In terms of distribution, the loads are mainly distributed in four special economic zones established by the D.R. Congo government, namely the west special economic zones (including the capital Kinshasa, Matadi in Bas-Congo Province and the port city of Banana), the south special economic zone (including the Kolwezi, Likasi and Lubumbashi in Katanga Province), the central special economic zone (including Ilebo, Tshikapa, Kananga in Kasai Occidental Province and Mbuji-Mayi in Kasai Oriental Province) and the northeast special economic zone (including Kisangani in Orientale Province, Kindu in Maniema Province and Bumba in the Equateur Province). In 2050, loads of the four major special economic zones accounted for more than 90% of the total demand. The maximum loads in the west, south and northeast special economic zones will reach 8 GW, 8 GW, and 5 GW respectively. Residential, processing, and commercial & service consumption of electricity are the main types of load in the west special economic zone. Main types of loads in the south and northeast special economic zones are from heavy industries such as mining and metallurgy. Main types of loads in the central special economic zone are the residential and processing of agricultural products of electricity consumptions. The load distribution of D.R. Congo in 2050 is shown in Fig. 4.3.

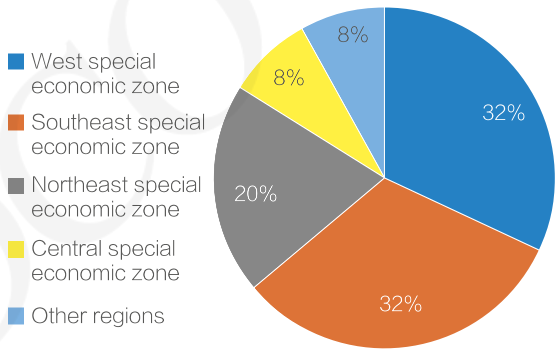


Fig. 4.3 Load Distribution of D.r. Congo in 2050

Calculated by the estimation that all of industrial and more than half of the residential power demand in D.R. Congo are supplied by the hydropower from downstream Congo River, local consumption of hydropower from downstream Congo River base will reach 80~100 TWh in 2050, with the installed capacity of about 14 GW. Other power demands will be satisfied by small and medium-sized hydropower in the upper stream of Congo River and tributaries such as Luvua River and Lualaba River, and biomass power generation. According to the power-balancing calculation, the installed capacity of hydropower in the mainstream of Congo River (excludes downstream bases) and tributaries is about 18 GW. The installed capacity of biomass and other power sources is 4 GW.

Coordinating the planning of hydropower development and scale, distribution and characteristics of loads, hydropower in the downstream of Congo River is positioned to meet the industrialization power needs of mining, metallurgical industry, processing and manufacturing industry, as well as power needs from nearby cities including Kinshasa, Matadi, Banana and others. 6 GW of power will be sent westwards to support urbanization and industrialization of these places. Also, 6 GW will be sent to Katanga Province in the south and 4 GW to Maniema Province and Orientale Province in the northeast, to meet the power demands from mining and metallurgical industry thus achieving optimized allocation of hydropower in the nationwide. The rest of the electricity can be sent internationally. The domestic market of electricity consumption in D.R. Congo by 2050 is shown in Table 4.3.

Table 4.3 Domestic Market of Electricity Consumption in D.R. Congo before 2050

Basin	Consumption Regions	Consumption Space (GW)
Mainstream of the Downstream of Congo River	West (Kinshasa, Matadi, Banana)	6
	South (Katanga Province)	6
	Northeast (Kindu, Kisangani)	4
	Total	16

Electricity from other hydropower stations in the Congo River are mainly used for local consumption to ensure the development of local industry and agriculture, improve the living standards of the people, and help to achieve 100% access to electricity by 2050 for D.R. Congo. **Hydropower from the upstream of Congo River** will be consumed in the south and the northeast special economic zones. **Hydropower from the Lualaba River** will be consumed in the south special economic zone. **Hydropower from Kasai River** will be consumed in the central special economic zone. And **hydropower from the Oubangui River** will be consumed in the northeast special economic zone.

For long-term development, the total electricity consumption in D.R. Congo in 2060 is expected to reach 200 TWh with a maximum load of 35 GW. Considering both regional hydropower exploitation and demands for diversified installation, electricity from the downstream Congo River hydropower base can satisfy about 50% of the country's total demand, corresponding to the installed capacity of 14 ~ 16 GW. Except for the downstream Congo River hydropower base, the installed capacity of all hydropower in the river is about 30 GW. Taking about 6 GW of biomass and other power sources, there are still 15 GW of untapped hydropower potential in D.R. Congo to develop.

4.2.2 R. Congo

Development Foundation

R. Congo is an important country in Central Africa and a relatively developed economy in sub-Saharan Africa. Before 2015, the economy of R. Congo maintained steady growth. In recent years, with the decline of international oil prices and iron ore prices, the economic growth rate has slowed down. The GDP in 2018 was about 11 billion USD with the per capita GDP of 2,100 USD. Oil industry is the pillar industry in R. Congo. In 2017, 110 million barrels of oil were produced, with an increase of 16% compared to 2016. Oil accounts for up to 70% of exports, and the industry accounts for nearly 30% of GDP.

R. Congo is rich in oil, gas and minerals. The proven reserves of oil are 1.6 billion barrels, with the reserve-production ratio about 15. The natural gas reserves are nearly 100 billion m^3 without large-scale exploitation yet. The oil and gas resources are mainly concentrated in coastal areas. In terms of minerals, iron ore reserves are about 25 billion tons, while potassium has the proven reserves of 6 billion tons, both mainly concentrated in the southwest and north regions. Besides, there are also reserves of gold, lead, copper, aluminum, phosphate and other minerals. Mineral distribution in R. Congo is shown in Fig. 4.4.

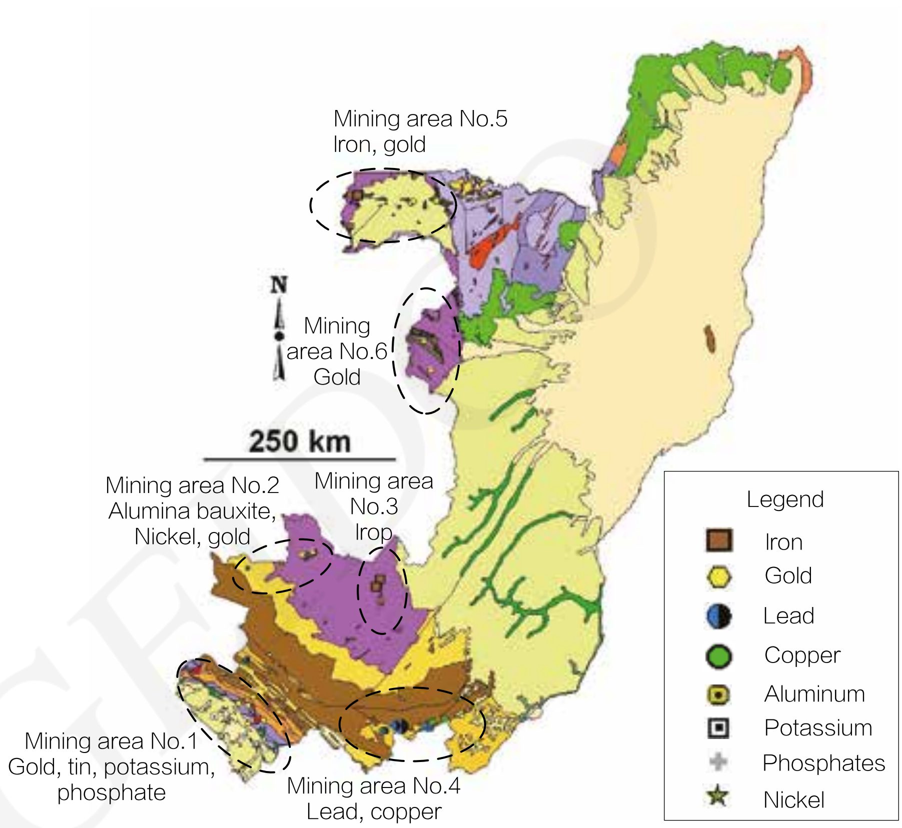


Fig. 4.4 Mineral Distribution in R. Congo[1]

Except for the Congo River, hydropower resources in R. Congo are mainly concentrated in the southwest of the Niari River and Kouilou River and its tributary of the Louesse River. The technological exploitable capacity in R. Congo is about 2.5 GW. There are 8 hydropower stations planned to be built with a total installed capacity of about 2.3 GW. Table 4.4 shows the hydropower station planning in the Kouilou River and its tributary in R. Congo.

1 Source: Ministry of Mines and Geology of R. Congo

Table 4.4 Hydropower Station Planning in the Kouilou River and its Tributaries[1]

Basin	Planned Hydropower Station	Installed Capacity (MW)
Kouilou River	Sounda	800
Upstream of Louesse River	Mourala	100
	Nyanga	230
Mid and Downstream of Louesse River	Bikongo	150
	Ibabanga	530
	Mpoukou	160
Niari River	Moukoukoulou	170
	Makabama	150
Total		2290

Development Perspective

The R. Congo government is actively pursuing policies to revitalize and diversify the economy, reducing excessive dependence on oil and promoting the all-round development of all sectors. In 2009, President Sassou proposed the "Road to the Future" plan, which is mainly aimed at diversified economic development and social progress. This plan placed the strengthening of infrastructure construction and education as the mainstay, focusing on the development of agriculture, mining and processing industries. In order to become an emerging developing country, the R. Congo government has established four special economic zones, namely Brazzaville, Pointe-Noire, Oyo Ollombo and Ouesso, and planned to develop different industries according to the characteristics of each special zone. R. Congo is the only country in the world that has established a ministerial unit of special economic zone affairs. In 2017, the Special Economic Zone Law was promulgated.

