BRI International Green Development Coalition
2024 Policy Study Series

China-Africa Renewable Energy Investment Cooperation under the Framework of the BRI: Opportunities and Challenges

In 2019, BRI International Green Development Coalition (BRIGC) was jointly launched at the Thematic Forum on Green Silk Road of the Second Belt and Road Forum for International Cooperation by Chinese and international partners. It is an international organization consisting of non-governmental organizations, research institutes and enterprises globally in the field of ecology, environment, or sustainable development in general. Currently, BRIGC has more than 170 partners, including 42 members, from over 40 countries.

The mission of BRIGC is to forge global consensus on BRI green development, promote cooperation and action on BRI green development in an open, inclusive, and win-win manner, and assist BRI partner countries to realize green, low-carbon and sustainable development.

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Abstract

Abstract

Africa possesses significant economic growth potential and abundant energy resource development opportunities, making it a key region for the investment, development, and deployment of renewable energy in the context of achieving the global "goal of tripling renewable power capacity". Over the years, China has established and maintained strong cooperative relations with African countries across various fields, including politics and economics, with a particular emphasis on energy cooperation. Sino-African energy collaboration has progressed through multiple stages, fostering a mutually beneficial partnership that has greatly contributed to Africa's energy transformation and green development. Nevertheless, given Africa's relatively small and structurally imbalanced economy, the development of renewable energy remains limited, significantly hindering the region's progress toward transformation and sustainable development. On September 5, 2024, during the opening ceremony of the Forum on China-Africa Cooperation (FOCAC) Beijing Summit, President Xi Jinping expressed China's commitment to implementing the Partnership Action for Green Development in Africa, which includes the execution of 30 clean energy projects to support Africa's green development. He further emphasized China's willingness to assist African countries in building "green growth engines", narrowing the gap in energy accessibility, adhering to the principle of "common but differentiated responsibilities", and jointly pushing for the global transition to green and low-carbon development. These statements provide clear guidance for the continued Sino-African cooperation in renewable energy investment under the framework of the Belt and Road Initiative.

In this context, the study on renewable energy investment cooperation in key African countries under the Belt and Road Initiative aims to analyze the current status and trends of Africa's electricity market, assess the challenges and potential innovative opportunities for renewable energy investment in Africa, and explore viable business models, all within the broader framework of advancing the Belt and Road Initiative and addressing global climate change. The study will also provide policy recommendations to promote Chinese enterprises' renewable energy investments in Africa.

The main conclusions of this study are as follows:

First, the study examines the development status of Africa's electricity market from three perspectives: power generation, the power grid, and electricity consumption. In terms of power generation, although the installed capacity of renewable energy in Africa has been growing rapidly, it remains relatively low in proportion due to factors such as inadequate power infrastructure, weak grid development, unstable power supply, and high electricity prices. Consequently, fossil fuel-based power generation still dominates the energy mix. In terms of the power grid, Africa currently has low grid coverage, with only about one-sixth of the countries having a grid coverage rate exceeding 30%. Additionally, there are significant disparities in the development levels of the five major power pools, with limited interconnection between them. In terms of electricity consumption, approximately 43% of Africa's population lacks access to reliable electricity, and per capita annual electricity consumption remains at a low level. Residential electricity prices have remained high over an extended period, which has constrained the progress of electricity expansion. Against this backdrop, it is projected that by 2030, Africa's total installed renewable energy capacity will reach between 127.7 and 170.2 gigawatts under various development scenarios, with an additional 74 to 116.5 gigawatts of renewable energy capacity to be added. The growth potential in Africa's renewable energy sector will unlock significant business and investment opportunities. Given the strong foundation of China-Africa cooperation in the renewable energy sector, as well as China's technological and financial strengths, successful collaboration outcomes, and established business models, the investment and development potential in Africa's renewable energy sector will provide substantial business and market opportunities for Chinese enterprises.

Second, renewable energy investment in Africa faces barriers across three key dimensions: technology, policy, and financing. Specifically, technological barriers include inadequate grid infrastructure, which hampers the transmission of electricity; the low compatibility of renewable energy technologies with local natural and climatic conditions, posing challenges to the design and operation of renewable energy systems; and a lack of local capacity for maintenance and manufacturing of renewable energy

technologies, which drives up the procurement, operation, and maintenance costs of renewable energy equipment. Policy barriers stem from political instability and a lack of continuity in policies, which undermine the long-term predictability of renewable energy investments; difficulties in policy implementation and approval processes, which slow the pace of project development and investment; and the absence of cross-regional cooperation and coordination, resulting in significant discrepancies in renewable energy laws, frameworks, and technical standards across countries, thereby complicating project integration. Financing barriers include a severe shortage of funds and stringent conditions for obtaining financing, particularly for initial prefeasibility studies of renewable energy projects, limiting the ability to launch projects with high upfront costs; underdeveloped financial markets, characterized by a lack of comprehensive financial institutions, products, tools, and models, which heighten the challenges of securing financing for renewable energy projects; and concerns about political, economic, and policy instability in Africa, which, to some extent, hindered the investment willingness of renewable energy investors.

Third, Africa's renewable energy sector presents significant opportunities for technological innovation, particularly in the development of solar, wind, hydropower, biomass energy, and energy storage. For instance, Africa has substantial potential for technological advancement in solar energy through the use of solar thermal technologies and energy storage solutions, as well as in the promotion of energy storage technologies via innovations in battery technology and the deployment of smart grids. Building on these technological opportunities, Africa can drive the deployment of renewable energy through various models, including distributed energy model, energy-as-a-service (EaaS) model, blended financing model, and international cooperation model. Specifically, the distributed energy model encompasses microgrid systems, community energy projects, and solar home systems; the energy-as-a-service model includes subscription and leasing, along with blockchain-based energy trading platforms; the blended financing model involves public-private partnerships, crowdfunding, and green bond financing; and the international cooperation model includes collaborations between multinational corporations and local businesses, as well as international funding support.

Fourth, in light of the current challenges and opportunities concerning renewable energy investment in Africa, this study offers the following recommendations to advance renewable energy investment cooperation in key African countries under the "Belt and Road" framework, thereby supporting Africa's green transformation and sustainable development: The first is to strengthen China-Africa policy coordination and strategic alignment in key fields such as renewable energy development strategies, evaluation frameworks, and financial support, so as to provide financial support and guarantees for the development of renewable energy projects in Africa. The second is to, taking into account the natural factors and economic conditions of different regions in Africa, implement region-specific market tracking, promote the development of diversified projects tailored to local contexts, and collaborate with developed countries and multilateral financial institutions to facilitate trilateral cooperation in Africa. The third is to enhance awareness of overseas risk prevention, using tools such as project insurance, due diligence, and debt warning systems, to establish a multi-stage, multi-process project risk prevention mechanism that effectively mitigates renewable energy project risks. The fourth is to leverage diversified financing models, with a particular emphasis on establishing feasibility assessment funds and developing international carbon financing mechanisms, to stimulate investment in renewable energy enterprises and drive the successful implementation and long-term sustainability of projects.

1

Introduction

Chapter 1 Introduction

1.1 Research Background

Energy serves as the bedrock of human civilization and progress, profoundly tied to national welfare, public livelihood, state security, and the survival and development of humanity. It plays an irreplaceable role in fostering economic growth, enhancing societal advancement, and improving people's well-being.

From a global perspective, during the 28th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP28), more than 130 countries—representing two-thirds of the global economy—jointly committed to limiting the rise in global temperatures to within 1.5°C. Achieving this requires a tripling of global renewable energy installed capacity by 2030[1], increasing from approximately 3,400 gigawatts at the end of 2022 to 11,000 gigawatts. This ambitious target has injected significant impetus into global renewable energy development, prompting accelerated measures for energy transition and significantly boosting investments in renewable energy projects worldwide.

From China's perspective, the Belt and Road Initiative (BRI) has yielded fruitful energy cooperation, particularly in key regions such as Africa. The facilitation of energy investment and trade has significantly improved, industrial cooperation has deepened, and the pace of green energy transitions has quickened. These advancements have enhanced energy utilization efficiency, fostered a more inclusive global energy governance framework, and established a regional energy community characterized by win-win collaboration. In September 2021, at the General Debate of the 76th session of the United Nations General Assembly, President Xi Jinping declared China's commitment to step up support for other developing countries in developing green and low-carbon energy, and pledged that China will not build new coal-fired power projects abroad. This pledge signals that future BRI energy cooperation will focus primarily on renewable energy. Additionally, during the 2024 Beijing Summit of the Forum on China-Africa Cooperation (FOCAC) in September, President Xi proposed that China is ready to launch 30 clean energy projects in Africa to help Africa build "green growth engines" and narrow the gap in energy accessibility. These commitments underscore the centrality of energy as a key domain for future China-Africa collaboration. Given the resource endowments, economic development levels, market potential, and recent policy directions in BRI countries, Africa is poised to become a focal region for energy cooperation under the BRI framework.

From Africa's perspective, the continent is endowed with some of the world's most abundant renewable energy resources. Africa accounts for 12% of global hydropower resources, 32% of global wind energy resources, and 40% of global solar energy resources[2]. It also boasts substantial reserves of geothermal, ocean, and biomass energy. Harnessing these resources for large-scale renewable energy development is an indispensable pathway for achieving sustainable economic and social development in Africa. Most African nations have already outlined ambitious targets for clean energy development, energy conservation, and emissions reduction. For example, countries such as Tanzania, Rwanda, and Niger have set ambitious goals of achieving 100% clean energy utilization by 2050. Nearly 30 African nations have defined explicit electrification goals, with Egypt, Morocco, and Tunisia achieving near-universal electricity access, and countries like Angola, Ghana, and Ethiopia aiming to eliminate electricity poverty by around 2030. To support these goals, African governments have introduced a series of measures to promote the development of renewable energy and the construction of transmission and distribution networks. These measures include electricity price subsidies, installed capacity auctions, support for independent renewable energy producers, rural electrification initiatives, and cooperative models between governments and public utilities for grid infrastructure. However, the overall economic development of African countries is imbalanced, especially in sub-Saharan Africa, where renewable energy industries remain underdeveloped, and grid infrastructure requires significant improvement.

Against this backdrop, identifying the renewable energy investment potential of Africa is essential to securing financial support for renewable energy development, improving the investment environment in African countries, and injecting momentum into the renewable energy sector in BRI-related African nations.

1.2 Research Objectives

This study focuses on African countries along the Belt and Road Initiative (BRI), conducting a comprehensive evaluation of technical barriers and policy challenges affecting renewable energy investment. The evaluation considers factors such as economic scale, growth rate, political stability, and resource endowments.

This study examines the endowment, distribution, and electricity market conditions of renewable energy in Africa and analyze Africa’s potential for renewable energy development.

This study explores the barriers and opportunities for renewable energy investment in Africa and investigate ways to encourage Chinese enterprises to invest in Africa’s renewable energy sector.

This study proposes policy recommendations for enhnaced renewable energy cooperation between China and Africa under the BRI framework

1.3 Research Scope and Content

This study examines the energy resources of African countries in conjunction with their electricity demand and market potential. By analyzing the investment environment and opportunities in key nations, the research identifies market prospects and collaboration opportunities, offering targeted recommendations for country-specific renewable energy development. The main research content is as follows:

Provide an overview of African socioeconomic and energy resources.

Analyze the current state and trends of Africa’s electricity market, as well as the impact of China’s clean energy investments on Africa’s energy supply.

Assess the opportunities for China-Africa cooperation in the field of renewable energy, as well as the main challenges in areas such as technology and policy.

Discuss opportunities for renewable energy investment and technological innovation in Africa, and identify applicable business models.

Propose recommendations for renewable energy investment and technological innovation in key African countries.

2

Overview of Africa's Socioeconomic and Energy Landscape

Chapter 2 Overview of Africa's Socioeconomic and Energy Landscape

2.1 Natural Geography

2.1.1 Geographical Location

Africa spans both the Eastern and Western Hemispheres and straddles the Equator, stretching across the northern and southern hemispheres. The continent is bordered by the Indian Ocean to the east and the Atlantic Ocean to the west, with the Mediterranean Sea and the Strait of Gibraltar separating it from Europe to the north, and the Red Sea and the Suez Canal linking it to Asia at its northeastern edge. The farthest geographical points of Africa are Ras Hafun in the east, Cape Agulhas in the south, Cape Verde in the west, and Ras ben Sakka in the north. Geographically, Africa is typically divided into five regions: North Africa, East Africa, West Africa, Central Africa, and Southern Africa. The continent covers an area of approximately 30.22 million square kilometers, accounting for 20.2% of the world's total land area, making it the second-largest continent after Asia. Africa consists of 60 countries and regions, including 54 sovereign states and six overseas territories or other special administrative regions. The geographical distribution of African countries is illustrated in Figure 2.1.

Figure 2.1 Geographic Location Map of African Countries

2.1.2 Climate Conditions

A significant portion of Africa lies between the Tropic of Cancer and the Tropic of Capricorn, resulting in vast areas experiencing high temperatures throughout the year, earning Africa the moniker "the Tropical Continent." The climate is characterized by high temperatures, low rainfall, and arid conditions, with climatic zones symmetrically distributed north and south of the Equator. The Equator traverses the middle of the continent, with temperatures generally decreasing as one moves away from the Equator toward higher latitudes. Approximately 95% of Africa's landmass has an average annual temperature exceeding 20°C, with more than half of the continent experiencing hot summers and warm winters. Rainfall is unevenly distributed, decreasing progressively from the Equator toward the northern and southern extremes. Northern Africa predominantly has subtropical savanna climates and desert climates, with annual rainfall below 200 millimeters, while sub-Saharan Africa is dominated by tropical savanna and tropical rainforest climates, where most areas receive over 1,000 millimeters of rainfall annually. The Mediterranean coastal regions experience hot, dry summers and warm, rainy winters, characteristic of a Mediterranean climate. In contrast, vast regions experience rainy summers and dry winters, typical of tropical savanna climates. Unique to the continent is Mount Kilimanjaro, located near the Equator, which is snow-capped year-round due to its high elevation, classified as a highland climate. The northeastern part of Ethiopia, including Dallol, holds the record for one of the highest average annual temperatures globally, at 34.5°C. Meanwhile, Aziziya in Libya recorded an extreme high of 57.8°C, marking the highest temperature ever recorded in Africa. Africa's climatic zones are depicted in Figure 2.2.

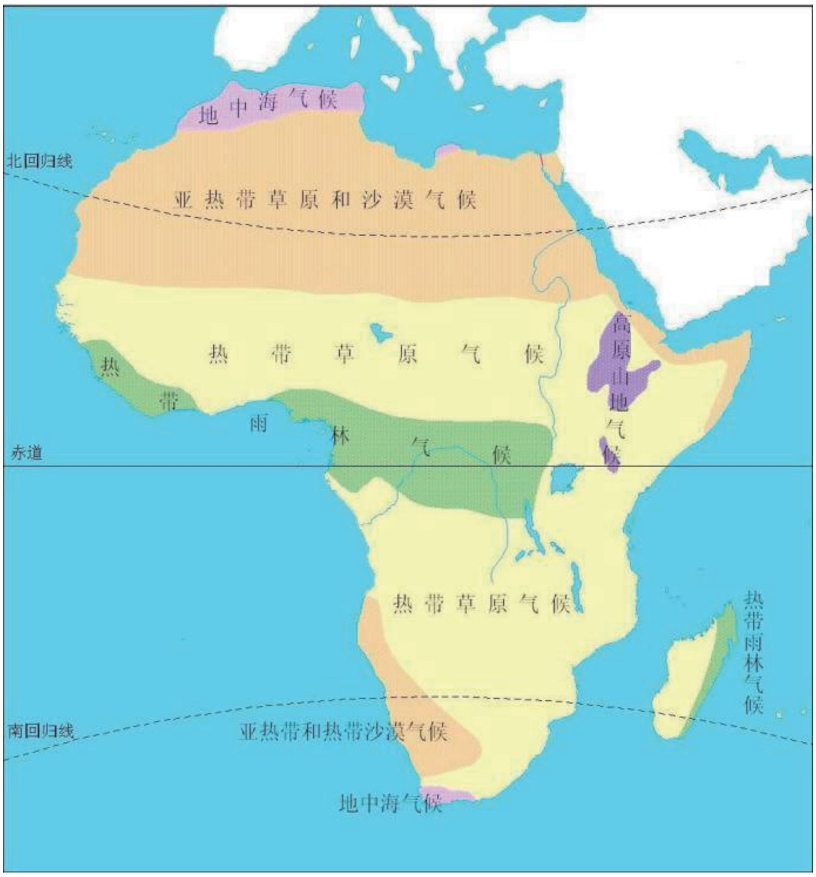

Figure 2.2 Climate Distribution Map of Africa

2.1.3 Natural Resources

Africa is a vast continent rich in natural resources, often referred to as the "treasure trove of the world." It remains one of the few regions globally where resources are underdeveloped. Africa boasts abundant agricultural, mineral, and energy resources:

(1)Agricultural Resources:

Agriculture holds a pivotal role in the national economies of African countries, serving as the backbone of many economies. The continent has an agricultural and arable land area more than double that of China. Southern Africa, with its ample sunlight, enables most areas to support two or even three harvests annually. Although Africa holds 40% of the world's freshwater reserves, less than 10% of these resources have been developed, presenting immense potential for agricultural development. However, historical factors have left African agriculture reliant on small-scale subsistence farming, with 95% of arable land cultivated using traditional methods. Major crops include wheat, rice, maize, millet, sorghum, potatoes, cassava, plantains, and palm dates. African cash crops, particularly tropical ones such as cotton, sisal, peanuts, palm oil, cashews, sesame, coffee, cocoa, sugarcane, tobacco, natural rubber, and cloves, hold significant global importance. The continent is also known for unique products such as frankincense, myrrh, shea nuts, kola nuts, and alfa grass. Tropical forests dominate the landscape, accounting for 21% of Africa's land area and home to many valuable tree species.

(2)Mineral Resources:

Africa's mineral wealth has earned it the nickname "the world's raw materials warehouse." The continent holds reserves of all the proven underground mineral resources in the world, particularly a wide range of minerals critical to high-tech industries, with substantial reserves of over 50 rare minerals. At least 17 of these minerals hold the largest global reserves, including platinum, manganese, chromium, ruthenium, and iridium, which collectively account for about 80% of the world's reserves. Phosphates, palladium, gold, diamonds, germanium, cobalt, and vanadium each make up over 50% of global reserves. Significant reserves of uranium, tantalum, cesium, bauxite, fluorite, zirconium, graphite, and hafnium account for over 30% of global totals. Morocco's Atlas Mountains rank among the world's top phosphate-producing regions, while countries such as the Democratic Republic of Congo (DRC), Botswana, and South Africa are rich in diamonds. Zambia, known as "the copper country," holds 15% of global copper reserves. Guinea leads the world in bauxite reserves. The geographical distribution of Africa's major mineral resources is shown in Figure 2.3.

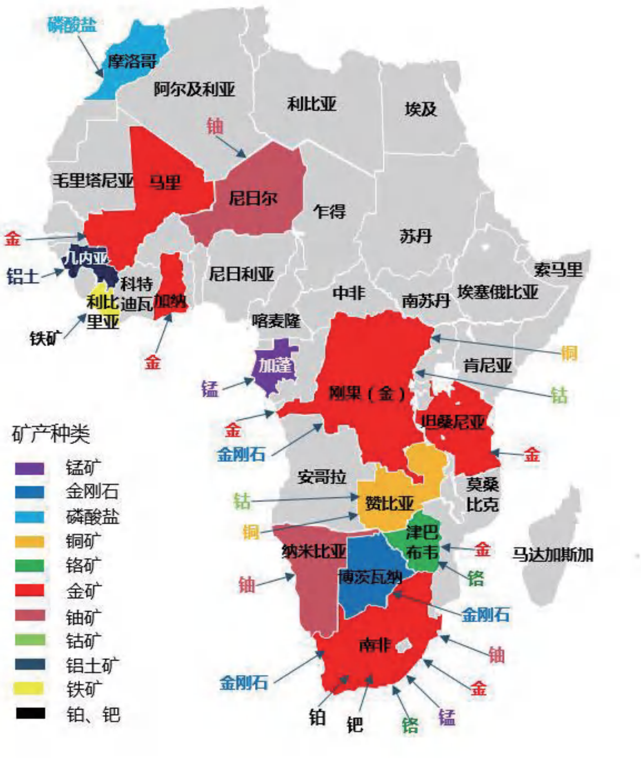

Figure 2.3 Distribution Map of Major Mineral Resources in Africa

(3)Energy Resources

Africa is endowed with abundant energy resources, including hydropower, wind, solar energy, and fossil fuels.

Oil and Gas Resources: Africa holds an important position in the global oil and gas market. Overall, the distribution of oil and gas resources in Africa follows the pattern of “more oil than gas, more in the north than the south, and more in the west than the east.” According to data from the International Energy Agency (IEA), in 2022, Africa’s proven oil reserves were 125.7 billion barrels, accounting for approximately 7% of the world’s total reserves. Proven natural gas reserves in Africa amounted to 14.6 trillion cubic meters, also about 7% of global reserves. Countries with abundant oil resources include Nigeria and Libya, while countries rich in natural gas resources include Nigeria and Algeria. According to IEA data, Sub-Saharan Africa accounts for only 23% of Africa’s total oil reserves but contributes 63% of the continent’s oil production and 72% of its oil exports. At the same time, North Africa holds 77% of Africa’s total natural gas reserves, but its production and export proportions are only 37% and 28%, respectively[3].

