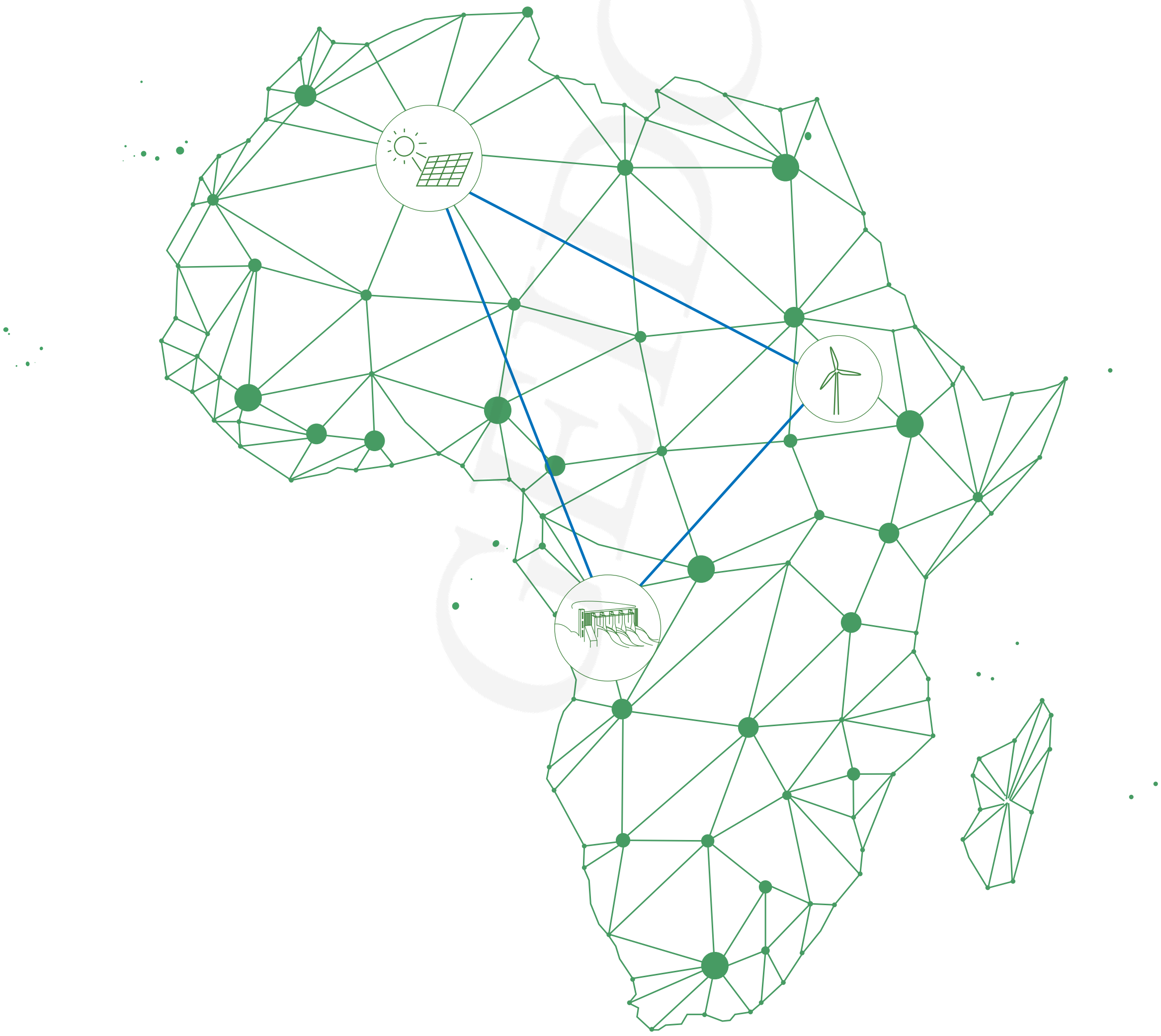
Global Energy Interconnection
Development and Cooperation Organization
全球能源互联网发展合作组织

Africa Energy Interconnection Planning Research Report



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Preface

Africa is the most promising region in the world. In recent years, Africa has experienced rapid economic growth and become an important growth pole in the world economy. This rapid economic growth is expected to maintain its high level in the future. Africa is endowed with especially abundant clean energy resources of which hydro, wind and solar respectively account for 12%, 32% and 40% of the world totals. Geothermal, marine and biomass energies are also widely distributed in Africa. These enviable nature gifts ensure large-scale exploitation and utilization which will be essential for sustainable development of society and economy in Africa. Through the construction of *Africa Energy Interconnection* and a cross-border/inter-regional energy distribution platform, large-scale exploitation, optimal distribution and efficient utilization of clean energies can be realized.

Based on the current situation of Africa, GEIDCO has conducted this *Africa Energy Interconnection Planning Research*, aiming to achieve clean and sustainable future. This research focuses on the difficulties and hot issues regarding development of energy and power in Africa, including the opportunities in sustainable development, the future trend of energy & power, the feasible mode and layout of clean energy exploitation, and the overall/regional energy interconnection planning. Furthermore, implementation timing and key projects are proposed in this research. Investment and comprehensive economic, social and environmental benefits are analyzed.

Accelerating the construction of Africa Energy Interconnection will promote cross-border and inter-regional interconnection, and potently ensure reliable and affordable supply of clean energy as a driving force for the development of industrialization and regional integration in Africa. In this way, the “2030 Agenda” of United Nations and the “2063 Agenda” of African Union can be implemented to realize the autonomously sustainable development of Africa and further promote the construction of the Community of Shared Future for Mankind.

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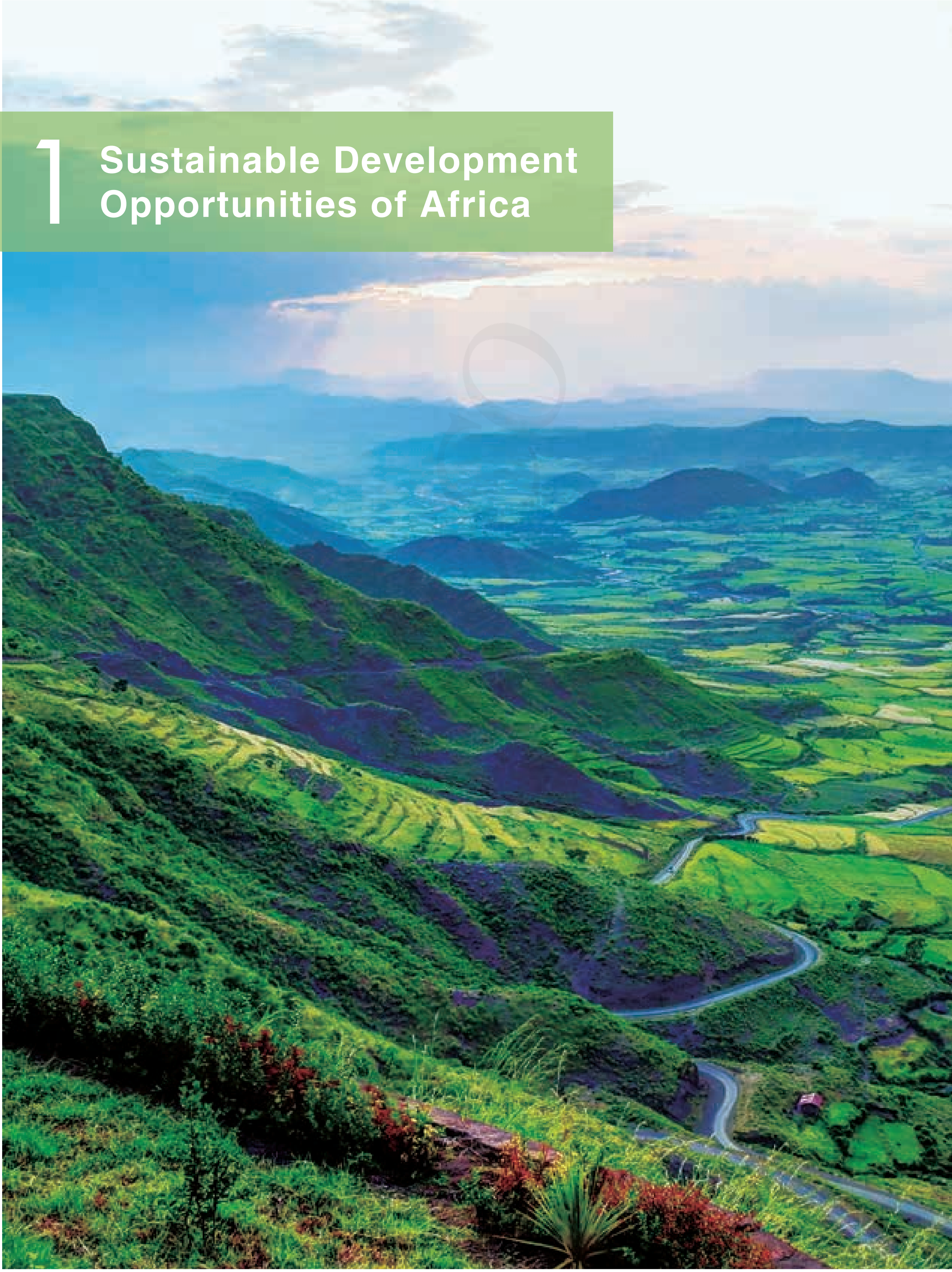
1 Sustainable Development Opportunities of Africa



Africa is experiencing an increasingly stable political situation, continuous release of demographic dividend and continuous improvement of business environment. Relying on its abundant mineral and clean energy resources, Africa is embracing a new opportunity characterized by industrialization, urbanization and regional integration, presenting higher requirement for energy and power development. The only way to solve the problem of energy shortage of Africa, to guarantee safe and reliable energy supply in Africa and to realize sustainable development of Africa is to accelerate the exploitation of clean energy resources and to form a structure of energy interconnection dominated by clean energy.

1.1 New Development Stage of Africa

New development achievements made by Africa: (1) The situation in Africa is constantly improving and its international status is being steadily enhanced. Africa has basically realized regional peace and stability, accompanied with minimal regional conflicts in history. With continuous improvement of integration, all African countries are taking an active part in international cooperation and global governance, to play important roles in the international politics and the global structure. **(2)** Africa has embraced rapid economic development, providing new driving force for the world economy. Since the new century, Africa's economy has witnessed the rapidest growth in the world, with the average annual growth rate more than 4%. In 2017, Africa's GDP was up to 2.4 trillion USD. **(3)** Africa is experiencing rapid improvement of urbanization level and continuous release of demographic dividend. With a population more than 1.2 billion dominated by the young, Africa enjoys extremely abundant labor resources. The urbanization rate in Africa had increased from 25% in 1975 to 41% in 2017 in general, and in some African countries has reached the level of developed countries.

2017
Africa's GDP per capita
<2,000 USD

Arduous task for Africa to realize sustainable development: (1) Africa's economy is at a relatively low development level as a whole. In 2017, Africa's GDP per capita was less than 2,000 USD, only 1/5 of the global average. According to relevant data provided by the UN, the poverty-stricken population in the world is about 750 million, half of which is from Sub-Saharan Africa. **(2)** Africa's economy is fragile due to single structure. Due to a relatively low level of industrialization, Africa highly depends on primary products. Currently, 40% of Africa's GDP is from the revenue of primary products. The dependence of oil producing countries' economic growth on crude oil export is generally higher than 20%, leading to a great impact of international bulk commodity price fluctuation on Africa's oil export. **(3)** Due to the imperfect financial market, financing of infrastructure projects is difficult for Africa. Africa is confronted with a relatively low domestic saving rate, a small available capital, imperfect financial systems including bank, insurance, security and guarantee, and single financing channels. Currently, the investment in Africa's infrastructures is mainly from governments. However, the government financial revenue which is generally small in scale and slow in growth rate cannot meet the huge fund demand from infrastructure construction. **(4)** African countries are carrying out urbanization without sufficient industrial accumulation and industry support, resulting in “hollowing” to a certain extent. Moreover, Africa’s infrastructure development mismatches its urbanization, restricting the sustainable socio-economic development.

Table 1.1 Top 10 Countries in the World in terms of Poverty-stricken Population and Poverty Incidence[1]

No.		1	2	3	4	5
Poverty-stricken population size	Country	India	D. R. Congo	Ethiopia	Bangladesh	China
	10,000 persons	26,441	5,318	2,938	2,815	2,579
Poverty incidence	Country	Madagascar	D. R. Congo	Burundi	Malawi	Mozambique
	%	77.8	77.1	73.7	70.9	68.7
No.		6	7	8	9	10
Poverty-stricken population size	Country	Tanzania	Madagascar	Uganda	Pakistan	Malawi
	10,000 persons	2,336	1,738	1,256	1,108	1,075
Poverty incidence	Country	Guinea-Bissau	Central African Republic	Zambia	Rwanda	Lesotho
	%	67.1	66.3	64.4	60.3	59.7

Relatively low level of energy development and prominent problems regarding the popularization of electricity in Africa: (1) High primary energy ratio and low efficiency. In African countries, the accessibility to oil, natural gas, electricity and other modern energy is relatively low. The accessibility to electricity is only 52% in Africa in general and less than 50% in 2/3 of African countries. Africa has totally about 600 million people without access to electricity, accounting for more than half of the population without access to electricity in world. **(2)** The cost of energy use is high, restricting the economic development and the improvement of people’s living standards. In view of end-use electricity price, the average electricity price in African countries is up to 0.14 USD/kWh, which is 2~3 times than in developing countries[2]. In 2015, the energy consumption per capita and electricity consumption in Africa were only 0.69 TCE and 535 kWh respectively, being 38% and 18% of the world average respectively. The electricity consumption accounted for 9.3% of the end-use energy consumption, only half of the world average. The residential electricity consumption was only 5.4%, less than 1/4 of the world average. **(3)** Low utilization rate of modern energy has caused severe health issues. Currently, the original biomass energy (including firewood, coal, charcoal and animal waste) is the mostly used energy in Africa, 70% of households in Africa depend on biomass energy for cooking

2015 Africa
Energy consumption per capita
0.69 TCE
Electricity consumption per capita
535 kWh

[1] Data source: UN.
[2] Data source: The World Bank.

and heating, resulting in severe indoor air pollution. In 2015, the expected longevity in Sub-Saharan Africa was about 61 years, 13 years lower than the world average.

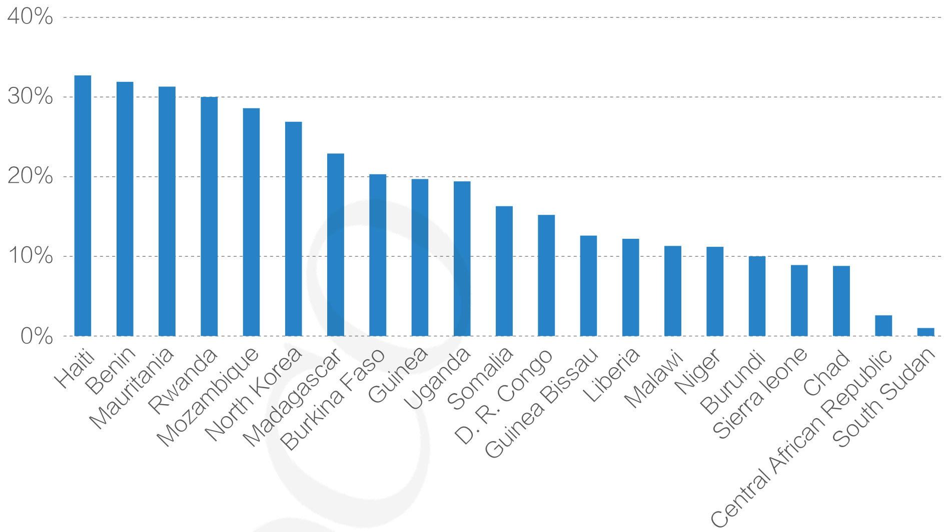


Fig. 1.1 Countries with the Lowest Popularizing Rate of Power in the World[1]

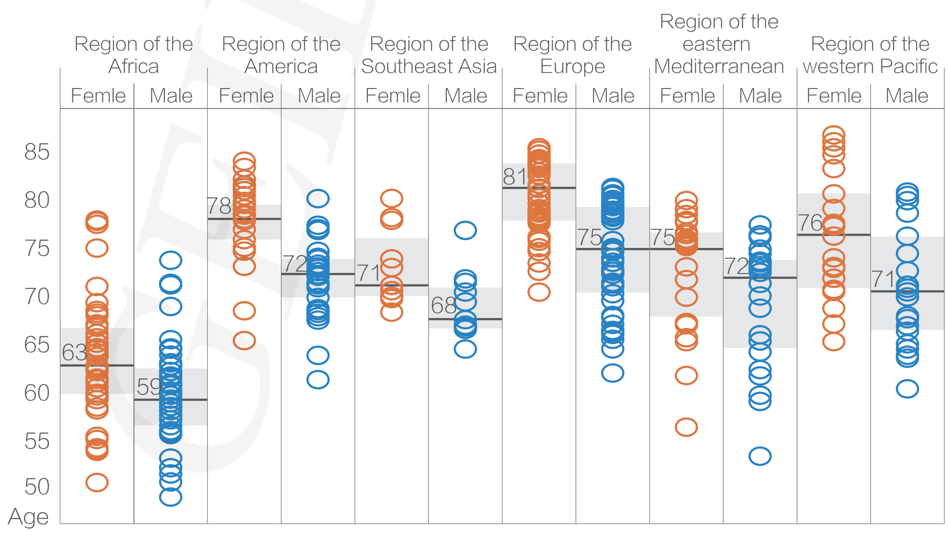


Fig. 1.2 Life Expectancy at Birth in All Regions in the World (by Gender)[2]

Severe environmental pollution and weak adaptability to climate change due to Africa's present energy structure: In 2013, more than 85% of Africa's population lived in an environment with $PM_{2.5}$ exceeding the standard specified by WHO.

1 Data source: IEA.
2 Data source: WHO.

In Sub-Saharan Africa average $PM_{2.5}$ concentration Increase by **60%**

This is closely related to the over utilization of biomass energy. The average $PM_{2.5}$ concentration in Sub-Saharan Africa has increased by nearly 60% in recent five years and its emission in Africa accounts for 25% of the global emission. [1]According to data from WHO, the $PM_{2.5}$ concentration in Cameroon, Uganda and other African countries greatly exceeds the standard, causing the air quality in these countries the worst in the world. Although Africa is not a main greenhouse gas emission region, the greenhouse gas emission here can easily cause adverse impacts due to Africa's sensitivity and vulnerability to climate change. If global temperature rise by 1.5~2℃, 40%~80% of the cultivated land suitable for the planting corn, millet and sorghum in Africa will be less desirable for cultivation[2].

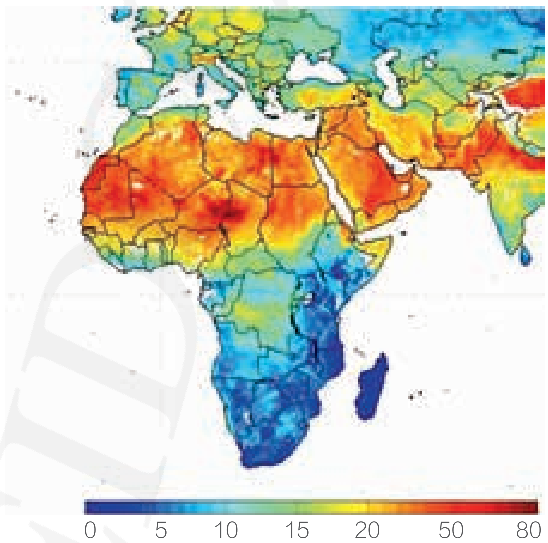


Fig. 1.3 $PM_{2.5}$ Concentration in Africa[3]

1.2 Enormous Sustainable Development Potential of Africa

1.2.1 Outstanding Resource Advantages

Abundant mineral resources: Africa obtains vast reserves of 14 major mineral resources. To be specific, the reserves of gold, chromium, platinum family, manganese, cobalt, bauxite and phosphorus take the first place in the world, accounting for about 40%, 87%, 89%, 56%, 50%, 30% and 62% of the total reserves in the world, respectively.

Enormous clean energy development potential: Africa is honored as a treasury of clean energy resources, where the reserves of hydro, wind and solar energy account for 12%, 32% and 40% of the total world amount, respectively. Africa

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1. Data source: *Energy and Air Pollution* issued by IEA.
2. Data source: special reports issued by the World Bank.
3. Data source: *Energy and Air Pollution* issued by IEA.

can meet its own development demand by these abundant clean energy resources and can also transform its resource advantages into economic advantages, to export clean energy and power to Europe and other regions in the world.

1.2.2 Gradual Release of Demographic Dividend

Rapid population growth in Africa: The population was more than 1.2 billion in 2017, doubled that in 1990 and accounted for about 16.3% of the world's total. With the highest population growth rate in the world, Africa population is expected to reach 2.5 billion by 2050.[1]

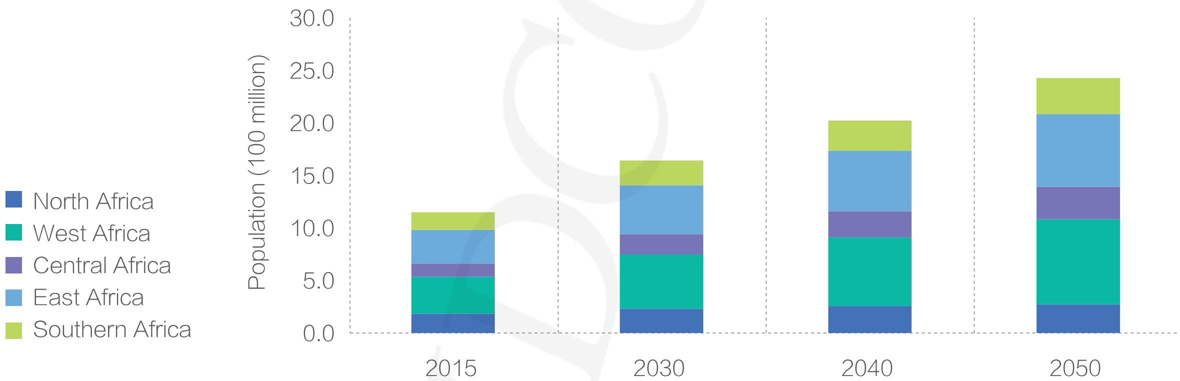

Fig. 1.4 Population Forecast of Africa[1]

2050
labor force in Africa
1.3 billion

Higher proportion of the young than other regions in the world: By 2030, Sub-Saharan Africa will see half of the global labor force growth. By 2050, the number of labor force in Africa will be more than 1.3 billion. The enormous labor force will provide potent support for Africa's industrialization and make up for the labor shortage caused by global aging.

Rapid improvement of the labor force quality: In the 21st century, the quality of the labor force in Africa is improved rapidly owing to gradual improvement of education and medical care in Africa and Africa's active participation in international educational and cultural exchange.

1.2.3 Huge Market Potential

Large internal market capacity: In 2010~2016, the average annual growth rate of personal expenditure in Africa was 3.6%, showing a strong expenditure trend. In the future, Africa's domestic spending power will be improved significantly

[1] Data source: UN.

along through rapid population growth and promotion of industrialization and urbanization.

Diversified trading partnership and large external market space: Over the past 20 years, the value of trade between Africa and other regions in the world had quadrupled, and Africa's main trading partners further covered emerging market economies in addition to European and American countries. In 2002~2012, the proportion of the EU in Africa's total foreign trade value decreased from 46.2% to 34.3% while the proportion of BRICS (except for South Africa) increased from 9.1% to 24%. Trading between Africa and China has maintained rapid growth. In 2017, the total value of imports and exports between Africa and China was 169.75 billion USD, with an annual growth rate of 13.8%. To be specific, the value of exports from China to Africa was about 94.5 billion USD, with an annual growth rate of 2.4%; the value of imports from Africa was about 75.25 billion USD, with an annual growth rate up to 32.2%.

1.2.4 Improved Development Environment

Domestic development environment

The governments of most African countries are continuously building a sound development environment. (1) Administrative efficiency is improved through institutional innovation. According to the Report 2016 issued by the World Economic Forum, Rwanda, Kenya, Senegal, Ethiopia and other African countries had witnessed a significant rise in government management index over the five years, and their global competitiveness had exceeded some Asian developing countries. **(2)** Active in construction of national industrial parks. Africa has launched attractive and competitive preferential measures to support the development of diversified emerging industries such as information technology, communication and bio-pharmaceuticals. **(3)** Improvement of financial stability and monetary policy discipline. According to the report issued by the World Bank, 19 of the 50 economies which have made the rapidest progress in global business environment reform since 2005 come from Africa. The foreign direct investment in Africa increased from 57.8 billion USD in 2008 to 179.7 billion USD in 2017. Moreover, investment flows are also increasingly diversified, with a significant increase of investment in industries such as consumables, finance and communication information.

The governments of most African countries attach great importance to the securing and supporting roles of energy and electricity. Most African countries have set development goals regarding clean energy development, energy saving and emission reduction. To be specific, Tanzania, Rwanda and Niger have set the ambitious goal of realizing 100% clean energy development before 2050, and nearly 30 countries have set clear development goals regarding accessibility of electricity. South Africa, Kenya and Côte d'Ivoire expect to realize 100% accessibility of electricity by around 2020, while the other 10 countries including Angola, Ghana and Ethiopia have decided to provide everyone with the access to electricity by around 2030. Meanwhile, the governments of all African countries are keen for clean development. To realize these goals, African countries have introduced a series of policies, such as tariff subsidy, capacity auction and independent renewable energy power producers, to encourage clean energy development and construction of transmission and distribution networks. Moreover, African countries have also established rural electrification actions and set up cooperative modes between state-owned power distribution networks and public utilities.

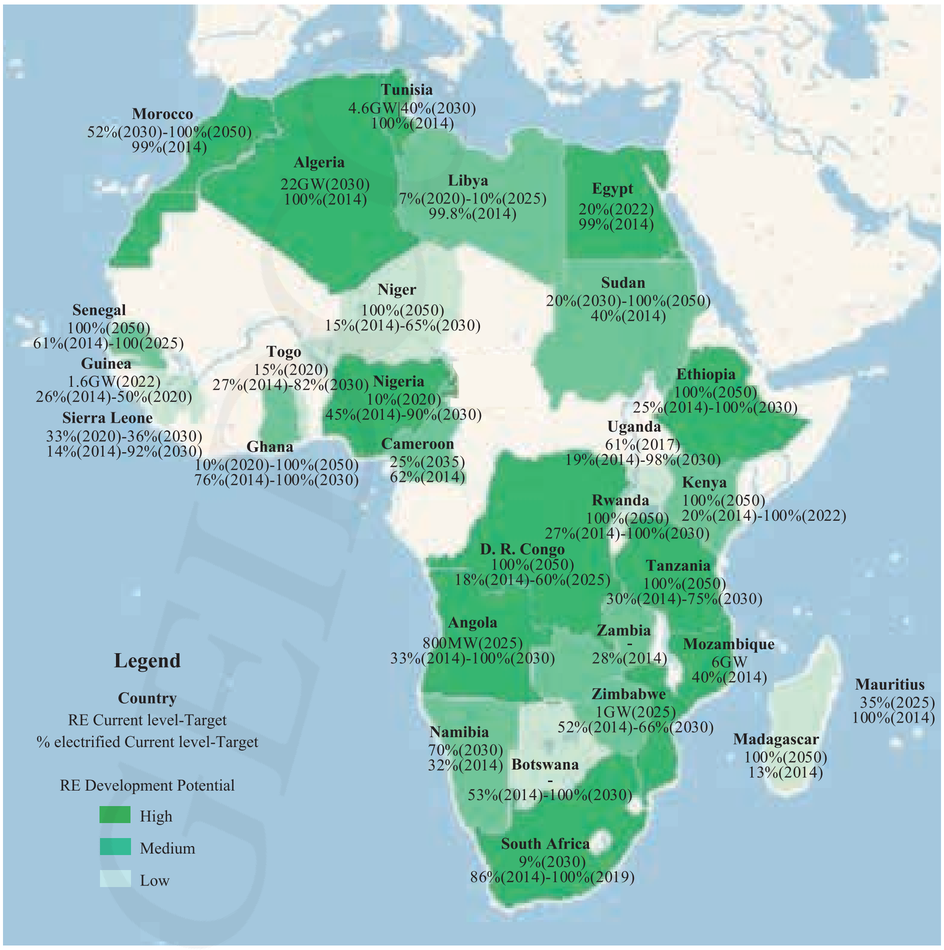

Fig. 1.5 Renewable Energy Development Targets of Africa[1,2]

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❶ Data source: IIR and REN21.

❷ This report takes no position on any territorial sovereignty and international boundary delimitation, as well as name of any territories, cities or regions, the same below.

Regional development environment

Momentum for common development in the African region is adequate. (1) The Pan-Africanism provides an important cultural basis for the joint development of African countries, and it mainly refers to "African Renaissance" in the new era, serving as a banner calling on the African people to accelerate political and economic unity and integration, fostering a common identity consciousness and creating a common development vision for the African people. **(2)** As the backbone force for boosting Africa's regional development, the African Union and sub-regional organizations have established joint development mechanisms, to boost regional development by focusing on energy and power. To respond to the AU Agenda 2063, African countries have jointly launched a series of energy and power development mechanisms, such as the Programme for Infrastructure Development in Africa (PIDA), the Action Plans on Energy and the Africa Renewable Energy Initiative (AREI). These mechanisms have established clear goals and short-term action plans for joint development of clean energy.

International development environment

Africa's sustainable development is a major concern of international organizations such as the UN. Africa's sustainable development is the key for the realization of the UN's Millennium Development Goals. The UN is enlarging and strengthening its support for the implementation of the AU Agenda 2063 and the New Partnership for Africa's Development, to promote regional economic integration and interconnection, and eradicate poverty in all its forms and dimensions, thereby making all the African people accessible to cheap, reliable and sustainable energy.

International organizations actively participate in and support Africa's sustainable development. The IMF promised its support to Africa's sustainable infrastructure development, and would particularly boost the sustainable, robust and inclusive growth of Sub-Saharan Africa, thereby realizing UN's Sustainable Development Goals. The Group of Twenty (G20) has paid attention to Africa's industrialization, and provided support for Africa's sustainable, inclusive and transparent industrial transformation. Now, the G20 works with Africa in the field of accessibility to energy, clean energy and energy efficiency, to support Africa to realize the goals established in the 2030 Agenda for Sustainable Development.

Africa's sustainable development is a major point of "The Belt and Road Initiative". The Belt and Road Initiative has broadened the win-win cooperation between China and Africa. According to the initiative, China has proposed "Ten Major China-Africa Cooperation Plans" with an amount of up to 60 billion USD and established a development fund of 20 billion USD. Meanwhile, China will actively support the infrastructure construction in Africa, providing equipment and materials for energy saving, emission reduction and utilization of renewable energy, carrying out cooperative projects regarding solar energy, biogas, hydropower and environmental-friendly cooking stoves, to assist Africa's clean sustainable development.

1.3 Clear Direction of Africa Sustainable Development

To accelerate industrialization, urbanization and regional integration has been a consensus of the African people. According to the AU "Agenda 2063 - the Africa We Want", Africa will implement the Action Plan for the Accelerated Industrial Development of Africa, to improve the productivity and the added value of natural resources by industrialization; boosting urbanization and realizing urban-rural integrated and balanced development can eradicate poverty and improve people's living standards; accelerating the integration progress and the establishment of African Continental Free Trade Area can promote the free circulation of population, capital, cargo and service, and accelerate infrastructure construction, thereby realizing comprehensive economic integration.

1.3.1 Industrialization

Industrialization is necessary for Africa's modernization. Before the Industrial Revolution. There was a relatively small economic gap among the continents and Europe's pioneering advantages were not significant. After the Industrial Revolution, European and American countries have witnessed economic take-off, rapid industrial development and rapid increase of per capita output and income. By contrast, Asia and Africa were still at the stage of traditional agricultural society experiencing slow economic growth, with the gap from Europe gradually enlarged.

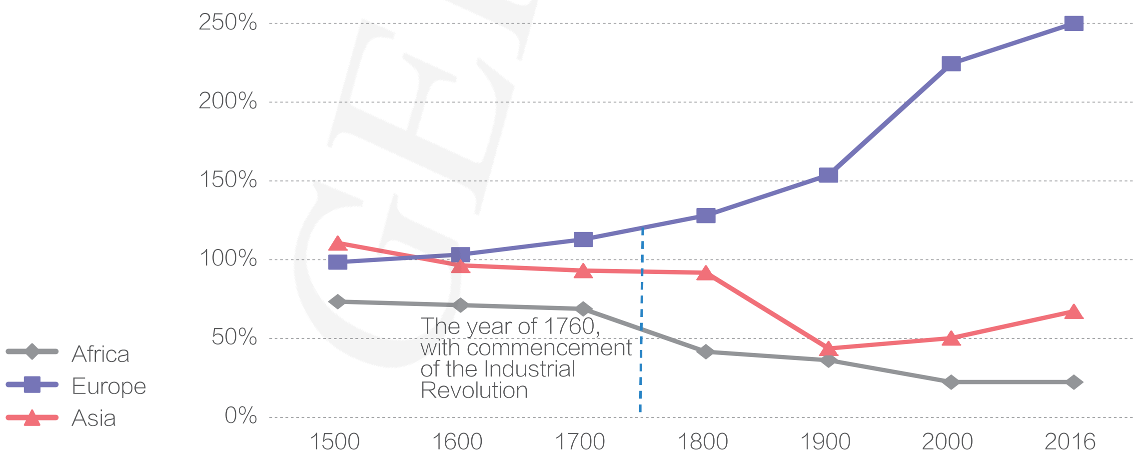


Fig. 1.6 Comparison of GDP per Capita between Three Continents and the World[1]

[1] Data source: Maddison Project, World Bank.

Box 1.1

Industrialization Achievements made by China

Since the 1950s, China has focused on industrialization particularly in the field of energy, mining and metallurgy, machinery, chemicals and other heavy industries, and established industrial systems in core cities throughout the country. Since the 1980s, China has boosted the industrialization mainly by focusing on the sectors of consumer goods (including household appliances) processing, urban fundamental construction and transportation, communication and export. Through industrialization, China's economy has been restructured deeply and has maintained rapid growth over 30 years. The average annual economic growth rate was up to 9.6% in 1980~2017. In 2017, China became the world's second largest economy, with the GDP of about 12 trillion USD and the GDP per capita of USD 8,800 USD.

African countries have gained rich experience in industrialization. After the national liberation movements in the 1960s, African countries had actively explored the ways of industrialization, such as import substitution, export processing, privatization and foreign investment attraction. However, under the common impacts of such factors as uneven resource distribution, market fragmentation, uneven international market, policy failure and poor implementation, Africa failed to achieve expected industrialization goals, and even suffered from regression to a certain extent in the industry and the manufacturing industry, with the proportion of industrial added value in GDP of Africa dropping from 33.9% to 27.1% in 1995~2015, and the proportion of the added value of Africa's manufacturing industry in the world's added value of manufacturing industry dropping from 9% to 4% in 1990~2014. African countries have gradually recognized that they must make full use of their respective resource endowments to take the integrated industrial road with complementary advantages and mutual benefits.

Africa's industrialization strategy has become increasingly clear. Since 2014, the international bulk commodity (particularly oil) price has plummeted constantly, causing a huge impact on Africa's economy and consequently highlighting Africa's fragile economic structure dominated by the export of primary raw materials. For this reason, regional integration organizations of Africa and the governments of African countries have adjusted their economic development strategies and policies and strengthen the industrialization. The AU Agenda 2063 considers the industrialization as a major development direction, to promote Africa's economic diversification by promoting skills training and business environment reform and unleashing the creativity and energy of the young. Côte d'Ivoire, Uganda, Egypt, Kenya, South Africa, Zimbabwe and other countries have formulated development plans and strategies, to extend the industry chain by virtue of their respective resource endowments, improve the added value and take the road of intensive development.

1.3.2 Urbanization

Urbanization injects new impetus into economic development in Africa. **(1)** Urbanization increases industrial productivity. Urbanization can effectively gather and allocate various production factors, especially the reallocation of labor resources. It can also reduce the transaction cost of production organization. **(2)** Urbanization brings the advantage of centralized economy. Scale economy is formed based on division of work and collaboration after population concentration, industrial concentration, market concentration and information concentration. **(3)** Urbanization promotes infrastructure construction. At present, the infrastructure construction projects in 2/3 African cities still need investments. Cities and towns need to construct traffic facility, residence, school, hospital, factory and other infrastructures. This construction will bring in a large amount of investments and promote the development of relevant industries. **(4)** Urbanization will bring a huge market space. Urbanization will change people's consumption mode, promote the economic increase, create the middle class and stimulate the growth of consumer demand.