According to resource endowment and industrial development foundation, **R. Congo can establish industrial parks relying on its own iron ore mines, potash mines and bauxite resources from Guinea or other countries, which in turn will drive the development of upstream and downstream industries in special economic zones, and gradually realize co-development of the whole industry chain of "electricity, mining, metallurgy, manufacturing and trade".** Four special economic zones, steel processing parks in Mayoko and Zanaga, and potash industry in the Kouilou Province are the key industries to be focused. The Pointe-Noire special economic zone is developed and built referring to Chinese developing mode. It is the flagship project of China-Africa cooperation in industry and production and a model for African intensive development. This special economic zone relies on mineral resources of R. Congo and the deep-water port in Pointe-Noire to focus on the development of the mining and processing industries, as well as the processing and export of petroleum, chemical and food products.

---

[1] Source: Power Construction Corporation of China

The Brazzaville special economic zone relies on the capital economic circle to focus on financial, construction and logistics industries. The Ouesso special economic zone relies on the industrial center in the northwest of the R. Congo to focus on mineral mining, agricultural product processing, wood processing and building materials industries. The Oyo-Ollombo special economic zone focuses on animal husbandry, forestry, cash crop cultivation and agro-processing industries. The industry development plan of R. Congo is shown in Fig. 4.5.

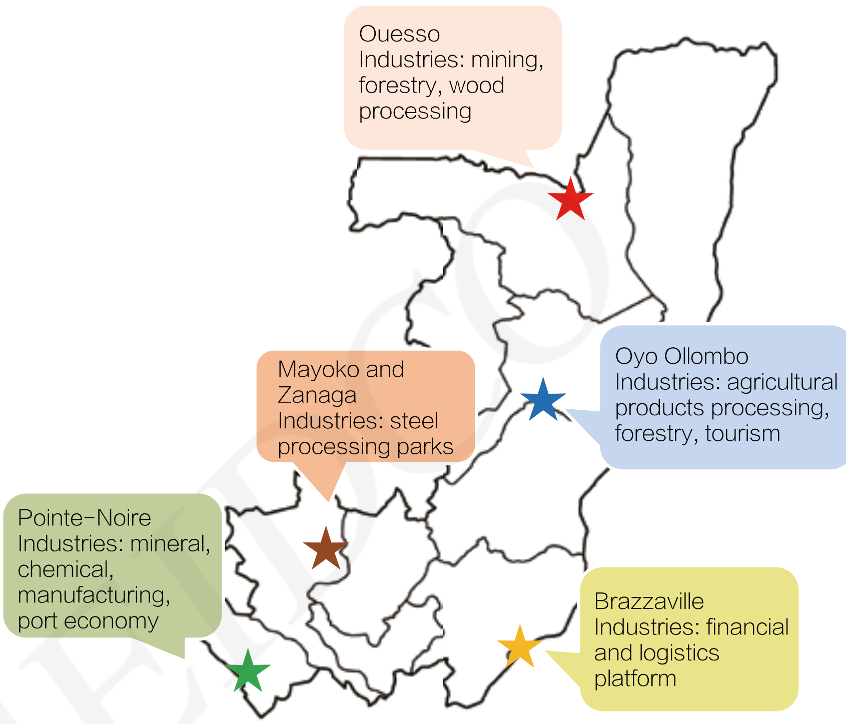


Fig. 4.5 Diagram of Industry Development Proposal of R. Congo

Taking into account the distribution of mineral resources, the layout of hydropower exploitation and infrastructure conditions, it is recommended that the R. Congo can achieve the mining development target of: before 2030, it is proposed to give priority on the development of electrolytic aluminum and potash fertilizer industrial park in the Pointe-Noire special economic zone. At the same time, steel processing parks in the mines of Mayoko, Zanaga and Ouesso and the special economic zones of Pointe-Noire and Brazzaville will be established. Therefore in 2030, the production of steel, electrolytic aluminum and potassium chloride will reach 20 million tons, 1 million tons and 2 million tons, respectively. Before 2050, construction of infrastructure such as railways and ports needs to be accelerated to develop sea-land combined transportation based on the advantages of Pointe-Noire. Exploitation of mineral resources in surrounding and remote provinces will be promoted. The scale of steel, electrolytic aluminum and potassium chloride industries will also be further expanded. The production of steel, electrolytic aluminum and potassium chloride will reach 60 million tons, 2 million tons and 6 million tons, respectively.

Electricity Consumption Market

Considering the high-speed development of electrolytic aluminum, steel industry, potash fertilizer industry in R. Congo and the needs to increase the accessibility to electricity, it is predicted that in 2030, total electricity consumption will reach 33 TWh, with the maximum load of 5 GW and the annual electricity consumption per capita of 4,500 kWh. In 2050, total electricity consumption will be 80 TWh, with the maximum load of 12 GW and the annual electricity consumption per capita of 7,000 kWh. The current and forecast power demand in R. Congo is shown in Table 4.5.

Table 4.5 Overall Power Demand in R. Congo

Year	Electricity Consumption (TWh)	Maximum Load (GW)	Electricity Consumption Per Capita (kWh/year)
2016	1	0.22	200
2030	33	5	4500
2040	50	7.8	5300
2050	80	12	7000

In terms of distribution, loads are concentrated in the southern Pointe-Noire special economic zone, Brazzaville and steel industry parks in Niari and the Lekoumou Province. In 2050, the load of these three regions will account for more than 90% of the national total. The Pointe-Noire special economic zone, with the rapid development of the electrolytic aluminum and steel industries, will have a maximum load of about 7 GW, becoming the power load center of the country. The load distribution of R. Congo in 2050 is shown in Fig. 4.6.

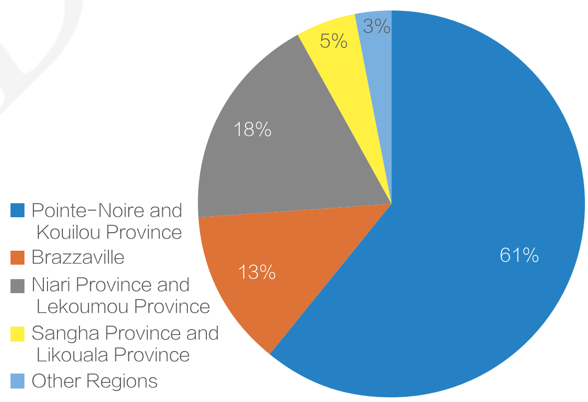


Fig. 4.6 Load Distribution of R. Congo in 2050

Coordinating the planning of hydropower exploitation, scale, distribution and characteristics of loads, and development potential of other power sources such as gas and biomass in R. Congo, hydropower in the downstream of Congo River is utilized mainly to support electrolytic aluminum and steel industries with high utilization hours and requirement of reliability in the Pointe-Noire special economic zone. For long-term development, electricity from the downstream of Congo River hydropower base consumed in R. Congo is about 50 TWh, with the corresponding installed capacity of about 8 GW. Other hydropower in R.

Congo is mainly consumed locally, to meet the demand for co-development of "electricity, mining, metallurgy, manufacturing and trade" and the goal of 100% accessibility to electricity. Hydropower from the **Kouilou River and its tributaries** will mainly be consumed in the Pointe-Noire special economic zone and steel industrial parks in Niari and Lekoumou. Hydropower from the **Sangha River** will be consumed in Ouesso special economic zone. Hydropower from **other tributaries of Congo River such as the Lefini River and the Djoue River** will be consumed in Brazzaville and other regions.

4.2.3 Other Countries within the Region

The Congo River Basin is mainly located in Central Africa. In 2016, the total population of the whole Central Africa was 130 million, accounting for 11% of total Africa. The GDP in 2016 was 102.8 billion USD, accounting for 5% of total Africa. Electricity consumption was 18 TWh with a maximum load of 2.8 GW. Except for D.R. Congo and R. Congo, Cameroon and Gabon are the main power load centers, electricity consumptions accounting for 47% of the total. The power generation installed capacity in Central Africa was 5.9 GW, of which the proportion of hydropower installed was 68%. The per capita electricity consumption in Central Africa was 140 kWh/year, and the per capita installed capacity was 0.05 kW, which was less than one-third of the African average. The accessibility to electricity was 27%, and there were still 95 million people living without electricity.

The political and social environment of Central African countries tends to be stable. With abundant minerals and forest resources, regional advantages of Central Africa are obvious. Demographic dividends are also prominent and rapid growth. Besides, with the launch of industrial and economic revitalization plans, Central African countries appear with great potential for economic development. In the future, development of industries such as mining, manufacturing, and agricultural products processing industries will lead to the rapid growth of energy and power demand, especially from those high-energy-consuming industries such as copper, electrolytic cobalt, electrolytic manganese, and steel. Also, urbanization and electrification in these countries are of urgent demand of electricity. It is estimated that in 2030, the total electricity consumption in Central Africa except D.R. Congo and R. Congo will reach 41 TWh, of which 20 TWh will be needed in mining, with a maximum load of 7.5 GW. In 2050, the total electricity consumption will reach 120 TWh and the maximum load 23 GW. Newly added electricity consumption of the mining industry will be 65 TWh. The trend of power demand in other countries in Central Africa is shown in Fig. 4.7.