Clean Energy Resources: Africa has a large total reserve of clean energy resources, which are diverse, widely distributed, and highly complementary across time zones and seasons. This has earned the continent the title of a “treasure trove” of clean energy resources. Hydropower, wind power, and solar power resources are abundant, but their development levels remain low, leaving significant potential for further exploitation. According to the latest statistics from the International Renewable Energy Agency (IRENA)[4]: Africa’s hydropower resources are rich, with theoretical reserves accounting for 12.3% of the global total. As of 2023, Africa’s installed hydropower capacity was 40.3 gigawatts, representing 2.9% of the global installed hydropower capacity; Africa’s wind power resources are highly abundant, with technically exploitable wind energy accounting for 39.8% of the global total. As of 2023, Africa’s installed wind power capacity stood at 8,654 megawatts, representing only 0.9% of the global installed wind capacity; Africa’s solar photovoltaic resources hold immense potential, with technically exploitable solar energy accounting for 51.9% of the global total. Conditions for large-scale solar energy development are particularly favorable, especially in the northern Sahara region and along the southwestern coastal areas. However, as of 2023, Africa’s installed solar power capacity was just 13.5 gigawatts, accounting for 1% of the global total.

2.2 Socioeconomic Conditions

Due to historical, geographical, political, and ethnic factors, Africa remains the most economically underdeveloped continent in the world. Most African nations have relatively low levels of social development, small economic scales, and economies dominated by traditional agriculture, with weak foundations and underdeveloped infrastructure.

Over the past two decades, Africa’s economy has experienced continuous growth, making it one of the fastest-growing regions globally. However, it remains generally underdeveloped, with significant disparities in development among countries. According to data from the International Monetary Fund (IMF)[5], Africa’s total GDP in 2023 was approximately $2.7 trillion. The “Big Three” economies of Africa—Nigeria, South Africa, and Egypt—rank at the forefront. Nigeria has consistently maintained its position as Africa’s largest economy, with a GDP of $506.6 billion in 2023, ranking 32nd globally. The combined GDP of the five largest African economies—Nigeria, South Africa, Egypt, Algeria, and Angola—accounts for over 60% of the continent’s total GDP.

In general, Africa’s economy exhibits the following characteristics:

(1) Unbalanced Economic Structure:

Most African nations rely heavily on the export of raw materials, resulting in relatively singular and unbalanced economic structures. Additionally, due to limited economic planning by policymakers, many African countries struggle to diversify their economies.

(2) Significant Income Inequality:

Political instability and internal conflicts have exacerbated income disparities in many African countries. Statistics show that approximately 70% of Africa's population lives in relative poverty.

(3) Issues with Foreign Investment and Debt:

Africa has attracted substantial foreign investment; however, much of this capital is concentrated in mining, drilling, and export industries, leading to relatively low net gains for the host countries. At the same time, African nations have accumulated significant debt, which not only hinders economic development but also traps them in long-term debt repayment crises.

2.3 China-Africa Relations

China and Africa share a long-standing relationship. Over the past decade since the Belt and Road Initiative (BRI) was introduced, China-Africa cooperation has deepened and expanded, entering a new phase of enhanced quality. Moving forward under the shared vision of building a closer China-Africa community with a shared future, the comprehensive strategic and cooperative partnership between China and Africa has stepped into a new era. Economic and trade ties have grown increasingly close, with trade volumes steadily rising. Under the framework of the Forum on China-Africa Cooperation (FOCAC), China has supported African countries by announcing initiatives such as the "Ten Cooperation Plans," "Eight Major Initiatives," and "Nine Programs." These efforts have helped African nations improve their capacity for independent and sustainable development, effectively addressing three major challenges: lagging infrastructure, talent shortages, and insufficient funding.

2.3.1 China-Africa Political Relations

In 2013, Chinese President Xi Jinping proposed the joint construction of the Silk Road Economic Belt and the 21st-Century Maritime Silk Road, collectively known as the Belt and Road Initiative (BRI). Africa, as a natural and historical extension of the BRI, plays a key role in its implementation. As of now, 52 African countries and the African Union have signed Memorandums of Understanding (MoUs) with China to participate in the BRI. Additionally, Algeria, Djibouti, Ethiopia, Mauritania, Morocco, Mozambique, and the African Union have signed cooperation plans with China under the BRI framework, making Africa one of the most important regions for the initiative.

In December 2015, the Johannesburg Declaration of the FOCAC explicitly called for aligning China's BRI with Africa's economic integration and sustainable development goals, thereby creating more opportunities for shared growth and development. In September 2018, the Beijing Declaration--Toward an Even Stronger China-Africa Community with a Shared Future was issued during the FOCAC Beijing Summit. Both sides agreed to align the BRI with the United Nations 2030 Agenda for Sustainable Development, the African Union's Agenda 2063, and national development strategies of African countries, injecting new momentum into China-Africa win-win cooperation. In November 2021, during the eighth FOCAC Ministerial Conference in Dakar, Senegal, President Xi Jinping proposed four key priorities for building a China-Africa community with a shared future. Among these, the third—advancing green development—emphasized the need to advocate green and low-carbon development, actively develop solar, wind, and other renewable energy sources, implement the Paris Agreement on climate change, and enhance our capacity for sustainable development. Meanwhile, the Dakar Action Plan (2022–2024) outlined commitments to strengthen pragmatic cooperation in the energy sector under the China-AU Energy Partnership Framework, enhancing Africa's electrification, increasing the share of clean energy, and addressing energy accessibility challenges for sustainable development. In August 2023, during the China-Africa Leaders' Dialogue, a joint statement reaffirmed the commitment to further aligning China-Africa high-quality BRI cooperation with the African Union's Agenda 2063 and national strategies of African countries. This partnership aims to upgrade the quality of cooperation and achieve mutual development between China and Africa.

From September 4th–6th, 2024, during the FOCAC Beijing Summit, President Xi Jinping announced that

China's bilateral relations with all African nations with diplomatic ties would be elevated to strategic levels. The overall positioning of China-Africa relations was upgraded to an All-Weather China-Africa Community with a Shared Future for the New Era.

2.3.2 China-Africa Economic and Trade Relations

(1)Deepening Trade Ties:

China has remained Africa's largest trading partner for 14 consecutive years. The proportion of China-Africa trade in Africa's total external trade continues to grow steadily. In 2022, China-Africa trade reached $282 billion, an 11.1% year-on-year increase. African agricultural products are increasingly popular among Chinese consumers. Since 2017, China's annual imports of services from Africa have grown by 20%, creating nearly 400,000 jobs annually for Africa.

(2)Emergence of New Trade Models:

The China-Africa "Silk Road E-commerce" cooperation has made solid progress, with its levels and scope of collaboration continuously expanding, becoming a new highlight in the deepening of bilateral trade development. Products such as Ethiopian coffee, Kenyan tea, Cameroonian white pepper, Senegalese peanuts, and Rwandan chili sauce have directly entered the Chinese market through e-commerce platforms. Chinese enterprises have also invested in building warehouses and logistics centers in Africa and launched initiatives such as "Bringing Livestreaming to Africa" to promote African products in China.

(3)Enhanced Trade Facilitation Mechanisms

China and Africa have steadily improved their cooperation mechanisms in areas such as customs, inspection and quarantine standards, and import-export verification and certification. These measures have facilitated market access for relevant products. China has established a $10 billion credit line to support African export trade, created "green channels" for African products entering China, and provided numerous preferential measures for African participation in major trade expos such as the China International Import Expo. Furthermore, China has implemented zero-tariff treatment for 98% of tariff lines for products originating from 21 of Africa's least-developed countries.

2.3.3 Investment and Business Environment

(1)Simultaneous Growth in the Volume and Quality of Trade and Investment with Africa

According to data released by China's Ministry of Commerce, the trade volume between China and Africa in 2023 reached $282.1 billion, an increase of nearly 11% compared to 2021, marking a new record high for the second consecutive year. China has maintained its position as Africa's largest trading partner for 15 consecutive years, with trade volumes for nearly half of African countries increasing by over 10% year-on-year. On the investment side, as of the end of 2023, China's cumulative direct investment stock in Africa exceeded $40 billion, making it one of the largest sources of foreign investment on the continent. Chinese enterprises in Africa, while achieving their own development, actively support African countries in enhancing their level of industrialization, improving industrial support systems, and strengthening export earning capabilities through measures such as technology transfer, increased local procurement, and employing local workers.

(2)Continuous Improvement of Investment Promotion Mechanisms

China and Africa have achieved significant results in reducing investment barriers and promoting the liberalization and facilitation of investment, benefiting businesses on both sides. As of now, China has signed bilateral agreements on investment promotion and protection with 34 African countries and agreements to avoid double taxation with 19 African countries. Additionally, 17 African countries have joined the Belt and Road Initiative's tax administration cooperation mechanism. Under the initiatives to promote trade and drive investments, several infrastructure and manufacturing projects have been successfully implemented, such as solar power plants in South Africa and home appliance factories in

Egypt. In October 2023, Egypt successfully issued 3.5 billion CNY of sustainable development Panda bonds in China's interbank market, with a term of three years and a coupon rate of 3.51%, further expanding financial support channels for China-Africa economic and trade cooperation.

(3)Steady Advancement of Capacity Cooperation

As of now, China has established capacity cooperation mechanisms with 15 African countries. Chinese enterprises have participated in the planning, construction, and operation of over 50 industrial parks in African countries, attracting investment from businesses worldwide. The proportion of local employees in these parks exceeds 80%, creating millions of direct and indirect jobs. As of the third quarter of 2023, the China-Africa Development Fund had invested a total of $5.4 billion in 39 African countries, leveraging over $31 billion in Chinese investment in Africa. These projects cover a wide range of fields, including infrastructure, agriculture, and manufacturing, significantly contributing to industrial development in African countries. Particulalry in recent years, driven by initiatives promoting green development and digital innovation, Chinese enterprises have implemented numerous clean energy projects in Africa, with a notable increase in the export of lithium batteries and photovoltaic products. The China-Africa Satellite Remote Sensing Application Cooperation Center was inaugurated in Beijing, and the China-Africa Digital Cooperation Forum was successfully held. Additionally, China and African countries have jointly established more than ten bilateral laboratories and research centers, carrying out collaborative research in fields such as resource remote sensing, renewable energy, and ecological agriculture.

2.4 Energy Environment

Africa is one of the cradles of ancient human civilizations and is rich in energy resources. Its technically exploitable hydropower potential is 1.75 trillion kilowatt-hours, accounting for approximately 12.3% of the world's total. Africa is home to the Nile, the world's longest river, and the Congo River, the world's second-largest river system. Its wind energy resources are estimated to provide 5,000 trillion to 7,000 trillion kWh of electricity annually, accounting for around 30% of the global total. Solar energy resources are abundant and evenly distributed, with three-quarters of Africa's land exposed to direct sunlight. The continent's solar radiation accounts for about 51% of the Earth's total land radiation. Africa's coal, oil, and natural gas reserves represent about 1.2%, 7%, and 7% of global totals, respectively.

2.4.1 Fossil Energy

(1)Oil

According to the World Energy Statistical Yearbook (2024 edition)[6] published by the Energy Research Institute, Africa's oil production in 2023 grew by 2.3% compared to 2022, reaching 7.228 million barrels per day and accounting for 7.5% of global production. Major oil-producing countries include Libya, Nigeria, Algeria, Angola, South Sudan, Egypt, Congo (Brazzaville), Gabon, Chad, Sudan, Equatorial Guinea, and Tunisia. Four countries—Libya, Nigeria, Algeria, and Angola—account for approximately 84% of Africa's total oil reserves. In contrast, more than half of the African countries have little or no oil resources. The distribution of major oil-producing countries in Africa is illustrated in Figure 2.4.

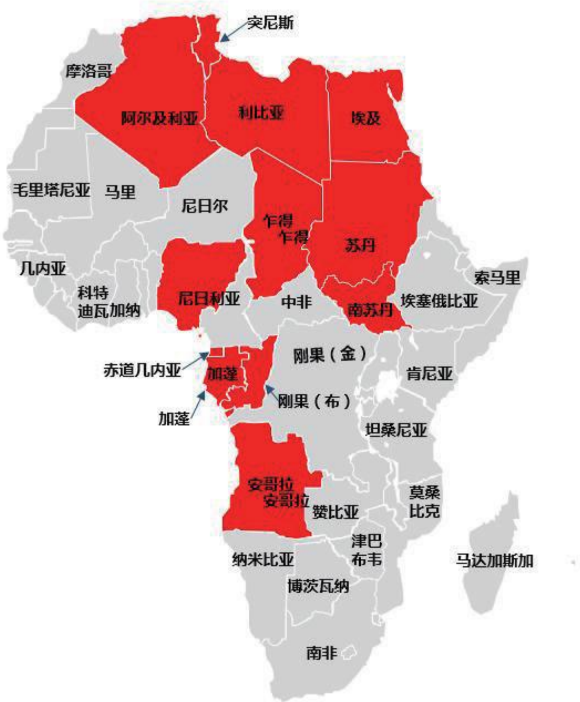

Figure 2.4 Major Countries in the Distribution of African Oil Resources

(2)Natural Gas

As of now, the world's proven natural gas reserves stand at 188.1 trillion cubic meters, with Africa accounting for 12.9 trillion cubic meters, representing 7% of the global total. Major natural gas-producing countries in Africa include Nigeria, Algeria, Egypt, and Libya. The distribution of major natural gas-producing countries in Africa is illustrated in Figure 2.5.

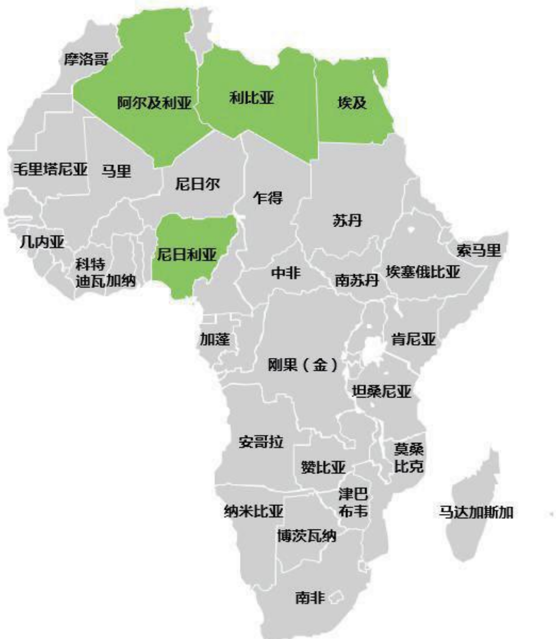

Figure 2.5 Major Countries in the Distribution of African Natural Gas Resources

(3)Coal

The world's proven coal reserves currently stand at 1,074.11 billion tons, with Africa accounting for 14.84 billion tons, representing 1.4% of the global total. The majority of these reserves consist of anthracite and bituminous coal (approximately 14.77 billion tons), with the remainder being sub-bituminous coal and lignite (approximately 660 million tons). Coal resources in Africa are primarily concentrated in Southern African countries such as South Africa, Botswana, Zimbabwe, and Mozambique. The distribution of coal resources in Africa is illustrated in Figure 2.6.

Figure 2.6 Major Countries in the Distribution of African Coal Resources

2.4.2 Hydropower

Africa's most important rivers include the Nile, the world's longest river; the Congo River (Zaire River), the world's second-largest river system; as well as the Niger River and Zambezi River. The distribution of major rivers in Africa is illustrated in Figure 2.7.

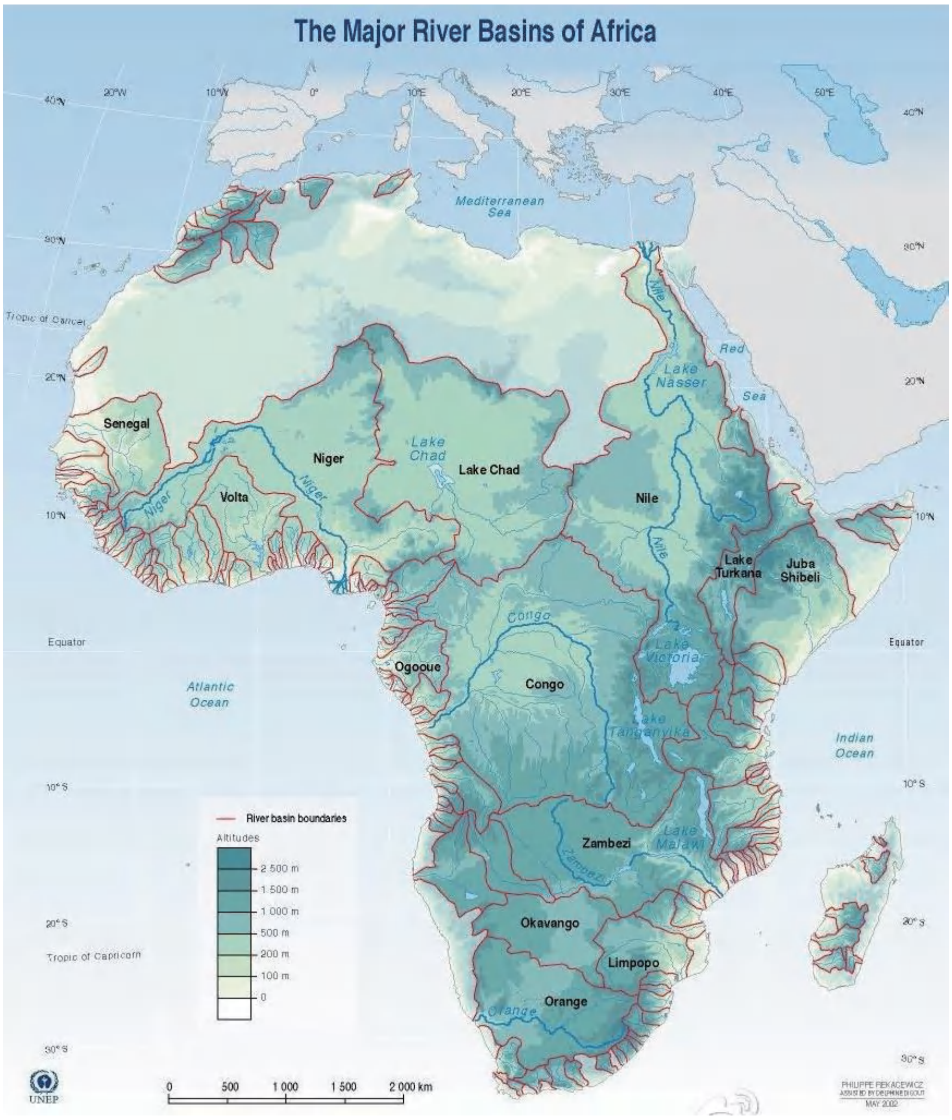

Figure 2.7 Distribution Map of Major Rivers Basins in Africa

The Nile River, located in northeastern Africa, spans approximately 6,670 kilometers, with a drainage area of 2.87 million square kilometers and an annual runoff of about 84 billion cubic meters. The Congo River, located in central and western Africa, spans approximately 4,640 kilometers, with a drainage area of 3.7 million square kilometers and an annual runoff of 1.3 trillion cubic meters, the highest in Africa. The Niger River, situated north of the Equator, spans approximately 4,200 kilometers, with a drainage area of 2.09 million square kilometers and an annual runoff of about 200 billion cubic meters. The Zambezi River, located in southeastern Africa, spans approximately 2,660 kilometers, with a drainage area of 1.35 million square kilometers and an annual runoff of about 223.2 billion cubic meters.

Africa is endowed with rich hydropower resources. The theoretical hydropower potential of Africa's rivers is estimated at 4 trillion kilowatt-hours, accounting for about 10.0% of the global total. Technically exploitable hydropower resources amount to 1.75 trillion kilowatt-hours, or approximately 12.3% of the global total. Economically exploitable hydropower resources are estimated at 1 trillion kilowatt-hours, accounting for 12.4% of the global total. Overall, Africa's hydropower resources are abundant but remain underutilized, with the current utilization rate of only about 9%.

The Nile River boasts significant hydropower resources. In Ethiopia alone, the theoretical hydropower potential of the Blue Nile River basin is 172 billion kilowatt-hours, with economically exploitable resources estimated at 38 billion kilowatt-hours. The Congo River also has substantial hydropower resources, with a theoretical potential of approximately 2.5 trillion kilowatt-hours and a technically exploitable capacity of around 150 gigawatts. The river's downstream section from Kinshasa to Matadi, spanning approximately 360 kilometers, is particularly rich in hydropower resources, with an average annual flow rate of 41,000 cubic meters per second and a theoretical capacity of about 850 billion kilowatt-hours. The distribution of African countries with significant hydropower resources is shown in Figure 2.8.