African urbanization development needs overall planning to achieve the integrative development of industries and cities, accommodate more people, and realize the sustainable development. **(1)** Strengthen the top-level design, complete the overall planning for urban development, and optimize the division of urban functional zones. Meanwhile, make full use of the leading role of big cities, encourage the development of small and medium-sized cities and form an urban system with a moderate development scale. **(2)** Set industrialization as a objective of urbanization development. Coordinate the synchronous development between urbanization and industrialization. Achieve the integrative development of industries and cities. **(3)** Accelerate the infrastructure construction in terms of urban traffic system, energy supply and the like in Africa. Improve the business environment. Reduce the living and business costs. Guarantee the sustainable development of urban economy.

1.3.3 Regional Integration

The sustainable development in Africa needs to accelerate the regional integration development. **(1)** The market scale of a single African country is relatively small and difficult to meet the demands of modern industrial development. **(2)** The resource distribution among African countries is unbalanced. Only a few of countries have complete industrial raw materials. Therefore, the regional integration is needed to realize the complementation. **(3)** African countries develop their relevant industries depending on their endowment advantages. A single African country is barely able to establish a complete industrial system. Therefore, the regional integration is needed to meet the demands of upstream-downstream industries of an industrial chain. **(4)** The African industrial development urgently needs the unrestricted flow of production factors. At present, production factors in Africa such as goods,

Internal trade volume of goods of Africa
16%
Total trade volume of goods of Africa

capitals and labors cannot achieve completely unrestricted flow. The internal trade volume of goods of Africa only accounts for 16% of the total (internal & external) trade volume of goods of Africa, severely restricting the progress of African industrialization.

It is gradually clear that Africa needs to promote the regional integration development.(1) Factor integration: The regional integration in Africa will effectively break the trade barriers between countries and generate the scale effects required by industrialization. The integration of capital and finance will provide a strongly economic support for industrialization, in favor of the construction of large-scale industrial projects. The integration of technology and labor will coordinate the divisions of production among multiple countries and form cooperation, to optimize the allocation of production factors, inspire the potential of scale economy, and enrich the regional market supply. The integration of cross-border traffic infrastructures will promote the development of relevant industries such as energy. **(2)** Market integration: The regional integration in Africa can break through the limitations of small market scale of each African country and meet the demands of market capacity in conformity with industrial development. On March 21, 2018, 44 African countries singed *African Continental Free Trade Area* (AfCFTA) to (a) further reduce tariff and eliminate trade barrier, (b) promote regional trade and investment development, (c) achieve unrestricted flows of commodity, service and capital within the African continent, and (d) gather various African economic entities to form a uniform big market. According to the combined estimates by U.N. Economic Commission for Africa, AFDB and African Union, after removal of tariff and non-tariff barriers, the internal trade volume proportion among African countries will rise from 10.2% (2010) to 21.9% (2022).

Internal trade volume proportion among African countries From
10.2% (2010)
to
21.9% (2022)

Box 1.2

European Union (EU): Model of Regional Integration

Like Africa, the market capacity of each European country is relatively small, and the strength of a single European country is relatively weak. Therefore, Europe urgently needs to achieve the regional integration to strengthen development momentum and increase influence on international affairs. Each European country has a compatible culture base and basically equivalent economic development level. These two advantages are conductive to the achievement of regional integration. Taking the customs union as the starting point, the EU further implements the policies of common market, and finally establishes an economic and political union. At present, it consists of 28 members and sets the most successful example of regional integration.

The EU injects new vitality into political, economic and diplomatic development of each member. The EU enjoys a complete decisionmaking body, executive brunches and so on. After the EU was established, although its members still have contradictions and disputes, they no longer start a war. Long-term stability and development are kept, and its external political influence increases significantly.

1.3.4 Prospect and Outlook

The industrialization level will increase significantly. It is expected that the proportion of African industrial added value to its GDP in 2030 will rise to about 35%. African countries with a relatively good industrial foundations, such as Nigeria, Mauritius, South Africa and Tunisia, will complete their industrialization process. In 2050, this proportion will increase to about 45%.

The urbanization level will increase significantly. It is estimated that Africa will make a historic leap by around 2035, and its number of urban population will exceed that of rural population. By 2050, the urbanization rate of Africa will be 56% and the urban population of Africa will increase by nearly 24 million/year, with the increase rate exceeding any country or region in the world.

The African economic aggregate will increase rapidly. In 2030, the African economic aggregate will reach 6.5 trillion USD which is 2.7 times the current level. In 2050, the African economic aggregate will reach 20 trillion USD and the per capita GDP in African will reach 8,000 USD. Some African countries will become medium-high income countries. The poverty in Africa will be basically eliminated.

1.4 Energy and Power: Key to Sustainable Development in Africa

To achieve the sustainable development, Africa needs to fundamentally break through the restriction on economic and social development caused by the current shortage in energy and power. In the AU Agenda 2063, high attention is paid to the development of energy and power in Africa. It clearly states that all energy resources in Africa will be utilized to (a) construct national/regional power pools and grids, and (b) implement the energy projects related to African infrastructure development plan, to provide modern, high-efficient, reliable, cost effective, renewable and clean energy for all families, enterprises, industries and organizations in Africa.

1.4.1 Energy and Power: Base and Motivation for Sustainable Development in Africa

Guarantee of energy supply is an important precondition for sustainable development in Africa. Energy is the material base of modern society. Each change in energy utilization by human is accompanied by a great leap in productivity and a significant progress in human civilization. In the future, fast population growth and increase in economic aggregate in Africa, especially the great development of industrialization and urbanization, will need the support from energy. Considering intensive development, energy-saving new technology and other favorable conditions, by 2050, the demand of primary energy in Africa will be at least twice the current level. Thus, guarantee of energy supply to achieve the sustainable development in Africa is a tough task.

Clean energy is fundamental to guarantee of energy supply to Africa. (1) Neither biomass energy nor fossil energy can meet the demands of economic and social development in Africa. At present, primary biomass energy is the main energy resource used in Africa, featuring low efficiency and severe pollution. It is difficult to meet the demands of modern industrial development. The fossil energy in Africa has limited reserves and uneven distribution. The proven oil reserves in Africa account for only 7.7% of the total amount in the world. The reserve-production ratio of oil in Africa is only 40.5, less than the world average level (53.3). The oil resource distribution in Africa is extremely unbalanced. The oil reserves of 4 countries, namely, Libya, Nigeria, Angola and Algeria, account for about 85% of the total amount in Africa. Over half of African countries have no oil resource. **(2)** Africa enjoys an exceptional advantage of clean energy. Its rich hydro, wind and solar energy are all suitable for large-scale centralized development. The utilization potential of solar energy is huge. Developing some of the high-quality clean resources can fully meet Africa's needs.

The proven oil reserves in Africa
7.7%
Total amount in the world

Electricity is the center of clean energy system in Africa. (1) Electric energy has a unique advantage compared with other energy. From the angle of production, over 90% of clean energy can only be used after they are converted into electricity. From the angle of configuration, electric energy can be instantaneously transmitted to each end-user at a remote place. From the angle of use, electric energy can be conveniently converted into other energy and controlled precisely. **(2)** Electrification promotes the increase of industrialization level. Industrialization in Africa, especially processing and manufacturing industries such as mining, steel, chemical, construction material and nonferrous metals, needs the rapid development of electrification as a support. Take the industrial development of aluminum oxide and electrolytic aluminum in Guinea as example. At least 15,000 GWh of power consumption will be required for local production of 1 million tons of aluminum ingots. According to China's experience, at the stage of industrial development, every one-percent-point growth in GDP is accompanied by the power demand of 1.2~2.3 percent points. Calculated based on the objective proposed in the AU Agenda 2063 that "the proportion of manufacturing industry output value to GDP reaches over 50%", in 2050, the development of manufacturing industry needs additional power consumption of 1,000,000 GWh. **(3)** Urban development needs the support from electrification. Urbanization will promote the rapid growth of power consumption in terms of traffic field (such as electrified railway and electric vehicle), public and civilian fields, and service field (such as business and logistics).

Box 1.3

Constructing UHV power transmission channel to help the industrialization of West Africa

The West Africa region is rich in mineral resources and has not entered the stage of large-scale development. Ore is mainly used for export, and local processing capability is weak. The industry is dominated by primary product processing and assembling, and manufacturing companies gather in the Gulf of Guinea and the coast of West Africa.

Take Guinea as an example, it owns 41 billion tons of **bauxite reserves**, accounting for 2/3 of the world's total reserves, among of which 29 billion tons are proven reserves, being the largest in the world. Most of Guinean bauxite resources are high-quality trihydrous bauxite, some of which contain more than 60% of aluminum. They are distributed over Guinean territory and easy to be mined. Guinea also owns about 15 billion tons of **iron ore reserves** which are of about 56 to 72 percent grade. Simandu and Ningba Mountain are two world-class iron deposits, with an average grade of 65.4% and 63.1% each. Due to the weak industrial foundation in Guinea, iron ore has not entered the stage of large-scale mining and processing.

Developing aluminum and steel industries is the key to Guinea's Industrialization. With abundant bauxite and iron ore, Guinea has a sound potential to incubate aluminum and steel industries. In May 2017, the president of Guinea, Alpha Condé, claimed that "We do not want Guinea to act only as a raw material seller, but wish to achieve more value conversion domestically." At present, most Guinean bauxite is exported directly. If bauxite can be processed and smelted locally, the aluminum products exported will generate more than seven times of the revenue. As such, if Guinean iron ore can be processed into steel products as export substitution, economical values will be increased by more than 6 times.

The aluminum and steel industries will act as the core motivator of Guinea's economic growth. By 2030, Guinea will produce 2 million tons of electrolytic aluminum and 10 million tons of steel; by 2050, 6 million tons and 40 million tons respectively. The aluminum and steel industries will contribute 57.8% to 67.4% of Guinean GDP in general. The total output value will exceed 80 billion USD and create about 1.1 million jobs.

Developing the aluminum and steel industries needs huge scale of power. Extracting one ton of alumina consumes 200~300 kWh of electricity, while producing one ton of electrolytic aluminums costs 13,000 to 15,000 kWh. Based on 6 million tons of aluminum ingots as 2050's annual output, the electricity consumption will exceed 80 TWh, which is more than 60 times compared with Guinea's annual power generation in 2016. Based on 40 million tons of steel as 2050's annual output, the total power consumption of the steel industry will be about 22 to 28 TWh (550~700 kWh/ton for steel production). Electricity will become a bottleneck for the future development of Guinea's aluminum and steel industry, and it is urgent to strengthen power interconnection to solve this huge power gap.

West African countries such as Ghana and Nigeria also have good conditions for developing mineral processing industries. Ghana’s bauxite reserves are about 1.5 billion tons, and the amount of mining is currently in a small scale. Ghana has the potential to produce more than 2 million tons of electrolytic aluminum in future. Nigeria possesses about 3 billion tons of proven high-grade iron ore reserves, but the current exploitation amount is limited. Nigeria has the potential to develop metallurgical industry in future.

Develop hydropower in Central Africa to meet the needs of industrial development in West Africa. Hydropower in Central Africa are highly complementary to the industrial development of West Africa. The Congo River has the most abundant hydro energy in the world, whose technically exploitable capacity is about 150 GW. The Inga basin’s installed capacity is expected to exceed 50.48 GW, and the number of annual utilization hours can reach 7,000 or more. Hydropower in Central Africa can be sent to the West African countries such as Guinea and Ghana through UHV/EHV transmission channels, to meet the energy needs of their industrial development.

1.4.2 Interconnection: Important Approach to Sustainable Development in Africa

Interconnection of energy and power is required to be accelerated to achieve the sustainable development in Africa. Infrastructures are cornerstones for the national economic development. Energy and power construction are the most important infrastructure construction. Improvement to interconnection of energy and power can greatly facilitate economic development. Clean energy resources in Africa feature a large total amount, various types, and huge development potential. However, the clean energy resources do not evenly distribute among African countries. Some landlocked countries are relatively lack of energy resources. Therefore, interconnection of energy resources is urgently needed to achieve mutual aid and complementation. Interconnection of energy and power is expected to (a) achieve large-scale development, allocation and use of clean energy, and (b) transform the resource advantage into the economic advantage.

Africa is at a relatively low level of energy integration, and its energy trade is dominated by fossil energy while its cross-border power interconnection is at the initial stage. The energy trade in Africa is dominated by the export of raw materials and the import of finished products, with a relatively small power

Power trade
0.8%
Total energy trade

exchange capacity. The gross volume of energy import and export is about 657 MTOE, consisting of 48.8% of crude oil export, 14% of oil products import and only 0.8% of power trade. In view of cross-border oil and gas pipeline network interconnection, oil and gas pipeline networks are of a relatively high density and interconnected closely in North Africa, while interconnected in an unconcentrated manner in other regions. In view of inter-continental interconnection, oil and gas pipelines has been built among African countries (i.e. Morocco, Algeria, Tunisia, Libya) and European countries (i.e. Spain, Italy and Malta), Egypt and Asian country (i.e. Jordan).

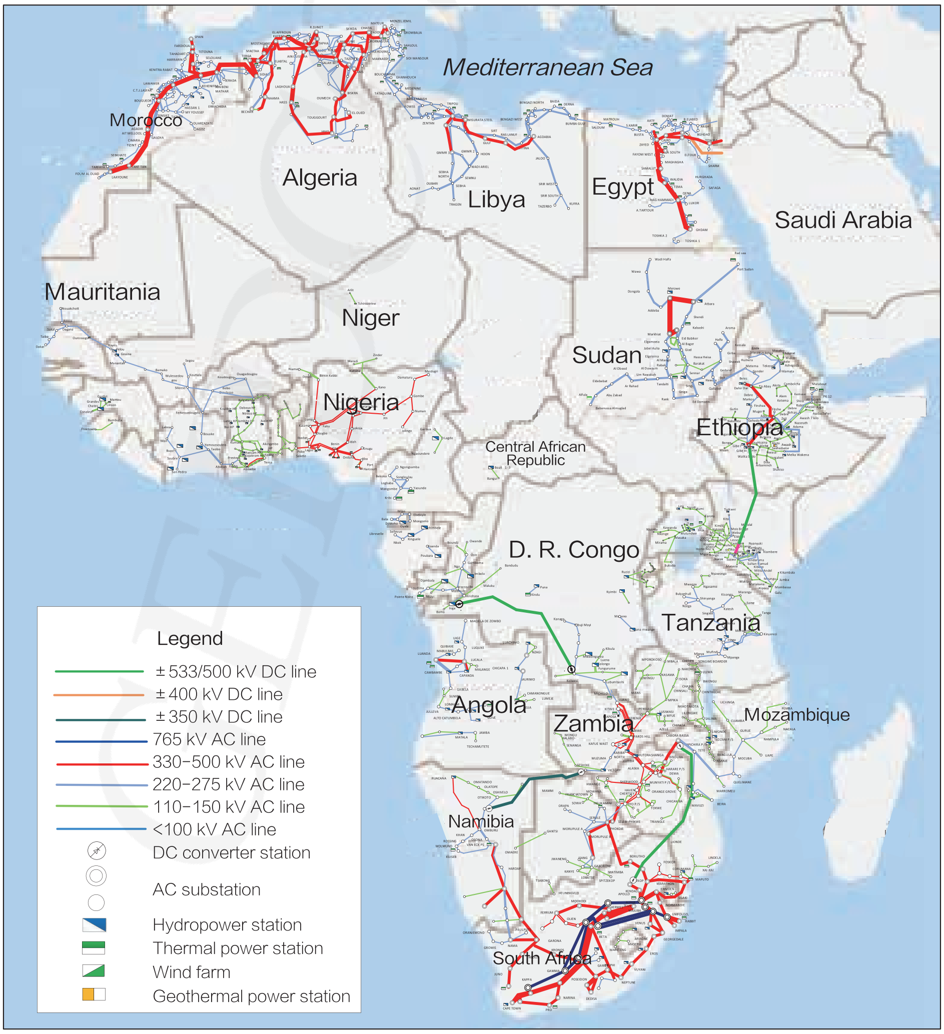


Fig. 1.7 Current Situation of Grid Interconnection in Africa

Table 1.2 Oil and Gas Pipeline Interconnection in Africa

Region	Country with Cross-border Channel	Country with Ongoing Cross-border Channel	Proportion of Country with Interconnection Realized
North Africa	5	0	100%
West Africa	5	1	33%
Central Africa	2	0	28.6%
East Africa	2	5	20%
Southern Africa	2	1	20%

In view of cross-border interconnection, power grids in Africa are interconnected in an unconcentrated manner instead of a unified manner, with a small power exchange capacity. Interconnected channels are at different voltage levels and dominated by AC interconnected ones, with only a ±533 kV DC Channel between Mozambique and the Republic of South Africa. Except North Africa and Southern Africa which are of relatively close interconnection, other regions are at a relatively low level of interconnection. Particularly in Central Africa, only R. Congo and D. R. Congo are interconnected through a 220 kV AC Channel. In view of inter-continental interconnection, North Africa is interconnected with Europe and Asia through a double-circuit 400 kV Morocco-Spain Channel and a 400 kV Egypt-Jordan AC Channel, respectively.

African countries have attached great importance to energy integration and laid a good foundation for grid interconnection. Most African countries have similar history, industry structure and resource endowment. In addition to political and economic integration, these countries have also paid great attention to energy integration in recent years, to realize the goals of reliable energy and power supply, efficient utilization of clean energy, reduction of energy subsidies and energy exports for earning foreign exchange. On this basis, Africa has established some regional energy and power organizations, including New Partnership for Africa's Development (NEPAD) and the Association of Power Utilities of Africa (APUA) and regional power pools. These organizations promote cross-border grid interconnection, establish a unified electric power market and realize efficient energy and power development by joint planning, coordinated regulation and design of power trading mechanisms.

Table 1.3 Important Energy and Power Organizations in Africa

Description	Abbreviation	Coverage Area	Number of Member	Date of Establishment	Location of Headquarters
New Partnership for Africa's Development	NEPAD	The whole Africa	51	2010	Johannesburg
Association of Power Utilities of Africa	APUA	The whole Africa	46	1970	Abidjan
Comite Maghrebin De L'Electricite (Maghreb Electricity Committee)	COMELEC	North Africa	5	1989	Rabat
Eastern Africa Power Pool	EAPP	East Africa	10	2005	Addis Ababa
West African Power Pool	WAPP	West Africa	14	2000	Cotonou
Southern African Power Pool	SAPP	Southern Africa	12	1995	Harare
Pool Energ é tique de l'Afrique Centrale	PEAC	Central Africa	10	2003	Brazzaville
Infrastructure Consortium for Africa	ICA	The whole Africa	–	2005	Abidjan

35

African countries have realized grid interconnection or cross-border direct power supply

With these regional energy and power organizations, 35 African countries have realized grid interconnection or cross-border direct power supply and have improved the foundation for grid interconnection. Since the establishment of WAPP and SAPP, the number of interconnected countries has increased by 40% in West Africa and 50% in Southern Africa.

The key points to achieve sustainable development in Africa are: (a) to properly exploit and utilize the rich, high-quality and centralized clean energy in Africa; (b) to greatly improve the electrification level; (c) to accelerate the grid interconnection; (d) to form a clean, safe and reliable energy development pattern.

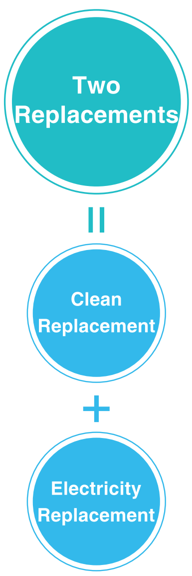
2 Africa Sustainable Development Driven by Africa Energy Interconnection

To address challenges for clean development in Africa, it is necessary to adhere to the idea of Global Energy Interconnection to accelerate the construction of African Energy Interconnection and meet the power demand of Africa in a clean and green manner, so as to provide safe, clean, economical and efficient energy supply to social and economic development of Africa and guarantee the realization of peace, stability, prosperity and sustainability in Africa.

2.1 Development Way of Africa Energy Interconnection

The Global Energy Interconnection is a major global initiative to promote energy transition and clean development, to tackle climate change, and to open a new path to sustainable energy development in the world. To promote the sustainable development of Africa driven by modernization of African energy, the most fundamental is to closely integrate the characteristics of economic, social and energy power development in Africa under the guidance of global energy interconnection to meet the needs of industrialization, urbanization and integration. We shall also develop and make good use of abundant and high-quality clean energy in Africa, promote the complementarity of hydropower, wind power and solar power, allocate and use them efficiently in a large scale. This will open up a new path for sustainable development of African distinctive energy focusing on construction of Africa Energy Interconnection.

2.1.1 Global Energy Interconnection is the essential way leading to clean development



To cope with the challenges brought by the large-scale exploitation and utilization of fossil energy for a long time and solve such problems as shortage of resources, environmental pollution, climate change and population without access to electricity, **following the road to sustainable development, in essence, is to promote clean development. The fundamental orientation is to implement "Two Replacements". "Clean Replacement"** is implemented on the energy production side to replace fossil energy with clean energies such as solar energy, wind energy and hydro energy for generation of clean power. **"Electricity Replacement"** is implemented on the energy consumption side to replace coal, oil, gas and primary biomass energy with clean power and get rid of the dependence on fossil energy, to achieve popularization of clean energy. To solve global energy issue and improve energy system friendliness, economy and development quality, we fundamentally shall promote "Two Replacements", improve electrification level and return the properties of the raw materials of fossil energy.

The global clean energy shows an unbalanced distribution. In continents of Asia, Europe and Africa, 85% clean energy resources are concentrated in the energy belt from North Africa through Central Asia to the Russian Far East, at an angle of about 45° with the equator. The load is mainly concentrated in East Asia, South Asia, Europe, Southern Africa and other regions, with hundreds to thousands of kilometers apart from the energy. It needs to be transformed into electric power for long-distance transmission and large-scale configuration. It determines that we must promote the global configuration of energy to develop clean energy in a large scale. **It is necessary to create a platform for the large-scale development and utilization of clean energy – global energy interconnection, to accelerate green and low-carbon development, to protect the ecological environment of the earth, to provide a fundamental guarantee for clean development, and to promote the sustainable development of the world.**

The Global Energy Interconnection is the carrier of clean development and the modern energy system to realize the global production, configuration and utilization of clean energy. In essence, it is "smart grid + UHV grid + clean energy". Smart grid is the foundation. It integrates modern smart technologies of advanced power transmission, smart operation and control, renewable energy integration and new energy storage. It can adapt to the integration and consumption of various centralized and distributed clean energy resources, meet the needs for the connection and interactive services of various types of smart electric equipment, and realize the collaborative development of source, grid, load and storage, multi-energy complement and efficient utilization. **UHV grid is the key.** UHV grid is mainly composed of 1,000 kV AC and ±800 kV/±1,100 kV DC transmission systems, bringing significant advantages, including long transmission distance, large capacity, high efficiency, low transmission losses, less land use and high security. It also enables electricity of 10 GW to be transmitted with thousands of kilometers and realizes cross-border and inter-continental grids interconnection. **Clean energy is the priority.** With technological progress and rapid cost reduction in the conversion of hydro, wind and solar power, such clean energy resources will totally overpass and quickly replace fossil energy in competitiveness, and finally become the dominant energy in the future. After the global energy interconnection is built, the power interconnection shall promote the full implementation of "Clean Replacement" and "Electricity Replacement" and allow the transformation of differences in resources, time zones, seasons and electricity prices into strong endogenous power for clean development. It shall enable the great leap of clean development efficiency, benefit and quality and make everyone has access to clean, safe, cheap and efficient energy, so as to establish a new pattern of harmony between man and nature as well as man and environment, and open up a road to green and low-carbon sustainable development.

2.1.2 Construction of Africa Energy Interconnection is a strategic measure for sustainable development of Africa

As part of the Global Energy Interconnection, African Energy Interconnection is of vital importance to sustainable development of Africa. **The general idea is as follows:** to accelerate the development of large hydropower bases, wind power bases in the south, north and east, and solar power bases and distributed generation in major river basins to solve the problem of energy scarcity at the source and reduce the use of primary biomass energy based on the urgent need for modern energy for economic and social development of Africa; to persist in ensuring local demand for electricity and expanding the power transmission to the outside world, speed up the construction of backbone grids of various countries, promote cross-border, transregional and transcontinental grids interconnection, give full play to the complementary advantages of African hydropower, wind power and solar power, and promote large-scale development, extensive configuration and efficient use of clean energy; to focus on the solution to the problem of population without access to electricity, build and upgrade the energy and power infrastructure, improve electrification level and energy efficiency, reduce the cost of energy and electricity, and make sustainable energy available to all. **In general, by speeding up the overall upgrading of energy and electricity production, configuration and consumption and building African Energy Interconnection of "close connection inside Africa, efficient interconnection outside Africa and multi-complementary energy sources", we can construct an important carrier for African clean development and provide a strong guarantee for implementation of the UN 2030 Agenda and AU Agenda 2063.**

1 We shall insist on green and low-carbon development to achieve leaping development of energy.

We shall construct African Energy Interconnection based on green and low-carbon development, accelerate the "Clean Replacement" and achieve the transition of energy production from fossil energy to clean energy so as to guarantee and accelerate the development of industrialization, urbanization and integration in Africa. We shall achieve leapfrog development from high-carbon and low-efficiency energy to low-carbon and high-efficiency energy, solve the problems of heavy pollution and high emission caused by large-scale exploitation and utilization of fossil energy, actively deal with climate change and protect the natural ecological environment to provide a strong impetus for sustainable development.

2 We shall strengthen the power to improve living and production quality.

We shall accelerate the "Electricity Replacement" and intensify the construction of energy infrastructure and public service capacity based on the modern energy supply and productivity development level of Africa so that the proportion of electric energy to end-use energy consumption is to be greatly increased. We shall work hard to extensively popularize electric transportation, machines and cooking appliance, transform energy consumption from primary biomass energy and fossil energy to power-centered energy, and promote the production and life of African people into a new era characterized by electrification so as to ensure and improve people's livelihood.

3 We shall strengthen interconnection and promote win-win cooperation.

Considering the differences of energy resource endowment, social development level and political and economic environment in all countries and regions as a whole, we shall strengthen the interconnection of energy and power to realize the transformation of local balanced distribution of energy to cross-border and transcontinental large-scale allocation. Adhering to the spirit of openness and inclusiveness and pragmatic cooperation, we shall create a new energy cooperation relationship that based on mutual discussion, co-construction, sharing and win-win outcomes, and promote the process of African integration with the interconnection of energy and power infrastructure, so as to achieve common development and progress.

2.2 Outlook of Energy Demand in Africa

According to the general idea of African Energy Interconnection development and based on population, economic growth and industrial development of all regions in Africa, we shall take technological innovation, climate and environmental development constraint into overall consideration and forecast the power supply and demand trend, power development and distribution in all regions of Africa on the basis of differences in resource endowment and development phase of different regions and countries, to provide reference for plan of African Energy Interconnection.

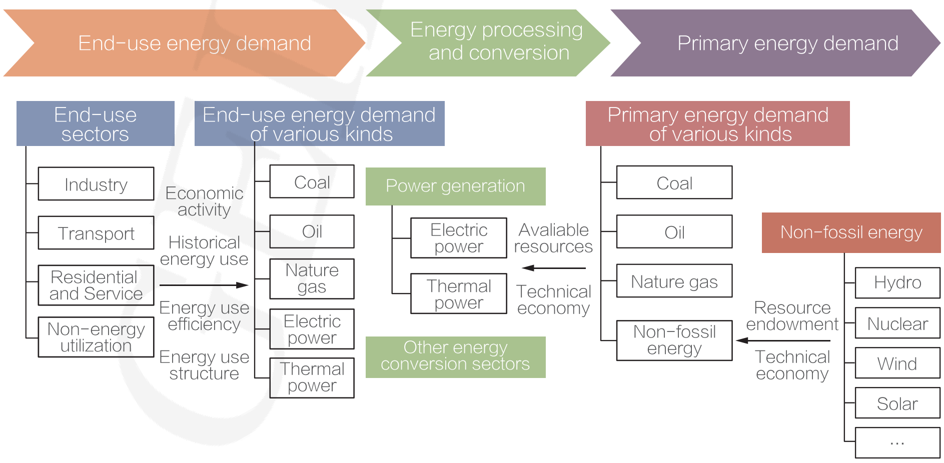


Fig. 2.1 Analysis Model for Outlook of Africa Energy System

2.2.1 Great Potential for Energy Demand

Primary energy demand is growing rapidly, doubling the total in 2050 compared with that in 2015. In 2015~2050, the primary energy demand in Africa is predicted to increase from 1.12 billion tons of coal equivalent to 2.41 billion tons of coal equivalent, with average annual growth rate of 2.2% and global proportion of 5.8% to 9.3%. With economic restructuring and improved energy efficiency, African energy intensity will fall to 0.07 kg of coal equivalent per USD in 2050, a decrease of 63% compared with that in 2015. In 2050, the per capita energy consumption is projected to increase to 1.0 tons of coal equivalent. There is still considerable room for growth.

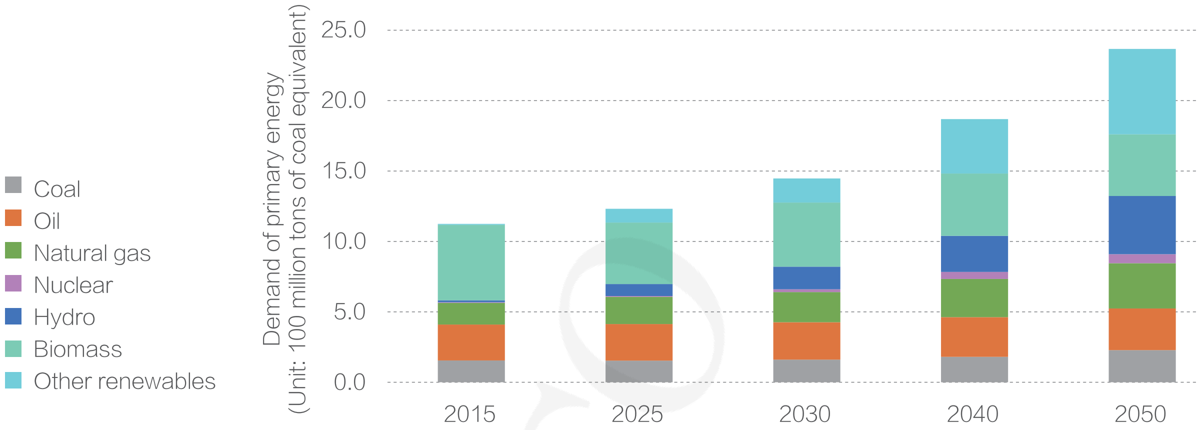


Fig. 2.2 Primary Energy Demand in Africa

North and Southern Africa lead the growth in energy demand, with average annual growth rate of each region exceeding 2%. In 2015~2050, the energy demand in North Africa is predicted to increase by 1.4 times, accounting for 30% of the total growth, with an average annual growth rate of 2.6%; the energy demand in West Africa is predicted to increase by 100%, accounting for 20% of the total growth, with an average annual growth rate of 2%; the energy demand in Central Africa is predicted to increase by 4.2 times, accounting for 17% of the total growth, with an average annual growth rate of 4.8%; the energy demand in East Africa is predicted to increase by 1.1 times, accounting for 13% of the total growth, with an average annual growth rate of 2.2%; the energy demand in Southern Africa is predicted to increase by 100%, accounting for 22% of the total growth, with an average annual growth rate of 2.0%.

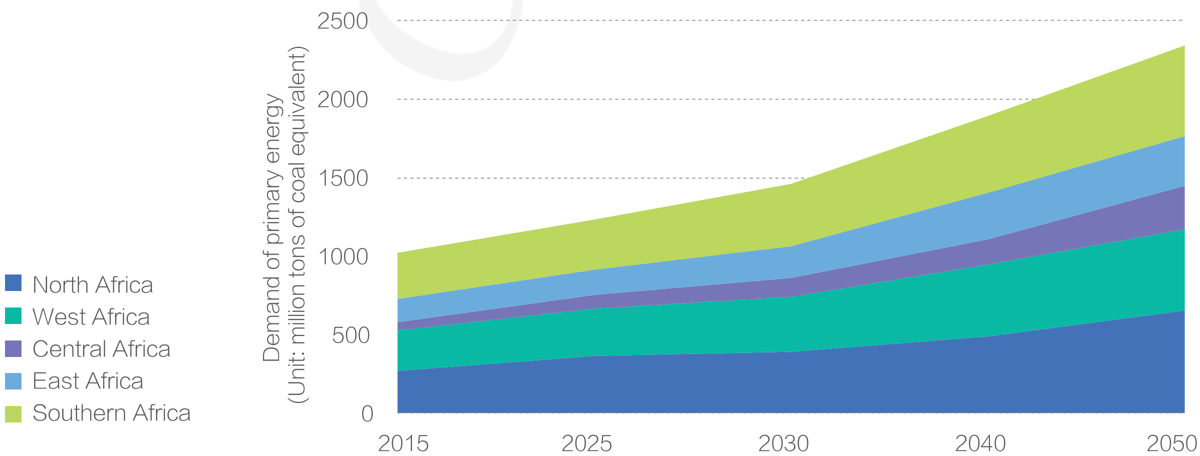


Fig. 2.3 Primary Energy Demand in Regions of Africa

The industrial, residential and service sectors lead the growth in end-use energy demand. In 2015~2050, the end-use sectors energy demand in Africa is predicted to increase to 1.39 billion tons of coal equivalent, with an average annual growth rate of 1.5%, including 420, 180 and 740 million tons of coal equivalent for industry, transport, and residential and service sectors respectively. The industrial energy demand is predicted to increase by 2.3 times, with an increased proportion in primary energy demand to 30.4%, mainly driven by the accelerated development of mining, iron and steel, chemical, non-ferrous, building materials and other manufacturing industries; The energy demand for transport is predicted to increase by 27%, which is mainly driven by the widespread use of automobiles and the development of transportation infrastructure; the energy demand for residential and service sectors is predicted to increase by 45%, mainly driven by population growth and urbanization development.

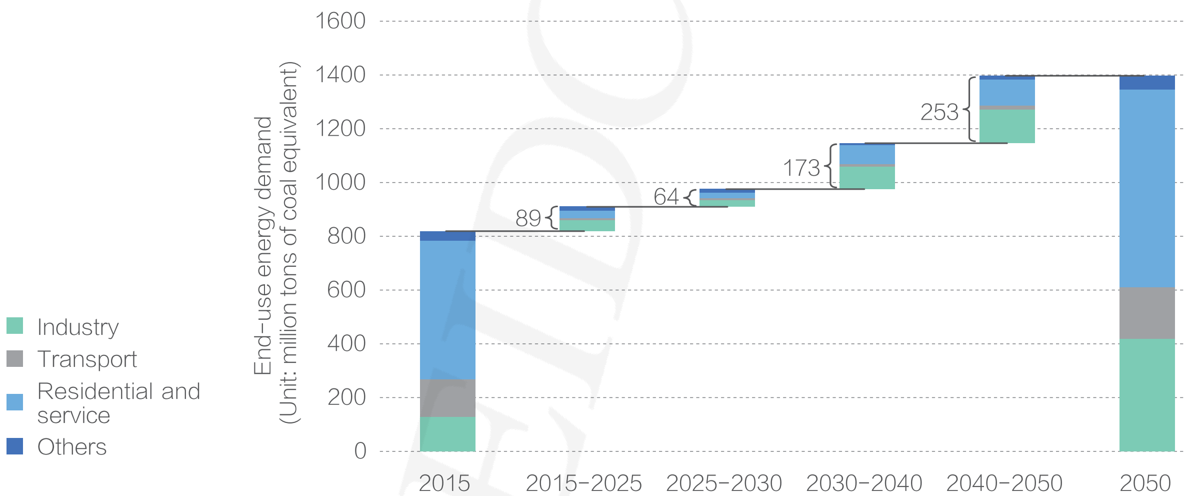


Fig. 2.4 End-use Energy Demand for Different Sectors of Africa

2.2.2 Clean and Low-carbon Energy Structure

In about 2040, clean energy will be the dominant energy in Africa[1]. In 2015~2050, the demand for clean energy in Africa is predicted to increase by 1.02 billion tons of coal equivalent, with an average annual growth of 11.1%, and the proportion in the primary energy is predicted to increase from 2.3% to 46.8%. The proportion of coal, oil and natural gas is predicted to decrease to 10.3%, 12.9% and 15.3% respectively.

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1 The clean energy does not contain primary biomass energy, the same below.

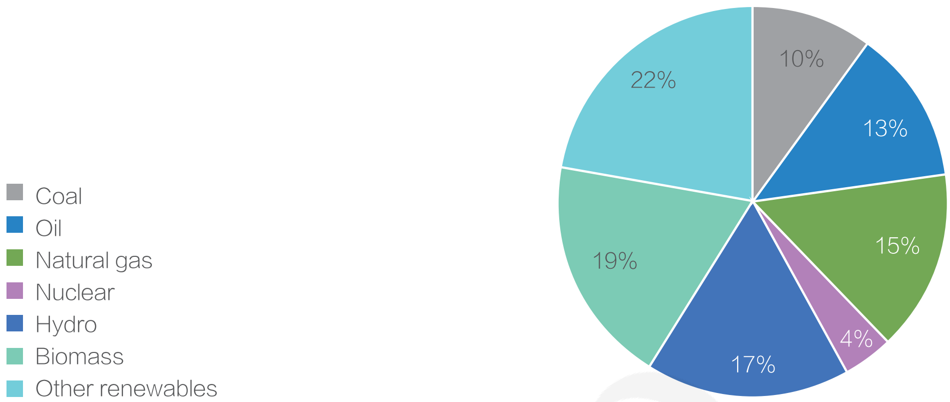


Fig. 2.5 Africa's Primary Energy Structure in 2050

The carbon emission per unit GDP is accelerated declining. It is predicted to decrease to 0.06 kg of CO_2 per USD in 2050 from 0.24 kg of CO_2 per USD in 2015. The proportion of clean energy in primary energy is predicted to improve rapidly. The growth of carbon emission is effectively controlled while ensuring energy supply and economic development.