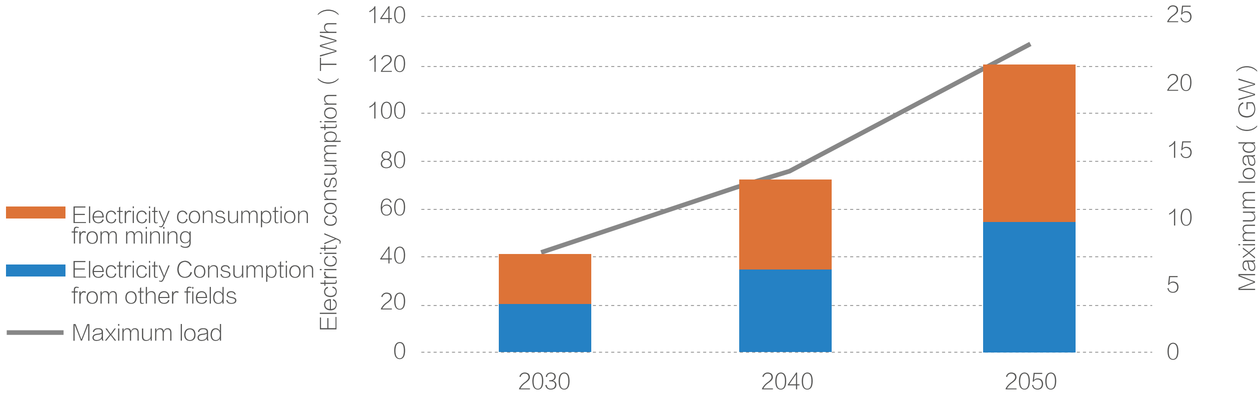


Fig. 4.7 Trend of Power Demand in Other Countries in Central Africa

Hydropower resources in Central Africa are extremely abundant without large-scale exploitation. Except for the Congo River, hydropower resources in the Sanaga River in Cameroon and the Ogooue River in Gabon are also rich with the technological exploitable capacity is 12 GW and 6 GW, respectively. In addition, Central Africa is rich in biomass resources. Some regions in Chad and Cameroon have considerable solar and wind energy resources. Countries such as Equatorial Guinea and Gabon are rich in oil and gas resources. In the future, it is highly suggested that Central African countries give priority to the exploitation of hydropower, develop wind and solar power generation according to local conditions, and moderately develop gas-fired power as adjusting sources. At the same time, Central African countries can receive electricity from other regions through the Central African interconnected power grid to meet the needs of electricity during the dry period. Taking into account the proportion of needed power receiving outside Central Africa, the proportion of volatility power supply installed, and the requirement of safe operation of the system, 3~4 GW of hydropower from the downstream of the Congo River is needed to be consume within Central Africa. Power receiving countries are Cameroon and Gabon. The variation of water flows of some rivers in Central Africa is shown in Fig. 4.8.

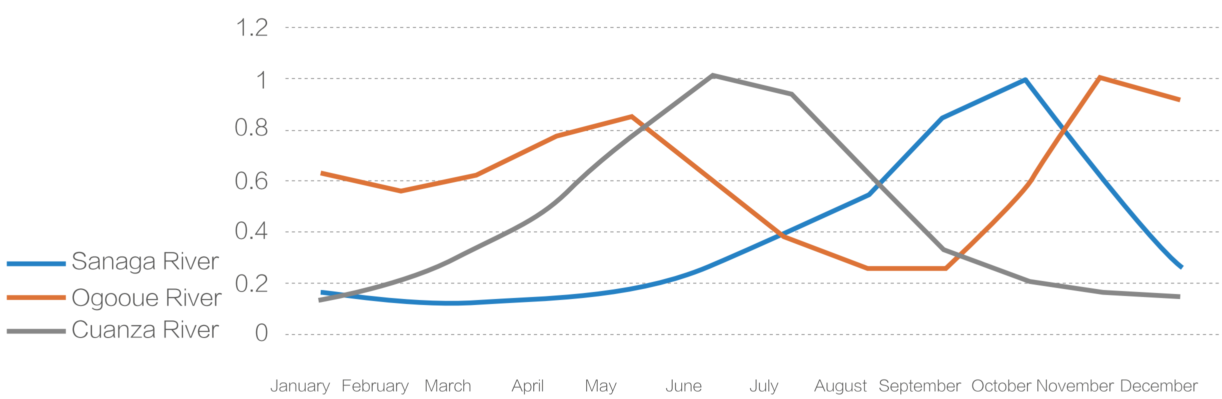


Fig. 4.8 Variations of Water Flows of Some Rivers in Central Africa

Cameroon is rich in bauxite and hydropower resources, and has favorable conditions for the development of electrolytic aluminum industry. In the near-term, it is suggested to focus on exploiting hydropower of the Sanaga River and tributaries of the Congo River to meet the power demands. After 2040, hydropower from the downstream of the Congo River can be received to support the demand for hydropower adjustment between seasons. **Gabon** has large reserves and high grade of manganese and iron ore with a certain mining foundation. In the future, it can take full use of the resource advantages of manganese and iron ore to develop deep processing industry. In the near-term, hydropower in the Ogooue River Basin can be exploited firstly as the power supply. In the long term, hydropower from the downstream of the Congo River can also be introduced to guarantee the power supply for the needs from rapid development of industrial and mining industries.

4.3 Inter-regional Consumption Market

4.3.1 Overall Development Trends

Since the new century, the political situation in Africa has become more and more stable. The demographic dividend has been continuously released, and the business environment kept to improve. In the past decade, the total economic volume in Africa has doubled to exceed 2 trillion USD with the economic growth rate of 3.7%. This achievement makes Africa one of regions with the fastest economic growth around the world. Relying on rich mineral resources, clean energy resources and outstanding labor advantage, Africa is welcoming new opportunities characterized by industrialization, urbanization and regional integration, and will become an important growth pole of the world economy. Considering factors such as population growth, economic development, and international production transfer, it is expected that the African economy will maintain a strong growth momentum in the future. The total GDP in 2050 will reach 3 to 6 times that in 2015 [1], and the growth rate is at the forefront of the world.

Industrialization, urbanization and regional integration will also drive the rapid growth of energy and power demand in Africa. In particular, industrialization following the co-development model of "electricity, mining, metallurgy, manufacturing and trade" and industrial upgrading based on sufficient energy and power supply. Power demand in Africa is expected to grow rapidly in the future, with electricity the consumption and maximum load in 2050 being 6.1 and 5.5 times that in 2016, respectively. From 2016 to 2050, the total electricity consumption in Africa will increase from 0.64 PWh to 4.0 PWh, with an average annual growth rate of 5.5%. The maximum load will increase from 130 GW to 710 GW, with an average annual growth rate of 5.2%. The per capita electricity consumption will increase from 520 kWh/year to 1,570 kWh/year, which is three times that of 2015 and reaches the 1980 level of the global total. There is still room for continuous improvement.

---

[1] Source: AfDB, IEA, MIT.

In 2063, Africa's total electricity consumption will reach 5.5 PWh, and the maximum load is about 1 TW The per capita electricity consumption is about 1,800 kWh/year, achieving the development goals of the AU's "2063 Agenda." Forecasts on Africa's electricity consumption and maximum load are shown in Fig. 4.9.

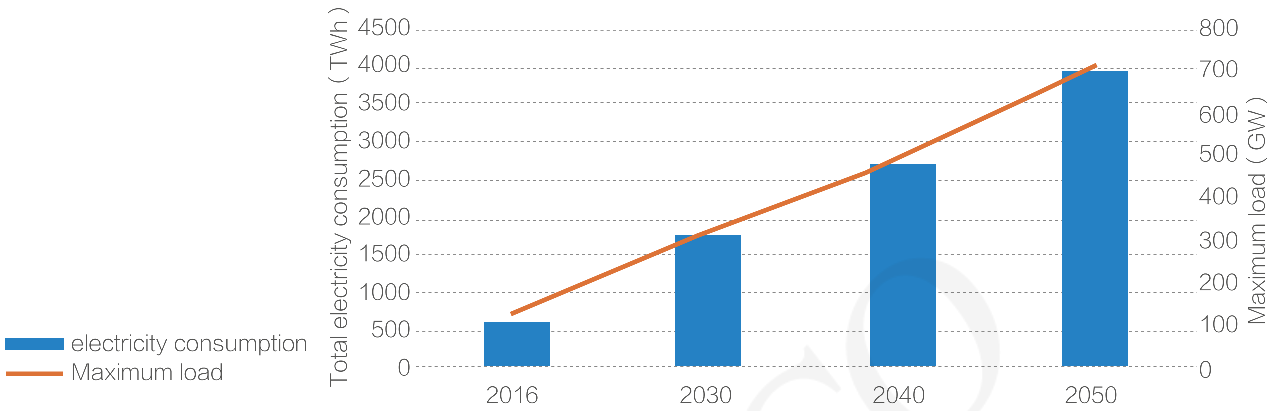


Fig. 4.9 Forecasts on Africa's Electricity Consumption and Maximum Load

Power supply capacity in Africa will increase significantly, with clean energy becoming the dominant power source. In 2050, the total installed generation capacity in Africa will reach 1.31 TW, with an average annual growth rate of 5.8%. The per capita installed capacity of 0.52 kW, increasing to 3.3 times that in 2016. Clean energy will become the dominant power source by 2030. In 2050, clean power installed capacity will exceed 1 TW, accounting for 77%. There will be 560 GW of solar power, 280 GW of hydropower, and 130 GW of wind power installed in Africa.

In 2063, the total installed capacity in Africa will reach 1.84 TW. The proportion of clean energy installed capacity is 85%, and the proportion of clean energy generation is 80%. The installed generation capacity in various regions of Africa is shown in Fig. 4.10.

