UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

COMMODITIES AT A GLANCE

Special issue on access to energy in sub-Saharan Africa

No. 17

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NOTE

The term "dollar" or the $ symbol refers to the United States dollar unless otherwise stated.

The term "billion" signifies 1,000 million; the term "tons" refers to metric tons.

ACRONYMS

AfDB .... African Development Bank
Btu .... British thermal units
CCF................ Clean Cooking Fund
CIS .... Commonwealth of Independent States
CO2 .... Carbon dioxide
EAPP.............. East African Power Pool
EAQIP .... Energy Access Quality Improvement Project
EIA .... Energy Information Agency
EPA .... United States Environmental Protection Agency
ESMAP........... Economic Sector Management Assistance Program
EU .... European Union
GHI................. Global horizontal irradiation
GW................. Gigawatts
IEA .... International Energy Agency
IMF................. International Monetary Fund
IRENA .... International Renewable Energy Agency
kWh................ kilowatt hours
kWh/m2 .... kilowatt-hours per square metre
LCOE .... Levelized cost of electricity
MJ/Kg .... megajoules of heat per kilogram
m/s................. metres per second
MT.................. megatons
Mtoe .... million tons of oil equivalent
MW .... megawatts
SAPP .... Southern African Power Pool
SDG .... Sustainable Development Goal
Tcf .... Trillion cubic feet
TW .... terrawatts
TWh .... Terawatt hours
UNCTAD .... United Nations Conference on Trade and Development
WAPP............. West African Power Pool
WHO .... World Health Organization

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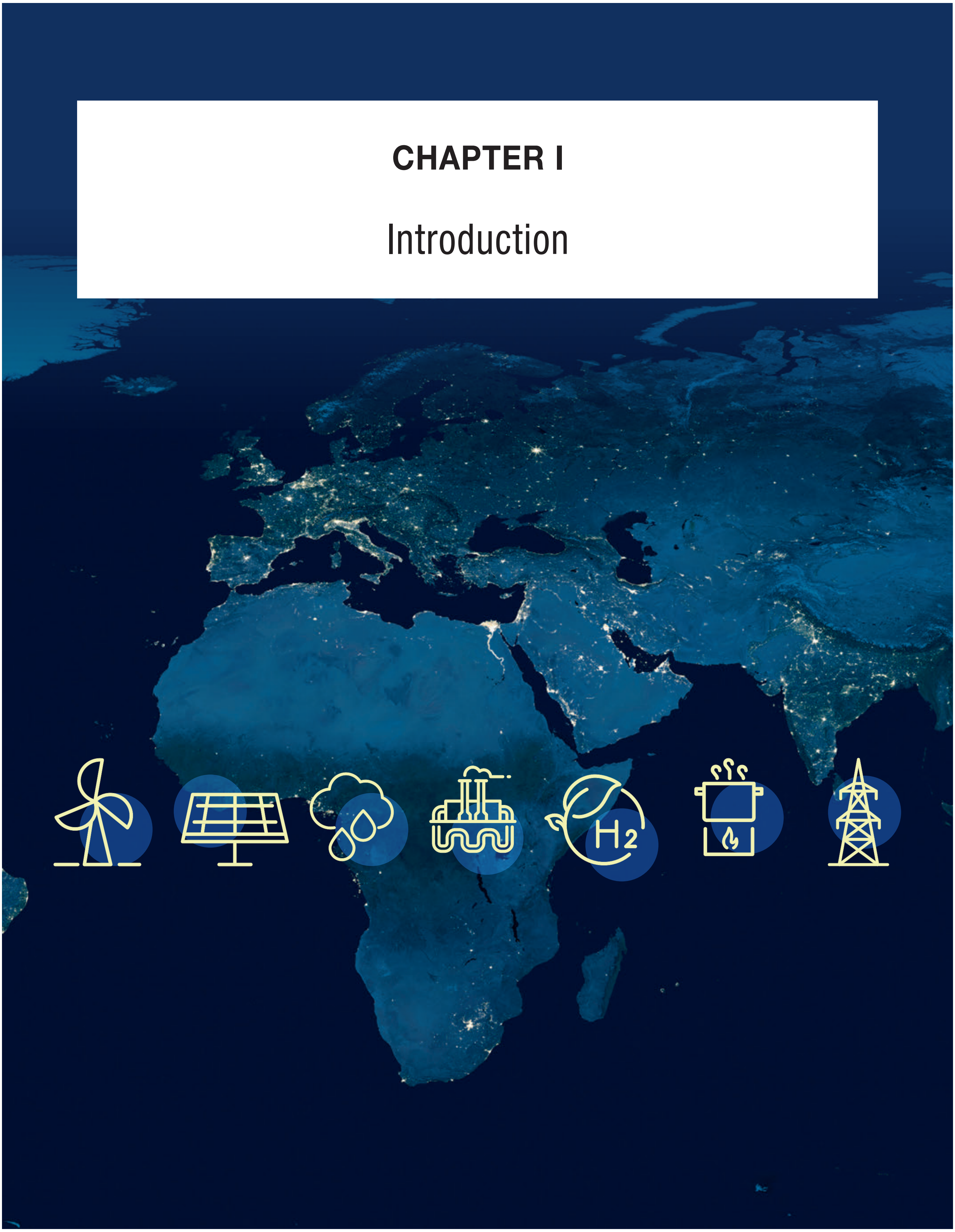
CHAPTER I

Introduction



Access to energy is defined in many ways, but most definitions include having reliable and affordable access to both cooking facilities and electricity that can be scaled up over time.[1] Access to a reliable and quality energy supply is vital to the economic development of any country (Bhatia and Angelou, 2015). It drives industrialization, boosts productivity and economic growth, spurs human development, and is crucial to achieve almost all of the United Nations Sustainable Development Goals (SDGs). For example, access to electricity can improve the functionality of healthcare facilities and the quality, accessibility and reliability of the health services delivered.[2] It enables the functioning of critically needed medical devices such as vaccine refrigerators, surgical, laboratory and diagnostic equipment. This can contribute to maintaining good health, reducing lost workdays and loss of income, and alleviating poverty (WHO, 2022). Access to electricity also supports quality education by allowing for the use of electronic teaching aids in classrooms, which is recognized as one of the most essential components of poverty reduction (Odarno, 2020). Furthermore, access to electricity facilitates access to safe drinking water, which is fundamental to eliminating poverty. It also provides power for household electrical appliances, which improves the quality of life.

Globally, 733 million people, or about 9.1 per cent of the world's population, lack access to electricity (World Bank, 2020a). In sub-Saharan Africa alone, 600 million people, or approximately 53 per cent of the region's population, live without access to electricity. Hundreds of millions more have only limited or unreliable electricity.[3] There are also an estimated 2.4 billion people worldwide (around a third of the global population) who cook using open fires or inefficient stoves fueled by kerosene, biomass (wood, animal dung or crop waste) and coal.[4] Their dependence on such fuels has serious health consequences. According to the World Health Organization (WHO), cooking with biomass and stoves fueled by kerosene and coal is linked to various illnesses and deaths, affecting mostly women and children.[5] A recent study highlighted that in 2019 there were about 700,000 deaths in Africa largely due to household air pollution.[6] Burning biomass for cooking and fossil fuels for purposes including power generation, transportation and industry also increases Africa's greenhouse gas emissions and raises concerns about achieving commitments to reduce carbon emissions to meet the Paris Agreement goals on climate change.

Overcoming the low levels of access to energy in sub-Saharan Africa and the negative impact of the types of energy dominating supply requires concerted efforts by all stakeholders to seek sustainable solutions to improve access to modern energy services. For example, exploiting the vast array of renewable energy sources available on the continent could present an opportunity

1 The International Energy Agency (IEA) defines energy access as "a household having reliable and affordable access to both clean cooking facilities and to electricity, which is enough to supply a basic bundle of energy services initially, and then an increasing level of electricity over time to reach the regional average." See IEA, 2020, Defining energy access: 2020 methodology, 13 October, available atwww.iea.org/articles/defining-energy-access-2020-methodology (accessed 24 December 2022).

2 World Health Organization, Accelerating access to electricity in health-care facilities, available at www.who.int/activities/accelerating-access-to-electricity-in-health-care-facilities (accessed 24 December 2022).

3 European Commission, 2021, Time to make energy poverty in Africa a thing of the past, press release, 17 June available at https://ec.europa.eu/commission/commissioners/2019-2024/timmermans/announcements/time-make-energy-poverty-africa-thing-past_en (accessed 24 December 2022).

4 World Health Organization, 2022, Household air pollution, 28 November, available at www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health (accessed 24 December 2022).

5 World Health Organization, Africa Region: Fact sheet: Air pollution, available at www.afro.who.int/health-topics/air-pollution (accessed 24 December 2022).

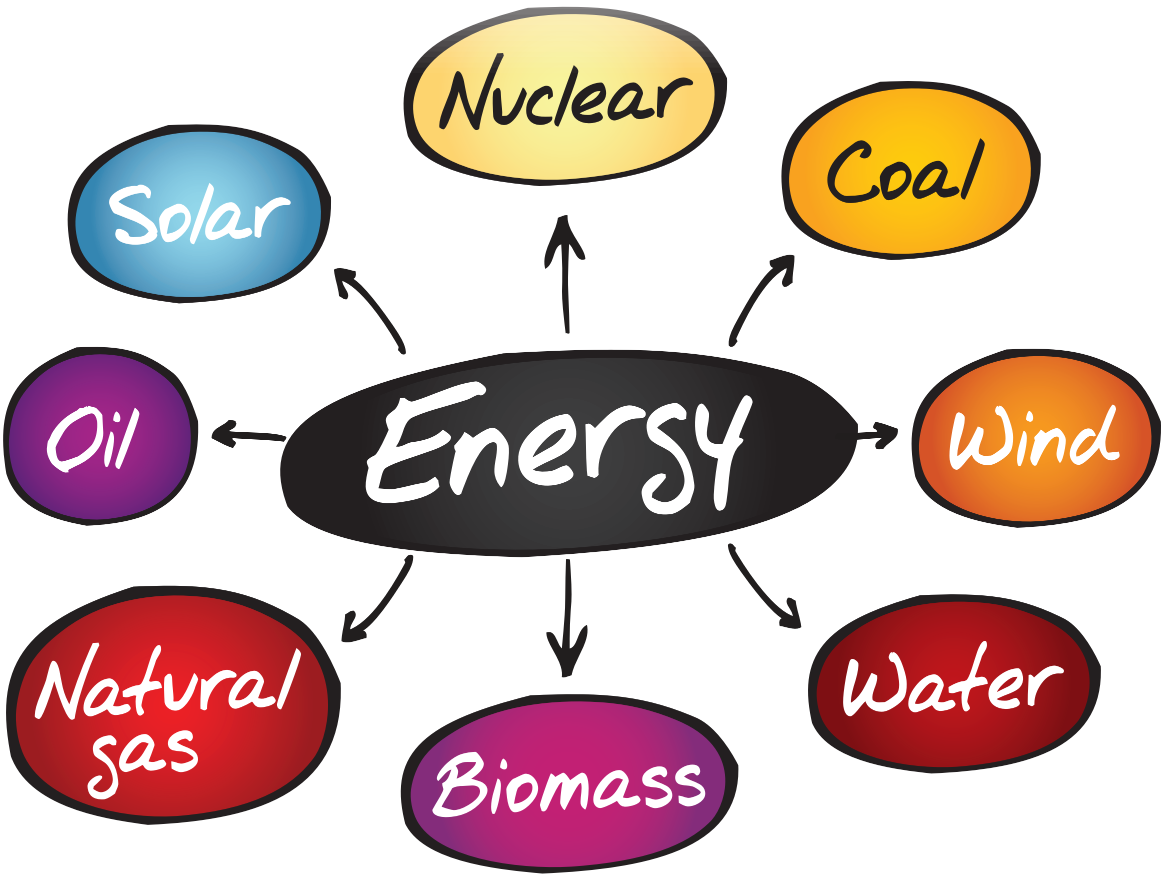
6 Science Daily, 2021, Air pollution caused 1.1 million deaths across Africa in 2019, 7 October, available at www.sciencedaily.com/releases/2021/10/211007224641.htm (accessed 24 December 2022).

to transition from the heavy polluting fuels that dominate the current energy mix to low-carbon or zero-emission energy sources. This would reduce the adverse health effects associated with the use of dirty fuels, introduce efficient fuels in the energy mix, and build a climate-resilient energy sector. The aim of this report is to provide information on the state of energy access in sub-Saharan Africa and identify policies that may contribute to enhancing access to modern energy services there while moving towards a successful transition to zero-emission fuels in a bid to align with global efforts to mitigate climate change.

This report has five chapters following this introductory chapter. Chapter 2 examines the evolution of energy trends and their influence on the composition of the energy mix. It also highlights the advantages and disadvantages of renewable and non-renewable energy resources. Chapter 3 discusses access to energy in sub-Saharan Africa, barriers to access, and the progress made between 2000 and 2020 in improving access to clean cooking fuels and technologies, as well as to electricity. Chapter 4 examines the prospects for improving access to clean cooking fuels and electricity using different energy resources. It also looks at different strategies that can be employed to improve access to energy. Chapter 5 explores financing options to develop the production capacity needed to boost energy supply. The final chapter highlights key policy actions to improve access to energy in sub-Saharan Africa.

CHAPTER II

Energy overview



2.1 HISTORICAL ENERGY TRENDS

Since ancient times, human beings have exploited various sources of primary energy (i.e. energy content that comes from non-renewable natural resources (such as fossil fuels like oil, coal and gas) and renewable resources (such as solar radiation, water, wind, geothermal) and transformed them into useful forms such as heat, light, and electricity (secondary energy).[7] The non-renewable sources are exhaustible after prolonged exploitation. Coal is the most abundant of the fossil fuels, and it has a long history of use by humans for heating, cooking and other basic needs.[8] Coal was preferred to wood because it has a much higher energy density by weight (a lot of energy stored in a small amount of mass).[9] This makes coal burn longer and, therefore, it does not have to be collected as often. Coal played a key role in powering tools and machines during the industrial revolution between the 18th and 19th centuries. It was used to fuel boilers to produce steam to power ships and trains. In the second half of the 19th century steam produced from burning coal was used to drive turbines to generate electricity for homes and factories. By the 20th century, coal had become the major fuel used to generate electricity in the United States.[10]

Growth in transportation brought oil to the spotlight and by the mid-20th century oil had overtaken coal as the world's largest source of energy. Oil was preferred to coal because it was a liquid fuel ideal for transportation and had a higher energy content, averaging twice that of coal by weight (Gross, 2020). Oil-fired power generation was also more efficient than coal-based power generation.

Increased technical expertise made it possible to harness natural gas for commercial use, and it was used to light houses and streets in the late 18th and early 19th century in Britain and the United States.[11] However, long distances separating natural gas deposits from the centers of consumption added to cost and distribution challenges. Therefore, there was little incentive to produce natural gas (Miser, 2015). The construction of gas pipelines in the early 1900s brought natural gas deposits closer to centers of consumption, reduced cost and distribution challenges, and enabled households to access to gas for heating and cooking.[12] Thereafter the use of gas expanded to manufacturing and processing plants and then to boilers to generate electricity. By 1960, the largest commercial use for gas in North America was for electricity generation. Natural gas is now widely integrated into the global energy mix because it has less negative environmental effects compared to the other fossil fuels.

Renewable energy comes from sources that are naturally replenished at a faster rate than they are consumed.[13] Humans have harnessed renewable energy from various sources including plant

7 All energy forms that have been subjected to human-made transformation constitute secondary energy. For example, when primary energy is converted into useful energy forms such as electricity and heat, those forms are known as secondary energy.

8 Fossil fuel study guide, available at www.energy.gov/sites/prod/files/Elem_Coal_Studyguide.pdf (accessed 24 December 2022).

9 Coal has three times the energy density by weight of dry wood (Gross, 2020).

10 Fossil fuel study guide, available at www.energy.gov/sites/prod/files/Elem_Coal_Studyguide.pdf (accessed 24 December 2022).

11 American Public Gas Association, A brief history of natural gas, available at www.apga.org/apgamainsite/aboutus/facts/history-of-natural-gas (accessed 24 December 2022).

12 Walton Gas, 2016, The history of natural gas, 23 September, available at www.waltongas.com/the-history-of-natural-gas-2/ (accessed 24 December 2022).

13 United Nations Climate Action, What is renewable energy? available at www.un.org/en/climatechange/what-is-renewable-energy (accessed 24 December 2022).

materials (biomass), the sun (solar) and wind, as well as from water in motion (ocean currents, waves) and from inside the earth (geothermal). Biomass in the form of wood is believed to be the first source of energy that was accessible to humans, and it is still an important source of renewable energy, providing about 6 per cent of the total global primary energy supply.[14] Some estimates show that over 2 billion people depend on wood as their primary source of energy supply in developing countries.[15]

Hydropower, wind, solar and geothermal also have long histories of use dating back thousands of years. Energy harnessed from the sun was used to light fires in ancient times, the ancient Greeks used hydro energy to turn water wheels to perform work (grind wheat into flour), and wind energy was used to sail ships along the Nile River and to power mills. After the discovery of electricity in the 19th century, water, wind and solar resources were exploited for electricity generation.[16] Several hydropower plants built in the 20th century were driven by innovations in technology, plant design and rising demand. In the late 20th century, hydro capacity growth stagnated and declined due to increasing financial constraints and the environmental and social impacts associated with hydropower development.[17]

The exploitation of wind and solar energy for electricity production expanded in the late 19th century for electricity production due to technological advances. This led to commercial wind turbines and solar photovoltaics in the latter part of the 20th century. Initial costs for electricity generation using wind and solar energy were high, but improvements in the efficiency of hardware and cheaper manufacturing processes contributed to a sharp decline in costs in the 21st century and widespread adoption in the energy mix.

The first use of geothermal energy for electric power generation began in Italy in the early 20th century. By the early 21st century the global geothermal industry was providing a steady source of electricity supply around the world, albeit in much smaller amounts than the other renewables (World Bank, 2012). In recent times, hydrogen, which has high energy content per unit weight, has been tapped as a fuel source in fuel cells to produce electricity and is getting attention as a zero-emission energy carrier.[18]

Throughout history, consumption of primary energy has transitioned from one form to another due in part to discoveries of denser energy resources that give options to consumers, advances in technology, convenience in the use of the resource (e.g. liquid fuels), affordability, social pressure and growth in industrial processes. More recently, the transition has largely been driven by efforts to reduce carbon emissions to achieve the Paris Agreement goal to halve greenhouse gas emissions by 2030 to limit global warming to well below 2 degrees Celsius, and to reach net zero emissions by 2050 to stabilize global temperature.[19] In this regard, efforts to increase access to energy around the world are likely to focus on using less heavy polluting primary fuels such

14 Food and Agriculture Organization of the United Nations, 2021, Wood energy, 3 February, available at www.fao.org/forestry/energy/en/ (accessed 24 December 2022).

15 Ibid.

16 International Hydropower Association, A brief history of hydropower, available at www.hydropower.org/iha/discover-history-of-hydropower (accessed 24 December 2022).

17 Ibid.

18 Blue hydrogen (hydrogen produced from natural gas through the process of steam methane reforming) and green hydrogen (hydrogen produced from electrolysis of water using renewable energy).

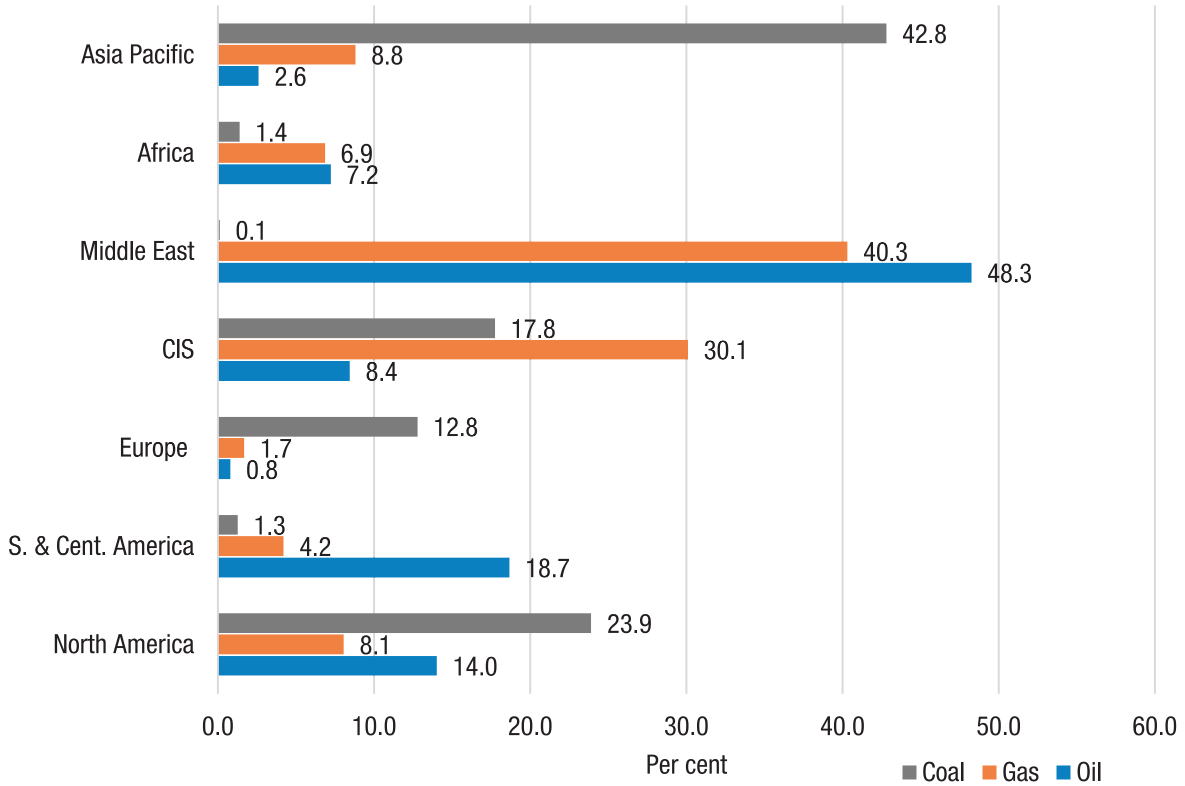
19 Intergovernmental Panel on Climate Change, 2022, The evidence is clear: the time for action is now. We can halve emissions by 2030, press release, 4 April, available at www.ipcc.ch/2022/04/04/ipcc-ar6-wgiii-pressrelease/ (accessed 24 December 2022).

as natural gas, and on energy sources that produce zero greenhouse gas emissions, such as renewables, to meet the energy needs of society. The next section discusses available renewable and non-renewable energy resources that can be used to address energy deficits, the advantages and disadvantages of those resources, and the trends observed in the energy mix globally and in Africa.

2.2 ENERGY RESOURCES

There are three major types of non-renewable energy resources that are transformed by humans to produce secondary energy: oil, coal and gas. They are exploited in a few countries because reserves are unevenly distributed across continents and regions in the world. For example, oil and coal reserves are mainly located in the Middle East and the Asian Pacific, respectively, accounting for almost 50 per cent and 42.8 per cent, respectively, of the world total. Gas reserves are dominated by the Middle East which has 40.3 per cent of the world total, followed by the Commonwealth of Independent States (CIS) with 30.1 per cent, Asia Pacific with 8.8 per cent, North America with 8.1 per cent, and Africa with 6.9 per cent. South and Central America account for 4.2 per cent and Europe for 1.7 per cent. These estimated reserves are generally revised over time as new data becomes available. Figure 1 summarizes the world region shares of major non-renewable energy reserves as of the end of 2020.

Figure 1. Shares of world non-renewable energy reserves, 2020
(per cent)

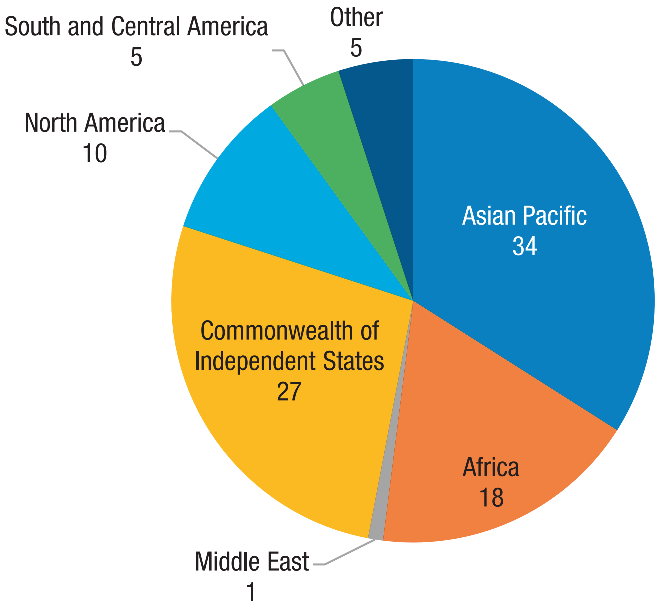


Source: UNCTAD secretariat based on data from British Petroleum, Statistical review of world energy, 2022 (www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html).

