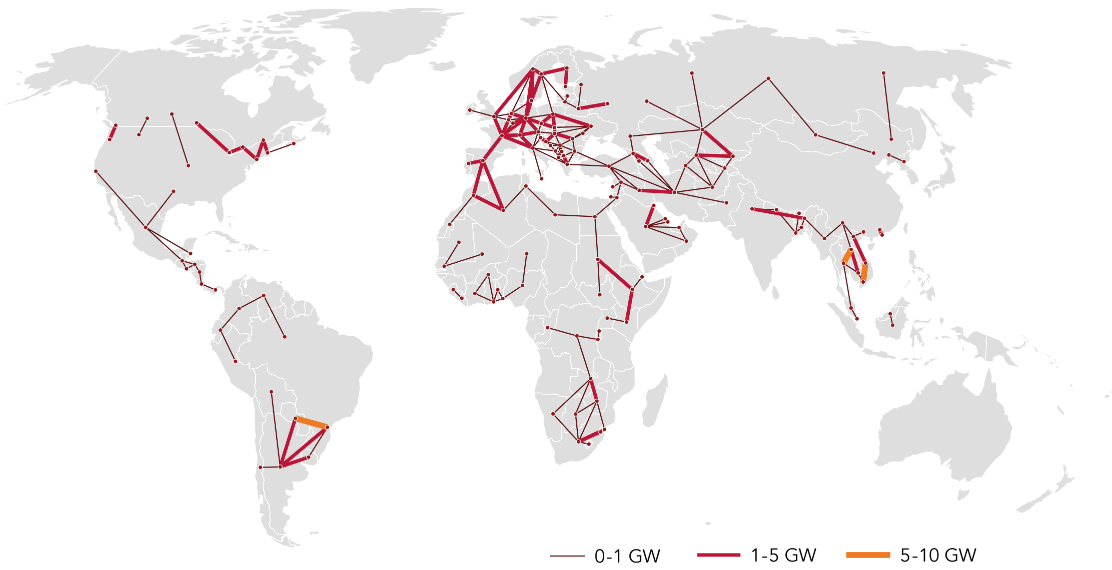
The global length of HVDC lines has almost tripled since 2010, surpassing 100,000 km by the end of 2021, with a total transmission capacity exceeding 350 gigawatts (GW).[16] Figure A.4 gives an overview of existing electricity interconnectors.

Interconnectors facilitate the integration of renewables into power networks and improve network system efficiency. This decreases reliance on fossil fuels without compromising reliability of supply. Increased interconnection can also unlock significant renewable potential in locations with abundant supplies, lowering the costs of energy and storage capacities required for decarbonization targets.

Global renewable capacity is expected to grow by 2.7 times by 2030 to reach 9,763.1 GW.[18] In this context, resource forecasting techniques are increasingly vital. These forecasts, which predict wind speeds, solar irradiance (i.e. a measure of the sun's intensity) and other relevant weather conditions, are used as inputs to models to estimate the potential energy output from renewable sources – see Box A.2. Accurate forecasts reduce the uncertainty associated with renewable energy generation, allowing grid operators to plan for periods of high or low renewable energy output.

Forecasting models are critical to efficiently schedule power generation and to manage the reserve requirements needed to accommodate the fluctuations in energy supply. Accurate forecasting allows grid operators to anticipate changes in renewable energy output, enabling them to balance supply and demand more effectively and minimize curtailment and reliance on back-up fossil fuel generation. It also reduces the costs associated with maintaining reserves.

Figure A.4: Existing electricity interconnectors (as of 1 February 2024)



Source: IRENA, Brinkerlink *et al.*[17]

Box A.2: WMO's Global Framework for Climate Services

The WMO plays a crucial role in supporting renewable energy integration into power networks by providing high-quality meteorological and climate data services. These services are essential for improving the accuracy of renewable energy forecasts and enhancing grid management practices.

GFCS GLOBAL FRAMEWORK FOR CLIMATE SERVICES

The WMO's Global Framework for Climate Services provides climate information and services to various sectors, including energy providers. It helps in the development of tailored climate services that can assist in renewable energy forecasting. This includes the provision of long-term climate data and seasonal forecasts, which are invaluable for planning the integration of renewables into the grid.

The real-time weather data and forecasts produced by national hydro-meteorological organizations are essential for short-term renewable energy forecasting. This data allows grid operators to anticipate changes in wind and solar output, making it easier to balance supply and demand in real time and to optimize power supply. The use of these services is essential for managing the variability and uncertainty of renewable energy sources. It ensures that renewable energy is reliably integrated into power grids, supporting the global clean energy transition.

Source: WMO.[19]

Interconnectors can reduce the amount of back-up storage capacity required, including in the form of battery storage technologies, to ensure reliability and energy security. They also lead to a more efficient use of renewable energy, minimizing curtailment losses and reducing overall electricity costs by allowing access to cheaper renewable electricity from other economies.

Real-time weather data and forecasts also play an important role in energy demand forecasting. In addition to helping grid operators balance supply and demand, forecasting is important to ensure the resilience of energy infrastructure e.g. in the face of extreme weather events.

Trading renewable electricity across borders can reduce the overall cost of the net zero energy transition – by up to USD 3 trillion according to one estimate.[20]

1.5 Trading renewable electricity enables economies to exploit their comparative advantages

Cross-border energy trading allows economies to benefit from their renewable energy endowments, taking advantage of geographic assets and time differences to participate in power generation.

This applies to countries along the Tropic of Cancer. For example, when India hits peak energy demand in the evening, the sun is still strong in the Gulf countries. In turn, when the sun is strong over India at midday, the surplus power it generates would serve the morning peak demand in the Gulf countries.[21]

To tap into the renewable electricity possibilities offered by these natural variations, work is underway on a Gulf-India undersea transmission project. It aims to create a HVDC electricity link between India and the Gulf Cooperation Council countries, particularly Saudi Arabia and the United Arab Emirates. The project is part of India's "One Sun, One World, One Grid" (OSOWOG) framework and the India-Middle East-Europe Economic Corridor announced during India's G20 Presidency in September 2023.[22]

Locations with favourable solar, wind and hydropower electricity generation potential are also frequently associated with high rates of energy poverty, low levels of economic development and limited integration into the global trading system.[23]

In Africa, renewable energy resources are plentiful, especially solar, but also wind, biomass (e.g. plants and wood), geothermal and hydropower – see Figure A.6.

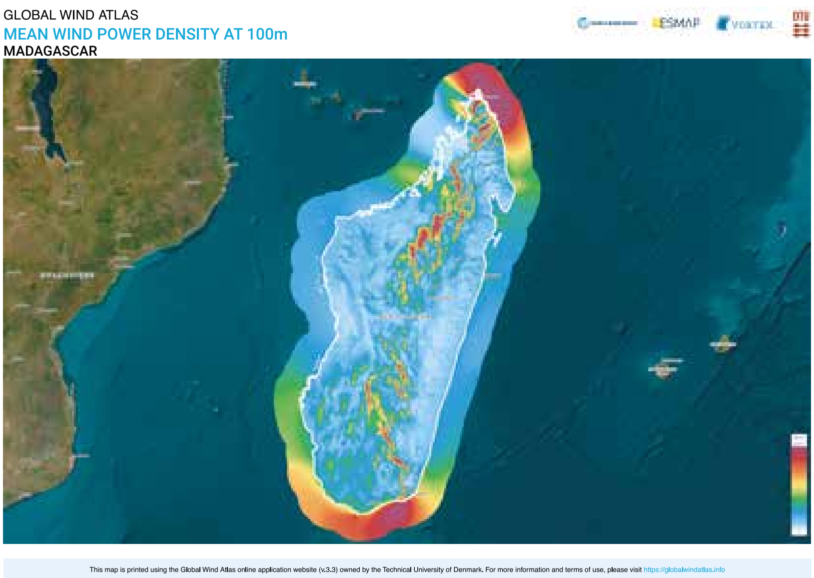
The African region has huge potential to deploy solar energy systems. The IEA estimates that Africa is home to 60 per cent of the best solar resources globally, yet only 1% of installed photovoltaic (PV) capacity.[24] IRENA estimates the continent's solar technical potential at 7,900 GW.[25] Africa's installed renewable energy production was 62GW in 2023.[26]

Morocco is an example of an African country seeking to take advantage of its endowments in solar energy through the export of solar-generated electricity. As of end 2021, renewable capacity accounted for 3,950 megawatts (MW), or 37 per cent of the country's installed electricity generation capacity – with 1,770 MW of hydro, 1,430 MW of wind and 750 MW of solar. The country aims to increase the share of renewable capacity to 52 per cent by 2030, 70 per cent by 2040 and 80 per cent by 2050.

At COP28, Morocco and Portugal signed a joint declaration on an electrical interconnection to boost the development of renewable energy. This declaration followed on from the Xlinks Morocco-UK Power Project, which seeks to construct a 4,000km HVDC subsea cable connecting the UK grid to the renewable energy-rich region of Guelmim Oued Nou in Morocco. The European Union signed in October 2022 a Green Partnership on energy, climate and the environment with Morocco, the first of its kind with a partner country, which will contribute to scaling up cooperation on the transition to renewable energy and decarbonization.

Similarly, Tunisia plans to construct an interconnector with Italy linking the Tataouine solar plant with the European energy market. This project will tap into Tunisia's natural endowments in solar energy generation and help relieve grid congestion in northern Italy.

Figure A.5: Map of Mean Wind Power Density of Madagascar



Source: Global Wind Atlas, World Bank Group.

IRENA estimates the potential of wind power generation in Africa at 461 GW[27] (see Figure A.5). Current installed capacity is 8,65 GW.[28] One example of untapped renewable wind energy potential is Madagascar, an LDC with the potential to generate up to 154 GW using offshore capacity.[29] Situated in the path of the Indian Ocean trade winds, Madagascar benefits from winds that blow consistently throughout the year.

Wind energy projects are at an early stage of development in Madagascar. They face several challenges, including the need for significant investments in grid infrastructure and the establishment of a supportive regulatory framework.[30] Low population densities and high poverty levels make it difficult to attract the necessary investment to expand renewable energy generation to service the domestic market.[31] In 2020, only an estimated 33.7 per cent of the population had access to electricity, compared to an average of 48.4 per cent for Sub-Saharan Africa.

Trading renewable electricity with the African mainland and neighbouring island states could offer Madagascar an opportunity to expand its trade footprint and to promote growth in its wind energy sector through external demand.