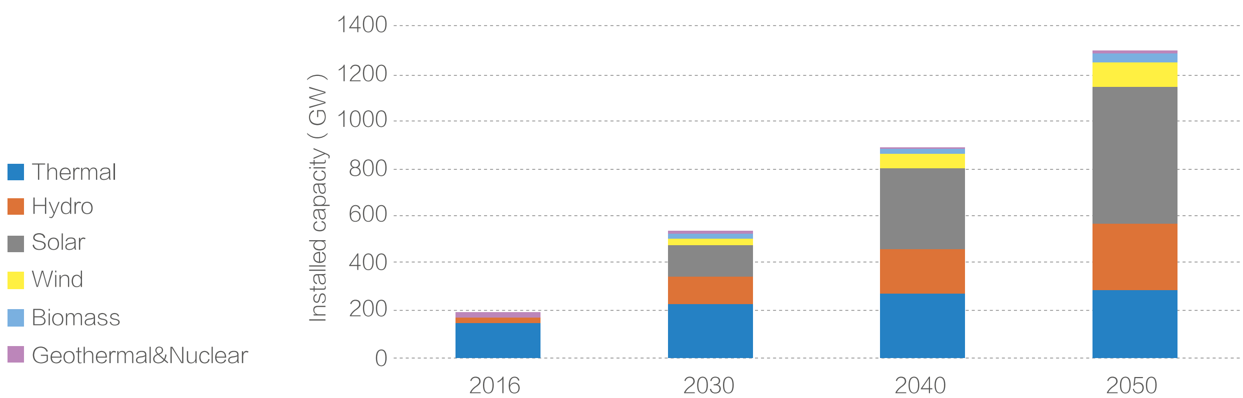


Fig. 4.10 The Installed Generation Capacity in Various Regions of Africa

4.3.2 Development Roles for Different Regions

According to the overall development trend of energy and power in Africa, future development role for each region of Africa is proposed with the consideration of development foundation, resource endowment, industrial advantage and policy orientation.

Central Africa

Is rich in hydropower and mineral resources. Large-scale exploitation of hydropower in the Congo River and the Sanaga River can not only satisfy the power demands from industrialization and people without accessibility to electricity, but also be outbound delivered to turn the resources advantages to economic benefits. In the future, Central Africa will be the main clean power bases of the whole Africa.

West Africa and Southern Africa

Are rich in mineral resources, prominent in demographic dividends, and have obvious advantages in location and great potential for industrialization. Following the co-development model of “electricity, mining, metallurgy, manufacturing and trade”, the power demand in this two regions will grow rapidly. At present, fossil fuel power sources still account for a relatively high proportion. Countries in West and Southern Africa are paying more and more attention to clean transformation. But local clean energy resources are limited in amount to ensure reliable power supply for industrial and mining loads. In the future, these two regions will become the main power receiving centers in Africa.

East Africa

Has obvious location advantage. The demographic dividend is outstanding. Countries within the region have a good development foundation of industrial park, and becoming one of the rapid developing areas in Africa. Hydro, solar, wind, geothermal and other clean energy resources are all abundant in East Africa. Hydropower in the Nile River and geothermal energy in the East African Rift Valley will be exploited in the early stage to meet power demands nearby. In the long run, with the increase of population and the further development of the manufacturing industry, East Africa will also become a power receiving center.

North Africa

Has abundant solar and wind energy resources. Exploitation conditions are excellent to build large-scale solar and wind power bases. The European continent on the other side of the Mediterranean is economically developed and has a large demand for electricity as the proportion of electric replacement increases. On the basis of satisfying its own electricity consumption, North Africa can send electricity to Europe across the Mediterranean to become a clean power base. Development roles of different regions in Africa are shown in Fig. 4.11.

Fig. 4.11 Development Roles for Different Regions in Africa

4.3.3 Regional Electricity Consumption Market Analysis

West Africa

There are 360 million people living in West Africa, accounting for 31% of Africa's total population. In 2016, GDP of West Africa was 566 billion USD accounting for 27% of Africa's total. Total electricity consumption was 56.4 TWh with the maximum load of 10.4 GW. Nigeria, Ghana and Côte d'Ivoire are the main power load centers, and the power demand in these three countries account for as much as 80% of the whole region. The installed generation capacity was 22.63 GW, of which the proportion of thermal power was 76%. The electricity consumption per capita in West Africa was 155 kWh/year. The per capita installed capacity was 0.06 kW, which is about one-third of the African average.

In the future, with the rapid development of mineral processing industries such as aluminum, steel and manganese ore and the construction of industrial parks including automobiles, machinery and textiles, power demand in West Africa will maintain rapid growth. It is estimated that in 2030, the total electricity consumption in West Africa will reach 340 TWh, of which 97 TWh will be from the mining industry. The maximum load will be 62.2 GW. In 2050, the total electricity consumption will reach 954 TWh. Electricity consumption of mining will contribute 310 TWh. The maximum load will be 160 GW. The trend of power demand in West Africa is shown in Fig. 4.12.

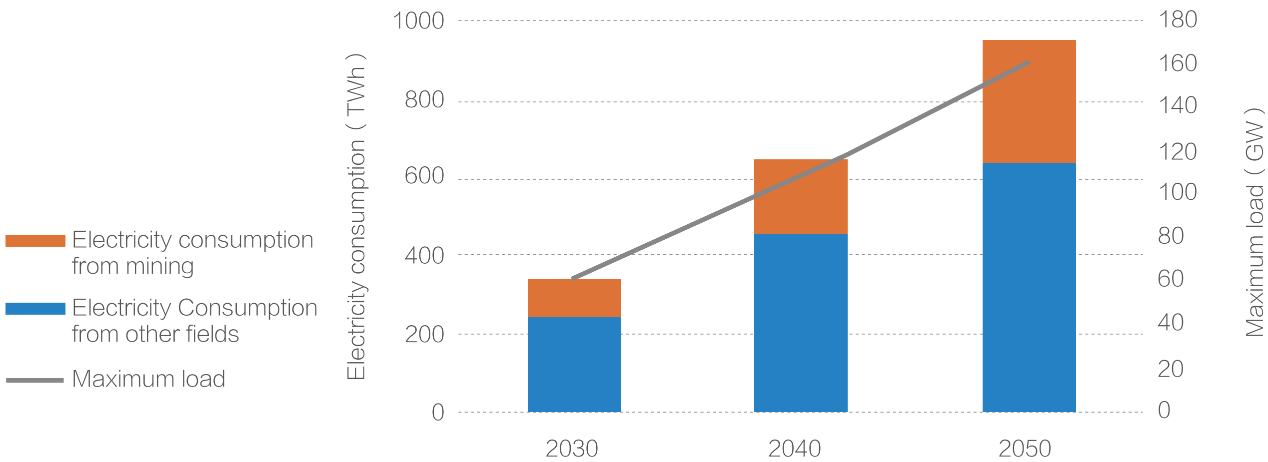


Fig. 4.12 Forecast of Power Demand in West Africa

West Africa has abundant solar energy, biomass, oil and gas, and also has some hydropower resources. Wind energy is at average. The development of power supply is: prioritize the exploitation of clean energy within the region, moderately develop gas-fired power generation, complement hydro, solar and gas power generation to form a clean energy dominated power supply structure. In 2030, the installed generation capacity of West Africa will be 96 GW, including 37 GW of thermal power and 29 GW of solar power. In 2050, the installed generation capacity will reach 240 GW, of which 990 GW will be solar power and 74 GW will be thermal power.

There are large power shortages in both wet and dry periods in West Africa. In 2030, 2040, and 2050, power shortage will be 16 GW, 32 GW, and 40 GW, respectively. These can be filled by hydropower in the downstream of the Congo River. The results of power balancing analysis in West Africa is shown in Table 4.6.

Table 4.6 Power Balancing Analysis in West Africa

Unit: GW

Year	Maximum Load	Installed Capacity	Wet Period		Dry Period	
			Available Installed Capacity	Power Shortage	Available Installed Capacity	Power Shortage
2030	62.2	95.8	59.5	12	55.5	16
2040	107.4	156	97.5	26	91.5	32
2050	160.9	241	150.5	34.5	145	40

The key countries for electricity consumption in West Africa are Nigeria, Guinea and Ghana. In 2050, electricity consumptions from these three countries will account for 44%, 16% and 13% of total in West Africa, respectively.

- **Nigeria** is the largest economy and has the largest population in Africa. It has a sound development foundation and a complete industrial structure. The industries of oil and gas, agriculture and light industry are developed. Its mineral resources and labor resources are abundant. The power shortage in 2030 and 2050 is estimated to be 8 GW. 12 GW, respectively. The load is mainly concentrated in the industrial parks in Lagos and Lokoja in the south.

- **Guinea** has the largest reserves of bauxite in the world, high grade and abundant iron ore. It is of great potential to develop large-scale electrolytic aluminum and steel industry. The technological exploitable capacity of domestic hydropower is 6 GW, which is difficult to meet the long-term power demand for industrial development. In 2030 and 2050, there will be 8 GW and 16 GW power shortage, respectively. The load is mainly concentrated in aluminum industrial parks in Boke and Boffa and steel industry park in Simandou.

- **Ghana** is one of the countries with the highest overall development level in West Africa. The bauxite and manganese ore resources are abundant. The domestic clean energy resources are to meet local power demand in the long run. The power supply and demand will be basically self-balancing before 2030. And the power shortage will reach 5 GW in 2050. The load is mainly concentrated in the aluminum industrial parks in Awaso and Nyinahin. In addition, the neighboring country of Côte d'Ivoire is also an important power load center in West Africa, with a power shortage of approximately 3 GW by 2050.

Southern Africa

The population in Southern Africa is 170 million, accounting for 15% of the total Africa. The total GDP is 468.2 billion USD, accounting for 22% of the total Africa. In 2016, electricity consumption in Southern Africa was 246.6 TWh, with the maximum load of 47.8 GW. South Africa is the main power load center with the electricity consumption ratio of 80%. The installed generation capacity is 63.55 GW, of which the proportion of thermal power installed is 73%. The overall development level of Southern Africa is relatively high in the whole Africa. The per capita electricity consumption is 1,240 kWh/year, which is about 2.6 times the African average. The development stage in this region is very different. The Republic of South Africa is the most developed country in Africa's power industry. Electricity consumptions in the rest countries are much lower.

In the future, relying on the location advantages of connecting the two oceans, Southern Africa can coordinate the development of minerals and industrial parks. Focusing on the development of steel, electrolytic aluminum, refined copper, automobile, chemical and other industries, three economic belts including the Zambezi River, the Atlantic coast and the Indian Ocean coast will be built to form the co-development of land and sea. It is estimated that in 2030, the total electricity consumption in Southern Africa will reach 535 TWh, of which the increased electricity consumption from the mining industry will be 38 TWh. The maximum load will reach 93.4 GW. In 2050, total electricity consumption will reach 965 TWh, of which the increased electricity consumption from the mining industry will be 137 TWh. The maximum load will be 170 GW. The forecast of electricity demand in Southern Africa is shown in Fig. 4.13.