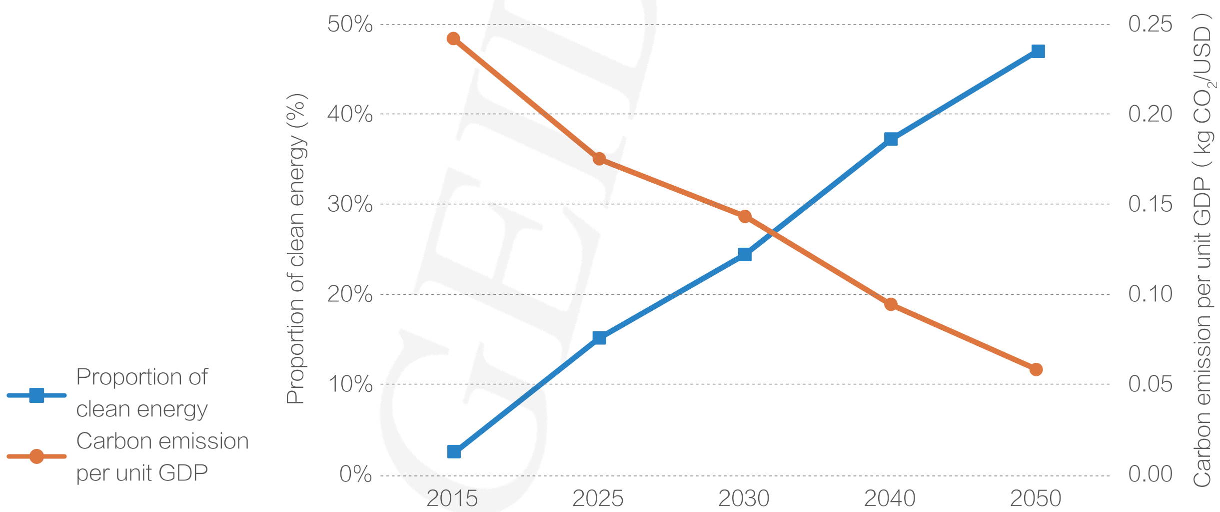


Fig. 2.6 Carbon Emission per unit GDP and Clean Energy Proportion of Primary Energy Demand in Africa

It is predicted that the primary biomass demand increases first and then falls and the utilization mode will change from direct combustion to clean and efficient multiple uses. Currently, the primary biomass energy, represented by firewood, straw and animal waste, is the first major source of Africa's energy, accounting for 48% of the primary energy demand. In a certain period of time, the biomass energy is still an important energy source. In 2015~2050, the total demand of biomass energy of Africa is predicted to increase first and then fall, with the proportion in the primary energy demand decreasing. In 2050, Africa's biomass energy is predicted to demand for 450 million tons of coal equivalent, accounting for 19% of primary energy demand. The biomass energy demand in North, West, Central, East and Southern Africa is predicted to fall to 1.9%, 34%, 19%, 37% and 18% respectively.

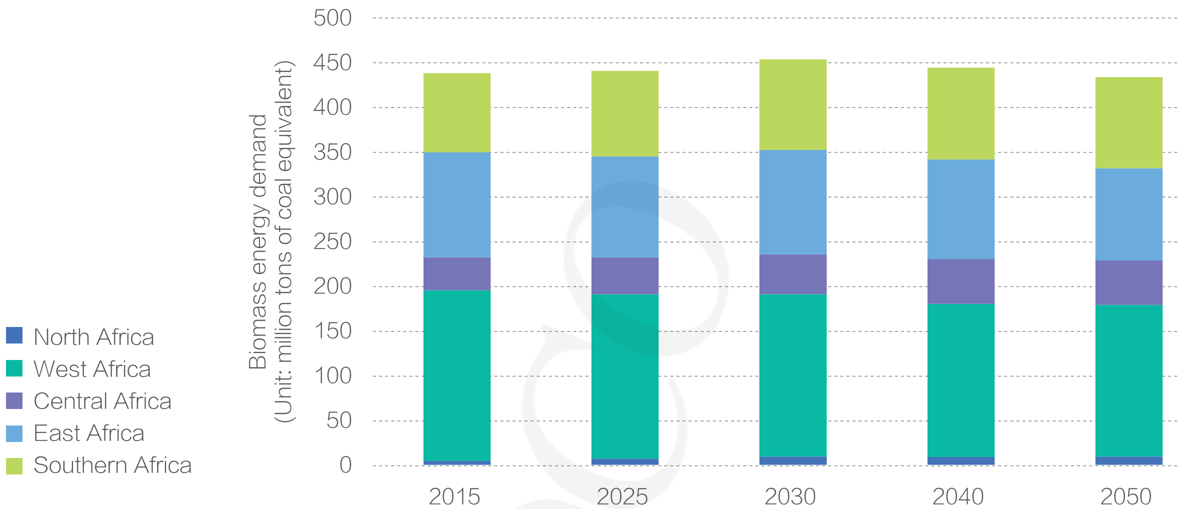


Fig. 2.7 Biomass Energy Demand in Regions of Africa

2.2.3 Electricity as the center of end-use energy

2050
Electricity in end-use energy
28%

Electricity is predicted to surpass oil, becoming the first commodity energy in end-use energy around 2040. In 2015~2050, the proportion of electricity in end-use energy is predicted to increase from 9.5% to 28%. The proportion of electricity in end-use energy for industrial sector, residential and service sector is predicted to increase to 36% and 31% respectively. The proportion of electricity in end-use energy for North Africa, West Africa, Central Africa, East Africa and Southern Africa is predicted to increase to 35%, 23%, 21%, 28% and 33% respectively.

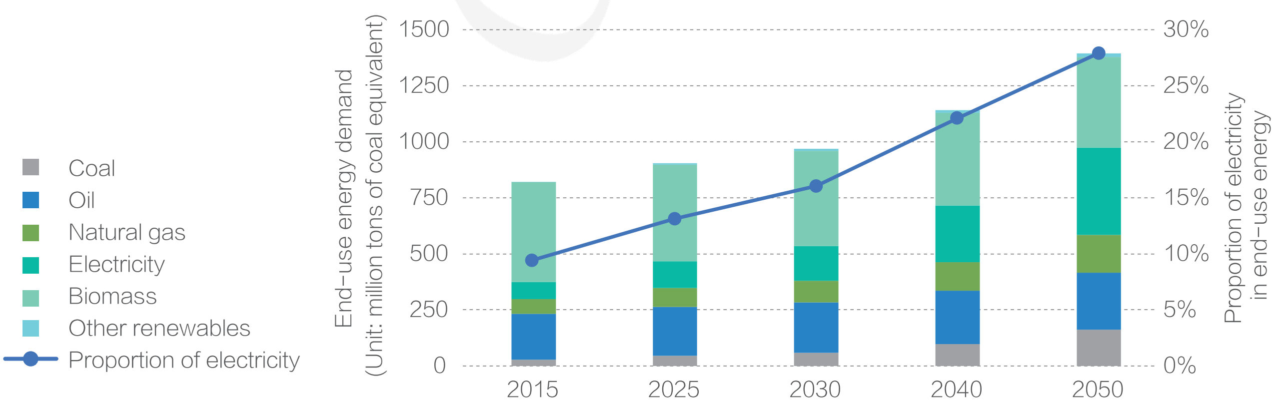


Fig. 2.8 End-use Energy Demand and
Proportion of Electricity in End-use Energy in Africa

2.3

Outlook of Power Demand in Africa

2.3.1 Rapid Growth of Power Demand

In 2050, the power demand and maximum load is predicted to be 5.2 and 4.8 times of that in 2015 respectively. The total power demand in Africa is predicted to increase from 614.4 TWh in 2015 to 1,500 TWh in 2030, 2,300 TWh in 2040, and 3,200 TWh in 2050, with average annual growth rates of 2015~2030, 2030~2040 and 2040~2050 being 6.1%, 4.4% and 3.3% respectively. The maximum load in Africa is predicted to increase from 120 GW in 2015 to 260 GW in 2030, 410 GW in 2040 and 580 GW in 2050, with an average annual growth rate of 4.6%.

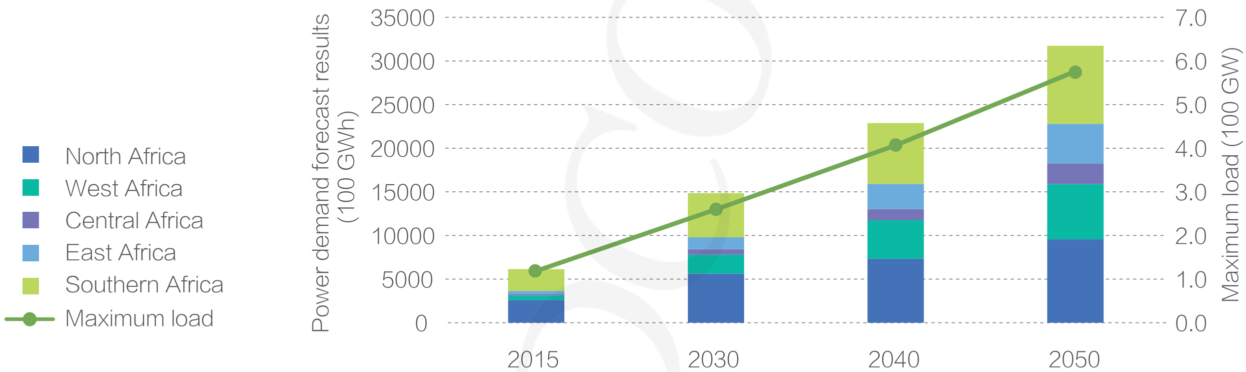


Fig. 2.9 Power Demand and Maximum Load in Regions of Africa

2050
per capita power consumption
1,322kWh/year

The per capita power consumption of Africa in 2050 is comparable to the world average in the 1970s, with higher levels in North and Southern Africa. Africa's per capita power consumption in 2050 is predicted to reach 1,322 kWh/year from 534 kWh/year in 2015, 2.5 times compared with that in 2015, which is equivalent to the world level in 1972. There is still room for a sustained rise. The per capita power consumption in North Africa and Southern Africa is predicted to reach the top, 3,500 kWh/year and 2,600 kWh/year in 2050, which are 2.6 and 2.0 times the amount of power used per capita in Africa respectively.

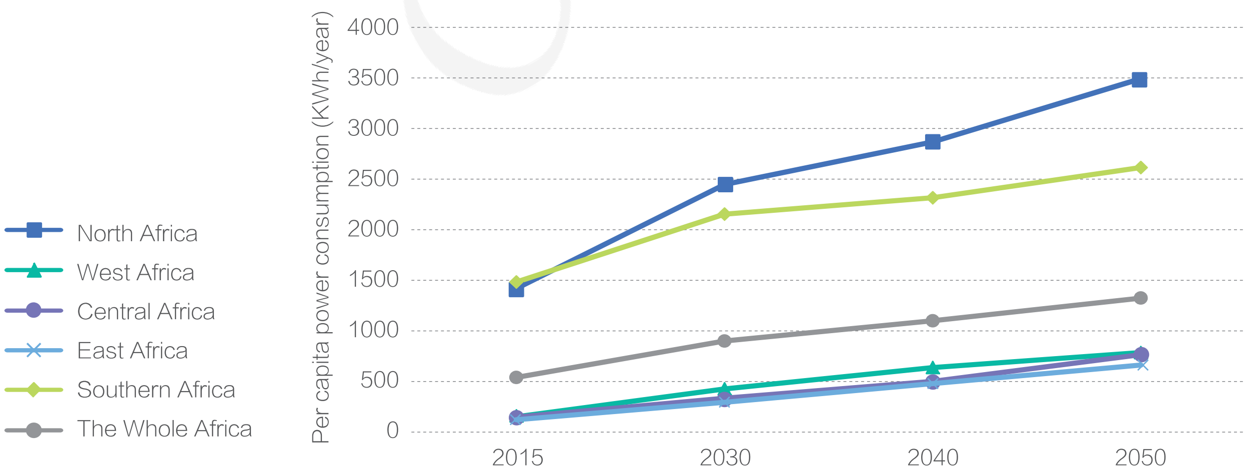


Fig. 2.10 Per Capita Power Consumption of All African Regions

2.3.2 Centralized Distribution of Load Centers

Loads in North and Southern Africa are relatively high. In 2050, the power demand in North Africa and Southern Africa is predicted to increase to 960 TWh and 900 TWh respectively, with the proportion in African power demand being 30% and 28% respectively.

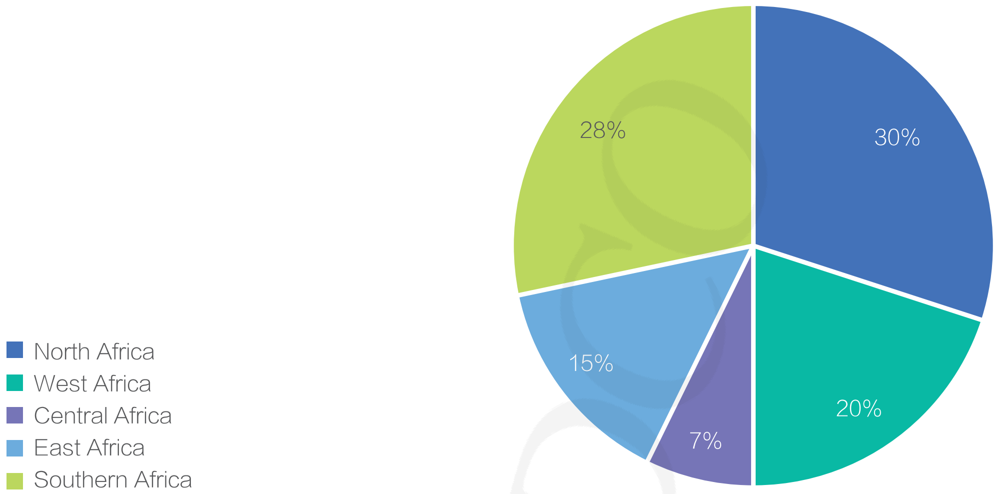


Fig. 2.11 Proportion of Power Demand in All African Regions in 2050

West Africa, East Africa and Central Africa are areas where demand for power is growing faster. In 2015, the power demand of the three areas accounts for 8.2%, 5.9% and 2.9% of the total power demand of Africa, which are predicted to increase to 19.9%, 14.4% and 7.4% respectively in 2050. In 2015~2050 West, East and Central Africa's average annual growth rates are predicted to be 7.5%, 7.5% and 7.7% respectively. However, the per capita power consumption is predicted to remain 600~800 kWh/year.

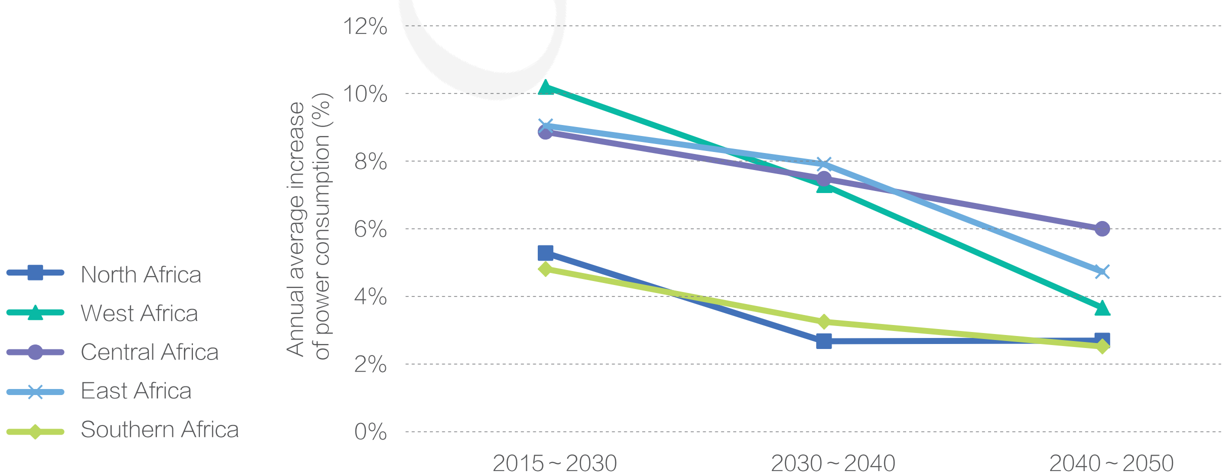


Fig. 2.12 Power Consumption Growth Rate of All African Regions

2.3.3 Significant Decrease of the Population Without Access to Electricity

2050
accessibility to electricity
>90%

The accessibility to electricity of Africa is predicted to increase to more than 90% by 2050. In 2030, the accessibility to electricity of Africa is predicted to reach about 66%, of which North Africa is predicted to reach 100%. In 2040, through coordinated development of power transmission and distribution networks in African countries, the accessibility to electricity in densely populated rural areas will be improved and reach 80% as a whole. In 2050, along with the further improvement of urbanization level and the gradual improvement of power distribution networks in remote areas, the accessibility to electricity will further increase to 90%.

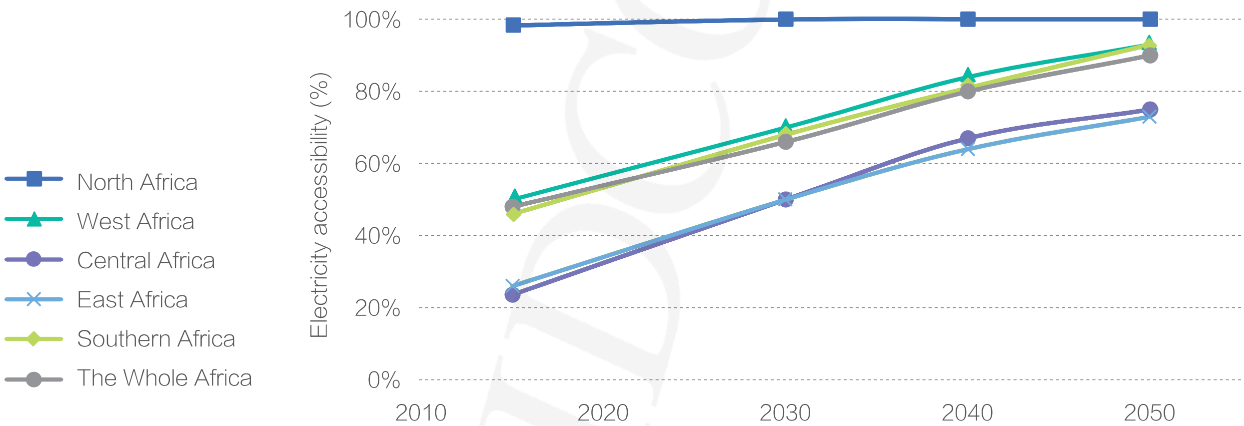


Fig. 2.13 Trend of Accessibility to Electricity in All African Regions

2.4 Outlook of Power Supply in Africa

2.4.1 Accelerated Replacement of Fossil Energy with Clean Energy for Power Generation

The competitiveness of clean energy power generation is increasing. Africa has abundant clean energy. The technical exploitation amount of hydro, wind and solar energy is 1.6 trillion, 67 trillion and 665 trillion kWh/year respectively. In 2017, the global hydropower, PV, and onshore wind power costs were about 5, 10, and 6 US cents/kWh, respectively, which are close to the cost of fossil energy power generation. At present, the tender price of photovoltaic power generation projects in Abu Dhabi has been as low as 1.79 US cents/kWh, and the price of wind power projects in Mexico has been as low as 1.77 US cents/kWh. It is expected that the competitiveness of photovoltaics and wind power will exceed that of fossil energy by 2025, and the economy will further strengthen with the advancement of technology. Large-scale energy storage technology is becoming more and more mature. With reasonable configuration of wind and solar power scale, and implementation of source-network-load-storage coordination optimization control, Clean energy is capable of flexible adjustment, which can become the main power source and ensure the safe operation of high-proportion clean energy power system.

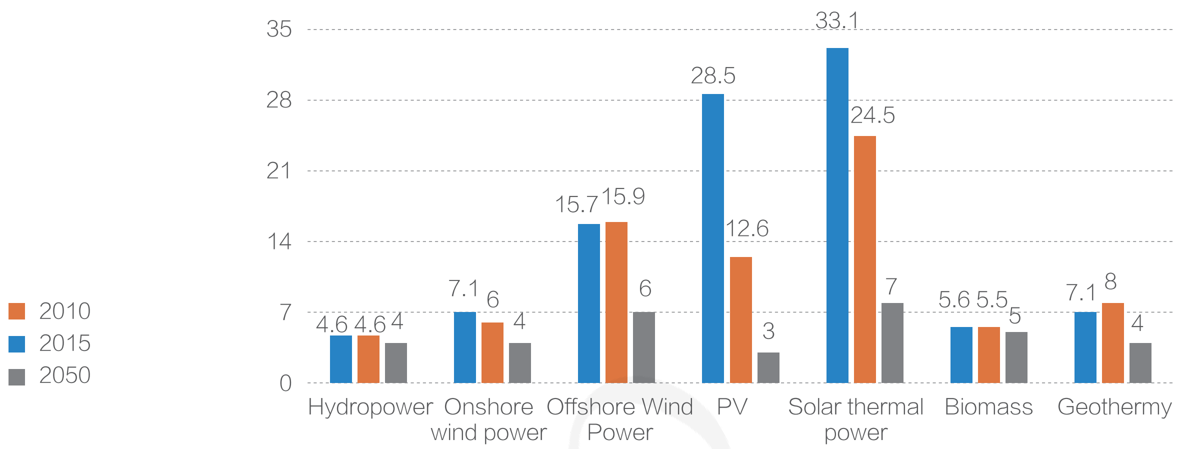


Fig. 2.14 Trend of Variation of Cost per kWh of Global Clean Energy (US Cent/kWh)

By 2030, clean energy will replace fossil energy and become the dominant energy for power generation. By 2030, the clean energy installed capacity will exceed 50%. By 2050, the clean energy installed capacity in Africa will be 880 GW, including 510 GW of solar energy installed capacity, 220 GW hydropower installed capacity and 98 GW wind power installed capacity, making its proportion increased to 78%. The role of fossil energy will be gradually changed from power generation to power load regulation. Traditional fossil energy installed capacity will be gradually reduced and gas turbine-generator sets will become the new turbine-generator sets. Power generation units using fossil energy will be used for load regulation between peaks and the wet & dry seasons instead of power supply.

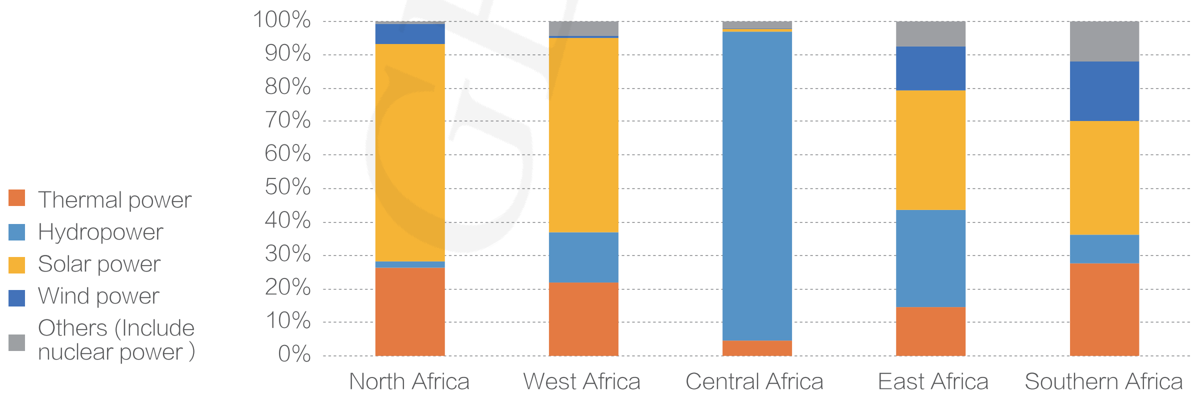


Fig. 2.15 Regional Structure of Installed Capacity of Power Supply in Africa by 2050

The power supply capacity is predicted to increase remarkably. Southern Africa and North Africa are the main regions with increase of power installed capacity. By 2050, the total power installed capacity of Africa will be 1,130 GW, with an annual average increase rate of 5.1%. The per capital installed capacity will increase to 0.46 kW, 2.7 times that of 2015, and equivalent to the world average level of 1981. The power installed capacities of Southern Africa and North Africa are predicted to increase by 230 GW and 290 GW respectively, more than 54% the total growth of installed capacity in Africa.

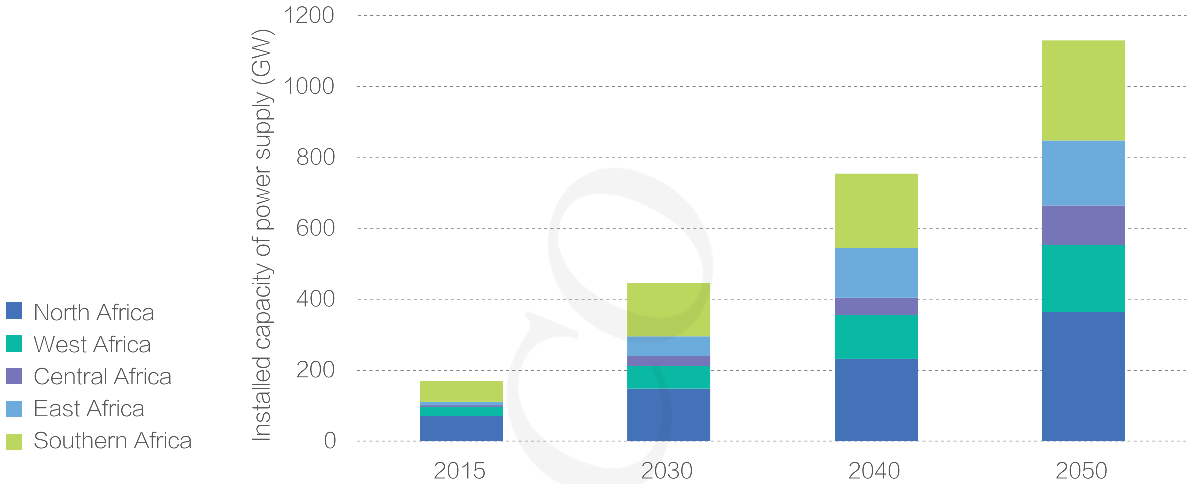


Fig. 2.16 Expected Scale of Installed Capacity of Power Supply in Africa

2.4.2 Large-scale Development of Clean Energy Bases According to Actual Conditions

Clean energy in Africa is subject to both centralized and distributed development. The whole Africa is relatively abundant in clean energy which is mainly distributed in deserts, rainforests and other sparsely populated and economically underdeveloped regions in a way reverse to that of the need. Large hydropower, solar power and wind power bases need to be developed in a centralized way to transmit power in a large scale and across a long distance to the load center to satisfy the power demands of densely populated areas for economic and social development. Compared with distributed power generation, centralized power generation has the advantages of economies of scale, and is reliable and maintainable. At present, the centralized development cost of all countries in Africa is about 30%~50% that of distributed

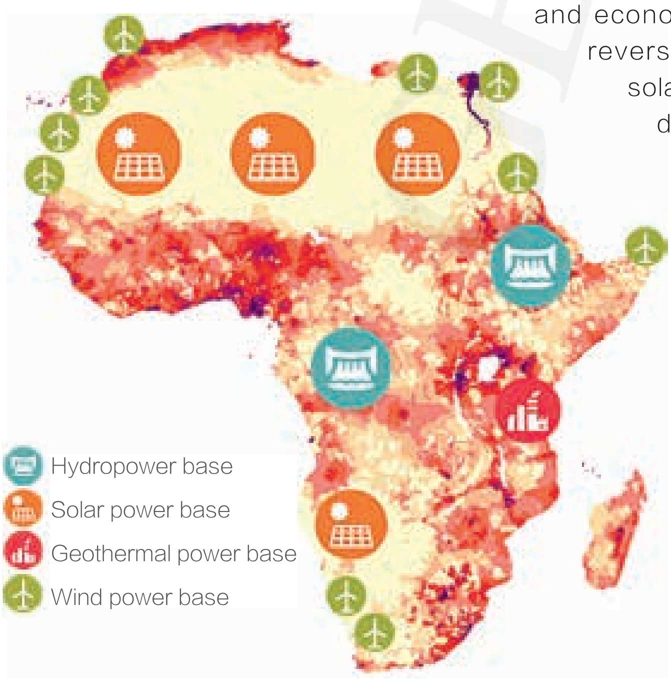


Fig. 2.17 Thermodynamic Diagram of African Population Distribution and Layout of Large Energy Bases

development. It is estimated that by 2050 the centralized solar power generation cost will be 30%~40% lower than that of distributed solar power development. In remote rural areas, mountainous areas and sparsely populated areas, it is suitable to adopt distributed photovoltaic and small hydropower plants to meet power demand.

North Africa

Clean energy mainly represented by solar energy will play a dominant role in the supply of power in North Africa. North Africa is extremely rich in solar energy resources with a technically exploitable potential of 939,000 GWh/year. The resources are mainly distributed in the south, close to the Sahara Desert where the terrain is vast and flat and the load center is far away. With the constantly maturing of solar power generation and storage, the cost of power generation and per kilowatt hour cost will drop rapidly, further accelerating solar power generation in North Africa in the future.

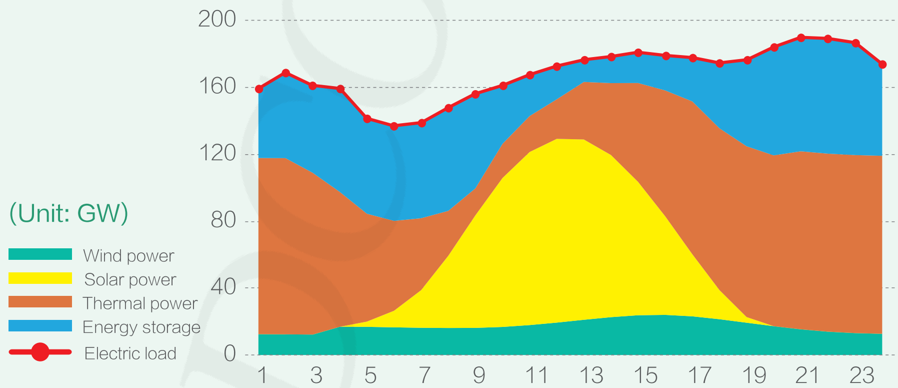
Create a clean energy pivotal platform by making the best of the geographical advantages of North Africa. As a hub connecting Asia, Europe and Africa border on one another, North Africa plays the part of coordinating resource endowment and the need of energy and power development. By realizing trans-national, inter-regional and inter-continental energy interconnection around the Mediterranean region, solar energy in Western Asia and hydropower in Central Africa are gathered in North Africa. After trans-time-and-space complementation and supporting of multiple types of energy resources, the power is transmitted to Europe for consumption after crossing the Mediterranean Sea, which can remarkably improve the utilization efficiency of clean energy resources and realize the large-scale and wide-scope optimized allocation of clean energy.

Box 2.1

North Africa's future energy storage scale

North Africa, extending far and wide, is extremely abundant in solar energy. The annual solar irradiance intensity in most regions of North Africa can be 2,200~2,300 kWh/m^2 and above, making it suitable for development of large solar power bases. In the future, with the constantly deepening of replacement with clean energy in North Africa, the proportion of power generation from fossil energy will rapidly decrease, gradually forming a new energy power generation structure with solar energy accounting for a large proportion. Being intermittent and random in power generation with solar power, wind power and other new energy resources, energy storage technology will become one of the key technologies in terms of supply and demand of power in North Africa in the future for supporting peak load regulation of all countries in North Africa.

According to the load characteristics of all countries in North Africa, the maximum load occurs from 8~10 p.m. while the minimum load occurs from 5~7 a.m. It is estimated that the maximum difference between peak and valley will be about 50 GW by 2050. According to calculation, if the installed capacity for gas power generation decreases to 30% by 2050 and that for solar and wind power generation increases to 65%, at least about 70 GW energy storage facilities (including solar-thermal and chemical energy storage) with a storage capacity of 1,050 GWh need to be equipped on the power generation side to satisfy the power supply and demand, and power operation requirements in North Africa.



Operation Simulation of North Africa Power System With High-proportion of Clean Energy on A Typical Day

West Africa

Hydropower development in West Africa will play an important role in the future. The hydropower resources of West Africa are mainly distributed in the Niger River, Senegal River, Volta River, and Gambia River Basins in a large area covering a large population. The technically exploitable hydropower potential is about 44 GW and the current exploitation ratio is only 12%, showing great development potential.

Give priority to acceleration of hydropower development and realize optimized configuration in a large scope with hydropower industry and solar power industry supporting each other through coordinated power grid energy development. Give priority to promotion of hydropower development in Niger River, Volta River, and Senegal River Basins. The seasonal dry and wet periods of rivers of West Africa are distinct, complementing strongly with solar energy of Niger, Mali and Mauritania. The discharge of Niger River mainly concentrates in September every year to the next February and the lowest solar irradiance intensity is found from October to the next February. The construction and upgrading of power grid infrastructures and trans-national interconnection of power grids of West Africa shall be strengthened and an east-to-west clean-energy power transmission corridor of West Africa shall be built to reduce the population with no access to electricity, and to promote modern and clean development of energy and power industries.

Box 2.2

Selection of Power and Gas Transmission of West Africa

Natural gas, as low-carbon energy, also plays an important role in energy transformation in the world. According to the endowment and development stage of African energy resources, the natural gas demand and scope of demand of Africa will further increase, making it hard for the way of delivering natural gas through pipelines to further exist. The technical plan of replacing natural gas with electricity and transmitting the electricity as important energy to abroad through power grids has the advantages of being economical, safe and stable.

According to full-life-cycle cost-efficiency analysis, due to relatively large investment in power stations, the total investment in power transmission projects is generally slightly higher than that in gas transmission. However, considering the carbon price and operation and maintenance costs, in terms of large-scale and long-distance energy configuration, the annual cost of power transmission is generally lower than that of gas transmission. According to estimation, when the natural gas price is higher than USD 0.15/cbm, power transmission is more economically advantageous than gas transmission; when the transmission distance exceeds 2,000 km, power transmission is more economical.

Nigeria in West Africa is rich in natural gas resources. At present, in addition to exploitation by the country itself, natural gas is also exported to Ghana, Côte d'Ivoire and other countries through gas transmission pipelines. In the future, apart from meeting the natural gas demands of Nigeria and its surrounding countries, natural gas can also be transmitted inter-regional to Southern Africa, inter-continental to Europe and to other energy demand centers. Considering that Nigeria is 3,500 km from Europe by directly crossing the Sahara Desert and above 5,000 km by detouring, and is also above 4,000 km from Southern Africa, replacement of natural gas with power and transmission of clean power at an ultra-high voltage on a large scale and across a long distance is more economical, and more convenient for operation and maintenance, greatly improving the safety and stability of energy supply.

Central Africa

The development of hydropower in the Congo River is of great significance for clean energy development in Africa. The clean energy of Central Africa is mainly represented by hydropower which is mainly distributed in Congo River, Ogoou é River and Sanaga River Basins with a technically installed capacity potential more than 180 GW. At present, the exploitation ratio is less than 3%. Among the rivers, Congo River has the most abundant hydropower resources in the world with a technically installed capacity potential of more than 150 GW. It has a wet period in the Northern Hemisphere and a dry period in the Southern Hemisphere from July to November, and a dry period in the Northern Hemisphere and a wet period in the Southern Hemisphere from December to the next June, which is unique because the dry and wet periods in the Southern and Northern Hemispheres complements with each other.

Vigorously promote development and export of Inga hydropower on the basis of meeting the power demand of Central Africa itself. The installed capacity of Inga Hydropower Stations can be 50.48 GW and the hydropower, which is of high quality with average annual utilization hours of more than 7,000, can be transmitted inter-continental to Europe and inter-regional to West Africa, Southern Africa, North Africa and East Africa on a large scale and across a long distance to realize configuration of clean, cheap and high-quality hydropower in a large scope.

Box 2.3

Inga hydropower consumption market

The installed capacity of the Inga Hydropower project is 50.48 GW. It needs more optimized and larger scale of allocation to overcome the limited local power consumption problem. Within the continent, West Africa and Southern Africa are important power receiving centers with relatively limited energy resources. They are the target markets for Inga hydropower. In the long run, East Africa will also meet the rapidly growing electric demand through cross-regional power delivery. Outside of the continent, Europe also has large demand for electricity. As the proportion of electricity replacement increases, there is also a large power gap, which makes Europe a potential market for Inga hydropower.