Hydropower is the largest source of renewable-based electricity in Africa, with sizeable unexploited potential – recently estimated at 1,753 GW (see Figure A.6).[32] In several African countries with major rivers crossing their territory, hydropower accounts for half or more of electricity generation. Africa's largest hydropower producers are Ethiopia, Angola, South Africa, Egypt, the Democratic Republic of Congo, Zambia, Mozambique, Nigeria, Sudan, Morocco and Ghana.[33]

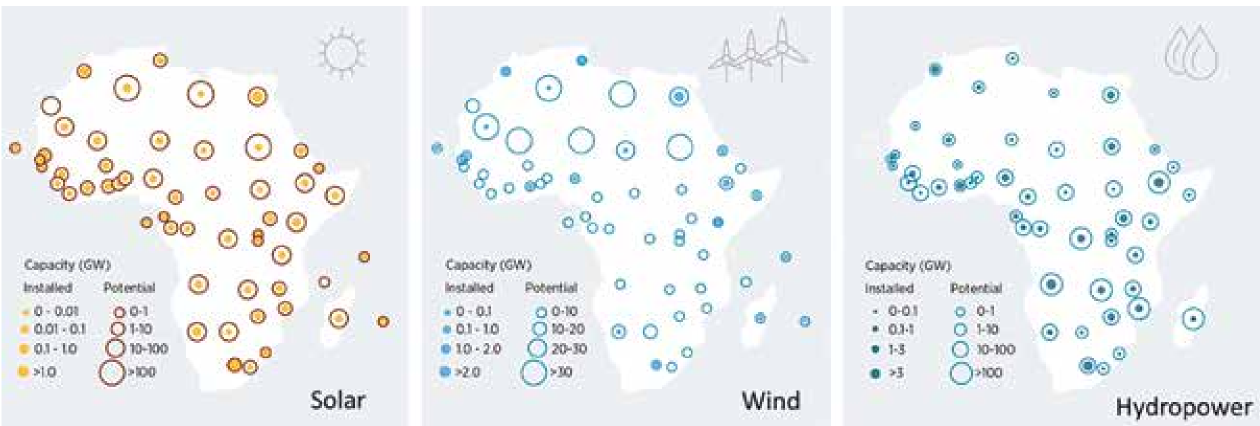
1.6 Trading renewable electricity across borders can help importing countries reach decarbonization targets

Importing electricity from economies with renewable energy surplus can help governments meet their nationally determined contributions under the Paris Agreement to move away from fossil fuels. Furthermore, technological innovation in high-voltage cable connection technology is enabling electricity to be carried across long distances with low power transmission losses and to be bundled with adjacent services, e.g. internet cables.

In South-East Europe, several EU countries have committed to phasing out coal generation, working towards net zero emissions by 2050 in line with the rest of the European Union. The planned coal phase-out dates for Hungary, Romania and Bulgaria are 2025, 2030 and 2038, respectively. These plans to phase out coal power generation will be greatly helped by expansion of renewable energy generation in the Caspian Sea and South Caucasus and transmission of resulting electricity through the planned Black Sea Submarine Cable.[34]

In September 2024, a project to create the Caspian Sea-European Union Green Energy Corridor was initiated, with the aim of enhancing the transmission of green energy from the Caspian region to Europe.[35] This corridor involves a strategic partnership between Azerbaijan, Georgia, Hungary and Romania. It focuses on the production and transmission of renewable energy, particularly through the use of undersea cables, across the Caspian Sea and the Black Sea.

Figure A.6: Renewable energy potential and capacity installed in Africa, for wind, solar and hydropower



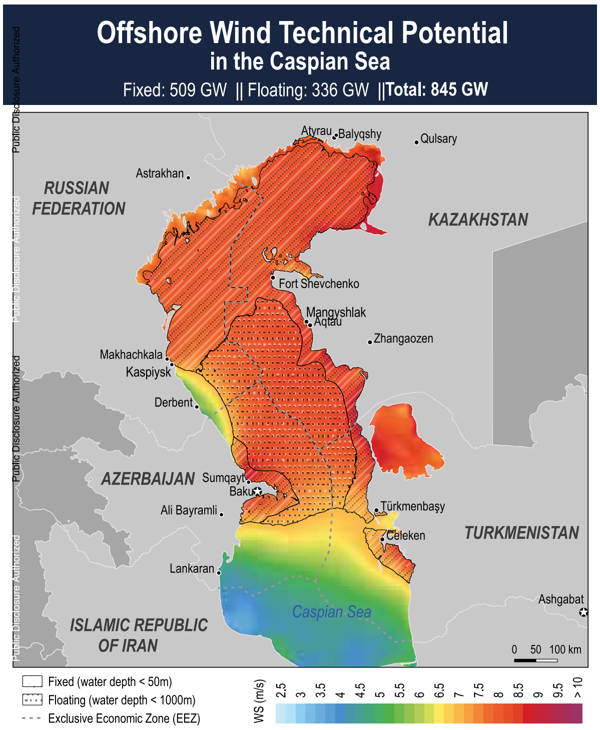
Source: WMO 2022.[36]

The project includes the construction of a Black Sea submarine cable with a capacity of 1,000 MW and a length of 1,195 kilometres. The World Bank has approved a USD 35 million loan for the first phase of the project, with the aim of beginning construction in early 2025 and completing the project by 2030. The project should improve energy security and decarbonize energy supply by transporting renewable energy from the Caucasus region to Europe. It also includes the laying of a parallel fibre-optic cable to enhance digital connectivity.

Both Azerbaijan and Kazakhstan are well-established energy exporters with significant surpluses and expertise in operating in complex energy markets. The Caspian Sea region enjoys significant renewable energy potential, notably in wind energy. A March 2020 assessment by the World Bank's Energy Sector Management Assistance Program (ESMAP) estimated the technical potential of offshore wind energy in the Caspian Sea at 845 GW – see Figure A.7.

Singapore is also collaborating with trading partners to import green energy to buttress its own energy transition plans and to meet rising demand for energy. Singapore imported renewable electricity for the first time in 2022. The Lao PDR-Thailand-Malaysia-Singapore Power Integration Project enables up to 100 MW of hydropower to be exported from Lao PDR to Singapore via Thailand and Malaysia using existing infrastructure.

Figure A.7: Potential of offshore wind in the Caspian Sea



Source: World Bank Group.[37]

Lao PDR, a least developed country scheduled to graduate from LDC status on 24 November 2026,[38] has seen its electricity exports reach nearly 28.5% of the country's total exports in 2023, representing USD 2.4 billion. This underscores the strategic importance of electricity trade for the nation's economy. Hydropower currently accounts for about 70% of total electricity generation output in Lao PDR. The country has about 10 onshore wind power projects with a total design capacity of 3.6 GW in the planning stage. It currently sells electricity to six countries, namely Cambodia, China, Myanmar, Singapore, Thailand and Viet Nam, and plans to increase electricity exports.[39]

Singapore also plans to import 100 MW equivalent of electricity from a solar farm in Pulau Bulan, Indonesia, through a new interconnector in 2024 or soon after.[40] Additionally, there are proposals to import 1 GW of clean electricity from Cambodia, an initiative that will further support Singapore's long-term objective of importing up to 4 GW of low-carbon electricity by 2035.[41]

Another project to support Singapore's transition is the Australia-Asia PowerLink, a private sector proposal that builds on Northern Australia's comparative advantage in producing solar electricity. Through the construction of a large-scale solar farm, the project would transmit as much as 1.75 GW of electricity to Singapore via a 4,200km subsea cable, covering up to 15% of Singapore's energy needs.[42]

Relevant also in this regional context is the United Nations' Economic and Social Commission for Asia and the Pacific (ESCAP) Regional Road Map on Power System Connectivity. The Road Map details nine strategies to support increased cross-border power system integration, suggesting key milestones, timeframes and responsible entities for realizing each element. ESCAP's Green Power Corridor Framework addresses Strategy 9 of the Road Map, providing a set of principles and metrics to ensure the coherence of energy connectivity initiatives and the Sustainable Development Goals.[43]

The United Kingdom is also importing renewable electricity to help it transition from fossil fuels. The UK's National Grid estimates that between 2020 and 2030 interconnectors will help the UK prevent 100 million tons of carbon emissions.[44]

1.7 Interconnectors create interdependence underscoring the case for a global grid

"We need new transmission lines crossing frontiers and connecting different time zones, creating a global ecosystem of interconnected renewables that are shared for mutual benefit and global sustainability. This must be combined with expanded and modernized national and regional grids and complemented with the rapid scale-up of mini-grids and off-grid solar solutions."[45]

One Sun Declaration, COP27

Building inter-regional or cross-border transmission grids, often referred to as "supergrids", can lower the cost of making the transition from fossil fuels and reduce fluctuations in supply. Studies show that wind power is a reliable source since the wind is always blowing sufficiently in some parts of the world to generate energy. Moreover, the seasonal patterns of wind and solar power are complementary, ensuring their combined supply remains relatively constant throughout the year.[46]

Since electricity can flow in both directions along HVDC cables, this interconnection and shared value could eventually lead to the establishment of a global green grid akin to the World Wide Web for the internet. In October 2018, Prime Minister Narendra Modi of India proposed the idea of "One Sun, One World, One Grid" (OSOWOG) for the first time at the First Assembly of the International Solar Alliance (ISA) in India.

During COP26 in Glasgow, Scotland, in November 2021, the Green Grids Initiative (GGI) was launched – see Box A.3. Initiatives such as the Global Energy Interconnection Development and Cooperation Organization (GEIDCO), a non-profit international organization based in Beijing, are also actively promoting inter-regional or cross-border transmission grids.

Box A.3: One Sun, One World, One Grid

The GGI and the OSOWOG initiatives were unveiled jointly by India and the UK as part of their bilateral collaboration in conjunction with the ISA and the World Bank Group. These initiatives, focusing on the global transition to renewable energy, work in partnership as GGI-OSOWOG, emphasizing the collective commitment to a common goal. This first-ever international network of interconnected solar grids seeks to connect 140 countries to continuous solar power and has been endorsed by 80 ISA member countries.

The vision behind the OSOWOG initiative is the mantra that "the sun never sets". The idea is to harness solar energy from different parts of the world, where the sun is shining at any given moment, and efficiently transmit that power to areas where it is needed. By creating a connected global grid, regions that experience daylight can contribute excess solar power to other regions that may be in darkness, balancing energy production and consumption on a global scale.

The OSOWOG initiative is to be carried out in three phases:

- In the first phase, the Indian grid would be connected to the grids of the Middle East, South Asia and South-East Asia to develop a common grid. This grid would then be used to share solar energy as needed, in addition to other renewable energy sources.
- The second phase would be to connect to the pool of renewable resources in Africa.
- The third phase would look at achieving global interconnection, with the aim of 2,600 GW of interconnection by 2050. The goal is to integrate as many economies as possible to create a single power grid of renewable energy. This can then be accessed by all economies.

ISA also aims to mobilise USD 1 trillion of funding by 2030 to assist developing economies in expanding their solar power to meet their energy needs.

Source: Invest India.[47]

Connecting national grids across borders can unlock significant benefits by enabling the sharing of renewable resources, balancing intermittency and enhancing energy security. As demonstrated in various regional initiatives, such interconnections can facilitate the transport of surplus energy from areas of high generation capacity to regions with unmet demand. This collaborative approach not only enhances the reliability and resilience of power systems but also accelerates the deployment of renewable energy by optimizing resource utilization and creating larger, more integrated electricity markets.

The goal of a single, fully interconnected "global grid" highlights the growing importance of cross-border electricity trade and regional grid interconnections to facilitate a global transition towards renewable energy.

Creating a global grid, however, currently faces significant challenges (see Section B below).

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Addressing issues facing cross-border transmission of renewable electricity

B

2.1 Overview

Global cross-border electricity trade is far below its potential. International electricity trade, measured by gross imports in each country, was 2.8 per cent of total electricity supplied, totalling 809 TWh in 2021.[1] Net imports (i.e. total global energy demand, including imports, in excess of aggregate total domestic generation) represented 1.12 per cent of total electricity production in 2022.[2]

In many parts of the world, progress on interconnector projects is slow or entirely stalled.[3] Grids are not keeping pace with the transition to renewables due to the time it takes to build and update them. There are also challenges related to the operation of grids with high levels of renewables.[4] Currently, over 3,000 GW of renewable generation capacity is in "grid queues", waiting to be exploited, with many projects in advanced stages of development.[5]

As grid operators seek to upgrade their networks, supply chain bottlenecks are emerging. The Utilities for Net Zero Alliance, which unites leading global utilities and power companies, is seeking to promote supply chain expansion for grid and interconnection development.[6] Diversifying associated global supply chains could offer new opportunities for developing country and LDC suppliers to join manufacturing supply chains.