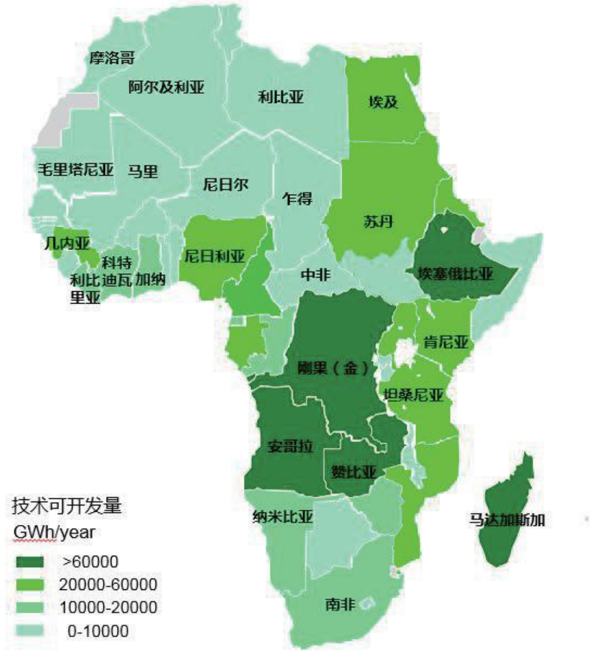

Figure 2.8 Distribution Map of Hydropower Resources by Country in Africa

According to IRENA statistics[4], the global installed hydropower capacity in 2023 totaled 1,407.75 gigawatts, with Africa accounting for 40.28 gigawatts, or 2.86% of the global total. African countries with hydropower installed capacities exceeding 2,000 megawatts include Ethiopia (4,883 MW), Angola (3,729 MW), South Africa (3,484 MW), the Democratic Republic of Congo (3,172 MW), Zambia (3,165 MW), Nigeria (2,851 MW), Egypt (2,832 MW), and Mozambique (2,192 MW). Countries equipped with pumped-storage hydropower facilities include South Africa and Morocco, with installed capacities of 2,732 MW and 464 MW, respectively.

2.4.3 Wind Energy

Africa's technically exploitable wind energy potential is estimated at approximately 67 trillion kilowatt-hours per year, representing about 32% of the global total. According to data from the Global Wind Atlas, wind energy resources are primarily concentrated in the Sahara Desert and its northern regions, as well as the southern and eastern coastal areas of Africa. The distribution of wind speed and wind power density at 100 meters above ground is illustrated in Figures 2.9 and 2.10, with red indicating favorable conditions and blue representing less favorable conditions. Countries with the richest wind energy resources include Somalia, Morocco, Mauritania, South Africa, and Madagascar, where the average wind speed at 100 meters height exceeds 8 m/s in certain areas.

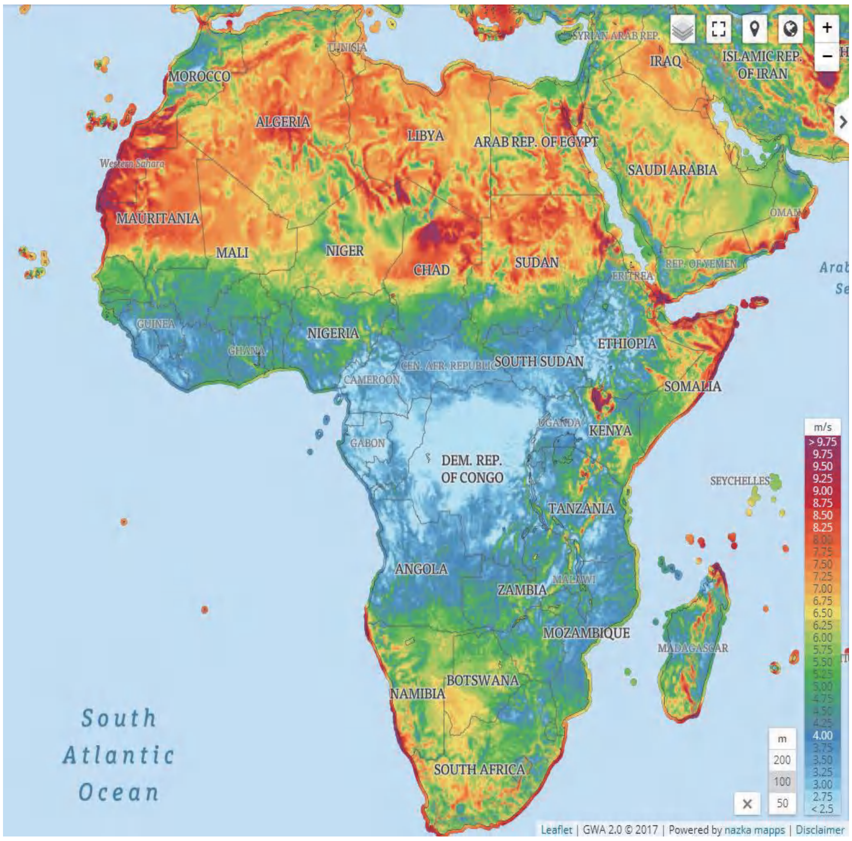

Figure 2.9 Wind Speed Distribution Map at 100m Height in Africa (Source: Global Wind Atlas)

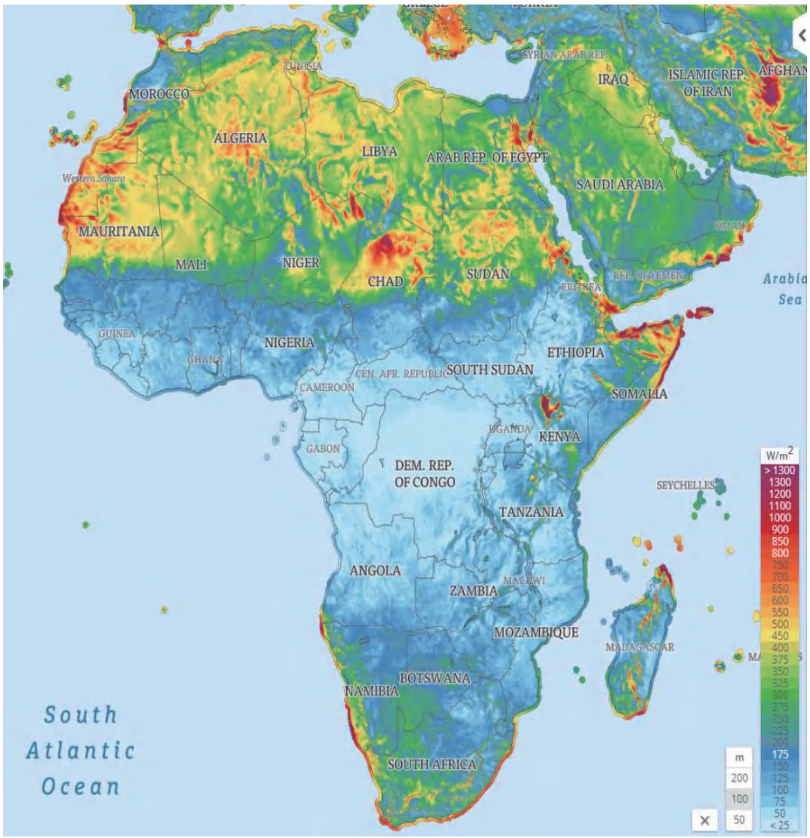

Figure 2.10 Wind Power Density Distribution Map at 100m Height in Africa (Source: Global Wind Atlas)

According to IRENA statistics4, as of 2023, the global cumulative installed wind power capacity reached 1,017.2 gigawatts, with Africa accounting for 8.66 gigawatts, or just 0.85% of the global total. African countries with wind power installed capacities exceeding 1,000 megawatts include South Africa (3,442 MW), Egypt (1,890 MW), and Morocco (1,858 MW).

2.4.4 Solar Energy

Africa possesses abundant and highly exploitable solar energy resources, with the richest solar energy areas located in the Sahara Desert, the Ethiopian Highlands, and the South Africa Plateau. The continent's technically exploitable solar energy potential is estimated at 665 billion kilowatt-hours per year, accounting for about 40% of the global total. Solar radiation is evenly distributed across Africa, with three-quarters of the land exposed to vertical sunlight. According to IRENA, Africa's technically exploitable solar enenrgy capacity is approximately 13,750 gigawatts, exceeding 50% of the global total. Nearly all African countries, except for small island nations, are suitable for developing solar power stations, with the Sahara Desert and its surrounding areas in North and Central Africa, the southern Atlantic coastal regions, and parts of the inland areas in Eastern Africa being particularly suitable for constructing large-scale solar power plants. The spatial distribution of solar energy resources in Africa is shown in Figure 2.11.

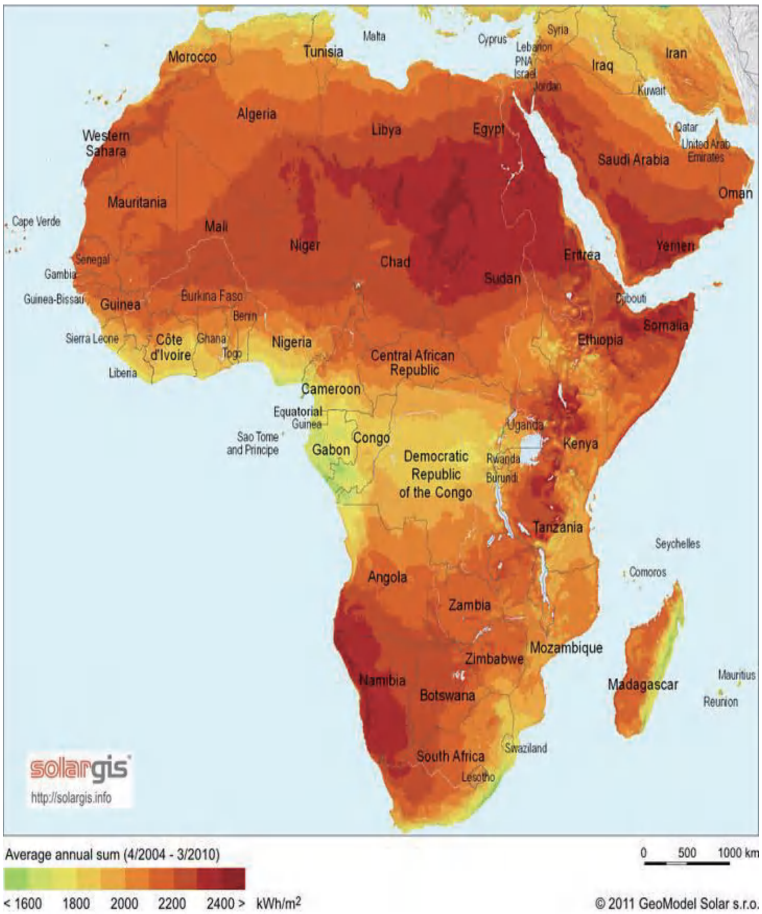

Figure 2.11 Spatial Distribution Map of Solar Energy Resources in Africa

According to IRENA statistics4, as of 2023, the global installed solar power capacity reached 1,418.97 gigawatts, with Africa accounting for 13.48 gigawatts, representing only 0.95% of the global total. African countries with solar power installed capacities exceeding 400 megawatts include South Africa, Egypt, Morocco, Tunisia, and Algeria, with installed capacities of 6,164 megawatts, 1,856 megawatts, 934 megawatts, 506 megawatts, and 451 megawatts, respectively.

In 2023, the global photovoltaic power capacity reached 1,412.09 gigawatts, with Africa accounting for 12.39 gigawatts, representing just 0.88% of the global total. African countries with photovoltaic power capacities exceeding 400 megawatts include South Africa, Egypt, Tunisia, and Algeria, with capacities of 5,664 megawatts, 1,836 megawatts, 506 megawatts, and 426 megawatts, respectively.

The global installed capacity for concentrated solar power (CSP) reached 6,876 megawatts in 2023, with Africa accounting for 1,085 megawatts, representing 15.8% of the global total. In Africa, four countries have developed CSP resources: Morocco, South Africa, Algeria, and Egypt, with installed capacities of 540 megawatts, 500 megawatts, 25 megawatts, and 20 megawatts, respectively.

2.4.5 Geothermal Energy

Africa's geothermal resources are primarily distributed in the East African Rift Valley, the Red Sea region, and the western part of the continent. Kenya, Ethiopia, and Tanzania have the richest geothermal resources, while Uganda, Rwanda, Djibouti, and Zambia have begun planning the use of new geothermal capacity. The distribution of geothermal resources in Africa is shown in Figure 2.12. Kenya, located in the Red Sea–Gulf of Aden–East African Rift geothermal belt, is the African country richest in geothermal resources and ranks eighth globally in geothermal resource potential. According to the China-Africa Trade Research Center, Kenya's potential installed capacity for geothermal power generation is estimated at 7,000 megawatts. Data from the Kenya National Bureau of Statistics (KNBS) indicate that by the end of 2017, geothermal power had become the country's primary source of electricity, accounting for 45.9% of the nation's total power generation.

According to IRENA statistics4, in 2023, global installed geothermal power generation capacity reached 15.03 gigawatts, with Africa contributing 991 megawatts, representing only 6.68% of the global total. Among African countries, Kenya and Ethiopia are the only two nations that have developed geothermal energy. Their installed capacities are 984 megawatts and 7 megawatts, respectively.

Figure 2.12 Distribution Map of Geothermal Resources in Africa

2.4.6 Biomass Energy

Biomass energy refers to various forms of energy produced using biomass with energy value, such as plants and organic waste. Africa possesses abundant biomass energy resources, which account for as much as 55% of the continent’s energy mix.

According to IRENA statistics4, in 2023, global installed biomass power generation capacity reached 150.26 gigawatts, with Africa accounting for 1,901 megawatts, or just 1.27% of the global total. African countries with biomass power generation capacities exceeding 100 megawatts include Ethiopia, South Africa, Sudan, Eswatini, and Zimbabwe, with capacities of 310 megawatts, 265 megawatts, 199 megawatts, 106 megawatts, and 100 megawatts, respectively.

2.4.7 Nuclear energy

Nuclear energy has significant development potential in Africa. Uranium, the most important natural nuclear fuel, constitutes over 30% of the world’s uranium reserves in Africa. Africa’s uranium production holds a critical position globally, with major deposits located in Niger, South Africa, and Namibia. Other countries, including Sudan, Uganda, Algeria, Côte d’Ivoire, the Central African Republic, Chad, Cameroon, Angola, Zimbabwe, and Malawi, also possess uranium reserves. Namibia and South Africa are particularly prominent, with their uranium reserves ranking among the world’s largest. The distribution of uranium resources in Africa is shown in Figure 2.13.

Figure 2.13 Distribution Map of Uranium Resources in Africa

South Africa has abundant uranium reserves and operates the Koeberg nuclear power station, with a total installed capacity of 1,860 megawatts. Koeberg is Africa’s only operational nuclear power plant. In 2022, South Africa’s nuclear energy consumption reached 0.09 exajoules, and its nuclear power generation totaled 10.4 terawatt-hours, accounting for 4% of the country's total power generation. Koeberg's Units 1 and 2 were commissioned in 1984 and 1985, respectively, with their current licenses valid until July 24, 2024, and November 9, 2025. In May 2021, Eskom, South Africa's national electricity company, applied to the National Nuclear Regulator (NNR) to extend the operating life of the two units by 20 years beyond their initial 40-year lifespan. In July 2024, the NNR approved a 20-year extension for Unit 1, extending its lifespan to July 21, 2044, while the safety assessment for Unit 2 is ongoing, with a decision expected by the end of 2025.

According to the International Atomic Energy Agency (IAEA), nearly one-third of the approximately 30 countries worldwide considering nuclear power development are in Africa. Countries such as Egypt, Ghana, Kenya, Morocco, Niger, Nigeria, and Sudan have engaged with the IAEA to evaluate their readiness to launch nuclear programs. Algeria, Tunisia, Uganda, and Zambia are also exploring the feasibility of developing nuclear energy[7].

3

Current Status and Trends of Africa's Electricity Market

Chapter 3 Current Status and Trends of Africa's Electricity Market

3.1 Current Status of the Electricity Market

3.1.1Current Status of Power Generation

The development of Africa's electricity sector generally lags behind, constrained by insufficient infrastructure, weak grid construction, and unreliable electricity supply. These challenges make electricity expensive and inaccessible, posing major hurdles to Africa's socioeconomic development. According to the latest report from the International Renewable Energy Agency (IRENA)4, as of the end of 2023, Africa's total installed power generation capacity was 255.91 gigawatts. The breakdown of this capacity includes: Thermal power: 188.67 gigawatts (73.7% of total capacity); Hydropower: 40.28 gigawatts (15.7%); Solar power: 13.48 gigawatts (5.3%); Wind power: 8.65 gigawatts (3.4%); Biomass and geothermal energy; 2.89 gigawatts (1.1%); Nuclear power: 1.9 gigawatts (0.8%). The distribution of installed capacity by power source is shown in Figure 3.1.

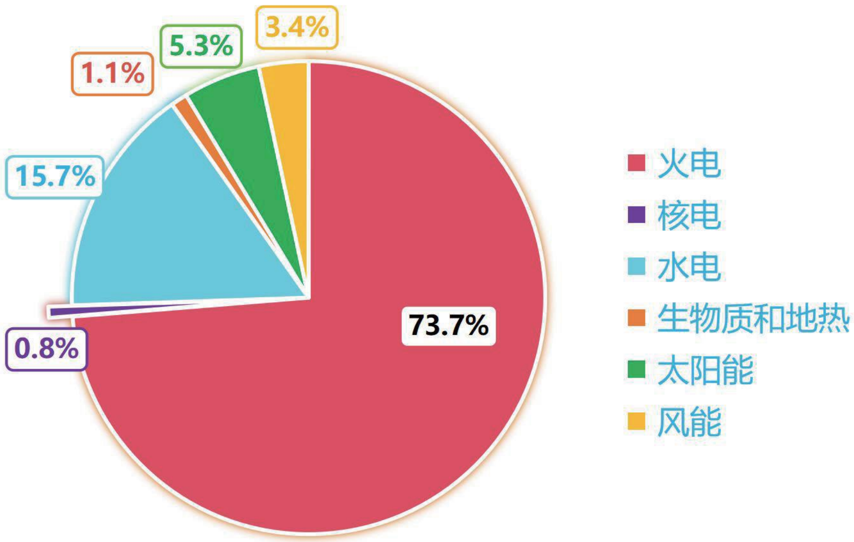

Figure 3.1 Proportion of Installed Capacity by Power Source in Africa

In recent years, Africa's renewable energy installed capacity has grown rapidly, increasing from 50.4 gigawatts in 2019 to approximately 62.1 gigawatts in 2023. South Africa, Morocco, Ethiopia, and Egypt lead in renewable energy installed capacity. Among renewable sources, hydropower remains the largest contributor, with a total capacity of 40.28 gigawatts as of 2023. Pumped-storage hydropower accounts for 3,196 megawatts of this total, with facilities located exclusively in Morocco and South Africa. The hydropower installed capacity and pumped storage power generation installed capacity of African countries are detailed in Tables 3.2 and 3.34.