West Africa, relatively close to the Inga hydropower base, has a large population, rich mineral resources, and rapid economic growth. The development of mining and smelting industry will drive the demand for electricity. Nigeria, Guinea, Ghana and other countries will have a large electricity gap in the future. Sending Inga Hydropower to West Africa will play their resource advantages, coordinate development, and achieve mutual benefit between Central and West Africa. It can become a breakthrough to solve the problem of large-scale development and efficient utilization of Inga hydropower.

South Africa, the country with the largest economy in Southern Africa, accounts for 80% of electricity use in the region. South Africa has rich mineral resources and relatively complete infrastructure, and it still has a large space for development in the future. With the gradual retirement of the old coal-fired power units, it is expected that the electricity gap will be large, and South Africa will become an important market for Inga Hydropower.

In East Africa, although it has more clean energy resources, with the rapid population growth and rapid development of the manufacturing industry in the future, the long-term local installed capacity will not be able to meet the fast-growing power demand. East Africa is also one of the potential markets for Inga Hydropower.

East Africa

Clean energy comes in various types and has a broad development prospect. East Africa is rich in water, wind, solar and geothermal energy resources. Hydropower is mainly found in Nile River, Jubba River and Rufiji River Basins with a technically exploitable potential of 69,000 MW; solar energy is mainly found in Sudan, Tanzania and Ethiopia with a technically exploitable potential of 770 GW; wind energy is mainly found along the coast of the Red Sea and the Gulf of Aden, the edge of Sahara Desert and on the highland on both sides of Great Rift Valley with a technically exploitable potential of 140 GW; geothermal energy is mainly found in the geothermal zone of the Red Sea-Gulf of Aden-Great Rift Valley with a technically exploitable potential of 17,000 MW.

Accelerate development of various types of clean energy so that they can complement one another and be transmitted outside for consumption. Priority shall be given to accelerating hydropower development of Ethiopia, development of geothermal energy shall be strengthened and development of solar and wind energy shall be carried out actively. Interconnection of power grids in East Africa shall be strengthened to realize complementing and supporting among various types of energy, improve the efficiency of utilization of clean energy in power generation, enhance clean energy configuration and consumption capacity within the region, support modernization, electrification and cleanliness in energy supply of East Africa and reduce the population with no access to electricity. Meanwhile, through inter-continental and inter-regional transmission, the large-scope consumption of power generated with clean energy can be realized.

Box 2.4

Ethiopia can be a regional hub of energy

Ethiopia's hydropower resource is extremely abundant and mainly found in Blue Nile with an installed capacity potential of 45 GW. Most of the water comes from seasonal precipitation on the Ethiopian Highland. The rainy season lasts from June to October every year with the maximum water flow rate of 5,800 cbm/s; the dry season lasts from November to the next May with a relatively small flow rate, only 3%~20% that of the rainy season, and

the minimum runoff is only 200 cbm/s with remarkable seasonal features. Relying on the interconnection of power grids and supplementing and supporting among various types of energy, Ethiopia has a great potential to become the hub of energy of East Africa. Geographically, Ethiopia, located in the heartland of East Africa, connects North Africa in the north, extends to Arabian Peninsula by crossing the Red Sea in the east and reaches the Southern Africa in the south, showcasing remarkable regional advantages. Since the southern region of the East Africa is abundant in geothermal energy, and its hydropower characteristics are seasonally reverse to those of the northern region, mutual complement between dry and wet seasons, among multiple types of energy, and flexible regulation can be realized in the regions through interconnection of energy of the southern and northern regions by Ethiopia. Meanwhile, through conveying of hydropower and other clean energy gathered in East Africa to the load centers of Southern Africa and Western Asia, the supply of multiple types of energy for the two regions is realized, contributing to the transformation to clean energy.

Southern Africa

Accelerate elimination of coal-fired power generation in energy and power development. The Zambezi River is rich in hydropower with a technically exploitable potential of 25 GW and a current development ratio of 24%. Solar energy and wind energy showing a great development potential have not yet been developed on a large scale at present. South Africa is the largest center of energy and power demand in Africa. The large consumption of coal has brought about serious hidden danger to the ecological environment. In the future, old coal-fired power generation projects will be gradually de-commissioned and the development of regional large hydropower, wind power and clean energy bases needs to be accelerated to satisfy the huge power demand within the region.

Take full advantage of being complementary among basins to receive inter-regional power generated with clean energy. The Zambezi River and Nile River complement each other seasonally: The wet season of the Zambezi River is from November to the next May while the dry period is from June to October; the flow characteristic of the Zambezi River is reverse to that of Nile River. Through interconnection of power grids, complementary and support among clean energy across regions are realized and the utilization hours of transmission lines connected can be more than 5,500 hours.

Box 2.5

The role of coal-fired power in the future energy structure of South Africa

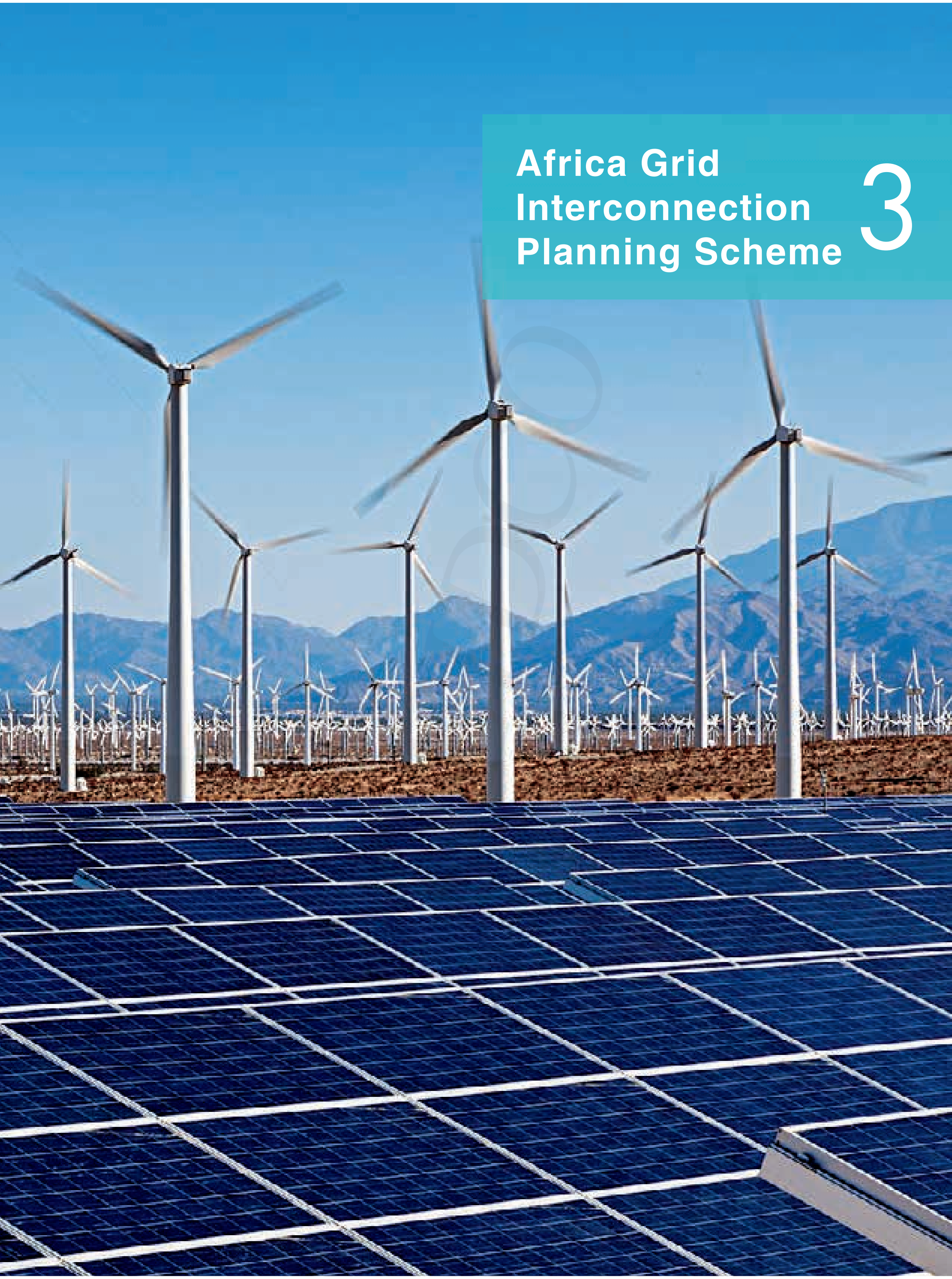
South Africa is the most industrially developed country in Africa and its energy resource consumption is huge. South Africa is short of oil gas resources and rich in coal reserve. Coal, playing a leading role in the energy structure of South Africa, guarantees supply of 90% of power and about one fourth liquid fuel, occupying an important position in the economy of South Africa and becoming a mineral product with the second largest export volume in South Africa. South Africa is the fifth largest coal producer and the fourth largest coal exporter in the world.

The large-scale use of coal has brought about a series of ecological and environmental issues such as generation of solid waste, water pollution, air pollution and large-scale emission of greenhouse gases. Carbon emission from coal industry accounts for 86% of the total of South Africa, and 40% of the total of the whole Africa. In terms of the current coal industry structure of South Africa, high-quality coal is exported for foreign exchanges while medium- and low-quality coal is used by itself for power generation, making coal-fired power generation a hidden source of coal pollution.

Considering the large reserve of coal in South Africa, coal-fired power will remain the main source of power for South Africa and coal will continue to play a leading role as primary energy in the short and middle terms. In the long term, with the development of clean energy and energy storage technologies as well as trans-national power grids interconnection, the proportion of installed capacity of coal-fired power will drop from the current 81% to 40%. The proportion of coal in primary energy will gradually drop and is estimated to be controlled within 20% by 2050.

Africa Grid Interconnection Planning Scheme

3



The construction of Africa Energy Interconnection aims at to meet the power demand from sustainable development of African society and economy, to accelerate exploitation and utilization of clean energy and upgrade of power grids, to realize orderly exploitation of large-scale hydro, solar and wind power bases, to coordinate development of generation and grid infrastructure, and to expand power supply range, electricity accessibility and reliability. Accelerating the construction of interconnection will forge a green, low-carbon, secure, reliable, flexible, complementary platform for clean energy distribution which can fully integrate with power grids of different countries and regions. Hense, the power demand in Africa can be satisfied in a clean and green way.

3.1 Distribution of Clean Energy Bases

Africa is endowed with abundant clean energy resources of which hydro, solar and wind energy respectively account for 12%, 40% and 32% of the world totals. Coordinating clean energy distribution, exploitation conditions and energy & power system development planning, by 2050, 37 large-scale clean energy bases with technically exploitation amount of 3.33 TW are planned to construct, including 4 large-scale hydropower bases, 21 solar power bases and 12 wind power bases.

3.1.1 Hydropower Base

Hydropower technical installed capacity
330GW
Overall development proportion
10%

Africa has rich hydropower resources, with the technical installed capacity of 330 GW. At present, the overall development proportion of hydropower accounts for only 10%. According to the distribution of hydropower resources, hydropower bases that can be developed on a large scale mainly lie in the basins of the Congo River in Central Africa, Nile River in East Africa, Niger River in West Africa, and Zambezi River in Southern Africa. In addition, hydropower bases can also be built in the basins of the Kwanza River in Southern Africa, Sanaga River in Central Africa, Volta River in West Africa and Rufiji River in East Africa where there are conditions for development.

01 Hydropower Base in Congo River

The Congo River is in the central Africa, mainly inside D. R. Congo, through D. R. Congo, Cameroon, Central Africa Republic, Rwanda, Burundi, Tanzania, Zambia and Angola.
The Congo River is 4,370 km long which is the second longest river in Africa. Its basin area is about 3.7 million km^2 and its average estuary runoff is about 41 thousand m^3/s which are both ranked top one in Africa and second to Amazon in the whole world. The Congo River's length is second to the Nile River in Africa while its runoff is 16 times larger. Its extraordinary hydro resource yields 150 GW technical potential, however not more than 2% of which has been exploited so far. Especially, there are 32 waterfalls and rapids in the 200 km distance between Kinshasa and Matadi which

measures 280 m height gap and two thirds the hydropower potential of the Congo River. This segment is the most abundant area of hydropower in the world. It is favorable to develop maga-hydropower stations here. Currently, three cascade hydropower stations which are Pioka, Inga and Matadi from upstream to downstream have been considered. The total installed capacity will be more than 100 GW.

Fig 3.1　Congo River Basin

Table 3.1　Future Downstream Hydropower Projects in the Congo River

Project	Cascade power station name		
	Pioka	Inga	Matadi
Location	Pioka region in the border area between R. Congo and D. R. Congo	Inga region in D. R. Congo	Near Matadi city in D. R. Congo
Capacity	35 GW	50.48 GW	16 GW
Current situation	Planning	Inga I and II completed, 1.78 GW.	Planning

02 Hydropower Base in Nile River

The Nile River, flowing through the East and North Africa, and flowing through Tanzania, Burundi, Rwanda, Kenya, Uganda, South Sudan, Ethiopia, Sudan and Egypt from south to north, and finally emptying into the Mediterranean Sea. The Nile River has three main tributaries including the White Nile River, Blue Nile River and Atbarah River.

Being 6,695 km long in total, it is the longest river in the world with a drainage area of 3.18 million km^2. The technically potential of hydropower is about 60 GW and the exploitation proportion at present is about 13%.

Fig 3.2
Nile River Basin

03
Hydropower Base in Zambezi River

The Zambezi River originates from the mountainous area at the northwest border of Zambia with its main stream flowing through such countries as Angola, Namibia, Botswana, Zimbabwe, Zambia and Mozambique, and emptying into Mozambique Channel of the Indian Ocean and its tributaries flowing through Malawi.

With a total length of 2,660 km, the Zambezi River has a drainage area of 1.3 million km^2, an average annual flow into the sea of 7,080 m^3/s, annual runoff of 223.2×10^9 m^3, technical potential of hydropower about 25 GW and a current exploitation proportion of 24%.

Fig 3.3
Zambezi River Basin

04 Hydropower Base in Niger River

As the third longest river in Africa (next only to the Nile River and Congo River) and the longest river in West Africa, the Niger River originates from the area where the Fouta Djallon Plateau is close to the border of Sierra Leone in Guinea with its main stream flowing through such countries as Guinea, Mali, Niger and Nigeria and emptying into the Gulf of Guinea, and its tributaries mainly the Benue River and Bani River, stretching to Cote d'Ivoire, Burkina Faso, Chad and Cameroon.

With a total length of 4,160 km, the Niger River has a drainage area of 1.5 million km^2, an average annual flow into the sea of 6,300 m^3/s, annual runoff of 200×109 m^3, technical potential of hydropower about 28 GW and a current exploitation proportion of only 9%.

Fig 3.4 Niger River Basin

05 Other Hydropower Bases

In addition to the above four hydropower bases, the rivers with a more than 2 GW technical potential of hydropower in Africa mainly include the Kwanza River in Southern Africa, Sanaga River in Central Africa, Volta River in West Africa and Rufiji River in East Africa. According to the actual conditions of these areas, it is planned to build hydropower bases in these basins to mainly satisfy the power demand in such areas.

Table 3.2 Basic Conditions of Other Hydropower Bases in Africa

Unit: GW

River	Main Countries Flowing Through	Technically Installed Capacity Potential	Current Exploitation Ratio
Sanaga River	Cameroon	12	6.0%
Ogooué River	Gabon	6	5.5%
Kwanza River	Angola	7	36.1%
Volta River	Ghana	<5	35.1%
Rufiji River	Tanzania	<5	12.8%

3.1.2 Solar Power Base

Solar power technical potential
665,000 TWh/year

Africa is generally rich in solar energy resources, with the technical potential of 665,000 TWh/year. Considering the resource characteristics and development conditions, it is suitable to build large solar power generation bases in the Sahara Desert (northern central Africa) and surrounding areas, the Atlantic coastal areas in the South and some inland areas in East Africa.

01 Solar Power Bases in North Africa

The annual solar irradiance intensity in North Africa can reach 2,200~2,400 kWh/m^2. Based on the characteristics and distribution of solar energy resources, 8 large solar power bases are preliminarily planned in North Africa, with a total technical potential of about 2,500 TWh and a total technical installed capacity potential of about 1.2 TW. They lie along the Nile River in Egypt, and in northwest Libya, southern Tunisia, eastern Algeria and southern Morocco.

Table 3.3 Large Solar Power Bases in North Africa

Unit: TWh/year, GW

S/N	Location	Country	Technical Potential	Installed Capacity Potential
1	Minya	Egypt	359.4	160
2	Aswan	Egypt	304.2	130
3	Ouargla	Algeria	629.1	320
4	Laghouat	Algeria	514.8	250
5	Jawsh	Libya	196.6	100
6	Zag	Morocco	226.5	110
7	Zagora	Morocco	164.7	80
8	Remada	Tunisia	100.6	50
Total			2,495.9	1,200

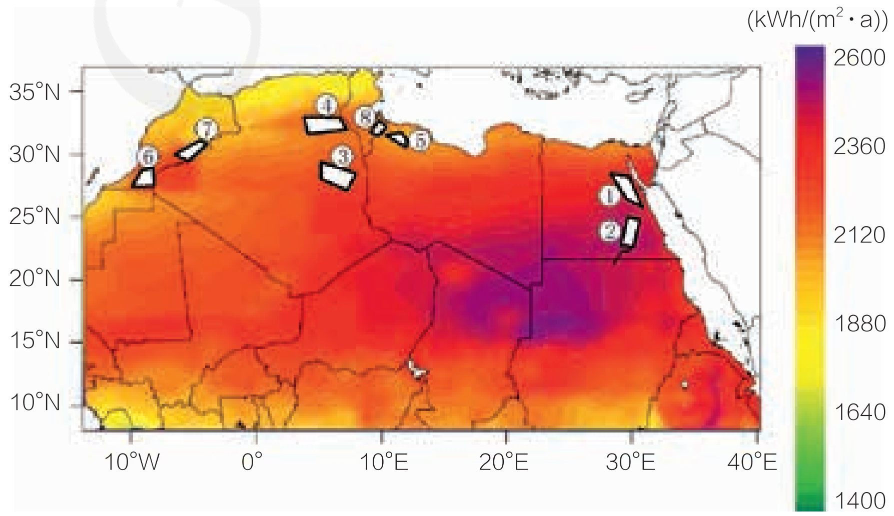


Fig 3.5 Distribution of Large Solar Power Bases in North Africa

02

Solar Power Bases in West Africa

The annual solar irradiance intensity in West Africa can reach 2,000~2,400 kWh/m^2. Based on the characteristics and distribution of solar energy resources, 5 large solar power bases are preliminarily planned in West Africa, with a total technical potential of about 1,000 TWh and a total technical installed capacity potential of about 480 GWh. They lie in the western and southern regions of Sahara.

Table 3.4 Large Solar Power Bases in West Africa

Unit: TWh/year, GW

S/N	Location	Country	Technical Potentia	Installed Capacity Potential
1	Agadez	Niger	241.4	120
2	Kayes	Mali	201.2	100
3	Rosso	Mauritania	221.3	110
4	Ouagadougou	Burkina Faso	140.8	70
5	Carnot	Nigeria	161	80
Total			965.8	480

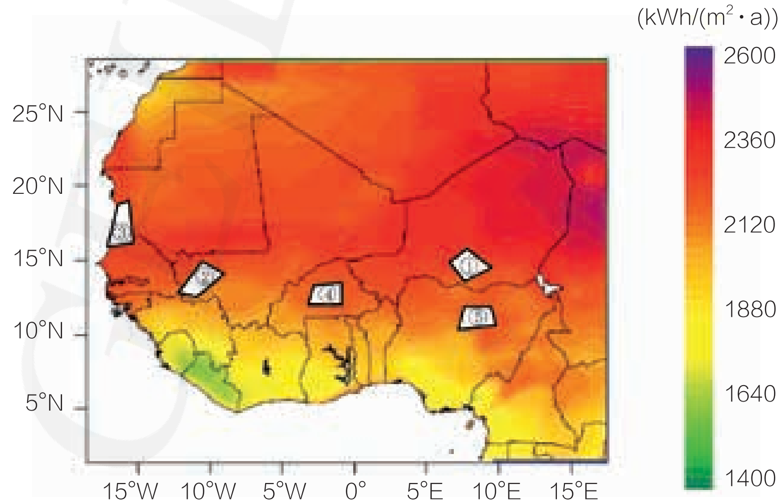


Fig 3.6 Distribution of Large Solar Power Bases in West Africa

03

Solar Power Bases in East Africa

The annual solar irradiance intensity in the Sahara Desert, coastal areas and rift zones of East Africa is about 2,100~2,300 kWh/m^2. Based on the characteristics and distribution of solar energy resources, 4 large solar power bases are preliminarily planned in East Africa, with a total technical potential of about 1,700 TWh and a total technical installed capacity potential of about 840 GWh. They lie in northern Sudan, eastern Ethiopia and northern Kenya.

Table 3.5　Large Solar Power Bases in East Africa

Unit: TWh/year, GW

S/N	Location	Country	Technical Potential	Installed Capacity Potential
1	Dongola	Sudan	576.5	280
2	Ad-damir	Sudan	535.4	260
3	Dire Dawa	Ethiopia	370.6	180
4	South Horr	Kenya	247.1	120
Total			1,729.6	840

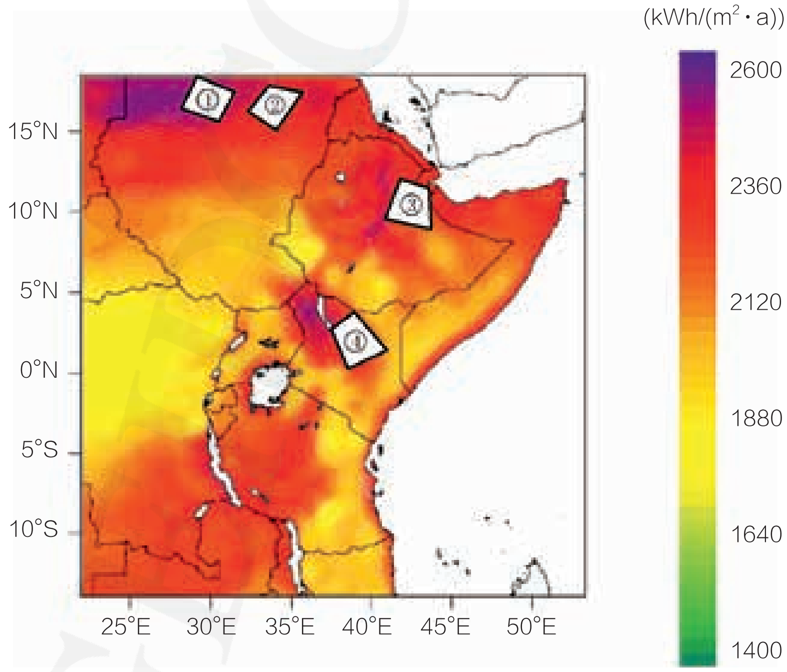


Fig 3.7　Distribution of Large Solar Power Bases in East Africa

04 Solar Power Bases in Southern Africa

The annual solar irradiance intensity in most of Southern Africa can reach 1,800~2,200 kWh/m^2. Based on the characteristics and distribution of solar energy resources, 4 large solar power bases are preliminarily planned in Southern Africa, with a total technical potential of about 720 TWh and a total technical installed capacity potential of about 360 GWh. They lie in Namibia, Botswana, South Africa and Angola.

Table 3.6 Large Solar Power Bases in Southern Africa

Unit: TWh/year, GW

S/N	Location	Country	Technical Potential	Installed Capacity Potential
1	Karasburg	Namibia	140.8	70
2	Tshabong	Botswana	100.6	50
3	Pretoria	South Africa	321.9	160
4	Lubango	Angola	161.0	80
Total			724.3	360

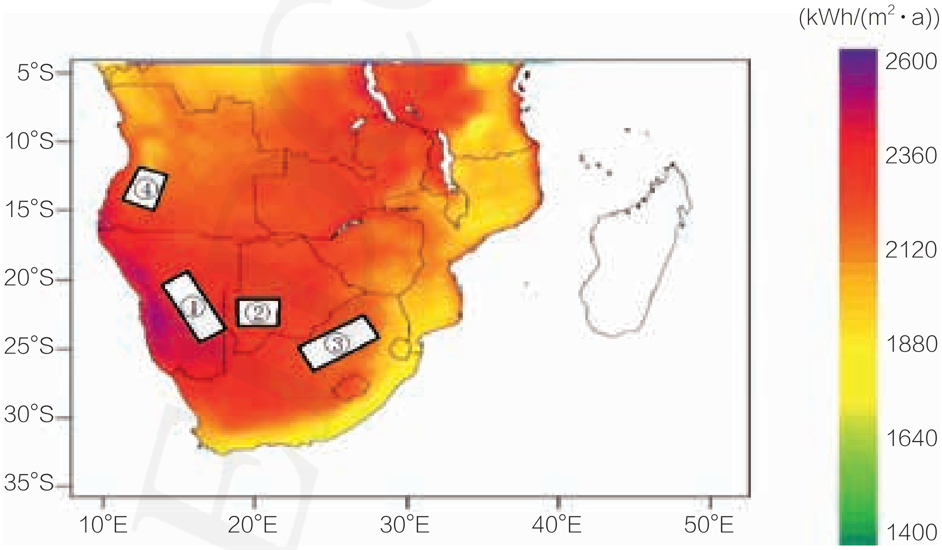


Fig 3.8 Distribution of Large Solar Power Bases in Southern Africa

3.1.3 Wind Power Base

Wind power theoretical reserves
67,000 TWh/year

Africa has rich wind energy resources, with the theoretical reserves of 67,000 TWh/year, and mainly distributed in the coastal regions of North, East and Southern Africa as well as the Sahara Region. Considering the resource characteristics and development conditions, it is suitable to build large wind power bases in the Sahara Desert (North Africa) and surrounding areas, the Atlantic coastal areas in the South and some inland areas in East Africa.

01 Wind Power Base in North Africa

The wind power resources along the Atlantic and Mediterranean coasts of North Africa are good with an average wind velocity of about 9 m/s. Based on the characteristics and distribution of solar energy resources, 5 large wind power bases are preliminarily planned, with a total technical potential of about 110 GW and mainly located in western Morocco, northwestern Algeria, eastern Tunisia, northwestern Libya and along the coast of northern Egypt.

Table 3.7 Large Wind Power Bases in North Africa

Unit: GW

S/N	Location	Country	Technical Installed Capacity Potential
1	Matruh	Egypt	25
2	Misrata	Libya	28
3	Monastir	Tunisia	8
4	Ghazaouet	Algeria	28
5	Essaouira	Morocco	20
Total			109

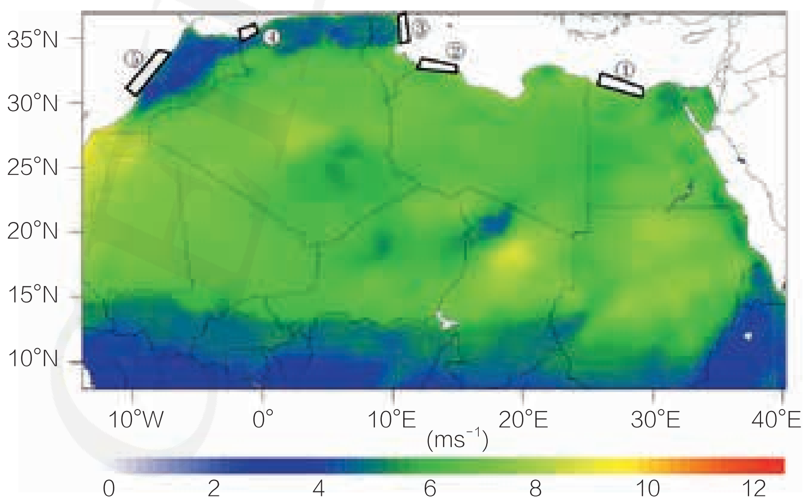


Fig 3.9 Distribution of Large Wind Power Bases in North Africa

02 Wind Power Base in East Africa

The wind power resources along the coastal areas in the northern and eastern of East Africa are good with an average wind velocity of about 6~9 m/s. Based on the characteristics and distribution of wind power resources, 4 large wind power bases are preliminarily planned, with a total technical potential of about 57 GW and mainly located in northern Sudan, eastern Ethiopia and northern Kenya.

Table 3.8 Large Wind Power Bases in East Africa

Unit: GW

S/N	Location	Country	Technical Installed Capacity Potential
1	Dongola	Sudan	20
2	Duweimu	Sudan	15
3	Jijiga	Ethiopia	10
4	North Horr	Kenya	12
Total			57

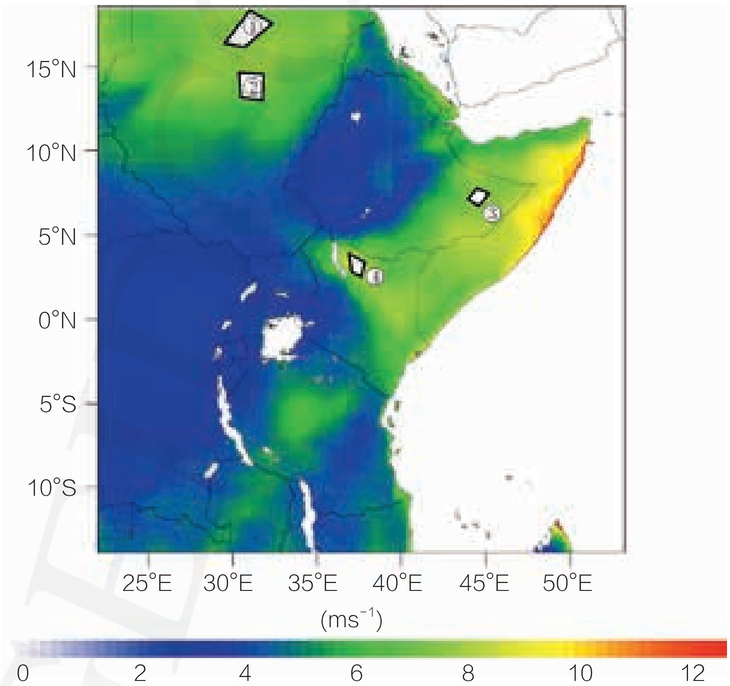


Fig 3.10 Distribution of Large Wind Power Bases in East Africa

03

Wind Power Base in Southern Africa

The wind power resources along the coastal areas of Southern Africa are good with an average wind velocity of above 9 m/s. Based on the characteristics and distribution of wind power resources, 3 large wind power bases are preliminarily planned, with a total technical potential of about 56 GW and mainly located in western central Namibia, the south of South Africa and northeastern Botswana.

Table 3.9 Large Wind Power Bases in Southern Africa

Unit: GW

S/N	Location	Country	Technical Installed Capacity Potential
1	Mariental	Namibia	12
2	Fraserburgh	South Africa	26
3	Orapa	Botswana	18
Total			56

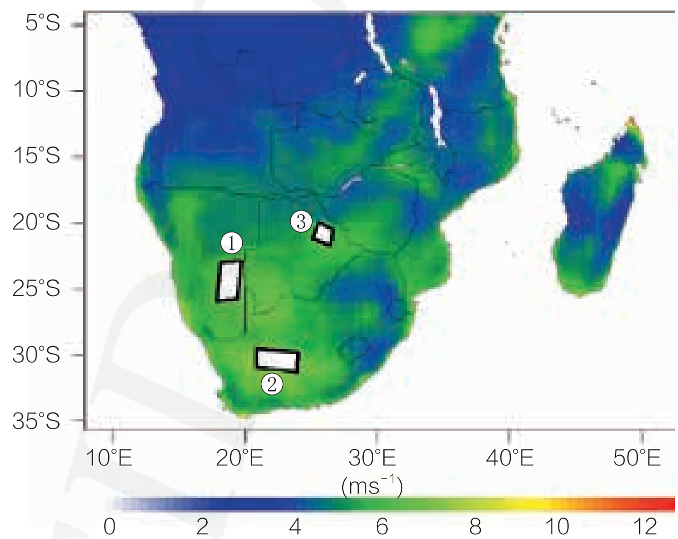


Fig 3.11 Distribution of Large Wind Power Bases in Southern Africa

3.2 Overall Pattern of Africa Grid Interconnection

3.2.1 Overall Power Flow Pattern

With the coordinated consideration of resources and power demand, West Africa and Southern Africa will become the main load centers, Central Africa and North Africa will be the main generation bases through the large-scale development of hydropower and solar power, and East Africa will meet the demand through the Nile River hydropower firstly and gradually convert to a load center in the long-term. Based on the analysis of power and energy balance of each region, the future power flow in Africa is generally in the pattern of **"Central Africa exporting power to North and Southern Africa, and realizing mutual complementation with Asia and Europe".**

2030

The inter-continental and inter-regional power flow will reach 31 GW, of which 14 GW is inter-continental. For the inter-regional power flow, the Congo River hydropower will transfer 8 GW power to Guinea and 1 GW to Angola, the Nile River hydropower will transfer 4 GW to South Africa, and the Sanaga River hydropower will transfer 4 GW to Nigeria. For the inter-continental power flow, the solar power bases in Morocco and Tunisia will transfer 3 GW and 8 GW to Portugal and Italy, respectively. And the Saudi Arabia solar power base will deliver 3 GW to Egypt.

Fig 3.12 Schematic Diagram of Inter-continental and Inter-regional Power Flow of Africa Energy Interconnection in 2030 (GW)

2040

The inter-continental and inter-regional power flow will reach 68 GW, of which 38 GW is inter-continental. For the inter-regional power flow, the Congo River hydropower and the Nile River hydropower will transfer 18 GW and 8 GW power respectively. The power from Inga hydropower station to Guinea and Angola will be increased to 8 GW and 2 GW respectively. In addition, 8 GW of the Congo River hydropower will be transferred to Nigeria. And the power from Nile River hydropower to South Africa will be increased to 8 GW. For the inter-continental power flow, the North Africa solar power base will transfer 27 GW power to Europe. Egypt will additionally transfer 8 GW to Greece and Italy, respectively. The Saudi Arabia solar energy base in West Asia will transfer 7 GW power to Egypt. Meanwhile, Ethiopia will transfer 4 GW to Saudi Arabia.