Interconnector projects are capital-intensive and require large up-front investment before revenues flow. Many grid operators are cash constrained, making access to finance challenging.[7] Since interconnectors do not distinguish between the production method used to generate electricity transmitted along HVDC lines, interconnector projects may not automatically meet climate finance criteria. This also affects access to trade finance provided by multilateral development banks (MDBs) as they have strict criteria for projects seeking to access sustainable trade finance.

In most jurisdictions, grids are required to go through extensive planning and processes to obtain permits that can take many years.[8] Interconnectors have the additional complication of involving regulators in multiple jurisdictions. Delays in one jurisdiction, including those of transit economies, can have a domino effect, extending already lengthy project delivery timeframes and leading to cost overruns. Transparency about regulatory approval and greater predictability on timelines would help to boost investor confidence.

A comparison of current and planned electricity interconnections with the far more extensive global cable network that supports the World Wide Web highlights the scope for growth. There may also be lessons that can be learned from the WTO's experience with trade rules concerning telecoms and information technologies. Government procurement disciplines are another area where grid operators may draw inspiration.

2.2 Cross-border electricity trade

Classification

Electricity is classified as a merchandise good by the World Customs Organization (WCO). The International Convention on the Harmonized Commodity Description and Coding System (HS Nomenclature), used to classify traded goods, designated the code 2716 to electrical energy. However, it is an optional heading, meaning that not all trading partners use it.[9] Its optional status reflects the view held by some that electricity should instead be considered a service.

Inclusion of electricity in the HS Nomenclature enables economies to uniformly categorize and report electricity trade, ensuring clarity and consistency in customs and trade statistics. Classifying electricity as a good acknowledges its role as a tradable commodity with significant economic value. It also assists statistical reporting and economic analysis. The WCO's HS Nomenclature makes no distinction on the method of power generation or whether it requires the input of other energy sources (i.e. primary or secondary electricity).[10]

Electricity shares several characteristics with traditional goods that are produced and consumed. The generation of electricity involves substantial infrastructure and investment similar to manufacturing processes in other industries. Moreover, electricity can be quantified and measured in terms of production, consumption and trade (e.g. in kilowatt-hours), making it straightforward for standardization and statistical tracking.

Global electricity trade

In 2023, the reported value of electricity trade to UN Comtrade was approximately USD 132.8 billion globally.[11] This compares with a market value of electricity generation worldwide, valued by Statista, at approximately USD 1.6 trillion in 2023.[12] Some 68 economies reported electricity exports worth USD 67.2 billion. A further 69 economies reported USD 65.6 billion in electricity imports. A total of 55 economies reported both exports and imports of electricity in 2023. Global electricity trade has grown in nominal terms by USD 99.8 billion since 2003, with 64% of that expansion occurring since 2013.

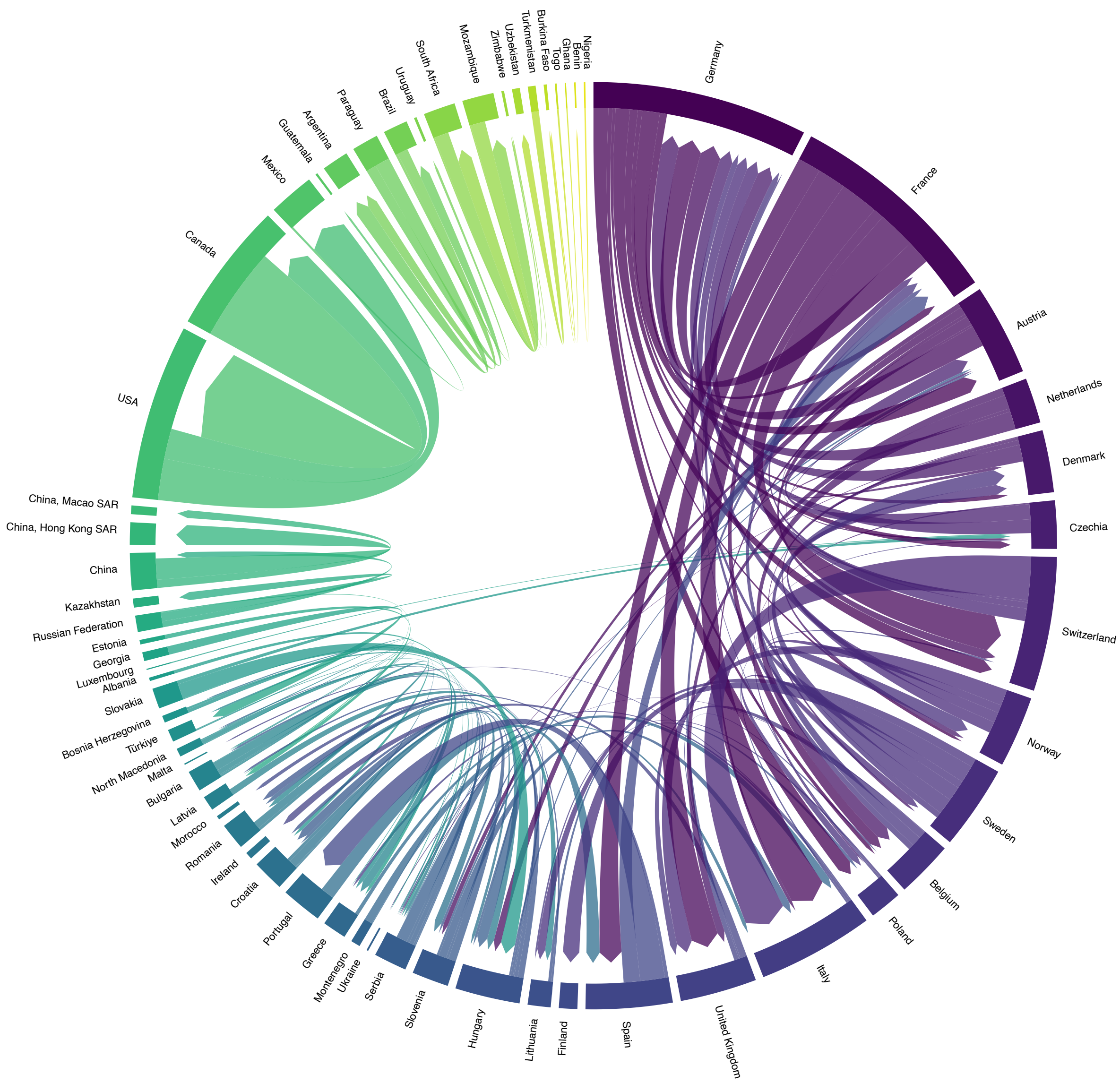
Most trade in electricity takes place in the EU single electricity market (see Figure 2.8). Seven of the ten largest exporters and importers of electrical energy are EU member states. Two other top ten exporters are EU-adjacent nations (Norway and Switzerland). A similar picture emerges on the import side, with Switzerland and the UK also in the top ten of global importers.

Figure B.1 below shows a chord diagram of imports in TWh where reported values were greater than USD 50 million.

In 2023, the largest importers of electricity were Germany, which imported 72 TWh from ten neighbouring countries, followed by Italy with 57 TWh and the United States with 51 TWh. The largest exporters were France (89 TWh), followed by Canada (51 TWh), Germany (40 TWh), the United States (39 TWh) and Sweden (38 TWh).

All European Union member states, including net exporters, benefit from electricity imports at times. During 2023, none of the 27 member countries was solely an exporter. The EU has set an interconnection target of at least 15% by 2030 to encourage EU countries to interconnect their installed electricity production capacity.[13]

Figure B.1: Bilateral imports (mirror exports) of electricity in 2023 (kWh)



Source: UN Comtrade, selected trade lines where quantity unit was in kWh and trade value higher than USD 50 million.

The EU's interconnection target means that each member state should have in place electricity cables that allow at least 15% of the electricity produced on its territory to be transported across its borders to neighbouring countries. This policy is based on the understanding that connecting Europe's electricity systems will allow the EU to boost its security of electricity supply and to integrate more renewables into energy markets, thus achieving its climate and energy goal.

The IEA highlights that different regional electricity trading "blocs" can be observed around the world:

- In North America, trade primarily involves Canada, the United States and Mexico, with Mexico also exporting to Guatemala.
- In Latin America, significant trade occurs between Argentina, Brazil, Paraguay and Uruguay.
- In Africa, major bilateral trade involves Mozambique and South Africa, with each importing around 8 TWh from the other and simultaneously exporting to Zimbabwe. Another African trading bloc includes Benin, Burkina Faso, Ghana, Nigeria and Togo.
- India plays a major role in cross-border trade and regional connectivity in South Asia. Presently, India benefits from hydropower imports from Bhutan and Nepal. Nepal has 5,000 MW in hydropower electricity above the needs of its domestic energy market. India's hydropower electricity imports from Bhutan and Nepal were valued at USD 500 million in 2023. Investments for further development of new hydro projects (about 1,200 MW) were agreed in mid-2022.[14]

In many cases, electricity trading is conducted within regional power pool arrangements. These are integrated power transmission grid and electricity markets across countries, often within regional trading arrangements, with the purpose of creating and leveraging economies of scale in the generation and transmission of electricity. Regional power pools and coordinated electricity markets aim to optimize the distribution of electricity, ensuring that supply meets demand more effectively across large areas, thereby reducing the possibility of redundant generation capacity within individual countries.

Box B.1 delves into the Southern African Power Pool (SAPP) arrangement and outlines some of SAPP's plans for new interconnectors. The African Union is seeking to develop a Single Electricity Market in Africa, building on the five existing power pool arrangements. Investments in cross-border transmission infrastructure to deepen electricity trade lie at the heart of these plans.

Box B.1: The Southern African Power Pool (SAPP)

Created in 1995 through a Southern African Development Community treaty, the Southern African Power Pool (SAPP) includes 12 member countries, represented by their respective national power utilities. It facilitates cross-border electricity trade in Southern Africa. The SAPP balances regional supply and demand through coordination mechanisms, a strong regulatory framework and ongoing investments in transmission infrastructure. It is actively working on new transmission projects, with a particular focus on integrating renewable energy sources into these projects and alleviating congestion in the current grid. Projects include:

- The ***Kalumbila-Kolwezi*** Interconnection Project, which involves the construction of a high-voltage line linking the Republic of Zambia and the Democratic Republic of the Congo.
- The ***Angola–Namibia*** interconnection, which aims to link the electricity networks in north-west Namibia with the southern part of Angola, potentially also integrating the proposed Baynes Hydro Power Station into the Namibian and Angolan national electricity networks. Angola was recognized in the SAPP pool plan as one of the countries with surplus hydropower.
- The ***Inga-Soyo*** interconnector project, through which Angola plans to tap into renewable electricity produced at the hydroelectric dam at Inga in the Democratic Republic of the Congo. Plans are underway to upgrade power generation at the Inga Falls.
- The ***Zimbabwe, Zambia, Botswana, Namibia (ZIZABONA)*** project, which consists of the development of new transmission facilities in Zimbabwe, Zambia, Botswana and Namibia, with the aim of creating a western transmission corridor to the SAPP.

Similar power pool arrangements are found in other regions. For example, the Central American Electrical Interconnection System (SIEPAC) connects the electricity grids of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama so promoting regional energy integration and cooperation. Since 2015, efforts have been underway to integrate larger amounts of renewable energy into the SIEPAC grid through the Clean Energy Corridor of Central America initiative supported by IRENA, bilateral donors and multilateral development banks (MDBs).