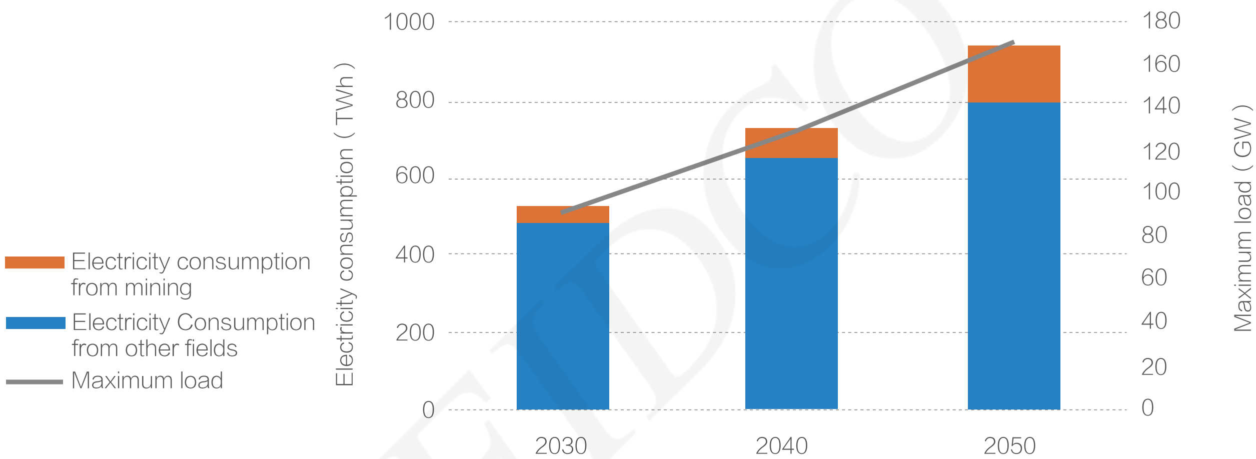


Fig. 4.13 Forecast of Power Demand in Southern Africa

Southern Africa has enormous coal resources. Solar, hydro, wind and biomass energy are also considerable in resources. The development of power supply is as follows: priority is given to the exploitation of hydropower in the Zambezi River and the Orange River, develop solar power and coastal wind power in Namibia, South Africa and Mozambique in large-scale, and supplement to install gas and coal power generations. In 2030, the installed generation capacity in Southern Africa will be 130 GW, including 63.3 GW of thermal power, 28.5 GW of solar power, and 25 GW of hydropower. The installed generation capacity in 2050 will reach 300 GW, including 130 GW of solar power, 72.8 GW of thermal power, and 44 GW of hydropower.

In 2030, there will be a slight surplus of power in the Southern Africa in the wet period. The power shortage in the dry period will be 8 GW. In 2040 and 2050, power shortage will reach 13 GW and 21 GW, respectively, which forms the market space for consuming hydropower from the downstream of the Congo River. The results of power balancing analysis in Southern Africa is shown in Table 4.7.

Table 4.7 Power Balancing Analysis in Southern Africa

Unit: GW

Year	Maximum Load	Installed Capacity	Wet Period		Dry Period	
			Available Installed Capacity	Power Shortage	Available Installed Capacity	Power Shortage
2030	93.4	132	109.4	-2	99.4	8
2040	132.8	218.3	154.2	5.5	139.7	13
2050	174.2	296.5	190	10	179.3	21

The key countries for electricity consumption in Southern Africa are the Republic of South Africa, Angola and Zambia. In 2050, electricity consumption in these three countries will account for 65%, 12% and 7% of the total Southern Africa.

South Africa is one of the most developed countries in Africa. It is currently in the middle stage of industrialization. The National Development Plan of 2030 proposes to increase investment in infrastructure such as roads, railways, ports and electric power to support rapid economic development. With the gradual decommissioning of the old coal-fired power generating units, there will be a power shortage of about 8 GW in the dry period after 2040. With rich iron ore reserves.

Angola proposes the National Development Plan of 2018~2022 to take measures to reduce dependence on the petroleum industry. Following the co-development model of “electricity, mining, metallurgy, manufacturing and trade”, the development of iron and steel smelting and processing industry is in need of power supply, which can be satisfied by the cheap and reliable hydropower from the downstream of the Congo River. In the future, 2 GW of hydropower can be received.

Zambia is rich in copper resources and ranks fourth in the world. The northern region bordering with the Katanga Province of D.R. Congo has the third largest copper mine in the world. Technological exploitable capacity of domestic hydropower is about 6.5 GW, which is concentrated in the southern region. Hydropower in Zambia is far from load centers and has obvious seasonal characteristics. Taking domestic hydropower into consideration, there will still be about 3 GW power shortage from the northern mining area in 2030.

East Africa

The total population of East Africa is 130 million, accounting for 28% of the total Africa. The GDP of East Africa is 319.3 billion USD, accounting for 15% of the total Africa. In 2016, electricity consumption in East Africa was 40 TWh with a maximum load of 8.5 GW. Sudan, Ethiopia and Kenya are the main power load centers, and in total contributes for 75%. The installed generation capacity was 13.6 GW, of which the hydropower was 56%. Most parts of East Africa are on a early stage of power sector development. The per capita electricity consumption was 120 kWh/year and the per capita installed capacity was 0.04 kW, less than a quarter of the African average.

In the future, it is proposed to promote the coordinated development of industries such as manufacturing, logistics, and modern services by building the Red Sea Economic Belt, the Indian Ocean Economic Belt, and the Great Rift Valley Economic Corridor. It is estimated that in 2030, the total electricity consumption in East Africa will reach 122 TWh, with a maximum load of 23.2 GW. In 2050, the total electricity consumption will reach 500 TWh and the maximum load will be 96.4 GW. The forecast of electricity demand in East Africa is shown in Fig. 4.14.

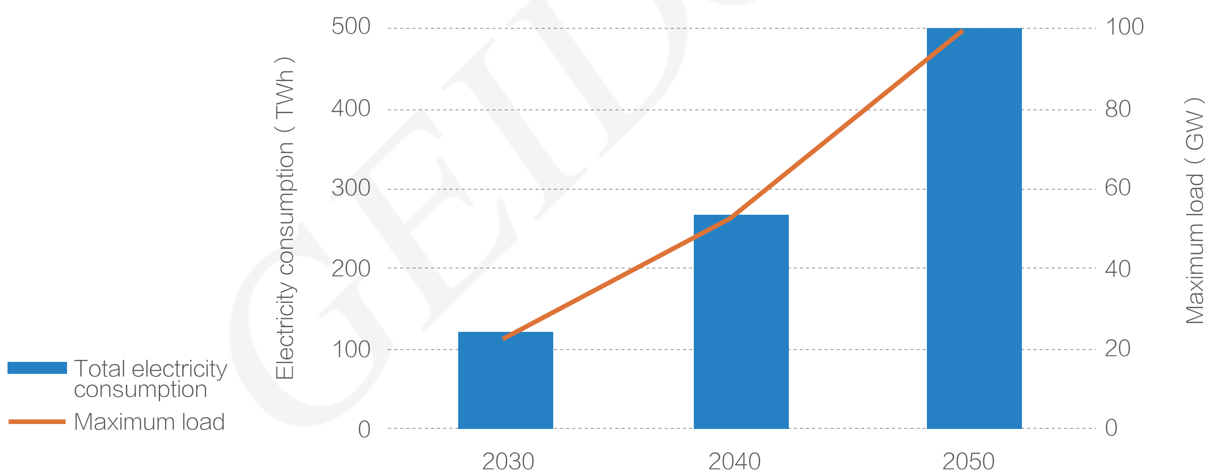


Fig. 4.14 Forecast of Power Demand in East Africa

East Africa has abundant clean energy resources including solar, hydro, wind and geothermal energy. The development of power supply is: accelerate the exploitation of hydropower in the upstream of the Nile River, the Juba River and the Rufiji River, vigorously develop solar power in the north, thermal power in the Great Rift Valley and wind power in the east, and moderately develop gas power generation. In 2030, the installed generation capacity in East Africa will be 65.3 GW, including 25.2 GW of hydropower, 18.6 GW of solar power, and 5.5 GW of geothermal power. In 2050, the installed generation capacity in East Africa will be 230 GW, including 110 GW of solar power, 53.3 GW of hydropower, 26.3 GW of wind power, and 11.4 GW of geothermal power.

In 2030, 2040, and 2050, there will always be surpluses of electricity in East Africa, which will be 4 GW, 12 GW, and 10 GW, respectively. The results of power balancing analysis in East Africa is shown in Table 4.8.

Table 4.8 Power Balancing Analysis in East Africa

Unit: GW

Year	Maximum Load	Installed Capacity	Wet Period		Dry Period	
			Available Installed Capacity	Power Shortage	Available Installed Capacity	Power Shortage
2030	23.2	65.3	34.8	-8	30.7	-4
2040	54.6	161.3	80.8	-18	74.8	-12
2050	96.4	230	122.8	-12	120.8	-10

The main power source in East Africa is PV and hydropower that has obvious seasonal characteristics. The annual utilization hours are both relatively low. In order to make full use of the existing inter-regional DC channels in East Africa to improve the utilization efficiency, in 2050, electricity needed to be sent in is about 45 TWh. Therefore 8 GW of hydropower from the downstream of the Congo River can be delivered to bring electricity efficiency of the Congo River. In 2050, as East Africa becomes the center of manufacturing in Africa, the power shortage will further increase, and it will be subject to the conditions of receiving hydropower from the downstream of the Congo River.