Note: CIS: Commonwealth of Independent States.

Uranium is another source of non-renewable energy that is used in generating electricity. It has an abundant source of concentrated energy; the largest energy density compared to any of the fossil fuels.[20] One uranium fuel pellet, typically about one centimetre in diameter and one centimetre long, generates energy equivalent to about 120 gallons of oil, or 17,000 cubic feet of gas or one ton of coal.[21] Uranium, is distributed across a few regions and countries around the world. The largest resources reported in 2019 are in the Asian Pacific region, accounting for 34 per cent of the world total, CIS with 27 per cent, Africa with 18 per cent, North America 10 per cent, South and Central America with 5 per cent. Smaller quantities are located in the rest of the world.[22] Figure 2 summarizes this information.

Figure 2. Regional shares of nuclear resources in the global total, 2019
(per cent)



Source: World Nuclear Association (https://world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-uranium.aspx)

By contrast, renewable energy resources are abundant and available everywhere in the world to some degree. The regions located in lower latitudes and in dry climates tend to receive more solar resources than other regions because of the sun's position in the sky.[23] Oceania and Africa receive some of the highest levels of energy per unit area over a specific period of time (also known as irradiation) from the sun.[24] The irradiation received on earth has different components; direct normal irradiation, diffuse horizontal irradiation, and global horizontal irradiation (GHI) measured in kilowatt-hours per square metre (kWh/m2).[25] The potential of the solar resource at any location

20 https://energyeducation.ca/encyclopedia/Uranium

21 https://elements.visualcapitalist.com/the-power-of-a-uranium-pellet/

22 https://world-nuclear.org/information-library/nuclear-fuel-cycle/uranium-resources/supply-of-uranium.aspx

23 United States Energy Information Administration, 2022, Solar explained: Where solar is found and used, 6 April, available at www.eia.gov/energyexplained/solar/where-solar-is-found.php (accessed 24 December 2022).

24 Global Solar Atlas, available at https://globalsolaratlas.info/support/faq (accessed 24 December 2022).

25 Global Solar Atlas, Global photovoltaic power potential by country, available athttps://globalsolaratlas.info/global-pv-potential-study and https://globalsolaratlas.info/support/faq (accessed 24 December 2022).

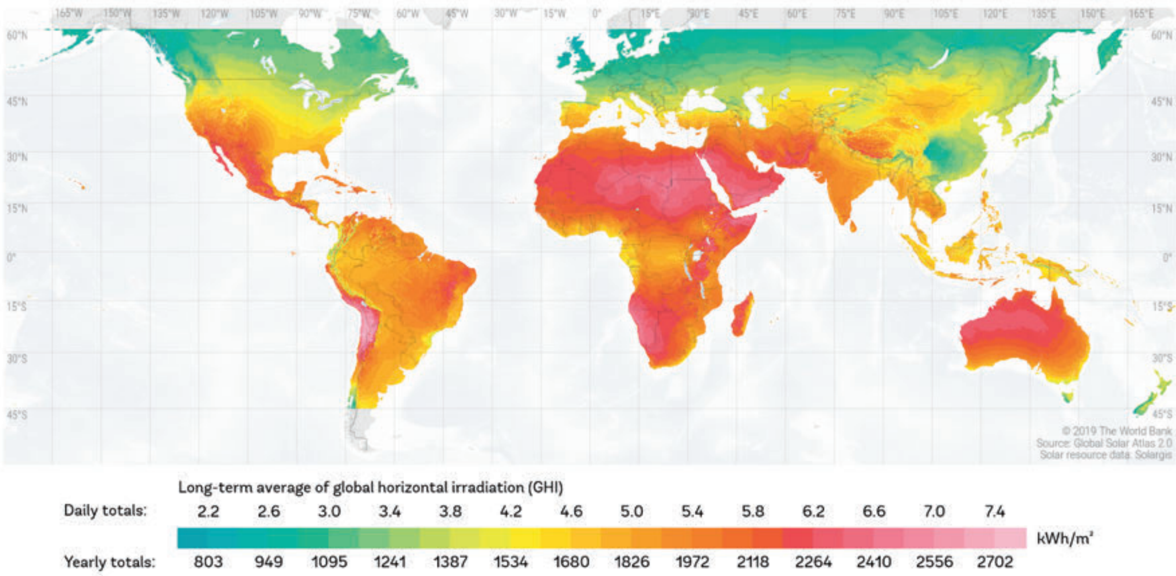
is measured by the GHI. Table 1 provides a summary of the different types of solar irradiation reaching different regions annually.

Table 1. Solar irradiation reaching different regions of the world annually (kWh/m2)

Region	Direct normal irradiation	Global horizontal irradiation	Diffuse horizontal irradiation
Africa	1,746.5	2,187.7	925.2
Europe	907.7	1,061.3	567.5
Asia	1,324.4	1,229.2	551.9
North America	1,717.1	1,388.3	515.9
South America	1,581.1	1,831.8	761.4
Oceania	1,557.2	1,845.2	731.6

Source: Global Solar Atlas (https://globalsolaratlas.info/map?c=-6.053161,12.832031,4&r=TCD).

Figure 3. Global horizontal irradiation worldwide, 2020



Sources: World Bank, Global solar atlas 2.0; and solar resource data from Solargis (https://solargis.com/maps-and-gis-data/download/world).

The best potential resources are found in Africa and Oceania, where the GHI is 2,187.7 kWh/m2 and 1,845.2 kW/m2 per year,[26] respectively.[27] Figure 3 illustrates the solar potential in different regions in the world.

[26] Global Solar Atlas, available at https://globalsolaratlas.info/map?c=51.208697,89.234375,11&s=51.208697,89.234375&m=site (accessed 24 December 2022).

[27] Global Solar Atlas, available at https://globalsolaratlas.info/map?c=-24.046464,-32.695313,2 (accessed 24 December 2022).

Wind resources vary by region because a minimum level of wind speed is required from which energy can be extracted to merit the development of a wind farm.[28] Good places to locate wind turbines are where the annual average wind speed is at least 4 metres per second (m/s) for small wind turbines and 5.8 m/s for utility-scale turbines.[29] The maximum power output is reached at wind speeds of 12 to 15 m/s. During storms, the wind turbine is usually switched off to prevent damage.[30] The greatest potential for harnessing wind resources is on tops of smooth, rounded hills; in open plains and water; and in mountain gaps that funnel and intensify wind.[31] The regions with the most wind resources harnessed for power generation are Asia and Oceania, followed by Europe and North America, Central and South America, Africa, Eurasia and the Middle East.[32] Geothermal resources are found everywhere throughout the world but the most active are near boundaries of the earth's tectonic plates.[33] The regions with the most geothermal resources are North America, North Europe and East Africa.

All renewable and non-renewable energy resources have their pros and cons. Therefore, developing a sustainable energy mix should consider fuels that provide the cleanest energy system at the most affordable cost. An optimal combination of different fuels in the mix will contribute to improving access to energy in sub-Saharan Africa and help drive development in the region. The next section discusses the advantages and disadvantages of both non-renewable and renewable energy resources.

2.3 ADVANTAGES OF NON-RENEWABLE AND RENEWABLE ENERGY

2.3.1 Non-renewable energy

A major advantage of fossil fuels is their capacity to generate enormous amounts of heat energy per unit of weight when burned. This results from the breaking down of complex bonds of carbon and hydrogen formed by heat and pressure on decayed organic matter over millions of years.[34] The heat value or the amount of heat released during combustion varies with the type of fossil fuel. Crude oil releases 42 to 47 megajoules of heat per kilogram (MJ/Kg), natural gas releases 42 to 55 MJ/Kg, and coal (sub-bituminous) releases between 17.4 and 23.9 MJ/Kg. By comparison, biomass (dry firewood) releases 16 MJ/Kg.[35] The high heat value of fossil fuels makes them a valuable fuel for generating electricity, running machines and heating buildings. In addition, the

28 European Wind Energy Association, Wind energy: The facts, available at www.wind-energy-the-facts.org/regional-wind-resources.html (accessed 24 December 2022).

29 United States Energy Information Administration, 2022, Wind explained: Where wind power is harnessed, 30 March, available at www.eia.gov/energyexplained/wind/where-wind-power-is-harnessed.php (accessed 24 December 2022).

30 Axpo, Wind power: The best locations in Europe, available at www.axpo.com/ch/en/about-us/energy-knowledge.detail.html/energy-knowledge/wind-power.html (accessed 24 December 2022).

31 United States Energy Information Administration,, 2022, Wind explained: Where wind power is harnessed, 30 March, available at www.eia.gov/energyexplained/wind/where-wind-power-is-harnessed.php (accessed 24 December 2022).

32 United States Energy Information Administration, available at www.eia.gov/international/data/world (accessed 24 December 2022).

33 United States Energy Information Administration, Energy kid's page, available at ei.lehigh.edu/learners/energy/readings/geothermal.pdf (accessed 24 December 2022).

34 National Geographic Resource Library, Fossil fuels, available at https://education.nationalgeographic.org/resource/fossil-fuels (accessed 24 December 2022).

35 World Nuclear Association, Heat values of various fuels, available athttps://world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels.aspx (accessed 24 December 2022).

high energy density of fossil fuels makes them important in the transportation sector because they reduce the weight of fuel carried by the vehicle (Gross, 2020).

Fossil fuels are also easy to transport and store. Gas and oil can be stored in underground spaces, such as depleted reservoirs and salt caverns, and in above-ground tanks (crude oil).[36] The ability to store oil and gas contributes to smoothing out supply and demand imbalances.[37] Furthermore, because oil and gas can be easily transported through pipelines, vast quantities can be efficiently transferred to geographically dispersed domestic and industrial users so that they have access to an uninterrupted flow of energy. Coal can also be easily stored and is less expensive than oil and gas, with lower price volatility than other fuels (National Academy of Sciences et al., 2009). By contrast, renewable energy cannot be transported, and long-term battery storage is difficult. The storage and easy transportation attributes of fossil fuels make them a desirable fuel for producers, grid operators and end users. Another important advantage of fossil fuels is that it is possible to efficiently ramp their production up and down to meet demand. Furthermore, there is well-developed technology available for turning them into secondary energy, as well as infrastructure to distribute them cheaply. This makes fossil fuels reliable sources of energy across the globe.

There are competitive renewable technologies available to produce carbon-neutral energy systems, but they have some drawbacks. For example, solar panels and wind turbines can generate electricity at a similar cost as coal or natural gas. However, they are intermittent and require high costs for large-scale storage, making them challenging to use as fuels to provide base-load power. Fossil fuels are also valued over renewables when providing energy for heavy industrial manufacturing sectors like steel and concrete, for which large amounts of energy are needed.[38]

2.3.2 Renewable energy

The most significant advantage of renewable energy sources (biomass, sun, wind, water, nuclear and heat from the earth), is that they are naturally replenished, sustainable, abundant, environmentally friendly, and emit very little or no carbon emissions when used in generating secondary energy. Furthermore, in terms of the levelized cost of electricity (LCOE),[39] renewable costs are falling and are competitive with conventional fossil fuel electricity generation (IEA, 2020c). This could make renewables very attractive as a fuel in the energy mix. Renewables also enhance the reliability, security and resilience of a nation’s power grid.[40]

36 United States Library of Congress, Oil and gas industry: A research guide, available at https://guides.loc.gov/oil-and-gas-industry/midstream/storage (accessed 24 December 2022).

37 Ibid.

38 MIT Climate Portal, 2020, Do we have the technology to go carbon neutral today? 28 September, available at https://climate.mit.edu/ask-mit/do-we-have-technology-go-carbon-neutral-today (accessed 24 December 2022).

39 The LCOE is a measurement used to assess and compare alternative methods of energy production. The LCOE of an energy-generating asset can be thought of as the average total cost of building and operating the asset per unit of total electricity generated over an assumed lifetime. Generation is the lifetime costs of generating electricity divided by energy produced. See Corporate Finance Institute, 2022, What is the levelized cost of energy (LCOE)? 8 December, available at https://corporatefinanceinstitute.com/resources/valuation/levelized-cost-of-energy-lcoe/ (accessed 24 December 2022).

40 United States Department of Energy, Office of Energy Efficiency and Renewable Energy, Renewable energy, available at www.energy.gov/eere/renewable-energy (accessed 24 December 2022).

2.4 DISADVANTAGES OF NON-RENEWABLE AND RENEWABLE ENERGY

2.4.1 Non-renewable energy

A big disadvantage of fossil fuels is pollution when they are burned. When coal is burned, it emits carbon dioxide, a greenhouse gas that contributes to climate change. It also emits sulfur dioxide that contributes to acid rain, and particulate matter that has adverse respiratory consequences. Burning oil and natural gas produces emissions of harmful gases such as nitrogen oxides, volatile organic compounds, sulfur dioxide, methane, carbon monoxide and particulate matter, which have adverse health effects as well as climate change consequences (Gullett et al., 2017). The quantities of emissions differ by type of fuel. For example, while bituminous coal (commonly used in electricity generation) emits 93.17 kilograms of carbon dioxide (CO2) per million British thermal units (Btu), diesel fuel and heating oil (derivatives of oil) emit 74.14 kg of CO2 per million Btu. Natural gas releases 52.91 Kg CO2 per million Btu.[41] Although natural gas has less CO2 emissions, the production and transportation of natural gas is associated with methane leakage, which at very high levels can have a dangerous impact on climate warming. According to the United States Environmental Protection Agency (EPA), every cubic foot of natural gas (methane) extracted from underground reservoirs releases 1.4 per cent of it into the atmosphere. The EPA also cautions that a leak rate higher than 3 per cent would not bring immediate climate change benefits for gas power plants replacing coal-fired power plants (Marchese and Zimmerle, 2018).

The mining of coal and extraction and transportation of oil and gas are also associated with environmental impacts. For example, coal mining can result in the destruction of wide tracts of land (surface mines) because power stations that utilize coal need large amounts of fuel on a regular basis to continue operating and generating electricity. Coal mining also leads to damage to the water environment from surface and underground activities, and through waste. It also endangers the lives of miners, particularly those working in underground mines, as they are exposed to accidents from high concentrations of methane gas in underground mines.[42] Extraction and transportation of crude oil may also lead to serious environmental problems due to spills and leaks that can be difficult to clean up, and to the release of toxic chemicals into bodies of water.

Another disadvantage of fossil fuels is that they are not renewable. Once they are consumed, they cannot be replaced quickly enough to meet global energy demands because they are formed at a slow rate over millions of years. This means that the supply of fossil fuels will eventually be exhausted. Some analysts believe that world production of oil will reach a maximum rate soon and then follow a long-term downward trend (Nakhla, 2022). Forecasts of maximum production vary because of the range of uncertainty, but the consensus among analysts and industry experts is that production will peak between the mid-2020s and the mid-2030s due to technological and economic factors, and scarcity of resources (Cohen, 2022). Some analysts predict that the decline in production will be driven largely by lower consumption rather than scarcity of resources by around 2040. Production of natural gas is expected to take a longer time before it reaches a maximum rate. However, like oil, it will be followed by a decline.

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41 American Geosciences Institute, How much carbon dioxide is produced when different fuels are burned? available at www.americangeosciences.org/critical-issues/faq/how-much-carbon-dioxide-produced-when-different-fuels-are-burned; and United States Energy Information Administration, 2022, Carbon Dioxide Emissions Coefficients, 5 October, available at www.eia.gov/environment/emissions/co2_vol_mass.php (accessed 24 December 2022).

42 United States Energy Information Administration, 2022, Coal explained: Coal and the environment, 16 November, available at www.eia.gov/energyexplained/coal/coal-and-the-environment.php (accessed 24 December 2022).

2.4.2 Renewable Energy

The most significant disadvantage of renewable energy sources is the unreliability of supply. Wind and solar energy can only be harnessed when there is strong wind and sunny weather, respectively. Therefore, energy storage systems that can store electrical energy and release it when required are needed to address the variability of secondary energy generated from such intermittent sources. So far, installation of utility-scale battery facilities needed to support renewable energy uptake has been slow. According to the International Energy Agency (IEA), the total installed global capacity at the end of 2020 was estimated at 16 gigawatts (GW), only a small part of the 680 GW of battery storage that has to be installed by 2030 under the Net Zero Emissions by 2050 Scenario.[43] Although investment in grid-scale battery storage rose in 2020, household investments declined by 12 per cent due in part to the impact of the COVID-19 pandemic on household spending.[44]

Another disadvantage of renewable energy systems is that they often rely on strategic minerals from a few countries, posing a risk to the continuity of supply. Also, the extraction of some of these minerals has harmful effects on the environment and on human rights (Pitron, 2018)

The advantages and disadvantages of fossil fuels and renewables have implications for countries that intend to choose an optimum and sustainable energy mix that will contribute to enhancing energy access and security. The environmental impacts of fossil fuels, economic viability of fuels delivered to utilities, cost to consumers, and intermittence of energy supply associated with renewables make it difficult to deploy only one type of energy source on a large scale to meet rising demand for energy amid a growing focus on addressing climate change. Therefore, to increase energy access around the world, one must carefully weigh the options available in the energy mix that will provide affordable and reliable energy supply while helping to transition to net zero-emission fuels.

2.5 ENERGY PRODUCTION AND SUPPLY

Access to energy depends in part on the availability and supply of affordable primary energy to consumers. The world's primary energy supply via production from renewables and non-renewables has been rising steadily over the years largely due to strong demand from industrial activity and population growth. From 1970 to 2020, primary energy production rose by approximately 268 per cent, from 138 exajoules to 509 exajoules. Figure 4 illustrates the information on total fossil fuels and renewable energy production from 1970 to 2020. The biggest contribution to this growth in production came from fossil fuels, due in part to high demand for fuels that are efficient, dense in energy, available, and adaptable to existing energy systems (Gross, 2020). In 2020, fossil fuel production accounted for 92 per cent of total energy produced. However, it is becoming more difficult to find and produce fossil fuels, even with improved technologies such as fracking and horizontal drilling to recover oil and gas in tight geological formations.

Global production of renewable energy increased from 4.6 per cent of total energy produced in 1970 to 5.5 per cent in 2020. Although demand for renewables is forecast to grow rapidly in the energy production mix due in part to competitive costs with fossil fuels and rising concerns over climate change and energy security, there are still large portions of demand that are economically satisfied by burning fossil fuels due to storage challenges. However, energy storage solutions could

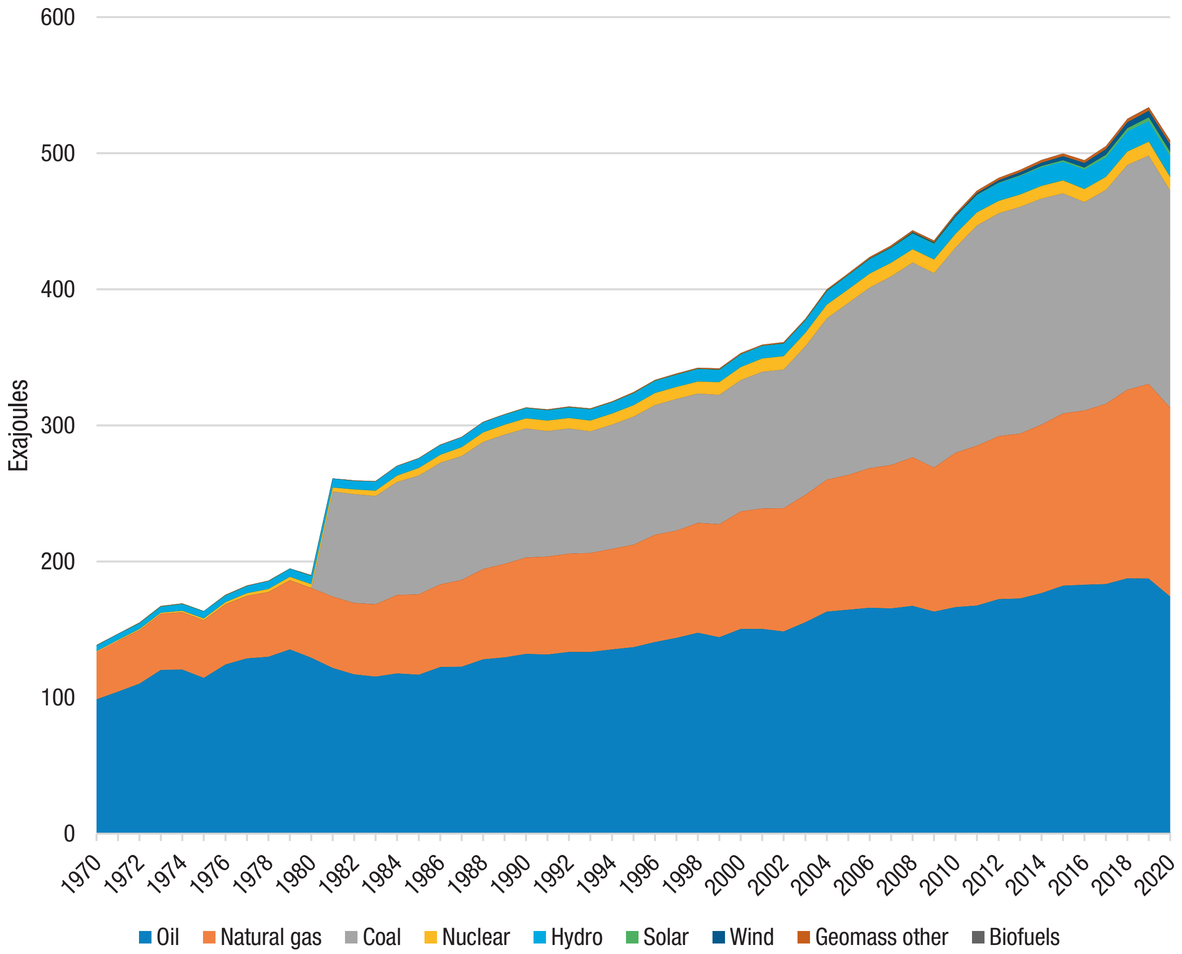
[43] International Energy Agency, 2021, Grid-scale storage, Tracking Report, September, available at https://www.iea.org/reports/grid-scale-storage(accessed 9 January 2023).

[44] Ibid.

drive rapid growth of renewables in the supply of energy, which could contribute to increasing access to energy.