Costa Rica's electricity system is already almost fully renewable due to high hydropower availability. Costa Rica's transmission system is connected to Panama and Nicaragua as part of SIEPAC. Electricity trade with neighbouring countries in recent years has usually remained under 1 TWh (less than 10% of national demand).[15]

In 2021, a World Bank Policy Research Paper examined the potential savings in electricity supply costs from unrestricted electricity trade between Latin American countries. The volume of cross-border regional electricity trade currently accounts for less than 5% of the total regional generation. One of the key impediments identified was a lack of regulatory/institutional reforms in the power sector to facilitate trade. Introducing these reforms would lead to savings of between USD 1.5 billion and almost USD 2 billion, and without expanding their current electricity generation capacity.[16]

Tariffs

In so far as it is considered a good and classified in the WCO HS nomenclature, cross-border trade may attract tariffs as well as other duties and charges imposed by an importing country. WTO members' tariff commitments on electricity imports vary. Many members opted not to make any commitments and left electricity trade unbound in their schedules of tariffs applied on goods, meaning that no upper limits were set. Others indicated tariff rates in these schedules. Furthermore, there are others who have no HS code for electrical energy in their schedules of commitments (e.g. Australia and New Zealand).

Among members of the SAPP, nine of the 12 participating members have not made tariff commitments on electrical energy in their goods schedules. Three others set their maximum tariff rates at 60% (Lesotho), 80% (Angola) and 100% (Democratic Republic of the Congo) respectively. Box B.2 provides a short explainer on tariffs and the WTO.

Among the WTO members that have made tariff commitments on electrical energy is the European Union (the largest electricity market worldwide), which has bound its tariff rates at 0%. This is a commitment not to apply tariffs on imports of electrical energy into the European Union from non-EU member states. In addition, no tariffs are applied on trade within the EU's Single Market.[17]

Box B.2: Tariffs and the WTO: an explainer

Customs duties on merchandise imports are called tariffs. Each WTO member has set out how it intends to treat the imports of other members' merchandise in a schedule of commitments, often referred to as "goods schedules". These schedules are legal instruments that form an integral part of the General Agreement on Tariffs and Trade (GATT) and the WTO Agreement. The schedules include so-called "bound" or maximum duties. Bound tariffs are commitments not to increase a rate of duty beyond an agreed level.

Where a tariff is indicated as "unbound", no commitment has been made. The member concerned can set the rate of duty at the level of its choice; the member is therefore at liberty to determine its own tariff rate. Applied rates are the duties that are actually charged on imports and are often below the bound rates. Goods schedules are one of the main WTO tools to ensure transparency, security and predictability for world trade.

Members' schedules also include commitments on "Other duties and charges" (ODCs). Like the customs tariff, ODCs have a maximum level for each product and are expressed either in *ad valorem* (i.e. charged as a percentage of the price of the product) or non-*ad valorem* format. A "null" value in the ODC column of the schedule means the ODC is duty free. The WTO Goods Schedules e-Library is an online platform that facilitates access to the legal instruments that embody the WTO Schedules of Concessions (https://goods-schedules.wto.org/)

Source: WTO Secretariat.

The United States has also bound its import tariff on electrical energy imports at 0%. Among other North American states, Mexico has bound an *ad valorem* duty rate at 35% and Canada has left this tariff line unbound.

Among countries that have joined the WTO since its creation in 1995 (recently acceded members), both Lao PDR (20% *ad valorem*) and Nepal (15% *ad valorem*) have made tariff bindings on electrical energy imports in their tariff schedules.[18]

WTO members do not distinguish between renewable and other energy sources in their tariffs (e.g. by listing a separate tariff line or binding their tariffs at different rates).

Based on the latest WTO tariff data covering the period 2020-2024, out of 107 economies (with the EU counted as one) that reported information on electricity trade, 66 applied a zero-tariff for electricity imports. A further five economies applied tariffs less than 5%. A total of 23 members applied a 5% tariff, while three more applied tariffs higher than 5% but less than 10%. A further six economies applied a 10% tariff.[19] One member applied a specific duty with an *ad valorem* equivalent of 29%.

Classifying electricity as a good raises some challenges for customs valuation. The WTO Customs Valuation Agreement (CVA), also known as the Agreement on Implementation of Article VII of the General Agreement on Tariffs and Trade 1994, "aims for a fair, uniform and neutral system for the valuation of goods for customs purposes – a system that conforms to commercial realities, and which outlaws the use of arbitrary or fictitious customs values."

For practical reasons, electrical energy is not cleared by customs in the normal way. Clearance is done after the entry of the good (i.e. electrical energy) into the territory and according to measurements at power plants. Valuation issues can potentially arise in situations when minimum payments are required which are not linked to consumption and payments are required relating to construction and maintenance of the transmission system in the exporting country.[20]

Transit

Another concern that can arise is the stacking of multiple transmission charges when electricity crosses different countries – a practice referred to as "pancaking". This phenomenon can occur when electricity is transmitted over long distances and crosses multiple transmission zones (i.e. legal jurisdictions), each managed by a different transmission system operator or governed by different regulatory frameworks.

Each transit country may impose its own transmission charge for the use of its infrastructure. As electricity flows from the point of generation to the point of consumption, these charges accumulate or "stack" up, similar to a stack of pancakes, hence the term "pancaking".

The stacking of transmission fees (i.e. transit fees) can significantly increase the overall cost of delivering electricity across regions. This in turn discourages long-distance electricity trade and reduces market efficiency. Box B.3 outlines WTO disciplines covering transit.

2.3 Supply disruptions and export restrictions

Since electricity is difficult to store in significant volumes and for long time periods, non-delivered amounts of electricity may necessitate the curtailment of supply to electricity users. For example, in South Africa, the energy company Eskom's load shedding protocols (i.e. supply restrictions) first impact large industrial users and then are extended to domestic users.[21]

When the source of electricity supply is external (i.e. an electricity exporter in another economy), measures taken to stabilize the domestic grid in that jurisdiction may lead to disruption of exports. For example, supply could be affected by issues such as a plant failure, which could cause a change in frequency to ripple throughout the entire network and extend beyond national borders.[22] Extreme weather events, labour disputes and other events may also lead to interruptions of supply.

Other risks of disruption in electricity supply may be regulatory or geopolitical in nature. Restrictions might be introduced to prioritize national energy needs, to control prices for domestic users, or for national security reasons. These factors also have a bearing on energy transit.

Article XI of the GATT 1994 deals with the General Elimination of Quantitative Restrictions. Broadly, it prohibits export bans and restrictions, but allows members to apply them temporarily to prevent or relieve critical shortages of foodstuffs or other essential products. The "general exceptions" in GATT Article XX may also be relevant – for example, these provide flexibilities for trade restrictions that are essential to the acquisition or distribution of products in general or local short supply.

Box B.3: WTO, the GATT and transit

To the extent that electricity is considered a good, the provisions of Article V of the General Agreement on Tariffs and Trade are relevant. (The GATT is the predecessor to the World Trade Organization). Article V covers "Freedom of Transit". The seven clauses of Article V variously define traffic in transit and impose obligations on members. These provisions cover *inter alia* transit routes, unnecessary delays and restrictions, transit duties and charges and contain non-discrimination provisions.

Non-discrimination is a fundamental principle of the GATT 1994 and the WTO. In essence, trade without discrimination implies that a member should not discriminate between its trading partners giving all of them "Most-Favoured-Nation" (or MFN) status. It also should not discriminate between its own and foreign products, services or nationals (giving all of them "national treatment").

In the context of transit, non-discrimination may imply not applying divergent treatment according to the mode of transport, country of origin, or destination or applying customs duties, transit duties, or other charges – except as necessary for transportation, administrative expenses, and cost of services rendered.

Article V:4 states: "All charges and regulations imposed by contracting parties on traffic in transit to or from the territories of other contracting parties shall be reasonable, having regard to the conditions of the traffic."

Also relevant are the accession commitments of members who have joined the WTO since 1995. Some recently acceded members have undertakings on Article V, including on charges for transportation of transit goods. Disciplines of the WTO Trade Facilitation Agreement and the findings in WTO disputes that have dealt with transit may also be relevant.[23, 24]

In addition, the General Agreement on Trade in Services (GATS) can apply to activities such as the laying of cables, their maintenance, the transmission of electricity, and the disposal of cables that may be undertaken in transit states. Much like the patchwork of commitments on tariffs, there is similar divergence between members with respect to the inclusion of core energy services, such as transport, transmission and distribution, in their schedules of services concessions.

Also relevant to transit are obligations contained in other conventions and treaties outside WTO rules and agreements. For example, the UN Convention on the Law of the Sea contains provisions providing the right to lay submarine cables and pipelines (Article 112) on the continental shelf, but stipulates that due regard is paid to cables or pipelines already in position (Article 79).[25] The Energy Charter Treaty, an international agreement on cross-border cooperation in the energy industry, also includes provisions on transit (Article 7).[26]

Source: WTO Secretariat.

Export restrictions are a prominent topic in trade policy. Measures taken during the 2007-2008 food price crisis and during the COVID-19 pandemic are prominent examples. These measures also came to the fore again as various WTO members sought to assure their agricultural supplies after the outbreak of the war in Ukraine.[27]

A WTO information note on export prohibitions and restrictions published in April 2020 explains how restrictions initiated by one economy may create a domino effect. If trade does not provide secure, predictable access to essential goods, economies may feel they have to pursue domestic production instead, even at much higher prices. Such a scenario results in lower supply and higher prices for a much-needed commodity.[28]

The WTO's 2021 World Trade Report further noted that export restrictions adopted to secure national supplies in response to a crisis can often lead to trade retaliation from other countries, as well as dwindling imports and escalating conflicts, leaving all those concerned less well-equipped to cope with and recover from the shock that motivated the trade restrictions in the first place.[29]

WTO rules promote transparency in trade policies, including through the notification of changes to members' regulations and procedures. These transparency rules also include export restrictions. Such measures should be notified to the WTO as soon as possible in line with the 2012 "Decision on Notification Procedures for Quantitative Restrictions".

By following WTO transparency rules, members provide assurance to their trading partners and investors, fostering a more predictable environment for trade, including cross-border electrical energy and transit.[30] This transparency is particularly helpful in the energy sector, where issues related to grid access, transit fees and regulatory practices can significantly impact trade flows.

A prominent initiative seeking to manage the risks associated with interconnection is the Quad Partnership for Cable Connectivity and Resilience announced by Australia, India, Japan and the United States at the 2023 Quad Summit in Hiroshima, Japan. In July 2024, the government of Australia announced the launch of a new USD 18 million Cable Connectivity and Resilience Centre to help ensure undersea cable networks in the Indo-Pacific are resilient and all countries can benefit from reliable connectivity.

2.4 Supply chain bottlenecks create opportunities to promote re-globalization

The acceleration of renewable energy deployment calls for modernizing distribution grids and establishing new transmission corridors to connect renewable resources – such as solar PV projects located far from demand centres in cities and industrial areas.[31]

Reaching national energy and climate goals means adding or refurbishing a total of over 80 million kilometres of grids by 2040, the equivalent of the entire existing global grid.[32]

Supply chain bottlenecks

In 2023, the IEA reported that the supply chain for grid infrastructure is showing tightness.[33] Manufacturers of transmission lines have struggled to cope with limited inventory, labour and material shortages, inflation, long lead times for the production of components and knock-on delays for customers.