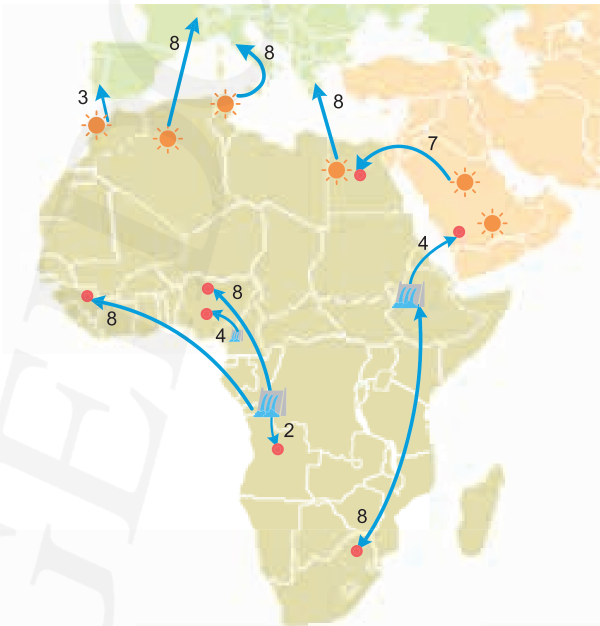
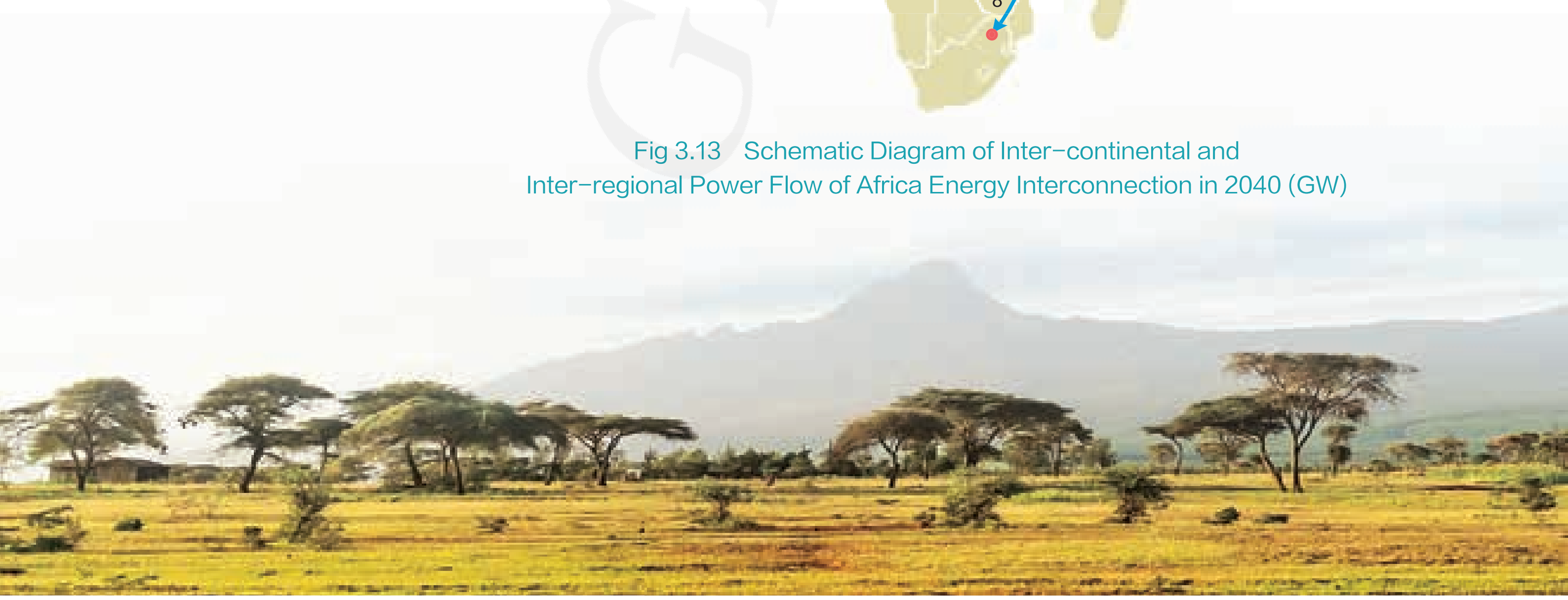


Fig 3.13 Schematic Diagram of Inter-continental and Inter-regional Power Flow of Africa Energy Interconnection in 2040 (GW)



2050

The inter-continental and inter-regional power flow will reach 130 GW, of which 50 GW is inter-continental. For the inter-regional power flow, the Congo River hydropower and the Nile River hydropower will transfer 60 GW and 8 GW power respectively. In addition, the Inga and Matadi station will transfer 10 GW to Morocco and 8 GW to Ethiopia, respectively. R. Congo will transfer 8 GW hydropower to Ghana, and Ethiopia will have 8 GW bidirectional power flow with Egypt. For the inter-continental power flow, Africa will transfer 39 GW power to Europe. In addition, the Morocco solar power base (co-regulated with the Congo River hydropower) will transfer 4 GW to Spain, Algeria will transfer 8 GW to France and Germany.

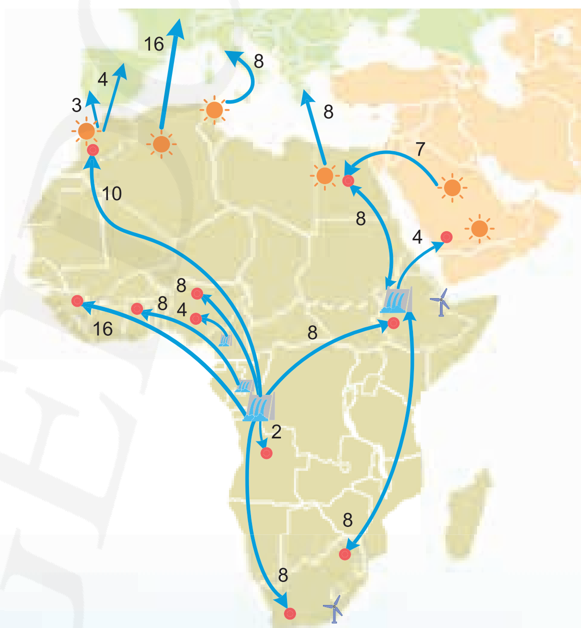


Fig 3.14 Schematic Diagram of Inter-continental and Inter-regional Power Flow of Africa Energy Interconnection in 2050 (GW)

3.2.2 Overall Power Grid Pattern

In five sub-regions of Africa, power grids in East, West and Central Africa are generally very weak and the accessibilities of electricity are low. The five countries in North Africa have achieved synchronous interconnection and synchronously connected to West Europe. Countries in Southern Africa have basically achieved interconnection. In 2015, the peak load in Africa is 120 GW, the installed capacity is 170 GW, and the population with no access to electricity is 600 million. The highest voltage level in South Africa is 765 kV, and the transmission grids of other countries are mainly at the voltage level of 220 kV and 400 kV.

The development of the African power grid will focus on satifying its own power demand, strengthening the construction of energy and power infrastructure, solving, and improving electricity accessibility. The resource advantages should turn into economic advantages by means of accelerating the development of clean energy and promoting intra-continental and inter-continental interconnection.

By **2050**
Peak load **580**GW
Installed capacity **1,130**GW

By 2050, the African power grid will have a peak load of 580 GW and an installed capacity of 1,130 GW. With the upgrade of power grid and the continuous expansion of interconnection, three synchronous power grids will gradually be formed in Africa: North Africa power grids, Central & West Africa power grids and East & Southern Africa power grids. Asynchronous grid connection will be realized via DC among the synchronous power grids, as shown in Fig. 3.15.

North Africa
synchronous power grid upgraded to
1,000kV

Central & West Africa synchronous power grid
South & East Africa synchronous power grids upgraded to
765kV

For the synchronous power grid in North Africa, the voltage level will be upgraded to 1,000 kV. A 1,000 kV AC channel from east to west will be constructed to connect the large solar power bases and load centers in North Africa, and provide support for power delivery of the large-scale solar power bases to Europe via DC. Relying on the significant regional advantages of North Africa, an important energy allocation platform will be formed to connect Asia, Europe and Africa. For the Central & West Africa and the East & Southern Africa synchronous power grids, internal strong 400/765 kV AC backbone power grid will be constructed to form a regional clean energy allocation platform. The power from large clean energy bases in the region will be transmitted directly to the main load centers via extra-high/ultra-high voltage DC.

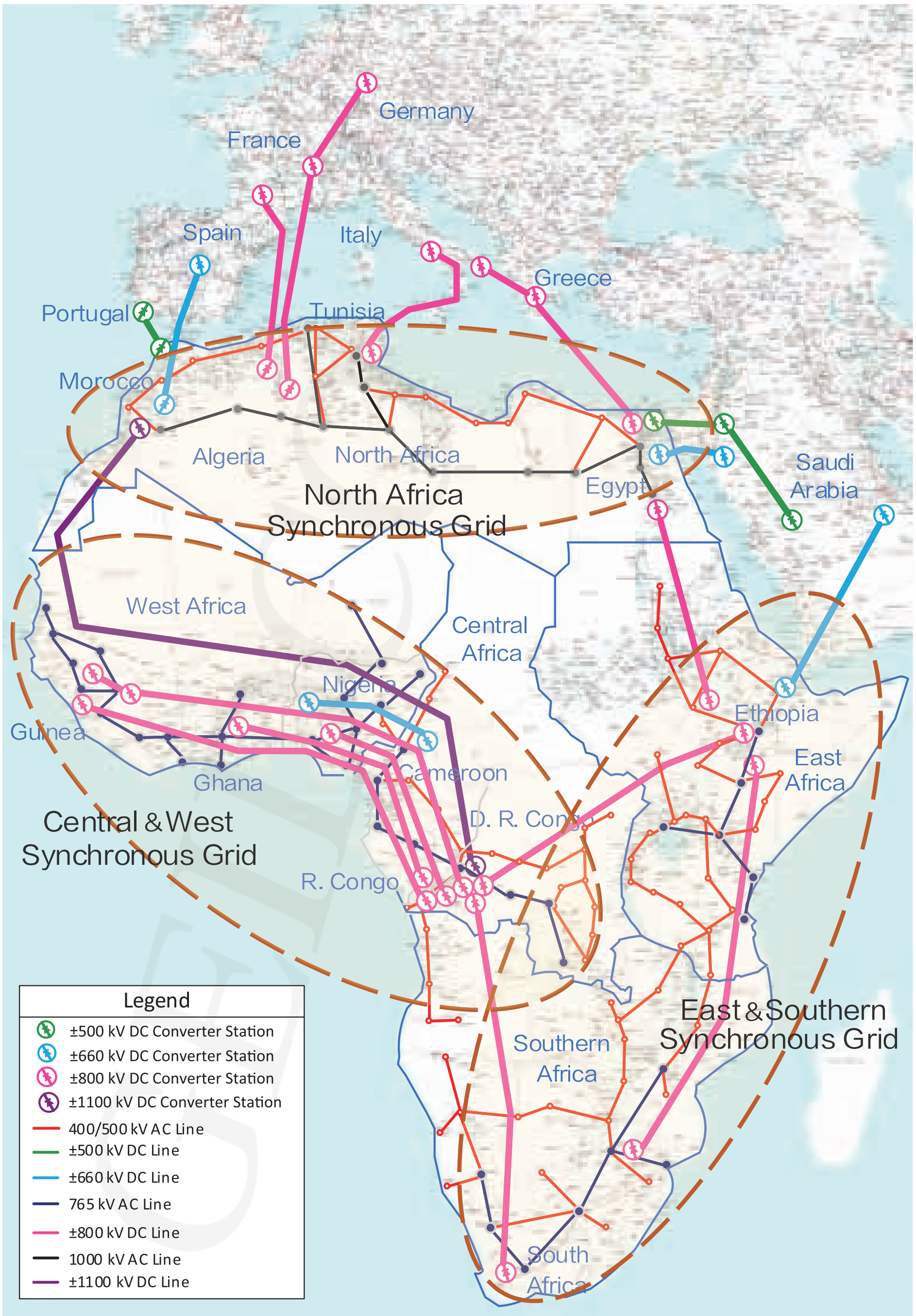


Fig 3.15 Schematic Diagram of African Overall Power Grid Pattern in 2050

3.3

Regional Grid Interconnection Planning

3.3.1 North Africa

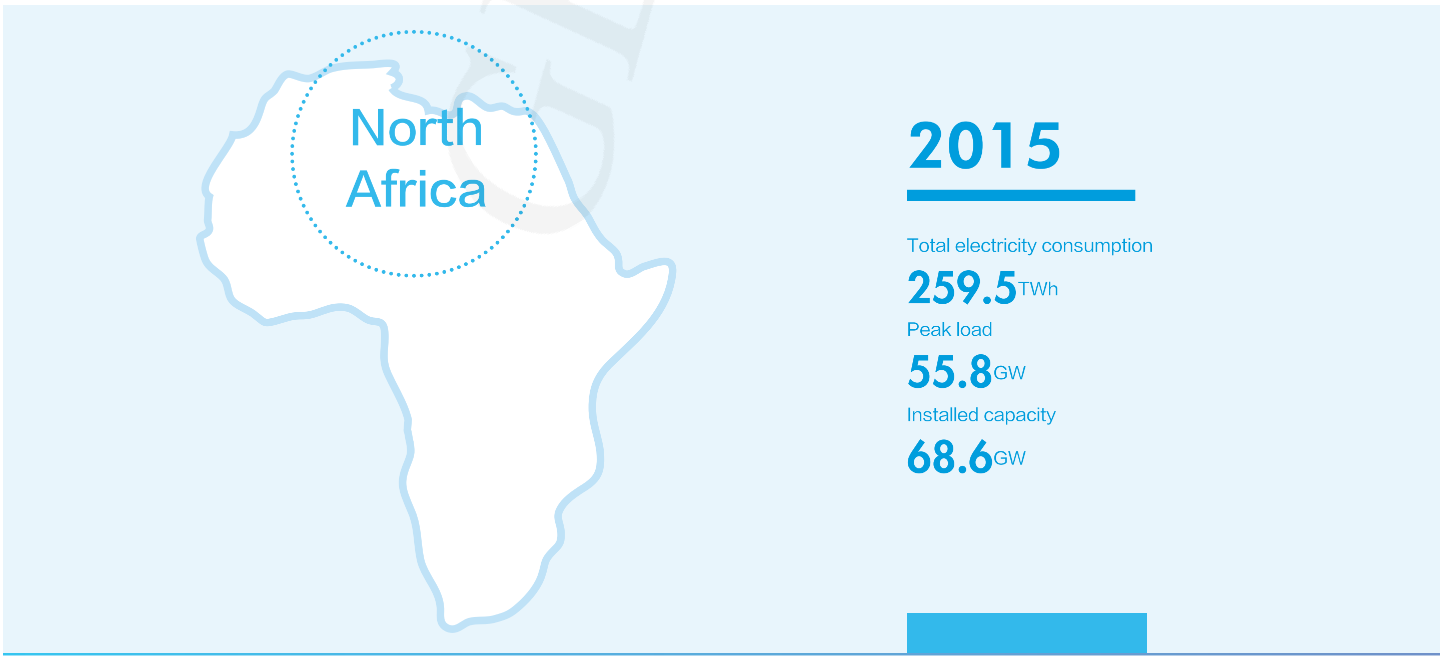
In 2015, the total electricity consumption in North Africa was 259.5 TWh, the maximum load was 55.8 GW, and the installed capacity of power sources was 68.6 GW. Egypt is the regional power demand center and has a power consumption proportion of 59%. A transnational interconnected 400/500 kV AC synchronous power grid has been initially formed in North Africa that runs from east to west along the coastline, forming a "long-chained, weakly-connected" structure.

North Africa has significant regional advantages. In the future, the reforms in education and infrastructure will be promoted by the implementation of economic diversification development plans and policies. Relying on international cooperation frameworks such as the "Belt and Road" Initiative, investment in infrastructure will become the main driving force of economic growth.

In the future, North Africa will focus on developing large solar energy bases and coastal wind power bases, and cooperating with low-carbon gas power generation projects to promote the clean development of power supply within the region. At the same time, by full utilization of its geographical advantages at the convergence of Asia, Africa and Europe, a regional clean energy hub platform can be constructed to receive clean energy from West Africa and other regions of Africa and transmit it to Europe across the Mediterranean.

North Africa is generally in a power flow pattern of "transmission of solar energy from south to north and mutual supply between east and west". The large solar energy bases in the region mainly transmits power to the northern coastal load centers and to Europe across the Mediterranean. In the future, Egypt will still be the important power demand center in North Africa.

By 2030, the electricity consumption in North Africa will reach 562.2 TWh, the maximum load will be 98.4 GW, and the installed capacity will be 150 GW. Within the region, priority will be given to the development of Zag, Laghouat,



Remada, Jawsh and Minya solar energy bases, and a 400/500 kV power grids along the Mediterranean coast in different countries will be constructed to realize a unified AC interconnected grid in North Africa. A 1,000 kV AC transmission channel will also be built to support the collection and delivery of solar power. For the trans-regional development, a Morocco-Portugal ± 500 kV DC line will be constructed to transmit 3 GW of solar energy to Portugal; a Tunisia-Italy ± 800 kV DC line will be constructed to transmit 8 GW solar power to Italy.

By 2040, the electricity consumption in North Africa will reach 732.3 TWh, the maximum load will be 140 GW, and the installed capacity will be 230 GW. Within the region, the highest voltage level will be increased to 1,000 kV, and a single-circuit 1,000 kV AC power transmission corridor running from east to west will be constructed to connect large solar energy bases, strengthen the 400/500 kV AC backbone power grids of these countries, and improve the power receiving capacity of power grid of load centers and the operation safety and reliability of power grid under the conditions of high-proportion new energy power generation. For the trans-regional development, an Egypt-Greece-Italy ±800 kV DC line will be constructed to transmit 4 GW of power from Egypt to Greece and Italy respectively; an Algeria-France ±800 kV DC line will be constructed to transmit 8 GW of power to Toulouse in France; a Saudi Arabia-Egypt ± 660 kV DC line will be constructed to transmit 4 GW of solar energy from Tabuk solar energy base in Saudi Arabia.

By 2050, the electricity consumption in North Africa will reach 955.8 TWh, the maximum load will be 170 GW, and the installed capacity will be 360 GW. Within the region, a 1-circuit 1,000 kV AC power transmission corridor will be built to form a double-circuit 1,000 kV AC channel in North Africa, and enhance the power collection capacity of Zag, Laghouat, Ouargla, Jawsh, Minya and Aswan solar energy bases. The regional 400/500 kV grid will be further strengthened to establish a strong AC interconnected power grid in North Africa. For the trans-regional development, a D. R. Congo-Morocco ± 1,100 kV DC line will be constructed, and the Inga HPP will transmit 10 GW of power to Morocco. After complementary regulation with the Morocco solar energy base, the Morocco-Spain ± 660 kV DC line will transmit 4 GW of power to Madrid; an Algeria-France-Germany ± 800 kV DC line will be constructed to transmit 4 GW solar power to Lyon, France and then 4 GW to Frankfurt, Germany.

2030

Total electricity consumption
562.2 TWh
Peak load
98.4 GW
Installed capacity
150 GW

2040

Total electricity consumption
732.3 TWh
Peak load
140 GW
Installed capacity
230 GW

2050

Total electricity consumption
955.8 TWh
Peak load
170 GW
Installed capacity
360 GW

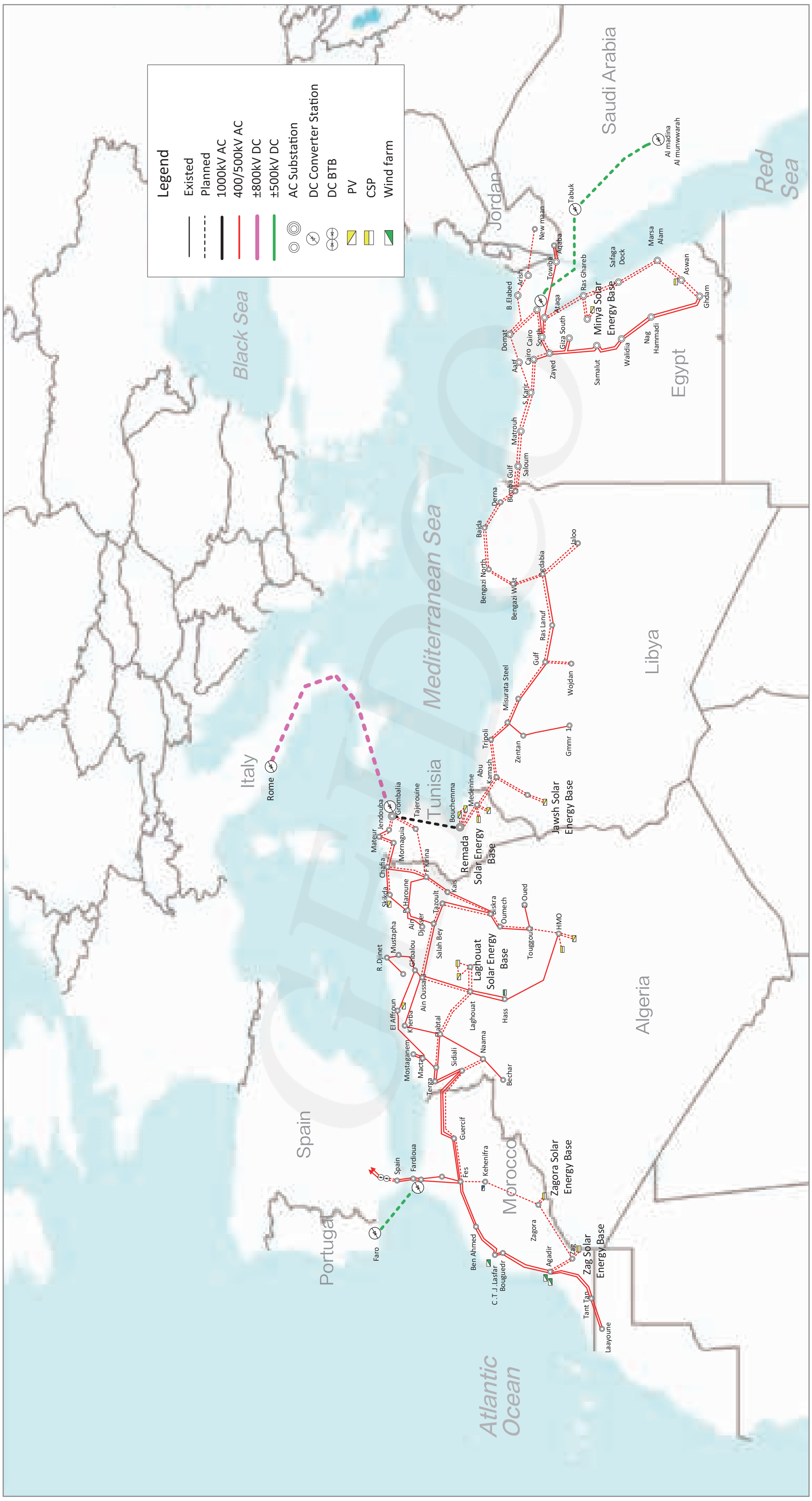


Fig 3.16 Grid Interconnection Planning of North Africa in 2030

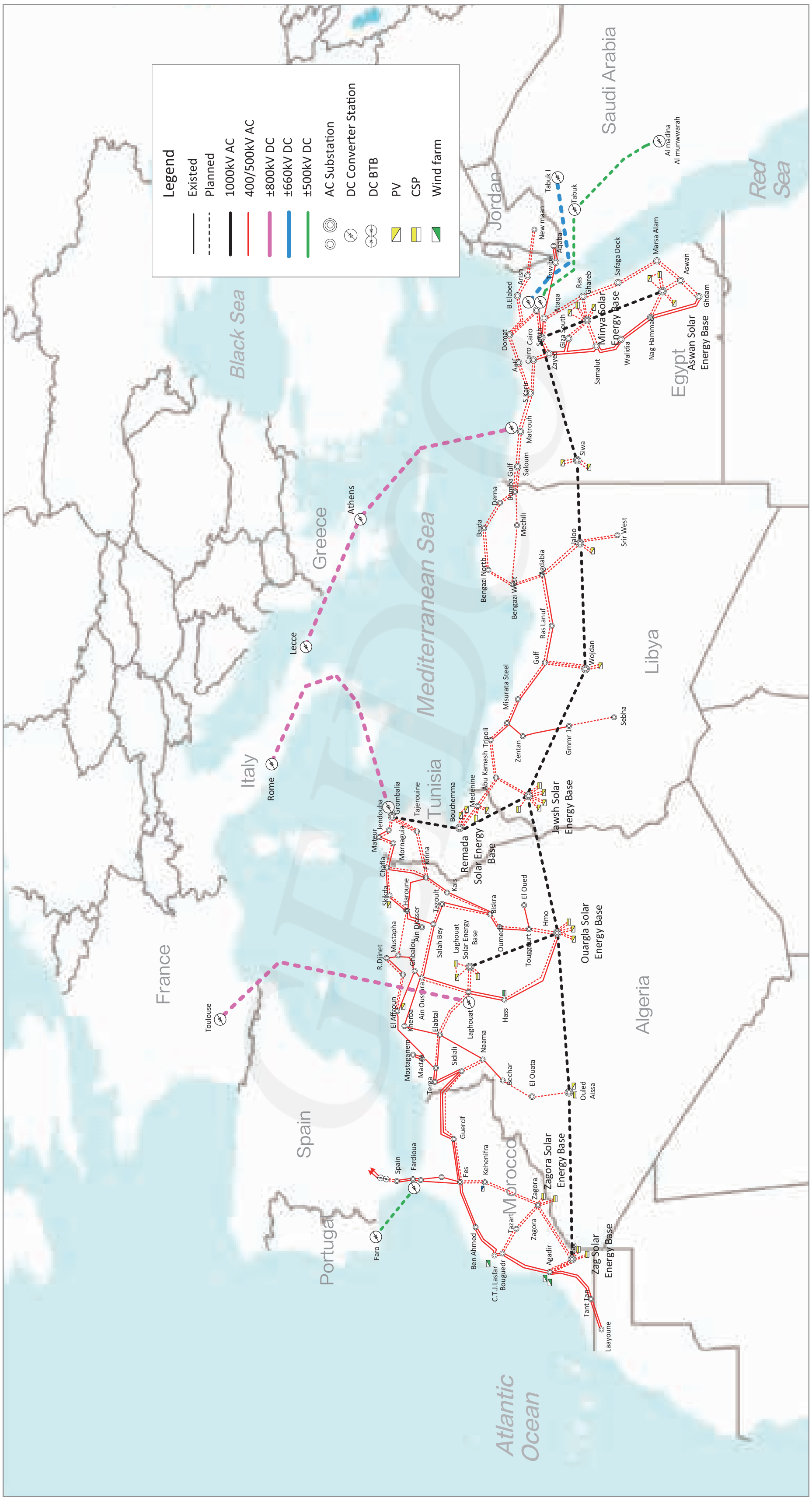


Fig 3.17 Grid Interconnection Planning of North Africa in 2040

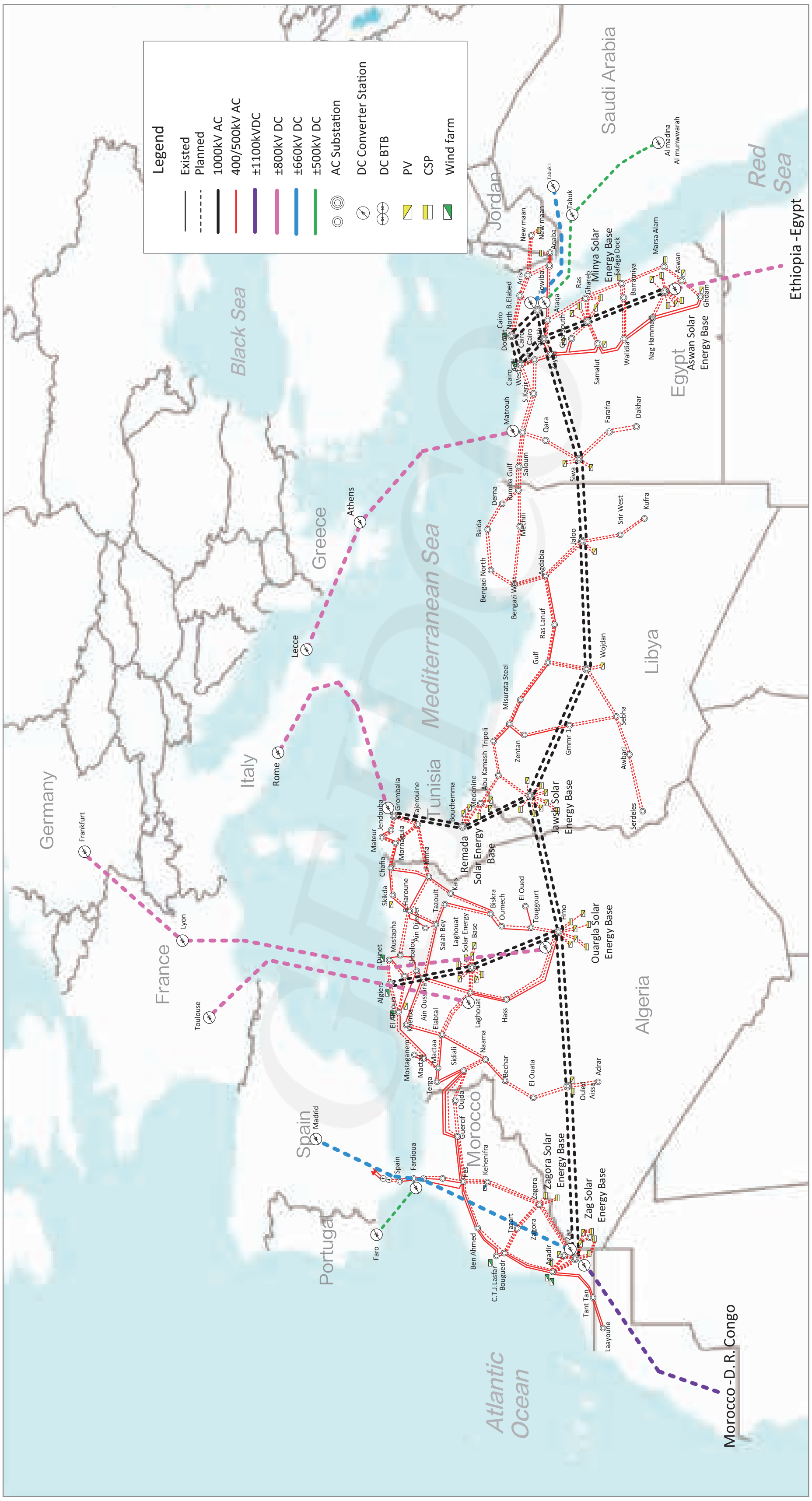


Fig 3.18 Grid Interconnection Planning of North Africa in 2050

3.3.2 West Africa

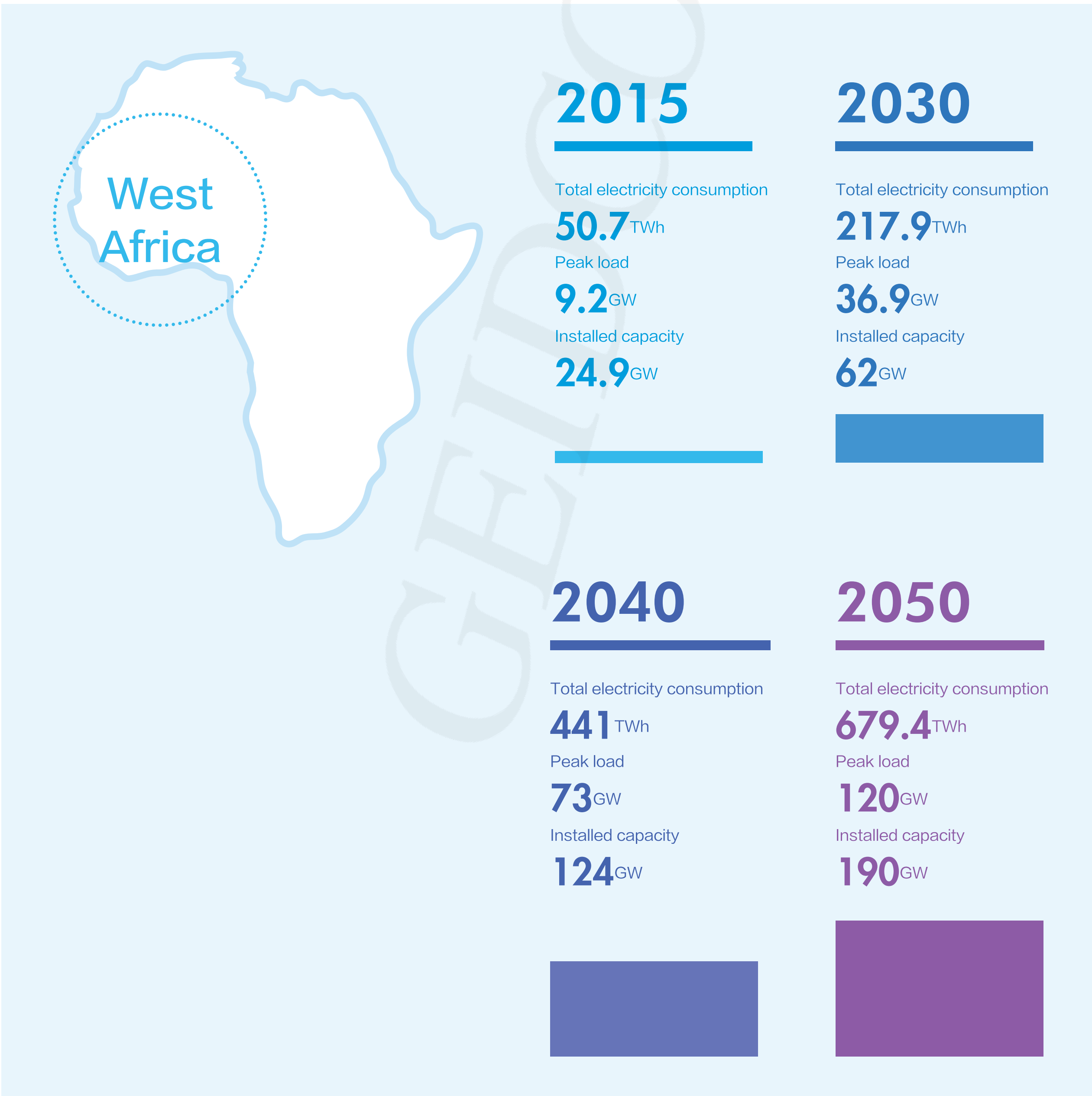
In 2015, the total power consumption in West Africa was 50.7 TWh, the peak load was 9.2 GW, and the installed capacity was 24.9 GW. Nigeria and Ghana are the regional power demand centers. The power consumption of Nigeria accounts for 50%, that of Ghana accounts for 19%, and that of other countries is less than 10%. The cross-border grid connection in West Africa is at the initial stage, and the accessibility of electricity is low. There is a single-circuit 330 kV cross-border power transmission channel in the east and a single-circuit 225 kV line along the Senegal River Basin in the west. West Africa is rich in mineral resources, with a prominent demographic dividend and huge industrial potential, which will promote the rapid development of regional society, economy and energy.

In the future, priority will be given to the development of hydropower along the Niger River, the Senegal River, the Gambia River, etc., and to the gradual development of large solar power bases in Niger, Mali, and Mauritania. Through the coordinated development of power generation and power grids, it is aimed to expand the coverage of power grids, greatly improve the power supply capability, security and reliability, reduce the population without access to electricity, accelerate the integration process of power grids, establish a unified interconnected power grid in West Africa, and receive hydropower from Central Africa to meet the power demand through complementary hydropower, wind power and solar power. West Africa is generally in a power flow pattern of “transmission of solar power from north to south, mutual complement between east and west, and multi-energy complementary”.

By 2030, the power consumption in West Africa will reach 217.9 TWh, the peak load will be 36.9 GW, and the installed capacity will be 62 GW. Within the region of West Africa, a unified AC interconnected power grid will be formed, forming a single-circuit 765 kV AC backbone power transmission channel from east to west. A 765/330 kV power grid in the east and a 765/225 kV power grid in the west will be constructed with the Ghana-Côte d’Ivoire section as the boundary. In the east, relying on the construction of Mambila hydropower plant in Nigeria, a Y-shaped 765 kV power grid will be formed and extended to Benin, Togo and Ghana. In the west, relying on the construction of Kaleta, Sambangalou and surrounding hydropower plants, a 225 kV double-circuit backbone grid will be constructed in Guinea and extended to the east and west ends, forming a horizontal 8-shaped cross-border interconnected power grids. Inter-regionally, a Cameroon-Nigeria ±660 kV DC line will be constructed to receive 4 GW hydropower from the Sanaga River; a D. R. Congo-Guinea ±800 kV DC line will be constructed to receive 8 GW hydropower from the Inga plant; a single-circuit 400 kV AC line from Nigeria to Cameroon will be constructed to realize mutual complementation with Central Africa.

By 2040, the power consumption in West Africa will reach 441 TWh, the peak load will be 73 GW, and the installed capacity will be 124 GW. Within the region, hydropower development will account for about 80%, and the 765 kV AC power transmission channel will be strengthened. The "two-horizontal and four-vertical" 330 kV power grid structure in the east and the "three-horizontal and four-vertical" 225 kV power grid structure in the west will be constructed and extended to the south and north via the 330/225 kV power grids. The "solar power from north to south and hydropower from south to north" will be connected to the 765 kV power transmission channel. Complementary hydropower and solar power will be adopted to support large-scale mutual power supply between the eastern and western power grids during the rainy and dry seasons. Inter-regionally, the D. R. Congo-Nigeria ±800 kV DC project will be constructed to receive 8 GW hydropower from the Congo River plant; and the AC interconnected line from Numan, Nigeria to Garoua, Cameroon will be strengthened to be double-circuit.

By 2050, the power consumption in West Africa will reach 679.4 TWh, the peak load will be 120 GW, and the installed capacity will be 190 GW. Within the region, the development of solar power bases in Niger, Mali and Mauritania will be accelerated. Relying on the demand for power transmission from the solar power bases, the 765 kV power grid in West Africa will be further strengthened and extended to Sakale, Senegal. The 330 kV power grid in the east and the 225 kV power grid in the west will be strengthened to improve the mutual power supply between these two grids, so as to achieve a strong AC interconnected power grid in West Africa. Inter-regionally, R. Congo-Ghana ±800 kV DC project will be constructed to transmit 8 GW hydropower from the Congo River to meet the power demand of Ghana and Côte d'Ivoire. A new ±800 kV DC project will be built between D. R. Congo and Guinea to transmit 8 GW Matadi hydropower.