In Africa, total energy supply by production rose by 153 per cent, from 12.53 exajoules in 1970 to 31.72 exajoules in 2020, largely driven by an increase in demand from a growing population and expanding export opportunities. Figure 5 illustrates Africa's energy production. During this period, fossil fuel production increased by 130 per cent of the total energy produced on the continent. Oil, gas and coal production increased by 43 per cent, 26 per cent and 20 per cent, respectively, but a large part of these commodities is exported outside the continent. Africa's supply of oil, gas and coal to the world accounted for approximately 8 per cent, 6 per cent and 3 per cent, respectively, of world energy production.[45] Renewable energy production in Africa increased by over 1,600 per cent, from 0.19 exajoules in 1970 to 3.17 exajoules in 2020. Hydro, solar, wind, biofuels and biomass accounted for approximately 10 per cent of the total primary energy produced on the continent in 2020. The potential for renewable energy production in Africa is very important

Figure 4. World energy production, 1970 to 2020
(exajoules)

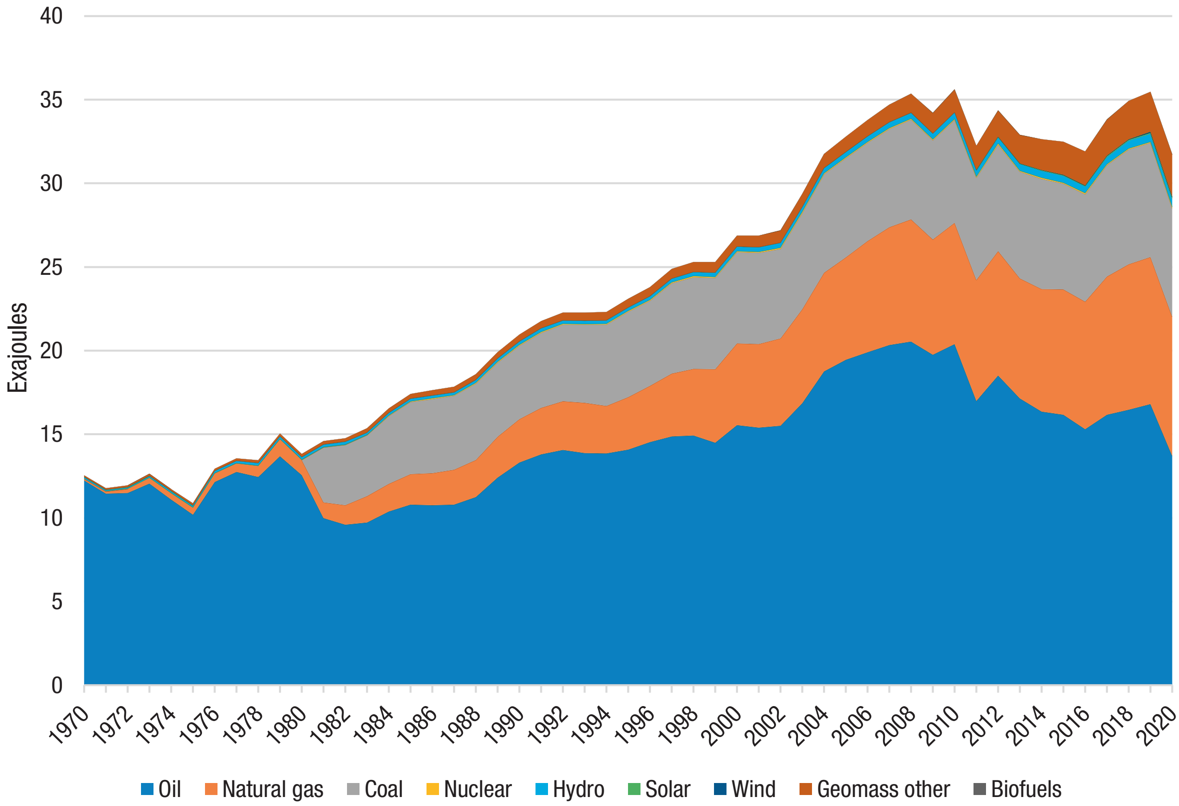


Source: UNCTAD secretariat calculations based on data from British Petroleum, Statistical review of world energy, 2022 (www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html).

[45] British Petroleum, 2022, Statistical review of world energy 2022, available at www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html (accessed 24 December 2022).

because of the vast resources of solar, wind, hydro, geothermal and biomass. However, several challenges remain in exploiting these resources in terms of developing adequate infrastructure, increasing access to finance, and establishing appropriate regulations and targets to diversify the continent's energy mix.

Figure 5. African energy production, 1970 to 2020 (exajoules)



Source: UNCTAD secretariat calculations based on data from British Petroleum, Statistical review of world energy, 2022 (www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html).

2.6 ENERGY MIX

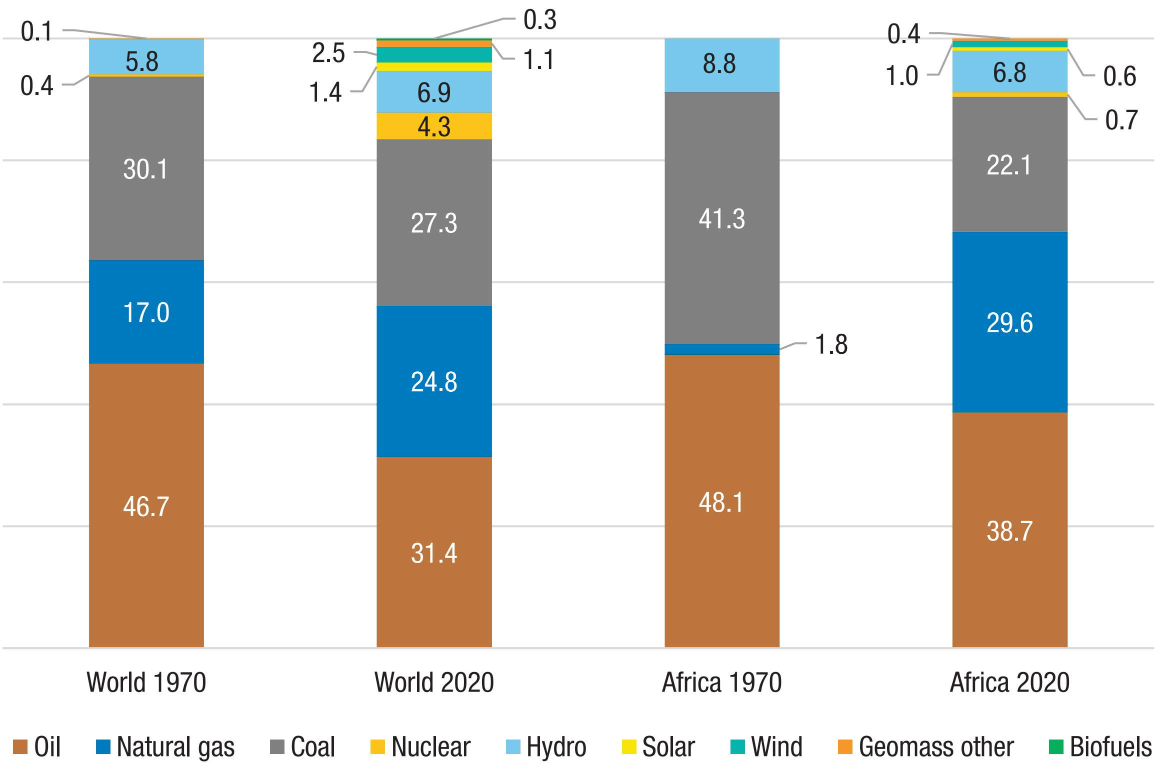
A mixture of energy resources is used in different proportions to meet energy consumption requirements, as this allows for minimum disruption if one source becomes unavailable. It also contributes to energy security. However, the composition of fuels in the energy mix is evolving partly due to availability of resources, cost of exploitation and production, effects of such fuels on climate, environmental conditions, changes in technology, and political factors such as policies to ban or encourage particular fuels.[46] In 1970, fossil fuels (coal, oil and natural gas) accounted for 93.7 per cent of total global primary energy sources consumed (oil accounted for 46.7 per cent, coal for 30 per cent, and natural gas for 17 per cent). Renewables accounted for 5.9 per cent (hydro energy accounted for 5.8 per cent, and biomass for about 0.1 per cent). However, by 2020,

46 Coolgeography.co.uk, Energy: Factors affecting energy supply, available at www.coolgeography.co.uk/gcsen/CRM_Energy_Factors_Supply.php (accessed 24 December 2022).

the share of fossil fuels in the energy mix had declined by 11 per cent to 83.5 per cent. During the period, consumption of oil declined by almost a third to 31.4 per cent and consumption of coal declined by 9.3 per cent of total energy consumed. By contrast, the share of natural gas in total energy consumed rose by almost 67 per cent and renewables increased by approximately 162 per cent from 1970 to 2020. Figure 6 shows shares of different primary energy types in the global energy mix in 1970 and 2020. The increased consumption of renewables was largely driven by wind, solar, and other renewables, which started from a very low or zero base in 1970.

Figure 6. Shares of different energy types in world energy consumption, 1970 and 2020 (per cent)

Figure 7. Shares of different energy types in Africa's energy consumption, 1970 and 2020 (per cent)



Source: UNCTAD secretariat calculations based on data from British Petroleum, Statistical review of world energy, 2022 (www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html).

In Africa, energy needs are also met through a mix of fossil fuels and renewables that predominantly come from solid biomass (wood), animal dung, crop waste, hydro, geothermal, wind and solar. The share of fossil fuels in the continent's energy mix declined slightly from 1970 to 2020, and the composition of individual fossil fuels making up the energy mix has changed significantly. In 1970, oil accounted for 48.1 per cent, coal 41.3 per cent and natural gas 1.8 per cent of the total energy consumed on the continent. But in 2020, the shares of these fuels in the energy mix were 38.7 per cent, 22.1 per cent and 29.6 per cent, respectively. Consumption of renewables in Africa also increased during this period, but at a very slow rate, from 8.8 per cent to 9.6 per cent of total energy consumed. Figure 7 summarizes shares of primary energy consumption in Africa in 1970 and 2020.

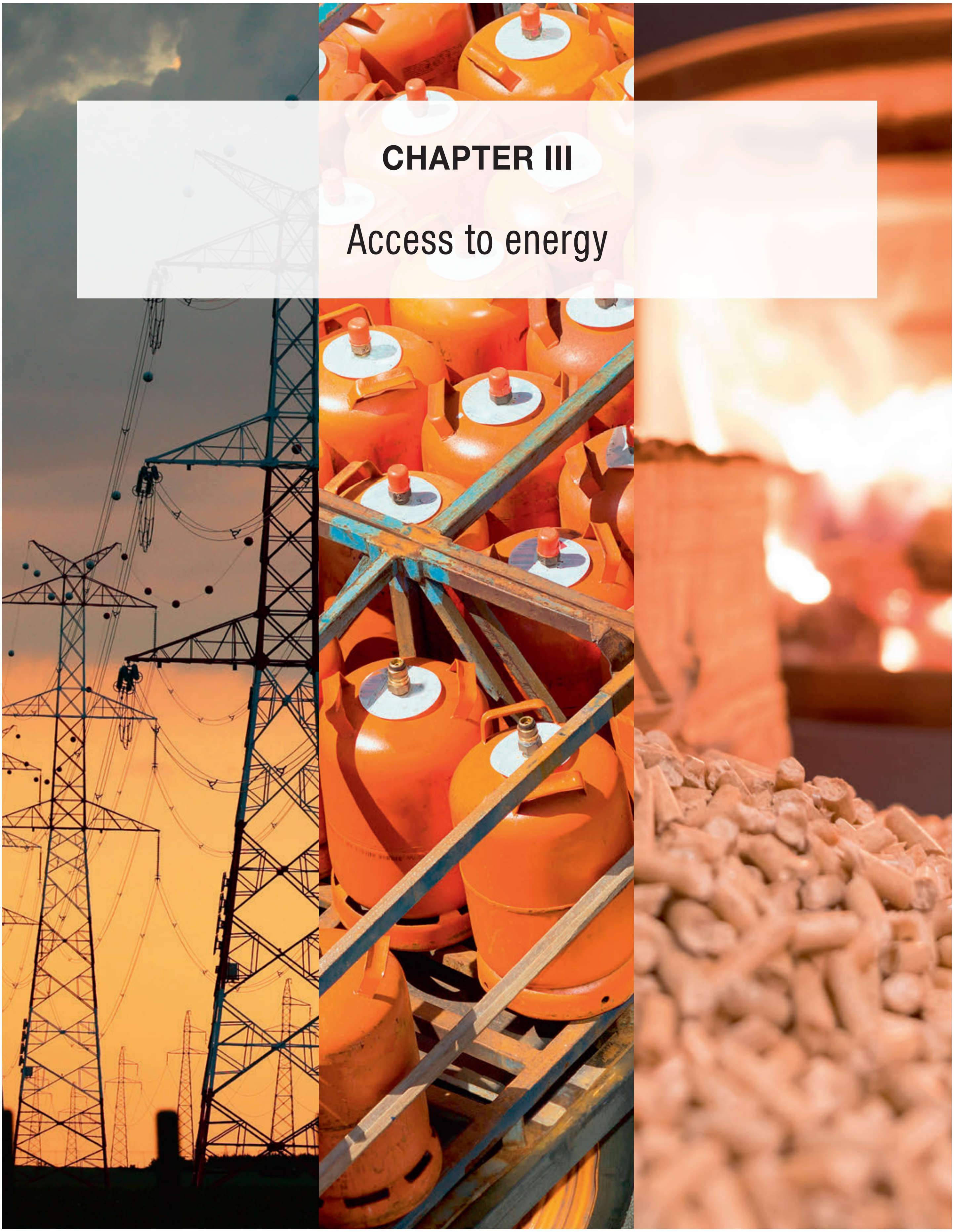
Despite the decline in coal and oil consumption globally and in Africa, both fuels continue to play leading roles in the energy mix. In 2020, coal and oil still accounted for 58.7 per cent of total world energy consumed, though down from 76.8 per cent in 1970. In Africa, the two fuels accounted for 60.8 per cent of total energy consumed, down from 89.4 per cent in 1970. In contrast, the global consumption of natural gas rose from 27 per cent of world total energy consumption in 1970 to 30 per cent in 2020, while Africa's consumption rose from 1.8 per cent to 29.6 per cent during the period. The key reasons why fossil fuels continue to dominate the energy mix, as highlighted in the advantages of non-renewable energy sources discussed earlier, include the efficiency of these fuels, their convenience of use, and their capacity to generate large amounts of heat needed for industrial processes. Renewable energy resources can offer alternatives to fossil fuels, but it is difficult to replicate the energy density in these non-renewable fuels. As a result, energy-intensive industrial processes such as the production of steel and cement are very reliant on heavy polluting fuels like coal, which is abundant and cheap.[47] This makes it challenging to dissociate fossil fuels from the energy mix, particularly in developing countries where increasing industrialization is expected to heighten demand for raw materials needed to develop infrastructure. Steel is also expected to play an important role in energy transition as solar panels, wind turbines, dams and electric vehicles all depend on it to varying degrees (IEA, 2020a). Some technologies such as carbon capture utilization and storage, and green hydrogen, may be deployed to decarbonize the steel industries, but they are currently at early stages of development and their rollout has been slow (IEA, 2020a).

Nonetheless, giant strides have been made in incorporating renewables into the global energy mix, though the gains have been modest and progress slow in many developing countries despite renewables such as solar photovoltaics and wind becoming competitive in recent years. This slow growth of renewables in developing countries is largely due to financial, technical and managerial constraints that limit large-scale development. As a result of these obstacles, there is less diversity in the energy mix, which reduces the availability of efficient fuels, affects energy security and creates fewer opportunities to expand access to energy in Africa. The future energy mix in Africa is likely to continue a path of decarbonization, but at a slower pace compared to developed countries because of the reasons highlighted. The emphasis is likely to be on natural gas to furnish energy-intensive industries owing to its lower greenhouse gas emissions. As the factors hindering expansion of renewables are continually addressed, these types of fuels can replace fossil fuel inputs in the energy mix. Although the production level of energy has increased significantly in Africa, mainly driven by natural gas production, access rates to energy in sub-Saharan African remains the lowest in the world. The next chapter discusses access to energy in sub-Saharan Africa.

[47] For example, steel blast furnaces operate at about 1,100 degrees Celsius and cement kilns at about 1,400 degrees Celsius.

CHAPTER III

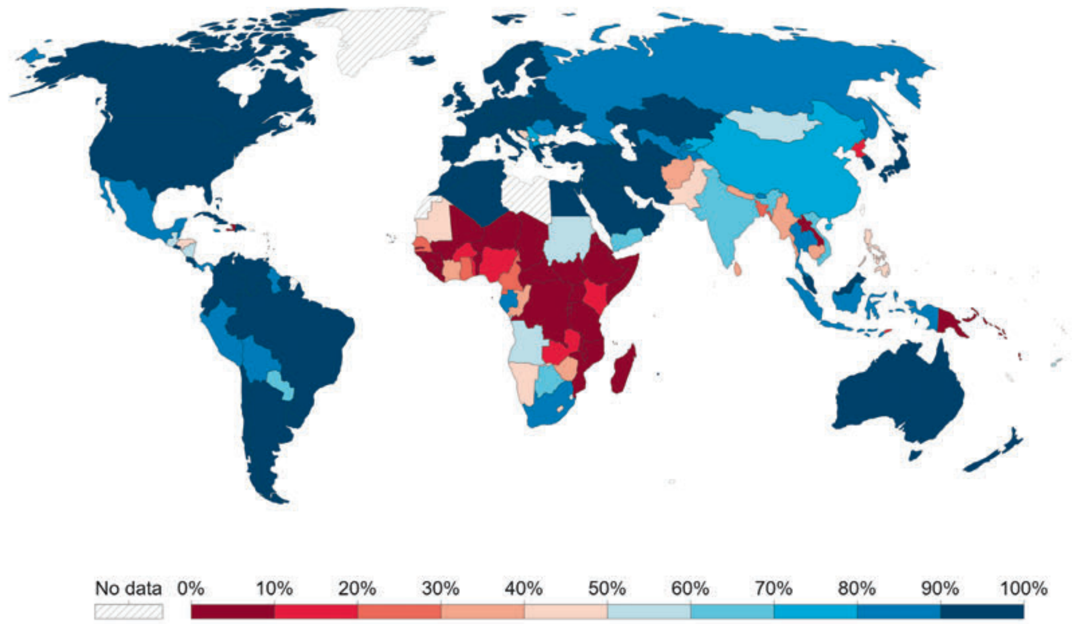
Access to energy



3.1 ACCESS TO CLEAN COOKING FUELS

Energy access is crucial to accelerate progress towards achieving several SDGs and boosting development. Insufficient access to energy in certain regions of the world means that inefficient forms of energy are used in cooking, and that modern energy services such as electricity are unavailable to millions of people.

Figure 8. Share of the population with access to clean fuels for cooking, by world region, 2020
(per cent)

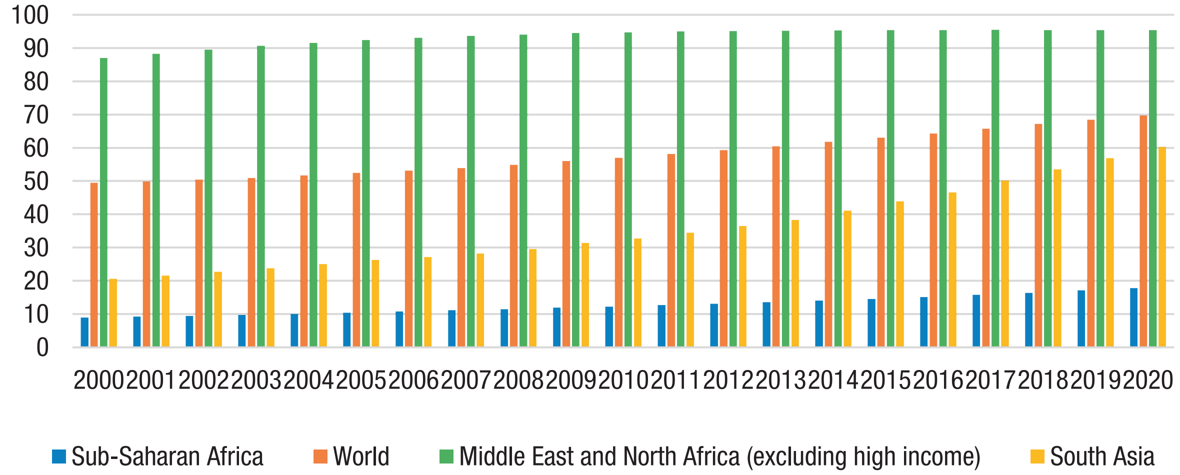


Sources: Our World in Data based on data from World Health Organization (https://ourworldindata.org/no-clean-cooking-fuels).

Approximately 4 billion people around the world lack access to clean, efficient, convenient, safe, reliable and affordable cooking energy. Figure 8 shows the share of the population with access to clean cooking fuels in 2020. About 1.25 billion people are considered to be moving towards access to improved cooking services, while the other 2.75 billion face significantly higher access barriers (World Bank, 2020b). The latter group relies on traditional polluting fuels for cooking, often leading to adverse impacts on health, gender equality, climate and the environment (World Bank, 2020b). For example, the pollution caused by cooking with inefficient fuels can result in chronic respiratory diseases, acute lower respiratory infections, lung cancer, stroke and cardiovascular diseases (Balmes et al. undated). Moreover, women and girls are disproportionately impacted, as they are more exposed to risks of injury from collecting firewood and from burns from cooking with such fuels. Finally, more time spent on these chores results in less time for leisure, learning and other pursuits, including market opportunities (Balmes et al., undated).

The World Bank estimates that only 18 per cent of the population in sub-Saharan Africa had access to clean fuels and technologies for cooking in 2020, compared to almost 96 per cent in the Middle East and North Africa, 60 per cent in South Asia, and 70 per cent globally (figure 9).

Figure 9. Access to clean fuels and technologies for cooking, by world region, 2000 to 2020
(per cent of population)



Source: UNCTAD secretariat calculations based on data from the World Bank.

The worst affected countries in sub-Saharan Africa were Uganda, South Sudan, Somalia, Sierra Leone, São Tomé and Principe, Rwanda, Mali, Malawi, Madagascar, Liberia, Guinea Bissau, Guinea, The Gambia, Democratic Republic of Congo, Central African Republic, Burundi and Benin. Less than 5 per cent of the population in these countries had access to clean fuels and technologies.[48]

In Africa, 130 million people need to be moved from dirty cooking fuels each year to achieve universal access to clean cooking fuels and technologies by 2030 (IEA, 2022). This requires urgent action to scale up clean cooking fuels and technologies to avoid falling short of universal access by 2030, particularly in sub-Saharan Africa. Some forecasts suggest that one-third of the global population will still use polluting fuels in 2030, with the majority residing in sub-Saharan Africa.

3.2 ACCESS TO ELECTRICITY

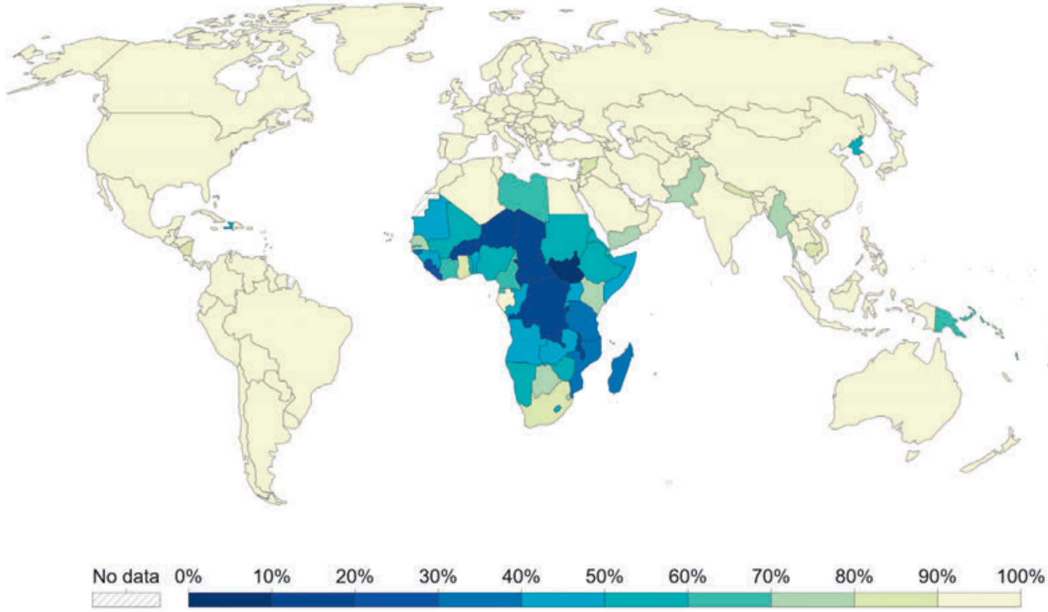
Several countries around the world have attained universal access to electricity, but almost 760 million people globally, mostly in the developing regions of Asia and Africa, do not have such access (figure 10). However, the share of people gaining access to electricity is progressively increasing. For example, from 2000 to 2020 in developing Asia, almost 1.2 billion people gained access to electricity. In 2020, access to electricity in that region was estimated at 97 per cent of the population compared with 67 per cent in 2000.[49] In contrast, the population in Africa with access to electricity increased by a mere 24 million from 2000 to 2019. This indicates that the issue of poor access to electricity is primarily a sub-Saharan African problem. Therefore, solutions must be focused on this region of the world where progress has persistently been elusive. Available

48 World Bank, Access to clean fuels and technologies for cooking, available at https://data.worldbank.org/indicator/EG.CFT.ACCS.ZS?locations=ZG (accessed 24 December 2022).

49 International Energy Agency, Access to electricity, available at www.iea.org/reports/sdg7-data-and-projections/access-to-electricity (accessed 24 December 2022).