Constructing a transmission line is a complex task, requiring a variety of components and technologies (e.g. cables, power lines, transformers, substations and control systems). Various materials are needed to manufacture these technologies and components. Aluminium and copper are the principal materials for the manufacture of cables and transmission lines. Aluminium is preferred for overhead power lines and increasingly used for underground and subsea transmission cables. [34]

An overhead HVDC transmission line requires around 5 kilogrammes of aluminium per megawatt and per kilometre (kg/MW/km) for an overhead HVDC line and 29 kg/MW/km of copper for an underground cable. Metal requirements are far higher for AC transmission lines. An overhead AC transmission line requires around 11 kilogrammes of aluminium per megawatt.[35] Wood, steel and concrete are used for the pylons in the distribution grid, while steel is also used for transmission towers to support the overhead conductors.

Power transformers are a further component of power systems. Almost half of the material (by weight) required for their manufacture is steel, of which more than 60% is grain-oriented electrical steel (GOES) while the remainder is construction steel. GOES is almost 2.5 times more expensive than construction steel and must meet minimum efficiency standards for transformers, such as the Energy Efficiency Program for Certain Commercial and Industrial Equipment in the United States and the Ecodesign Directive in the European Union.[36]

GOES is another segment of the supply chain where the IEA reports pressure. Growing demand for non-GOES electrical steel for making electric vehicles (EVs) is leading some steel producers to switch part of their production away from GOES. Production of GOES is also under pressure as it is used in EV charging stations as well.

Semiconductors are a further product for which the IEA is reporting supply shortages. High-power semiconductors are a central component of HVDC converter valves, used in HVDC converter stations. In turn, many materials are required in the supply chains of the components of the HVDC stations, including silicon, steel, aluminium, copper, nickel, polymer and zinc.[37]

The IEA suggests that the expected increase in demand for HVDC equipment over the next ten years might put supply chains under additional pressure, potentially amplified by a lack of experienced personnel in manufacturing and in areas such as engineering, construction and project management.

Constructing new transmission lines can also be affected by shortages in related service markets. Subsea cables, for example, require cable-laying vessels operated by specialist providers. Depending on the future deployment of offshore wind and subsea interconnectors, additional vessels could be needed. If their construction is not planned well in advance, there could be a shortage and a delay to projects.[38]

To help address supply chain issues, the Utilities for Net Zero Alliance (UNEZA) was established at COP28 in 2023. This Alliance unites leading global utilities and power companies with the aim of spearheading the development of grids that are ready for renewable energy, promoting clean energy solutions and advancing electrification efforts. In UNEZA's Roadmap to 2030 and beyond, two of the four priority actions speak to IRENA's projection that grid investment must be boosted from the benchmark figure of USD 368 billion per year to USD 720 billion per year by 2030 and to de-risk supply chains by addressing bottlenecks that are leading to a significant mismatch between supply and demand.[39]

UNEZA's roadmap runs parallel to discussions at the WTO about environmental goods and services, in particular under the Trade and Environmental Sustainability Structured Discussions (TESSD) initiative among a group of WTO members. At the WTO's 13th Ministerial Conference (MC13), TESSD convenors issued an analytical summary of their work to date on the topic and outlined the path to achieving concrete outcomes by MC14 (WT/MIN(24)/11/Add.3). The "living" document will be further updated based on discussions and contributions under the working group (see Box B.4).

Re-globalization opportunities

A major factor in the location of cable manufacturing is the cost and time associated with transporting finished cables. With expansion of grid networks and interconnectors needed in areas of comparative advantage in renewable energy production, there may be re-globalization opportunities to expand manufacturing in new locations and increase manufacturing capacity.

The market for electrical cables has been growing significantly, with the demand for insulated wires increasing by 35% over the past decade.[40] Africa's demand for transmission cables is expected to grow by 6.8% annually between 2022 and 2027, driven by substantial investments in grid expansion and renewable energy projects.[41] For example, Africa's cross-border grid interconnection projects, such as the West African Power Pool (WAPP) and the SAPP, are expected to require an estimated 10,000 kilometres of new transmission cables over the next decade.[42]

Box B.4: WTO TESSD discussions on environmental goods and services

In November 2020, Trade and Environmental Sustainability Structured Discussions (TESSD) were launched as an initiative by a group of WTO members to intensify work on the topic, complementing the work of other WTO committees and bodies, including the Committee on Trade and Environment. The initiative is open to all members. It currently has 76 co-sponsors representing more than 85% of global trade and including members from all regions and at all levels of development. A unique feature is the participation of stakeholders from the business community, civil society, academic institutions and other international organizations, who enrich the deliberations in TESSD with their technical expertise.

After intense technical work, in February 2024, during the WTO's 13th Ministerial Conference in Abu Dhabi, Canada and Costa Rica, the co-convenors of the initiative, released a "package" of outcomes. In particular, the outcome documents identified:

- practices to guide the design and implementation of trade-related climate measures;
- renewable energy goods and services that are key for the energy transition;
- trade-related action areas to support a circular economy;
- considerations that can guide subsidy design to benefit the environment while avoiding trade distortions.

In particular, the analytical summary of discussions on environmental goods and services and renewable energy (WT/MIN(24)/11/Add.3) included: (i) indicative lists of renewable energy goods and services, including goods such as photovoltaic cells for solar energy, gearboxes for wind turbines, generators for hydropower, and electrolysers for green hydrogen production, and services such as engineering, testing and analysis, environmental consulting, operation, maintenance and repair, and recycling; (ii) trade barriers and supply chain bottlenecks; (iii) developing country perspectives; and (iv) opportunities and approaches for promoting and facilitating trade in these goods and services.

The group continues its regular work towards potential future outcomes on the topic.

Source: WTO Secretariat

The African market for insulated electrical cables is currently valued at approximately USD 4.3 billion, with South Africa and Egypt being the largest importers of these products, accounting for 22% and 15% of Africa's total imports, respectively.[43] Countries in East and North Africa are key regions where grid expansion is taking place. For example, Kenya is expected to invest over USD 1.5 billion in transmission infrastructure over the next five years, with cables accounting for a significant portion of the investment.[44]

The International Trade Centre's Export Potential Map suggests that there are some USD 5.6 billion in untapped export opportunities regarding electrical cable (HS Code 8544).[45] Several LDCs may have potential to expand exports of these cables. The Export Potential Map indicates Ethiopia, Bangladesh and Myanmar have an estimated untapped export potential of USD 150 million in electrical cables.

A 2019 report by the Beijing-based GEIDCO asserts that energy interconnection can open opportunities for the co-development of electricity, mining, metallurgy, manufacturing and trade on the African continent.[46] The report argues that by coordinating the planning and construction of clean energy (notably hydropower), an integrated industrial development plan is feasible that covers value addition activities such as mining, smelting and mineral-processing. Solving the problems of power shortages in industrial development and limited power markets would unlock enormous economic and social benefits according to the authors.

Compliance with new technical regulations and standards

One requirement that new entrants, existing manufacturers of electrical cables and other related electricity grid products as well as electricity generators must respect is compliance with technical regulations and standards. Renewable energy projects must comply with the technical specifications and standards set by grid operators, and meet power quality standards defined by grid operators. They must also meet requirements for safety and security, including cybersecurity, and adhere to grid codes that define the necessary measures for maintaining grid stability.[47]

Additionally, manufacturers and generators must respect other procedures, standards and technical requirements, including those related to environmental impact. One discernible trend is towards more standards and technical regulations requiring greater sustainability in the manufacture of components used in power grid components. For example, some new measures require the phasing out of certain materials, such as lead in grid equipment and sulphur hexafluoride (SF6), a highly potent greenhouse gas, used to keep networks running safely.

WTO rules and committee work covering transparency have a role to play by ensuring a flow of information from WTO members about the scope of new measures and their entry into force. WTO committees also provide an avenue for members to make comments on other members' draft rules (see Box B.5).

2.5 Access to finance

Overview

Achieving the transition to net zero and universal electricity access will require significant up-front capital investment to modernize grids and roll out new cross-border interconnection infrastructure.[48] In 2021, there were almost 80 million km of overhead power lines and underground cables worldwide of varying voltage levels. This equates to roughly a hundred trips to the moon and back.[49]

IEA projections suggest that meeting national climate pledges requires a three-fold increase in grid investments over the next five years from current levels. Meeting a Net Zero Emissions Scenario requires a five-fold increase. Of the USD 770 billion funnelled each year into clean energy for what IEA terms as "emerging markets and developing economies" (EMDEs), only one-fifth is currently directed into building, scaling and future-proofing electricity grids.[50] Figure B.2 highlights the IEA's projection of the required levels of grid and battery storage investment needed to meet their Net Zero Emissions Scenario.

In many developing economies, securing the necessary investment to upgrade grids and roll out interconnectors is proving difficult to find. Many projects are stalling due to lack of funds. A World Bank database tracking the financial and operational performance of more than 180 utilities in over 90 countries shows that fewer than 40% of utilities collect enough revenue to meet their annual operating and debt service costs – the minimum for financial sustainability.[51]

The World Bank argues that this situation is especially delicate for utilities in low-income economies and lower-middle-income economies where high costs of supply, low charges, operational inefficiency and poor sector planning and procurement often create persistent cycles of underperformance.

Box B.5: TBT notifications affecting electrical transmission equipment

The WTO Agreement on Technical Barriers to Trade (TBT Agreement) seeks to ensure that technical regulations, standards and conformity assessment procedures do not create unnecessary obstacles to trade nor unjustifiable or arbitrary discrimination. The TBT Agreement also strongly encourages the use of international standards by requiring them to be used as a basis of standards and regulations, when appropriate. Transparency through specific notifications obligations for WTO members is one of the principles under the TBT Agreement to minimize trade barriers.

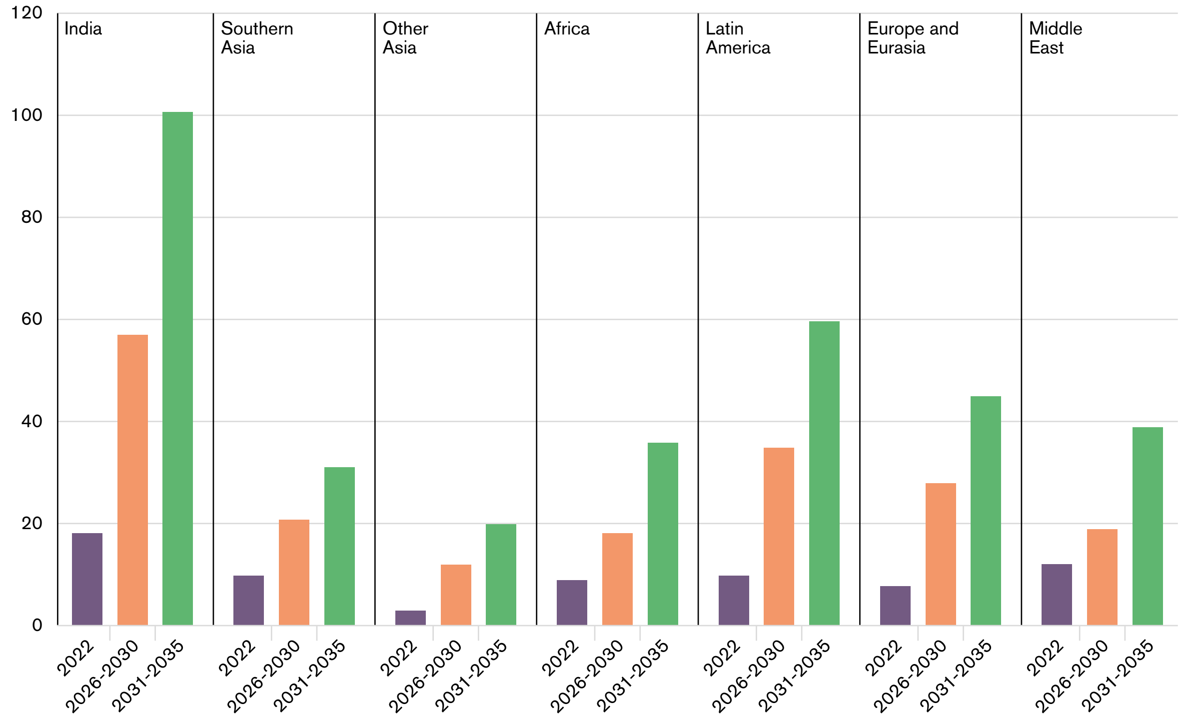
A number of notifications have been made by members regarding electrical transmission products over the period 2023-2024. Measures have focused on ensuring improved safety, energy efficiency and adherence to updated international standards. Examples of regulations introduced include the following:

- China issued new regulations for energy-efficient electrical transmission systems, aligning with its broader energy-saving and emission reduction targets under national green energy policies.[52]
- The United States revised its safety and environmental standards for high-voltage electrical transmission equipment, focusing on minimizing environmental impacts and enhancing public safety protocols.[53]
- Japan introduced new conformity assessment procedures for electrical transmission components, aimed at harmonizing standards with international energy efficiency guidelines.[54]
- The Republic of Korea updated its regulations for the import and manufacturing of electrical transmission systems, enhancing compliance with digital safety standards and cybersecurity protocols in smart grids.[55]

The WTO's ePing system for notifications (https://eping.wto.org/en/Search) can play an important role in ensuring transparency and facilitating members' ability to review and comment on draft regulations.