The key countries for electricity consumption in East Africa are Ethiopia, Tanzania, and Kenya. In 2050, electricity consumption in these three countries will account for 30%, 20%, and 19% of the total East Africa.

Ethiopia is one of the fastest growing countries in Africa in recent years. It has obvious labor advantages and abundant hydro resources. The government has formulated the "Growth and Transformation Plan" to focus on industrialization, infrastructure construction and agricultural development. In the future, with the completion of large-scale hydropower stations such as Grand Ethiopian Renaissance Dam, Gibe IV, and Upstream Mandaya, Ethiopia will become the clean power generation base in East Africa. However, due to the strong seasonal characteristics of domestic hydropower, power shortage will still exist in the dry period in 2050.

Tanzania has abundant natural gas resources and rapid population growth. The government has formulated the "Vision 2025" plan, focusing on promoting industrial development. The future energy and power demand will maintain rapid growth.

Kenya are very rich in wind, solar, geothermal and other clean energy resources. With a complete range of industry and good foundations, Kenya can become a hub for interconnected power grids in East Africa with the help of the geographical advantages. In 2050, with the reception of hydropower from the downstream of the Congo River, power demands from Kenya, Tanzania and the whole East Africa will be satisfied based on the united electricity market.

North Africa

The total population of North Africa is 190 million, accounting for 16% of the total Africa. The GDP of North Africa is 669 billion USD, accounting for 31% of the total Africa. In 2016, the electricity consumption in North Africa was 275.2 TWh, and the maximum load was about 60 GW. Egypt is the main power load center, accounting for 59%. The installed generation capacity was 87.86 GW, of which 91% was thermal power. North Africa is the region with relatively high level of development in Africa. The per capita electricity consumption was 1,450 kWh/year, and the per capita installed capacity was 0.46 kW, which was nearly three times the average level in Africa.

In the future, three economic development axes will be built based on the network with roads, power grids, ports and airports to promote coordinated development of various regions. North Africa will deeply participate in global value chains to become the energy and logistics hub connecting Asia, Europe and Africa. It is estimated that in 2030, the total electricity consumption in North Africa will reach 663 TWh and the maximum load will be 120 GW. In 2050, the total electricity consumption will reach 1170 TWh and the maximum load will be 220 GW. The forecast of electricity demand in North Africa is shown in Fig. 4.15.

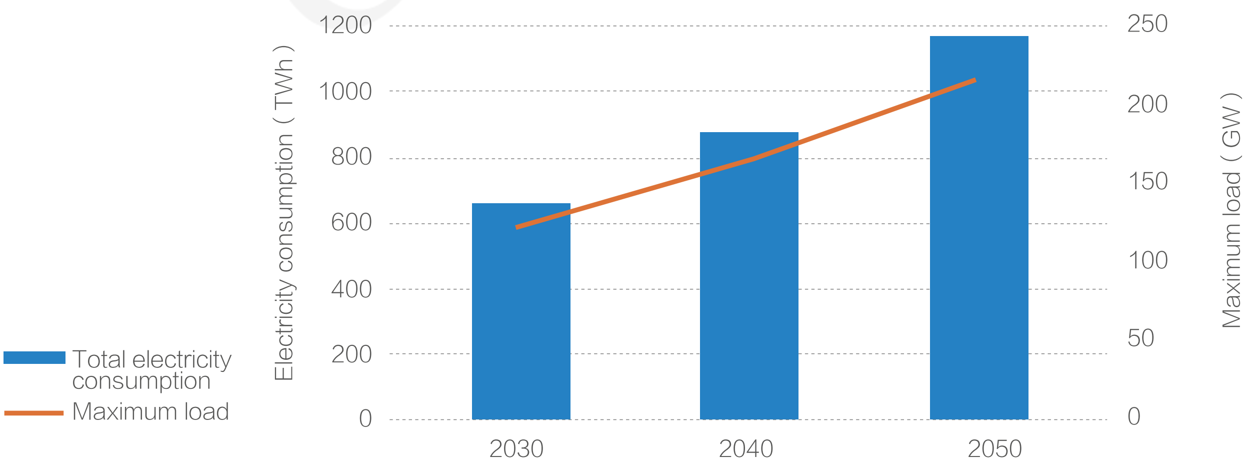


Fig. 4.15 Forecast of Power Demand in North Africa

Coordinating clean energy development conditions and European market demand, the development of power supply is: vigorously develop solar power in Sahara and the wind power in the coasts of Atlantic, Mediterranean and Red Sea, promote low-carbon and clean transition in power generation, moderately develop gas-fired power generation, and equip with a certain scale of energy storage to meet large-scale inter-continental power delivery and load peak adjustment needs. In 2030, the installed generation capacity of North Africa will be 180 GW, including 120 GW of thermal power and 48 GW of solar power. In 2050, the installed generation capacity is 359 GW, of which 210 GW of solar power and 120 GW of thermal power.

In 2030, 2040, and 2050, North Africa has surpluses of electricity of 8 GW, 20 GW, and 18 GW, respectively. The results of power balancing analysis in North Africa is shown in Table 4.9.

Table 4.9 Power Balancing Analysis in North Africa

Unit: GW

Year	Maximum Load	Installed Capacity	Available Installed Capacity	Power Shortage
2030	123.4	183	115.4	-8
2040	165.4	297	145.4	-20
2050	216	359	198	-18

The proportion of oil and gas generation in North Africa will rapidly decline. Power generation in North Africa will be a solar power dominated structure with high clean energy penetration. Due to the intermittent and volatility nature of clean energy generation such as solar and wind power, the system in North Africa needs to have high peak-shaving capability for local power supply. Meanwhile, only PV and wind power can not guarantee the utilization efficiency of the outbound transmission channels. This situation will be improved by receiving hydropower from the downstream of the Congo River to achieve mutual complementarity of hydro, wind and solar both in time and space. The joint transmission of these three types energy to Europe will be more conducive to the safe operation of the North African power system and efficient use of the transmission channels.

The key countries for electricity consumption in North Africa are Egypt, Algeria and Morocco. In 2050, electricity consumption in these three countries will account for 64%, 17% and 13% of total North Africa, respectively. These three countries all have a higher proportion of solar installed capacity and transmission capacity to Europe across the Mediterranean.

Egypt is a large developing country and representative of emerging economies in Arab and African countries. Its influence in international and regional affairs is kept rising. Egypt has leading development foundation for industry, sufficient human resources and superior geographical position, which lead to convenient conditions of international trade and low cost of production factors. The government formulates the "2030 Vision" strategy and is committed to building a new Egypt that is good at innovation and focuses on people's livelihood and sustainable development. Energy and electricity demand will continue to rapid grow in the long-term. In 2050, there will still appear a large power shortage even with increasing proportion of solar installed capacity.

Algeria has abundant solar resources and a strong willingness to transmit solar power to the Europe. Multiple transmission channels are projected across the Mediterranean Sea.

Morocco is rich in solar and wind energy. It is one of the countries with the largest installed capacity of PV, CSP and wind power in Africa. With the reception of hydropower from the downstream of the Congo River in 2050, it can form a united adjusting platform for multiple energy including hydro, wind and solar based on the 1,000 kV AC backbone corridor. With the geographic advantage of short distance to Europe, utilization efficiency of trans-Mediterranean power transmission channels in Morocco and Algeria will be both improved.

4.4 Overall Transmission Scheme

4.4.1 Power Transmission Pattern

According to the development orientation, power balance, and market space within the Central Africa and other sub-regions in Africa, coordinated considering the short term and long term development, the reasonable scale of intra-regional and inter-regional delivery can be determined. The installed capacity of upper stream of the Congo River and its tributaries will exceed 30 GW, mainly transmitting to the Congo River Basin countries such as D. R. Congo, R. Congo, Cameroon and Central African Republic. By 2060, the development of hydropower bases in the downstream of Congo River, with a total installation generation capacity of 110 GW will be accomplished. Among them, 22 GW will be used to meet local demands in D.R. Congo and R. Congo; and 3 GW will be transmitted to neighboring countries, such as Cameroon, with a total inter-regional transmission capacity of 85 GW.

From the perspective of inter-regional power divlivery, countries in West Africa, such as Nigeria, Guinea, and Ghana, will receive about 36 GW of power; and countries in southern Africa, such as Zambia, Angola, and South Africa, will receive about 13 GW of power; countries in East Africa, such as Ethiopia and Kenya, will receive about 16 GW of power; 20 GW will be sent to countries in North Africa, such as Egypt and Morocco, and then be jointly regulated and sent to Europe with local solar power.

Jointly considering the progress of hydropower development in the lower Congo River, and the power demand of each country, **by 2030,** the installed generation capacity of hydropower bases in the downstream of Congo River will be about 29.8 GW . Among them, 10.8 GW is for local consumption, 3 GW for intra-region consumption, and 16 GW for inter-region consumption, mainly the West Africa and the Southern Africa. 12 GW of Power will be sent to countries in West Africa: 8 GW to Guinea and 4 GW to Nigeria. 4 GW of Power will be sent to countries in Southern Africa: 3 GW to Zambia and 4 GW to Angola.

By 2040, the installed generation capacity of hydropower bases in the downstream of the Congo River will be about 54 GW. Among them, 18 GW is for local consumption, 3 GW for intra-region consumption, and 33 GW for inter-region consumption, mainly the West Africa and the Southern Africa. 28 GW of Power will be sent to countries in West Africa: 8 GW to Guinea and 8 GW to Nigeria. The capacity for Southern Africa will increase to 5 GW.

By 2050, the installed generation capacity of hydropower bases in the downstream of the Congo River will be about 95 GW. Among them, 24 GW is for local consumption, 4 GW for intra-regional consumption, and 67 GW for inter-regional consumption, the increment of which will be sent to North Africa and East Africa. The capacity for West Africa will increase to 36 GW，including 8 GW more to Guinea; 8 GW will be sent to Ethiopia in East Africa, and 10 GW to Morocco in North Africa.