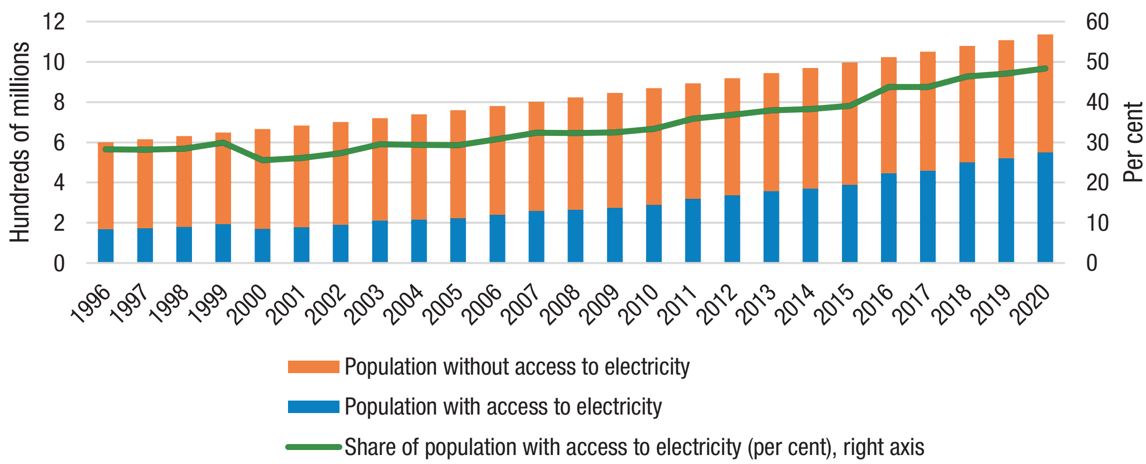
data indicate that over 50 per cent of the population of sub-Saharan Africa does not have access to electricity compared to the global access rate of 90.4 per cent.[50] Figure 11 illustrates the share of the population in Africa with and without access to electricity.

Figure 10. Share of population with access to electricity access, by world region, 2020 (per cent)



Source: Our World in Data based on data from the World Bank (https://ourworldindata.org/energy-access).

Figure 11. Access to electricity in Africa, 1996 to 2020



Source: UNCTAD secretariat calculations based on data from the World Bank.

50 World Bank, Access to electricity – Sub-Saharan Africa, available at https://data.worldbank.org/indicator/EG.ELC.ACCS.ZS?locations=ZG&name_desc=false (accessed 24 December 2022).

The average person in sub-Saharan Africa consumes about 200 kilowatt hours (kWh) of electricity per year compared to 1,442 kWh in North African countries and 4,418 kWh in South Africa. In rural areas, consumption is as low as 50 kWh per year (Hafner et al., 2018). Moreover, even when there is access to electricity, it is in urban areas and often intermittent, and there is not enough for everyone. The low level of energy access in sub–Saharan Africa, particularly for those living in rural areas, limits the ability to improve livelihoods, secure high-quality public services such as healthcare, and reduce levels of poverty (IEA et al., 2022).

3.3 FACTORS INFLUENCING ACCESS TO CLEAN COOKING FUELS AND ELECTRICITY

A variety of supply- and demand-side factors influence access to energy in sub-Saharan Africa. For example, with respect to electricity access, one of the biggest impediments is the poor state of supply caused by lack of sufficient generation capacity, coupled with poor transmission and distribution infrastructure (Arlet et al., 2019). Up to a quarter of installed capacity is unavailable because of aging plants.[51] Furthermore, aging high-voltage cables and transformers often lead to failure to move electricity from its point of generation (e.g. coal or gas plant, or wind farm) to an electrical substation. From there, a lack of poles and wires hinders the ability to transport electricity from the substation to end users. Additional challenges include the funding of utilities to maintain infrastructure and provide reliable service, the high costs of supply to remote areas, reliance on energy imports (primary and secondary) and vulnerability to price fluctuations, and the cost of exploiting available energy resources (e.g. renewable energy resources). These factors alone or in combination contribute to an unreliable supply of and low access to energy for businesses, individuals and households. Many of the utilities in sub-Saharan Africa are state-owned, and they operate monopolies on transmission and distribution infrastructure (Moss and Kincer, 2019). Therefore, due to political economy issues, electricity tariffs and other charges are sometimes set without fully reflecting true costs. Additionally, high indebtedness of African governments negatively impacts the capacity of publicly owned utilities and energy distribution companies to finance necessary investments (Moss and Kincer, 2019). This makes it very challenging to adequately maintain and expand energy infrastructure in order to deliver reliable service. For off-grid access, the biggest challenges include low electrification caused by lack of infrastructure, planning and institutional support, lack of financing for off-grid entrepreneurs, and affordability for poorer households.

On the demand side, high fees are charged to consumers to connect to an established distribution network (connection charges) relative to their level of income, and unpredictable income flows prevent households from connecting to electricity services (Blimpo and Cosgrove-Davies, 2019). In addition, high electricity tariffs make electricity unaffordable to some segments of the population such as poor communities in urban areas, rural households and small businesses. The tariff and connection charges to grids in some sub-Saharan Africa countries are among the highest in the world. For example, the population with access to electricity pays on average nearly double that of consumers in other regions of the world (Schwerhoff and Sy, 2020). This makes access to electricity even more challenging as income levels in sub-Saharan Africa are much lower.

With respect to access to clean cooking fuels and technology, supply-side barriers such as high upfront costs for improved cooking stoves make it difficult to switch from traditional fuels to improved cooking stoves, as this represents an additional financial burden on low-income

51 Africa Energy Portal, 2018, Sub-Saharan Africa power 2018, 17 October, available at https://africa-energy-portal.org/events/sub-saharan-africa-power-2018 (accessed 24 December 2022).

households. Other barriers to adoption of clean cooking fuels include fuel availability, low awareness about the impact of traditional stoves, resistance to new technology due to lack of knowledge about the availability of alternative technologies, preservation of cultural norms with respect to cooking traditional meals, and social norms such as gathering around a traditional stove for social interaction (Vigolo et al., 2018).

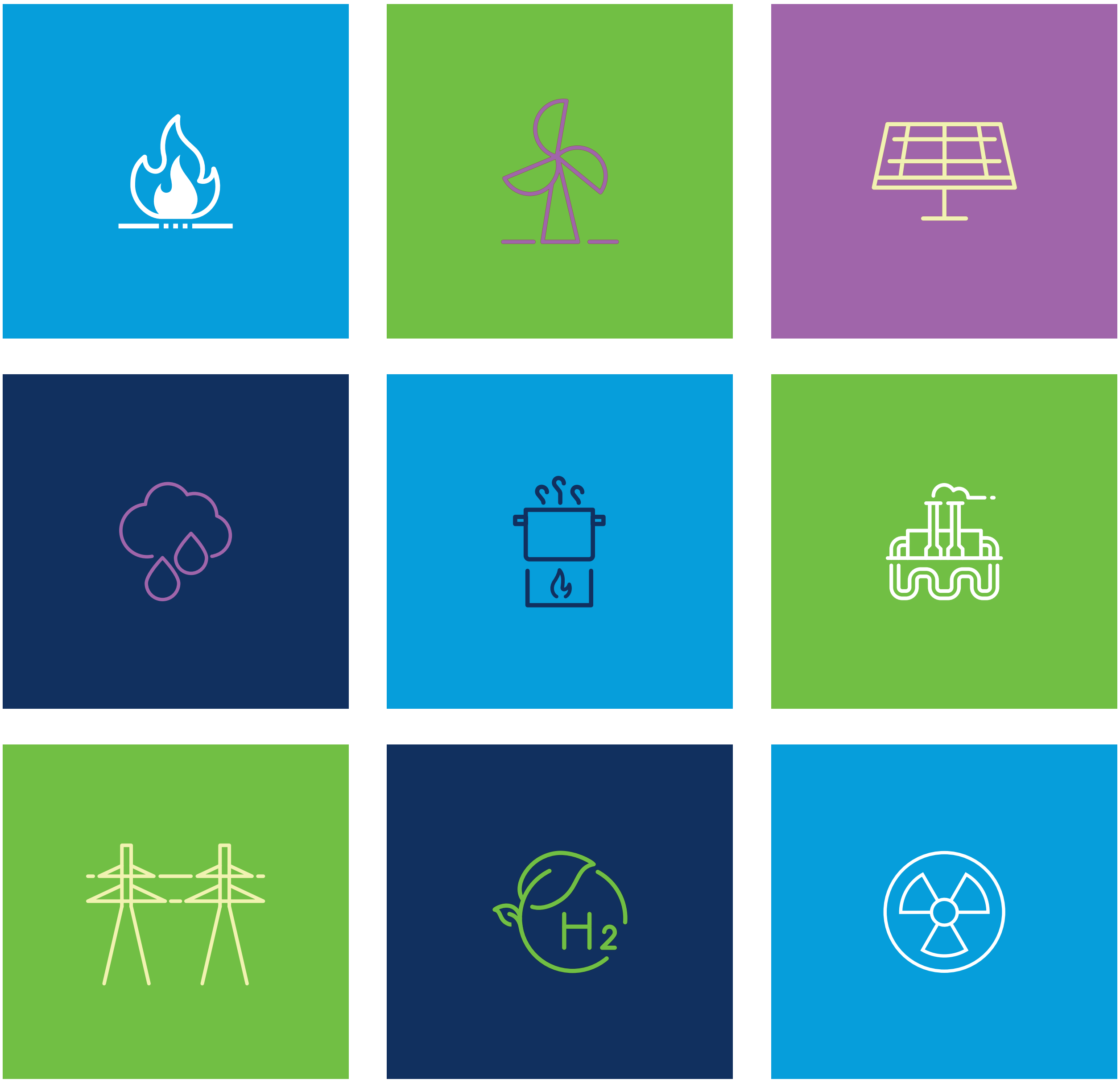
The share of the global population with access to clean cooking fuels and technologies has been increasing around the world. From 2000 to 2020, this share increased from 49 to 69.7 per cent of the population globally, and in sub–Saharan Africa it increased from approximately 9 to 18 per cent. This slow rate of progress in sub-Saharan Africa suggests that without urgent attention, its population will not have universal access to clean cooking fuels and technologies by 2030 (SDG 7).[52] With respect to electricity access, the IEA notes that the number of people without electricity in sub-Saharan Africa declined progressively from a peak of 613 million in 2013 to around 572 million in 2019.[53] However, the number of people without access increased in 2020 during the COVID-19 pandemic, and sub-Saharan Africa's share of the global population without access to electricity rose from 74 per cent before the pandemic to 77 per cent. This was largely due to a slowed rate of both new-grid and off-grid connections because of pandemic-induced job losses or reductions in income leading to affordability issues (Banerjee, 2022). Adding to the challenge is the need to deliver services and fuels that are sustainable so that global carbon dioxide emissions from the power sector are reduced and the SDG objectives related to universal energy access and cleaner air are met. This requires sufficient supply of affordable green energy in the energy mix, less dependence on heavy polluting fuels such as coal and oil for generating power and on biomass for cooking. In this regard, meeting the large energy access deficits in Africa will require carefully balancing the energy mix so that energy needs are met while reducing greenhouse gas emissions. Chapter 4 discusses the prospects for improving access to clean cooking fuels and electricity through the use of different primary energy fuels.

52 World Health Organization 2021, Global launch: Tracking SDG7: The energy progress report, press release, 7 June, available atwww.who.int/news/item/07-06-2021-global-launch-tracking-sdg7-the-energy-progress-report (accessed 24 December 2022).

53 International Energy Agency, Access to electricity, available at www.iea.org/reports/sdg7-data-and-projections/access-to-electricity (accessed 24 December 2022).

CHAPTER IV

Prospects for improving energy access

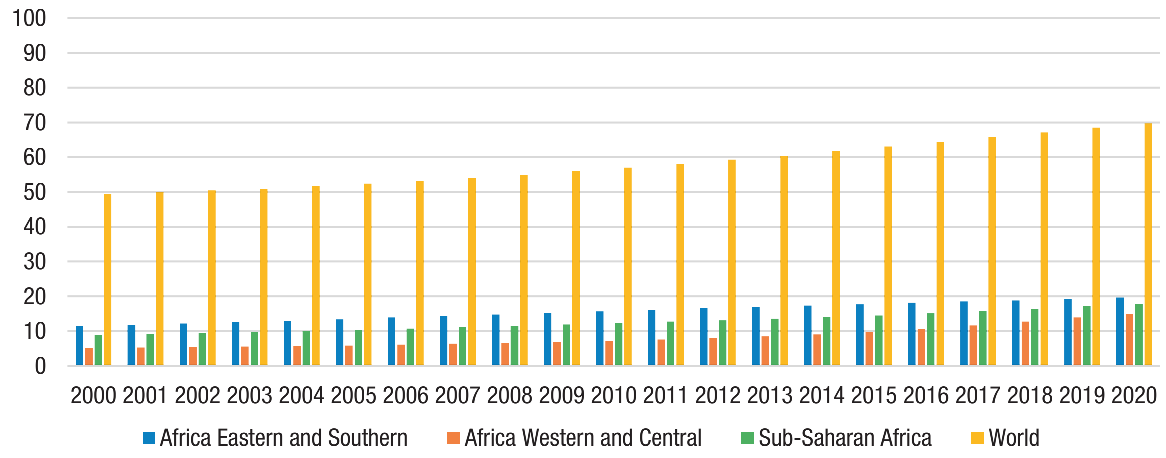


4.1 CLEAN COOKING FUELS

A global effort to improve access to clean cooking fuels is driving progress in eliminating polluting fuels. According to the WHO, the number of people using polluting fuels declined from over 50 per cent of the world's population in 1990 to around 36 per cent in 2020.[54] Various modern sources of energy such as biogas, liquefied petroleum gas, electricity and clean-combustion biofuel pellets used in biomass stoves (improved cooking stoves) offer improved and less polluting fuels compared to the traditional biomass. Generating biogas through domestic scale biodigesters can potentially provide locally produced low-carbon energy to millions of households in sub-Saharan Africa if funding is provided for the cost of installing the biodigester. According to IEA estimates, Africa has the potential to produce about 50 million tons of oil equivalent (Mtoe) of low carbon biogas from agricultural residues, animal manure and municipal solid waste, largely via household-scale biodigesters. The potential doubles to almost 100 Mtoe by 2040, at an average cost of around US$15 per million Btu (IEA, 2020b).

The main economic barrier to increased uptake is the upfront cost of installing a biodigester. For example, a small-scale anaerobic digester plant (treating under 5,000 tons of waste per year) could cost from GBP750,000 to GBP1 million (between US$920,000 and US$1.2 million).[55] Other barriers such as maintenance requirements and feedstock availability can be overcome with well-targeted policies and programmes (IEA, 2020b). Liquefied petroleum gas is the leading solution because it is a low-carbon alternative and has low emissions of toxic gases such as nitrous oxide and has low sulphur content. Liquefied petroleum gas also emits 35 per cent less CO2 than coal and 12 per cent less CO2 than oil, as well as practically no particulate matter (Christofides, 2021). Improved cooking stoves also have good prospects to replace traditional fuels because of their environmental benefits. They contribute to reducing black carbon, which is an air pollutant

Figure 12. Share of the population with access to clean cooking fuels, Africa and worldwide, 2000 to 2020
(per cent)



Source: UNCTAD secretariat using data from the World Bank.

[54] World Health Organization, 2022, WHO publishes new global data on the use of clean and polluting fuels for cooking by fuel type, news release, 20 January, available at www.who.int/news/item/20-01-2022-who-publishes-new-global-data-on-the-use-of-clean-and-polluting-fuels-for-cooking-by-fuel-type (accessed 24 December 2202).

[55] Birch Solutions, 2012, How much does it cost to build a biogas plant? 9 July, available at https://birchsolutions.co.uk/how-much-does-it-cost-to-build-a-biogas-plant/ (accessed 24 December 2202).

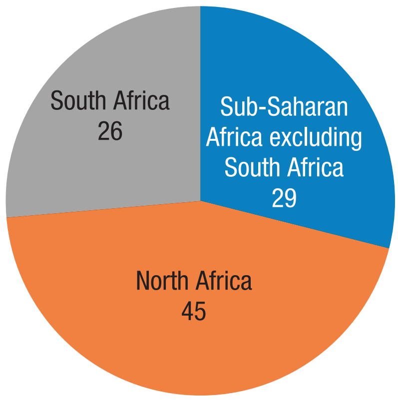
that forms a significant portion of particulate matter.[56] They also contribute to preserving forests and associated ecosystem services, and to reducing emissions that contribute to global climate change (Jeuland and Pattanayak, 2012). In addition, improved cooking stoves, biogas, bioliquids and liquefied petroleum gas can contribute to boosting energy efficiency and lowering household demand for energy. This in turn will help increase energy availability, reduce energy bills and promote wider access to clean fuels.

Electricity is another option for cooking that is worth considering, but this will depend on access, affordability and reliability of supply. Electric cooking stoves, which are gradually increasing in importance in the cooking energy mix, are the most efficient (IEA, 2020b). Figure 12 provides information on clean cooking fuels in sub-Saharan Africa and the world average.

4.2 INCREASING ELECTRICITY CAPACITY

Chapter 3 highlighted electricity generation as one of the obstacles to expanding access to energy in sub-Saharan Africa. The installed capacity in the region in 2020, excluding South Africa, was estimated at 69 GW, a level comparable to the installed capacity in Indonesia (69.8 GW). South Africa alone has installed capacity of 63 GW and North Africa has a capacity of 107.2 GW.[57] The power producers in the region struggle to deliver reliable and affordable electricity to their customers or to others who rely on inadequate alternatives to electricity due to a dilapidated and aging generation fleet and infrastructure (Puliti, 2022). Some estimates show that up to a quarter of the capacity in sub-Saharan Africa is unavailable because of aging plants and poor maintenance.[58] Adjusted for purchasing power, many of these households in sub-Saharan Africa pay higher rates than countries in the Organization for Economic Co-operation Development (The Economist 2022). Figure 13 shows the share of sub-Saharan African electricity capacity in Africa.

Figure 13. Share of electricity capacity in Africa by region
(per cent)



Source: UNCTAD secretariat based on data from the United States Energy Information Administration.

[56] United States Environmental Protection Agency, 2011, Black carbon research and future strategies: Reducing emissions, improving human health and taking action on climate change, Science in Action, October, available at www.epa.gov/sites/default/files/2013-12/documents/black-carbon-fact-sheet_0.pdf (accessed 24 December 2202).

[57] United States Energy Information Administration, International: Electricity, available at www.eia.gov/international/data/world/electricity/electricity-capacity (accessed 24 December 2022).

[58] Africa Energy Portal, 2018, Sub-Saharan Africa power 2018, 17 October, available at https://africa-energy-portal.org/events/sub-saharan-africa-power-2018 (accessed 24 December 2022).

The inability to generate sufficient electricity from installed capacity, which by itself is small for a population of 1.109 billion, contributes in part to the low access to electricity in sub-Saharan Africa. As highlighted in Chapter 3, average per capita electricity consumption in sub-Saharan Africa is approximately 200 kWh, which is far less than consumption levels of around 6,500 kWh in Europe and 12,700 kWh in the United States (The Economist, 2022). This large discrepancy in electricity consumption in sub-Saharan Africa compared to developed countries is largely due to a higher concentration of industry, higher level of car ownership and higher usage of electric appliances in developed countries. Average consumption in sub-Saharan Africa also falls below the minimum IEA threshold of 250 kWh for rural households and 500 kWh for urban households (Ritchie et al., 2022). In rural areas, this level of consumption is assumed to provide for the use of, for example, a floor fan, two compact fluorescent light bulbs and a radio for about five hours per day, while for urban households consumption could also include a television and another appliance, such as an efficient refrigerator or a computer (IEA, 2010).

As the population in sub-Saharan Africa is expected to grow to over 2 billion people in 2050, electricity generation capacity would have to increase to meet demand of a rising population that already has difficulty accessing modern energy services. A variety of electricity generation options from renewable and non-renewable sources (mainly natural gas because it has less of an environmental impact than oil and coal) could be developed to tackle the huge deficit in access to electricity, as well as to help alleviate the persistent shortages in sub-Saharan Africa. The next section discusses the prospects for geothermal, hydropower, wind, solar, hydrogen, nuclear and natural gas fuels in Africa.

4.2.1 Geothermal power

Geothermal energy is extracted by drilling wells to tap concentrations of steam at high pressures and at depths shallow enough to be economically justifiable. The steam is used to drive electricity-generating turbines.

The geothermal potential in Africa is mainly located in the geologically active area of the Great Rift Valley in East Africa, which extends from Djibouti to Mozambique. The rift system is estimated to have the potential to generate approximately 15 GW of electrical energy.[59] Kenya is the largest geothermal energy producer in the region and ranks in the top 10 producers of the world. Installed geothermal capacity connected to the grid was estimated at 0.863 GW in 2021 (IRENA, 2022b), accounting for over 40 per cent of the country's electricity generation (Mammoser, 2022). Ethiopia has also started harnessing its geothermal capacity and is expected to have a power generation potential of about 10 GW of electrical energy.[60] A few countries, such as Djibouti, Democratic Republic of Congo and Zambia, have undertaken preliminary exploration for geothermal potential and have confirmed resources (IRENA, 2020c). However, they have not developed large usage of geothermal energy due in part to financial barriers and a lack of a conducive regulatory and legal framework for private investment.

The main advantage of geothermal is that it is a renewable indigenous source of energy. This makes it an important resource that can provide a reliable electric power baseload and contribute

59 Global Forum on Sustainable Energy, 2022, IRENA: Renewable energy market analysis: Africa and its regions, GFSE Newsletter, April, available at www.gfse.at/fileadmin/7_newsletter/newsletter_april_2022.pdf (accessed 24 December 2022).

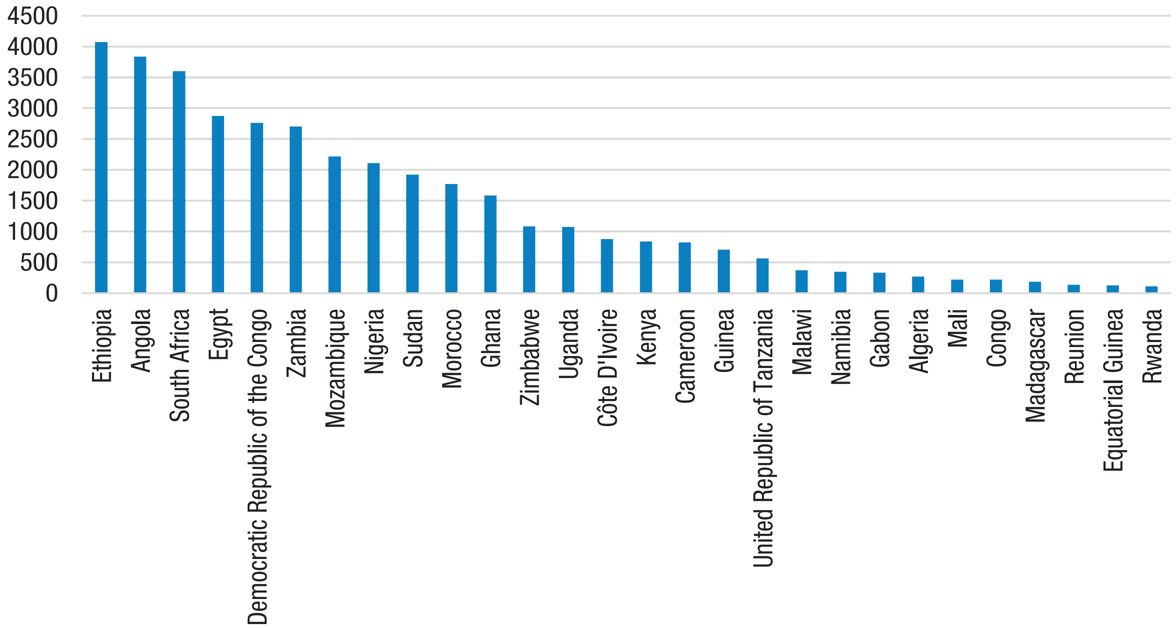
60 Geothermal Energy and Thermal Fluids, Magnetotelluric investigation of active rifting and the formation of geothermal energy resources in Ethiopia (MIRIGE), available at https://geg.ethz.ch/project-ethiopia-geothermal/ (accessed 24 December 2022).

to providing long-term, sustainable energy to the continent as well as security of supply, especially for countries that depend on imported fossil fuels (IRENA, 2020b). The disadvantages of geothermal energy include that it is location-specific, has environmental side effects (gases are released into the atmosphere during digging), and setting up geothermal plants is very costly. For example, a 1 MW capacity plant is estimated to cost between US$2 million to US$7 million.[61] However once it is up and running, it can provide continuous electricity, and the power output is very predictable and stable, thus making it easy to plan with accuracy.[62]

4.2.2 Hydropower

Africa's hydropower potential is enormous, but most of it is largely untapped. In 2021, the continent's total installed hydropower capacity was estimated at about 38,468 MW (38.5 GW), spread across 43 countries.[63] This is about a tenth of the continent's potential capacity of 350 GW, of which about half is located in the Democratic Republic of Congo (Odunowo, 2018). However, 60 per cent of the hydropower-installed capacity in the region is over 20 years old, and modernization is essential to improve access to clean and reliable hydro energy.[64] Figure 14 shows countries with installed capacity above 100 MW.