Source: WTO Secretariat.

Figure B.2: Grid and batteries average investment in the IEA's Net Zero Emissions Scenario (USD billions)



Source: IEA (2024).[56]

Electricity is a key enabler of social and economic development, and governments may subsidize their systems (e.g. by not fully recovering costs) for public policy reasons. However, this can result in underinvestment in critical maintenance, upgrades and system expansion, with increased dependence on government subsidies.[57] Many projects are stalling due to lack of funds.[58] Box B.6 focuses on challenges in scaling up grid investment.

Not all grid projects may qualify for climate finance

Expenditure on grid upgrades and interconnection do not automatically meet the criteria to be considered as climate finance. Cables are technology neutral (i.e. they do not distinguish between whether electricity is generated by renewable or other forms of energy). Because grid projects are an enabler of decarbonization, not direct contributors to emission reductions, additional criteria are applied. If these criteria are met, the grid or interconnection project is designated as eligible for climate finance and the applicant can access climate-related concessional finance.

A 2021 paper by the Global Grids Initiative estimated that only 40% of the required investment qualifies as climate finance.[59] Two main approaches set criteria on whether a project investment can be designated as eligible for climate finance: the EU Taxonomy and the Common Principles adopted by the MDBs and the International Development Finance Club, a partnership of development banks.[60] If grid projects meet the EU Taxonomy and Common Principles criteria, almost any investment within it is eligible, resulting in low verification costs and wide inclusivity of beneficiaries across potential projects. Box B.7 sets out the MDBs' Common Principles criteria relating to the transmission of electricity.

Box B.6: Challenges in scale-up of grid investment

A 2022 working paper for the Green Grids Initiative outlines challenges that investors face in deploying capital to finance grid investments, including the following:

- Lack of solid creditworthiness from utilities: Historically, utilities located in Emerging Markets and Developing Economies (EMDEs) have often been viewed as high-risk borrowers and have low credit ratings. Consequently, it has meant that it is more costly for debt and equity investments in EMDE economies compared to advanced economies, with capital investments being up to seven times more expensive in EMDEs. This can act as a deterrent in encouraging further investment from the private sector.
- The need for "patient" capital: The approval process to obtain finance can be a time-intensive process for utility companies. The Rocky Mountain Institute's Climate Finance Access Network suggests that the approval process from major funds could take up to four years, with utility companies facing difficulties in preparing and packaging grid projects into financially viable assets. This may result in utility companies often being discouraged to seek climate finance to obtain urgent forms of capital.
- Global supply chains disruptions: Severe supply shortages in recent years have delayed the supply of critical raw materials needed for grid infrastructure, such as semiconductors. These delays can cause inflationary pressures and lead to overall increases in component costs, thereby impacting the economic feasibility of projects.
- Pipeline projects have extensive lead times: Construction of electric grids is extremely capital-intensive and requires extensive lead times from the initial investment decision to commissioning. Coupled with the growing shortage of technical personnel, this is likely to result in further delays in project lead times.
- Availability of sufficient data: Investors have stressed lack of information and data – for instance, data on anticipated project performance. This can act as an additional barrier in mobilizing further private investment.
- Political decisions around end-user tariffs and private ownership / operation of assets: Grid investments, like many infrastructure investments, are often subject to risks due to political sensitivities related to foreign direct investments and vulnerabilities to local currency due to tariffs and user fees. Investments in less mature markets have a higher associated regulatory and country risk due to the possibility of country-specific factors eroding the profitability of conducting business.

Source: Green Grids Working Paper.[61]

Box B.7: MDBs' Common Principles for Climate Mitigation Finance relating to transmission of electricity

Criteria

- Non-nuclear, very-low-carbon electricity shall be either renewable electricity meeting the criteria for lifecycle GHG emissions in activity 2.1 (Generation of renewable energy with low lifecycle GHG emissions to supply electricity, heating, mechanical energy or cooling), or fossil-fuel-based generation with carbon capture and storage or utilization as described in activity 12.5 (Carbon capture, transport, storage, or utilization).
- Apportionment of financing eligible for climate mitigation finance shall differ by type of investment:

1. If the transmission or distribution system is dedicated to, or is required for, the evacuation of non-nuclear, very-low-carbon electricity or reducing its curtailment, the financing of such investment shall be fully eligible. Where such investment is a part of a larger investment programme, eligible financing shall be apportioned according to the capacity required for the evacuation of the non-nuclear, very-low-carbon electricity.

Any additional capacity beyond the above shall be apportioned as described below depending on the nature of the investment.

2. Financing of general transmission or distribution investments within an existing grid shall be apportioned according to the share of additional electricity delivered that can be characterized as non-nuclear, very-low-carbon electricity during a 10-year period comprising five years before and five years after the start of the operation of the new infrastructure.
3. Financing of a new grid system not connected to an existing system shall be apportioned according to the share of non-nuclear, very-low-carbon electricity delivered at the start of the operation of the grid and in the five following years.
4. Financing of interconnections between grid systems, including transborder transmission of electricity, shall be apportioned according to the weighted average of the share of new non-nuclear, very-low-carbon electricity in the respective grids during the 10-year period described in (2), weighted according to the expected flows of electricity (in both directions where applicable).

The entity applying the Common Principles shall demonstrate that the grid in which transmission or distribution infrastructure is being built will either maintain or increase the share of non-nuclear, very-low-carbon electricity delivered. The only exception is a new grid system for which historical comparison is not possible.

Source: Common Principles for Climate Mitigation Finance Tracking, Revision (version dated 5 December 2023).[62]

The difficulty for many developing economy grid projects in meeting the transmission of electricity criteria is that they are still high in carbon content. Grid upgrades may not lead to the near-term reduction of GHG emissions or addition of renewable capacity needed to qualify according to either the EU Taxonomy or Common Principles.

With grid investment enabling future renewable electricity capacity expansion, but not necessarily adding it straightaway, projects may not meet the criteria to be classified as climate finance. Grids with high carbon intensity may not receive climate financing because the percentage of any new clean energy added is not deemed high enough to take a project forward. Furthermore, measures such as smart grid technologies that increase network stability or flexibility but have only marginal effects on integration or uptake of renewable energy are not eligible according to the Common Principles.

Access to trade finance is a potential constraint facing grid equipment suppliers

Trade finance plays a vital role in supporting inclusive participation in world trade. However, there is a persistent global trade finance gap that limits participation in global supply chains. In 2023, the Asian Development Bank (ADB) estimated the gap to be USD 2.5 trillion, mainly affecting firms in developing economies.[63] The WTO is working with MDBs to improve access to trade finance and bridge the gap between demand and supply.

Trade finance comprises credit facilities used by importers and exporters to facilitate international trade. These instruments reduce risks and the time gap between when the exporter wants to receive payment for producing and shipping goods and when the importer receives them, making it easier for importers and exporters to engage in international trade transactions. Some 60-80% of world trade relies on trade finance, mostly of a short-term nature.

Projects essential to decarbonize economies, such as grid upgrades and interconnectors, also depend on importing inputs from manufacturers in other economies. Hence, in addition to scaling up access to climate finance, MDBs are also beefing up their efforts to support trade flows that contribute to the advancement of sustainable trade.

One initiative to facilitate access to financing programmes and solutions linked to sustainable trade has been taken by the ADB and the International Finance Corporation (IFC). In 2024, they jointly issued a reference note on sustainable trade finance. The reference note identifies goods, equipment and commodities which may be considered as sustainable. It also outlines ways in which parties seeking trade financing related to sustainable trade can effectively present their financing requests.

The reference note covers some equipment used in grid and interconnection projects (e.g. high-efficiency electric transmission and distribution cables). It is unclear if the list encompasses all of the products and components being examined by UNEZA in its work on addressing supply chain constraints.[64]

Improving government procurement could help to reduce project costs

Government procurement is an important source of economic activity accounting for some 10-15% of national GDP, on average, and about 13% of world GDP[65] It is estimated that governments spend around USD 13 trillion annually through government procurement.[66] At the same time, government procurement can be a potential source of GHG emissions that harm the environment and are detrimental to the fight against climate change.[67]

The buying power of governments can help to mitigate climate change and promote a just transition to a low-carbon economy through green government procurement (GGP) policies. These policies allow governments to create markets for new green goods and services, thus incentivizing companies to adopt greener approaches.

In the electricity sector, government procurement can play an important role in grid investment and the clean energy transition given that many national electricity grid operators are in public ownership. The WTO Environmental Database indicates that members have notified the WTO of at least 81 environment-related government procurement measures since 2009, including some measures in the energy sector.[68]

Government procurement has a critical role to play in integrating new renewable energy production into national grids. Auctions – or competitive bidding programmes – have emerged as a powerful tool for accelerating the deployment of renewable energy projects, fostering competition and enhancing project realization rates. One factor for success is aligning auction programmes with the demands of the grid and system operator.[69] Aligning interests reduces the danger of competing interests and tensions arising among key stakeholders over procurement processes, including over such issues as managing long term contracts, risk, uncertainty and developing the institutional and human capacity to transition to low-carbon energy while promoting competition.

WTO rules and committee work – including under the Agreement on Government Procurement (GPA 2012) – can play an important role in ensuring that open government procurement markets are leveraged to support climate objectives, including grid interconnection. By creating more competitive and predictable domestic government procurement systems, the GPA 2012 seeks to enhance investment in infrastructure projects. Currently, 49 WTO members are covered by the GPA 2012, with 35 other members observing the work of the Committee on Government Procurement.

The GPA 2012 mandates that its parties open the specified areas of their government procurement markets to suppliers from other parties, ensuring that procurement processes are transparent and based on non-discriminatory criteria. This opens up opportunities for foreign firms from GPA parties to participate in bids for procurement projects. By allowing broader participation, the GPA 2012 increases competition, potentially lowering costs and/or improving the quality of projects. A more competitive bidding environment can attract more suppliers able to deliver emerging climate-related technologies. It can also help governments to overcome a potentially costly and climate-inefficient home bias in government procurement.