Table 3.1 Installed Capacity of Renewable Energy in African Countries

Unit： MW

FIVE REGIONS	NATION	2019	2020	2021	2022	2023
NORTHERN	Algeria	604	585	505	590	590

FIVE REGIONS	NATION	2019	2020	2021	2022	2023
AFRICA	Egypt	5690	5934	6258	6322	6709
	Libya	5	5	6	6	8
	Morocco	3272	3522	3638	3725	4105
	South Sudan	1	1	1	15	28
	Sudan	1761	1798	1817	1817	1817
	Tunisia	391	406	406	508	817
CENTRAL AFRICA	Central African Republic	19	19	19	19	44
	Cameroon	826	827	827	828	864
	Chad	4	4	4	5	5
	Equatorial Guinea	378	604	829	830	830
	Gabon	332	332	332	332	332
	Democratic Republic of the Congo	2632	2632	2632	2961	3201
	Republic of the Congo	226	227	227	227	227
	The Democratic Republic of Sao Tome and Principe	2	2	2	2	2
SOUTHERN AFRICA	South Africa	8014	9523	9827	10505	10623
	Angola	3448	3782	3782	4066	4091
	Botswana	6	6	6	6	6
	Zimbabwe	1192	1194	1208	1221	1221
	Comoros	3	3	2	5	5
	Lesotho	75	75	75	251	252
	Madagascar	198	197	197	197	197
	Malawi	472	472	551	592	592
	Mauritius	262	270	272	270	270
	Mayotte	17	19	30	30	31
	Mozambique	2307	2310	2310	2351	2351
	Namibia	504	508	508	533	533
	Eswatini	169	169	179	179	179
	Zambia	2531	2532	2838	3297	3332
WESTERN AFRICA	Benin	3	3	3	28	28
	Burkina Faso	91	91	92	123	214
	Côte d’Ivoire	883	885	887	888	925
	Togo	72	74	124	124	124
	Cape Verde	54	54	61	76	76
	Guinea	378	604	829	830	830
	Guinea-Bissau	1	1	1	1	1
	Gambia	3	3	3	3	3
	Ghana	1676	1700	1758	1761	1761
	Liberia	96	96	96	96	96
	Mali	367	418	449	593	593
	Mauritania	122	122	122	123	260
	Niger	27	27	27	62	92
	Nigeria	2157	2216	2245	2274	2984
	Senegal	253	357	423	446	446
	Sierra Leone	99	99	99	104	104
EASTERN AFRICA	Djibouti	0	0	20	20	80
	Burundi	54	54	61	76	76
	Eritrea	27	27	26	26	26
	Ethiopia	4451	4713	4759	5589	5545

FIVE REGIONS	NATION	2019	2020	2021	2022	2023
	Kenya	2085	2297	2472	2660	2736
	Réunion	436	445	463	470	474
	Rwanda	135	145	145	150	150
	Seychelles	10	13	19	20	20
	Somalia	11	19	27	51	54
	Tanzania	682	686	686	687	687
	Uganda	1178	1196	1198	1224	1224
TOTAL FOR AFRICA		50429	53812	55665	59398	62107

Table 3.2 Installed Capacity of Hydropower in African Countries

Unit： MW

FIVE REGIONS	NATION	2019	2020	2021	2022	2023
NORTHERN AFRICA	Algeria	228	209	129	129	129
	Egypt	2832	2832	2832	2832	2832
	Morocco	1770	1770	1770	1770	1770
	Sudan	1482	1482	1482	1482	1482
	Tunisia	62	66	66	66	66
CENTRAL AFRICA	Central African Republic	19	19	19	19	19
	Cameroon	812	812	812	814	814
	Equatorial Guinea	127	127	127	127	127
	Gabon	331	331	331	331	331
	Democratic Republic of the Congo	2608	2608	2608	2932	3172
	Republic of the Congo	214	214	214	214	214
	Sao Tome and Principe	2	2	2	2	2
SOUTHERN AFRICA	South Africa	3480	3480	3484	3484	3484
	Zimbabwe	781	1081	1081	1081	1081
	Angola	3395	3729	3729	3729	3729
	Lesotho	74	74	74	74	74
	Madagascar	164	164	164	192	193
	Malawi	373	373	392	392	392
	Mauritius	61	61	61	61	61
	Mozambique	2191	2192	2192	2192	2192
	Namibia	347	351	351	351	351
	Eswatini	62	62	62	62	62
	Zambia	2398	2398	2399	2400	2705
WESTERN AFRICA	Benin	1	1	1	1	1
	Burkina Faso	35	35	35	35	37
	Côte d’Ivoire	879	879	879	879	879
	Togo	67	67	67	67	67
	Guinea	364	589	814	814	814
	Ghana	1584	1584	1584	1584	1584
	Liberia	93	93	93	93	93

FIVE REGIONS	NATION	2019	2020	2021	2022	2023
	Mali	315	315	315	455	455
	Nigeria	2111	2151	2151	2151	2851
	Sierra Leone	61	61	61	61	61
EASTERN AFRICA	Ethiopia	3817	4071	4071	4821	4883
	Comoros	1	1	1	1	1
	Burundi	48	48	48	63	63
	Kenya	852	854	858	858	859
	Réunion	133	133	133	134	134
	Rwanda	109	119	119	124	124
	Tanzania	596	598	598	599	599
	Uganda	1004	1011	1011	1033	1033
TOTAL FOR AFRICA		36187	37047	37527	39273	40278

Table 3.3 Installed Capacity of Pumped Storage Power Generation in African Countries

Unit： MW

INSTALLED CAPACITY (MW)	2019	2020	2021	2022	2023
MOROCCO	464	464	464	464	464
SOUTH AFRICA	2732	2732	2732	2732	2732
TOTAL FOR AFRICA	3196	3196	3196	3196	3196

In contrast, the share of wind and solar power installed capacity in Africa’s renewable energy mix is relatively low. As of 2023, Africa’s installed wind power capacity was 8,654 megawatts, primarily concentrated in South Africa, Morocco, Egypt, and Kenya. Solar power installed capacity reached 13,479 megawatts, mainly distributed in South Africa, Egypt, Morocco, and Algeria. Among these, photovoltaic (PV) installations accounted for 12,394 megawatts, while concentrated solar power (CSP) installations amounted to 1,085 megawatts, primarily located in Algeria, South Africa, Egypt, and Morocco4. For details on the installed capacities of wind power, photovoltaic power, and concentrated solar power in African countries, refer to Tables 3.4, 3.5, and 3.6. Biomass energy generation is another increasingly valued energy source in Africa. By the end of 2023, the installed biomass power capacity across African countries reached 1,901 megawatts. For details on biomass power capacity in African countries, refer to Table 3.7. Regarding other renewable energy sources, Africa has abundant geothermal resources, primarily concentrated in Eastern Africa. The exploitable potential exceeds 15 gigawatts, although the current development and utilization levels remain low. Kenya, which has abundant geothermal resources, has an installed capacity of 984 megawatts. Additionally, Eastern African countries such as Ethiopia, Djibouti, Eritrea, Tanzania, and Uganda are actively preparing for geothermal resource development. For details on the installed geothermal power capacity in African countries, refer to Table 3.84.

Table 3.4 Installed Capacity of Wind Power in African Countries

Unit： MW

FIVE REGIONS	NATION	2019	2020	2021	2022	2023
NORTHERN AFRICA	Algeria	10	10	10	10	10
	Egypt	1132	1380	1640	1643	1890
	Morocco	1225	1435	1471	1558	1858
	Tunisia	245	245	245	245	245
CENTRAL AFRICA	Chad	1	1	1	1	1
SOUTHERN	South Africa	2094	2516	2495	3163	3442

FIVE REGIONS	NATION	2019	2020	2021	2022	2023
AFRICA	Namibia	5	5	5	5	5
	Mauritius	11	11	11	11	11
WESTERN AFRICA	Cape Verde	27	27	27	27	27
	Senegal	55	159	159	159	159
	The Gambia	1	1	1	1	1
	Mauritania	34	34	34	34	34
EASTERN AFRICA	Eritrea	1	1	1	1	1
	Ethiopia	324	324	324	404	324
	Kenya	336	336	436	436	436
	Réunion	17	17	17	15	15
	Somalia	4	4	4	4	4
	Seychelles	6	6	6	6	6
	Djibouti	0	0	20	20	80
	Tanzania	0	2	2	2	2
TOTAL FOR AFRICA		5528	6514	6909	7745	8654

Table 3.5 Installed Capacity of Photovoltaic Power Generation in African Countries

Unit： MW

FIVE REGIONS	NATION	2019	2020	2021	2022	2023
NORTHERN AFRICA	Algeria	341	341	341	426	426
	Egypt	1627	1623	1643	1704	1836
	Morocco	194	234	314	314	394
	Libya	5	5	6	6	8
	South Sudan	1	1	1	15	28
	Sudan	80	117	136	190	190
	Tunisia	80	95	95	197	506
CENTRAL AFRICA	Cameroon	14	14	14	14	50
	Democratic Republic of the Congo	22	22	22	25	25
	Republic of the Congo	0	1	1	1	1
	Gabon	0	0	1	1	1
	Central African Republic	0	0	0	0	25
	Chad	1	1	1	2	2
SOUTHERN AFRICA	South Africa	4408	5494	5816	5826	5664
	Angola	1	1	1	285	310
	Botswana	6	6	6	6	6
	Zimbabwe	12	14	28	41	41
	Madagascar	33	33	33	59	59
	Malawi	80	80	140	181	181
	Mayotte	17	19	30	30	31
	Mauritius	99	108	110	108	108
	Mozambique	41	42	42	83	83
	Namibia	151	151	151	176	176
	Eswatini	1	1	11	11	11
	Zambia	89	89	89	89	124
	Lesotho	0	0	1	1	29

FIVE REGIONS	NATION	2019	2020	2021	2022	2023
WESTERN AFRICA	Benin	3	3	3	28	28
	Burkina Faso	55	56	57	87	177
	Côte d’Ivoire	4	6	8	9	46
	Togo	5	7	57	57	57
	Cape Verde	14	15	17	23	26
	Guinea	14	15	15	16	16
	Guinea-Bissau	1	1	1	1	1
	The Gambia	2	2	2	2	2
	Ghana	83	108	165	169	169
	Liberia	3	3	3	3	3
	Mali	11	62	93	97	97
	Mauritania	88	88	88	89	123
	Niger	27	27	27	62	92
	Nigeria	37	53	73	102	112
	Senegal	173	173	240	263	263
	Sierra Leone	4	4	4	9	9
EASTERN AFRICA	Burundi	2	2	9	9	9
	Eritrea	26	26	25	25	25
	Ethiopia	12	20	21	21	21
	Kenya	126	146	216	318	358
	Réunion	199	207	224	234	239
	Rwanda	25	25	25	25	25
	Seychelles	4	7	13	14	14
	Somalia	7	16	24	47	51
	Tanzania	16	16	16	16	16
	Uganda	78	88	90	95	95
	Comoros	1	1	0	4	4
TOTAL FOR AFRICA		8327	9671	10550	11617	12394

Table 3.6 Installed Capacity of Solar Thermal Power Generation in African Countries

Unit：MW

NATION	2019	2020	2021	2022	2023
ALGERIA	25	25	25	25	25
EGYPT	20	20	20	20	20
MOROCCO	540	540	540	540	540
SOUTH AFRICA	500	400	500	500	500
TOTAL FOR AFRICA	1085	1085	1085	1085	1085

Table 3.7 Installed Capacity of Biomass Power Generation in African Countries

Unit：MW

Five Regions	Nation	2019	2020	2021	2022	2023
Northern Africa	Egypt	79	79	123	123	131
	Morocco	7	7	7	7	7
	Sudan	199	199	199	199	199

Central Africa	Gabon	1	1	1	1	1
	Democratic Republic of the Congo	3	3	3	3	3
	Republic of the Congo	12	12	12	12	12
	Chad	2	2	2	2	2
Southern Africa	South Africa	265	265	265	265	265
	Angola	51	51	51	51	51
	Zimbabwe	100	100	100	100	100
	Malawi	19	19	19	19	19
	Mozambique	75	75	75	75	75
	Eswatini	106	106	106	106	106
	Zambia	43	43	43	43	43
	Mauritius	91	91	91	91	91
Western Africa	Burkina Faso	1	1	1	1	1
	Mali	41	41	41	41	41
	Nigeria	9	13	21	21	21
	Ghana	8	8	8	8	8
	Senegal	25	25	25	25	25
	Sierra Leone	34	34	34	34	34
Eastern Africa	Burundi	4	4	4	4	4
	Tanzania	70	70	70	70	70
	Uganda	96	96	96	96	96
	Rwanda	1	1	1	1	1
	Ethiopia	290	290	335	335	310
	Kenya	88	99	99	99	99
	Réunion	87	87	87	86	86
Total for Africa		1807	1821	1919	1918	1901

Table 3.8 Installed Capacity of Geothermal Power Generation in African Countries

Unit： MW

NATION	2019	2020	2021	2022	2023
ETHIOPIA	7	7	7	7	7
KENYA	684	863	863	949	984
TOTAL FOR AFRICA	691	870	870	956	991

3.1.2 Current Status of the Power Grid

The overall development of Africa's power grid remains underdeveloped, with insufficient transmission infrastructure being a major factor contributing to inadequate electricity supply in Sub-Saharan Africa. Currently, only about one-sixth of African countries have a national grid coverage rate exceeding 30%, while many countries have coverage rates below 10%. Additionally, approximately 600 million people in Sub-Saharan Africa lack access to electricity[8]. Among rural African populations, only about 5% have access to electricity services. This is primarily due to the sparse distribution of settlements, low levels of economic activity, significant distances from existing grid networks, and low population density. The current status of Africa's power grid is illustrated in Figure 3.2.

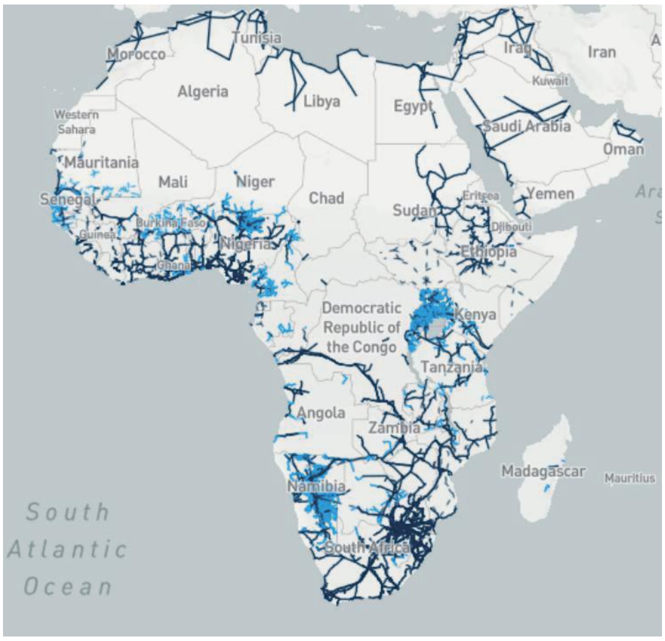

Figure 3.2 Current Status Map of the Power Grid in Africa

Africa currently has five power interconnections (also known as power pools), namely the Eastern Africa Power Pool (EAPP), the North Africa Power Pool (also known as the Maghreb Electricity Committee or COMELEC), the Central Africa Power Pool (CAPP), the West Africa Power Pool (WAPP), and the Southern Africa Power Pool (SAPP), covering 49 African countries, excluding Somalia, Eritrea, South Sudan, Mauritius, and Comoros[9]. The Eastern Africa Power Pool was established in 2005 and covers 27 African countries. The Maghreb Electricity Committee, established in 2000, is the only African power pool interconnected with power systems on other continents. The Central Africa Power Pool, founded in 2003, covers 15 African countries. The West Africa Power Pool, established in 2000, spans 14 countries. West African nations generally have relatively sufficient electricity generation capacity, enabling them to undertake large-scale cross-national infrastructure projects such as the Fomi Hydropower Plant and the Souapiti Hydropower Plant. The Southern Africa Power Pool was founded in 1995. The distribution of Africa’s five power pools is shown in Figure 3.3.

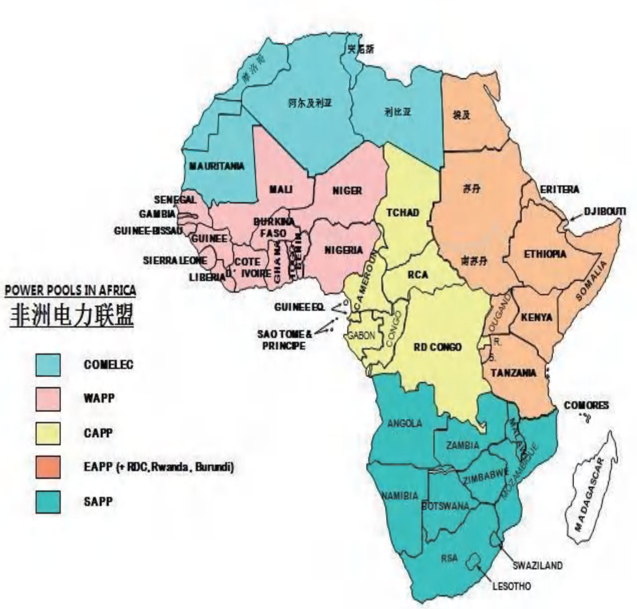

Figure 3.3 Diagram of the Five Major Power Pools in Africa

Power transmission lines have been constructed or are being planned for electricity exchange both between member countries within each power pool and among the various power pools. Additionally, island nations such as Mauritius, Madagascar, and Cape Verde operate independent power grids. Currently, Africa's power pool organizations mainly undertake two key tasks: first, coordinating the transfer of surplus electricity from electricity-rich countries to electricity-deficit countries to achieve the rational allocation of regional power resources; and second, pooling regional human, material, and power resources to support the construction of key energy infrastructure projects within the region.

According to a World Bank report[10], Africa's population is expected to reach nearly 2.4 billion by 2050, leading to a rapid increase in electricity demand and an urgent need to address power supply challenges. At present, Africa's major power pool organizations primarily rely on clean energy sources such as hydropower, wind power, and photovoltaics for electricity generation. These efforts not only support Africa's green development but also facilitate the rational utilization of power resources across regions. In terms of clean energy access and promotion, African countries have a latecomer advantage. In the future, Africa should leverage power pool organizations to strengthen regional cooperation in power and energy, build consensus, and balance short-term market growth with long-term development strategies. By rationally allocating resources, Africa can benefit the entire continent.

Case 3.1: Ethiopia–Kenya High-Voltage Transmission Line

To make better use of regional electricity resources, in May 2006, the governments of Ethiopia and Kenya signed a Memorandum of Understanding to construct the Ethiopia - Kenya high-voltage transmission line. Known as the "East Africa Power Highway," this project is the first cross-border direct current (DC) transmission interconnection on the African continent and serves as the backbone of the Eastern Africa Power Interconnection Plan.

In November 2022, the Ethiopia - Kenya ±500 kV DC transmission project, implemented by the China Electric Power Equipment and Technology Co., Ltd., a subsidiary of the State Grid Corporation of China, entered the trial operation phase. Upon completion, the project will not only enable more efficient development and utilization of electricity resources within both countries and alleviate power shortages, but it will also achieve coordinated development of Eastern Africa's power infrastructure and grid interconnection. Furthermore, it will lay the foundation for the future vertical integration of the North Africa and Southern Africa power grids.

Case 3.2: Guinea's Souapiti Hydropower Station

Among the 14 member countries of the West Africa Power Pool, Guinea was historically a power-deficient country, relying on electricity imports from neighboring nations. Despite its electricity shortages, Guinea possesses abundant energy reserves. Due to its equatorial rainy climate, the country receives an average annual rainfall of 150 inches, earning it the nickname "Water Tower of West Africa." Guinea's hydropower potential is estimated to exceed 6,000 megawatts.

To address the power shortages in Guinea and neighboring countries, construction of the Souapiti Hydropower Project officially commenced in April 2016. Undertaken by the Third Bureau of the Power Construction Corporation of China, this project represents the largest investment under bilateral economic and trade cooperation between China and Guinea. It is also the largest hydropower infrastructure project in terms of dam height, reservoir capacity, and installed capacity in Guinea and the wider West Africa region. The project is a key initiative under China's Belt and Road Initiative and is often referred to as Guinea's "Three Gorges Project."

In November 2021, the first generating unit successfully began operation. As of now, the Souapiti Hydropower Station has produced a cumulative power output of approximately 1.908 billion kilowatt-hours, generating direct economic benefits of 175 million yuan. The project has not only driven Guinea's economic development but has also allowed the country to export surplus electricity to neighboring nations, including Senegal, Guinea-Bissau, Sierra Leone, Liberia, and Mali. This marks Guinea's transformation into a power-exporting country within West Africa.

In 2023, the project was awarded China's prestigious "Luban Award for Construction Engineering" (Overseas Projects).

Case 3.3: Morocco–Spain Power Interconnection Project

In August 1997, the first Morocco–Spain power interconnection project was officially put into operation, achieving interconnection between the African and European power grids. The project has an annual transmission capacity of 250 million kilowatt-hours, equivalent to the annual output of a 300 MW thermal power plant, accounting for 20% of Morocco's annual electricity production capacity.

To further expand the energy exchange market, a second submarine cable between the two countries was commissioned in the summer of 2016. A third cable is currently under construction and is expected to be operational before 2026.

3.1.3 Current Status of Electricity Consumption

The level of electricity development in Africa is relatively low, and inadequate power supply has become a key constraint to its economic development. African countries have the lowest per capita electricity consumption in the world. Significant issues include insufficient electricity generation, misalignment between electrification development and population growth, frequent interruptions in power supply services, low levels of renewable energy development, and severe underinvestment in the power sector.

(1)Electricity System Status

Currently, Africa's power industry is primarily concentrated in Southern Africa and Northern Africa, particularly in Egypt, Libya, Algeria, and Morocco. Together, these regions account for over three-quarters of Africa's total electricity generation, with thermal power being the dominant energy source. In most other countries, the power industry mainly relies on small to medium-sized hydropower plants, with small-scale power grids. Africa's overall annual per capita electricity consumption is less than 550 kilowatt-hours, and in many countries, it is less than 100 kilowatt-hours per year. Among Africa's 54 countries, only a few—such as South Africa, Egypt, Tunisia, Libya, Algeria, Morocco, Mauritius, Ghana, and Côte d'Ivoire—have relatively high levels of electrification. The continent's overall power system is in urgent need of development.

(2)Electricity Accessibility

According to data from the International Energy Agency (IEA)[11], approximately 600 million people across the African continent, accounting for 43% of the total population, lacked access to electricity in 2022. Most of these populations reside in Sub-Saharan African countries, with the highest concentrations of people without electricity found in the Democratic Republic of Congo (DRC), Ethiopia, Nigeria, Tanzania, and Uganda. The trend in Africa's population without electricity is illustrated in Figure 3.4.