Figure 14. Total installed hydropower capacity by country with over 100 MW in subSaharan Africa, 2021
(megawatts)



Source: International Hydropower Association (www.hydropower.org/status-report).

61 TWI Ltd., What are the advantages and disadvantages of geothermal energy? available at www.twi-global.com/technical-knowledge/faqs/geothermal-energy/pros-and-cons#HugePotential (accessed 24 December 2022).

62 United States Office of Energy Efficiency and Renewable Energy, 2018, 5 things to know about geothermal power, 14 February, available at www.energy.gov/eere/articles/5-things-know-about-geothermal-power (accessed 24 December 2022).

63 International Hydropower Association, Region profile: Africa, available at www.hydropower.org/region-profiles/africa (accessed 24 December 2022).

64 Ibid.

New projects are steadily increasing hydropower capacity in Africa, and it remains the main renewable energy resource in the region that is contributing to expanding access to affordable electricity.[65] The Grand Ethiopian Renaissance Dam, which is currently operating with an installed capacity of 375 MW, is one such project.[66] It has a potential capacity of more than 5 GW, one of the largest in the world.[67] According to the International Renewable Energy Agency (IRENA), the cost of electricity from new hydropower projects remains among the cheapest renewable energy sources globally. Given that Africa's hydropower potential exceeds current and medium-term demand, developing the available resources could make a significant contribution to increasing supply and alleviating power interruptions caused by generating shortages.

However, developing hydropower faces several challenges. First, it is costly, which may lead to rising debt levels and can sometimes be associated with corruption (Karekezi and Kithyoma, 2003). Second, hydropower development can lead to nefarious environmental impacts. Third, where hydropower is the main source of electricity, droughts caused by low precipitation due to changing climatic conditions can lead to huge shortfalls in electricity generation and power rationing, reducing access to electricity. Fourth, over time, silt builds up in the bed of reservoirs, reducing the amount of electricity generated. Desilting can be costly, so some plants only provide electricity for 20 to 30 years because of siltation.[68] Fifth, hydropower requires a good balance between environmental, social and economic objectives to exploit its potential (Schwerhoff and Sy, 2020). Finally, some tariffs associated with hydropower use are not cost-reflective, hence the sector remains unattractive to potential investors.

4.2.3 Wind power

One of the significant advantages of wind energy over other renewables is that it is an unlimited resource and one of the cleanest forms of energy. Land-based, utility-scale wind turbines generate cost-effective electricity, and their competitiveness continues to improve with advances in wind technology. Between 2010 and 2021 the levelized cost of electricity (LCOE) fell by 68 per cent to reach US$0.033 per kWh, which is in the range of fossil fuel prices (IRENA, 2021). However, initial capital costs are high and may discourage low-income countries from developing wind farms to expand electricity supply to deliver reliable electricity to consumers. In addition, ideal sites for wind farms are often in locations far away from where demand is. This could present challenges in bringing electricity to the market. Above all, the absence of wind leads to supply fluctuations, posing a challenge to reliability.

Africa's wind power generation has barely been harnessed despite the abundance of wind resources on the continent. A study for the International Finance Corporation highlights that the continent's onshore wind potential of almost 180,000 terawatt hours (TWh) per year is enough to meet the electricity demand of the entire continent by more than 250 times.[69] The study also emphasizes that the best wind resources are in Algeria, where the potential is about 7,700 GW,

65 Ibid.

66 Africanews, 2021, Ethiopia's Grand Renaissance Dam starts generating power, February, available at www.africanews.com/2022/02/20/ethiopia-s-grand-renaissance-dam-starts-generating-power/ (accessed 24 December 2022).

67 Ibid.

68 National Geographic, Hydroelectric energy: The power of running water, available at https://education.nationalgeographic.org/resource/hydroelectric-energy-power-running-water (accessed 24 December 2022).

69 International Finance Corporation, 2020, New analysis shows onshore wind potential across Africa enough to power the entire continent many times over, 30 September, available at https://pressroom.ifc.org/all/pages/PressDetail.aspx?ID=24607 (accessed 24 December 2022).

equivalent to over 11 times current global installed wind capacity. Technical wind potential of over 1,000 GW can be found in 15 African countries, including Mauritania, Mali, Egypt, Namibia, South Africa, Ethiopia and Kenya.[70] The Lake Turkana wind farm in Kenya is the largest in Africa, with a generating capacity of 310 MW.[71] The project provides between 15 and 17 per cent of the country's installed capacity and serves the national grid with low-cost electricity.[72]

The offshore wind potential for generating power in sub-Saharan Africa is not clear because of lack of information on this topic. However, globally, offshore wind has the potential to generate more than 420,000 TWh per year worldwide, which is equivalent to meeting global electricity demand 18 times over (IEA, 2019a).

4.2.4 Solar power

Africa is home to 60 per cent of the best global solar resources that mostly remain undeveloped.[73] The solar potential on the continent is estimated at over 10 terrawatts (TW) (AfDB, 2017). Solar power generation has the biggest prospect for increasing access to energy in Africa because it is relatively cheap and quick to install. According to IRENA, solar photovoltaic offers a rapid, cost-effective way to provide utility-scale electricity for the grid and modern energy services to millions of Africans who lack electricity access.[74] Solar photovoltaic is affordable, and installation costs (i.e. the total costs associated with installation of the renewable energy technology, solar photovoltaic system installation) have declined fastest among electricity generated from wind, geothermal, biopower and hydro technology. From 2010 to 2021, solar photovoltaics installation costs declined by 82 per cent. Other costs such as the LCOE, which is a useful metric to measure the average cost of building projects including operating and maintaining them over their lifetime, has also declined. For example, the global weighted average LCOE from utility-scale solar photovoltaics declined by 88 per cent from 2010 to 2021, from US$0.417 per kWh in 2010 to US$0.048 per kWh in 2020, which is one of the lowest costs compared to other renewable sources of energy (IRENA, 2022a). The capacity factor, which represents the annual energy output from a plant expressed as a per cent of the plant's maximum annual energy output, is also increasing for some technologies. For example, concentrated solar power increased by 167 per cent from 2010 to 2021.

Table 2 provides a comparison of solar LCOE costs with other renewable sources of energy. The LCOE of solar is forecast to decline even further by 2030 to a range of US$0.018 per kWh to US$0.049 per kWh, cheaper than wind power or gas (Hall, 2022). Solar photovoltaic is the cheapest source of power in many parts of Africa, and by 2030 it is forecast to out-compete all sources of energy continent-wide.[75] The biggest disadvantage of solar energy is that it is weather-

70 Ibid.

71 East African Development Bank, An update of Lake Turkana wind power project, available at www.eadb.org/news-events/an-update-of-lake-turkana-wind-power-project (accessed 24 December 2022).

72 Norfund 25, 2021, Lake Turkana wind power, press release, 30 July, available at www.norfund.no/lake-turkana/ (accessed 24 December 2022).

73 International Energy Agency, 2022, Key findings: Africa energy outlook 2022, available at www.iea.org/reports/africa-energy-outlook-2022/key-findings (accessed 24 December 2022).

74 International Renewable Energy Agency, 2022, Off-grid energy emerges to plug energy access gaps, 21 December, available at www.irena.org/publications/2016/Sep/Solar-PV-in-Africa-Costs-and-Markets (accessed 29 December 2022).

75 International Energy Agency, 2022, Key findings: Africa energy outlook 2022, available at www.iea.org/reports/africa-energy-outlook-2022/key-findings (accessed 24 December 2022).

dependent, so the efficiency of the system drops when there is no sunlight (e.g. on cloudy and rainy days). Moreover, solar energy cannot be harnessed during the night.

In sub-Saharan Africa, photovoltaics is contributing to improving access to electricity, driven in part by off-grid users replacing diesel-generating units with solar devices and usage across the agricultural and industrial sectors.[76] Some estimates show that off-grid solar was instrumental in increasing energy access by 32 per cent from 2008 to 2017.[77] Utilities are also exploring ways to boost power generation with solar energy. According to the Africa Solar Industry Association, 1.88 GW of large-scale solar projects were commissioned, awarded or confirmed in 2021 (Rodriguez, 2021). For example, in Zambia a 200 MW photovoltaic plant has been awarded for construction and the electricity generated will be added to the national grid. Installed renewable energy capacity on the continent is estimated at 55.2 GW.[78]

Table 2. Comparison of total installed costs (measured as global-weighted averages), capacity factors, and levelized cost of electricity by technology, 2010 and 2021

Energy type	Total installed costs (2021 US$/kW)			Capacity factors (per cent)			Levelized cost of electricity (2021 US$/kWh)		
	2010	2021	Per cent change	2010	2021	Per cent change	2010	2021	Per cent change
Bioenergy	2 714	2 353	-13	72	68	-6	0.078	0.067	-14
Geothermal	2 714	3 991	47	87	77	-11	0.050	0.068	34
Hydropower	1 315	2 135	62	44	45	2	0.039	0.048	24
Solar photo-voltaic	4 808	857	-82	14	17	25	0.417	0.048	-88
Concentrated solar power	9 422	9 091	-4	30	80	167	0.358	0.114	-68
Onshore wind	2 042	1 325	-35	27	39	44	0.102	0.033	-68
Offshore wind	4 876	2 858	-41	38	39	3	0.188	0.075	-60

Source: Adapted from the International Renewable Energy Agency (www.irena.org/publications/2022/Jul/Renewable-Power-Generation-Costs-in-2021)

4.2.5 Hydrogen

Hydrogen is another form of renewable energy that could be leveraged to expand access to energy in Africa. It is mostly extracted from fossil fuels using a catalyst to react with methane and steam to produce what is called grey hydrogen.[79] However the process is laborious and energy-intensive

[76] Energy Sector Management Assistance Program, 2019, Empowering farmers in Africa: Productive Use Leveraging Solar Energy (PULSE), World Bank, 10 December, available athttps://esmap.org/empowering-farmers-in-africa-productive-use-levering-solar- (accessed 24 December 2022).

[77] World Economic Forum, 2020, How to ensure schools and hospitals benefit from Africa's solar boom, 14 July, available at www.weforum.org/agenda/2020/07/schools-hospitals-africas-solar-power-boom/ (accessed 24 December 2022).

[78] International Renewable Energy Agency, Africa: Overview, available at www.irena.org/How-we-work/Africa (accessed 24 December 2022).

[79] United Nations Climate Change, 2021, Can green hydrogen play a bigger role in renewables? 3 May, available at https://unfccc.int/blog/can-green-hydrogen-play-a-bigger-role-in-renewables?gclid=EAIaIQobChMIjMHNppCy-gIVFZzVCh3EUgXQEAAYAiAAEgIEy_D_BwE (accessed 24 December 2022).

and results in production of carbon dioxide. On the other hand, production of green hydrogen, which is the end result of decoupling the hydrogen molecule from other elements with which it is associated (such as water) by using renewable power sources, does not produce carbon dioxide but it is more expensive to extract than using the traditional "grey hydrogen" method.

Hydrogen has varied uses in industry and transport. In power generation, large hydrogen fuel cells can supply electricity to electric power grids, supply backup or emergency power in buildings, and supply electricity in places that are not connected to electric power grids.[80] Furthermore, green hydrogen allows vast quantities of renewable energy to be stored for a long duration. This is because excess renewable electricity during peak production hours can be used to electrolyze water to produce hydrogen and oxygen, and then be converted back to electricity when it is needed. In effect, electricity is converted into another form of energy that can be used in stationary fuel cells for power generation or stored as a compressed gas, cryogenic liquid or wide variety of loosely bonded hydride compounds for longer-term use.[81] Hydrogen has a big advantage over wind and solar because it can be stored in fuel cells, which makes it more reliable as a source of energy. Fuel cells can either be connected to the grid or operate independently (IEA, 2019b).

Hydrogen can also be used in gas turbines to increase power system flexibility (IEA, 2019b). According to the IEA, the potential for producing hydrogen from low-cost renewable electricity in Africa could reach 5,000 megatons (MT) per year at less than US$2 per kilogram.[82] This is partly due to the continent's potential for generating renewable electricity. Countries such as Egypt, Mauritania, Morocco, Namibia and South Africa have already started looking at low-carbon hydrogen projects. [83] In sub-Saharan Africa, Namibia is investing US$9.4 billion to produce 300 MT of green energy per year for regional and global markets.[84] The project includes production of green hydrogen for conversion into green ammonia for fertilizer and renewable electricity generation. This could boost energy supply and access, as well as opportunities for trade. However, there are some challenges holding back hydrogen development, such as cost of production and slow growth of infrastructure to transport, store and deliver to end users.

4.2.6 Natural gas as a transition fuel

The renewable energy sources that have so far been discussed will make a major impact on increasing electricity generating capacity and improving access to energy in sub-Saharan Africa. However, various energy market players expect fossil fuels, notably natural gas, to continue playing a critical role for decades, but in lower volumes as the world transitions to cleaner fuels. For example, the IEA points out that parts of the fossil fuel system, such as gas-fired power for peak electricity needs and refineries to supply residual users of transport fuels, remain critical to energy security. Therefore, unplanned or premature retirement of this infrastructure could have

80 United States Energy Information Administration, 2022, Hydrogen explained, 20 January, available at www.eia.gov/energyexplained/hydrogen/use-of-hydrogen.php (accessed 24 December 2022).

81 Fuel Cell & Hydrogen Energy Association, Hydrogen as energy storage, available at www.fchea.org/hydrogen-as-storage (accessed 24 December 2022).

82 International Energy Agency, 2022, Key findings: Africa energy outlook 2022, available at www.iea.org/reports/africa-energy-outlook-2022/key-findings (accessed 24 December 2022).

83 Ibid.

84 FuelCellsWorks, 2021, Namibia announces a $9.4 million green hydrogen project, 5 November, available at https://fuelcellsworks.com/news/namibia-announces-9-4-billion-green-hydrogen-project/ (accessed 24 December 2022).

negative consequences for energy security.[85] The IEA also projects increased consumption of gas through 2050 mainly due to demand from the industrial sector.[86] Bloomberg's latest New Energy Outlook projects that natural gas will be the only hydrocarbon fuel continuing to grow through mid-century without major policy interventions (Bullard, 2022). It underscores that some of this growth substitutes for oil, for example in power generation. However, much of the growth will be driven by expanding demand for heat, industry and petrochemical uses (Bullard, 2022).

During the energy transition towards a low-carbon future, countries in sub-Saharan Africa (especially lower-income ones, such as least-developed countries) face challenges due to the upfront cost implications and infrastructure upgrade requirements of quickly transitioning to renewable energies. By contrast, natural gas is readily available in several countries in the region, typically burns more efficiently than coal or oil (traditional fuels used in electricity generation) and produces significantly less greenhouse gas emissions than coal or oil. In addition, repurposing coal and oil-fired power plants to lower-carbon gas-powered plants requires a lower upfront capital investment and can reduce the need for new investments in transmission infrastructure. Given the variability associated with renewables in power generation and the challenges associated with large-scale storage capabilities, gas-fired plants can complement the generation profiles of renewable sources. This is because gas can be easily stored and used to generate uninterrupted electricity supply, thereby increasing the reliability and availability of power needed to boost energy access for both household and industrial consumers.

Coal played a critical role in the industrialization of developed countries, but this option is no longer sustainable in the current environment of mitigating greenhouse gases to meet the objectives of the Paris Agreement. Natural gas could be used as a transition fuel to renewables because of its lower carbon properties. Africa has the fifth largest natural gas reserves in the world, estimated at 455.2 trillion cubic feet (Tcf), i.e. 12.9 trillion cubic metres, or approximately 6.9 per cent of the world's natural gas resources.[87] Figure 15 presents a breakdown of gas reserves by world region. In Africa, these reserves are largely concentrated in Nigeria (193.5 Tcf), Algeria (80.5 Tcf), Egypt (75.5 Tcf) and Libya (50.5 Tcf). However, many other countries, including Senegal, Mozambique, United Republic of Tanzania, Libya, Angola, Cameroon, Congo, Equatorial Guinea, Cameroon and Sudan, also have quantifiable proven reserves.[88]

Based on known reserves, there is potential for approximately 400 GW of gas-generated power in sub-Saharan Africa. However, it is estimated that only 5 per cent of this potential has been exploited on the continent (Elliot and Lalor, 2021). More than 5,000 billion cubic metres of gas resources have been discovered but not yet approved for development.[89] According to the IEA, such resources may provide a crucial input to the continent's industrialization, particularly in the

85 International Energy Agency, 2022, Executive summary: Russia's invasion of Ukraine has sparked a global energy crisis, available at www.iea.org/reports/world-energy-outlook-2022/executive-summary (accessed 24 December 2022).

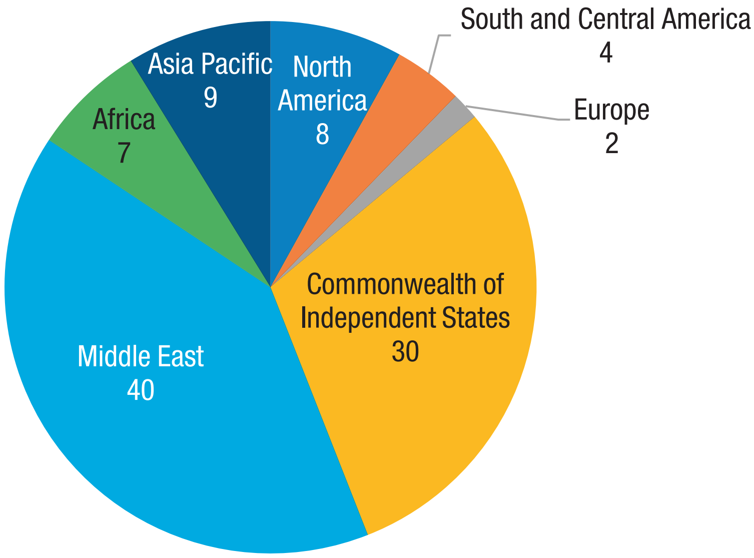
86 United States Energy Information Administration, 2021, EIA projects nearly 50% increase in world energy use by 2050, led by growth in renewables, Today in Energy, 7 October, available at www.eia.gov/todayinenergy/detail.php?id=49876(accessed 24 December 2022).

87 British Petroleum, 2022, Statistical review of world energy 2022, available at www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html (accessed 24 December 2022).

88 Energy Capital & Power, 2021, Top 10 African countries sitting on the most natural gas, 16 July, available at https://energycapitalpower.com/top-ten-african-countries-sitting-on-the-most-natural-gas/ (accessed 24 December 2022).

89 International Energy Agency, 2022, Key findings: Africa energy outlook 2022, available at www.iea.org/reports/africa-energy-outlook-2022/key-findings (accessed 24 December 2022).

Figure 15. Regional shares of gas reserves in the global total, 2020
(per cent)



Source: UNCTAD secretariat based on data from British Petroleum.

fertilizer, steel and cement industries and in water desalination.[90] Furthermore given the enormous energy needs of Africa's rapidly growing population and urbanization, sub-Saharan Africa's massive gas reserves could be developed to provide reliable and affordable electricity baseloads to improve access to energy while the continent transitions steadily to renewables. Many countries around the world are promoting gas to power projects as a climate-friendly alternative to coal and oil. For example, the European Union (EU) classification of natural gas as a "transition" energy source makes it possible for investment in natural gas projects compatible with the EU's 2050 net-zero goal.

Development of gas could also present an opportunity to monetize Africa's gas resources by trading with other regions where consumption of gas constitutes a part of their strategy to decarbonize their energy mix while scaling up zero-emission energy technologies. This demand for gas could potentially be met through investment in gas export infrastructure such as liquefied natural gas export terminals or continental/transcontinental gas pipeline projects to deliver gas to local, regional and international end-use consumers. Plans to use gas as a transition fuel could present some short-term opportunities for African gas producers. However, care must be exercised that the needs of the continent are prioritized over efforts to monetize gas so that the abundant energy that is produced can contribute to boosting energy access within Africa itself.

In the long term, efforts should intensify to transition entirely from all fossil fuels to renewables, as this could lead to energy independence and economic diversification, and contribute to sustainable economic growth. Dependence on natural gas may also expose countries to the risks of stranded assets, with beginning to develop manufacturing capabilities caught between changing approaches to energy.[91] According to IRENA, a systematic shift in Africa away from

90 Ibid.

91 World Economic Forum, 2022, Renewables could do much more than just transform Africa's energy sectors. Here's how, 9 September, available at www.weforum.org/agenda/2022/09/renewables-energy-transition-africa-jobs/ (accessed 24 December 2022).

fossil fuels towards an energy system based on renewable energy from 2020 to 2050 could lead to 6.4 per cent higher GDP, 3.5 per cent more economy-wide jobs, and a 25.4 per cent higher welfare index if the shift is accompanied by an appropriate policy basket.[92]

The transition from fossil fuels directly to renewables can take time given the scale of the technological and economic challenges facing African countries and current policy frameworks for decarbonization in electricity generation. The huge energy deficits in sub–Saharan Africa and the constraint in transitioning suggest that some flexibility is needed in the type of energy resources necessary to boost electricity generation to meet rising demand. Barring natural gas in the energy mix is likely to raise energy costs on the most vulnerable populations and suppress incomes and job creation.[93]

4.2.7 Nuclear power

Uranium, the critical raw material used to produce fuel for nuclear power plants generating electricity, is available in only a few countries in Africa, namely Namibia, South Africa, Niger, Botswana and the United Republic of Tanzania.[94] Two of these countries, Namibia and Niger, are among the top ten global producers.[95] The resources available in Africa have potential to supply nuclear energy to the whole continent. However, South Africa is the only country that has commercial nuclear power generation on the continent. It generates 1,940 MW but there is increasing government interest in many countries, such as Ghana, Kenya, Egypt, Morocco, Niger and Nigeria, in developing commercial nuclear power and they have engaged with the IAEA to assess their readiness to embark on a nuclear programme.[96] Algeria, Tunisia, Uganda and Zambia are also evaluating the feasibility of nuclear power.[97] The main advantage of nuclear power is that it provides a clean source of power. However, building new nuclear power plants is very expensive. In addition to the capital costs, new plants require licensing and regulation approvals, coupled with long lead times and construction delays, which deter public interest. Evolving technology is making it possible to construct small nuclear reactors or small modular reactors. These reactors have generating capacity of about a third of the traditional power reactors, and they are designed with modal technology making it possible for factory fabrication, thus reducing construction times.[98] Another challenge with nuclear power is that it produces radioactive waste that must be safely treated and disposed of, and the process is often viewed as dangerous or unstable.[99] Although the risk of accidents in nuclear power plants is low, the public perception is that nuclear power is dangerous because of previous global accidents.[100] This often leads to anti-nuclear groups lobbying governments against setting up nuclear plants.[101]

92 Ibid.

93 World Economic Forum, 2022, 12 reasons why gas should be part of Africa's clean energy future, 23 July, available at www.weforum.org/agenda/2020/07/12-reasons-gas-africas-renewable-energy-future/ (accessed 24 December 2022).