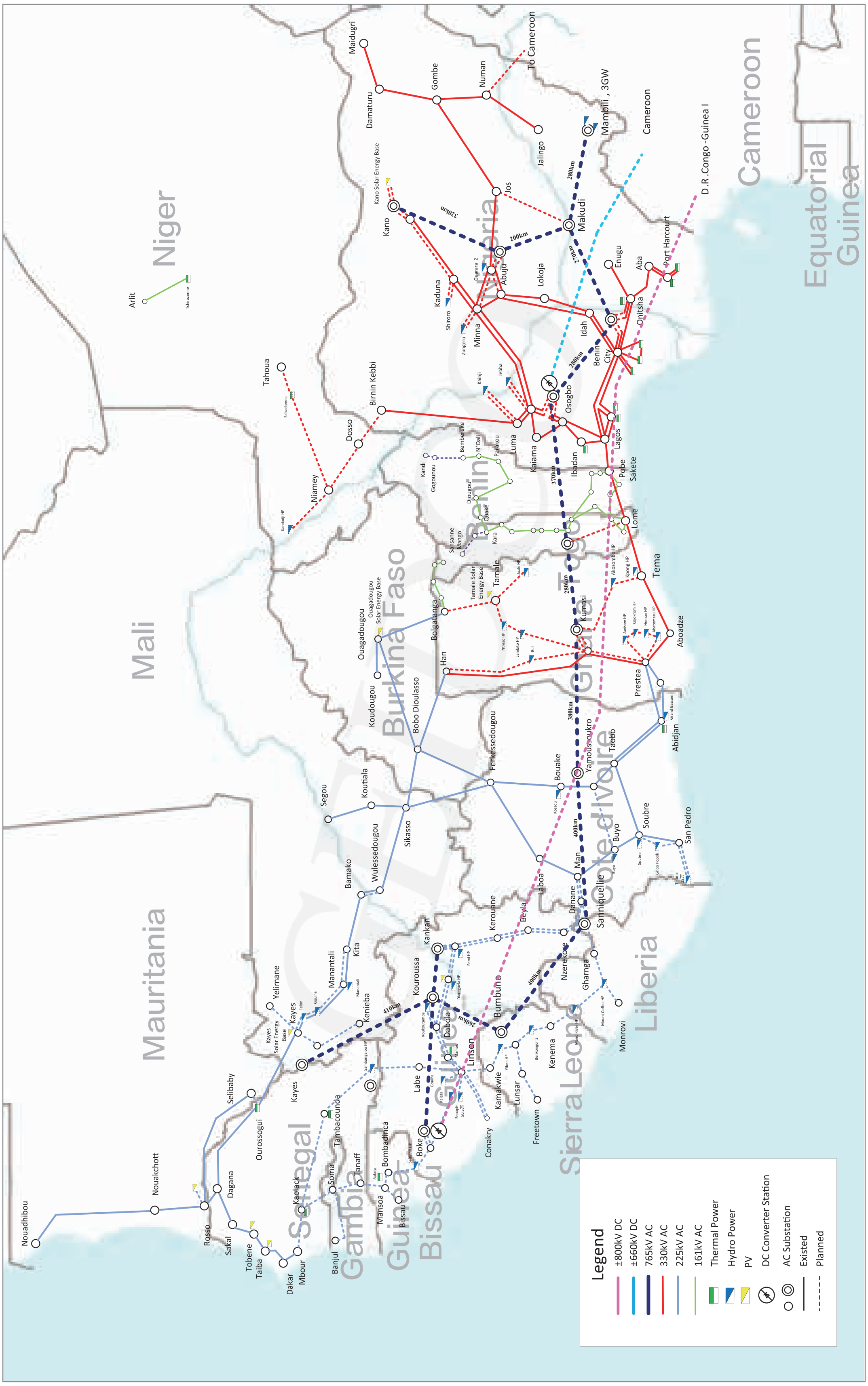


Fig 3.19 Grid Interconnection Planning of West Africa in 2030

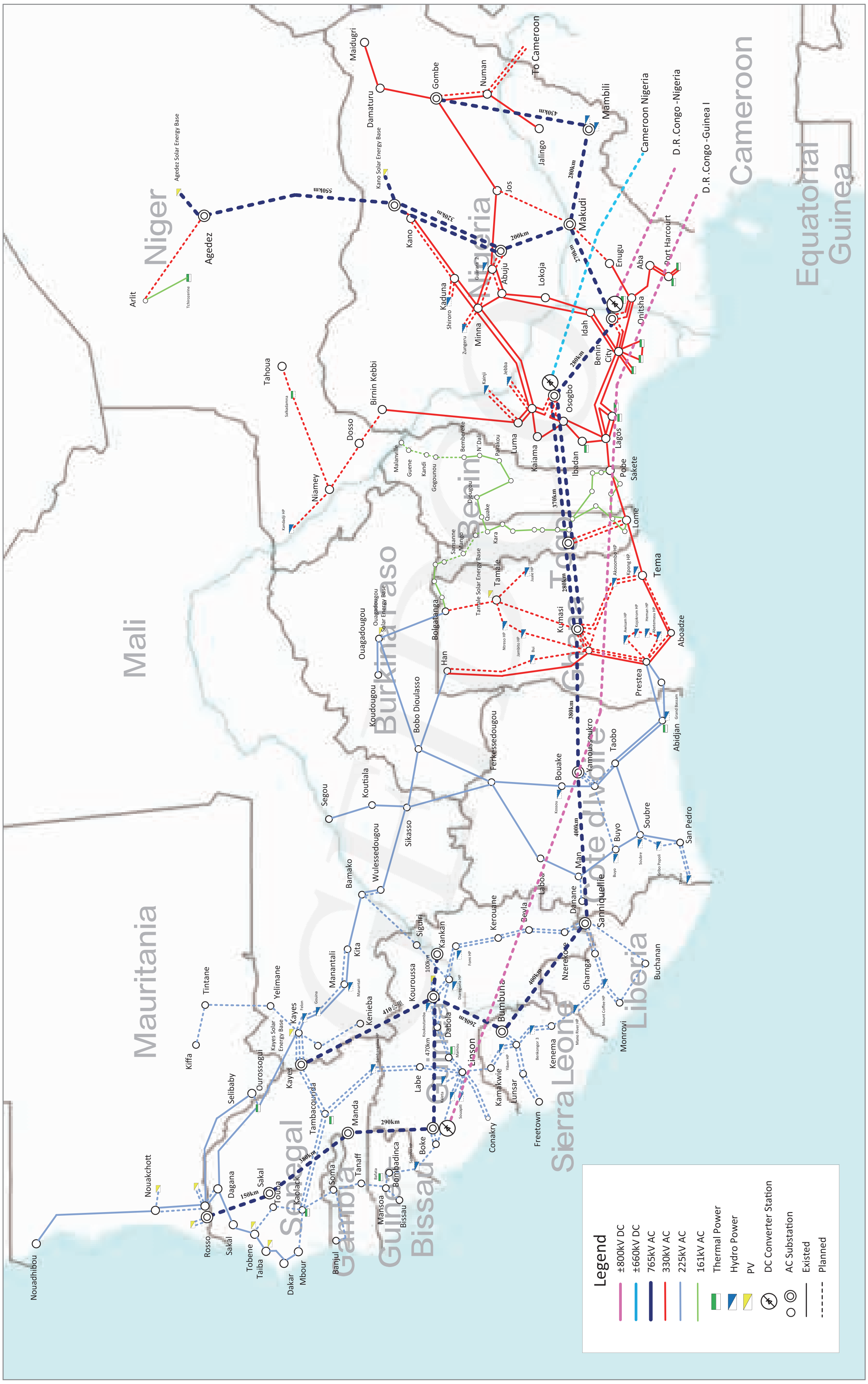


Fig 3.20 Grid Interconnection Planning of West Africa in 2040

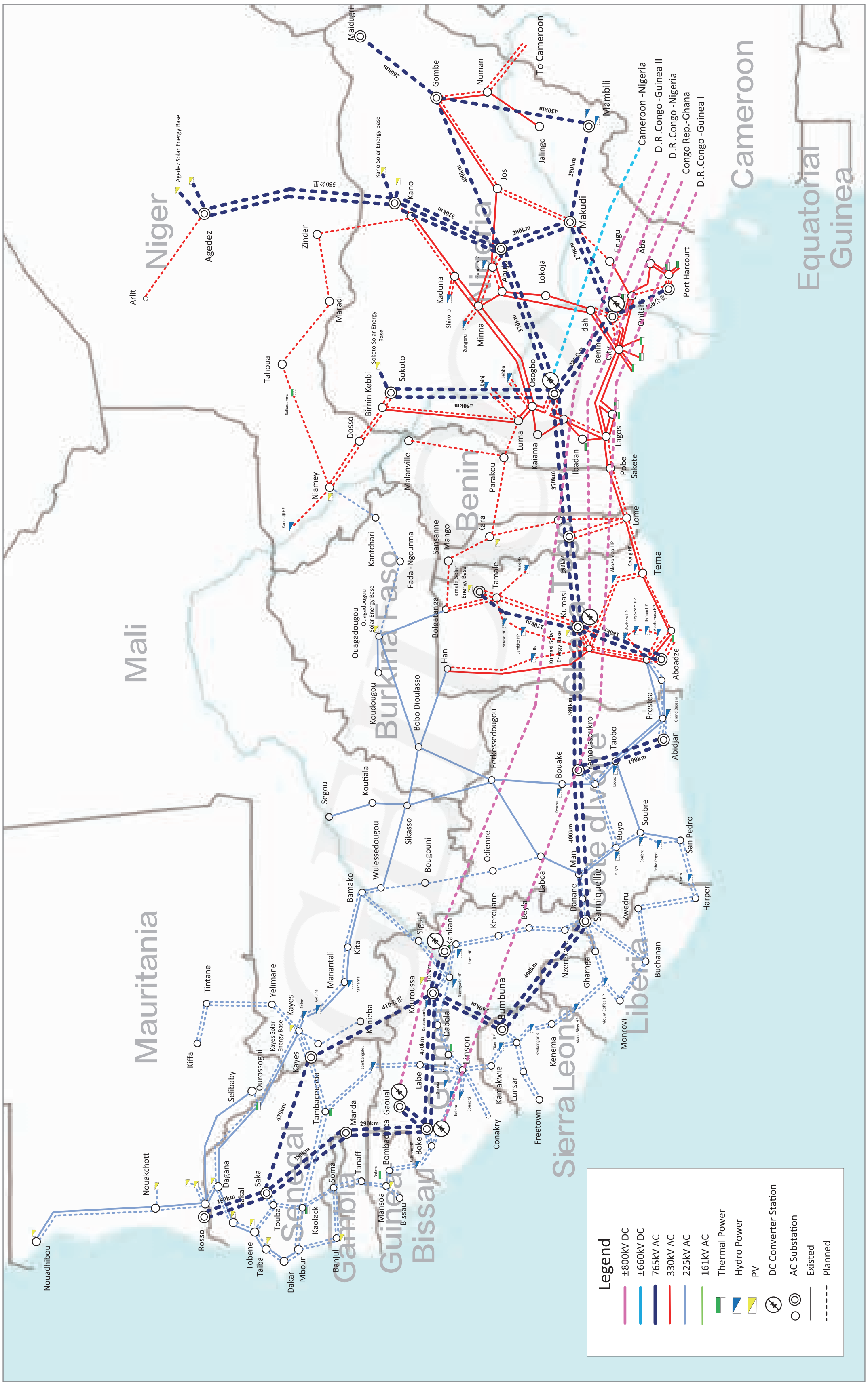


Fig 3.21 Grid Interconnection Planning of West Africa in 2050

3.3.3 Central Africa

In 2015, the total power consumption in Central Africa was 17.1 TWh, the peak load was 2.8 GW, and the installed capacity was 5.3 GW. D .R. Congo and Cameroon are the main power load centers in this region, accounting for up to 80% power demand. The power grid facilities suffer from severe aging, and the power supply is of poor reliability. No country in Central Africa has achieved nationwide grid connection. Except for Gabon whose accessibility of electricity is 89.6%, there is still a large population with no access to electricity in other countries. The cross-border power interconnection is at the initial stage, and there is only one single-circuit 220 kV AC line from the R. Congo to D. R. Congo. The political and social environment tends to become stable in Central Africa. With significant demographic dividends and rapidly growing economic development potential, energy demand in Central Africa will fast increase.

The future development of Central Africa power grid will focus on improving the power grid coverage and promoting cross-border and inter-regional interconnection. In order to meet the development and power transmission needs of hydropower bases in the Congo River, the Sanaga River and the Ogooué River Basins, a strong main power grid connecting to the clean energy base and the regional load centers will be constructed. Power grid coverage area and the regional power exchange capacity will all be improved to realize long-distance and large-scale allocation of hydropower. Advantages of clean energy resources will be transfomed into economic advantages.

By 2030, the total power consumption in Central Africa will reach 63.4TWh, the peakload will be 10.1 GW, and the installed capacity will be 29 GW. Within the region, a D. R. Congo-R. Congo-Gabon-Cameroon 765 kV vertical power transmission channel will be constructed and extended towards to Chad and the Central African Republic via 400/225 kV AC line. The regional 765/400/225 kV synchronous grid is formed. In order to collect the clean hydropower from Cameroon and the northern part of R. Congo, a 400

2015

Total electricity consumption

17.1 TWh

Peak load

2.8 GW

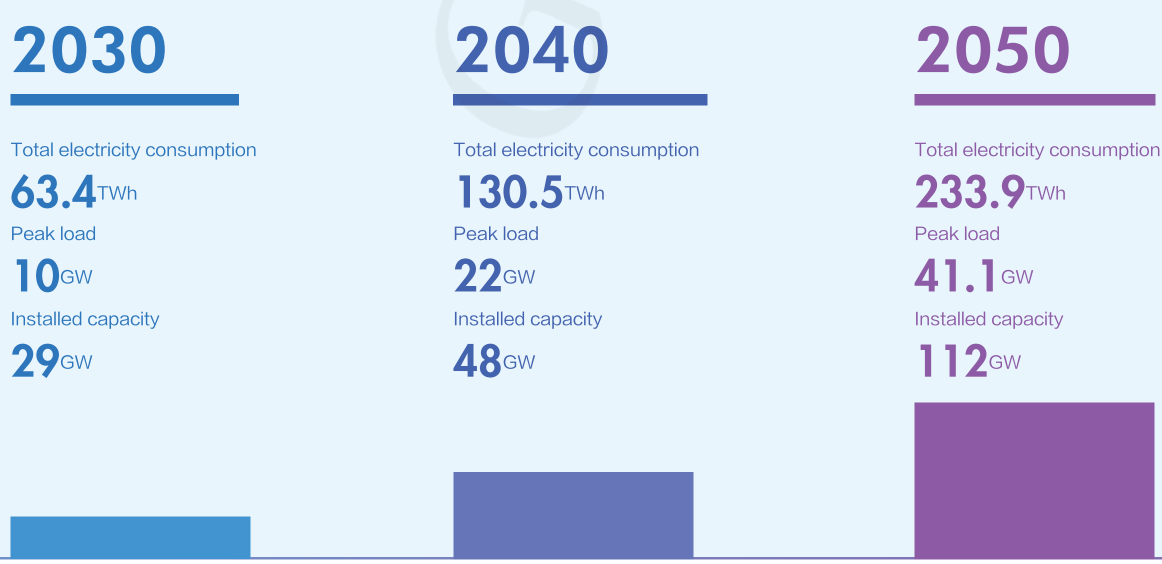
Installed capacity

5.3 GW

kV power transmission channel will be constructed. Inter-regionally, a D. R. Congo-R. Congo-Angola 400 kV circular power grid and a D. R. Congo-Angola one single-circuit 400 kV AC power transmission line will be constructed to receive hydropower from the Inga III. Interconnection with West Africa will be strengthened. A Cameroon-Nigeria ± 660 kV DC project and a D. R. Congo-Guinea ± 800 kV DC project will be constructed to transmit the hydropower from the Sanaga River and the Congo River to West Africa. A Cameroon-Nigeria one single-circuit 400 kV grid-connected line will be constructed to form an AC synchronous power grid between Central Africa and West Africa765 kV grids.

By 2040, the total power consumption in Central Africa will reach 130.5 TWh, the peak load will be 22 GW, and the installed capacity of power sources will be 48 GW. Within the region, the regional vertical 400 kV power transmission channel will be strengthened to 2-circuit. Transmission channels of all countries will be enhanced to cover the key regional hydropower bases and load centers. Inter-regionally, D. R. Congo-R. Congo-Angola 400 kV circular power grid will be strengthened. The 2nd circuit of D. R. Congo-Angola 400 kV power transmission channel will be constructed to receive hydropower from the Inga. D. R. Congo-Nigeria ± 800 kV DC project and the second circuit of Cameroon-Nigeria 400 kV AC line will also be constructed.

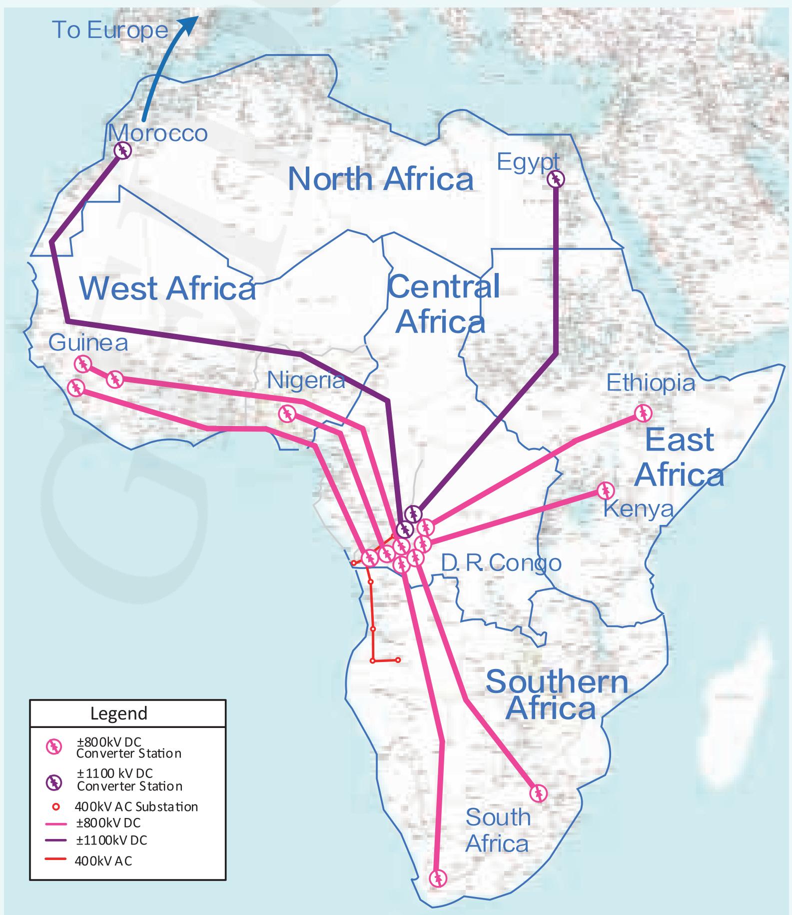
By 2050, the total power consumption in Central Africa will reach 233.9 TWh, the peak load will be 41.1 GW, and the installed capacity will be 112 GW. Within the region, the vertical 765 kV transmission channel is upgraded to double-circuit, and the voltage level of Cameroon-Chad interconnection will be boosted to 400 kV. Inter-regionally, D. R. Congo-Ghana, D. R. Congo-South Africa and D. R. Congo-Guinea ±800 kV DC projects will be constructed to transmit hydropower from Inga to the West and South Africa load centers, and a D. R. Congo-Ethiopia ± 800 kV DC project will be constructed. A D. R. Congo-Morocco ±1100 kV UHV DC project will also be constructed to transmit the co-regulated hydropower from the Congo River and solar power from North Africa to the Europe.



Box 3.1

Future Planning of Hydropower from the Downstream of Congo River

By 2050, the Inga and Matadi hydropower projects will be exploited in the downstream Congo River with totally 66 GW installed capacity of which approximately 52 GW will be transmitted outwards. Beyond 2050, 35 GW Pioka hydropower project will be gradually constructed that the total installed capacity of the downstream Congo River will reach more than 100 GW of which approximately 78 GW will be transmitted outwards. Regarding transmission distance and grid infrastructure, EHVAC technology will be applied for cross-border transmission inside Central Africa and other neighbor countries, to Angola for example. UHVDC technology will be applied for distant inter-regional transmission with large capacity. To meet increasing power demand, before 2050, Guinea, Nigeria, South Africa, Ethiopia will receive power from the Congo River hydropower plants and beyond 2060 Egypt and Kenya will also join the list.



Future Delivery Planning of Hydropower from the Downstream of Congo River

Fig 3.22 Grid Interconnection Planning of Central Africa in 2030

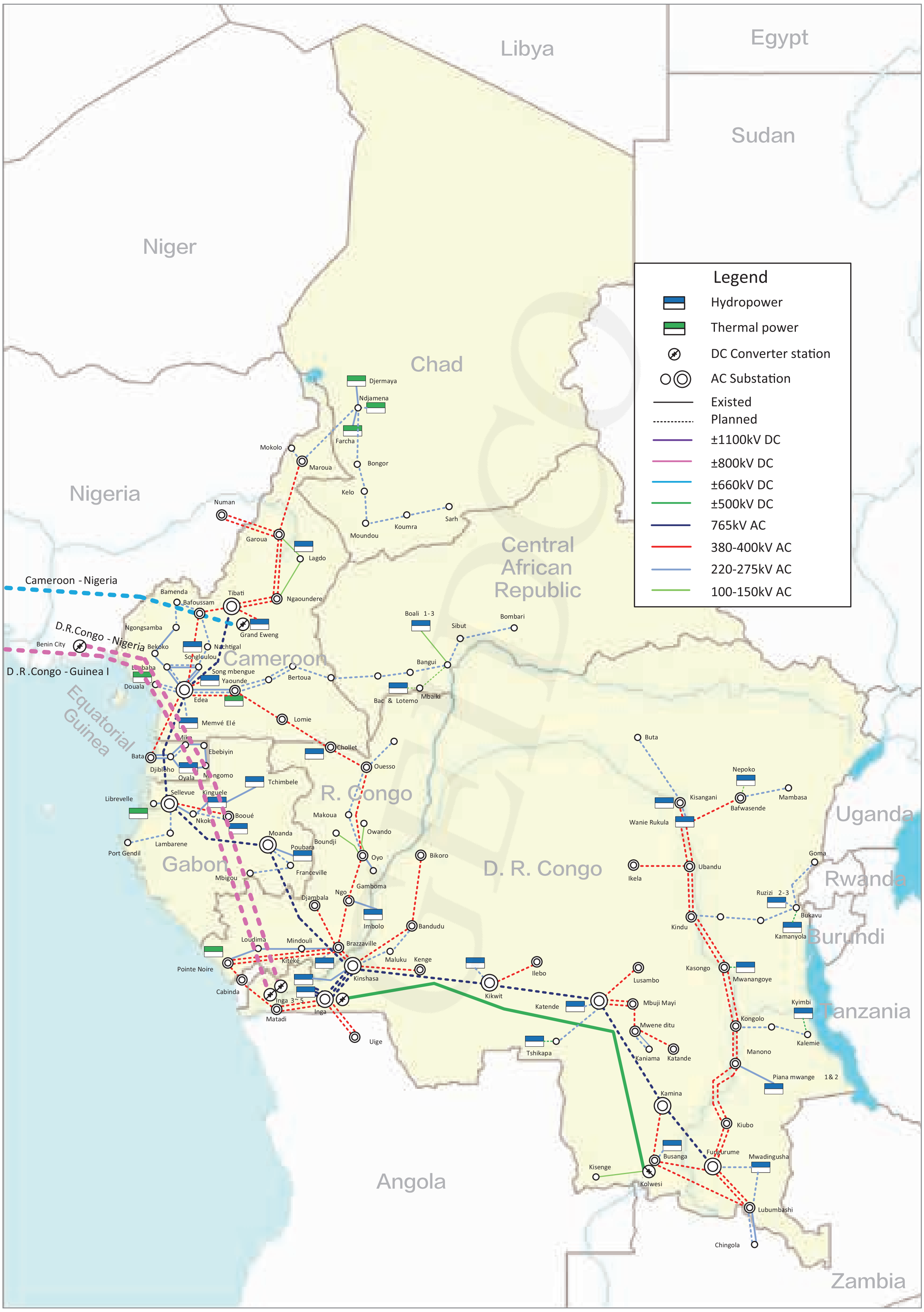


Fig 3.23 Grid Interconnection Planning of Central Africa in 2040

Fig 3.24 Grid Interconnection Planning of Central Africa in 2050

3.3.4 East Africa

In 2015, the total power consumption in East Africa was 36.6 TWh, the peakload was 7.8 GW, and the installed capacity was 10.9 GW. Sudan, Ethiopia, Kenya and Tanzania are the largest power countries in the region, with their power consumption and installed capacity accounting for 88% and 89%, respectively. The power grid infrastructure in East Africa is weak. East Africa is the region in Africa with the highest proportion of population with no access to electricity (with a total of 220 million). The gap is significant between urban and rural areas. The capacity of cross-border power exchange is small, some countries are interconnected via 245/132 kV, and some countries such as South Sudan are still operating in island mode. East Africa has significant regional advantages and rapid population growth. These countries attach great importance to industrialization. East Africa is currently the fastest growing region in Africa.

The future development of power grid in East Africa will focus on strengthening the interconnection between northern and southern power grids and improving the power grid coverage. In order to realize large-scale development and complementation of various clean energy resources in East Africa, such as hydro energy, solar energy, wind energy and geothermal energy, a strong backbone power grid will be constructed to connect the northern Nile River hydropower base, the Sudan solar powerbase, the Ethiopia wind powerbase, the southern Rufigi River hydropower base, the Kenya geothermal powerbase, and various regional load centers to improve the power grid coverage and the power exchange capabilitybetween the north and the south within the region. At the same time, this region will be interconnected with Southern Africa to make full use of the complementary characteristics of cross-basin water energy during the rainy and dry seasons, interconnected with Central Africa to receive hydropower from the Congo River hydropower plant, and interconnected with West Asia to transmit the hydropower from the Nile River hydropower plant to Saudi Arabia in West Asia.

By 2030, the total power consumption in East Africa will reach 134.2 TWh, the peak load will be 25.7 GW, and the installed capacity will be 55.5 GW. Within the region, Sudan-Ethiopia 500 kV and Ethiopia-Eritrea 220 kV AC lines will be constructed in the north, the Ethiopia-Djibouti 220 kV AC project will be expanded, and Kenya-Uganda and Kenya-Tanzania 400 kV AC tie lines will be constructed in the south. With Ethiopia and Kenya as the sections, two major regional power grids will be formed in the north and the south. Ethiopia-Kenya 765 kV AC and Ethiopia-Kenya ±500 kV DC transmission channels will be constructed to achieve complementation of hydropower from the northern Nile River hydropower plant and geothermal power from the southern Great Rift Valley. Inter-regionally, interconnection with Southern Africa will be achieved, and an Ethiopia-South Africa ± 800 kV DC project will be constructed to transmit hydropower from the Nile River hydropower plant to the South Africa load center. A Tanzania-Zambia single-circuit 400 kV AC grid-connected line will be constructed to initially form a 765/500/400 kV AC synchronous power grid between East Africa and Southern Africa.

By 2040, the total power consumption in East Africa will reach 287.7 TWh, the peak load will be 53.1 GW, and the installed capacity will be 140 GW. Within the region, the two major regional power grids in the north and the south will be further strengthened, the third circuit of Sudan-Ethiopia 500 kV AC line will be constructed in the north. The southern 765 AC Synchronous grid will extend to Tanzania, and 400 AC synchronous grid will extend to South Sudan and Burundi. Ethiopia-South Sudan double-circuit 220 kV AC lines will be constructed. Inter-regionally, an Ethiopia-Saudi Arabia ± 660 kV DC project will be constructed to achieve grid interconnection between East Africa and Western Asia, and the Tanzania-Zambia 400 kV line will be upgraded into a double-circuit line to strengthen the synchronous East & South Africa synchronous grid.

By 2050, the total power consumption in East Africa will reach 457.1 TWh, the peak load will be 84.3 GW, and the installed capacity will be 180 GW. Within the region, the northern Sudan-Ethiopia 500 kV power transmission channel will be strengthened to 4-circuit, and a Victoria Lake 400 kV circular power grid will be formed in the south. The 765 kV power transmission network will extend to Uganda, and another Uganda-South Sudan circuit will be built. The Ethiopia-Kenya 765 kV AC power transmission channel will be upgraded to double circuit, and the power flow capacity between the north and the south will be significantly improved. Inter-regionally, D. R. Congo-Ethiopia ± 800 kV DC and Ethiopia-Egypt ± 800 kV DC projects will be constructed to achieve interconnection between East and North, East and Central Africa.

2015

Total electricity consumption
36.6TWh
Peak load
7.8GW
Installed capacity
10.9GW

2030

Total electricity consumption
134.2TWh
Peak load
25.7GW
Installed capacity
55.5GW

2040

Total electricity consumption
287.7TWh
Peak load
53.1GW
Installed capacity
140GW

2050

Total electricity consumption
457.1TWh
Peak load
84.3GW
Installed capacity
180GW

Fig 3.25 Grid Interconnection Planning of East Africa in 2030

Fig 3.26 Grid Interconnection Planning of East Africa in 2040

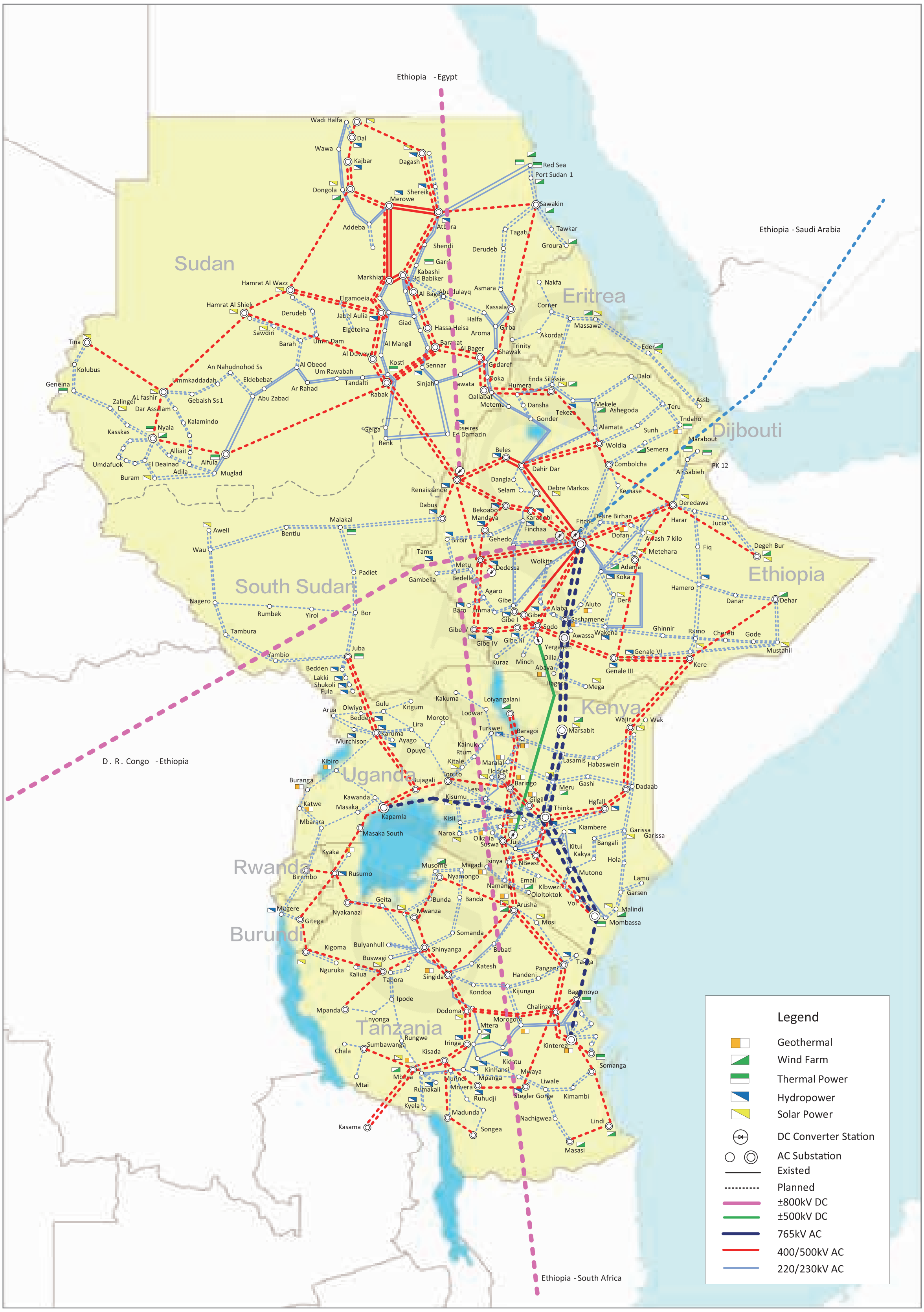


Fig 3.27 Grid Interconnection Planning of East Africa in 2050

3.3.5 Southern Africa

In 2015, the total power consumption in Southern Africa was 250 TWh, the peak load was 48.4 GW, and the installed capacity was 58 GW. The development of power grid in Southern Africa is very unbalanced. South Africa is the most developed country, with its power demand accounting for up to 80%. Other countries have weak power infrastructure and low accessibility of electricity. Except for Angola and Malawi, other countries have achieved 132~400 kV AC grid interconnection. Southern Africa has abundant mineral resources, large fossil energy reserves such as coal, oil and natural gas, rapid population growth, and large economic development potential, which will drive the rapid growth of energy and power demand.

Taking into account the distribution of resources and power demand in Southern Africa, the power flow is generally in the pattern that hydropower from the Nile River hydropower plant and the Congo River hydropower plant outside the region, and wind power from Mozambique, hydropower from the Zambezi River hydropower plant, solar power from Botswana and Namibia, and wind power from southern coastline in the region to the South Africa load center. The future development of power grid will focus on strengthening grid interconnection, meeting the needs of large-scale optimized allocation of clean energy power, constructing a strong main grid that connects regional clean energy bases and load centers, improving regional power exchange capability and power supply reliability, and expanding coverage of grid interconnection and overall accessibility of electricity in the region. At the same time, inter-regional complementation of clean power (such as hydropower) with East Africa and Central Africa will be strengthened to achieve multi-energy complementary and efficient utilization and meet the growing power demand in Southern Africa.

By 2030, the total power consumption in Southern Africa will reach 506.3 TWh, the peak load will be 88.4 GW, and the installed capacity will be 150 GW. Within the region, a Zambia-Zimbabwe-Botswana-South Africa 400 kV AC vertical clean energy transmission channel will be constructed to transmit hydropower from the Zambezi River hydropower plant and power from the Botswana solar powerbase to South Africa. An Angola-Namibia 400 kV AC project will be constructed to form a 400/765 kV AC synchronous power grid. Inter-regionally, interconnection with East Africa will be strengthened, and an Ethiopia-South Africa ± 800 kV DC project will be constructed to transmit hydropower from the Nile River hydropower plant to the South Africa load center. A D. R. Congo-Angola single-circuit 400 kV AC grid-connected line will be constructed to receive hydropower from the Congo River hydropower plants. A Tanzania-Zambia single-circuit 400 kV AC grid-connected line will be constructed to form a 400 kV AC synchronous power grid in East Africa and Southern Africa.

By 2040, the total power consumption in Southern Africa will reach 697.5 TWh, the peak load will be 120 GW, and the installed capacity will be 210 GW. Within the region, the grid-connected channels among Namibia, Botswana, Mozambique and South Africa will be strengthened, and the South Africa 765 kV main power grid will be further enhanced and extended to load centers, such as the southwest coastal port. A regional 765/400 kV double-circuit power grid structure will be formed in Southern Africa to greatly improve the cross-border power exchange capability and the reliability of power supply. Inter-regionally, the secondcircuit of D. R. Congo-Angola and Tanzania-Zambia 400 kV AC grid-connected lines will be constructed to improve the capacity of power exchange among Southern Africa, Central Africa and East Africa.

By 2050, the total power consumption in Southern Africa will reach 895.1 TWh, the peak load will be 160 GW, and the installed capacity will be 280 GW. Within the region, the voltage level of Botswana-Namibia grid connection will be increased to 400 kV, and the 765/400 kV main power grid will be further strengthened to cover large clean energy bases and main load centers. Inter-regionally, the interconnection with Central Africa will be further strengthened, and a D. R. Congo-South Africa ±800 kV DC project will be constructed hydropower from the Congo River hydropower plant to the South Africa load center.