By 2060, the scale of inter-regional power flow will amount to 85 GW, with 10 GW more for Egypt in North Africa, and 8 GW more for Kenya in East Africa.

Table 4.10 Development and Delivery Status of Hydropower of Congo River

Unit: GW

Year	Installed Generation Capacity	Local Demand	Intra-Region	Inter-Region	Orientation
2016	17.8	1.78	0	0	-
2030	29.8	10.8	3	16	West and Southern Africa
2040	54	18	3	33	West and Southern Africa
2050	95	24	4	67	West, Southern, North and East Africa
2060	110	22	3	85	West, Southern, North and East Africa

Fig. 4.16 Scale of Inter-Regional Power Delivery of Congo Hydropower (MW)

4.4.2 Transmission Mode and Scheme

Central Africa's power grid infrastructure is weak. Power grid coverage is low, and power grid interconnection is in very initial stage. The hydropower bases in the downstream of the Congo River is about 300~500 kilometers away from intra-regional load centers in Central Africa and adjacent countries. Intra-regionally, it is advisable to adopt AC transmission mode so as to give full play to the flexibility of AC transmission in integration, transmission and accommodation. In this way, the transmission need of the hydropower in lower Congo River will be met, and the cross-border power interconnection in Central Africa will be promoted as well.

The scale of inter-regional hydropower transmission in the downstream Congo River is large, which will reach 85 GW in the long term. The transmission distance is as long as 2000 ~ 4500 km, and the longest transmission distance to North Africa is more than 6000 km. There exist huge technical problems when AC transmission is adopted for cross-regional, long-distance and large-capacity power transmission, such as the security, stability and economy problem of the interconnection with long-chain AC lines. Therefore, DC transmission mode is more appropriate in this scenario.

In recent years, China has vigorously developed UHV AC and DC transmission technology. 22 projects, which are consist of 8 AC projects and 14 DC projects, have been completed, and 9 projects, which are consist of 6 AC projects and 3 DC projects, are under construction. The total length of the existing lines and those under construction is 43,000 km, with total transformer (converter) capacity of 430 GW and total inter-regional transmission capacity of 140 GW. Practical experience demonstrates that long-distance and large-capacity power transmission with UHV DC technology could effectively save construction costs and transmission corridor, which is not only more economical, but also save valuable transmission corridor resources for subsequent development.

UHV DC technology is used for the inter-regional hydropower transmission in the lower Congo river. Taking the transmission capacity and distance into consideration, the conFiguration schemes are: ±660 kV, 4 GW; ±800 kV, 8 GW; ±1100 kV, 10 GW.

Considering both range and scale of hydropower transmission, 765/400 kV AC and UHV DC are adopted to supply the intra-region load centers. Inter-regionally, 11 EHV/UHV DC transmission channels are used to transmit electricity to various regions in Africa.

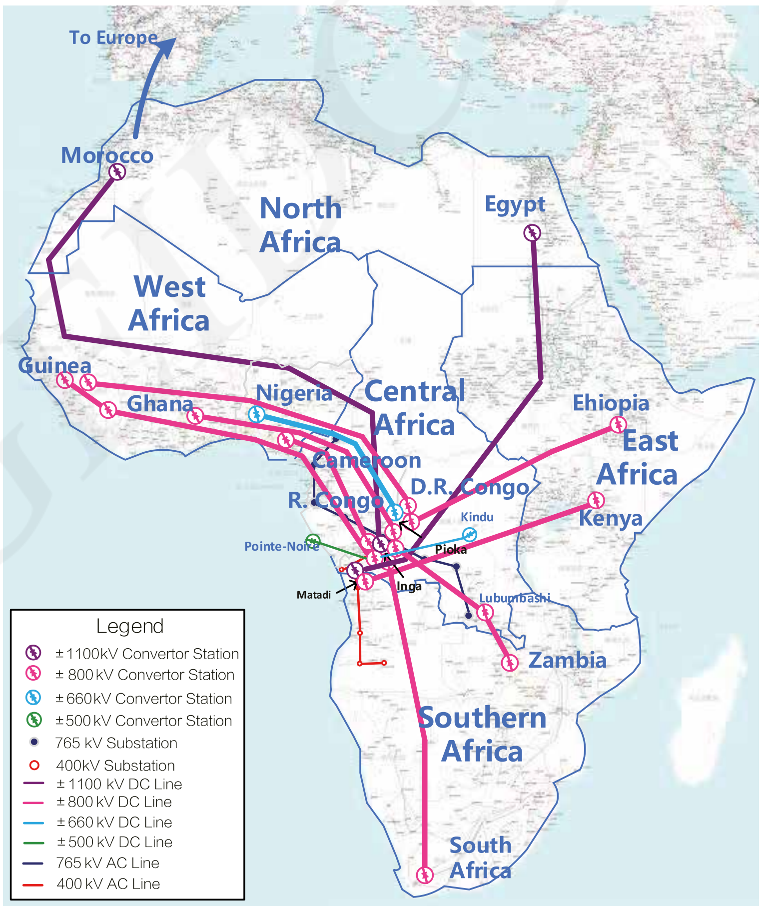


Fig. 4.17 Overall Transmission Pattern of the Hydropower in the Downstream of Congo River

4.5

Construction Sequence

4.5.1 Construction Sequence Analysis of Hydropower Stations

Hydropower bases in the downstream of Congo River: Inga Hydropower Station in the downstream of the Congo River is a large-scale hydropower station with good economy, which is suitable for priority development and phased implementation. Matadi Hydropower Station utilizes water head of 30 meters. The plant size is large, with a large number of units that are less constrained by water head. In terms of economic indicator, Pioka hydropower station is better. Considering such factors as the economy of the project and the distribution of hydropower of the boundary river, priority should be given to the development of Inga Hydropower Station, which will be implemented by stages and completed before 2050. At the same time, Pioka Hydropower Station will also be developed by stages, and completed by 2050. The development of Matadi Hydropower Station will be the last, which will be completed by 2060. The construction sequence of hydropower bases in the downstream of the Congo River is shown in Fig. 4.18.

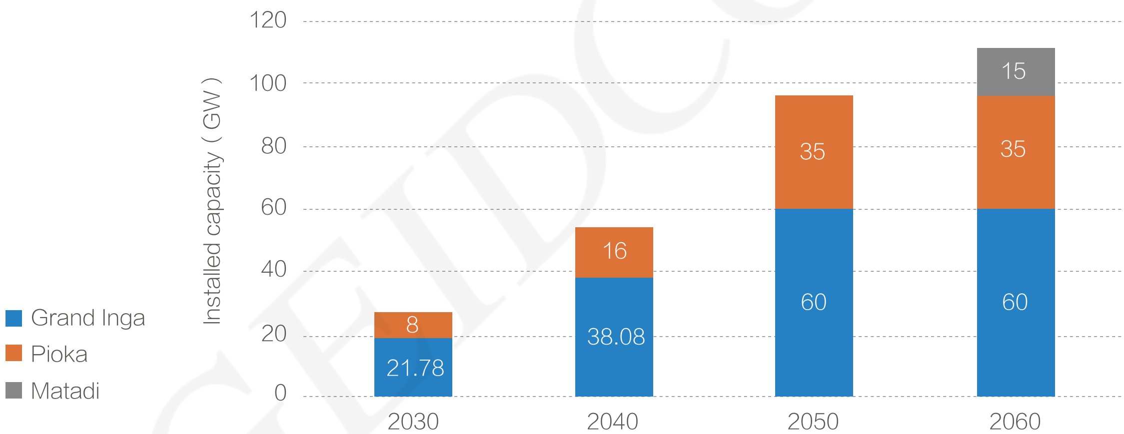


Fig. 4.18 Construction Sequence of the Hydropower Bases in the Downstream of Congo River

Hydropower in the upper and middle reaches of the Congo River and its tributaries: the upper reaches of the mainstream and the Lualaba River are close to the southern and eastern mining areas of the D.R. Congo, and the demand for power load is large in the near and medium term. It is advisable to jointly consider the sequence of development and transmission of the hydropower in the downstream, and consider hydropower projects with better development and construction conditions as priorities. For towns around the Kaisai River and the Sangha River, the demand is small in the near and medium term, but will gradually increase in the long term. Besides, as some of the river sections are boundary rivers, an orderly development in accordance with the demand growth will be appropriate. The population along the Ubangi River is sparse with rather small demand, and most of the main river sections are boundary rivers. Therefore, the hydropower development should be in harmony with the shipping demand as well.

4.5.2 Phased Power Transmission Schemes

The transmission of the hydropower of lower Congo River mainly relies on UHV DC technology. Hydropower is directly transmitted intra-regionally and inter-regionally, to large load centers in Africa, such as mineral smelting and processing load centers. The hydropower of the upper reaches of the mainstream and the Lualaba River are mainly transmitted to southern special economic zones, such as Katanga Province. It is firstly converged with 400 kV transmission channels and then integrate into the 765 kV main grid in the south of the D.R. Congo. The hydropower of the Kasai River and its tributaries mainly meets the power demands of the central special economic zones such as the Western Kasai Province and the Eastern Kasai Province. It is advisable to use 220 kV transmission channels to directly transmit power to large cities and towns such as Kananga and Kiwete. The Hydropower of the Sangha River and its tributaries mainly meets the demands of the Ouesso Special Economic Zone in the north of R. Congo and southern Cameroon. The 400 kV AC transmission channel between R. Congo and Cameroon can be built via the development of Chollet hydropower station, and hydropower of small-sized and middle-sized station can be converged in 110 kV AC transmission channels. The Oubangui River hydropower mainly meets the demands of the northern D.R. Congo and the Central African Republic. After converging in 110 kV transmission channel, they can be transmitted to large cities and towns such as Bangui.

In the following, emphasis will be placed on the construction sequence analysis of the three-stage hydropower bases in the downstream of Congo River.