94 https://www.statista.com/statistics/1298888/uranium-resources-in-africa-by-country/

95 https://world-nuclear.org/information-library/nuclear-fuel-cycle/mining-of-uranium/world-uranium-mining-production.aspx

96 https://www.pwc.com/ng/en/assets/pdf/africa-energy-review-2021.pdf

97 Ibid

98 https://www.iaea.org/newscenter/news/what-are-small-modular-reactors-smrs

99 The International Atomic Energy Agency provides safe guidelines for processing nuclear waste https://www.iaea.org/topics/processing

100 https://www.iaea.org/newscenter/news/qa-public-opinion-of-nuclear-and-why-it-matters-to-the-clean-energy-transition (accessed 2 February 2022)

101 https://www.cnet.com/science/how-nuclear-power-plants-could-help-solve-climate-crisis/ (accessed 2 February 2022)

4.3 EXTENDING NATIONAL GRIDS

Power grids are vital in moving electricity from where it is generated to where it is needed. In sub-Saharan Africa, many countries have electricity grids that are not capable of adequately serving residents. Very often, national grids do not extend to cover rural areas. A survey of 34 African countries, including the North African countries of Tunisia, and Morocco, reveals that an average of 68 per cent of the population living in surveyed areas are served by a grid but only 57 per cent of households are connected to the grid because the remaining households cannot afford the high connection costs (Lee et al., 2022). The survey also highlights that less than 50 per cent of the population has access to a grid in countries such as Uganda, Malawi, Mali, Guinea, Liberia, Sierra Leone, Niger, Ethiopia, and Burkina Faso (Lee et al., 2022). A World Bank study shows that access rates would be on average well over 60 per cent if all households in Africa living within range of the electrical grid were connected to it, and that the current rate in many countries would nearly double (Blimpo and Cosgrove-Davies, 2019).

Extending national power grids nationally and beyond borders could contribute to expanding access to energy across a country by extending electricity supply to where it is needed. It would also foster the integration of renewable energy sources into the electricity transmission network. The electrical grid infrastructure in Africa is around 26,000 kilometres, compared to 430,000 kilometres in India, which has a comparable population size.[102] The lack of grid infrastructure poses challenges for connecting generating plants such as wind turbines and solar farms to transmission lines, especially for those located in remote areas far from existing grid infrastructure.

4.4 MINI-GRIDS AND ELECTRICITY ACCESS

Mini-grid and off-grid electricity can also be employed to improve access to electricity in sub-Saharan Africa's rural areas, where it might be costly to extend the national grid. Expanding access to electricity by using mini-grids usually involves building a set of small-scale electricity generating plants that are interconnected with a distribution network that supplies electricity to a small, localized group of customers. It usually operates independently from the national transmission grid (Burrell, 2021). Renewable energy sources are commonly used in this type of electricity generation because of their proximity to consumers. According to World Bank estimates, a US$220 billion investment is needed to connect 490 million people globally to 210,000 mini-grids by 2030 (Lawrence, 2020). In Africa, a few countries, including the United Republic of Tanzania, Kenya, Uganda, Nigeria and Ghana, have put in place frameworks and supportive policies to expand energy access through mini-grids, and more than 4,000 of such grids are currently in planning stages across the continent (ESMAP, 2019). Costs to implement solar energy mini-grids have declined by over 30 per cent from US$0.55 per kWh in 2018 to US$0.38 per kWh today, largely due to falling costs of key components such as solar and battery storage technologies. Thus, solar mini-grid solutions have become economically viable and present an opportunity to connect towns and cities to a reliable supply of electricity off the main grid (Lawrence, 2020).

[102] International Hydropower Association, Region profile: Africa, available at www.hydropower.org/region-profiles/africa (accessed 24 December 2022).

4.5 IMPROVING ACCESS THROUGH INTRA-REGIONAL ELECTRICITY TRADE

The capacity for electricity generation varies across countries in sub-Saharan Africa. Therefore, pooling resources and national grids can unleash the potential of a regional power market in terms of providing regular and reliable energy and lowering the cost of electricity to consumers. The benefits of harmonizing power sectors and improving conditions for cross-border trade are diverse. For example, countries can reduce their capital investment on local generation capacity and increase the diversity of energy resources (including renewable energies) available across many countries in sub-Saharan Africa. This can provide the flexibility needed to accommodate higher shares of renewables in the region's energy mix and contribute to bolstering energy security.[103] Furthermore, by sharing production capacity for renewable energy sources across borders, countries can strengthen the reliability of their power supplies, improve access to electricity by enabling countries with surplus energy to exchange power with countries experiencing energy deficits, and also meet national climate commitments by reducing carbon dioxide emissions traditionally associated with power generation.[104] However, there are some challenges that need to be addressed to facilitate cross-border trade in energy, including the need for participating countries to harmonize legal and regulatory frameworks that set out clear rules and standards, and to upgrade power transmission and distribution infrastructure.

The West African Power Pool (WAPP) is one such project created with the aim of integrating national power systems into a unified regional electricity market with the ultimate goal of providing regular and reliable energy at competitive cost to the citizenry of the Economic Community of West African States in the medium and long term.[105] When the WAPP becomes fully operational it is expected to boost electricity supply in the region, significantly increasing access to electricity. The government of Ghana is linking a transmission line for power export from Kumasi to Burkina Faso, at an estimated cost of US$174 million. The project, which is an integral part of the WAPP initiative, ensures the export of at least 100 MW of electricity to Burkina Faso that will increase access to stable, reliable and affordable energy for the citizens in that country (Baffoe Donkor, 2022). The project will also help Burkina Faso improve the security of electricity supply and boost the reliability of networks and availability of grids in both Ghana and Burkina Faso.

Other regional power pools such as the East African Power Pool (EAPP) and the Southern African Power Pool (SAPP) are at different stages of development and operation. Examples of cross-border electricity infrastructure to facilitate trade in the EAPP include a 2,000 MW capacity transmission line connecting Kenya to Ethiopia, which is the longest in East and Central Africa.[106] In the SAPP, Angola, in collaboration with the African Development Bank (AfDB), is building transmission and distribution infrastructure that will connect the north of the country, where a surplus of more than 1,000 MW is generated mostly from hydropower, with the south grids that rely on expensive

103 National Association of Regulatory Utilities Commissioners, 2021, Regulators in Southern Africa make progress towards promotingprogress cross-border electricity trade, November, available atwww.naruc.org/international/news/regulators-in-southern-africa-make-progress-towards-promoting-cross-border-electricity-trade/ (accessed 24 December 2022).

104 Ibid.

105 The WAPP is made up of Senegal, The Gambia, Guinea, Sierra Leone, Liberia, Mali, Côte d'Ivoire, Ghana, Burkina Faso, Niger, Togo Benin, and Nigeria.

106 Transformers Magazine, 2022, Ethiopia-Kenya electrical line set to go live, 9 August, available at https://transformers-magazine.com/tm-news/ethiopia-kenya-electricity-line-set-to-go-live/ (accessed 24 December 2022).

diesel generators.[107] When the SAPP becomes operational in 2023, it will improve access to electricity across the country, strengthen the financial viability of the power sector, and connect Angola to regional markets.[108]

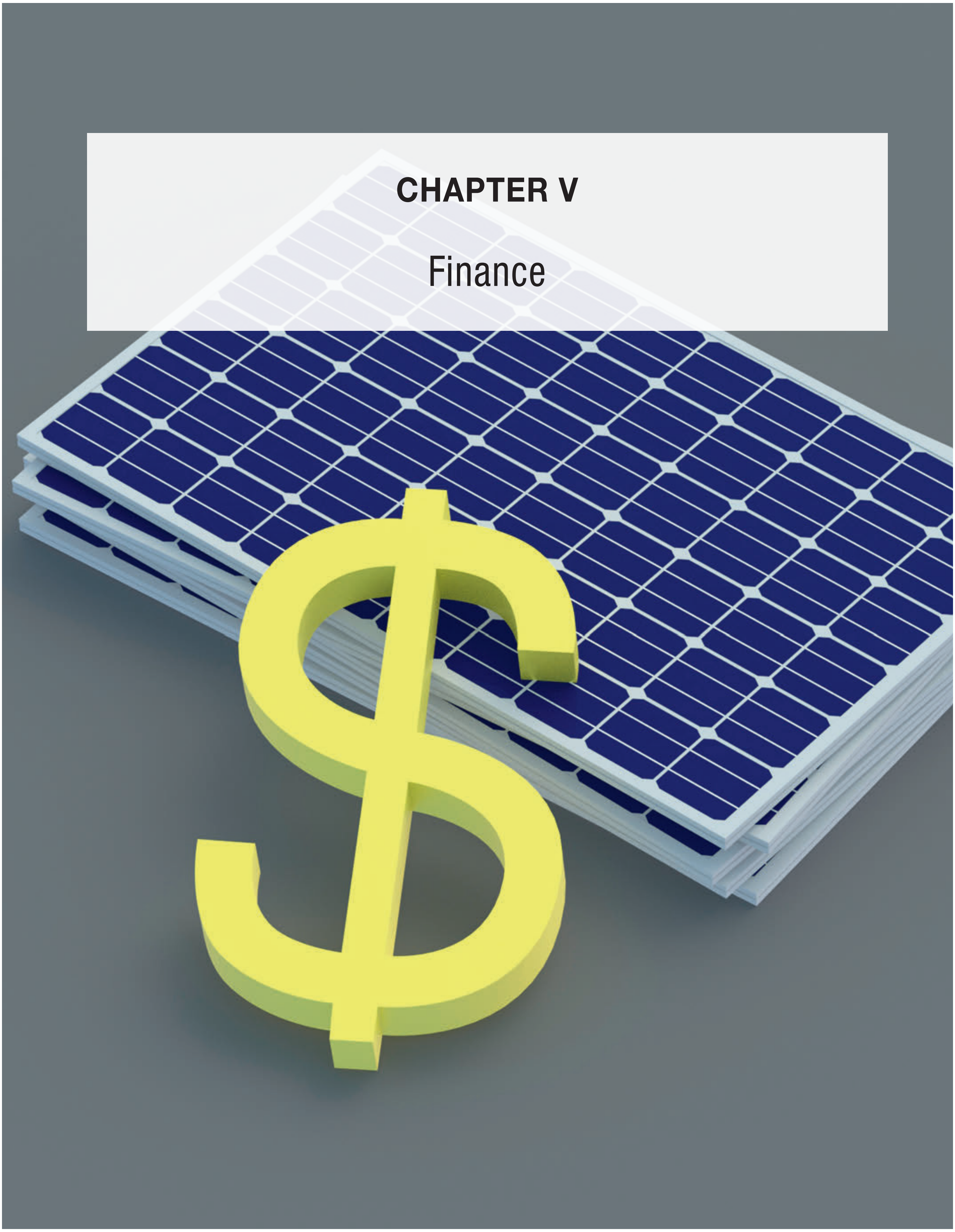
The potential of electricity generation, distribution and cross-border trade in sub-Saharan Africa can significantly improve access to energy and open opportunities for international trade. However, the appropriate infrastructure needs to be put in place, and it is costly. The next chapter looks at the scale of investments needed and some potential financing mechanisms to achieve this.

107 African Development Bank, 2021, Angola: African Development Bank funds $530 million electricity project to expand renewable energy and regional connectivity, press release, 16 March, available at www.afdb.org/en/news-and-events/press-releases/angola-african-development-bank-funds-530-million-electricity-project-expand-renewable-energy-and-regional-connectivity-42723 (accessed 24 December 2022).

108 Power Africa, 2021, Bridging the power gap in Angola, 18 March, available at https://powerafrica.medium.com/bridging-the-power-gap-in-angola-db7ece305c97 (accessed 24 December 2022).

CHAPTER V

Finance



5.1 ENERGY CAPACITY AND INFRASTRUCTURE INVESTMENT

Developing Africa's vast energy wealth will play a vital role in improving access to modern cooking fuels and expanding access to electricity services in sub-Saharan Africa. However, the scale of investments to develop the right fuels and infrastructure to provide modern energy services is massive. Some estimates show that providing universal access to electricity in sub-Saharan Africa by 2025 would require about 160 GW of new capacity, including clean and renewable energy solutions, 130 million new on-grid connections, and 75 million new off-grid connections. It would also require providing 150 million households with access to clean cooking solutions (AfDB, 2017). Furthermore, inadequate or weak grids and transmission infrastructure need to be revamped to ensure reliable distribution and to expand and facilitate access. It is estimated that the operating losses of all African utilities in 2020 totaled more than US$150 billion (IEA, 2022).

The massive amount of investment needed to increase installed capacity, modify old generation plants, and build other related infrastructure to help countries increase electricity supply and distribution is due in part to the large energy deficits and low access to modern energy services. Africa's large hydro, geothermal, solar and wind, and natural gas resources mean that there is potential to achieve universal access in sub-Saharan Africa without turning to heavily polluting fossil fuels. This would greatly modify the continent's energy mix towards zero emissions. According to the IEA, achieving universal access to modern energy in Africa would requires investments of US$25 billion per year, which is about 1 per cent of the current global energy investment.[109] Public utilities tend to be responsible for much of the investment to upgrade electricity systems across the African continent, but the scale of the investment will also require stimulating more foreign investment. To achieve this, the IEA underscores the need for international support aided by stronger national institutions on the ground laying out clear access strategies.[110]

Investing in natural gas projects may present challenges because more emphasis is placed on renewable energy projects to reduce greenhouse gases, and because of rising political and market risks. Some banks are gradually phasing down financing the oil and gas industry and scaling up lending for renewables (Jessop and Sterling, 2022). From 2000 to 2009, investment in African renewable energy projects was estimated at US$5 billion, while from 2010 to 2020 it increased to approximately US$55 billion, with about 70 per cent destined for projects in Southern Africa and North Africa (Leke et al., 2022). On the other hand, global investments from 2010 to 2020 in the upstream oil and gas sector in nominal terms have declined from US$511 billion to US$328 billion.[111] Many hydrocarbon-based projects have been designed in Africa, but they have difficulty starting because of the challenges of securing sufficient financing from international banks. For example, in November 2021, China announced that it would no longer finance a 3 MW coal power plant in South Africa's Limpopo province (S&P Global, 2022). A number of financial institutions have also pulled out of midstream oil and gas projects such as the East African Crude Oil Pipeline project, which is being built to transport oil drilled in a biodiverse national park in Uganda more than 870 miles to a port in the United Republic of Tanzania for export (Carrington, 2022). Therefore, countries may need to increasingly seek other sources of financing other than project finance to unlock lower-carbon energy projects. Governments, sovereign wealth funds and export/import banks could play an important role as anchor investors.

109 International Energy Agency, 2022, Key findings: Africa energy outlook 2022, available at www.iea.org/reports/africa-energy-outlook-2022/key-findings (accessed 24 December 2022).

110 Ibid.

111 International Energy Agency, 2020, World energy investment 2020: Fuel supply, available at www.iea.org/reports/world-energy-investment-2020/fuel-supply (accessed 24 December 2022).

5.2 SCALE OF INVESTMENT

The scale of renewable energy investments that might be necessary to achieve modern energy access in Africa is massive. The United Nations estimates that at least US$4 trillion a year needs to be invested in renewable energy by 2030, including investments in technology and infrastructure, to reach net-zero emissions by 2050.[112] It is estimated that the current average annual investment in energy systems in Africa must double by 2030 to around US$40 billion to US$65 billion to accelerate the energy transition (IRENA, 2020a). From 2000 to 2020, renewable energy investments in Africa (excluding large hydropower) totaled almost US$60 billion, but that represents only about 2 per cent of global investments in renewables during this period (IRENA, 2022a). Table 3 summarizes this information.

Table 3. Renewable energy spending in Africa and globally, 2000 to 2020
(billions of United States dollars)

	2000–2009	2010–2020	Cumulative 2000–2020
Global	587	2 254	2 841
Africa	4.8	55	60
North Africa	1.9	17.5	19.4
West Africa	0.5	3.9	4.4
East Africa	2.0	9.7	11.7
Central Africa	0	1.3	1.3
Southern Africa	0.3	22.4	22.7

Source: UNCTAD Secretariat adapted from the International Renewable Energy Agency.

Thus, support from international development agencies and multilateral banks will be vital to expand clean energy services on the continent. The AfDB is ramping up its support for the energy sector with plans to invest in 10 GW of solar generation capacity in the Sahel region through its Desert to Power Programme, which will provide electricity to some 250 million people.[113] In addition, Power Africa, a United States government-led partnership with public and private sector institutions whose goal is to enable access to electricity on the continent, is committed to investing in sub-Saharan Africa to develop 30 GW of new and cleaner power generation and establish 60 million new electricity connections.[114]

Access to clean fuels or technologies for cooking also requires significant financing requirements to accelerate progress toward universal access by 2030. It is estimated that an annual investment of US$4.4 billion is required to achieve the SDG 7 target of universal access to clean fuels and technologies for cooking by 2030.[115] The World Bank has leveraged some funding through its Efficient, Clean Cooking and Heating Programme to advance its clean cooking agenda through technical advice and country/regional grants to its operational teams. The Economic Sector

112 United Nations, Five ways to jump-start the renewable energy transition now, available at www.un.org/en/climatechange/raising-ambition/renewable-energy-transition (accessed 24 December 2022).

113 African Development Bank, 2022, Desert to power progress report, 3 September, available at www.afdb.org/en/documents/desert-power-progress-report-2021 (accessed 24 December 2022).

114 United States Agency for International Development, Power Africa partners, available at www.usaid.gov/powerafrica/partners (accessed 24 December 2022).

115 Sustainable Energy for All, SDG 7 – Access to energy, available at www.seforall.org/goal-7-targets/access (accessed 24 December 2022).

Management Assistance Programme (ESMAP) also launched a US$500 million Clean Cooking Fund (CCF) in 2019 that was operationalized in 2020 to scale up investments in the clean cooking sector (World Bank, 2020c). The fund is planning to leverage US$2 billion in investments to support businesses delivering clean cooking solutions.[116] The first CCF project is the Energy Access Quality Improvement Project (EAQIP) in Rwanda, which is the largest World Bank-financed clean cooking project in Africa to date.[117] The EAQIP will expand access to clean cooking solutions for 500,000 households across Rwanda and leverage US$30 million in public and private sector investment. Other African countries in the pipeline include Uganda, Burundi, Ghana, Niger and Mozambique.[118]

The wide gap in funding needs for electricity generation and the associated infrastructure to boost distribution and access, as well as clean fuels, requires employing a wide range of financing. The scale of investment means that multiple sources of financing are needed from multilateral development banks and other public and private financial institutions, as well as from a variety of innovative financing instruments. For example, countries can look at blended finance, crowd funding, green credit, sustainable green bonds, funding for financing renewable energy projects, guarantee mechanisms, and insurance.

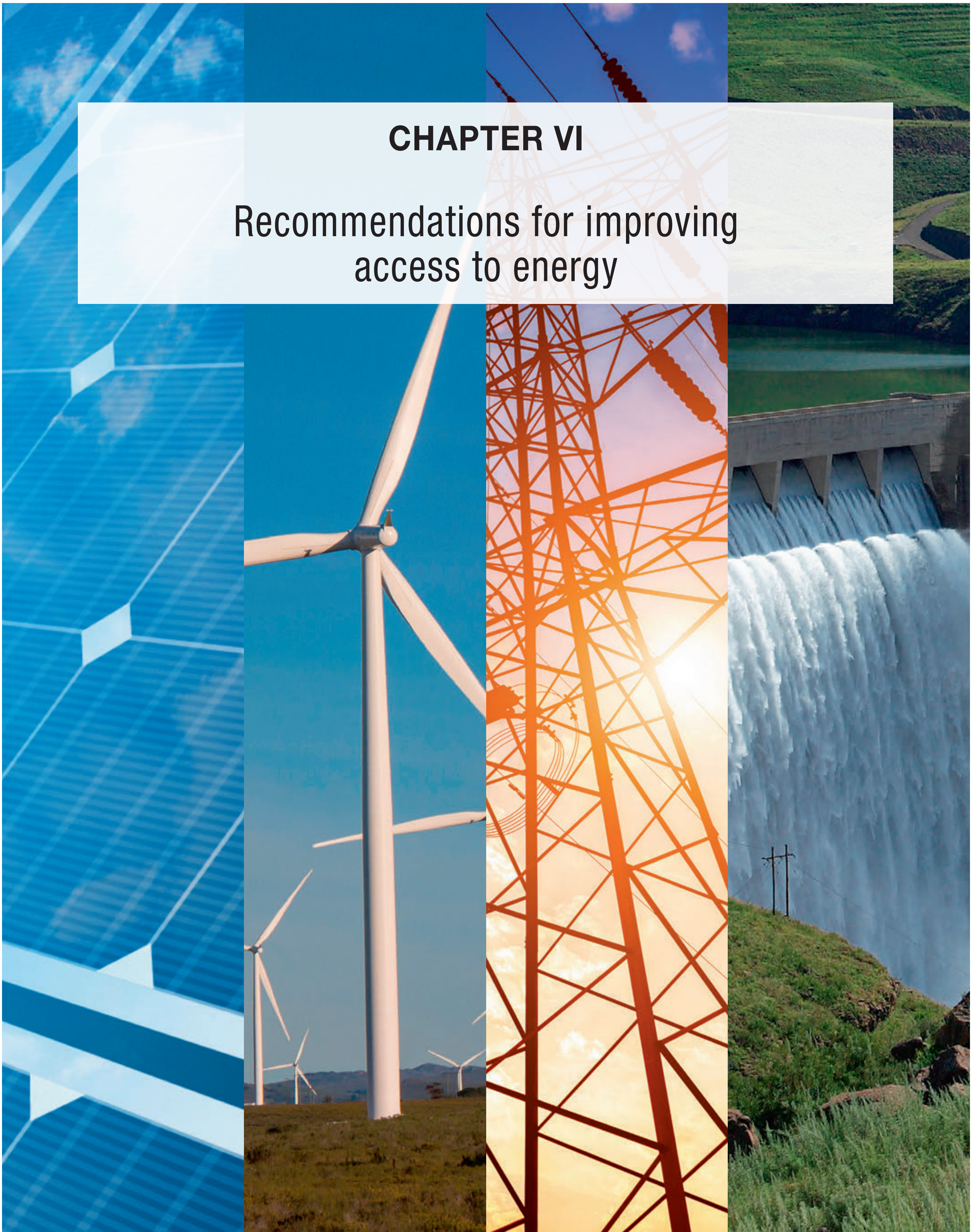
116 Ibid.

117 World Bank Energy Sector Management Assistance Fund, Clean Cooking Fund, available at www.esmap.org/clean-cooking-fund (accessed 24 December 2022).

118 Ibid.

CHAPTER VI

Recommendations for improving access to energy



6.1 SUMMARY

Demand for energy services in sub-Saharan Africa is increasing rapidly, largely due to population growth. The population of the region is forecast to increase from 1.15 billion in 2020 to 1.401 billion in 2030 (IEA, 2022). Based on the IEA Stated Policies Scenario, which takes into account energy and climate measures put in place by governments, electricity demand on the continent is forecast to rise from about 700 TWh in 2019 to over 1,600 TWh in 2040 (IEA 2019). The fastest growth is expected in countries excluding those in the North Africa region and in South Africa (IEA, 2019d). This suggests that implementation of projects to boost energy supply in sub-Saharan Africa is likely to increase in order to ensure access to modern energy services by the population continent-wide. As discussed in Chapter 4, a variety of primary energy sources are available that can be developed, but such projects must also be viable and sustainable. For example, developing gas projects should incorporate decarbonization, given the risk of having stranded assets as the world transitions to zero-emission fuels.

Investment in lower-carbon-energy infrastructure projects, especially gas pipelines, processing infrastructure and liquefied petroleum gas, could enable African countries to promote intraregional trade and boost global exports of African energy products, while also helping to strengthen regional energy access. The current pace of electrification and access to clean cooking fuels and technology is not fast enough to meet the target of SDG 7 by 2030. The various factors contributing to low access to electricity in sub-Saharan Africa discussed in Chapter 3 – such as aging infrastructure, high costs of generation, low levels of income to take up available services, lack of grid coverage, and unreliability of the grid – are prevalent across countries in the region. Furthermore, utility companies find it difficult to generate a good return on investment in new power plants because of low demand, so there is limited desire to expand.[119] Therefore, achieving universal access to electricity would require a good understanding of both supply-side and demand-side challenges, as well as well-targeted policies and programmes to stimulate demand and develop available resources.

6.2 POLICY IMPLICATIONS AND ACTIONS[120]

Traditional cooking systems using firewood, cow dung and other forms of biomass energy still dominate the cooking fuels and technologies used in sub-Saharan Africa. As highlighted in this report, the lack of clean cooking fuels comes at enormous risks to the health and welfare of the population, particularly women and children. An assessment of recent trends indicates that without additional efforts to scale up clean cooking, the clean fuels access deficit will increase from 923 million people in 2020 to over 1.1 billion people in 2030 largely due to population growth outpacing small gains in the percentage of people gaining access to clean cooking fuels and technology (IEA et al., 2022: chapter 2). Moreover, the use of biomass for cooking will contribute to accelerating forest degradation and greenhouse gas emissions through inefficient burning. Urgent action is therefore needed to scale up access to clean cooking fuels and technologies. This could be achieved through a range of methods, such as raising awareness about modern

119 African Development Bank Group2013, The high cost of electricity generation in Africa, blog, 18 February, available at https://blogs.afdb.org/fr/blogs/afdb-championing-inclusive-growth-across-africa/post/the-high-cost-of-electricity-generation-in-africa-11496 (accessed 24 December 2022).