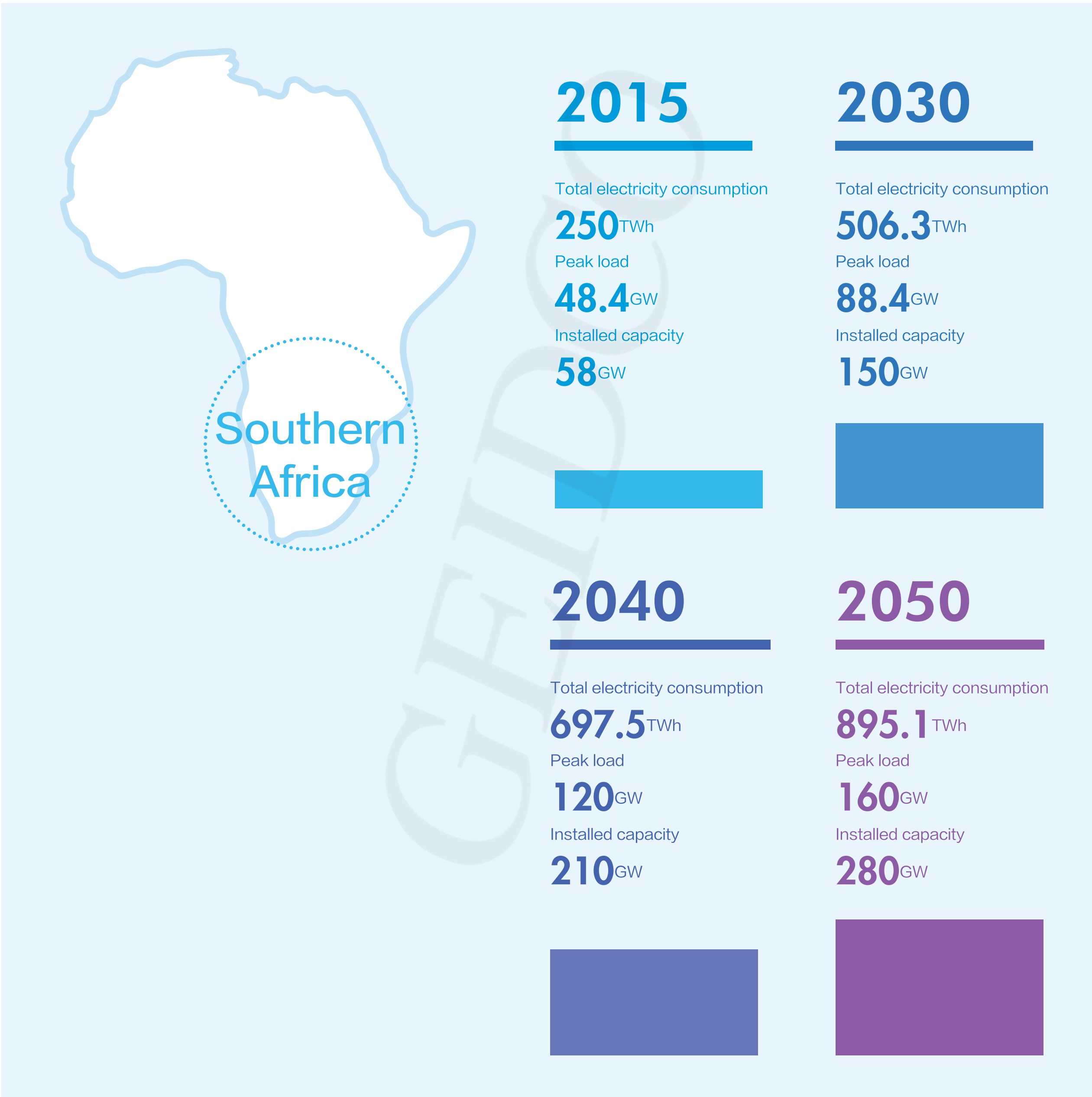


Fig 3.28 Grid Interconnection Planning of Southern Africa in 2030

Fig 3.29 Grid Interconnection Planning of Southern Africa in 2040

Fig 3.30 Grid Interconnection Planning of Southern Africa in 2050

3.4

Phased Implementation Scheme and Investment Estimate

3.4.1 Phased Implementation Scheme

The Africa Energy Interconnection shall take initial shape by 2030. Inter-regional synchronous grid interconnection will be realized between East Africa and Southern Africa, as well as West Africa and Central Africa. Meanwhile, inter-continental grid interconnection will be realized among Asia, Europe and Africa. With power grids in different countries and regions being improved continuously, in terms of **intra-continental interconnection,** the D. R. Congo–Guinea, Ethiopia–South Africa and Cameroon–Nigeria DC projects will be constructed, to transmit hydropower generated in Inga on the Congo River, the Nile River and the Sanaga River to load centers of West and Southern Africa. In terms of **inter-continental interconnection,** Morocco–Portugal and Tunisia–Italy DC projects will be constructed to transmit solar power of North Africa to Europe, realizing grid interconnection of Africa and Europe; Saudi Arabia–Egypt DC project will be constructed to realize grid interconnection of Asia and Africa.

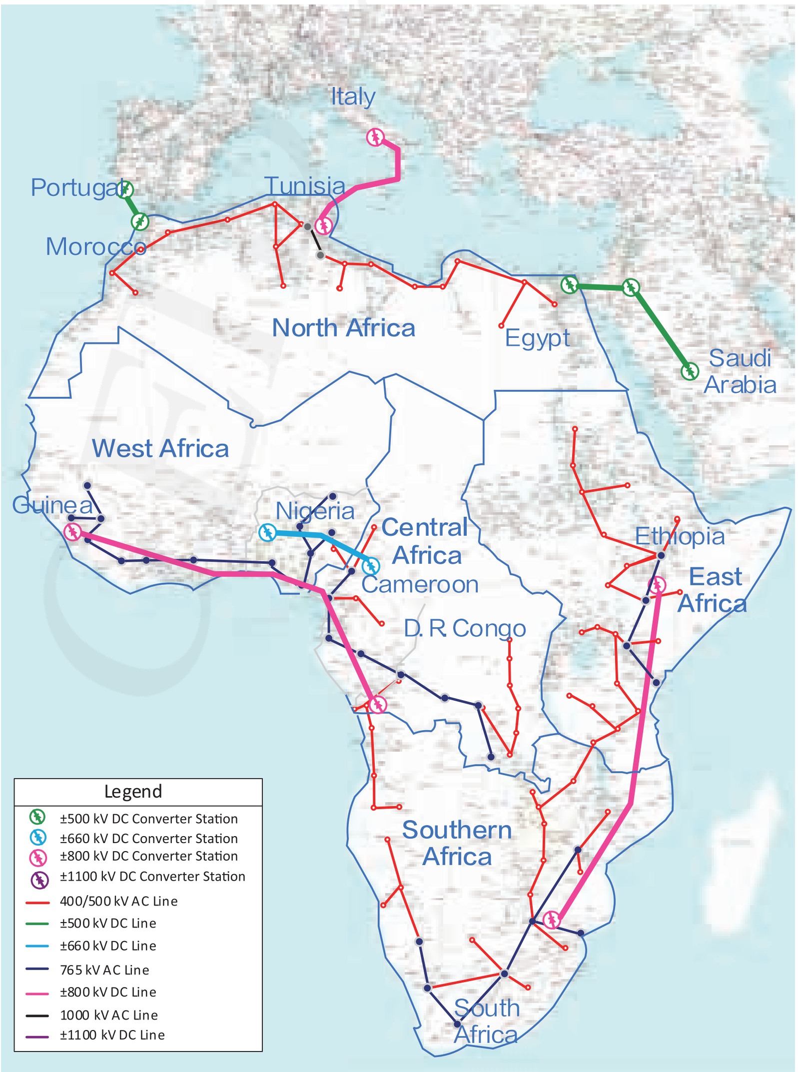


Fig 3.31 Planning Diagram of Africa Grid Interconnection in 2030

By 2040, Africa will form "one-horizontal and two-vertical" backbone power grids, and inter-continental grid interconnection channels will be further strengthened. In terms of **intra-continental interconnection:** D. R. Congo-Nigeria DC project will be constructed to expand the transmission scale of hydropower generated on the Congo River; 1,000 kV AC power transmission channel of North Africa crossing the five countries will be constructed, to connect the large solar power bases and load centers. The power transmission channel connects the Western Asia power grid, achieving mutual complementation between North Africa and Western Asia. In terms of **inter-continental interconnection,** Egypt-Greece-Italy DC project and Algeria-France DC project will be constructed to further expand the scale of solar power transmission from North Africa to Europe; Saudi Arabia-Egypt and Ethiopia-Saudi Arabia DC projects will be constructed to improve the mutual complement capacity of power among North Africa, East Africa and West Asia.

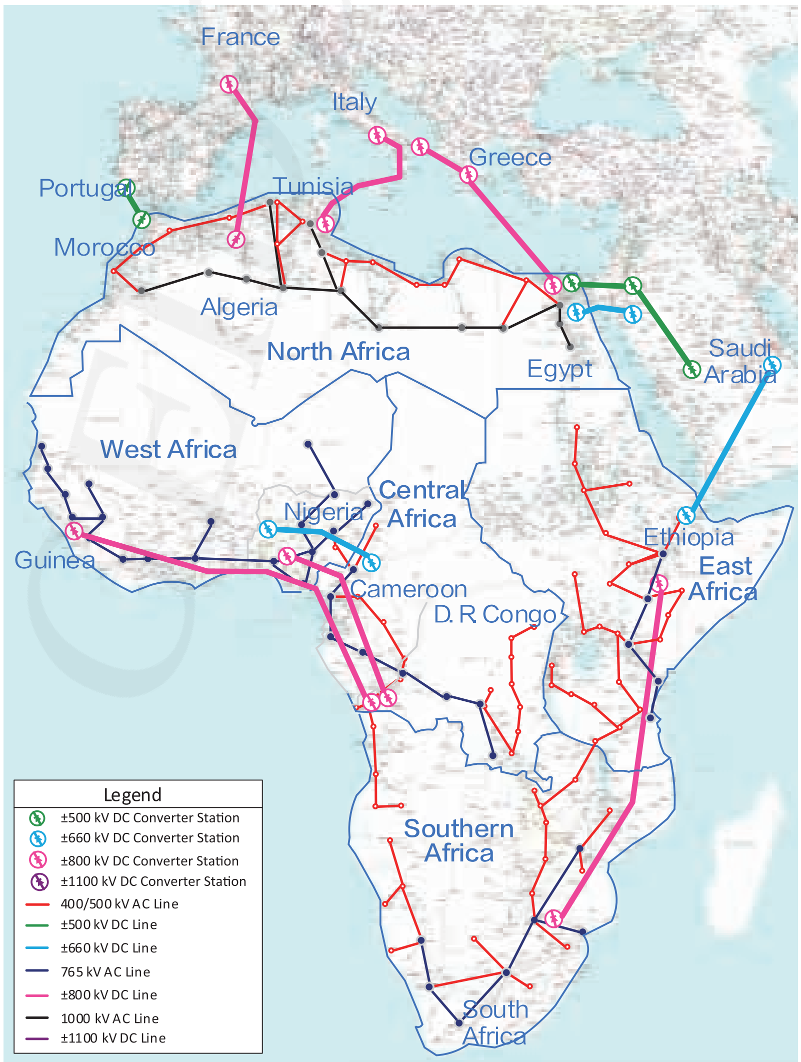


Fig 3.32 Schematic Diagram of Africa Grid Interconnection in 2040

By 2050, with strong Energy Interconnection basically established, Africa will have "two-horizontal and two-vertical" backbone power grids and the scale of Asia, Europe and Africa Interconnection will grow continuously. In terms of **intra-continental interconnection:** The 1,000 kV AC power transmission channel of North Africa and 765/400 kV AC main power grids of other regions would be further improved. North, Central & West and East & Southern Africa power grids will form 3 strong synchronous power grids. DC interconnection among synchronous power grids will be improved and the D. R. Congo-South Africa, D. R. Congo-Ghana, 2nd D. R. Congo-Guinea, D. R. Congo-Morocco and D. R. Congo-Ethiopia DC projects will be constructed. The hydropower of East Africa and solar power of North Africa will complement with each other. In terms of **inter-continental interconnection**, Morocco-Spain and Algeria-France-Germany DC projects will be constructed to transmit hydropower of the Congo River, co-regulated with solar power of North Africa, to the load centers of the continental Europe.

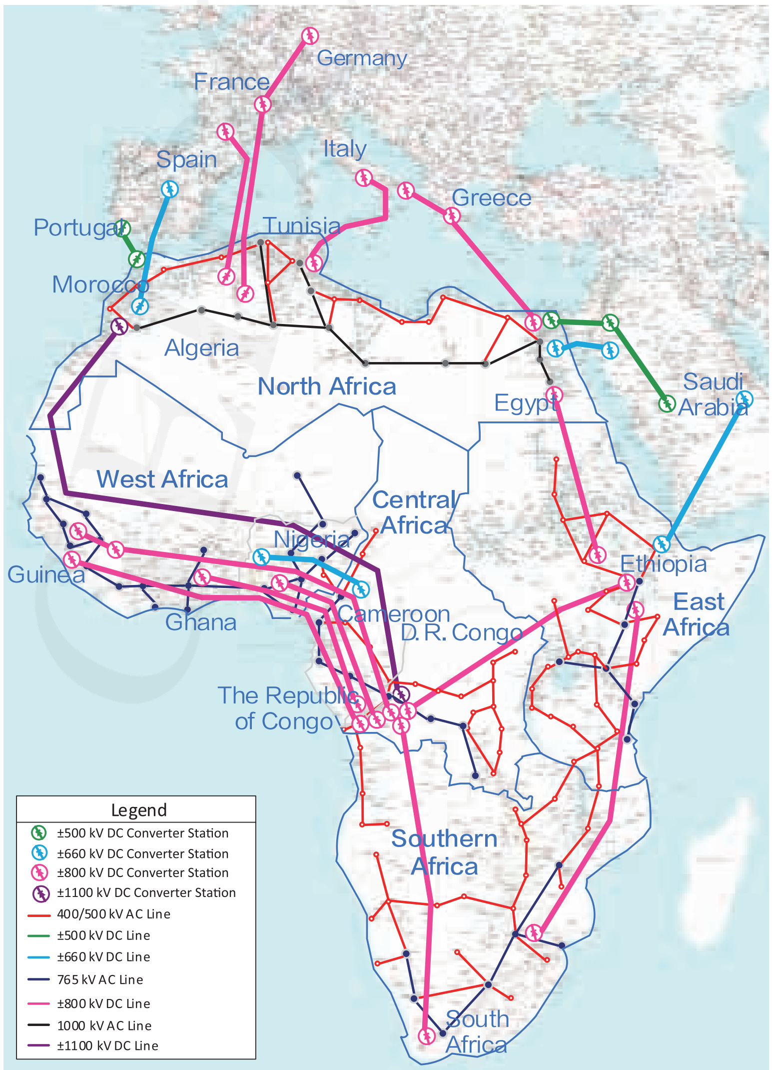


Fig 3.33 Schematic Diagram of Africa Grid Interconnection in 2050

3.4.2 Investment Estimate

Investment estimate principle

Investment in the Africa Energy Interconnection consists of power source investment and power grid investment. Power source investment shall be calculated based on unit investment cost and capacity put into operation of each horizon, while power gird investment shall be estimated based on power grid investment cost of each voltage level.

In view of the development trend of various power source technologies and based on research results of International Energy Agency, International Renewable Energy Agency, Bloomberg New Energy Finance and other international energy agencies, it is predicted, after calculation, that the unit investment cost of solar power and wind power will decrease by 70 % and 50 % by 2050 compared with those in 2015, respectively. By then, the unit investment cost of PV will decrease to 550 USD/kW, solar thermal power to 2,000 USD/kW, onshore wind power to 800 USD/kW and offshore wind power to 2,500 USD/kW.

For power grid investment, the investment in UHV grid is estimated by referring to that of similar projects in China, and is also adjusted as appropriate based on that of similar projects in Africa and surrounding countries. Investment in 220/400/500/765 kV power grids is estimated based on those of similar projects in the region. For power grids below 400/500/765 kV, the investment is considered as 1:5 to those of 400/500/765 kV power grids.

Table 3.10 Parameters of Power Grid Investment Estimate of Each Voltage Level

Unit: USD/kVA (kW), 10,000 USD/km

Project Category	Substation / Converter substation	Line	Submarine cable
1,000 kV AC	67	830	/
765 kV	41	53	
500 kV AC	39	34	/
400 kV AC	33	22	/
± 500 kV DC	118	38	250
± 660 kV DC	119	52	300
± 800 kV DC	126	90	700
± 1,100 KV DC	108	111	/

Investment estimate

By 2050, the total investment of Africa Energy Interconnection is 2.9 trillion USD. 1.58 trillion USD will be invested in new power generation, including 1.38 trillion in clean energy (accounts for 86.9%). 1.32 trillion USD will be invested in power grid construction (accounts for 46%). Investments of regional energy interconnections are shown in Fig 3.34.

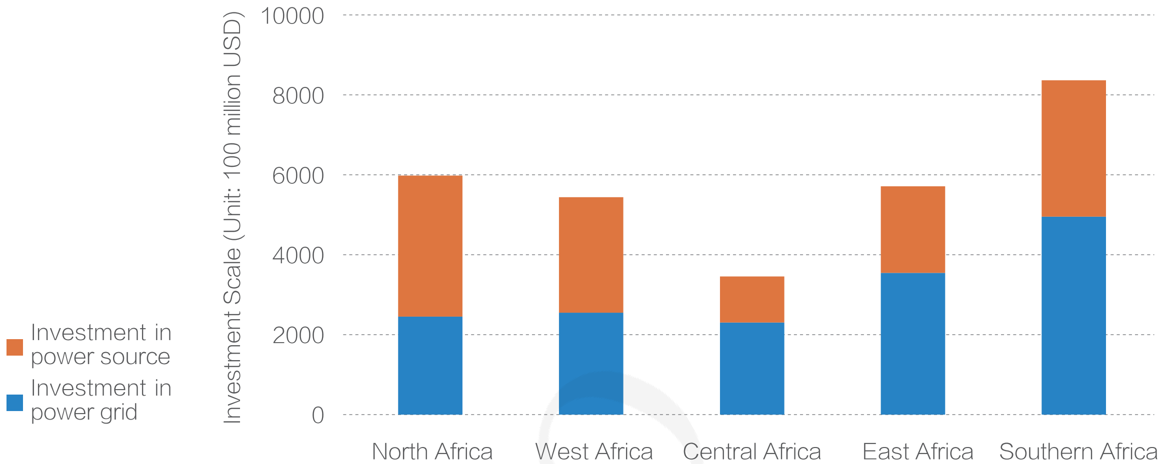
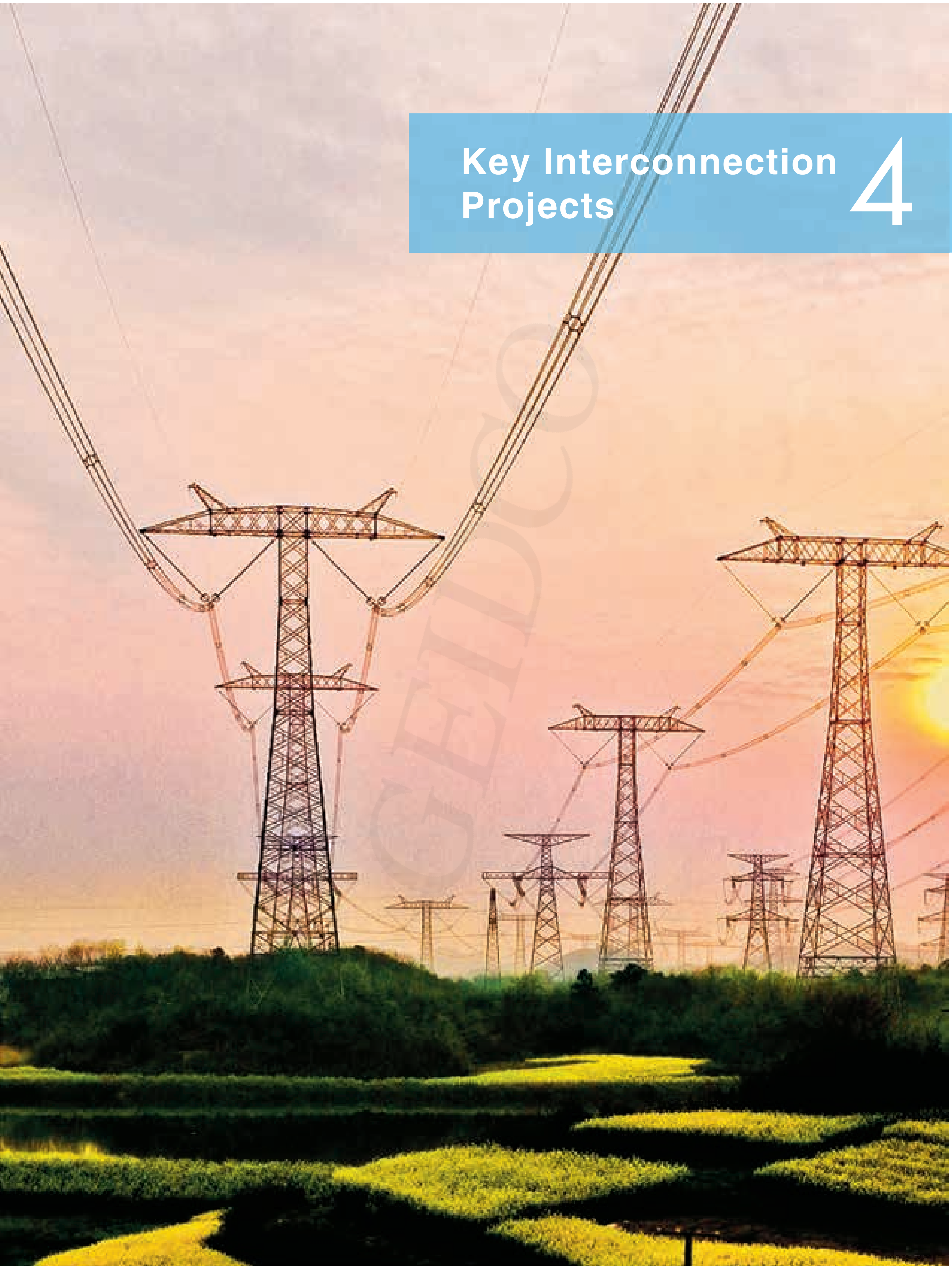


Fig 3.34 Investment in Energy Interconnection of different regions in Africa from 2018 to 2050



Key Interconnection Projects 4

4.1

Key Power Generation Projects

Inga hydropower project
total installed capacity
50.48 GW

Inga hydropower project, with a total installed capacity of 50.48 GW is located at the Congo River of D. R. Congo, of which Inga hydropower phase 1 and 2 have already been constructed with installed capacities of 350 MW and 1,430 MW respectively. Phase 3 to 8 will be installed with totally 48.7 GW capacity. The annual generation hours will be more than 7,000 hours.

Fig 4.1 The Inga Hydropower Project Layout

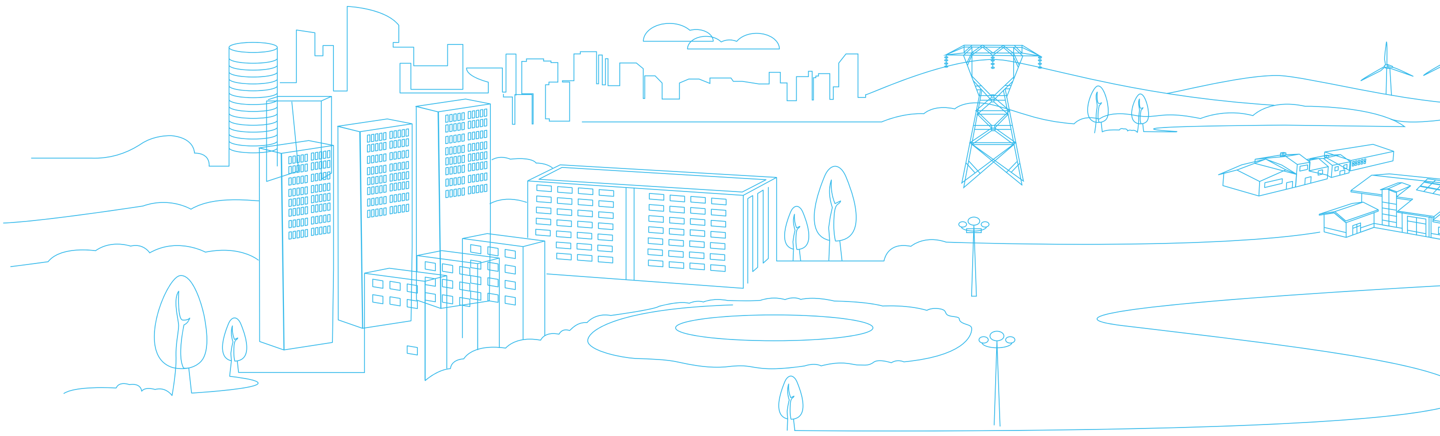


Table 4.1 Inga Hydropower Project

Unit: 10 MW, hours

Project	Installed Capacity	Average Annual Generation Hours
Phase 1, 2	178	>7,000
Phase 3-6	4,420	>7,000
Phase 7 (Sikila Hydropower)	180	>7,000
Phase 8 (Eco Power Station)	270	>7,000
Total	5,048	>7,000

By 2030, the capacity of Inga hydropower projects will be 12.83 GW, of which 2.83 GW will be consumed locally in D. R. Congo and 1 GW will be delivered within Central Africa countries. Totally 9 GW will be delivered inter-regionally, of which 1 GW will be transmitted to northern Angola and 8 GW will be delivered to Guinea.

By 2040, the capacity of Inga hydropower projects will be 29.08 GW, of which 7.8 GW will be consumed locally in D. R. Congo and 3.28 GW will be delivered within Central Africa countries. Totally 18 GW will be delivered inter-regionally, of which 2 GW will be transmitted to Angola and 8 GW will be delivered to Nigeria.

By 2050, the installed capacity of the Inga area will reach 50.48 GW that all Inga hydropower projects will be put into operation. 8.48 GW will be consumed locally in D. R. Congo. The cross-border transmission capacity within Central Africa will further increase to 6 GW. Totally 36 GW will be delivered inter-regionally, of which 10 GW will be delivered to Morocco and 8 GW will be delivered to South Africa.

Matadi hydropower project, with an installed capacity of 16 GW is located at the Congo River of D. R. Congo and planned to be constructed by 2050.

Linzolo hydropower project, with an installed capacity of 3 GW is located at the Congo River of R. Congo and planned to be constructed by 2050.

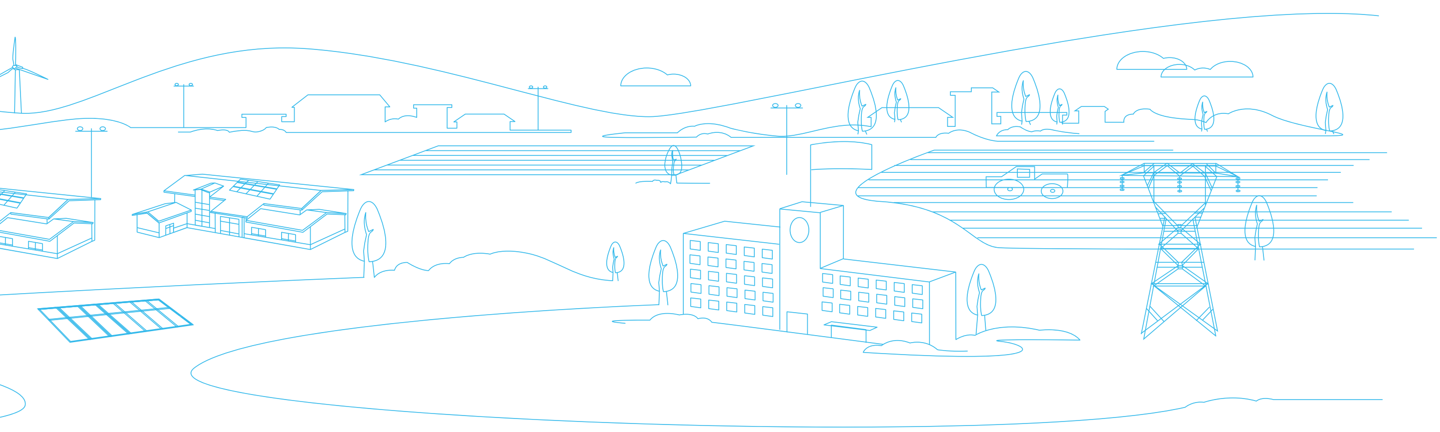


Fig 4.2 The Grand Renaissance Dam Project

The Grand Renaissance Dam project total installed capacity
6.45GW

The Grand Renaissance Dam project, with a total installed capacity of 6.45 GW is located at the Nile River of Ethiopia and planned to be constructed by 2025.

Gibe IV hydropower project, with an installed capacity of 1.47 GW is located at the Nile River of Ethiopia and planned to be constructed by 2030.

Tams hydropower project,with an installed capacity of 1 GW is located at the Nile River of Ethiopia and planned to be constructed by 2030.

Upper Mandaya hydropower project, with an installed capacity of 1.7 GW is located at the Nile River of Ethiopia and planned to be constructed by 2040.

Batoka gorge hydropower project, with an installed capacity of 1.6 GW is located at the Zambezi River of Zambia and planned to be constructed by 2030.

M.Nkuwa hydropower project, with an installed capacity of 2.4 GW is located at the Zambezi River of Mozambique and planned to be constructed by 2040.

Grand Eweng hydropower project, with an installed capacity of 1.8 GW is located at the Sanaga River of Cameroon and planned to be constructed by 2030.

4.2

Key Power Grid Projects

4.2.1 Inter-regional Projects

(1) Cameroon-Nigeria ±660 kV DC Project

The project will send hydropower collected in Sanaga River and northern R. Congo to Osogbo of Nigeria through ±660 kV DC transmission with the capacity of 4 GW and length of 1,100 km. This project is intended to be constructed before 2030.

According to preliminary analysis, the total investment of this project is 1.5 billion USD, within which transmission lines cost 0.5 billion USD and converter stations cost 1 billion USD. Considering transmission utilization hours of 5,000 hours, the transmission tariff is about 1.06 US cents/kWh.

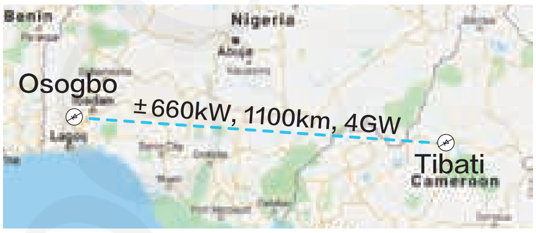


Fig 4.3 Cameroon-Nigeria ±660 kV DC Project Diagram

(2) D. R. Congo-Guinea ±800 kV DC Project I

The project will send Inga hydropower of the Congo River to Boke of Guinea through ±800 kV DC transmission with the capacity of 8 GW and length of 4,000 km. This project is intended to be constructed before 2030.

According to preliminary analysis, the total investment of this project is 5.6 billion USD, within which transmission lines cost 3.6 billion USD and converter stations cost 2 billion USD. Considering transmission utilization hours of 7,000 hours, the transmission tariff is about 1.53 US cents/kWh.

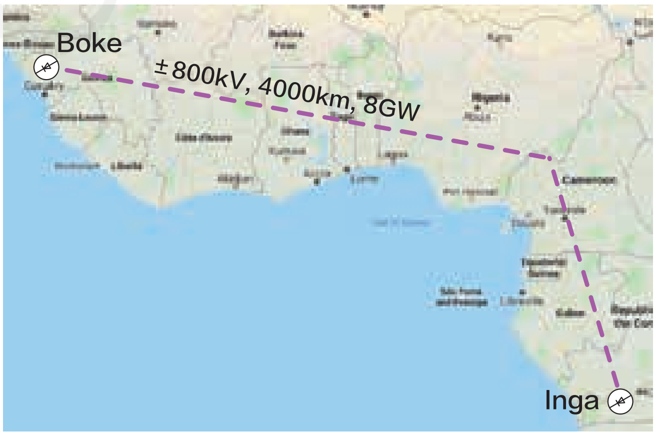


Fig 4.4 D. R. Congo-Guinea ±800 kV DC Project I Diagram

(3) D. R. Congo-Nigeria ±800 kV DC Project

The project will send Inga hydropower of the Congo River to Benin City of Nigeria through ±800 kV DC transmission with the capacity of 8 GW and length of 2,000 km. This project is intended to be constructed before 2040.

According to preliminary analysis, the total investment of this project is 3.8 billion USD, within which transmission lines cost 1.8 billion USD and converter stations cost 2 billion USD. Considering transmission utilization hours of 7,000 hours, the transmission tariff is about 0.98 US cents/kWh.

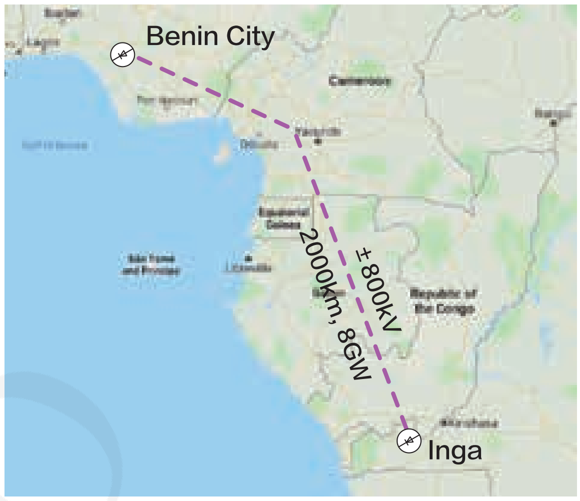


Fig 4.5　D. R. Congo–Nigeria ±800 kV DC Project Diagram

(4) D. R. Congo-South Africa ±800 kV DC Project

The project will send Inga hydropower of the Congo River to Cape Town of South Africa through ±800 kV DC transmission with the capacity of 8 GW and length of 3,800 km. This project is intended to be constructed before 2050.

According to preliminary analysis, the total investment of this project is 5.4 billion USD, within which transmission lines cost 3.4 billion USD and converter stations cost 2 billion USD. Considering transmission utilization hours of 7,000 hours, the transmission tariff is about 1.47 US cents/kWh.

Fig 4.6　D. R. Congo–South Africa ±800 kV DC Project Diagram

(5) D. R. Congo-Morocco ±1100 kV DC Project

The project will send Inga hydropower of the Congo River to Zag of Morocco through ±1,100 kV DC transmission with the capacity of 10 GW and length of 6,500 km. 2 GW power will be consumed locally in Morocco and the rest 8 GW will be further sent to Europe through Morocco-Spain and Algeria-France-Germany DC transmission channels. This project is intended to be constructed before 2050.

Fig 4.7 D. R. Congo-Morocco ±1100 kV DC Project Diagram

According to preliminary analysis, the total investment of this project is 9.4 billion USD, within which transmission lines cost 7.2 billion USD and converter stations cost 2.2 billion USD. Considering transmission utilization hours of 7,000 hours, the transmission tariff is about 1.92 US cents/kWh.

(6) D. R. Congo-Ethiopia ±800 kV DC Project

The project will send Inga hydropower of the Congo River to Addis Ababa of Ethiopia through ±800 kV DC transmission with the capacity of 8 GW and length of 4,000 km. This project is intended to be constructed before 2050.

According to preliminary analysis, the total investment of this project is 5.6 billion USD, within which transmission lines cost 3.6 billion USD and converter stations cost 2 billion USD. Considering transmission utilization hours of 7,000 hours, the transmission tariff is about 1.48 US cents/kWh.,

Fig 4.8 D. R. Congo-Ethiopia ±800 kV DC Project Diagram

(7) D. R. Congo-Guinea ±800 kV DC Project II

The project will send Matadi hydropower of the Congo River to Gaoual and Kankan of Guinea through ±800 kV DC transmission with the capacity of 8 GW and length of 4,100 km. This project is intended to be constructed before 2050.

According to preliminary analysis, the total investment of this project is 6.7 billion USD, within which transmission lines cost 3.7 billion USD and converter stations cost 3 billion USD. Considering transmission utilization hours of 7,000 hours, the transmission tariff is about 1.82 US cents/kWh.

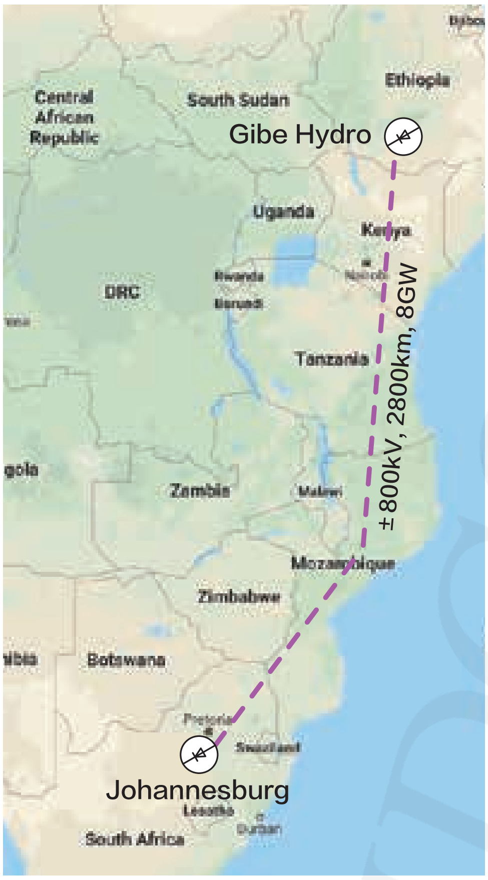
Fig 4.9 D. R. Congo–Guinea ±800 kV DC Project II Diagram

(8) R. Congo-Ghana ±800 kV DC Project

The project will send central south hydropower of Congo Brazzaville to Kumasi of Ghana through ±800 kV DC transmission with the capacity of 8 GW and length of 2,800 km. This project is intended to be constructed before 2050.