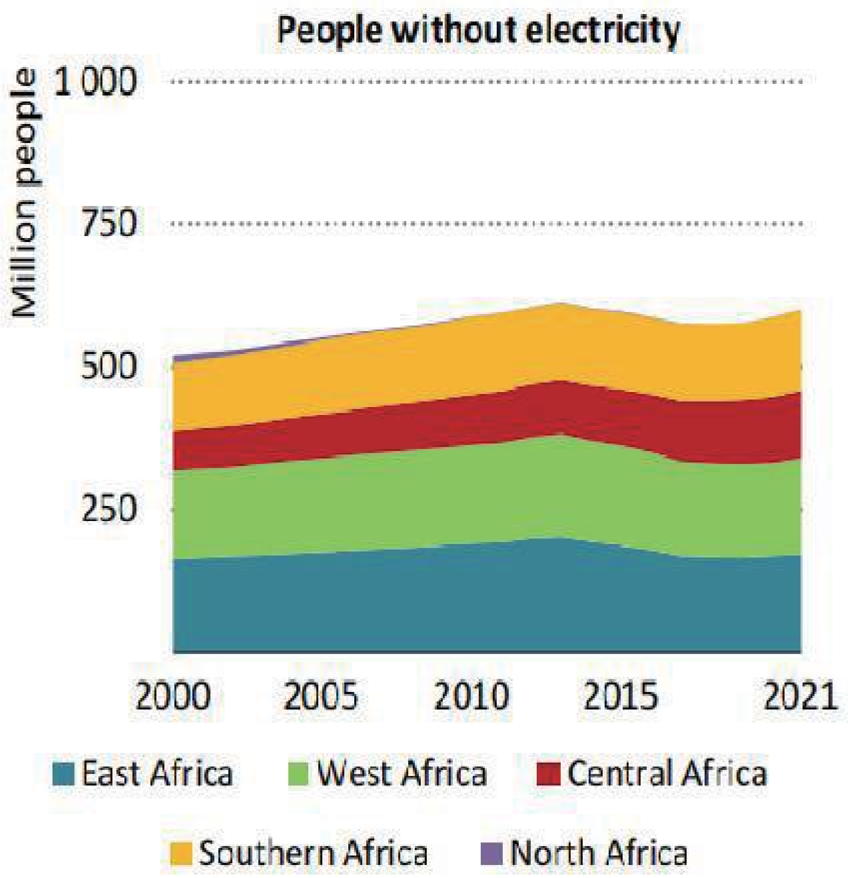

Figure 3.4 Trend of Population Without Access to Electricity in Africa

(3)Electricity Consumption

Currently, Africa's annual per capita electricity consumption is approximately 550 kilowatt-hours. In comparison, the global average annual per capita electricity consumption is about 3,300 kilowatt-hours, while China's is approximately 5,364 kilowatt-hours, and the United States' is about 10,984 kilowatt-hours. This indicates that Africa's overall electricity consumption remains at a very low level9. Additionally, most African countries face severe power shortages, making it difficult to meet the electricity demands of socioeconomic development. Transmission and distribution networks in many areas suffer from varying degrees of outdated and aging infrastructure, resulting in high transmission and distribution losses. Frequent electricity theft further exacerbates these issues, causing electricity prices in Africa to remain high for extended periods. Residential electricity prices in Africa are generally 2 to 4 times higher than China's current electricity pricing standards, which poses a significant obstacle to local economic development.

Africa’s energy transition faces the dual challenge of improving electricity accessibility and achieving energy transformation. Difficulties in accessing electricity have become one of the most pressing issues for African governments to address. Rapid urbanization, combined with population and economic growth, has created higher demands for electricity generation capacity and transmission and distribution infrastructure. Moreover, the increasing need for power supply to support infrastructure construction and industrialization processes is further driving the demand for electricity. In the future, the capacity of Africa’s electricity market to absorb and utilize power is expected to increase year by year.

3.2 Trends in the Development of the Electricity Market

Recently, IRENA released a report on the current status of Africa’s electricity systems and renewable energy development[12]. The report outlines three scenarios for renewable energy development in Africa: the Current Development Scenario, the Positive Development Scenario, and the Leapfrog Development Scenario. These scenarios provide planning and predictive analysis for the continent’s renewable energy development, with the forecast results summarized in Table 3.9.

Table 3.9 Demand for Renewable Energy Development in Africa

DEVELOPMENT SCENARIO	SCENARIO ASSUMPTION	ITEM	UNIT	2025	2030	2050
CURRENT DEVELOPMENT SCENARIO	Estimating future growth rates based on current data	Proportion of Renewable Energy	%	25	30	45
		Total Installed Capacity of Renewable Energy	GW	79.2	127.7	289.6
		Newly Installed Capacity of Renewable Energy	GW	25.5	74	171
		Additional Renewable Energy Generation	TWh	48.8	155.4	316
POSITIVE DEVELOPMENT SCENARIO	Impact of favorable policies	Proportion of Renewable Energy	%	30	35	50
		Total Installed Capacity of Renewable Energy	GW	95.1	148.9	321.8
		Newly Installed Capacity of Renewable Energy	GW	41.4	95.2	202.8
		Additional Renewable Energy Generation	TWh	58.5	181.3	375
LEAPFROG DEVELOPMENT SCENARIO	Active development by African countries, with significant increase in proportion	Proportion of Renewable Energy	%	35	40	55
		Total Installed Capacity of Renewable Energy	GW	110.9	170.2	353.9
		Newly Installed Capacity of Renewable Energy	GW	57.2	116.5	235.1
		Additional Renewable Energy Generation	TWh	68.2	207.2	435

(1)Current Development Scenario

Under the Current Development Scenario, projections are based on the proportion of renewable energy installed capacity and generation within the region’s total capacity and generation, as well as the current growth rate of renewable energy installations. By 2025, Africa’s total installed renewable energy capacity is expected to reach 79.2 gigawatts, including 25.5 gigawatts of newly added renewable energy capacity. By 2030, total installed capacity is projected to grow to 127.7 gigawatts, with 74 gigawatts of new capacity added. By 2050, the total installed renewable energy capacity is expected to reach 289.6 gigawatts, with 171 gigawatts of new capacity added.

(2)Positive Development Scenario

Under the Positive Development Scenario, projections assume that the region implements additional favorable policies to encourage renewable energy development. These assumptions are based on related energy policy studies and forecasts by the IEA and IRENA. By 2025, Africa’s total installed renewable energy capacity is expected to reach 95.1 gigawatts, including 41.4 gigawatts of newly added capacity. By 2030, total installed capacity is projected to grow to 148.9 gigawatts, with 95.2 gigawatts of new capacity added. By 2050, the total installed renewable energy capacity is expected to reach 321.8 gigawatts, with 202.8 gigawatts of new capacity added.

(3)Leapfrog Development Scenario

Under the Leapfrog Development Scenario, projections are based on the nationally determined contributions (NDCs) set by various countries for autonomous emission reductions. The focus is on promoting sustainable development by aggressively developing renewable energy and increasing the share of renewable energy in total final energy consumption. These projections consider a steady increase in development speed based on current levels and aim to increase the share of renewable energy in installed capacity and electricity generation. By 2025, Africa’s total installed renewable energy capacity is expected to reach 110.9 gigawatts, including 57.2 gigawatts of newly added capacity. By 2030, total installed capacity is projected to grow to 170.2 gigawatts, with 116.5 gigawatts of new capacity added. By 2050, the total installed renewable energy capacity is expected to reach 353.9 gigawatts, with 235.1 gigawatts of new capacity added.

3.3 Opportunities for Chinese Renewable Energy Investment and Its Impact on Africa

Over the past decade, China has become a significant investor in African renewable energy projects. Africa is endowed with abundant solar, wind, and hydropower resources, offering immense potential for renewable energy development. At the same time, most African countries face severe energy shortages and are heavily reliant on fossil fuel-based power generation. This combination of energy demand and resource endowment makes the continent an exceptionally attractive destination for renewable energy investment from China. Chinese investments in Africa’s renewable energy sector are currently experiencing rapid growth, a trend expected to continue in the coming years. With the increasing global demand for low-carbon economic transitions and Africa’s growing energy needs, Chinese renewable energy companies are poised to play an increasingly significant role in the continent’s energy development. This cooperation not only strongly supports Africa’s sustainable development efforts but also enables China to better implement its strategic positioning in the global energy market. Furthermore, it accelerates China’s progress toward achieving its green development goals.

4

China-Africa Cooperation in the Renewable Energy

Chapter 4 China-Africa Cooperation in the Renewable Energy

4.1 History of China-Africa Energy Cooperation

China and Africa have enjoyed a long history in energy and power cooperation, going through 4 phases, i.e. foreign aid, oil & gas, EPC in the power sector, and clean energy.

Phase One (Foreign Aid): Since 1950s, China has provided aid to several African countries in the power sector, including Tanzania, Ethiopia, Sudan, and Nigeria, among others, covering all stages of power generation, transmission, distribution, and consumption. Entering the new century, China encouraged various enterprises to implement the strategy of “going global”.

Phase Two (Oil & Gas): From 1995 to 2004, Chinese oil companies, led by China National Petroleum Corporation (CNPC), made large-scale investments and engaged in construction and operations in oil and gas projects in northern African countries such as Sudan (including present-day South Sudan) and Algeria. From 2005 to 2010, China’s three major state-owned oil companies, i.e. Sinopec, CNOOC, and CNPC, achieved multiple breakthroughs in West Africa. From 2010 to 2015, world-class natural gas fields were discovered in Mozambique, Southern Africa, and in Tanzania, Eastern Africa by ENI (Italy’s national oil company) and Anadarko Petroleum (an independent USA oil company). In March 2013, CNPC spent USD4.2 billion to acquire a 20% stake in key blocks operated by ENI.

Phase Three (EPC in the Power Sector): China’s engagement in Africa’s infrastructure dated back to its foreign aid efforts before the reform and opening-up. In 2013, President Xi Jinping unveiled the Belt and Road Initiative (BRI), marking the beginning of a new era of comprehensive cooperation in the energy sector between China and Africa.

Phase Four (Clean Energy): In December 2015, at the Forum on China-Africa Cooperation (FOCAC) held in Johannesburg, South Africa, President Xi announced 10 major China-Africa cooperation plans for the first time, supporting Africa in implementing 100 clean energy projects and offering USD60 billion of funding to put these plans into practice. According to preliminary statistics, since the launch of these plans, completed and on-going projects in Africa carried out by Chinese companies would facilitate nearly 20,000 MW of power generation capacity and more than 30,000 kilometers of transmission and transformation lines.

In 2018, China raised to strengthen practical cooperation in the energy sector with African countries under the China-AU Energy Partnership, to jointly improve Africa’s electrification level, increase the share of clean energy, gradually address the issue of energy accessibility, and promote sustainable energy development for both sides. Following the MOUs and other related documents of the Energy Partnership, China will dispatch a technical team to the AU as soon as possible to continue boosting policy dialogues, technical exchanges and development strategies in the energy sector, carrying out joint research. China will also support African countries in developing specialized planning in water resources and integrated watershed management.

In September 2018, the Beijing Summit of FOCAC proposed that China will work with Africa to achieve the shared goal of building a closer China-Africa community with a shared future, launching eight major initiatives in close collaboration with African countries, in which the “infrastructure connectivity initiative” highlighted the focus on enhancing cooperation in the energy sector. In 2019, the Belt and Road Energy Partnership (BREP) was established during the second Belt and Road Forum for International Cooperation (BRF). As of now, such multilateral mechanism has hosted 33 members, including several African nations such as Algeria, Chad, Equatorial Guinea, Niger, the Republic of Congo, Sudan, Cape Verde, and Gambia.

In November 2021, at the Eighth Ministerial Conference of the FOCAC, with the China-Africa Cooperation Vision 2035 prepared, President Xi Jinping proposed that China would work closely with African countries to implement nine programs. The conference adopted the Forum on China-Africa Cooperation Dakar Action Plan (2022–2024) and the Declaration on China-Africa Cooperation on Combating Climate Change. China will work with African countries to advocate for green and low-carbon principles, with efforts made in developing photovoltaic, wind and other renewable energies. In assisting Africa in green and climate change mitigation projects, China will work with Africa to build low-carbon demonstration zones and climate adaptation demonstration zones, providing feasible support in technology and capacity building. China will also support Africa in increasing the use of hydropower, nuclear energy and other clean energy sources. Based on the development level and energy needs of each country, China will actively promote the development of renewable energy, provide stable and affordable electricity to remote regions in Africa through distributed power supply technologies, and support the growth of the photovoltaic industry.

In August 2023, the Joint Statement: China-Africa Leaders' Roundtable Dialogue emphasized that both sides will continue to synergize China-Africa high quality Belt and Road cooperation with AU's Agenda 2063 and the national development strategies of African countries, to elevate China-Africa cooperation to higher levels. During the Third BRF, the Ministry of Commerce of China signed the Framework Agreement on Promoting Investment Cooperation in Green Energy Power with the Ministry for Electricity of the Government of South Africa. China and Africa jointly launched the BRI Green Talent Program and the "Africa Solar Belt" Program of South-South Cooperation on Climate Change.

On September 4 to 6, 2024, at the Beijing Summit of the FOCAC, President Xi Jinping delivered a keynote speech themed Joining Hands to Advance Modernization and Build a Community with a Shared Future. He pointed out that China is ready to help Africa build "green growth engines," narrow the gap in energy accessibility, adhere to the principle of common but differentiated responsibilities, and jointly push for the global transition to green and low-carbon development. China is ready to launch 30 clean energy projects in Africa. To implement the ten partnership actions, the Chinese government will provide RMB360 billion yuan of financial support through the next three years.

The history of China-Africa cooperation in the energy sector demonstrates that China and Africa have formed a community with a shared future and share a common stake and interests for win-win cooperation. China has long been committed to helping Africa address challenges in power development and supply, establishing cooperative platforms and channels at governmental and corporate levels, which substantially upgraded Africa's economic growth and people's living standards. Currently, China and African countries are engaging in extensive and in-depth collaboration in the energy and electricity sectors, with projects spanning various areas, including hydropower, thermal, wind, photovoltaic, geothermal, and nuclear, as well as grid construction and modernization (see Table 4.1). The success of these projects has not only generated benefits for Chinese enterprises, but has also largely geared up the economic and social development of African countries, ultimately improving the well-being of their people.

Table 4.1 China-Africa Cooperation in the Renewable Energy: Mechanism

Year	Name	Contents
2015	The Johannesburg Summit of the FOCAC	Rolling out 10 major plans to boost cooperation with Africa in the coming three years, China will offer USD60 billion of funding support. The Chinese government released its second Afica policy paper, proposing to innovate on the models of energy cooperation with Africa, in the principles of "green and renewable development." Renewable energy development and cooperation was formally listed as the priority agenda for China's Africa policy.
2017	The China-Africa Renewable Energy Cooperation and Innovation Alliance (CARECIA)	China and Africa signed a MoU, agreeing to enhance Africa's renewable energy generation capacity through bilateral cooperation. Smart grid experts and renewable energy equipment manufacturers from China will provide technological and financial support needed.

2018	The Beijing Summit of the FOCAC	China and Africa will jointly implement eight major initiatives, namely, industrial promotion, infrastructure connectivity, trade facilitation, green development, capacity building, health care, people-to-people exchange, and peace and security.
2020	The Cooperation Plan on Jointly Promoting the Belt and Road between the Government of the People's Republic of China and the African Union	The Plan will promote an effective synergy between the BRI and the AU's Agenda 2063, chartering a new course for China-Africa cooperation in promoting BRI's high-quality development.
2021	The 8th Ministerial Conference of the FOCAC	China will work closely with African countries to implement nine programs, in which, the green development program will undertake 10 green development, environmental protection and climate action projects for Africa, support the development of the "Great Green Wall", and build in Africa centers of excellence on low-carbon development and climate change adaptation.
2021	The China-Africa Cooperation Vision 2035	Setting up mid- and long-term direction and goals for future cooperation, to construct a closer China-Africa community with a shared future.
2021	The Declaration on China-Africa Cooperation on Combating Climate Change	Establish a China-Africa partnership of strategic cooperation of the new era for the fight against climate change, starting a new chapter for advancing green and low-carbon development between the two sides.
2024	The Beijing Summit of the FOCAC	China is ready to release the Joint Statement on Deepening Cooperation within the Framework of the Global Development Initiative with Africa, to joinly build up the network for the Global Development Promotion Center (GDPC), and implement 1,000 "small and beautiful" livelihood projects.

4.2 Trend of Chinese Investments

China is the largest public financier in Africa's clean energy sector. According to the International Renewable Energy Agency (IRENA), between 2010 and 2019, Africa's clean energy sector (including project development, planning, and technology transfer) received a total of USD64.7 billion in public funding, with China, the largest contributor, offering 51%. Such substantial investment has ensured the successful implementation of various clean energy projects across Africa, addressing the pressing funding needs faced by many countries. A report jointly published by the African Climate Foundation, the Natural Resources Defense Council, and Boston University's Global Development Policy Center shows that since 2000, China has provided over USD13 billion in funding to Africa and developed more than 10 gigawatts of clean energy capacity. Between 2010 and 2020, Africa's renewable energy utilization grew at an average annual rate of 26%, with solar, hydro, and wind power ranking as the top three.

(1) Policy-driven

In 2021, China pledged not to build new coal-fired power projects abroad and step up support for other developing countries in developing green and low-carbon energy. By 2030, China aims to establish a landscape for BRI's green development, which will directly accelerate the transition of China's overseas energy investments towards low-carbon solutions, potentially providing more public funding for clean energy development in developing countries, including those in Africa. Overseas investment in renewable energy has become a focal point for Chinese international engineering investors, contractors, and equipment manufacturers. In recent years, relevant Chinese authorities have issued policies, such as the Action Plan for Carbon Dioxide Peaking Before 2030, the Green Development Guidelines for Overseas Investment and Cooperation, and the Belt and Road Green Energy Cooperation Qingdao Initiative, further clarifying key directions for promoting BRI's green development. China aims to play a significant role in global climate governance and will accelerate BRI cooperation in areas such as green energy and green finance.

(2) Market Scale

China's investment in Africa's renewable energy sector has been growing increasingly, covering a broader range, particularly in countries rich in resources, such as Ethiopia, Kenya, and South Africa. According to IRENA statistics, between 2000 and 2009, China's average annual investment in Africa's renewable energy sector was less than USD500 million. However, for the next decade from 2010 to 2020, this figure increased tenfold to approximately USD5 billion annually. Forms of investments are diversifying. While solar and wind projects dominate China's investments in Africa's renewable energy, hydropower and geothermal and other forms of projects are also on the rise. Not only evolved in energy production, Chinese companies also invested in building infrastructure, including the construction and upgrading of power grid.

(3) Technological Progress

Not limited to capital injection, the trend of investments also closely links to technology transfer and capacity building. In recent years, China has made remarkable progress in renewable energy technologies (especially in solar and wind). Chinese companies are world leaders in manufacturing solar panels and wind turbines, with competitive advantages in cost control and large-scale production. Exporting these technologies not only facilitates better expansion of international markets for Chinese enterprises, but also establishes greener and more economic energy systems for African countries. Moreover, China's innovations in battery storage and smart grid solutions provide effective means for addressing grid instability and insufficient electricity coverage in Africa.

(4) Cooperation Fields

China has been extending its investments in Africa's renewable energy sector, from traditional areas such as hydropower, photovoltaics, and wind power, to cutting-edge technologies like hydrogen and smart grid. With numerous solar plants and wind farms built in Africa, Chinese companies now actively participate in developing hydrogen projects and constructing smart grid, which is favorable for the reliability and stability of Africa's energy supply and the optimization and upgrading of the continent's energy structure.

(5) Cooperative Models

Featuring diversification in renewable energy investments, Chinese enterprises are continuously carring out innovative cooperation models. On the one hand, through EPC (Engineering, Procurement, and Construction) contracts, they offered turnkey energy solutions to African countries; on the other, they established partnerships with local African enterprises and financial institutions to jointly invest in and operate renewable energy projects. These models not only help share risks and resources but also leverage each party's strengths, enhancing project success rates and efficiency. By offering project financing and technical support, Chinese companies often build long-term partnerships with African countries, contributing to China's greater influence in global energy governance.

4.3 Impacts on Africa's Energy Structure

Chinese investments have significantly transformed Africa's energy landscape, enabling many countries to transition to renewable energy. Since 2000, China has financed and developed about one-third of the new grid-connected renewable energy capacity in Sub-Saharan Africa. At present, the main areas of China-Africa renewable energy cooperation are hydropower, solar power, and wind power, with project investment and EPC contracts being the primary models. Chinese companies have also engaged in renewable energy projects in Africa through greenfield investments. Sourced from a database of international investments, as of March 2022, Chinese companies had invested in 15 renewable energy projects in Africa through greenfield investments, totaling about USD4.5 billion, which were mainly concentrated in countries like Zambia, Egypt, Ghana, Morocco, and South Africa.

However, the energy transition across African countries remains uneven. Projects carried out by Chinese enterprises mainly targeted at key countries such as South Africa, expanding EPC business by leveraging the foundation established through other collaborative projects. Meanwhile, Africa's renewable energy industry faces both challenges and opportunities in areas such as investment and financing, policy, regulatory and institutional framework, and technical capacity. It is particularly noteworthy that most African countries have relatively limited fiscal resources, making it essential to carefully consider financing channels and ensure adequate capital during collaboration. Given the diverse and varied economic and social landscapes across Africa, renewable energy investments should emphasize leveraging non-institutional factors and adapt to the unique contexts of each country.

(1) China-Africa Cooperation in Hydropower

Hydropower, an abundant resource found in Africa, dominates the energy consumption in many African countries. For example, 90% of electricity consumption relies on hydropower in eight countries, while more than 50% in 22.

Enjoying advanced technology in the sector, China's initial renewable energy investments in Africa were hydropower projects, making it the primary source of public investment in Africa's renewable energy sector, including hydropower. Between 2010 and 2019, China invested around USD19 billion in over 20 African hydropower projects, including the Akosombo Dam in Ghana, the Karuma Hydropower Plant in Uganda, and the Bui Dam in Ghana, accounting for about 38% of the total public investment in Africa's renewable energy sector.