120 UNCTAD, 2021, Over half of the people in least developed countries lack access to electricity, 1 July, available at https://unctad.org/topic/least-developed-countries/chart-july-2021 (accessed 24 December 2022).

stoves and fuels; mobilizing investments and creating enabling environments to drive growth of a robust clean cooking industry; prioritizing access to clean cooking in national planning and policies; and providing technical assistance to countries that lack access to clean cooking fuels to develop appropriate technology (Energy Compacts and Clean Cooking Alliance, undated).

Access to electricity in sub-Saharan Africa is the lowest of any world region due in part to lack of grids that distribute electricity to consumers, and in part to the fact that where grids do exist, they are outdated, unstable and lack customer connections. Updating and expanding grids will require substantial infrastructure investment that includes the use of financing instruments such as grants, loans, insurance and guarantees. Housing will also need to be upgraded to accommodate electricity connections. In addition, improving the regulatory and legal framework for investments in the sector could contribute to increasing private sector involvement in developing much-needed infrastructure and reduce pressure on public finances.

As a large part of the population in rural sub-Saharan Africa lives away from the main grids, another promising approach to improving access to energy is to set up localized distribution systems whose energy supply is from local energy resources such as solar and wind. These so-called mini-grids or isolated grids are built with a set of small-scale electricity generators interconnected to a distribution network that supplies electricity to a small, localized group of customers (Burrell, 2021). They require less capital expenditure and can be deployed more rapidly than the main grid because their planning and implementation is more conducive to spontaneous entrepreneurial development (World Bank, 2019). The IEA underscores that mini-grids are the most cost-efficient option to deliver electricity to millions of unconnected households. According to the IEA, with US$300 billion in investment and supportive policies, mini-grids could serve 450 million people by 2030.[121] In sub-Saharan Africa, where access to energy services is much lower than the global average and where power grids are highly unreliable, governments should develop legislation and regulation to support mini-grids so that they can achieve scale, flourish and become economically viable (SEforALL, 2020).

The global transition away from fossil fuels towards renewable energy fuels has implications for energy production in sub-Saharan Africa. In 2019, over 60 per cent of the total energy consumed for electricity and the production of heat came from fossil fuels.[122] Those fuels emitted about 14.1 gigatons of carbon dioxide (IEA, 2021), approximately 30 per cent of the world's total greenhouse gas emissions. The IEA estimates that the switch from coal to gas alone reduces CO2 emissions by around 40 per cent for each unit of energy output (IEA, 2019c). Sub-Saharan Africa's vast resources of renewable energy could be exploited to boost electricity generation in a greener and more sustainable way. In this regard, developing renewable resources or scaling up generation plants can make a significant contribution to improving access to energy while reducing emissions of greenhouse gases.

There is potential in Africa to scale up production and, when it is integrated into micro grids or as individual energy generation (off-grid), this could significantly increase access to energy services. But all of this requires a high level of investment. Mobilizing financial resources for such investments from domestic sources is a major challenge for many countries, particularly those in sub-Saharan Africa. Governments should therefore take a closer look at their energy investment needs and the various domestic and international sources of financing that can be explored. For

121 World Economic Forum, 2018, How mini grids could solve global energy poverty, 2 July, available at www.weforum.org/agenda/2018/07/mini-grids-a-small-solution-to-one-of-our-biggest-problems/ (accessed 24 December 2022).

122 International Energy Agency, World energy balances: Overview, available at www.iea.org/reports/world-energy-balances-overview/world (accessed 24 December 2022).

example, moving subsidies targeted at fossil fuel production and power generation towards clean energy access could contribute to generating cleaner fuels. Various financing options should also be explored to develop renewable resources, as discussed in Chapter 5. Addressing energy access will require policy measures that focus on balancing the affordability of energy services and the financial viability of individual projects.

In conclusion, increasing access to modern energy services in sub-Saharan Africa is not going to be an easy task given the scale of the investment required to boost supply and the associated infrastructure for distribution. However, making clean and safe cooking fuels and reliable clean and affordable energy universally available in sub-Saharan Africa would represent a tremendous benefit to the population. Achieving the SDG 7 target to ensure access to affordable, reliable, sustainable and modern energy for all will have health, economic, and environmental benefits. Energy access at this scale through a low-carbon pathway will also provide an opportunity to drive large-scale industrialization and economic growth on the continent, as envisaged in the African Union Agenda 2063. As the scale of investment needed to improve the pace of energy access is massive, it is essential to develop policies that attract investments from all possible sources, including private and foreign sources, multilateral financial institutions and international development agencies.

ANNEX: STATISTICAL DATA

Table A1. Access to clean fuels and technologies for cooking, Africa and other country groupings, 2015 to 2020
(per cent of population)

Countries	2015	2016	2017	2018	2019	2020
Algeria	99.5	99.6	99.6	99.6	99.7	99.7
Angola	47.2	47.8	48.4	49.1	49.5	50.2
Benin	4.3	4.3	4.2	4.2	4.0	4.0
Botswana	61.7	62.4	63.0	63.8	63.9	64.7
Burkina Faso	8.1	8.7	9.0	9.5	10.1	10.6
Burundi	0.2	0.2	0.2	0.2	0.2	0.2
Cabo Verde	75.5	76.5	77.8	78.9	80.2	81.0
Cameroon	22.0	22.2	22.2	22.1	22.2	21.9
Central African Republic	0.6	0.7	0.7	0.7	0.7	0.8
Chad	4.1	4.6	5.1	5.5	6.1	6.8
Comoros	5.7	6.3	6.8	7.3	7.8	8.4
Congo	25.4	27.4	29.5	31.1	32.6	34.9
Côte d'Ivoire	23.1	24.9	26.6	28.4	30.3	31.8
Democratic Republic of the Congo	3.7	3.7	3.8	3.6	3.8	3.7
Djibouti	8.4	8.8	9.0	9.3	9.5	9.7
Egypt	99.8	99.8	99.9	99.9	99.9	99.9
Equatorial Guinea	24.0	23.9	24.2	24.1	24.0	24.5
Eritrea	9.0	9.0	9.2	9.1	9.2	9.3
Eswatini	47.6	49.2	50.6	52.4	53.8	55.4
Ethiopia	4.3	4.9	5.5	6.2	7.0	7.8
Gabon	85.6	86.2	86.8	87.4	87.8	88.1
Gambia (the)	2.0	1.9	1.9	1.8	1.8	1.7
Ghana	21.1	21.8	21.9	22.2	22.4	22.2
Guinea	1.0	1.1	1.2	1.4	1.6	1.9
Guinea-Bissau	1.1	1.1	1.1	1.2	1.0	1.1
Kenya	11.6	13.0	14.4	16.0	17.7	19.5
Lesotho	36.5	37.4	38.1	38.7	39.3	40.1
Liberia	0.4	0.4	0.4	0.4	0.4	0.4
Libya	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Madagascar	0.9	0.9	0.9	0.9	0.9	1.0
Malawi	2.0	1.8	1.6	1.3	1.2	1.0
Mali	0.9	0.9	0.9	0.9	0.9	0.9
Mauritania	43.1	43.3	43.2	43.3	43.0	42.6
Mauritius	97.2	97.1	97.1	97.0	96.9	96.8
Morocco	97.7	97.8	97.9	97.9	98.0	98.1
Mozambique	3.9	4.2	4.4	4.6	4.8	5.1
Namibia	44.3	45.2	45.6	46.0	46.5	46.8

Countries	2015	2016	2017	2018	2019	2020
Niger	1.7	1.8	1.9	2.1	2.3	2.4
Nigeria	5.4	6.9	8.7	10.7	12.9	15.0
Rwanda	0.6	0.9	1.1	1.4	1.9	2.4
Sao Tome and Principe	2.1	2.3	2.6	2.7	3.0	3.3
Senegal	27.3	26.5	25.9	25.2	24.7	24.2
Seychelles	100.0	100.0	100.0	100.0	100.0	100.0
Sierra Leone	0.5	0.5	0.6	0.7	0.7	0.8
Somalia	2.0	2.3	2.4	2.7	2.9	3.2
South Africa	83.4	84.4	85.2	85.7	86.3	86.8
South Sudan	0.0	0.0	0.0	0.0	0.0	0.0
Sudan	45.4	47.9	49.8	51.3	53.6	54.7
Togo	6.6	7.3	8.0	8.6	9.3	10.1
Tunisia	99.7	99.8	99.8	99.8	99.8	99.8
Uganda	0.7	0.7	0.6	0.6	0.5	0.5
United Republic of Tanzania (the)	2.9	3.3	3.6	3.9	4.3	4.5
Zambia	14.0	13.4	12.5	11.9	11.2	10.4
Zimbabwe	29.5	29.8	29.8	29.9	30.1	30.4
Eastern and Southern Africa	17.7	18.1	18.5	18.8	19.3	19.6
Western and Central Africa	9.8	10.6	11.6	12.7	13.9	14.9
Middle East & North Africa	13.0	13.3	13.5	13.7	14.0	14.4
Sub-Saharan Africa	14.5	15.1	15.7	16.4	17.1	17.7
Heavily indebted poor countries (HIPC)	96.1	96.1	96.2	96.1	96.1	96.1
Least developed countries: UN classification	63.1	64.3	65.8	67.1	68.5	69.7
Low income	14.0	14.6	15.2	15.8	16.5	17.2
World	11.8	12.2	12.6	12.9	13.3	13.6

Source: World Bank (https://data.worldbank.org/indicator/EG.CFT.ACCS.RU.ZS?locations=ZG).

Table A2. Access to clean fuels and technologies for cooking, rural Africa, 2015 to 2020
(per cent of population)

Countries	2015	2016	2017	2018	2019	2020
Algeria	98.5	98.6	98.6	98.7	98.7	98.8
Angola	7.8	7.9	8.0	8.1	8.2	8.3
Benin	0.8	0.8	0.8	0.8	0.8	0.9
Botswana	26.8	26.6	26.3	25.6	25.8	25.2
Burkina Faso	1.0	1.0	1.0	0.9	0.9	0.9
Burundi	0.2	0.2	0.2	0.2	0.2	0.2
Cabo Verde	40.3	42.3	44.4	46.5	48.6	50.4
Cameroon	2.4	2.4	2.4	2.5	2.4	2.4
Central African Republic	0.0	0.0	0.0	0.0	0.0	0.0
Chad	0.2	0.2	0.2	0.2	0.2	0.2
Comoros	2.1	2.2	2.4	2.5	2.6	2.8
Congo	2.9	3.1	3.1	3.3	3.4	3.6
Côte d'Ivoire	1.3	1.3	1.4	1.4	1.4	1.4
Democratic Republic of the Congo	0.3	0.3	0.4	0.4	0.5	0.5
Djibouti	0.5	0.5	0.5	0.4	0.4	0.4
Egypt	99.8	99.9	99.9	99.9	99.9	99.9
Equatorial Guinea	4.8	4.9	4.6	4.5	4.6	4.2
Eritrea	0.8	0.8	0.8	0.8	0.9	0.8
Eswatini	31.8	33.4	35.2	37.0	38.5	40.7
Ethiopia	0.2	0.2	0.3	0.2	0.3	0.3
Gabon	39.2	40.5	42.4	43.3	44.5	45.9
Gambia (the)	0.4	0.4	0.3	0.3	0.2	0.2
Ghana	6.6	7.0	7.3	7.6	8.0	8.6
Guinea	0.3	0.3	0.3	0.3	0.3	0.3
Guinea-Bissau	0.1	0.1	0.1	0.1	0.1	0.1
Kenya	2.7	3.0	3.4	3.8	4.2	4.7
Lesotho	18.2	18.8	19.1	19.5	19.7	20.0
Liberia	0.1	0.1	0.1	0.1	0.1	0.1
Libya	N/A	N/A	N/A	N/A	N/A	N/A
Madagascar	0.5	0.5	0.5	0.5	0.5	0.5
Malawi	0.5	0.5	0.4	0.3	0.3	0.2
Mali	0.3	0.3	0.3	0.3	0.3	0.3
Mauritania	18.4	18.5	18.5	18.1	17.8	17.9
Mauritius	96.4	96.5	96.5	96.6	96.5	96.5
Morocco	94.9	95.1	95.6	95.7	96.0	96.2
Mozambique	0.3	0.2	0.2	0.2	0.2	0.2
Namibia	12.1	12.1	12.4	12.8	13.2	13.3
Niger	0.1	0.1	0.1	0.1	0.1	0.2
Nigeria	1.9	2.3	2.7	3.2	3.7	4.2

Countries	2015	2016	2017	2018	2019	2020
Rwanda	0.2	0.2	0.2	0.2	0.2	0.3
Sao Tome and Principe	0.5	0.6	0.6	0.7	0.7	0.7
Senegal	5.0	4.8	4.5	4.3	4.3	4.1
Seychelles	100.0	100.0	100.0	100.0	100.0	100.0
Sierra Leone	0.1	0.1	0.1	0.1	0.0	0.0
Somalia	0.3	0.3	0.4	0.4	0.3	0.3
South Africa	63.5	64.2	64.6	65.5	65.5	65.9
South Sudan	0.0	0.0	0.0	0.0	0.0	0.0
Sudan	36.2	38.7	40.6	42.7	45.3	47.2
Tanzania	0.7	0.7	0.8	0.8	0.9	1.0
Togo	0.7	0.7	0.7	0.7	0.8	0.8
Tunisia	99.4	99.4	99.5	99.6	99.6	99.6
Uganda	0.3	0.2	0.2	0.2	0.2	0.2
Zambia	2.3	2.2	2.1	2.1	2.1	2.0
Zimbabwe	5.5	5.8	6.0	6.4	6.7	6.8
Africa Eastern and Southern	6.9	7.0	7.2	7.3	7.5	7.7
Africa Western and Central	2.0	2.1	2.3	2.5	2.7	3.0
Sub-Saharan Africa	5.1	5.3	5.4	5.6	5.8	6.0
World	37.7	39.7	41.7	44.1	46.2	48.5

Source: World Bank (https://data.worldbank.org/indicator/EG.CFT.ACCS.ZS?locations=ZG).

Table A3. Access to clean fuels and technologies for cooking, urban Africa, 2015 to 2020

(per cent of population)

Country Name	2015	2016	2017	2018	2019	2020
Algeria	100	100	100	100	100	99.9
Angola	77.6	77.75	77.9	77.7	77.9	77.6
Benin	8.5	8.4	8	7.8	7.5	7.2
Botswana	84	84.5	84.9	84.95	85.3	85.6
Burkina Faso	28.2	29.2	30.6	31.9	33.5	34.6
Burundi	0.3	0.3	0.3	0.2	0.2	0.2
Cabo Verde	93	93.4	93.6	93.8	94.2	94.4
Cameroon	40.1	39.7	39.7	39.3	38.7	37.9
Central African Republic	1.3	1.3	1.3	1.4	1.4	1.5
Chad	17.1	19.0	21.2	23.5	26.2	28.6
Comoros	13.1	13.9	15	16	16.8	17.4
Congo	37	39.6	42	44.2	46.9	49.2
Côte d’Ivoire	46.7	49.7	52.6	55.9	58.9	62.2
Democratic Republic of the Congo	9.8	9.5	9.2	8.7	8.5	8.3
Djibouti	10.1	10.6	11	11.5	11.7	11.8
Egypt	99.9	99.9	99.9	99.9	99.9	99.9
Equatorial Guinea	33.6	33.8	33.4	33.3	32.75	32.65
Eritrea	21.2	21.4	20.8	20.5	19.8	19.5
Eswatini	85.9	86.8	87.4	88	88.6	89.3
Ethiopia	18.2	20.1	22.3	24.3	26.7	28.9
Gabon	92.7	93	93.2	93.6	93.7	93.8
Gambia (the)	2.9	2.8	2.7	2.6	2.6	2.4
Ghana	36.2	36.4	35.8	35.6	35.1	34.5
Guinea	2	2.3	2.7	3.1	3.7	4.3
Guinea-Bissau	2.5	2.5	2.4	2.3	2.3	2.2
Kenya	29.5	32	34.7	37.6	40.85	44.5
Lesotho	77.5	77.9	78.3	78.5	78.7	78.8
Liberia	0.5	0.5	0.5	0.5	0.5	0.5
Libya	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Malawi	8.9	7.9	6.7	5.7	4.6	3.9
Mali	1.9	1.9	1.9	1.9	1.8	1.8
Mauritania	67.9	67	66.2	65.2	64.6	63.5
Mauritius	98.7	98.6	98.6	98.5	98.5	98.4
Morocco	99.6	99.6	99.6	99.6	99.5	99.4
Mozambique	11.4	11.7	12	12.5	12.8	13.5
Namibia	74.7	74.1	74.1	73.4	73.2	72.4
Niger	9	9.5	10.3	11.2	11.9	12.5
Nigeria	11.1	14	17.7	22	26.3	30.2

Country Name	2015	2016	2017	2018	2019	2020
Rwanda	2.8	3.6	4.7	6.1	7.8	9.9
Sao Tome and Principe	2.8	3	3.3	3.7	3.9	4.1
Senegal	52	50.5	49.1	48	47.1	45.8
Seychelles	100	100	100	100	100	100
Sierra Leone	0.9	1	1	1.1	1.3	1.2
Somalia	3.5	3.9	4.3	4.6	5	5.4
South Africa	93.2	93.6	94.2	94.65	94.9	95.2
South Sudan	0	0	0	0	0	0
Sudan	64.3	65.2	66.4	66.5	67.3	67.9
United Republic of Tanzania	7.6	8.6	9.3	10.1	10.8	10.7
Togo	14.7	16	17.2	18.7	19.9	21.1
Tunisia	99.9	99.9	99.9	99.9	99.9	99.9
Uganda	2	1.9	1.7	1.5	1.3	1.1
World	84.1	84.7	85.2	85.7	86.1	86.5
Zambia	30.4	28.6	26.5	24.6	22.5	20.5
Zimbabwe	79.6	79.3	79.3	79.1	79.1	78.6
Africa Eastern and Southern	38.3	38.5	38.7	38.7	38.9	39.0
Africa Western and Central	20.7	22.3	24.3	26.6	28.9	31.0
Sub-Saharan Africa	30.1	30.9	31.9	33.0	34.2	35.3

Source: World Bank (https://data.worldbank.org/indicator/EG.CFT.ACCS.UR.ZS?locations=ZG).

Table A4. Natural gas reserves, 2000, 2010, and 2020
(trillions of cubic metres)

	At end-2000	At end-2010	At end-2020
Canada	1.641	1.883	2.354
Mexico	0.814	0.350	0.178
United States of America	4.811	8.259	12.619
Total North America	7.266	10.493	15.151
Argentina	0.759	0.349	0.386
Bolivia	0.188	0.272	0.213
Brazil	0.215	0.436	0.349
Colombia	0.126	0.147	0.086
Peru	0.241	0.340	0.261
Trinidad and Tobago	0.543	0.371	0.290
Venezuela	4.609	6.132	6.260
Other South and Central America	0.118	0.061	0.053
Total South and Central America	6.800	8.107	7.897
Denmark	0.140	0.054	0.028
Germany	0.232	0.077	0.020
Italy	0.194	0.063	0.042
Netherlands	1.571	1.153	0.130
Norway	1.250	2.027	1.429
Poland	0.088	0.081	0.072
Romania	0.197	0.107	0.079
Ukraine	0.785	0.730	1.091
United Kingdom	0.731	0.251	0.187
Other Europe	0.183	0.127	0.090
Total Europe	5.370	4.669	3.169
Azerbaijan	0.990	1.021	2.504
Kazakhstan	1.713	1.713	2.257
Russian Federation	33.156	34.116	37.392
Turkmenistan	1.815	13.601	13.601
Uzbekistan	0.914	0.874	0.845
Other Commonwealth of Independent States (CIS)	0.009	0.005	0.003
Total CIS	38.597	51.331	56.602
Bahrain	0.269	0.208	0.065
Iran	25.350	32.263	32.101
Iraq	2.954	3.000	3.529
Israel	0.044	0.197	0.589

	At end-2000	At end-2010	At end-2020
Kuwait	1.479	1.695	1.695
Oman	0.810	0.490	0.666
Qatar	14.949	25.924	24.665
Saudi Arabia	5.986	7.505	6.019
Syria	0.235	0.269	0.269
United Arab Emirates	5.844	5.939	5.939
Yemen	0.325	0.316	0.266
Other Middle East	0.007	0.005	0.005
Total Middle East	58.250	77.810	75.807
Algeria	4.353	4.335	2.279
Egypt	1.379	2.127	2.138
Libya	1.248	1.420	1.430
Nigeria	3.901	4.919	5.473
Other Africa	1.043	1.209	1.569
Total Africa	11.925	14.010	12.889
Australia	1.718	2.860	2.390
Bangladesh	0.298	0.345	0.110
Brunei	0.357	0.294	0.222
China	1.378	2.747	8.399
India	0.731	1.105	1.320
Indonesia	2.722	3.010	1.252
Malaysia	1.064	1.027	0.908
Myanmar	0.280	0.217	0.432
Pakistan	0.501	0.551	0.385
Papua New Guinea	0.003	0.149	0.163
Thailand	0.351	0.310	0.143
Viet Nam	0.166	0.646	0.646
Other Asia Pacific	0.246	0.260	0.189
Total Asia Pacific	9.815	13.522	16.560
Total world	**138.023**	**179.941**	**188.074**

Source: British Petroleum statistical review of world energy, 2022 (www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html).

Table A5. Electricity generation capacity in Africa, 2015 to 2021
(gigawatts)

Country	2015	2016	2017	2018	2019	2020	2021
Algeria	17.119	19.078	19.602	21.208	21.695	21.694	21.694
Angola	2.108	2.618	4.551	5.445	6.943	7.344	7.344
Benin	0.346	0.348	0.348	0.348	0.475	0.475	0.475
Botswana	0.622	0.623	0.755	0.799	0.766	0.766	0.766
Burkina Faso	0.334	0.336	0.373	0.388	0.390	0.392	0.392
Burundi	0.069	0.068	0.083	0.100	0.100	0.100	0.100
Capo Verde	0.163	0.169	0.199	0.204	0.204	0.205	0.205
Cameroon	1.906	1.941	2.037	1.682	1.724	1.754	1.754
Central African Republic	0.038	0.038	0.038	0.038	0.038	0.038	0.038
Chad	0.088	0.089	0.089	0.089	0.089	0.090	0.090
Comoros	0.027	0.027	0.035	0.035	0.035	0.035	0.035
Congo	0.598	0.607	0.622	0.636	0.641	0.641	0.641
Côte d'Ivoire	1.914	1.914	2.203	2.197	2.197	2.197	2.197
Democratic Republic of the Congo	2.649	2.684	2.684	2.899	2.899	2.919	2.919
Djibouti	0.130	0.130	0.130	0.130	0.130	0.130	0.150
Egypt	36.132	39.593	47.216	57.391	59.345	59.807	60.073
Equatorial Guinea	0.348	0.348	0.348	0.349	0.349	0.349	0.350
Eritrea	0.168	0.168	0.216	0.224	0.226	0.228	0.230
Eswatini	0.282	0.282	0.282	0.286	0.286	0.286	0.296
Ethiopia	2.763	2.791	4.506	4.591	4.594	4.856	4.902
Gabon	0.672	0.684	0.692	0.750	0.783	0.784	0.784
Gambia (the)	0.119	0.120	0.121	0.126	0.137	0.137	0.137
Ghana	3.886	4.032	4.645	5.146	5.436	5.349	5.349
Guinea	0.609	0.607	0.624	0.629	0.635	0.992	0.992
Guinea Bissau	0.023	0.027	0.027	0.027	0.028	0.028	0.028
Kenya	2.410	2.413	2.424	3.257	3.154	3.342	3.483
Lesotho	0.080	0.081	0.081	0.081	0.081	0.074	0.074
Libya	9.460	10.249	10.243	10.516	10.516	10.516	10.517
Liberia	0.097	0.128	0.192	0.193	0.193	0.196	0.196
Madagascar	0.555	0.544	0.676	0.672	0.561	0.583	0.583
Malawi	0.585	0.585	0.612	0.619	0.673	0.676	0.736
Mali	0.645	0.732	0.803	0.803	0.803	0.890	0.920
Mauritania	0.494	0.511	0.590	0.620	0.658	0.656	0.656
Mauritius	0.883	0.939	0.928	0.965	0.930	0.930	0.930
Morocco	11.502	11.611	12.132	12.887	14.012	14.192	14.262
Mozambique	2.621	2.626	2.644	2.669	2.749	2.765	2.765
Namibia	0.508	0.529	0.573	0.591	0.613	0.610	0.610
Niger	0.277	0.288	0.290	0.318	0.318	0.324	0.324
Nigeria	10.597	12.544	12.284	12.284	11.690	11.691	11.696

Country	2015	2016	2017	2018	2019	2020	2021
Rwanda	0.197	0.219	0.240	0.260	0.261	0.272	0.272
Sao Tome and Principe	0.026	0.027	0.028	0.028	0.028	0.028	0.028
Senegal	0.943	0.982	1.091	1.249	1.327	1.437	1.504
Seychelles	0.117	0.136	0.154	0.155	0.158	0.160	0.166
Sierra Leone	0.168	0.169	0.176	0.174	0.176	0.180	0.180
Somalia	0.083	0.087	0.090	0.091	0.091	0.100	0.108
South Africa	47.183	50.140	53.862	58.112	61.099	62.727	63.276
South Sudan	0.080	0.080	0.120	0.121	0.121	0.121	0.121
Sudan	3.536	3.760	4.139	4.191	4.412	4.452	4.471
United Republic of Tanzania	1.459	1.473	1.498	1.694	1.608	1.623	1.589
Togo	0.197	0.195	0.196	0.196	0.197	0.214	0.264
Tunisia	5.458	5.522	5.729	5.727	5.763	5.778	5.778
Uganda	0.959	0.961	1.004	1.084	1.095	1.422	1.460
Zambia	2.505	2.871	2.941	2.943	3.032	3.062	3.365
Zimbabwe	2.139	2.150	2.311	2.456	2.461	2.474	2.476

Source: U.S Energy Information Administration (www.eia.gov/international/data/world).