One of the key principles of the GPA 2012 is transparency in procurement procedures. This includes the advance publication of procurement opportunities, criteria for evaluation and the selection of suppliers as well as informing the market about the outcome of the procurement. For energy interconnector projects, which often involve significant public investment and are subject to complex regulatory and technical standards, transparency is crucial.

WTO committee work and discussions can help to provide examples of policies that members are already implementing in the area of government procurement, including by providing a dedicated forum for policy learning and exchange through the Committee on Government Procurement. The WTO also provides technical assistance to developing economy members seeking to explore this topic further.

2.6 Transparency on regulatory approval processes and timelines

Overview

A critical obstacle faced by new interconnection projects is securing regulatory approval for new grid connection projects. Developing any transmission project is challenging, requiring among other things the development of feasibility studies, a stakeholder engagement process and regulatory compliance. Interconnectors have the additional complicating factor of involving more than one jurisdiction. This means coordination of planning, alignment with and integration into existing regulatory regimes, agreements on cost sharing and cost recovery, and many other complicating factors.[70] Such approvals may be required from multiple jurisdictions, including those in transit economies. Delays in one jurisdiction can have a domino effect.

Processes for obtaining licences, permits, rights and other approvals to build, own or operate an energy asset are critical factors in investment planning. When not well designed or implemented, these can add economic burdens and uncertainties to project development, contributing to cost overruns and delays. Streamlining the processes to obtains permits and licensing procedures in a way that still addresses system requirements and broader public policy objectives can reassure developers as well as reduce the costs and increase the speed of project development.[71]

The Green Grids Initiative has developed Principles for Interconnection (see Box B.8). One of the recommended steps for developers during the project development phase is to identify and map all required approvals, including regulatory, licensing and permits.

Box B.8: Green Grids Principles for Interconnection Development

In 2023, the Green Grids Initiative (GGI) published Principles for Interconnection Development. The document was drafted by the GGI Asia-Pacific Working Group, but offers insights and recommendations based on global experiences. It is therefore designed to provide universal principles for interconnector development. The principles cover the effective development of projects and offer recommendations for the five primary stages in the interconnection lifecycle.

Key principles for effective development

- Governmental and intergovernmental coordination: Early and consistent engagement at the political and technical levels is critical to align national and regional interests and streamline approval processes.
- Stakeholder engagement: Transparent communication, early engagement with affected communities and fair compensation schemes are essential to mitigate opposition and foster local support.
- Environmental and social responsibility: Adhere to the "do no harm" principle by conducting thorough impact assessments and ensuring that interconnector projects benefit local communities and broader markets.
- Flexibility and adaptability: Prepare for evolving market and environmental conditions by incorporating adaptive management strategies and continuous evaluation mechanisms.

Primary stages of the interconnector lifecycle

1. Concept stage:
    - Preliminary feasibility studies: Assess the technical specifications, supply and demand profiles, social and environmental impacts, economic benefits and supply chain considerations. These studies often involve seabed surveys, route planning, and input from governments, grid operators and other stakeholders. Early governmental support and facilitation are essential due to the long development timelines and political complexities involved.

- Regulatory and Permit requirements: Outline necessary permits and approvals from all jurisdictions involved. This includes understanding existing regulations and identifying any need for reform to accommodate interconnectors.

2. Project development:

- Feasibility studies: Conducted by credible third parties or in-house, these studies should cover technical, economic, social and environmental implications. This stage includes cost-benefit analysis to measure social economic welfare, which encompasses consumer and producer surpluses and congestion income.
- Approval mapping: Identify and map all required approvals, including regulatory, licensing and permits. Develop frameworks such as Power Purchase Agreements or Transmission Service Agreements to secure financing.
- Financial planning and capital raising: Early engagement with financial advisors, legal experts and technical specialists is crucial for defining the project's financial structure. Development grants and concessional financing can significantly de-risk this stage, making projects more attractive to private investors.

3. Project construction:

- This stage involves the actual construction of the interconnector, including the procurement of materials, securing supply chains, and adhering to the agreed timelines and regulations. Regular progress reporting and adherence to agreed frameworks are necessary for maintaining momentum and stakeholder confidence.

4. Operations:

- Operational protocols and agreements: Develop trilateral agreements that govern the coordinated operation of the interconnector, covering trading arrangements, emergency protocols and maintenance schedules. This ensures the continuous and efficient interconnector operation, adapting to evolving market conditions.
- Ongoing evaluation and adjustment: Review and update operating protocols, trading agreements and technical parameters to adapt to new conditions.

5. Decommissioning:

- Planning for decommissioning: Develop a plan for safely decommissioning interconnector infrastructure at the end of its life. This includes technical, economic, environmental and social assessments to minimize impacts. Ensure safe disposal of materials and restoration of sites to their original or agreed conditions.

Source: WTO Secretariat summary of Green Grids Principles for Interconnection.[72]

Services are involved in the entire renewable energy supply chain

Services trade plays a critical role in the renewable energy transition. A wide range of service activities support the development, deployment and management of renewable energy systems. Services also enable the integration of renewable electricity into grid networks, and allow renewable electricity to be transmitted and distributed to where it is needed. Economic research highlights that most of the value added in the renewable energy supply chain is in the form of services.[73]

As illustrated in Figure B.3, the renewable energy supply chain consists of three phases: the upstream process dealing with renewable energy sources; the production phase converting renewable energy sources into electricity or heat using specific devices or facilities developed for this purpose; and the downstream process where electricity/heat produced from renewable energy sources is transmitted and distributed to industries and consumers.

Services are involved in the entire renewable energy supply chain, from research and development (R&D), technical consulting, testing and analysis, evaluation, planning and siting in the upstream phase, to the design, construction, installation, operation, management and monitoring services in the production phase. Services are also involved in transmission, distribution and sale of electricity in the downstream phase.

Figure B.3: Services in the renewable energy supply chain

Upstream process

- Research and development related to renewable energy;
- Renewable energy related scientific and technical consulting services;
- Renewable energy related technical testing and analysis services;
- Resource assessment;
- Evaluation, planning or siting of renewable energy projects or facilities;
- Environmental impact analysis

Production process

- Design, construction, engineering, and installation services for renewable energy equipment and facilities;
- Operation, management, and monitoring of renewable energy projects or facilities

Downstream process

- Transmission of electricity and heat produced through the use of renewable energy sources;
- Distribution of electricity and heat produced through the use of renewable energy sources;
- Sale and marketing;
- After-sale services, maintenance and repair

Source: WTO Secretariat.

The infrastructure role of services such as telecoms, financial and business services (e.g. legal, accounting, advertising etc.) constitute other necessary services inputs to renewable energy supply chains. Services are also critical inputs in the manufacturing of renewable energy equipment and facilities.

Renewable energy services can be traded through the four modes of supply as defined in the GATS.[74] Establishing an affiliate in another country and supplying services through that affiliate, so-called mode 3, is the dominant mode of trade transactions for renewable energy services. In other words, renewable energy services are mostly traded through foreign direct investment.

As renewable energy projects are capital-intensive, foreign investment may be involved across renewable energy supply chains, from R&D, impact assessment, design, construction/installation, maintenance, to transmission and distribution. In particular, foreign investment plays a key role in renewable energy generation. International investment in renewable energy has nearly tripled since the adoption of the Paris Agreement in 2015. However, much of this growth has been concentrated in developed countries, with most developing economies left behind.[75]

Movement of individuals, such as consultants, from their own country to supply services in another, i.e. mode 4, is also an important mode of supply for renewable energy services, in particular for construction, installation and maintenance services which are not only labour-intensive, but also require skills. Foreign engineers and technicians often work in foreign-invested renewable energy projects or as independent consultants.

Regulatory delays are a brake on services' trade growth

The costs of trading services are about twice as high as trade costs for goods. A significant portion of these costs is attributable to regulatory divergence, as well as opaque regulations and cumbersome procedures.[76] As the costs of renewable energy goods have reduced dramatically, the services costs have become more prominent.

Early-stage energy project development involves contract negotiations, acquisition of land and permits and navigation of legal frameworks, all of which can raise trade barriers. Many projects – in all parts of the world – fail at this stage, some because they do not clear legitimate hurdles, but others because of complex or unclear procedures.[77]

Rolling out a new wind or solar project can take between one to five years, but new transmission and distribution networks often take 10 to 15 years to plan, obtain permits and complete. An enabling regulatory framework embedded with supportive policies that provides transparency and long-term certainty is necessary for building investors' confidence and scaling up investments in grid infrastructure.

Programmes to streamline permits and licensing depend on the individual country although general principles can help reduce transaction costs and ease the process. A recent World Bank study highlights seven principles of well-functioning licensing or permit processes to authorize renewable energy projects, as well as an evaluation checklist. These principles include legal consistency, transparency, institutional capacity, a clear timeframe, public consultation, monitoring and evaluation, and enforcement and recourse.[78] Box B.9 explains how a new phase in the creation of Africa's Single Electricity Market will also involve a focus on strengthening planning processes.

WTO rules on trade in services play an important role in electricity generation and transmission. The GATS requires governments to ensure open and non-discriminatory market conditions for the supply of services. Governments are also required to establish favourable regulatory frameworks to safeguard the certainty and predictability of market conditions.

WTO services trade rules can help to facilitate foreign investment in grid construction and operation. For example, governments' market access and national treatment commitments on technical testing, engineering, construction and energy distribution services can encourage investment. The newly adopted WTO disciplines on services domestic regulation will help mitigate the unintended trade-restrictive effects of economies' measures relating to licensing requirements and procedures, qualification requirements and procedures, and technical standards. These disciplines are highly relevant for simplifying permission processes for renewable energy projects.

The WTO Investment Facilitation for Development (IFD) initiative is another important development. Launched in spring 2017 by a group of developing and least developed WTO members, the IFD initiative seeks to improve the investment and business climate and make it easier for investors in all sectors of the economy to invest, conduct their day-to-day business and expand their operations.

In February 2024, IFD participants finalized the IFD Agreement after more than six years of negotiations. This MFN-based agreement is open for all WTO members to join. The initiative boasts participation from over 120 WTO members spanning all regions, representing three-quarters of the WTO membership. This includes over 85 developing economies, among which 25 are LDCs.

Proponents of the IFD Agreement argue that it holds significant potential to boost investments in critical infrastructure. The Agreement promises to streamline administrative processes, enhance transparency and information sharing, and facilitate public-private partnerships. By simplifying procedures, the Agreement can make it easier and quicker to obtain necessary permits and approvals, thus accelerating project timelines.

However, agreement has not been reached by WTO members on incorporating the Investment Facilitation for Development Agreement into the WTO framework (i.e. Annex 4 of the WTO Agreement).[79]

Box B.9: Continental Master Plan for electricity generation and transmission in Africa

In 2019, African energy ministers tasked the African Union Development Agency to lead the development of a Continental Master Plan (CMP) for electricity generation and transmission. By anchoring the continent's five power pools, the CMP will support the creation of Africa's Single Electricity Market, supporting the clean energy transition by sourcing electricity from a wide range of competitive resources.[80]

The CMP aims to curb the electricity deficit in Africa and allow a well-balanced sharing of affordable, reliable and clean energy resources. It envisages achieving universal electricity access by 2040, necessitating a substantial increase in investments to elevate the continent's installed capacity from 266 GW to approximately 1,218 GW. To realize this ambitious target, an estimated USD 1.29 trillion in cumulative investments will be essential, potentially culminating in the establishment of a robust continental electricity market valued at USD 136 billion by 2040.[81]

In September 2023, IRENA and the African Union Development Agency's New Partnership for Africa's Development (AUDA-NEPAD) signed an agreement supporting African countries in their efforts to achieve the African Union's Agenda 2063, which identifies key programmes for achieving economic growth, and the United Nations Sustainable Development Goal 7, which aims to ensure access to affordable, reliable, sustainable and modern energy for all.