(2) China-Africa Cooperation in Solar Power

Africa's PV industry is rapidly advancing, with countries like South Africa, Morocco, and Egypt taking the lead. The Garissa Solar Power Plant in Kenya, constructed by China Jiangxi International Economic and Technical Cooperation Co., Ltd. (CJIC), has an installed capacity of 50 megawatts, making it the largest PV power station in East Africa to date. The project was funded by a concessional loan of 13 billion Kenyan shillings (approximately 860 million RMB) from the Export-Import Bank of China. It was the first power generation project in Kenya supported by a Chinese concessional loan. Upon completion, it will be the largest grid-connected PV power station in Kenya and one of the largest in Africa, with an annual power output of 87.54 million kilowatt-hours. The plant can meet the electricity needs of 70,000 households, benefiting over 380,000 people, and will supply power to half the population of Garissa County, the capital of Kenya's North Eastern Province.

(3) China-Africa Cooperation in Wind Power

Africa's abundant wind energy resources are primarily due to its extensive coastline. The five countries with the greatest wind energy potential are Egypt, Morocco, Kenya, Ethiopia, and South Africa. According to the United Nations Commodity Trade Statistics Database (UN Comtrade), in 2020, China exported wind turbines to 19 African countries, totaling USD98.44 million, which accounted for 8.87% of China's total wind turbine exports. The main export destinations were South Africa and Ethiopia. Wind turbine exports to South Africa amounted to USD53.9 million, representing 54.75% of China's total wind turbine exports to Africa; exports to Ethiopia totaled USD44.4 million, for 45.14%.

The De Aar Wind Energy Facility is a flagship project of win-win cooperation between South Africa and China in the renewable energy sector. Completed and put into operation in 2017 by Longyuan South Africa, a wholly-owned subsidiary of CHN Energy, the project was China's first wind power project in Africa that integrates investment, construction, and operation. With an installed capacity of 244,500 kW, the project provides approximately 760 million kWh of clean and stable electricity annually. Such an output is equivalent to saving 215,800 tons of standard coal and reducing carbon dioxide emissions by 619,900 tons. The project supplies power to around 300,000 households, effectively optimizing the local energy structure and promoting clean and low-carbon development.

Case 4.1: Adama Wind Farm, Ethiopia

The Adama Wind Farm is Ethiopia's first wind power project and also China's first wind power project to fully export its technology, standards, management, and equipment. It was contracted by China Hydropower Engineering Consulting Group Corporation (HYDROCHINA), with 85% of the financing provided by the EXIM Bank of China, and wind turbine equipment supplied by Xinjiang Goldwind Science & Technology Co. Ltd. (Goldwind). The project involved the construction of the 53-megawatt Adama I Wind Farm. Sany Group has chosen Ethiopia as its wind power base in Africa and has invested in the construction of a wind farm with a capacity of 120 megawatts. It plans to conduct talent training programs in Ethiopia to cultivate local engineering technicians in the renewable energy sector, ensuring a connection with the group's production capacity in the country.

5

Challenges to the Investments in Africa's Renewable Energy

Chapter 5 Challenges to the Investments in Africa's Renewable Energy

Abundant, clean, renewable and sustainable, renewable energy enjoys superior position in Africa. Better utilization of renewable energy enables less reliance on fossil fuels, higher level of energy security, and lower carbon emissions to combat climate change. In addition, renewable energy technologies can stimulate economic growth, create jobs, and promote sustainable social development. However, there are limitations to the development of renewable energy in Africa. According to the IEA's annual World Energy Investment report, released during the UN Climate Change Conferences, Africa is expected to receive USD110 billion in energy investments in 2024, but less than 40% of these funds are projected to go toward clean energy.

Challenges in renewable energy investment in Africa are mainly reflected in three areas: technology, policy, and financing.

Technology: African countries face barriers in accessing advanced renewable energy technologies due to high costs, complex import regulations, and intellectual property issues. These factors make it difficult for local industries to adopt new technologies.

Policy: Though, some African countries have introduced policies supporting renewable energy, they often lack consistency and a long-term vision. Insufficient policy enforcement and uncertainty in policy changes also impact investor decisions.

Financing: High initial investment costs, underdeveloped financial markets, and difficulties in accessing international funding limited the financing capacity for renewable energy projects in Africa.

5.1 Technical Barriers

5.1.1 Lack of Infrastructure

In many African countries, aging grid infrastructure, insufficient capacity, and limited coverage hindered the delivery of renewable energy. According to data published by Germany's Statista, as of 2021, electricity coverage has been relatively high in countries of Northern Africa, like Tunisia, reaching 98%. By contrast, the rate in Eastern, Southern, and Western Africa, countries such as Mauritius and South Africa, ranges between 52% and 56%. Meanwhile, in Central African countries like Zimbabwe, less than one-third of the population has access to electricity. An analysis of grid infrastructure across 39 African countries shows that electricity coverage is 35% in rural areas and 86% in urban, with an overall rate of nearly 60%.

Most of Africa's population without electricity lived in remote rural areas. These communities are often impoverished, widely dispersed, and lack reliable transportation infrastructure, posing significant challenges and high economic costs for grid expansion. To address this issue, two key strategies are essential: 1) more investments in grid infrastructure, while adopting smart grid and energy storage technologies, to enhance the stability and reliability of the power supply; and 2) developing renewable energy microgrids or off-grid power generation systems, without relying on the main grid.

5.1.2 Lack of Technological Adaptation

Africa's diverse climate conditions and frequent extreme weather pose severe challenges for the design and operation of renewable energy equipment. Technologies must be adapted to withstand varying climatic conditions. For instance, solar equipment needs to endure high temperatures, high humidity, and sandstorms. However, many current solar devices are not designed in consideration of these extreme conditions, leading to reduced performance, shorter lifespans, and premature failures.

Data from the International Solar Energy Society (ISES) shows, due to Africa's climatic diversity, companies need to conduct specialized design and adaptive testing for solar equipment. Yet, currently, only about 30% of solar equipment manufacturers have adequately tested and adapted their products for African climate conditions.

To address the issue of technological adaptation, African countries need to enhance research and development (R&D) and focus on customized design. By collaborating with international partners, they can conduct studies and tests tailored to Africa's climatic conditions and establish technical standards and specifications suited to local environments. Meanwhile, African countries should encourage and support local enterprises to participate in the manufacturing and customization of solar equipment to meet the diverse energy needs of different regions and climate zones. For instance, solar projects in the Sahara Desert must consider not only the impact of high temperatures on equipment but also the abrasive effects of sandstorms. The Noor Solar Project in Morocco serves as a successful example: it introduced cleaning and cooling technologies to mitigate these challenges, ensuring the efficient operation of solar equipment.

Column 5.1: Types and the Statue-quo of Application of Renewable Energy Technologies in Africa

Solar: Africa enjoys abundant sunlight, providing significant potential for solar power generation. While solar technology has made progress on the continent, challenges remain in certain regions. For example, in some sub-Saharan areas, despite the decreasing cost of solar technology, the initial investment remains high, and grid access is insufficient. Additionally, the durability and performance of solar panels can be affected by the high temperatures and humidity. Customized designs suited to Africa's climate are required.

Wind: Africa, particularly in coastal regions of Eastern and Southern Africa, is home to rich wind resources. However, the application of wind technology faces geographical limitations. Wind resources are often concentrated in remote or topographically challenging areas, increasing the cost and complexity of building transmission lines and wind farms. Moreover, wind power's intermittent nature poses challenges for grid stability, necessitating the development of energy storage systems to mitigate the impact of fluctuations.

Geothermal: The East African Rift Valley is one of the world's most significant geothermal resource areas, with enormous development potential. According to the African Development Bank (AfDB), geothermal resources in this region could meet over 90% of Africa's energy needs. However, geothermal energy is often located deep underground, requiring complex geological exploration and drilling, which raises development costs and risks. It also encounters challenges related to immature technology, environmental protection, and geological safety. Science-based and well-managed development planning is crucial to overcome these obstacles.

Biomass: Africa has abundant biomass resources, including agricultural residues, wood waste, and municipal solid waste. But biomass energy accounts for less than 1% of the continent's energy supply, according to the IEA. This underutilization is primarily due to outdated biomass technologies. Most biomass energy use involves traditional combustion methods, which are inefficient and environmentally harmful. Technological improvements, equipment upgrades, and suitable policies are necessary to enhance energy efficiency, economic viability, and environmental sustainabilitv.

5.1.3 Lack of Technological Maintenance and Local Manufacturing

Remote areas of Africa bore inconvient traffic, which means high costs for equipment maintenance and replacement, and a shortage of skilled personnel. According to IRENA, approximately 70% of renewable energy projects in Africa face issues with delayed maintenance, leading to reduced operational efficiency. On the other side, most renewable energy equipment of Africa came from imports, without the support of local manufacturing and technology, resulting in higher procurement and operational costs, and narrowed application and dissemination of renewable energy across the continent.

To address these challenges, African countries should boost technical training and support for professionals, to improve their capacity in repairing and maintaining renewable energy equipment. More technical training centers are to be established, partnering with international organizations or institutions to facilitate technology transfer and skill development. This will build a local workforce capable of maintaining and operating systems. At the same time, African countries should adopt proper measures for maintenance, which can extend equipment lifespan and reduce costs.

5.2 Policy Barriers

5.2.1 Policy Stability and Constancy

Africa's political landscape is complex, with 54 countries exhibiting diverse political environments. Such diversity presents both opportunities and significant challenges for renewable energy development. For countries like South Africa, Morocco, and Kenya, political stability and well-defined policy frameworks brought them with more investors. Conversely, countries such as Libya, South Sudan, and the Democratic Republic of the Congo face persistent political turmoil, which severely hampers the development of energy infrastructure. Libya, especially, has experienced political fragmentation since the outbreak of civil war in 2011. Energy policies were unable to sustain and deliver positive results, putting up the withdrawal of foreign investments due to security concerns. Between 2004 and 2022, Libya saw no growth in solar power generation, with renewable energy projects remaining stagnant. No substaintial progress was witnessed in solar power generation in Libya during the past years.

Another significant factor affecting renewable energy development in Africa is the lack of consistent and sustained policies. Frequent changes in energy policies increase uncertainty for investors. For instance, Nigeria has undergone numerous policy revisions over the past decade, creating a challenging environment for long-term investment. Despite being the largest economy in Africa, Nigeria did not enjoy a stable political state, which severely influenced its development in renewable energy. In 2018, the Nigerian government reduced direct fiscal support for solar projects to alleviate financial pressures. This abrupt policy shift led to delays or cancellations of several solar initiatives, undermining investor confidence and slowing renewable energy progress.

5.2.2 Policy Execution and Approval

A critical issue affecting the implementation of renewable energy projects in Africa is the difficulty of intergovernmental coordination and bureaucratic inefficiency. Many governments in Africa lack coordination in policy formulation and execution, leading to lengthy and cumbersome approval processes. For instance, developing a geothermal project in Kenya requires approval from various departments, with an average approval time of up to 18 months, which largely stalled off the project progress. Moreover, a lack of communication between departments often results in redundant steps, complicating the process further and raising costs.

Incomplete governance structures and weak accountability mechanisms exacerbate the situation. For example, Ethiopia's Gibe III hydropower project, the largest in the Omo River basin, faced repeated delays due to poor interdepartmental coordination. Additionally, many local governments lack the capacity and resources to implement national policies effectively. This disconnect often leads to complications such as land acquisition disputes and community protests, which further delay projects.

Prohibitvely long approval processes are one of the key elements affecting the implementation of renewable energy projects. In many African countries, such projects need to go through multiple government departments, and the processes and requirements of each department are different, which increases the time and cost of project approval. In addition, in terms of project financing, the terms and conditions for accessing prefeasibility facilities are not standardized across the seven development financial institutions (DFIs) in the Southern African Development Community (SADC), not even between the two South Africa DFIs (DBSA and IDC). For instance, to review a wind power project in South Africa, one should go through multiple links such as environmental assessment, land use permits, and grid access, and the average approval time might be over two years. Cumbersome approval procedure not only increased time costs, but also brought more uncertainties.

5.2.3 Challenges of Multinational Cooperation and Regional Integration

Regional cooperation in Africa holds significant potential though, it faces numerous challenges in practice, such as inconsistent policies and standards, and difficulties in coordinating cross-border power grids. While the West African Power Pool (WAPP) and the Eastern African Power Pool (EAPP) have made substantial efforts in promoting regional grid interconnection, progress has been slow. Inconsistent policy standards and conflicts of national interests made cooperation difficult to advance. For example, notable differences were seen between member countries of the WAPP in electricity regulations, standards, and pricing mechanisms, which significantly increased the cost and complexity of cross-border electricity trading. Specifically, some countries (such as Nigeria) are transitioning to market-based pricing mechanisms, cutting down government subsidies step by step, to ensure electricity fees reflect actual generation costs and market supply-demand conditions. However, other countries (such as Mali and Niger) maintain high electricity prices through substantial government subsidies, causing a disconnect between electricity prices and real market costs.

Cross-border cooperation can also face legal and technical obstacles, as significant differences exist between countries in legal frameworks and technical standards related to grid interoperability, data sharing, and management protocols. These discrepancies require complex coordination and technical integration, increasing the difficulty of project implementation. For instance, in harmonizing electricity regulations and standards among member countries, the WAPP faced immense challenges, who had to slow down the progress of cross-border electricity trading and grid interconnection projects. In Western Africa, grid voltage levels and management models vary considerably. For example, Ghana primarily uses 330 kV and 161 kV transmission lines, Nigeria's 330 kV and 132 kV, while Burkina Faso mainly for 225 kV and 90 kV, which did not meet the requirements for cross-border interconnection. Differences were also found in grid stability and fault management capabilities among these countries, affecting the quality and efficiency of cross-border power transmission. As a result, the WAPP has developed a plan for integrating the regional electricity market though, inconsistent policies and technical standards across countries continue to slow project progress. Table 5.1 shows a summary of renewable energy policies of African countries; and for an overview of Africa's regional renewable energy programs and institutions, see Table 5.2.

Table 5.1 Renewable Energy Related Policies in African countries

Region	Country	Regulations & Pricing Mechanism	Tax Incentives	Financial Incentives
Northern Africa	Algeria	√	√	
	Egypt	√	√	√
	Libya		√	
	Morocco	√		
	Sudan			√
Eastern Africa	Burundi		√	√
	Comoros			√
	Djibouti			√
	Eritrea			
	Ethiopia	√	√	√

Region	Country	Regulations & Pricing Mechanism	Tax Incentives	Financial Incentives
	Tunisia	√	√	√
Western Africa	Benin	√	√	
	Burkina Faso	√	√	√
	Cape Verde	√	√	√
	Ivory Coast		√	
	Gambia	√	√	√
	Ghana	√	√	
	Guinea		√	
	Guinea-Bissau	√		
	Liberia		√	
	Mali	√	√	√
	Mauritania			
	Niger	√	√	
	Nigeria	√	√	√
	Senegal	√	√	√
	Sierra Leone	√	√	
	Togo	√	√	
Central Africa	Angola	√		
	Cameroon			√
	Central African Republic			
	Chad		√	
	Republic of the Congo			
	Democratic Republic of the Congo	√	√	
	Equatorial Guinea			
	Gabon			√
	Sao Tome and Principe			

Region	Country	Regulations & Pricing Mechanism	Tax Incentives	Financial Incentives
	Kenya	√	√	√
	Mauritius	√		√
	Rwanda	√	√	√
	Seychelles	√	√	√
	Somalia			
	South Sudan			
	Uganda	√	√	√
	Tanzania	√	√	√
Southern Africa	Botswana	√		
	Swaziland			√
	Lesotho			
	Madagascar	√	√	√
	Malawi	√	√	
	Mozambique	√	√	√
	Namibia	√		√
	South Africa	√	√	√
	Zambia	√	√	
	Zimbabwe	√	√	

Table 5.2 Africa's Regional Renewable Energy Programs and Institutions

Region	Regional Renewable Energy Programs and Institutions
Northern Africa	Countries in Northern Africa have set out national targets and jointly established the Regional Center for Renewable Energy and Energy Efficiency (RCREEE) with other Pan-Arab member states, to support renewable energy development and improve energy efficiency across the Pan-Arab region. In 2018, the Arab Renewable Energy Development Strategy 2010–2030 was expanded into the Pan-Arab Sustainable Energy Strategy 2030, incorporating aspects such as energy efficiency and energy access. This strategy aims to increase the share of renewable energy in the power

	structure to 12.4% and includes implementation plans for 17 projects (6 regional and 11 national). These projects were built on individual country efforts and involve regional and international cooperation. It suggested to increase the share of renewable energy in the electricity markets of Pan-Arab countries, ensuring necessary public and private investments, reducing risks and challenges associated with grid planning, expansion, and operation, and integrating smart services and quality assurance measures. Instrument for the strategy include policies, laws and regulations, standards, technologies, and capacity-building initiatives, mapping out customized templates to guide Pan-Arab countries in developing national renewable energy action plans tailored to their specific conditions.
West Africa	In July 2013, the heads of state and government of the Economic Community of West African States (ECOWAS) adopted the ECOWAS Renewable Energy Policy (EREP). This policy aims to increase the share of renewable energy (excluding large hydropower) in the region's electricity mix to 35% by 2020 and to 48% by 2030. On the other hand, the ECOWAS Energy Efficiency Policy (EEEP) played its role in enhancing energy efficiency, offering 2,000 MW of power capacity and ultimately doubling the rate of energy efficiency improvement. Following the adoption of the regional policy, all ECOWAS member states developed their national renewable energy action plans, or national energy efficiency action plans, as well as Sustainable Energy for All (SE4ALL) Action Agendas between 2014 and 2015. Consequently, the national goals expressed in these action plans align with the regional targets outlined in EREP. The ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE), established in 2010, aims to create favorable conditions for the renewable energy and energy efficiency markets within the region.
East Africa	In 2016, the East African Community (EAC) established the East African Centre of Excellence for Renewable Energy and Energy Efficiency (EACREEE) to promote renewable energy development and create favorable conditions for energy efficiency markets and investments. While all member countries have set renewable energy development targets at the national level, as of 2021, no regional plans or targets had been formulated.
Central Africa	In June 2021, the 11 energy ministers of the Economic Community of Central African States (ECCAS) approved the Central Africa Renewable Energy Roadmap and established the Centre for Renewable Energy and Energy Efficiency for Central African (CEREEAC). The roadmap outlines a goal for renewable energy to supply 77% of the region's electricity (including large hydropower) by 2030.
Southern Africa	In July 2017, the SADC adopted the Renewable Energy and Energy Efficiency Strategy and Action Plan. The region aims to increase the share of renewable energy installed capacity in its power structure to 39% by 2030. By the same year, the proportion of renewable energy generation in the total grid output is expected to reach 7.5%. Established in 2015, the Southern African Centre for Renewable Energy and Energy Efficiency (SACREEE) focuses on facilitating market-driven adoption of renewable energy, energy efficiency, and energy services to enhance access to modern energy and ensure energy security in the region.

5.3 Financing Barriers

5.3.1 High Costs and Inadequate Funds

(1) Inadequate prefeasibility facilities

A research report from Boston University's Global Development Policy Center highlights that prefeasibility facilities are crucial in the lifecycle of renewable energy projects in Africa, impacting financing, construction, operation, and maintenance. However, across the entire continent, only a few project preparation facilities in the region have cross-border mandates, i.e. the Development Bank of Southern Africa (DBSA)'s Project Preparation Facility, the DBSA managed SADC Project Preparation Development Facility (SADC PPDF), and the Southern African Power Pool's Project Advisory Unit (SAPP PAU) Project Preparation Fund. Notably, there is no preparation fund specifically dedicated to renewable energy projects.

Such lack of prefeasibility facilities hampers renewable energy development in Africa, failing to provide full support at the early stage of project development. For instance, Nigeria's renewable energy development faces significant barriers due to high early-stage investment requirements. Despite government efforts to attract investments through tax incentives and feed-in tariffs, the results have been limited. Without adequate financial support and international funding, many planned solar and wind projects remain stalled. Currently, renewable energy accounts for less than 5% of Nigeria's total power generation, far from the government's target of achieving 40% renewable energy by 2030.

(2) High early-stage costs

Renewable energy projects, especially large-scale solar and wind facilities, require high-volume upfront investments, which many African countries struggle to finance domestically. According to data from the IEA, solar projects in Africa typically require an initial investment of USD1 to 1.5 million per megawatt, while wind projects range from USD1.5 to 2 million per megawatt, both of which are considerably higher than similar projects in Asia or Europe. Such high initial investment costs posed major challenges to African countries, particularly for those with underdeveloped capital markets and limited financing channels. Furthermore, since African power project investments are often denominated in U.S. dollars or euros, while revenues and assets are in local currencies, renewable energy projects are exposed to foreign exchange and currency depreciation risks, adding another layer of financial uncertainty.

(3) Funding shortage

Due to government budget constraints and insufficient private sector investment, many African countries struggled to raise enough funds for renewable energy projects. As a result, many projects rely heavily on international aid and loans, which further complicate and increase the risks associated with these projects. According to the World Bank, sub-Saharan Africa requires approximately USD30 billion in energy investments annually, but actual investment amounts to only about one-third of this figure. The funding shortage has led to delays or cancellations of many planned projects, impacting the speed and scale of renewable energy development.

5.3.2 Inmature Financial Market and Limited Financing Services

(1) Limited Development of Financial Markets

Underdeveloped, financial markets in many African countries were in lack of the financial tools and institutions required to support large-scale renewable energy project financing. Thus, commercial banks could only offer limited loan amounts for projects, and the interest rates were relatively high, increasing the cost of financing for businesses. Take Kenya for example. The commercial loan rates in Kenya typically range from 12% to 15%, while the rates in developed countries were generally below 5%. Such high-interest rate environment elevated the cost for project financing, reducing the economic viability and attractiveness of projects. The Kenyan government attempted to improve the financing environment through measures like establishing a national green energy fund and offering tax incentives, many projects still struggle to secure sufficient funding due to the limitations of the domestic financial market.