Fig 4.10 Congo Brazzaville–Ghana ±800 kV DC Project Diagram

According to preliminary analysis, the total investment of this project is 4.5 billion USD, within which transmission lines cost 2.5 billion USD and converter stations cost 2 billion USD. Considering transmission utilization hours of 6,000 hours, the transmission tariff is about 1.41 US cents/kWh.



(9) Ethiopia-South Africa ±800 kV DC Project

The project will realize mutual complementation between the Nile River hydropower and the Zambezi River hydropower seasonally. 8 GW power can be send through a ±800 kV DC transmission channel with the length of 2,800 km. This project is intended to be constructed before 2030 and transmits 4 GW power at first. Until around 2040, the project will operate at full capacity of 8 GW transmission power.

According to preliminary analysis, the total investment of this project is 4.5 billion USD, within which transmission lines cost 2.5 billion USD and converter stations cost 2 billion USD. Considering transmission utilization hours of 5,000 hours, the transmission tariff is about 1.66 US cents/kWh.

Fig 4.11 Ethiopia–South Africa ±800 kV DC Project Diagram

(10) Ethiopia-Egypt ±800 kV DC Project

The project will realize the complementary operation between hydropower from Ethiopia and solar power from Egypt through ±800 kV DC transmission with the capacity of 8 GW and length of 1,900 km. This project is intended to be constructed before 2050.

According to preliminary analysis, the total investment of this project is 3.7 billion USD, within which transmission lines cost 1.7 billion USD and converter stations cost 2 billion USD. Considering transmission utilization hours of 5,000 hours, the transmission tariff is about 1.34 US cents/kWh.

Fig 4.12 Ethiopia–Egypt ±800 kV DC Project Diagram

4.2.2 Cross-border Projects

(1) North Africa 1,000 kV Transmission Corridor Project

This project will construct North Africa 1,000 kV AC transmission corridor and strengthen 500/400 kV AC grids in the region to fully exploit North Africa solar power resources. Clean electricity of large solar power bases will be collected through the 1,000 kV AC corridor. After optimal allocation and consumption within the region, the solar power will be further gathered and delivered to Europe at Morocco, Tunisia, Egypt and Algeria.

This project includes 15 substations of 1,000 kV and its route is about 6,920 km long. The total investment is estimated to be 18.8 billion USD within which the substations cost 7.3 billion USD and transmission lines cost 11.5 billion USD.

Fig 4.13 North Africa 1000 kV Transmission Corridor Project Diagram

(2) East Africa 765/500/400 kV Transmission Corridor Project

This project will construct the 765/500/400 kV AC transmission corridor in East Africa. The voltage level of the Sudan-Ethiopia part will be 500/400 kV, and that of the Kenya-Tanzania part will be 765 kV. The 765 kV corridor will be extended to Uganda and then connected with Kasama in Zambia through 400 kV AC lines synchronously. Along with Ethiopia-Kenya ±500 kV DC, hydropower in the Nile River and Rufiji River basins, solar power in Sudan and geothermal power in the East Africa Rift Valley area will be fully exploited. The capability of power exchange between the southern and northern areas will be enhanced to realize regional multi-energy and southern-northern complementation.

This project includes 7 substations of 765 kV, 7 substations of 500 kV and 5 substations of 400 kV. Its route is about 5,300 km long with 2,800 km of 765 kV lines. The total investment is estimated to be 4.5 billion USD within which the substations cost 1.0 billion USD and transmission lines cost 3.5 billion USD.

Fig 4.14　East Africa Transmission Corridor Project Diagram

(3) West Africa 765 kV Transmission Corridor Project

This project will construct West Africa 765 kV AC transmission corridor and strengthen 330/225 kV AC grids in the region to fully exploit hydro and solar power resources and to realize complementation of multi-energy between eastern and western areas.

This project includes 9 substations of 765 kV and its route is about 3,110 km long. The total investment is estimated to be 3.4 billion USD within which the substations cost 1.2 billion USD and transmission lines cost 2.2 billion USD.

Fig 4.15　West Africa 765 kV Transmission Corridor Project Diagram

(4) Southern Africa 765/400 kV Transmission Corridor Project

765 kV Transmission Corridor. This project will construct South Africa-Namibia-Mozambique 765 kV AC transmission corridor and strengthen the existing 765 kV AC grids in South Africa to send wind and solar power of Namibia and Mozambique to the eastern and western load centers of South Africa and increase the reliability of local power supply.

This project includes 10 substations of 765 kV and its route is about 3,000 km long. The total investment is estimated to be 6.6 billion USD within which the substations cost 0.9 billion USD and transmission lines cost 5.7 billion USD.

400 kV Transmission Corridor. This project will construct Zambia-Zimbabwe-Botswana-South Africa 400 kV AC transmission corridor (further extented to Tanzania and Kenya). Hydropower from Batoka Gorge and Kariba of the Zambezi River and solar & wind power from Botswana can realize mutual complementation among each other because of the wet-dry characteristics of the Zambezi River. At the same time, the synchronous 400 kV AC grid will be constructed between East and Southern Africa, to improve the reliability of the system.

This project includes 10 substations of 400 kV and its route is about 2,800 km long. The total investment is estimated to be 1.3 billion USD within which the substations cost 0.7 billion USD and transmission lines cost 0.6 billion USD.

Fig 4.16 South Africa 765/400 kV Transmission Corridor Project Diagram

(5) Central Africa 765kV Transmission Corridor Project

This project will construct D. R. Congo-Gabon-Cameroon 765 kV AC transmission corridor and strengthen the 400/225 kV AC grids in the region to interconnect hydropower bases of the Congo River, Sanaga River and Ogooue River, and to support hydropower delivery and mining industry development in D. R. Congo and Gabon.

This project includes 10 substations of 765 kV and its route is about 3810 km long with 1,960 km in D. R. Congo. The total investment is estimated to be 4.3 billion USD within which the substations cost 1.1 billion USD and transmission lines cost 3.2 billion USD.

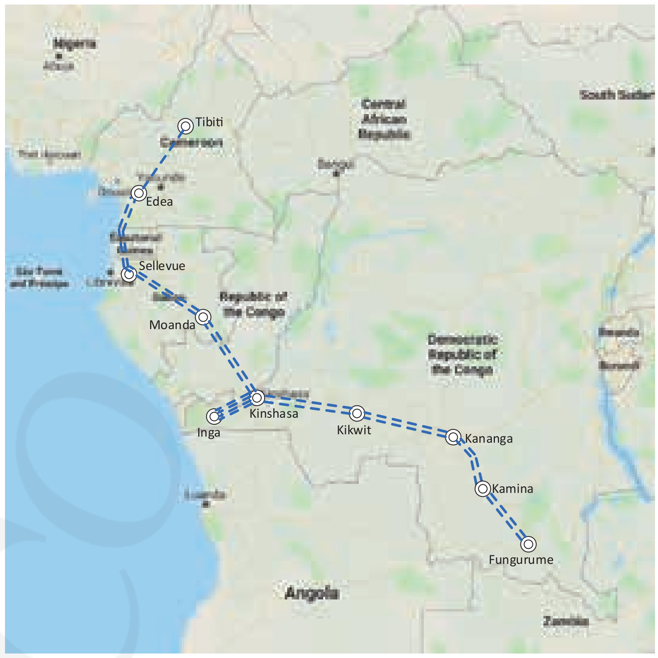


Fig 4.17 Central Africa 765 kV Transmission Corridor Project Diagram

4.2.3 Inter-continental Projects

(1) Morocco-Portugal ±500 kV DC Project

The project will send solar power of Morocco solar power bases to Faro of Portugal through ±500 kV DC transmission with the capacity of 3 GW and length of 260 km (of which 200 km is submarine cable). This project is intended to be constructed before 2030.

According to preliminary analysis, the total investment of this project is 1.2 billion USD, within which transmission lines cost 0.5 billion USD and converter stations cost 0.7 billion USD. Considering transmission utilization hours of 5000 h, the transmission tariff is about 1.14 US cents/kWh.

Fig 4.18 Morocco-Portugal ±500kV DC Project Diagram

(2) Tunisia-Italy ±800 kV DC Project

The project will send clean electricity collected from Remada solar power base of Tunisia and Josh solar power base of Lybia to Rome of Italy through ±800 kV DC transmission with the capacity of 8 GW and length of 1,300 km (of which 200 km is submarine cable). This project is intended to be constructed before 2030.

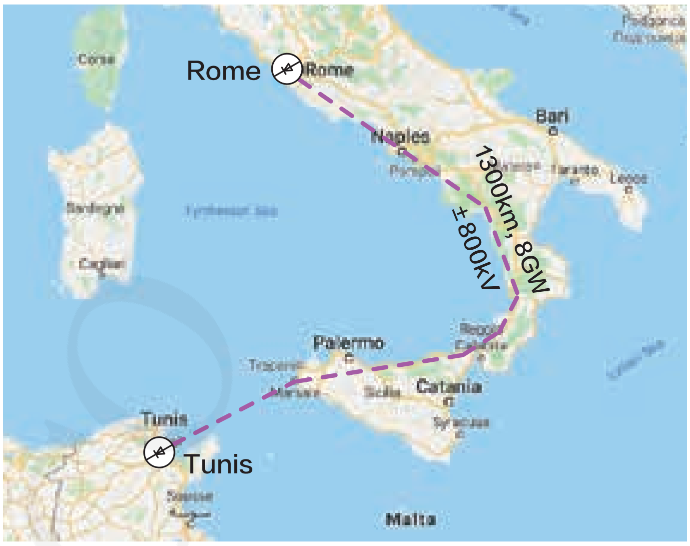


Fig 4.19 Tunisia–Italy ±800kV DC Project Diagram

According to preliminary analysis, the total investment of this project is 4.4 billion USD, within which transmission lines cost 2.4 billion USD and converter stations cost 2 billion USD. Considering transmission utilization hours of 5,000 hours, the transmission tariff is about 1.56 US cents/kWh.

(3) Ethiopia-Saudi Arabia ±660 kV DC Project

The project will send Ethiopia hydropower to Riyadh of Saudi Arabia through ±660 kV DC transmission with the capacity of 4 GW and length of 2,000 km (of which 40 km is submarine cable). This project is intended to be constructed before 2040.

According to preliminary analysis, the total investment of this project is 2.2 billion USD, within which transmission lines cost 1.2 billion USD and converter stations cost 1 billion USD. Considering transmission utilization hours of 3,000 hours, the transmission tariff is about 2.46 US cents/kWh.

Fig 4.20 Ethiopia–Saudi Arabia ±660 kV DC Project Diagram

(4) Egypt-Greece-Italy ±800 kV DC Project

The project will send Egypt solar power to Athens of Greece and Lecce of Italy through three terminal ±800 kV DC transmission with the capacity of 8 GW and length of 1,700 km (of which 960 km is submarine cable). 4 GW will be consumed in Greece, Albania and Bulgaria and the rest 4 GW will be delivered to Italy. This project is intended to be constructed before 2040.

Fig 4.21 Egypt–Greece–Italy ±800 kV DC Project Diagram

According to preliminary analysis, the total investment of this project is 10.4 billion USD, within which transmission lines cost 7.4 billion USD and converter stations cost 3 billion USD. Considering transmission utilization hours of 5,000 hours, the transmission tariff is about 3.75 US cents/kWh.

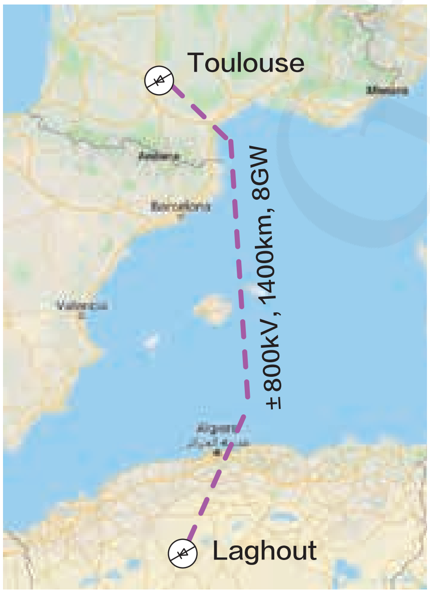


Fig 4.22 Algeria–France ±800 kV DC Project Diagram

(5) Algeria-France ±800 kV DC Project

The project will send Algeria solar power to Toulouse of France through ±800 kV DC transmission with the capacity of 8 GW and length of 1,400 km (of which 750 km is submarine cable). This project is intended to be constructed before 2040.

According to preliminary analysis, the total investment of this project is 7.8 billion USD, within which transmission lines cost 5.8 billion USD and converter stations cost 2 billion USD. Considering transmission utilization hours of 5,000 hours, the transmission tariff is about 2.81 US cents/kWh.

(6) Saudi Arabia-Egypt ±660 kV DC Project

The project will send Saudi Arabia solar power to Cairo of Egypt through ±660 kV DC transmission with the capacity of 4 GW and length of 700 km. This project is intended to be constructed before 2040.

According to preliminary analysis, the total investment of this project is 1.4 billion USD, within which transmission lines cost 0.4 billion USD and converter stations cost 1 billion USD. Considering transmission utilization hours of 5,000 hours, the transmission tariff is about 0.92 US cents/kWh.

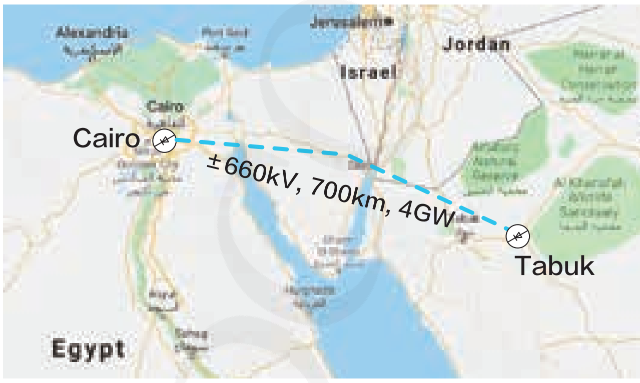


Fig 4.23 Saudi Arabia–Egypt ±660 kV DC Project Diagram

(7) Morocco-Spain ±660 kV DC Project

Inga hydropower of the Congo River will be sent to Morocco. After complementation with Morocco solar power, the 4 GW power will be sent to Madrid of Spain through ±660 kV DC transmission with the capacity of 4 GW and length of 1,800 km (of which 30 km is submarine cable). This project is intended to be constructed before 2050.

According to preliminary analysis, the total investment of this project is 2 billion USD, within which transmission lines cost 1 billion USD and converter stations cost 1 billion USD. Considering transmission utilization hours of 7,000 hours, the transmission tariff is about 1.01 US cents/kWh.

Fig 4.24 Morocco–Spain ±660 kV DC Project Diagram

(8) Algeria-France-Germany ±800 kV DC Project

The project will send Algeria solar power together with hydropower from the Congo River to Lyon of France and Frankfurt of Germany through three terminal ±800 kV DC transmission with the capacity of 8 GW, including 4 GW consumed in France and another 4 GW transferred to Germany. The length of the project is 2,400 km (of which 840 km is submarine cable). This project is intended to be constructed before 2050.

According to preliminary analysis, the total investment of this project is 10.3 billion USD, within which transmission lines cost 7.3 billion USD and converter stations cost 3 billion USD. Considering transmission utilization hours of 5,000 hours, the transmission tariff is about 3.78 US cents/kWh.

Fig 4.25 Algeria-France-Germany ±800 kV DC Project Diagram

5 Values and Benefits of Africa Energy Interconnection

5.1 Economy

(1) Realizing sustainable clean energy and power supply. In the future, energy and electricity needs of African economic and social development will be met in a clean and green way, getting rid of dependence on fossil energy and realizing sustainable clean energy and power supply. By 2050, the proportion of clean energy to primary energy will be more than 45%, and electricity generated by clean energy will account for about 73% of African total electricity generation.

(2) Stimulating economy growth. Constructing Africa Energy Interconnection will greatly stimulate emerging industries such as new energy, power, mining, smelting, processing, etc., and therefore forge a new engine for African economy growth. Total investment for Africa Energy Interconnection is about 2.9 trillion USD, which will raise annual average economy growth by 0.4 percentage points.

(3) Reducing development cost. Through large-scale exploitation of clean energy with low marginal cost, Africa's average power supply cost will effectively decrease. By 2050, the LCOEs (Levelized Cost of Electricity) of various power sources can all reach 9 cents/kWh and below (Fig. 6.1). Africa's average LCOE will be 8.6 US cents/kWh. This cost is about 5.1 US cents/kWh lower than the present level, leading to about 158 billion USD electricity cost be saved annually.

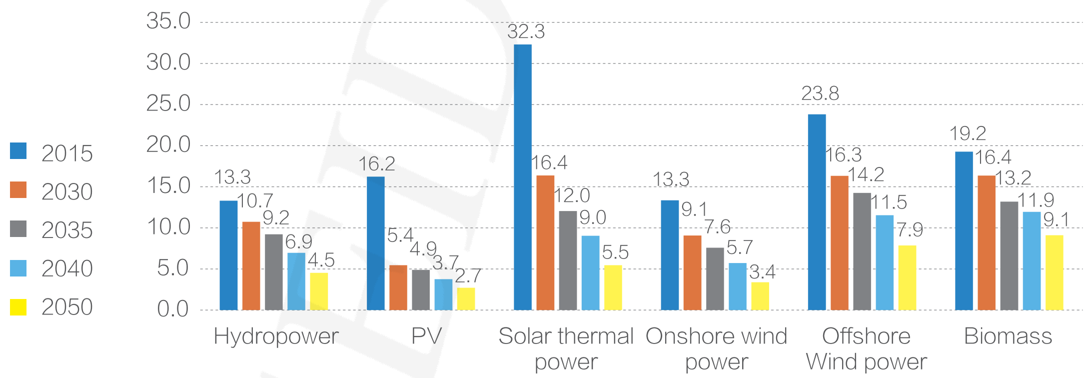


Fig 5.1 Prediction of Average Cost per KWH of Various Power Sources in Africa (US cent/kWh)

(4) Increasing foreign exchange earnings. Through large-scale exploitation of clean energy power generation bases and cross-border, inter-regional and inter-continental interconnections, clean power delivery and consumption will be achieved, which will also vigorously expand the scale of the import and export trade of electricity. By 2050, Africa's electricity import and export trade will generate about 30 billion USD in foreign exchange earnings.

(5) Realizing balanced development. Africa is comparatively less developed with on the contrary abundant clean energy resources, but it can convert the resources advantage into economic superiority, which will potently boost economy. African people could have fair chance of developing. The wealth gap will be reduced, the unbalanced economy development and poverty issues will be settled.

5.2 Society

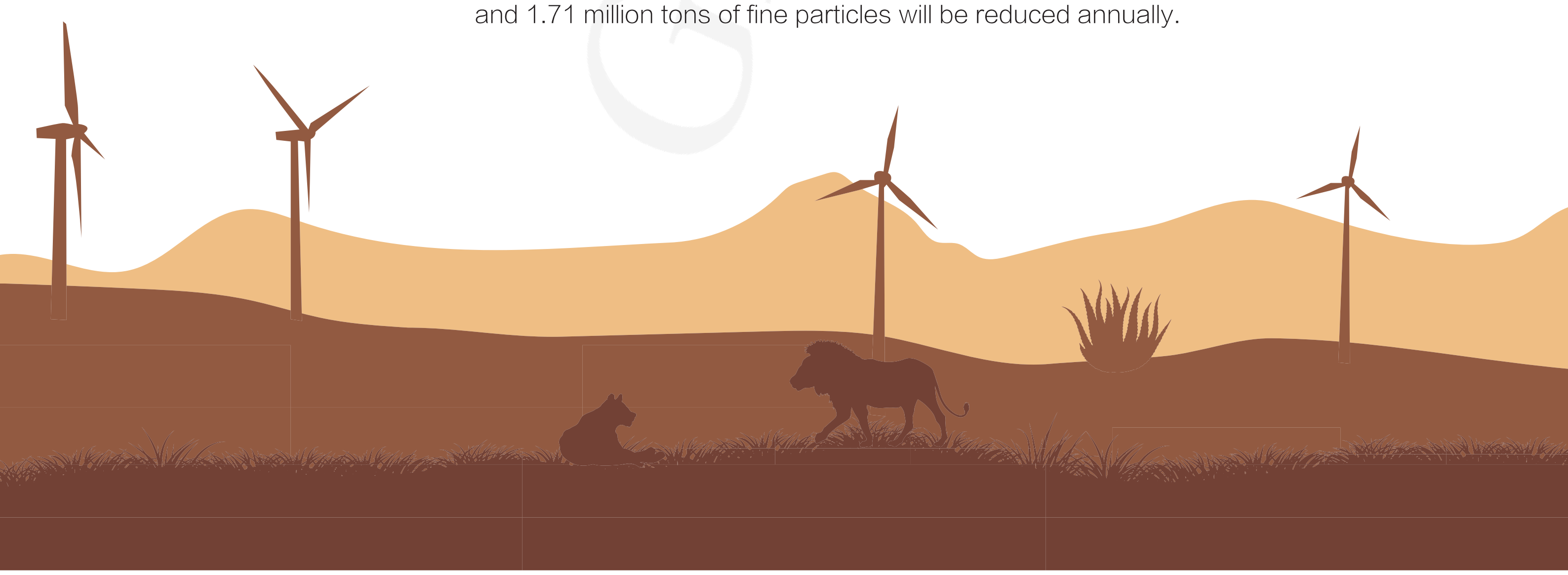
(1) Reducing percentage of population without access to electricity. Africa's current percentage of population with access to electricity is only 48%. Less than one third of African countries have this figure exceeding 50%. There are still 600 million African people living without electricity. With rapid development of clean energy generation and decrease of electricity price, by 2030, percentage of population with access to electricity will raise to 66%. By 2050, accessibility of electricity will reach 90%. In the future, all African people will be able to access affordable green and clean electricity and enjoy the achievement of modern civilization, ultimately solving energy poverty issue.

(2) Improving health. Sulfur dioxide, oxynitride and inhalable particulate matter (PM) are the primary pollutants, which mostly come from energy production and utilization by burning fossil fuels and biomass. Through construction of Africa Energy Interconnection and large-scale exploitation of clean energy, pollution from energy production and utilization will be effectively relieved, reducing diseases and death resulted from air pollution. That alone will avoid 2 to 3 million cases of disease annually.

(3) Creating employment. The construction of Africa Energy Interconnection involves fields such as energy exploitation, electricity generation, grid construction, electric equipment, electricity replacement, smart technology, new types of material, information and communication, will support large scale industrial development such as mining, smelting and processing, and also will create lots of employment. By 2050, accumulatively more than 30 million employments will be created in Africa.

5.3 Environment

(1) Reducing atmospheric pollution. Emission of atmospheric pollutants from fossil energy will reduce greatly in Africa. By 2050, electricity generated by clean energy will reach 2.7 trillion kWh/year. In this way, emission of 2.4 billion tons of carbon dioxide, 8.13 million tons of sulfur dioxide, 8.91 million tons of oxynitride and 1.71 million tons of fine particles will be reduced annually.



(2) Saving land and water resources. Through replacement of thermal power generation with clean energy generation such as wind and solar power, 39 billion square meters of land and 180 billion tons of water will be saved in Africa by 2050.

(3) Protecting and improving eco-environment. With reduced exploitation and utilization of fossil energy, underground water contamination, geological damage, land and marine eco-environment deterioration caused by processes such as mining, machining, transportation, storage and burning will be gradually mitigated. Africa's eco-environment will be protected and recovered.

5.4 Politics

(1) Strengthening political mutual trust. Through construction of Africa Energy Interconnection, clean energy sharing, power interconnection, inter-continental and cross-border power trade will be realized to strengthen energy and economy cooperation. Political mutual trust in Africa will also be effectively enhanced.

(2) Promoting world peace. African countries will share common interests in clean energy exploitation and Africa Energy Interconnection construction. The current international energy order of confrontation and competition will be changed to a new one of open cooperation, interconnection and mutual benefits. Political, military, diplomatic conflicts will be well appeased. Peaceful and harmonic development will be promoted.

(3) Serving the construction of community with shared future for humanity. Through the construction of Africa Energy Interconnection, cooperation in the field of energy among countries in all regions of Africa will be strengthened. A solid partnership among all parties will also be built. To strengthen interconnections between countries, to enhance mutual political mutual trust between countries, to reduce and eliminate disputes arising from the struggle for energy resources are all important actions in promoting peace and harmony in Africa and serving the construction of community with shared future for humanity.

6 Conclusion

This report is prepared based on the analysis of Africa's economic, social and environmental development characteristics, the endowment of Africa's clean energy resources and trends of technical development. Following the goal of constructing a clean energy dominated and electricity centered interconnection platform, this report has analyzed Africa's energy demand, power demand, overall power flow pattern, and proposed the planning scheme of Africa Energy Interconnection. Meanwhile, the construction schemes, positionings, investment scales of key interconnection projects in Africa Energy Interconnection has been provided. The comprehensive benefits of Africa Energy Interconnection has also been evaluated. The main conclusions are as follows:

1 — **Africa has strong driving force for economy development. Its energy and power demands will usher in rapid growth.** The political situation in Africa has gradually become stable, leading to continuously released demographic dividend and improved business environment. With rich mineral resources and clean energy resources, Africa is facing new opportunities for sustainable development characterized by industrialization, urbanization and integration. By 2050, its per capita GDP will reach 8,000 USD and economic aggregate will be 20 trillion USD, 8.3 times of current level. By that time, several countries will become high-income countries and basically eradicate poverty. The rapid growth of Africa's population and economic aggregate, especially the rapid development of industrialization and urbanization, put forward higher requirements for the development of energy and electricity in Africa. In particular, the aluminum and steel industries in Guinea, Ghana, Nigeria and other West African countries have great potential for development. In the future, their electricity consumptions will be several times or even dozens of times their current power generations. Therefore it is urgent to accelerate the exploitation of clean energy and interconnection of power grids in Africa to solve the problem of power shortage.

2 — **The path of clean and sustainable development is essential to Africa.** The current energy development model of Africa which is based on primary biomass and fossil energy not only can not meet the needs of African economic development but also leads to serious environmental pollution problems. At the same time, Africa's weak ability to adapt to climate change results in the urgent task of reducing emissions. To learn from the lessons of "pollution first, treatment afterwards" and to take the new "intensive and leapfrog" development path can help Africa grasp the general trend of clean development, leap over the stage of traditional fossil energy development and finally realize transition from the simple and extensive way of energy utilization to an intensive and efficient one. African sustainable development can be fundamentally safeguarded by the leapfrog mode changes from the use of primary biomass and fossil energy to clean energy.

3 — **Africa Energy Interconnection will help Africa sustainable development to present obvious clean, low-carbon, electrified and networked characteristics in the future.** To meet the challenges of clean development in Africa, it is necessary to uphold the concept of *Global Energy Interconnection*, to accelerate the construction of Africa Energy Interconnection that will closely and effectively connect both intra- and inter-continental countries, and to meet their energy and power demand in a clean and green way. The future development of energy and electricity in Africa mainly presents the following characteristics. **Huge potential for energy demand.** In 2050, primary energy demand in Africa will increase from 2.41 billion tons of coal equivalent, accounting for 9.3% of the global share. The per capita energy consumption will increase to 1.0 tons of coal equivalent per person. The total end-use energy demand will increase to 1.39 billion tons of coal equivalent, in which the industrial, residential and service

sectors lead the growth of end-use energy demands. **Clean and low carbon energy structure.** By 2050, clean energy demand in Africa will increase by 1.02 billion tons of coal equivalent, accounting for 46.8% of primary energy. Clean energy will overtake fossil fuels as the dominant energy source around 2040. The intensity of carbon emissions per unit GDP will accelerate to decline to 0.06 kg CO_2/USD in 2050. The total demand for biomass energy will first increase and then fall, while the proportion of primary energy demand will continue to decline to 19%. The proportion of electricity will keep rising to 28%. Around 2040, electric power will overtake oil as the largest end-use energy source. In 2050, **power demand will rapidly grow to 3.2 trillion kWh**. Per capita electricity consumption will increase to 1,322 kWh/year. The North, Southern and West Africa will become the main power load centers, while the West, East and Central Africa are the key areas where power demand is growing rapidly. **The accessibility of electricity will increase significantly.** By 2050, African electricity accessibility can reach more than 90%. In terms of development conditions, development costs and flexible regulation capabilities, **clean energy will become the dominant power source and accelerate the alternative of fossil energy power generation.**

4 — **African clean energy will be exploited in a way that combined centralized and distributed methods, which will gradually replace fossil energy and hold a dominant position.** Resource endowment of clean energy and power demand distribution in Africa will be coordinated. Large clean energy bases will be developed through a centralized and intensive manner. Meanwhile, due to sparse distributed houses in remote areas such as rural areas, it is suggested that distributed PV generation and small hydropower plant should be built to satisfy the power demand. According to the planning scheme, by 2050, 21 large solar power bases will be built in North Africa, East Africa and Southern Africa. 12 large wind power bases will be built in North Africa, East Africa and Southern Africa. 4 large hydropower bases will be built in such drainage basins as the Congo River, the Nile River, the Zambezi River and the Niger River. In 2030, 2040 and 2050, **the total installed capacity of power supply** in Africa will reach 450 GW, 750 GW and 1130 GW, respectively. **The per capita installed capacity** will be 0.27 kW in 2030, 0.36 kW in 2040 and 0.46 kW in 2050, which are respectively 1.8 times, 2.5 times and 3.1 times that of 2015. As for **the proportion of installed capacity of clean energy**, before 2030, it will exceed that of fossil energy. The installed capacity of clean energy in 2030, 2040 and 2050 will reach 59%, 70% and 78% respectively. The proportion of generating capacity of clean energy will increase from 16.3% in 2015 to 48% in 2030, 59% in 2040 and 73% in 2050.

5 — **The power flow in Africa will take on the pattern of "Central Africa exporting power to North and Southern Africa, and realizing mutual complementation with Asia and Europe". Clean energy delivery channels will be built to connect the large clean energy bases and load centers, realizing Asia-Europe-Africa grid interconnection and large-scale complementation of clean energy.**

With the upgrade of power grid and the continuous expansion of interconnection, three synchronous power grids will gradually be formed in Africa: North power grid, Central & West power grid and East & Southern power grid. Asynchronous grid connection will be realized via DC channels among the synchronous power grids. For the synchronous power grid in North Africa, the voltage level will be upgraded to 1,000 kV. A 1,000 kV AC channel from east to west will be constructed to connect the large solar power bases and load centers, forming an important energy allocation platform connecting Asia, Europe and Africa. For the Central-West power grid and the East & Southern power grid, internal strong 765/400 kV AC backbone power grid will be constructed to form a regional clean energy allocation optimization platform. The power from large clean energy bases in the region will be transmitted directly to the main load centers via EHV/UHV DC channels.

In 2030, Africa's power exchange across continents and regions will reach 31 GW, of which 14 GW will be delivered across continents. The African Energy Interconnection will appear in an initial shape. **Within Africa:** On the basis of continuous improvement of power grids in different countries and regions, DC projects of D. R. Congo-Guinea, Ethiopia-South Africa and Cameroon-Nigeria will be built to transmit hydropower from Inga of the Congo River and hydropower from the Nile River and the Sanaga River to load centers at West Africa and Southern Africa. **In terms of inter-continental interconnection,** DC projects of Morocco-Portugal and Tunisia-Italy will be built to transmit solar energy of North Africa to Europe, realizing grid interconnection between Africa and Europe; Saudi Arabia-Egypt DC project will be constructed to realize interconnection between Asia and Africa.

In 2040, Power exchange of Africa across continents and regions will reach 68 GW, of which 38 GW will be delivered across continents. **In terms of intra-continental interconnection:** D. R. Congo-Nigeria DC projects will be constructed, to expand the transmission scale of hydropower from Congo River; 1,000 kV AC power transmission channel of North Africa crossing the five countries there will be constructed, to connect the large solar power bases and load centers. The power transmission channel connects the West Asia power grid on the east, achieving mutual complementation between North Africa and West Asia. **In terms of inter-continental interconnection,** Egypt-Greece-Italy and Algeria-France DC projects will be constructed to further expand the scale of solar power transmission from North Africa to Europe; Saudi Arabia-Egypt and Ethiopia-Saudi Arabia DC projects will be constructed to improve the mutual complementation capacity of clean energy among North Africa, East Africa and West Africa.

In 2050, Africa's power exchange across continents and regions will reach 130 GW, of which 50 GW will be delivered across continents. In terms of **intra-continental interconnection,** the 1,000 kV AC power transmission channel of North Africa and regional 400/765 kV AC main power grids will be further improved. 3 synchronous power grids in the North, Central & West and East & Southern will all form strong power grids. DC interconnection among synchronous power grids will be improved unceasingly and D. R. Congo-South Africa, D. R. Congo-Ethiopia, D. R. Congo-Morocco, D. R. Congo-Ethiopia, R. Congo-Ghana and Ethiopia-Egypt DC projects will be built. In terms of **inter-continental interconnection,** Morocco-Spain and Algeria-France-Germany DC projects will be constructed to transmit solar energy of North Africa and hydropower from the Congo River to load centers of Europe after co-regulation.

6 — **Strong regional energy interconnection will be built to form a widely interconnected, economical and efficient platform for optimal allocation of clean energy resources. In North Africa,** the 1,000 kV AC transmission channel will be built to raise the ability of solar power collection. The 400/500 kV power grid will be strengthened to form strong power grid in North Africa. Cross-sea power transmission channels from North Africa to Europe and power transmission channels from North Africa to West Asia will be built inter-regionally. And the connection with Central Africa will enable local solar power and hydropower of Central Africa to be transmitted to Europe. **In West Africa,** based on the development of solar power bases in

Niger, Mali and Mauritania and the hydropower from the Niger River, the Sanaga River and the Gambia River, a "Two Horizontal, Three Vertical" strong 765 KV AC power grid will be formed to comprehensively feed the delivery needs of clean energy. 5 DC transmission channels will be built inter-regionally to receive hydropower from the Congo River and the Sanaga River, which can meet the demand of mining industry development. **In Central Africa,** a 765/400 KV AC power grid will be formed connecting south and North. The hydropower from the Congo River and the Sanaga River will be transmitted to load centers of West Africa,Southern Africa and East Africa through DC channels. Hydropower of Inga will be transmitted inter-regionally, and be delivered to Europe together with solar power of North Africa after co-regulation through DC channels. **In East Africa,** a regional 765/500 KV power transmission channel and a 400 KV regional double loop network will be built to connect main energy bases and load centers, so as to strengthen power exchange capacity of interconnected section of each country. As for inter-regional interconnection, Ethiopia will be taken as a hub. The interconnection channels between East and North Africa, East and West Asia will be built. A DC channel from East Africa to South Africa will be constructed to transmit clean energy of East Africa to eastern load centers of South Africa. **In Southern Africa,** a 765/400 KV AC synchronous power grid will be formed to strengthen 765 KV main power grid frame of South Africa and receive large-scale clean energy from within and outside the region. Central Zambia- Botswana-South Africa interconnection channels will be strengthened to realize complementary of solar power and hydropower in the region. East Africa-Southern Africa and Central Africa-Southern Africa DC channels will be built across regions, receiving hydropower from the Nile River and the Congo River.

7 — **Africa Energy Interconnection will be built to expedite development and utilization of clean energy. The comprehensive economic, social, environmental and political benefits are remarkable. In economy,** energy and power demands of Africa will be met **in a clean and green way,** which will improve efficiency of energy use and reduce energy supply cost, **realizing sustainable supply of clean energy. The economic growth of Africa will be stimulated.** Total investment of Africa Energy Interconnection is about 2.9 trillion USD and African economic growth will be driven by 0.4% on average per year. **African development cost will be lowered effectively.** In 2050, average electricity price of Africa will be around 5.1 US cents/kWh lower than current one. Electricity price of 158 billion USD will be saved each year. **Foreign exchange earnings will be increased** because of expand of the import and export trade of electricity. By 2050, African electricity import and export trade will generate about 30 billion USD in foreign exchange earnings. Also, African resources advantages can be converted into economic advantages, **realizing balanced development. In society,** Africa Energy Interconnection will help to **reduce the percentage of population without access to electricity.** By 2050, accessibility of electricity will reach 90%. **Health condition will be relieved** by reducing the pollution from energy production and utilization. That alone will avoid 2 to 3 million cases of disease annually. Also, by 2050, accumulatively **more than 30 million employments will be created** in Africa because of Africa Energy Interconnection. **In environment, emission of atmospheric pollutants from fossil energy will reduce greatly in Africa,** including 2.5 billion tons of carbon dioxide. 180 billion tons of **water and** 39 billion square meters of **land will be saved** in Africa by 2050. **Ecological environment will be protected and improved. In politics,** by building Africa Energy Interconnection and strengthening the cooperation of African regions and countries in energy field, stronger partnerships will be built among each party. **Political mutual trust of each country will be strengthened** and disputes over energy and resources will be reduced and even eliminated, so as to **promote peace and harmony of Africa and contribute to the building of a community with a shared future for mankind.**