The next phase of the CMP will include a special focus on strengthening the planning processes and accelerating the preparation of a pipeline of priority projects at both the regional and country levels. This brings an opportunity for African countries to align their energy-planning processes to a pan-Africa vision and accelerate the realization of Agenda 2063. The agreement will also facilitate access for project developers to IRENA's Climate Investment Platform, which facilitates the development of renewable energy technologies through technical assistance programmes.

Source: IRENA.[82]

2.7 Drawing inspiration from the submarine cable network enabling the internet

As of early 2024, some 1.4 million kilometres of submarine telecommunications cables were in service globally.[83] Between 2023 and 2025, a new cable boom valued at a record USD 10 billion will bring an estimated 78 systems online measuring over 300,000 km in length.[84] The global network of subsea and overland cables that form the backbone of the World Wide Web indicate what may be possible in terms of a global electricity grid infrastructure.

Digital technologies are used in both internet cabling and renewable energy projects. The Black Sea submarine cable project to transport renewable energy from the Caucasus region to Europe also integrates a fibre-optic cable to enhance digital connectivity.

Digital technologies are also key to integrating renewables into electricity systems, improving the reliability of power grids and reducing the cost of access to electricity. For example, integrating large quantities of solar and wind generation, whose peak output may not match periods of peak demand, requires sophisticated management of electricity grids, which is now enabled by digital technologies. Related services, such as monitoring of electricity transmission and related data analysis, can be supplied cross-border, namely through mode 1 of services trade (i.e. services supplied from one country to another). Renewable energy-related consulting services are also often supplied cross-border.

Parallels can be drawn between the international electricity market and telecommunications at the start of the technological revolution of the 1990s and 2000s. The trade rules that apply to telecommunications services include the GATS, which contains the principles for trade in services, and its Annex on Telecommunications, whose rules apply to all WTO members.

The Telecommunications Annex provides guarantees for reasonable access to, and use of, public telecommunications in a given market by suppliers of all services benefiting from commitments scheduled by the member concerned. It requires each member

Box B.10: Opinion piece

Submarine high-voltage cables are a must to meet net zero – so how can we scale them up?

Georgie Skipper, Co-Founder, Murray Lab for Innovation, Geopolitics and Entrepreneurship, MIT Sloan School of Management

Hindsight shows that today's vital fibre-optic cables only proliferated when governments put in place international legal frameworks to resolve issues of transit rights, cable protection, freedom to lay cables and the right to send traffic through international networks. Such initiatives reflect the understanding that commercially led projects rely on international regulatory and policy actions that are within the remit of governments to implement, without which the building of existing telecommunications infrastructure would not have been possible.

There are compelling reasons to move with speed and at scale. Energy, like telecommunications and the internet, is a vital public commodity directly correlated to economic inclusiveness and growth. Large, interconnected power systems will play an important role in the decarbonization of industries and economies, providing access to cleaner sources of renewable energy.

As the global power system becomes increasingly dependent on cross-border transmission, HVDC links will correspondingly increase in importance to global energy supply and security. Setting up the technical and regulatory dimensions of cross-border energy trading is more complex than in the case of fibre-optic links, due to an array of standards and generation capacities as well as uneven demand across economies.

The relative complexity makes it all the more necessary for governments to work together to enable the growth of an industry that is likely to prove as strategically important as the telecommunications one it follows.[85]

Disclaimer

Opinion pieces are the sole responsibility of their authors. They do not necessarily reflect the opinions or views of WTO members or the WTO Secretariat.

to ensure that the suppliers of committed services are accorded access to, and use of, public basic telecommunications, both networks and services, on a reasonable and non-discriminatory basis.

Another document of potential relevance to today's electricity market is the Reference Paper on Telecommunications, a set of principles on the regulatory framework for basic telecommunications services. It provides broad guidelines but leaves it to individual members to interpret and translate them into specific legislation. WTO members that adopted the Reference Paper (more than two-thirds of WTO members) mainly committed to:

- establish a regulatory authority that is independent of all suppliers of telecommunications services and networks;
- maintain measures that prevent and safeguard against anti-competitive practices by major suppliers (i.e. a supplier who through control of essential facilities or use of market position, can materially affect the price and supply in the relevant market);
- require major suppliers to interconnect other suppliers at any technically feasible point on a non-discriminatory, cost-oriented basis following transparent procedures and subject to dispute settlement by an independent body;
- administer universal service programmes in a transparent, non-discriminatory, and competitively neutral manner; and
- allocate and assign use of scarce resources, including the radio spectrum, numbering blocks, and rights of way, in an objective, timely, transparent and non-discriminatory manner.

The Reference Paper provided a blueprint for telecommunications reform, at a time when competition was being introduced, that largely reflected "best practice" in sector regulation, and in large part continues to do so today. Many of these principles could also be relevant for today's electricity market.

Also potentially relevant is the WTO's Information Technology Agreement (ITA). The first ITA, signed in December 1996, aimed to eliminate all import duties and other charges on information technology products. Over 80 WTO members participate in the ITA, which covers products such as computers, semiconductors, and telecommunication apparatus.

In 2015, the ITA Expansion (ITA 2) Agreement was endorsed, expanding coverage to over 200 more products, including medical equipment and other IT-enabled products. Both the ITA and ITA 2 Agreements have facilitated the use of IT technologies, increased productivity and spurred the creation of IT-enabled industries and services by lowering the cost of communication networks and IT equipment.

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Conclusions

Expanded grid interconnection can advance the transition to low-carbon energy and unlock trade opportunities in renewable electricity, including for developing economies and LDCs.

Renewable energy is an example of where variations in climate and natural endowments across the world can be directed to positive effect. Cross-border trade in renewable electricity illustrates the role of trade in helping to meet supply and demand across countries.

Grid infrastructure is the backbone of power systems. As the share of renewable energy in these systems increases, the ability to transfer power from wherever it is generated to wherever it is needed will grow in importance. Even a relatively limited amount of cross-border trade can bring real benefits, allowing system operators to take advantage of larger and more diverse power systems than any one country or jurisdiction could develop on its own.[1]

"Renewable energy, by its very nature, tends to be more evenly distributed geographically than fossil fuels, offering greater potential for diversified supply sources and reduced reliance on dominant, often geopolitically sensitive suppliers."

IRENA [2]

Interconnected energy systems are able to more effectively and efficiently react to changes in supply and demand. High-quality meteorological data and forecasting are an essential tool to help manage variability in the supply of renewable energy and energy demand. Interconnectors can play a very important role in helping to manage demand peaks through the sharing of surplus supply and reserves.

Interconnection also gives areas with renewable energy endowments (i.e. green comparative advantage) access to regions with high and growing demand, increasing the economic case for developing new forms of renewable energy. Interconnectors can therefore lead to greater integration of renewable energy and other low-carbon resources into energy supplies. [3]

Globally, over 80 million kilometres of grid infrastructure will need to be added or refurbished worldwide by 2040 if countries are to fulfil their national climate commitments on time and in full.

IEA [4] .

Globally, forecasts suggest that to meet net zero CO_2 emissions by 2050, investment in grids will need to grow significantly. Much of this investment is needed within developing economies. The IEA suggests that grid investments will need to increase by approximately five times by 2035 (relative to 2022 levels) to achieve net zero. Without this investment, there is a risk that grids become a critical bottleneck to transitioning to a clean energy system.

Expanding grid interconnections can create re-globalization opportunities. This occurs by tapping into the significant renewable energy endowments of many LDCs and by integrating new suppliers of goods and services into electricity grid supply chains.

Some LDCs are already building on their renewable energy comparative advantages, but more can be done to catalyse this process. Improving access to climate finance and sustainable trade finance is essential in view of the fact that domestic budgets are limited and levels of private sector investment are modest.[5]

More information about regulatory requirements (e.g. permits, transit rights, tariffs, export restrictions etc.) in individual countries and greater predictability about the timelines for approvals would contribute to investor confidence. Improving government procurement approaches, with a greater focus on green procurement, might also help bring down the costs of interconnector projects and promote sustainability.

Although there is no specific agreement covering trade in energy among WTO rules, the WTO framework contains a series of provisions across various agreements that play an important role in energy trade and in realizing re-globalization opportunities. Discussions are also ongoing on how trade in environmental goods and services can further support climate and environmental objectives.

Realizing trade opportunities created by natural variation in renewable electricity supply and demand will require international collaboration and much can be learned from cross-border cooperation underlying the evolution of the World Wide Web.

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GLOSSARY OF ACRONYMS

ADB	Asian Development Bank
AUDA-NEPAD	African Union Development Agency – New Partnership for Africa's Development
CO_2	Carbon dioxide
COP28	Twenty-eighth Conference of the Parties United Nations Framework Convention on Climate Change
EMDE	Emerging Markets and Developing Economies
ESMAP	Energy Sector Management Assistance Program
GATT	General Agreement on Tariffs and Trade
GEIDCO	Global Energy Interconnection Development and Cooperation Organization
GHG	Greenhouse gas
GGI	Green Grids Initiative
GOES	Grain-oriented electrical steel
GPA	Government Procurement Agreement
GW	A gigawatt (a unit of power equal to 1 billion watts or 1,000 megawatts)
HS	Harmonized System (commodity description and coding system for traded merchandise goods)
HVDC	High-voltage direct current
IEA	International Energy Agency
IFC	International Finance Corporation
ISA	International Solar Alliance
IRENA	International Renewable Energy Agency
LDCs	Least developed countries
MDB	Multilateral development bank
MFN	Most-favoured-nation
MW	A megawatt (a unit of power equal to 1 million watts or 1,000 kilowatts)
ODCs	Other duties and charges
OSOWOG	One Sun, One World, One Grid
PV	Photovoltaic
SAPP	Southern African Power Pool
SIEPAC	Central American Electrical Interconnection System
TWh	Terawatt hours representing 1 trillion watt hours.
UNEZA	Utilities for Net Zero Alliance
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
WCO	World Customs Organization
WMO	World Meteorological Organization
WTO	World Trade Organization

World Meteorological Organization
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Supporting the renewable electricity transition through trade

Natural energy sources, such as solar, wind and water, are abundant, but they are not evenly distributed worldwide. The transmission of power across borders can help address imbalances between electricity supply and demand from renewable sources, contributing to security of supply.

Security of energy supply is a core concern for countries around the world, especially in the context of the transition to renewable energy, which lies at the heart of efforts to mitigate the effects of climate change. However, only 2.8% of electricity generated is traded across borders.

As the share of weather-dependent renewable power generation increases in the global energy mix, the World Meteorological Organization has a critical role to play in upgrading climate services to support decision-making in the energy sector. Trade also has a role to play to help balance power grids through interconnection with overland and undersea electricity cables. Such cables open up the possibility of bringing new suppliers with significant natural solar, wind and water endowments into energy trade. However, interconnection cables are complex and costly infrastructure, with projects taking 10-15 years to complete.

This report discusses how to speed up interconnection projects. Actions identified include ensuring better access to sustainable trade finance and climate finance. Also important is improving the predictability and transparency of regulatory approval processes for these projects. WTO rules may also help to address bottlenecks in the supply chains of goods and services needed for grid and interconnection expansion. Trading renewable energy across borders could help economies meet their decarbonization commitments and reduce the overall cost of the global transition to low-carbon energy.

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