Table A6. Electricity generation in regions of Africa and in South Africa, 2000 to 2021 (terawatt-hours)							
Year	North Africa	South Africa	Eastern Africa	Middle Africa	Western Africa	Other Southern Africa	Total AFrica
2000	137.77	210.67	43.65	12.68	32.02	3.39	440.18
2001	149.97	210.10	48.74	13.05	34.03	3.22	459.11
2002	158.57	220.58	51.33	13.31	40.36	3.43	487.58
2003	168.56	234.23	51.30	14.05	37.63	3.29	509.05
2004	179.38	244.61	55.18	15.82	42.70	3.11	540.80
2005	194.01	244.92	58.30	16.53	43.17	3.51	560.44
2006	205.25	253.80	60.37	18.84	44.56	3.35	586.17
2007	217.56	263.48	64.09	18.89	43.46	3.24	610.72
2008	233.14	258.29	65.03	20.46	43.49	3.13	623.55
2009	244.75	249.56	68.73	21.50	42.61	2.96	630.11
2010	262.87	259.60	74.00	22.55	50.84	2.83	672.70
2011	270.58	262.54	78.46	23.06	52.77	2.89	690.30
2012	300.32	257.92	81.66	23.80	55.36	3.47	722.53
2013	309.47	256.14	86.93	28.43	60.36	4.14	745.47
2014	321.79	254.77	93.17	31.36	64.02	4.97	770.09
2015	338.26	250.39	98.56	33.76	64.43	5.05	790.45
2016	341.27	253.08	97.44	34.31	69.26	4.76	800.12
2017	354.82	255.43	103.45	35.50	71.77	5.66	826.64
2018	365.78	256.34	108.65	39.57	74.34	5.06	849.74
2019	378.14	252.58	108.54	43.65	80.28	4.46	867.64
2020	369.72	239.46	109.82	45.65	85.70	4.73	855.08
2021	393.09	244.32	116.40	46.83	92.47	4.37	897.49

Source: British Petroleum statistical review of world energy, 2022 (www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html).

Table A7. Electricity generation in different regions of the world, 2000 to 2021 (terawatt-hours)

Year	North America	South and Central America	Europe	Commonwealth of Independent States	Middle East	Asia Pacific	Africa
2000	4 859.70	808.75	3 619.61	1 071.70	478.26	4 285.95	440.18
2001	4 782.43	796.43	3 685.41	1 089.08	509.06	4 478.26	459.11
2002	4 927.29	821.33	3 718.65	1 093.27	546.47	4 762.46	487.58
2003	4 951.15	861.20	3 811.13	1 129.70	574.16	5 098.93	509.05
2004	5 065.59	901.93	3 897.38	1 156.95	608.11	5 567.83	540.80
2005	5 191.24	943.26	3 959.91	1 180.58	658.48	5 971.50	560.44
2006	5 195.60	988.45	4 015.75	1 226.64	697.35	6 457.09	586.17
2007	5 329.27	1 034.26	4 064.66	1 257.04	748.08	7 015.04	610.72
2008	5 294.51	1 071.77	4 088.49	1 281.95	773.66	7 302.55	623.55
2009	5 088.17	1 083.06	3 894.90	1 226.24	818.40	7 537.82	630.11
2010	5 276.80	1 140.50	4 065.41	1 283.98	883.90	8 257.98	672.70
2011	5 293.80	1 181.21	4 019.27	1 308.51	900.36	8 875.48	690.30
2012	5 243.51	1 231.39	4 052.22	1 330.41	959.10	9 278.32	722.53
2013	5 283.09	1 270.27	4 021.42	1 323.67	993.53	9 814.99	745.47
2014	5 314.19	1 289.82	3 937.54	1 337.94	1 064.48	10 335.76	770.09
2015	5 318.37	1 298.22	3 981.43	1 340.89	1 121.71	10 440.94	790.45
2016	5 331.10	1 305.20	4 020.37	1 369.32	1 147.03	10 951.10	800.12
2017	5 292.18	1 305.70	4 060.22	1 383.05	1 204.34	11 575.60	826.64
2018	5 452.46	1 319.00	4 063.15	1 416.36	1 204.19	12.372.43	849.74
2019	5 406.55	1 327.29	3 993.38	1 428.80	1 229.30	12 783.65	867.64
2020	5 259.65	1 302.47	3 878.96	1 400.66	1 243.00	12 949.35	855.08
2021	5 383.47	1 364.82	4 032.46	1 487.99	1 305.62	13.994.45	897.49

Source: British Petroleum, Statistical review of world energy, 2022 (www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html).

Table A8. World population by region, 2000 to 2021
(millions)

Year	Sub-Saharan Africa	Africa	Latin America and Caribbean	North America	Europe	Oceania	Asia
2000	646.63	818.95	522.51	313.21	726.97	31.22	3 736.04
2001	663.98	839.46	529.91	316.60	726.88	31.71	3 786.18
2002	681.92	860.61	537.16	319.80	726.94	32.23	3 835.67
2003	700.43	882.35	544.20	322.85	727.42	32.76	3 884.31
2004	719.58	904.78	551.12	325.99	728.16	33.28	3 932.42
2005	739.33	927.90	557.96	329.18	728.95	33.81	3 980.37
2006	759.70	951.74	564.66	332.41	729.86	34.40	4 028.35
2007	780.79	976.46	571.25	335.73	731.39	35.04	4 076.07
2008	802.57	1 001.98	577.69	339.04	733.26	35.74	4 123.88
2009	824.97	1 028.20	584.07	342.23	734.90	36.45	4 172.45
2010	848.12	1 055.23	590.55	345.27	736.28	37.10	4 221.17
2011	871.96	1 082.68	597.18	348.33	737.59	37.73	4 269.62
2012	896.29	1 110.80	603.82	351.47	738.91	38.38	4 318.32
2013	921.26	1 140.18	610.32	354.56	740.01	39.06	4 366.45
2014	946.69	1 170.30	616.73	357.56	741.01	39.73	4 413.67
2015	972.75	1 201.11	623.08	360.46	742.11	40.40	4 459.44
2016	999.03	1 232.11	629.34	363.45	743.32	41.10	4 504.15
2017	1 025.49	1 263.33	635.45	366.47	744.45	41.82	4 548.30
2018	1 052.73	1 295.27	641.30	369.30	745.36	42.54	4 590.02
2019	1 080.68	1 327.70	646.85	371.97	746.19	43.28	4 628.97
2020	1 109.26	1 360.68	651.84	373.96	746.23	43.93	4 664.32
2021	1 137.94	1 393.68	656.10	375.28	745.17	44.49	4 694.58

Source: United Nations Data Portal Division (https://population.un.org/dataportal/data/indicators/49/locations/935,908,904,905,909,903,947/start/1990/end/2030/table/pivotbylocation).

REFERENCES

AfDB (2017). The new deal on energy for Africa: A transformative partnership to light up power Africa by 2025. African Development Bank. Available at www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Brochure_New_Deal_2_red.pdf

Arlet J, Ereshcenko and Lopez Rocha S (2019). Barriers to urban electrification in Sub-Saharan Africa from the perspective of end-users. World Bank blog (2 May). Available at https://blogs.worldbank.org/developmenttalk/barriers-urban-electrification-sub-saharan-africa-perspective-end-users

Baffoe Donkor K (2022). 330kV line commissioned; It'll carry power to Burkina Faso. Graphic Online (18 October). Available at www.graphic.com.gh/news/general-news/kumasi-bolgatanga-330kv-line-commissioned-it-ll-carry-power-to-burkina-faso.html

Balmes J, Pope D, Dherani, M, Zhang J, Duan X, Bates M, Lin W, Adair-Rohani H, Mehta S and Cohen A (Undated). WHO indoor air quality guidelines: Household fuel combustion, Review 4: Health effects of household air pollution (HAP) exposure. World Health Organization. Geneva. Available at https://cdn.who.int/media/docs/default-source/air-pollution-documents/who-indoor-air-quality-guidelines-household-fuel-combustion.pdf?sfvrsn=c385a360_1&download=true

Banerjee M (2022). Influence of the Covid-19 pandemic on electricity access. Observer Research Foundation (4 January). Available at www.orfonline.org/expert-speak/influence-of-the-covid-19-pandemic-on-electricity-access/

Bhatia, M and Angelou N (2015). Beyond connections: Energy access redefined. ESMAP Technical Report No. 008/15. World Bank Energy Sector Management Assistance Program. Washington, DC. Available at www.worldbank.org/en/topic/energy/publication/energy-access-redefined

Blimpo MP and Cosgrove-Davies M (2019). Electricity access in sub-Sahara Africa: Uptake, reliability, and complementary factors for economic impact. World Bank. Washington, DC. Available at https://openknowledge.worldbank.org/bitstream/handle/10986/31333/9781464813610.pdf

Bullard N (2022). Natural gas is a hard habit to quit. Bloomberg (24 March). Available at http://www.bloomberg.com/news/articles/2022-03-24/natural-gas-consumption-is-growing-faster-than-oil

Burrell L (2021). What's so important about mini-grids? United Nations Industrial Development Organization (30 March). Available at www.unido.org/stories/whats-so-important-about-mini-grids

Carrington D (2022). "Monstrous" East African oil project will emit vast amounts of carbon, data shows. The Guardian (27 October). Available at www.theguardian.com/environment/2022/oct/27/east-african-crude-oil-pipeline-carbon

Cohen A (2022). Peak oil: The perennial prophecy that went wrong. Forbes (30 November). Available at www.forbes.com/sites/arielcohen/2022/11/30/peak-oil-the-perennial-prophecy-that-went-wrong/?sh=7c3b69d82bbe

Christofides C (2021). The most sustainable fossil fuel: Why LPG makes sense. Liquid Gas Europe (September). Available at www.liquidgaseurope.eu/news/the-most-sustainable-fossil-fuel-why-lpg-makes-sense

Elliot S and Lalor D (2021). Sub-Saharan Africa could green-light 74 mil mt/year LNG capacity by 2030: ACTING. S&P Commodity Insights (9 February). Available at www.spglobal.com/commodityinsights/en/market-insights/latest-news/natural-gas/020921-sub-saharan-africa-could-green-light-74-mil-mtyear-lng-capacity-by-2030-acting

Energy Compacts and Clean Cooking Alliance (Undated). Unlock the SDGs and net-zero with clean cooking SDG7 multi-stakeholder energy compact. Available at https://cleancooking.org/wp-content/uploads/2021/10/Clean_Cooking_Energy_Compact.pdf

ESMAP (2019). Mini grids for half a billion people: Market outlook and handbook for decision makers. Energy Sector Management Assistance Program Technical Report 014/19. World Bank. Washington, DC. Available at https://openknowledge.worldbank.org/bitstream/handle/10986/31926/Mini-Grids-for-Half-a-Billion-People-Market-Outlook-and-Handbook-for-Decision-Makers-Executive-Summary.pdf

Gross S (2020). Why are fossil fuels so hard to quit? Brookings Institute (June). Available at www.brookings.edu/essay/why-are-fossil-fuels-so-hard-to-quit/

Gullet B.K, Aurell J. and Holder E (2017). Characterization of emissions and residues from simulations of the *Deepwater Horizon* surface oil burns. Marine Pollution Bulletin 117(1–2) : 392–495. doi: 10.1016/j.marpolbul.2017.01.083

Hafner M, Tagliapietra S and de Strasser L (2018). The challenge of energy access in Africa. In: *Energy in Africa.* Springer. Available at https://doi.org/10.1007/978-3-319-92219-5_1

Hall D (2020). Solar LCOE may drop to $0.018/kWh in Africa by 2030, says IEA. PV Magazine (23 June). Available at www.pv-magazine.com/2022/06/23/solar-lcoe-may-drop-to-0-018-kwh-in-africa-by-2030-says-iea/

IEA (2010). Energy poverty: How to make modern energy access universal? Special early excerpt of the World Energy Outlook 2010 for the UN General Assembly on the Millennium Development Goals (September). International Energy Agency. Paris. Available at https://iea.blob.core.windows.net/assets/fdbdd604-de2c-4977-8a3f-20f93e68e738/HowtoMakeModernEnergyAccessUniversal.pdf

IEA (2019a). Offshore wind outlook 2019. World Energy Outlook Special Report. International Energy Agency. Paris. Available at www.iea.org/reports/offshore-wind-outlook-2019.

IEA (2019b). The future of hydrogen. International Energy Agency. Paris. Available at www.iea.org/reports/the-future-of-hydrogen

IEA (2019c). The role of gas in today's energy transitions. International Energy Agency. Paris. Available at https://iea.blob.core.windows.net/assets/cc35f20f-7a94-44dc-a750-41c117517e93/TheRoleofGas.pdf

IEA (2019d). Africa energy outlook 2019: Overview Mozambique. International Energy Association. Paris. Available at https://iea.blob.core.windows.net/assets/1d996108-18cc-41d7-9da3-55496cec6310/AEO2019_MOZAMBIQUE.pdf

IEA (2020a). Iron and steel technology roadmap. International Energy Association. Paris. October. Available at www.iea.org/reports/iron-and-steel-technology-roadmap

IEA (2020b). The outlook for biogas and biomethane: Prospects for organic growth, International Energy Agency. Paris. Available at www.iea.org/reports/outlook-for-biogas-and-biomethane-prospects-for-organic-growth

IEA (2020c). Project cost of generating electricity: 2020 edition. International Energy Agency. Paris.

IEA (2021). Global energy review: CO2 emissions in 2020. International Energy Agency. Paris. Available at https://iea.blob.core.windows.net/assets/c3086240-732b-4f6a-89d7-db01be018f5e/GlobalEnergyReviewCO2Emissionsin2021.pdf

IEA (2022). Africa energy outlook 2022. International Energy Agency. Paris. Available at https://iea.blob.core.windows.net/assets/27f568cc-1f9e-4c5b-9b09-b18a55fc850b/AfricaEnergyOutlook2022.pdf

IEA, IRENA, UNSD, World Bank and WHO (2022). Tracking SDG7: The energy progress report 2022. International Energy Agency, International Renewable Energy Agency, United Nations Statistics Division, World Bank and World Health Organization. Washington, DC. Available at https://iea.blob.core.windows.net/assets/8b276fc2-c1ae-4a54-9681-eea1eb143d7f/TrackingSDG7TheEnergyProgressReport2022.pdf

IRENA (2016). Solar PV in Africa: Costs and markets. International Renewable Energy Agency. Abu Dhabi. Available at www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/Brochure_New_Deal_2_red.pdf

IRENA (2020a). The renewable energy transition in Africa: Powering access, resilience and prosperity. International Renewable Energy Agency. Abu Dhabi. Available at www.irena.org/-/media/Files/IRENA/Agency/Publication/2021/March/Renewable_Energy_Transition_Africa_2021.pdf

IRENA (2020b). Geothermal development in Eastern Africa; Recommendations for power and direct use. International Renewable Energy Agency. Abu Dhabi. Available at www.irena.org/-/media/Files/IRENA/Agency/Publication/2020/Nov/IRENA_Geothermal_Eastern_Africa_2020.pdf

IRENA (2021). Renewable power generation costs in 2021. International Renewable Energy Agency. Abu Dhabi. Available at www.irena.org/publications/2022/Jul/Renewable-Power-Generation-Costs-in-2021

IRENA (2022a). Renewable energy market analysis, Africa and its regions. International Renewable Energy Agency. Abu Dhabi. Available at www.irena.org/publications/2022/Jan/Renewable-Energy-Market-Analysis-Africa

IRENA (2022b). Renewable capacity statistics 2022. International Renewable Energy Agency. Abu Dhabi. Available at www.irena.org/-/media/Files/IRENA/Agency/Publication/2022/Apr/IRENA_RE_Capacity_Statistics_2022.pdf?rev=460f190dea15442eba8373d9625341ae

Jessop S and Sterling T (2022). Dutch bank ING ends financing or new oil and gas projects. Reuters (23 March). Available at www.reuters.com/business/sustainable-business/exclusive-dutch-bank-ing-ends-financing-new-oil-gas-projects-2022-03-23

Jeuland MA and Pattanayak SK (2012). Benefits and costs of improved cookstoves: Assessing the implications of variability in health, forest and climate impacts. PLoS One. 7(2): e30338. Available at www.ncbi.nlm.nih.gov/pmc/articles/PMC3278415/

Karekezi S and Kithyoma W (2003). Renewable energy in Africa: Prospects and limits. Available at https://sdgs.un.org/sites/default/files/documents/nepadkarekezi.pdf

Lawrence D (2020). Investors forecast bright future for mini-grids in Africa. IFC Insights (June). International Finance Corporation. Washington, DC. Available at www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/insights/africa-mini-grids

Lee HE, Woo YK, Kang H and Han K (2022). Still lacking reliable electricity from the grid, many Africans turn to other sources. Afrobarometer Dispatch No. 514 (8 April). Available at www.afrobarometer.org/wp-content/uploads/2022/04/ad514-pap10-still_lacking_reliable_electricity_from_the_grid-many_africans_turn_to_alternative_sources-afrobarometer-10april22.pdf

Leke A, Gaius-Obaseki P and Onyekweli O (2022). The future of African oil and gas: Positioning for the energy transition. McKinsey & Company (8 June). Available at www.mckinsey.com/industries/oil-and-gas/our-insights/the-future-of-african-oil-and-gas-positioning-for-the-energy-transition

Marchese A and Zimmerle D (2018). Natural gas production releases more methane than estimated: Why that matters. GreenBiz (10 July). Available at www.greenbiz.com/article/natural-gas-production-releases-more-methane-estimated-why-matters

Mammoser A (2022). Ethiopia advances geothermal power with fresh funding for UK driller. Energy & Utilities (2 September). Available at https://energy-utilities.com/ethiopia-advances-geothermal-power-with-fresh-news118628.html

Miser T (2015). A short history of the evolving use of natural gas. Power Engineering (13 February). Available at www.power-eng.com/coal/a-short-history-of-the-evolving-uses-of-natural-gas/#gref

Moss T and Kincer J (2019). Power Africa key obstacles in each market. Energy for Growth Hub (September 5). Available at www.energyforgrowth.org/memo/power-africas-top-obstacles-in-each-power-market/

Naklah C (2022). Peak oil demand will change market dynamics. Geopolitical Intelligence Services (1 June). Available at www.gisreportsonline.com/r/peak-oil-demand/

National Academy of Sciences, National Academy of Engineering, and National Research Council (2009). *America's Energy Future: Technology and Transformation*. The National Academies Press. Washington, DC. Available at https://nap.nationalacademies.org/read/12091/chapter/11#332

Odarno L (2020). Missing links between electricity access and development priorities in Africa. World Resources Institute (29 July). Available at www.wri.org/insights/missing-links-between-electricity-access-and-development-priorities-africa

Odunowo O (2018). Hydropower dominates Africa's renewables but over 80% of its potential remains untapped. Techcabal (20 September). Available at https://techcabal.com/2018/09/20/hydropower-dominates-africas-renewables-but-over-80-of-its-potential-remains-untapped/

Pitron G (2018). La Guerre des métaux rares. La face cachée de la transition énergétique et numérique. *Revue Project*. 2018/2 (363): 90–92.

Puliti R (2022). Putting Africa on the path to universal electricity access. World Bank blog (31 January). Available at https://blogs.worldbank.org/energy/putting-africa-path-universal-electricity-access

Ritchie H, Roser M and Rosado P (2022). Energy. Our World in Data. Available at https://ourworldindata.org/energy

Rodriguez L (2021). Solar energy in sub-Saharan Africa: 5 trends driving the growth. RatedPower (September 15). Available at https://ratedpower.com/blog/solar-trends-sub-saharan-africa/

S&P Global (2022). Financing sub-Saharan Africa's energy transition. ESG & Climate Research. 38 (9 June). Available at www.spglobal.com/esg/images/financing-sub-saharan-africa-s-energy-transition/sp_esg_research_note_v11.pdf

Schwerhoff G and Sy M (2020). Renewable energy sources, especially solar, are ideal for meeting Africa's electrical power needs. Finance and Development (March). Available at www.imf.org/en/Publications/fandd/issues/2020/03/powering-Africa-with-solar-energy-sy

SEforALL (2020). State of the global mini grids market report 2020: Trends of renewable energy hybrid mini grids in sub-Saharan Africa, Asia and island nations. Sustainable Energy for All. Available at www.seforall.org/system/files/2020-06/MGP-2020-SEforALL.pdf

The Economist (2022). Africa will remain poor unless it uses more energy. 3 November. Available at www.economist.com/middle-east-and-africa/2022/11/03/africa-will-remain-poor-unless-it-uses-more-energy

Vigolo V, Sallaku R and Testa F (2018). Drivers and barriers to clean cooking: A systemic literature review from a consumer behavior perspective. 18 November. Available at www.mdpi.com/journal/sustainability.

WHO (2021). Sustainable solutions must target African countries left behind in quest for global energy access. Global Launch: Tracking SDG7: The Energy Progress Report. World Health Organization Geneva.

World Bank (2012). Geothermal handbook: Planning and financing power generation. Energy Sector Management Assistance Programme Technical Report 002/12. World Bank. Washington, DC. Available at www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_Geothermal%20Handbook_TR002-12_Reduced.pdf

World Bank (2019). Investing in mini grids now, integrating with the main grid later: A menu of good policy and regulatory options. Live Wire Series 2019/97. World Bank. Washington, DC. Available at https://documents1.worldbank.org/curated/en/732841558714625815/pdf/Investing-in-Mini-Grids-Now-Integrating-with-the-Main-Grid-Later-A-Menu-of-Good-Policy-and-Regulatory-Option.pdf

World Bank (2020a). Tracking SDG-7: The energy progress report. Press release (1 June). World Bank, Washington, DC. Available at www.worldbank.org/en/topic/energy/publication/tracking-sdg-7-the-energy-progress-report-2022

World Bank (2020b). The state of access to modern energy cooking services. World Bank. Washington, DC. Available at www.worldbank.org/en/topic/energy/publication/the-state-of-access-to-modern-energy-cooking-services

World Bank (2020c). Accelerating access to clean cooking: The Efficient, Clean Cooking and Heating Program and the Clean Cooking Fund. World Bank. Washington, DC. Available at www.worldbank.org/en/results/2020/11/10/accelerating-access-to-clean-cooking-the-efficient-clean-cooking-and-heating-program-and-the-clean-cooking-fund

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