(2) Lack of Diverse Financing Products and Services

In lack of long-term bonds, green bonds, equity and other financing products, Africa's financial market had only limited financing options and less flexibility. As green bonds are becoming increasingly popular in global markets, their issuance in Africa remains low. According to the International Finance Corporation (IFC), the size of Africa's green bond market accounts for only about 1% of the global market, which largely lags behind regions such as Asia and Latin America. The shortage of these financing tools presents a major challenge for renewable energy projects in securing long-term, stable financial support.

(3) Rigid Project Financing Models

Due to the underdeveloped credit markets in Africa, Chinese financial institutions typically adopted a model of "offshore guarantees for onshore loans" for overseas clean energy projects. Chinese investors must use domestic assets as collateral to obtain a letter of guarantee or a standby letter of credit from domestic banks before applying for loans from foreign banks. If a default occurs, the foreign bank can seek repayment from the Chinese investors. This model ties up significant collateral resources, restricting the investor's ability to secure further financing. It's especially challenging for private companies in the renewable energy sector, many of which lack credit lines from banks, making it difficult for them to bear the burden of such collateral-based financing. As a result, many Chinese PV and wind turbine equipment companies in Africa are limited to equipment supply and cannot engage in project development.

5.3.3 Mismatching Risk-Benefit Ratio

(1) Credit risk premium driving up financing costs

Concerned about the political and economic environment in Africa, many international investors adopted a cautious stance toward the African market, which limited the flow of international capital. International investors normally demand higher risk premiums to compensate for the risks associated with political and economic instability, thus increasing the financing costs. For example, the interest rates charged by international financial institutions, as well as the return rate demanded by investors for African projects were usually higher than those in other regions, further restricting the financing capacity of projects.

(2) Policy and market instability increasing uncertainties in project returns

In many African countries, policy and market instability would lead to frequent changes in the terms of power purchase agreements (PPAs), increasing the uncertainty of project returns. It mainly manifests in price adjustments, changes in contract duration, and insufficient payment guarantees. Governments, for instance, may adjust feed-in tariffs due to fiscal pressures, affecting the expected returns of projects; changes in contract durations increase long-term risks; and insufficient payment guarantees heighten the risk of delayed revenue recovery.

5.3.4 Strict Conditions for Access to Capital

(1) High costs for accessing capital

The funding requirements for renewable energy projects in Africa can be categorized into four main types: co-financing requirements, track record and/or balance sheet, the need to prove concept, and equity sell-down as development capital. Projects need to have at least secured the land acces rights before developers can access the prefeasibility funding from financial institutions. DFIs and other financial institutions often request developers to co-finance the development work. Developers are therefore expected to spend more money at a time when they would have exhausted their lifetime savings and social capital to get the project through the early stages before accessing funding. Although early-stage funding represents a small proportion of total project cost, due to the capital-intensive nature of projects, it is a significant amount, especially for local developers and new entrants into the renewable energy market. This often results in low uptake of project development funding by developers and stalls the project development process.

(2) Complex approval processes

Many African countries are increasingly emphasizing environmental and social responsibility in infrastructure development, with an increasing number of related requirements. Some Chinese companies find it difficult to adapt to the complex approval processes and compliance demands of host countries. For example, under South Africa's Black Economic Empowerment (BEE), electricity companies entering the country's market through greenfield or acquisition models must find local black partners to form joint ventures and meet several criteria set by the Act. However, Chinese companies bidding for renewable energy projects in South Africa often focus more on technical and economic indicators while neglecting social responsibility and local operations, which not only reduces their chances of winning bids but also damages their corporate image. Similarly, the application processes for funding from the Global Environment Facility (GEF) and the Green Climate Fund (GCF) are complex, imposing strict requirements on project sustainability and environmental impact, conditions that many African countries struggle to meet.

Case 5.1: Noor Solar Power Project, Morocco

The Morocco Noor Solar Power Project is a typical large-scale renewable energy project that relies on international financial support. The project secured over USD3 billion in funding through cooperation with the World Bank, the European Investment Bank, and the African Development Bank. However, the project faced complex conditions and strict environmental assessment requirements during the funding application and approval process, which delayed the availability of funds and impacted the project's implementation timeline. Despite these challenges, the Moroccan government overcame the difficulties in securing funding through active international cooperation and effective project management, ensuring the smooth progress of the project.

6

Innovation Opportunities and Business Models

Chapter 6 Innovation Opportunities and Business Models

6.1 Opportunities in technological innovation

6.1.1 Solar energy

The widespread adoption of solar energy technology in Africa is driven by its abundant resources and technological advancements, particularly in sub-Saharan Africa, where the potential for solar utilization is enormous. In recent years, remarkable progress has been made in solar energy technology, which has greatly enhanced efficiency in power generation while reducing costs.

i. Photovoltaic

Photovoltaic (PV) technology is a primary way to utilize solar energy. In recent years, with the development of new materials and manufacturing processes, solar cells have become increasingly efficient. Perovskite solar cells, known for their high efficiency and low cost, have attracted widespread attention. Studies show that the laboratory efficiency of perovskite solar cells has surpassed 25%, suggesting that their commercial production costs are likely to further decrease in the coming years. Specifically, the photoelectric conversion efficiency of perovskite solar cells has increased from 3.8% in 2010 to 25.7% in 2023, notably narrowing the efficiency gap with traditional silicon-based solar cells. In addition, bifacial PV cell technology is also making rapid progress, allowing for the use of light from both the front and back sides of the cells, which has impressively increased power generation per unit area. According to IRENA statistics, the use of bifacial PV cells can increase power generation by 10% to 20%, with particular advantages in high-reflectivity surface conditions, such as desert areas.

ii. Heat collection technology and energy storage solution

Heat collection technology, another major method of solar energy utilization, generates electricity by concentrating solar energy to produce heat. Recent technological advances have focused on high-temperature molten salt energy storage systems, which can store large amounts of thermal energy and release it when needed, making solar power generation remarkably more stable and reliable. The thermal efficiency of high-temperature molten salt systems can exceed 90%, effectively addressing the intermittent nature of solar power. Advanced materials like graphene have also been used to improve the thermal conductivity of heat collector tubes, further enhancing system efficiency. Graphene materials, known for their excellent thermal conductivity and high-temperature resistance, have successfully reduced heat loss in collector tubes by more than 20%, delivering a strong boost to overall system efficiency.

iii. Innovations in new materials and manufacturing processes

The development of new materials is a key factor driving the progress of PV technology. In addition to perovskite solar cells, silicon heterojunction cells and organic PV cells have shown great potential in experiments. Silicon heterojunction cells, which add a layer of silicon thin film to traditional silicon cells, significantly improve the light-to-electricity conversion efficiency, reaching up to 26%. In terms of manufacturing processes, the application of printing electronics technology has made solar cell production more flexible and cost-effective, with the potential for large-scale deployment in remote areas. This technology has not only increased the production speed of solar cells by 30%, but also reduced the production costs by 50%, greatly facilitating the extensive adoption of solar technology.

6.1.2 Wind energy

Wind energy holds substantial potential in the coastal regions of Eastern and Southern Africa, with technological innovations primarily focused on improving the design and efficiency of wind turbines.

i. Improving wind turbine design and efficiency

Modern wind turbines are increasingly designed for large-scale operations and enhanced efficiency. For example, new direct-drive permanent magnet synchronous generators (PMSGs) reduce mechanical losses in order to improve power generation efficiency. Data shows that the power generation efficiency of direct-drive PMSGs can increase by around 5%, and less reliance on gearbox also lowers maintenance costs. Moreover, advancements in aerodynamic optimization, active control technologies, and the use of advanced composite materials have significantly improved both the efficiency and lifespan of wind turbines. Aerodynamic optimization designs have boosted energy capture efficiency by 10% to 15%, while the adoption of new composite materials, such as carbon fiber, has reduced the weight of turbine blades by over 20%, enhancing their structural strength and durability.

ii. Potentials of offshore wind power technology

Offshore wind power is regarded as a key focus for the future of wind energy development, thanks to strong and stable wind speeds at sea. The development of floating wind turbines has overcome installation challenges in deep-water areas, expanding the potential for harnessing wind energy. Data indicates that the cost of floating wind turbines has decreased by approximately 40% since 2010 and is expected to further decline by 30% by 2030. Automated and intelligent maintenance systems are also gradually applied, which has improved the operational reliability and economic viability of offshore wind power. For example, the use of drones and robots for wind turbine maintenance and inspection can reduce time and costs by more than 50%, significantly enhancing the economic feasibility of wind power projects.

6.1.3 Hydropower

Hydropower is one of Africa’s traditional renewable energy sources, with small-scale hydropower plants and micro-hydro technologies being particularly suitable for remote mountainous and rural areas there.

i. Small-Scale hydropower plants and micro-hydro technologies

Small-scale hydropower plants, known for their cost-effectiveness and shorter construction timelines, are particularly well-suited for regions crisscrossed with rivers. The application of new turbines and intelligent control systems has improved the efficiency of water energy utilization. Data shows that modern small-scale hydropower plants can achieve energy conversion efficiencies exceeding 90%, a 15% improvement compared with traditional ones. Micro-hydro technology, through innovative designs (such as portable turbines and water flow regulation systems), enables efficient power generation in small rivers and mountain springs, which can help remote communities achieve energy self-sufficiency. The portable turbine design makes the installation and maintenance of micro-hydro systems more convenient, reducing installation costs and time by an average of 30%.

ii. Marine energy technological innovations

Marine energy, including tidal and wave energy, is still in its early stages of application in Africa, but its technological potential is immense. Advanced wave energy converters and tidal turbine technologies are gradually maturing and expected to be widely adopted in Africa’s coastal regions in the future. The energy conversion efficiency of wave energy converters has increased by over 50% in the past decade, reaching around 40%. With further technological advancements, this efficiency is expected to improve by another 10% to 15% in the next five years.

6.1.4 Biomass energy

Biomass energy has a broad resource base in Africa’s major agricultural countries, and its efficient conversion technologies keep making progress.

i. Efficient biomass conversion technologies

Efficient conversion technologies, such as pyrolysis and gasification, can transform biomass into high-energy gas or liquid fuels through thermochemical processing. Studies show that biomass gasification can achieve energy conversion efficiency of over 60%, twice that of traditional technologies. New catalysts and reactor designs can further enhance biomass conversion efficiency and reduce carbon emissions. For example, biomass pyrolysis with nano-catalysts not only improves conversion efficiency but also reduces carbon emissions by approximately 30%.

ii. Biomass fuels

Biomass fuels, such as bioethanol and biodiesel, are key alternatives to fossil fuels. The production costs of biomass fuels are gradually decreasing, with genetic engineering to improve plant materials and optimize fermentation processes. For instance, the application of gene-editing technology has shortened the growth cycle of oilseed crops by more than 20%, significantly increasing yield and enhancing the economic viability of biomass fuels. In additional, the distributed production and utilization model of biomass fuels is well-suited to Africa's extensive rural areas, promoting their energy diversification and sustainable development. Data shows that the construction cost of distributed biomass fuel production systems is around 25% lower than centralized ones, improving energy autonomy in rural Africa.

6.1.5 Energy storage

Energy storage technology is crucial for the stable operation of renewable energy systems, especially for solar and wind energy.

i. Innovations in battery technology

Lithium battery technology has made significant advancements in the past decade, tripling its energy density while reducing costs by approximately 80%. Data shows that the energy density of lithium batteries has increased from 100 Wh/kg in 2010 to 300 Wh/kg in 2023, while their costs have dropped from USD1,000/kWh to below USD200/kWh. New types of batteries, such as sodium-ion and solid-state batteries, are attracting widespread attention due to their abundant resources and high safety. Sodium-ion batteries have material costs about 30% lower than lithium batteries and perform more stably in low-temperature environments. The development of ultra-large capacity battery systems, such as lithium-air batteries, is expected to significantly enhance the capacity and stability of energy storage systems. In theory, energy density for lithium-air batteries can reach 3,500 Wh/kg, ten times that of conventional lithium batteries, and it is expected to greatly increase the energy density of storage systems in the future.

ii. Smart grid and microgrid technologies

Thanks to advanced control and communication technologies, smart grids enable efficient electricity transmission and distribution, while supporting the integration of large-scale distributed energy sources. Data shows that the application of smart grid technology can improve power transmission efficiency by about 15%, reducing power losses by more than 10%. Microgrid technology, combined with energy storage systems, provides independent and reliable power supply solutions for remote areas. Microgrid systems can operate autonomously during main grid failures, improving the reliability and resilience of power systems. The use of blockchain technology in energy trading has improved transparency and efficiency in energy management. Peer-to-peer (P2P) energy trading enabled by blockchain can cut transaction costs by about 20%, improving the efficiency of energy resource utilization.

6.2 Business models

6.2.1 Distributed energy model

The distributed energy model has vast potentials for application in Africa, particularly in remote areas not covered by the main power grid.

i. Microgrid system model

A microgrid system integrates multiple distributed energy sources and storage units to create an independent power network, providing stable electricity supply to small communities and villages. Data shows that the stability of power supply in microgrid systems is approximately 20% higher than in traditional ones, particularly in areas prone to natural disasters, demonstrating higher resilience to risks. Microgrids are considered the most affordable electrification option for over 100 million people in Africa. A white paper published by researchers from Boston University highlights that microgrid projects could play a major role in supporting Africa's power grid, with an estimated USD1 trillion investment needed in the continent.

Currently, a number of African countries are formulating plans for microgrid development. For example, the Ghanaian government plans to add 1,000 off-grid projects by 2030, with total installed capacity of 244 MW. The Ministry of Energy and Mineral Development of Uganda has launched a decentralized renewable energy development plan, aiming to start off-grid electrification projects on islands in Lake Victoria. In 2017, Kenya's Ministry of Energy initiated the Off-Grid Solar Access Project, aiming to provide electricity to approximately 1.3 million households in large areas of northeastern and northern regions, where the national grid does not reach. Since 2020, the African Development Bank has invested USD200 million in Nigeria to build microgrids/off-grid solutions across this Western African country to improve its electricity supply. In South Africa, where energy demand is more dispersed, microgrids are primarily used for electricity supply in remote areas. The Algerian government has prioritized microgrids and off-grid solutions, with plans to conduct three off-grid project tenders from 2022 to 2024. The National Office of Electricity and Drinking Water (ONEE) in Morocco plans to build 19,438 off-grid projects in over 1,000 villages by 2030. JUMEME, a joint venture between Germany, Austria, and Tanzania, plans to deploy 300 solar microgrid systems in Tanzania by 2022, to meet electricity needs for over one million people in the country's rural areas. The government of Côte d'Ivoire plans to add 462 MW of off-grid capacity by 2030. Ethiopia plans to achieve universal electricity access by 2030, with 35% of its power supply coming from off-grid systems.

ii. Community energy project model

The community energy project model refers to a development approach where renewable energy technologies are used to provide energy services to local residents within a specific community. This model typically involves collaboration among community members, local governments, NGOs, and businesses to improve energy accessibility, reduce energy costs, and promote sustainable development. This model will integrate community participation, design appropriate energy solutions using renewable energy technologies, establish diverse financing channels to ensure economic feasibility, and provide training and knowledge transfer to enhance community members' skills.

Case 6.1: Solar Sister Project in Kenya

The project was founded by the nonprofit organization Solar Sister. Through direct sales and distribution models, it provides small loans and comprehensive training to women, enabling them to establish small solar businesses and become distributors and service providers of solar products such as solar lamps, solar chargers, and home solar systems. These women are known as "Solar Sisters".

Data shows the project has trained over 5,000 female entrepreneurs, providing many women with job opportunities and helping them achieve economic independence. It has also led to less use of fossil fuels in many households, improving community energy autonomy and economic vitality, with an estimated reduction of about 10,000 tons of CO2 emissions annually. In additional, the project has improved children's education conditions, reduced health risks related to fuels like wood, and enhanced living standards and economic income for local residents.

iii. Solar Home System (SHS) model

Solar home systems (SHS), combined with energy storage devices, enable independent electricity supply for households and small commercial users. Case studies show that households using rooftop solar systems can reduce their energy expenditure by over 30%. SHS, thanks to its low cost, has transformed the lives of millions of Africans, enabling them to access basic services and enjoy greater comfort and convenience. Unlike grid electricity, SHS and its associated appliances rely on direct current (DC) power, which was often perceived as providing lower-quality power and service standards. However, SHS has made significant progress in improving component quality and service standards, and the range of applications and devices compatible with SHS has diversified substantially. Currently, SHS manufacturers offer products from 5 watts to 1 kW, including rooftop solar systems and microgrid solutions, to meet a wide variety of power needs across Africa. It is estimated that there are about 100,000 healthcare facilities across Africa, half of which are located in rural areas and provide primary healthcare services, including maternal care and vaccination. For these facilities, SHS offers both a technically and commercially perfect solution. Today, a full set of DC-powered appliances—including lights, vaccine refrigeration equipment, medical instruments, and communication devices—can be powered by a 300W SHS system with cost less than USD1,000. In contrast, an equivalent AC-powered system can cost 3 to 5 times more.

Case 6.2: Zola Electric Project

Zola Electric, a company that provides off-grid solar solutions, primarily operates in countries like Tanzania, Rwanda and Ghana, with the goal of providing clean and reliable power to remote communities and helping users reduce their reliance on kerosene and diesel.

Zola Electric's solar home system includes solar panels, battery storage, LED lighting appliances, USB charging ports, and small appliances such as TVs and radios. The system comes in various configurations and can be customized according to household needs.

Zola Electric has already provided power services to over 200,000 households and small businesses, which has cut the use of harmful fuels and delivered clean lighting and power services, offering a viable solution to Africa's energy poverty.

6.2.2 Energy as a Service (EaaS) model

Energy as a service (EaaS) is an innovative business model. Its core component is to meet the diversified needs of users by providing energy solutions instead of energy products alone. The EaaS model provides more flexible and efficient energy solutions through innovative payment methods and trading platforms, effectively driving the popularization and application of renewable energy in Africa. EaaS not only provides users with economical energy solutions, but also improves the overall efficiency and sustainability of the energy system through technological innovation and optimized business models.

i. Subscription and leasing model

The subscription and leasing model enables users to enjoy the right to use solar equipment and energy storage systems without a huge initial investment, which greatly lowers the threshold for the popularization of solar energy, especially for communities with limited resources. This business model greatly popularizes solar energy, making it especially suitable for the vast rural areas in Africa with insufficient power grid coverage, limited funds and growing demand for energy. Through the subscription and leasing model, residents in relevant areas can access stable energy supplies and significantly improve their quality of life. The subscription and leasing model usually has the following main features:

Low initial installation costs: Users only need to pay a small amount of fee for initial installation, avoiding the burden of a large initial investment. For example, M-KOPA's leasing model only requires users to pay a monthly rent equal to a small part of their electricity bill, which makes the use of solar systems economical.

Flexible payment methods: The subscription and leasing model usually adopt flexible payment methods, such as monthly payment and usage-based billing, allowing users to choose the best plan for them based on their needs. For example, M-KOPA’s system allows users to pay via mobile payment platforms, and they only need to pay a small amount of monthly fee through a simple and fast procedure.

Equipment maintenance and upgrading are guaranteed: The service provider is responsible for equipment maintenance and regular upgrade to ensure that the system is always at its best, and there is no need for users to worry about maintenance costs and technical problems. Data shows that user satisfaction and working life for equipment under solar systems adopting this model have been significantly improved.

Case 6.3: Kenya's M-KOPA platform

Founded in 2021, M-KOPA aims to provide clean and affordable energy solutions for families without electricity access by providing equipment for renewable energies.

Under this model, users only need to pay a small fee for initial installation and then monthly rent to get a complete solar system, which greatly lowers the threshold for entry and popularizes solar systems. Data shows that M-KOPA has provided solar services to over 1 million households, with an average annual growth of 30%. With payment by installment, users could significantly reduce their costs of energy use and get easier access to energy.

Through an innovative leasing model, M-KOPA has enabled more than 1 million households to obtain solar power. The project uses the IoT technology for remote monitoring of equipment and payment management, tracks power consumption of users in real time, ensures sound operation for equipment, and provides remote services and maintenance, reducing operating costs and enhancing customer satisfaction. Data shows that since the project was launched, the average electricity bill of users has been reduced by 40%, with greatly enhanced quality of life. The project has deployed over 500,000 solar systems in Kenya, Uganda and Tanzania, reducing carbon dioxide emissions by more than 100,000 tons per year.

The M-KOPA project not only provides clean energy, but also creates a lot of job opportunities, especially opportunities for women to start a business. The success of this project shows that the combination of innovative business models and technologies could effectively popularize renewable energy in developing countries. Data shows that the project has directly and indirectly created more than 10,000 jobs and improved the income and living standards of local residents.

ii. The model of energy trading platforms based on blockchain

The decentralized and tamper-proof features of blockchain technologies provide a transparent and efficient solution for energy trading. An energy trading platform based on blockchain allows users to directly trade surplus energy, optimizes resource utilization, makes renewable energy more economical and more active in the market. This model presents the following advantages:

First, it is highly transparent and secure. The transparency and security of blockchain technologies ensure that transactions are open, fair and tamper-proof. Every transaction record is publicly available, which reduces transaction disputes and builds user trust.

Second, it could reduce transaction costs. This model does not need traditional intermediaries and significantly reduces transaction costs through a decentralized trading platform. Data shows that transaction costs of energy trading platforms based on blockchain is about 15% lower than those of traditional energy trading platforms.

Third, it allocates resources efficiently. Users could buy and sell surplus energy freely through the platform, achieving efficient distribution and use of energy resources. South Africa's Sun Exchange platform connects investors of solar projects and energy consumers with blockchain technologies, which simplifies the transaction process and reduces costs. Data shows that the average annual growth of the number of users on Sun Exchange exceeds 25%, greatly improving energy use.

Fourth, it could arouse market interest. Blockchain technologies have made the energy market more diversified and competitive, luring more investors and consumers. This model not only promotes the renewable energy market in Africa, but also provides valuable experience and reference for global energy transformation. With continuous technological progress and as the market gradually becomes more mature, the EaaS model is expected to play a greater role in the future and facilitate the development of renewable energy in Africa and even the world beyond.

Case 6.4: Sun Exchange, a renewable energy platform based on blockchain in South Africa.

Founded in 2015, South Africa's Sun Exchange is committed to resolving financing difficulties for solar projects in Africa through crowdfunding and blockchain technologies, popularizing renewable energy in Africa, and providing sustainable investment opportunities with considerable returns for individual investors. Its basic operation model is as follows:

1. Project release: The platform would publish solar projects available for investment, detailing the required funding, power generation capacity and expected returns for investors.

2. Crowdfunding for the purchase of solar panels: Global investors could buy solar panels through the Sun Exchange platform, or buy a part of panels. Each solar panel or part of it is "rented" to end users, such as schools or community centers. There is no need for investors to buy the entire solar panel, instead, they can invest in a part of it, which reduces the threshold for entry.

3. Contract leasing: Once the solar panels are installed for a project, the end users will pay investors their rent according to electricity production and use. Leasing contracts are usually long-term agreements with a stable cash flow.

4. Earnings and returns: Investors get rental income on a regular basis according to the number of panels they own and the amount of power generated. The income is paid in cryptocurrency (such as bitcoin) or local currency, which is flexible.

The platform connects investors of solar projects and energy consumers through blockchain technologies, allowing users to invest in solar projects around the world, sharing project benefits, simplifying transaction processes, reducing costs and encouraging more people to participate in the development of renewable energy. With the blockchain platform, investors could easily track the real effects of their investment and make investment more transparent and secure.

Data shows that the transaction costs on Sun Exchange is about 15% lower than those of traditional energy trading platforms, and the average annual growth of users exceeds 25%.

The success of EaaS model lies in its innovative business models and technical application, which has solved many problems for traditional energy systems and provided strong support for the development of renewable energy in Africa. The subscription and leasing model reduces the entry threshold of solar technologies, and enables more people to enjoy the convenience and economic benefits brought by clean energy. Energy trading platforms based on blockchain could optimize the distribution of energy and resources and makes the market more active and diversified by making transactions more transparent and efficient.

6.2.3 Mixed financing model

Mixed financing models provide flexible and effective financial support for renewable energy projects in Africa by leveraging multiple funding sources. This model usually combines public funds, private investment and international assistance to form a diversified financing structure, which provides a strong guarantee for the implementation and sustainable development of projects.

i. Public-Private Partnership (PPP)

Public-Private Partnership (PPP) is widely applied in large-scale infrastructure projects, which combines government policy support with capital and technical advantages of the private sector, not only improving financing capacity for projects, but also improving their management and operation efficiency.

Government support and policy incentives: The government usually provides land, preferential policies and partial financial support to PPP projects, which reduces upfront investment risks for projects. The Ethiopian government has attracted a large number of international investors to participate in its wind power projects by providing land and offering tax incentives.

Financial and technical advantages of the private sector: The private sector provides advanced technological and management expertise, which improves the efficiency of project construction and operation. Data shows that participation of the private sector shortens the construction schedule of projects by more than 20% on average and reduces the cost by about 15%.

Risk and revenue sharing: PPP model clearly defines the power and responsibility between the government and the private sector with contracts, effectively reduces investment risks for each party, and encourages both parties to work together to improve project efficiency with revenue sharing mechanisms.

Case 6.5: Ashegoba Wind Farm in Ethiopia

The project is located in Tigray Region in northern Ethiopia and is one of the largest wind power projects in the country. The construction of this project started in 2009. In 2013, international investment was channeled in through the PPP model, and several large-scale wind farms were successfully built, which significantly increased the installed capacity of wind power in the country. It was estimated that the annual amount of power generated could reach 400 GWh, which could provide clean electricity for hundreds of thousands of households and reduce annual carbon dioxide emissions by 250,000 tons.

Under this model, the Ethiopian government, the French Development Agency and other international financial institutions have improved financing capacity and implementation efficiency for the project through cooperation and risk sharing, with a total investment of about EUR290 million.

The success of Ashegoba Wind Farm not only demonstrates the effectiveness of the PPP model, but also provides valuable experience for other developing countries. The project combined government policy support with technical and financial advantages of international capital, successfully overcame many challenges in financing, technology and management, and achieved sustainable development of renewable energy. The successful implementation of the project has significantly improved the installed capacity of wind power in Ethiopia, promoted local economic development and contributed to environmental protection.

Crowdfunding and green bonds provide new financing channels for small and medium-sized renewable energy projects. Crowdfunding platforms have rapidly launched and promoted projects by pooling the funds of small investors, and promoted the implementation of more renewable energy projects. Crowdfunding and green bond financing provide flexible and diverse financial support for renewable energy projects in Africa, especially for small and medium-sized projects. Through crowdfunding platforms, project sponsors can quickly raise start-up funds and build social influence of projects. Through green bonds, project executors can get low-cost long-term financial support and implement more projects for sustainable development.

1. Crowdfunding platform: Through crowdfunding platforms, project sponsors could pool funding from a large number of small investors through the Internet to quickly launch and popularize projects. The crowdfunding model is characterized by flexibility, transparency and high participation rate. Data shows that in the past five years, crowdfunding platforms in Africa raised more than USD100 million and supported hundreds of small and medium-sized renewable energy projects.

Flexible financing channels: The crowdfunding platform allows individual investors to participate in large-scale projects with a small amount of investment, which lowers the investment threshold. Through the Internet, project sponsors can talk directly with investors, improving transparency and credibility for projects.

Enhanced public participation: the crowdfunding model encourages the public to participate in renewable energy projects, which not only raises funds, but also enhances public awareness and support for renewable energy.

Case 6.6: Egypt's Infinity Solar Project

The project is located in Benban Solar Park in southern Egypt and is led by Infinity Solar, a local renewable energy company in Egypt.

When the project was first implemented, USD5 million was raised through the crowdfunding platform of Crowd Fund Energy, and a 10 MW solar power station was built. During the crowdfunding process, the project attracted over 5,000 individual investors, raised enough start-up funds for the project, and greatly enhanced its social impact.

Data shows that the project started full-scale operations in 2019, providing clean electricity to more than 10,000 households every year, significantly improving local power supply capacity, creating more than 200 jobs during construction and operation, and raising the income level of local residents. At the same time, the project could reduce about 10,000 tons of carbon dioxide emissions per year, facilitating local sustainable development.

The success of this project demonstrates the great potential of crowdfunding in renewable energy projects. Through online financing platforms, the project has attracted a large number of individual investors, which not only provided funding, but also improved public recognition and influence for the project. The successful implementation of the project has significantly improved locally-installed solar capacity, driven local economic growth and contributed to environmental protection.

2. Green bond: This model could attract a lot of international capital to invest in renewable energy in Africa by issuing bonds to investors and raising funds for environmental and sustainable development projects. The rapid development of the green bond market has provided vital financial support for renewable energy projects in Africa.

Low-interest loans and tax incentives: Green bonds usually enjoy low-interest loans and tax incentives from the government, which reduces financing costs and makes projects more economical. Data shows that the scale of African green bond market increased by over 200% in the past five years, providing important financial support for many renewable energy projects.

Appeal for international investment: Green bonds have attracted the interest and participation of a large number of international investors as the bonds are characterized by environmental protection and sustainable development. For example, South Africa successfully raised USD200 million for renewable energy projects through green bonds. The funds were used to build a number of wind and solar projects, significantly increasing the installed capacity of renewable energy in South Afric

Case 6.7: South Africa supports renewable energy projects with green bonds

The related projects cover wind and solar projects, with a total installed capacity of about 250 MW. It is located in many South African provinces, including Western Cape and Gauteng Provinces.

The relevant bonds are issued by the Development Bank of Southern Africa, which is jointly invested by international financial institutions and private investors, and local governments and renewable energy developers are partners for the project. The institutions above successfully issued green bonds in early 2018, raising a total of USD200 million. During its construction and operation, the project created about 1,000 jobs and improved the income of local residents. The project provided clean electricity for over 200,000 households, which significantly improved stability and reliability of local power supply.

The issuance of green bonds has achieved the following: First, project executors could quickly raise the funds required, improving transparency and credibility for projects. Second, it attracted a lot of international capital, resolved the funding issue and enhanced the impact of projects. Third, it actively cooperates with local communities to solve the problems of land use and ecological conservation, with support and participation of communities. Fourth, the parties have established an effective communication and management mechanism during cooperation, ensuring the smooth progress of projects.

6.2.4 Models of international cooperation

Multinationals and international financial assistance play a vital role in the development of renewable energy projects in Africa. Cooperation between multinationals and local businesses, as well as the support of international aid and investment, could ensure that the projects receive sufficient funding and technical support. At the same time, this could also realize technology transfer and facilitate local capacity building, and expand the market for renewable energy projects in Africa.

i. Cooperation model between multinationals and local enterprises

Multinationals could leverage their technical and financial advantages to cooperate with local enterprises and jointly develop and promote renewable energy projects. To be more specific, cooperation between multinationals and local enterprises enjoys the following advantages: First, promoting technology transfer and localized production. Second, providing financial support and sharing risk. Third, joint management, operation and maintenance.

Case 6.8: Egyptian wind power project built by Siemens

In June 2015, the Egyptian government announced that it would cooperate with Siemens to introduce a power generation project focused on wind farms. The installed capacity of this project was 2 million KW, which would be built by Siemens from Germany. Through technology transfer and localized production, the technologies and competitiveness of local enterprises were enhanced.

Data showed that Siemens played the following roles in the project: First, it provided strong financial support for the project. Second, through technical training and joint development, it trained local enterprises on the latest direct-drive wind turbine technologies, which helped local technicians become more professional. Third, local manufacturing of wind power components in Egypt increased the local production ratio of the project to over 60%, creating more than 5,000 local jobs and promoted the development of related industries.

At the same time, the project set up a joint management committee to regularly evaluate the progress and operation of the project to ensure its smooth progress. After the project started operation, Siemens provided long-term technology support and training to ensure its efficient operation and sustainable development.

ii. Model of international financial support

International aid organizations and development banks also play an important role in renewable energy projects in Africa, and support the smooth implementation and sustainable development of projects by providing low-interest loans, technical assistance and capacity building. They have played the following specific roles: first, providing low-interest loans and financial support, reducing financing costs and making projects more economical. Second, providing technical assistance and capacity building to help local enterprises and governments improve their technical and management capabilities.

Case 6.9: Lighting Africa Program by the World Bank

The Lighting Africa program was jointly initiated by the World Bank and the International Finance Corporation (IFC). Under the leadership of the World Bank and IFC, through the joint efforts of governments, relevant organizations and production and marketing enterprises for off-grid lighting from countries all over the world (especially African countries), the program aims to promote small solar products, build an independent and sustainable off-grid lighting market in Africa, and provide clean and affordable power solutions for rural areas in Africa.

The project provides low-cost off-grid lighting and energy solutions, and helps many African countries promote solar power through the steps of market research and demand analysis, technical support and product development, product standardization, financing support and marketing, capacity building and partner development.

Data shows that the project has been implemented in 20 countries, and more than 2.5 million small solar systems have been promoted, with an accumulated installed capacity of more than 200 MW, providing clean energy for millions of families and improving living standards of a large number of households.

7

Investment Recommendations

Chapter 7 Investment Recommendations

7.1 Strengthening policy coordination and strategic alignment, and providing more financing support and guarantee.

First, energy policy dialogue. Chinese and African governments should hold high-level energy policy dialogues on a regular basis, and conduct in-depth discussions on energy development strategies, policy orientation and cooperation directions through high-level policy dialogues, so as to ensure that their cooperation on clean energy is consistent with their respective national development strategies and international commitments, and build high-level consensus for cooperation on renewable energy. An expert group could be established on renewable energy to carry out joint research and technical exchanges around issues such as energy transformation, technological innovation and fund raising. Road maps and action plans for the development of clean energy could be formulated to clarify the objectives, principles and priority areas of cooperation, and map out the vision for the long-term development of renewable energy projects. They could also share experiences and cases, sum up and promote successful experience and best practices of renewable energy projects by Chinese enterprises in Africa, and further deepen their cooperation on renewable energy.

Second, financial support for projects. Giving full play to the positive roles of the Green Investment and Finance Partnership (GIFP), mobilizing African countries, China's renewable energy enterprises, multilateral development banks, international non-governmental organizations and other players to jointly take risks, actively leveraging funds, providing support for clean energy projects in Africa through various channels, and providing diversified and pragmatic solutions for the development of renewable energy projects in African countries. Financial institutions, such as China-Africa Development Fund, and policy banks, such as the Export-Import Bank of China and China Development Bank, could provide more support to renewable energy projects in Africa, and support China's renewable energy businesses in investing in Africa.

Third, alignment of project rules. China and Africa could work together to establish a risk assessment system for renewable energy projects, guide China's renewable energy enterprises to conduct a comprehensive risk assessment of investment projects, including political, commercial and environmental risks, and formulate corresponding measures for risk mitigation. They could work together to strengthen the alignment of technical standards on renewable energy, and encourage China and Africa to follow common rules and standards in the design, construction and operation of renewable energy projects. At the same time, communication and coordination of laws and regulations should be strengthened to ensure smooth progress of the projects while ensuring legal compliance.

7.2 Tracking key markets by districts and developing projects in light of local conditions.

First, developing renewable energy projects in light of local conditions. Given the difference of African countries in levels of economic development, unbalanced industrial electrification levels, and varied natural and geographical conditions, renewable energy businesses in China need to develop renewable energy projects based on local conditions, considering risk controllability, difficulties in project management and development, market development potential and other factors. Among them, the development of power industries in sub-Saharan LDCs and remote areas of some countries is still in their infancy, and their national power grid has yet to take shape, thus they are not equipped to access and accommodate large power supplies. It is recommended that they should actively construct microgrids and decentralized renewable energy systems as projects meeting basic livelihood needs and ensuring people's wellbeing. For countries with political stability, sound economic foundation and great market potential, the recommendation is to further boost renewable energy cooperation focusing on hydro, wind and PV power, and actively participate in intergovernmental energy cooperation mechanisms to bring projects to a reality. To be more specific, hydropower is recommended for Nigeria, Ethiopia and other countries, wind power for Egypt, South Africa, Algeria and other countries, PV for Egypt, Algeria and other countries, and geothermal energy for Kenya and other countries.

Second, working with developed countries for tripartite cooperation in Africa. At present, Global Gateway Strategy of the European Union and the Build Back Better World (B3W) Initiative of the United States all regard African countries as major cooperation partners, and renewable energy as an important cooperation area. They have deployed a number of renewable energy projects in Africa. Chinese enterprises could strengthen tripartite cooperation with enterprises from developed countries, such as those in Europe and America, and international financial institutions, and jointly conduct renewable energy projects in African countries, featuring shared risks and benefits.

7.3 Raising the awareness of overseas risk prevention and improving risk control mechanisms for the process.

First, better manage and control risks when projects are conducted. Specifically, it covers the following four aspects: On risk identification, identifying the types of investment risks, predicting how risks are likely to played out and their consequences, and establishing an early warning mechanism. On risk analysis and evaluation, analyzing the probability of various risks and the depth and breadth of their possible impact. On risk responses, upholding the principles of risk avoidance and acceptability, and formulating countermeasures. Common measures would include risk avoidance, risk retention, risk transfer and risk control. On risk monitoring, it is necessary to monitor the risks already identified and try to control them as they arise. For risks that have already occurred, it is necessary to minimize losses from the risks according to response measures formulated in advance.

Second, due diligence on the realities of projects. In order to find out the realities of projects, renewable energy businesses could rely on international organizations with green dedication, such as the BRI International Green Development Coalition (BRIGC), or hire professional market research analysts for field surveys on politics, society, economy and people's livelihood of the place where the projects are located, or conduct discussion and exchanges with China's economic and commercial offices in the host country and Chinese-invested enterprises that are more familiar with the local situation, so as to fully grasp the basic background of the project. Businesses could also review the conditions for access proposed by the host government, such as project evaluation, financial insurance, exit mechanism and diversified participation, and predict potential risks of the project according to the results of the preliminary feasibility study, and formulate corresponding strategies for risk control.

Third, strengthened prevention and control of financial risks related to the project. In view of the complex and changeable features of investment risks for projects in Africa, it is necessary to strengthen risk awareness. On political risks, overseas investment insurance provides protection against economic losses caused by political risks, such as war, political riots and breach of contract in the host country. On exchange rate risks, it is recommended to agree on favorable terms of the contract, make good use of hedging instruments, such as forward settlement and sale of foreign exchange (A customer signs a forward exchange settlement or sale agreement with the bank, agreeing on the foreign currency type, amount, exchange rate and term for settlement or sale to be conducted in the future after execution of agreement.), protection with foreign exchange swap (The bank and the customer determine RMB and foreign currency principals based on agreed exchange rate and foreign currency amount, exchange principals according to a certain mode. On the delivery date of the two transactions, the foreign exchange settlement or purchase shall be handled according to the currency type, amount and exchange rate agreed in the swap contract.), forward exchange transactions (The customer signs the forward FX transaction agreement with the bank, agreeing to settle the funds based on the specified exchange rate and maturity on a day in the future.), in order to adapt to risks from two-way fluctuations of exchanges rate and maintain financial neutrality. On financing risk, it is recommended to establish strategic partnership with financial institutions and make the best use of sovereign-backed financing. On risk related to accommodation, as conditions allow, local consultants should be hired for due diligence and comprehensive evaluation of the market, management, technical and capital risks that the investors may face regarding the project. On pricing risk, a complete market analysis and forecast for equipment prices are recommended. It is necessary to lock in a good price for investment and purchase, keep a margin of safety for yields, reasonably control costs and improve efficiency. On payment risks from the owner, it is necessary to timely follow the changes in national debt and inflation and give an early warning to avoid major changes in the real payment ability of project funds due to various factors.

7.4 Combining diversified financing models for the successful implementation and sustainable development of projects.

When investing in renewable energy projects in Africa, combining multiple financing models is the key to make more projects a success and ensure that they are sustainable.

First, strengthening green financial innovation. Development financial institutions in China should take the lead in raising the standards of green investment, facilitating green credit, bonds and insurance, among other products, channeling more public funds to clean energy, improving risk assessment mechanisms for overseas clean energy projects (especially PV and wind projects), and avoiding overemphasizing risks related to the country and neglecting objective evaluations of specific industries and projects.

Second, launching preliminary feasibility funds. Drawing on the experience of multilateral financial institutions and European and American policy banks, it is recommended to try to set up preliminary feasibility funds in early development phases of projects to support renewable energy businesses or developers to make an overall assessment of the environment, grid connection, renewable energy resources and power plant capacity, energy costs, electricity rate and related risks. Such funds can be provided by government or donor agencies to support preliminary feasibility study of the project and pave the way for the next stage of bankable feasibility study. Once the project makes progress, the preliminary feasibility funds will be purchased by mid-term construction funds at commercial prices and converted into equity investment in the project.

Third, innovating coordination mechanisms for funds. Innovating the collaborative financing mechanism of "aid + loan + investment + trade", formulating tailored assistance plans for each African country in need, guiding solvent beneficiary countries to use this collaborative financing mechanism, and using foreign aid funds to encourage private capital and businesses to participate, in order to reduce sovereign debt burden of the host country, let a small amount of official development assistance play catalytic role in landing major projects, and provide growth opportunities for the long-term development of the partner countries.

Fourth, developing international carbon financing mechanisms. Article 6 of the Paris Agreement provides a new opportunity for African countries to participate in the global carbon market and sell carbon credits generated by renewable energy projects. Among them, Article 6.2 of the Paris Agreement outlines the possibility of cooperative approaches and the transfer of Internationally Transferrable Mitigation Outcomes (ITMOs) between different actors through bilateral agreements. Article 6.4 allows countries to issue carbon credits under the Sustainable Development Mechanism (SDM) of the international carbon market under the jurisdiction of the new UNFCCC. Under this mechanism, all Parties to the Paris Agreement can provide funds and technologies to other countries to reduce emissions, and the reductions achieved will be used for emission reduction targets set out in their NDCs under the Paris Agreement. The Africa Energy Outlook 2022[11] published by IEA evaluated the economic potential that Article 6 of the Paris Agreement could generate for African countries. The results of evaluation show that by 2030, ITMOs could generate USD225-245 billion in net financial flows to African countries and the implementation of Article 6 mechanisms could deliver financial flows that exceed 20% of investment in clean energy in Africa, helping clean energy projects reach bankable status.

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