Power Transmission Schemes by 2030

Intra-regionally, focus will be put on D.R. Congo Inga-R. Congo Pointe Noire DC project, and east-west transmission corridor of Inga, i.e. the Inga-Matadi-Soyo-Pointe Noire, and the Pioka-Pointe Noire AC projects. Inter-regionally, the focus will be put on the construction of three DC projects, i.e. the Inga-Lubumbashi-Zambia, the Inga-Guinea I, and Pioka-Nigeria, with a total transmission capacity of 15GW.

D.R. Congo Inga-R. Congo Pointe Noire ±500 kV DC transmission project will transmit the hydropower of Inga to industrial parks in Pointe Noire with a path length of 400 km, and a transmission capacity of 3 GW.

The east-west transmission corridor of Inga in D. R. Congo will send the hydropower of Inga III to the capital of D.R. Congo, Kinshasa, the southern mining area as well as load centers along the way. It will support the safe operation of the DC project from Inga to the southern mining area, realizing the synchronization of the two major regional power grids in D.R. Congo, and play an important part of the transmission corridor in southern Central Africa. The length of the 765 kV AC line is about 2,200 kilometers, with a transmission capacity of about 4 GW.

The Inga-Matadi-Soyo-Pointe Noire AC transmission project will send Inga III hydropower to the Matadi, Banana Port in D.R. Congo, and the load center in northern Angola, to meet the demands of the Atlantic coastal industrial parks, and improve the reliability of power supply in mining and processing parks in Pointe Noire. The length of the 400 kV AC line is about 450 km, with a transmission capacity of about 2 GW.

The Pioka-Pointe Noire AC transmission project will send Pioka hydropower to the special economic zone in Pointe Noire, to meet the industrial demands such as electrolytic aluminum, steel and port processing. The length of the double-circuit 765 kV AC line is about 350 km, with a transmission capacity of about 4 GW. The power transmission scheme of Inga III and Pioka is shown in Fig 4.19.

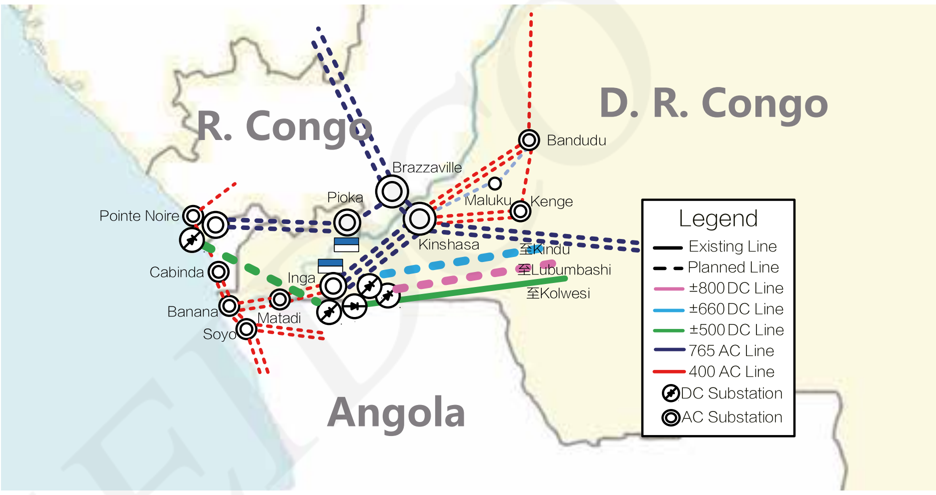


Fig. 4.19 Inga III, Pioka Intra-Regional Transmission Scheme

The Inga-Lubumbashi-Zambia DC transmission project will bring the Inga hydropower to the Lubumbashi copper, cobalt industrial parks in D. R. Congo, and Zambia copper industrial parks. The length of the 3 terminal ±800 kV DC line is about 4,500 km, and the transmission capacity is about 8 GW, with 5 GW to Lubumbashi and 3 GW to Lusaka. The annual transmission capacity will be about 48 TWh.

The Inga-Guinea I DC transmission project will bring the Inga hydropower to the eastern iron mine area and western bauxite mine area in Guinea. The length of the 3 terminal ±800 kV DC line is about 4,500 km, with a transmission capacity of about 8GW, and an annual transmission capacity of about 48 TWh.

Pioka-Nigeria DC transmission project will send Pioka hydropower to the Nigerian economic center Lagos to meet the industrial demands of steel, construction machinery, and automotive. The length of the ±660 kV EHV DC line is about 2,000 km, with a transmission capacity of about 4 GW, and an annual transmission capacity of about 24 TWh. The hydropower transmission projects in the downstream of Congo River by 2030 are shown in Fig 4.20.

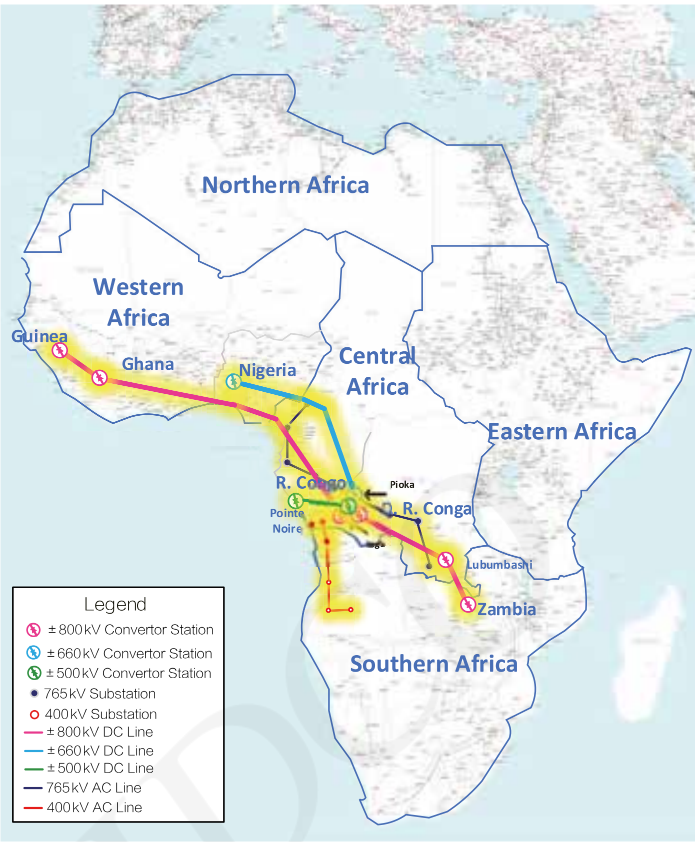


Fig. 4.20 The Hydropower Transmission Projects in the Downstream of Congo River by 2030

Power Transmission Schemes by 2040

Intra-regionally, focus will be put on Inga-Kindu DC project. Inter-regionally, focus will be put on the construction of two DC projects, i.e. the Inga-Nigeria, and Pioka-Nigeria. The total number of DC transmission projects will be five, with a total transmission capacity of 31 GW.

The Inga-Kindu DC transmission project will send the Inga hydropower to Kindu to meet the demands of the special economic zones in the northeast Kindu and Kisangani through the 660 kV main grid. The length of the ±660 kV EHV DC line is about 1500 km, with a transmission capacity of about 4 GW, and an annual transmission capacity of about 24 TWh.

The Inga-Nigeria DC transmission project will send Inga hydropower to Benin in eastern Nigeria, supplies power to Locoja iron and steel industrial park, Aba textile industrial park and Enugu construction machinery industrial park through the 765/330 kV main grid. The length of the ±800 kV UHV DC line is about 2000 km, with a transmission capacity of about 8 GW, and an annual transmission capacity of about 48 TWh.

The Pioka-Ghana DC project will send Pioka hydropower to Kumasi in Ghana, and supplies power to electrolytic aluminum industrial parks in Awaso and Nyinahin, and iron and steel industrial parks in Cote d'Ivoire through 765 kV east-west transmission channel in West Africa. The length of the ±800 kV UHV DC line is about 2,800 km, with a transmission capacity of about 8 GW, and an annual transmission capacity of about 48 TWh. The hydropower transmission projects in the downstream of Congo River by 2040 are shown in Fig 4.21.

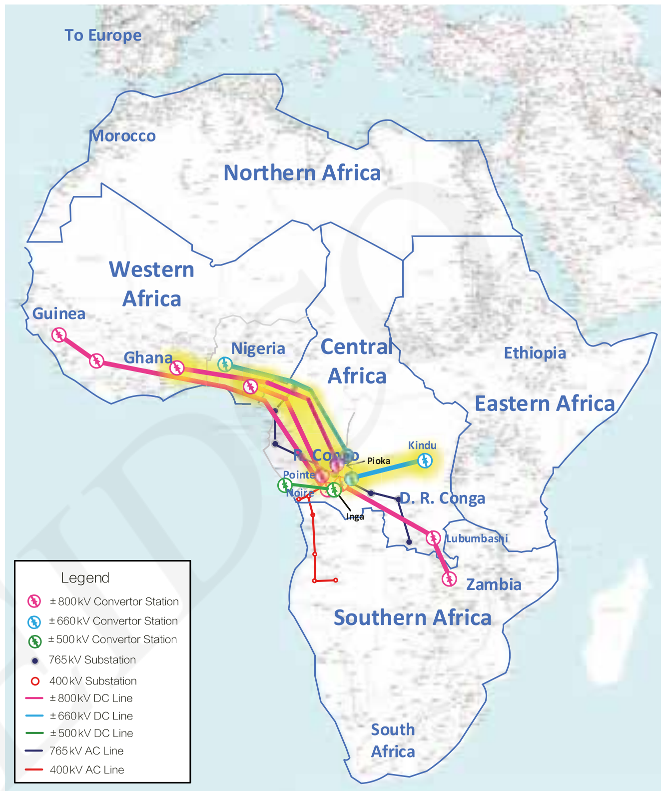


Fig. 4.21 The Hydropower Transmission Projects in the Downstream of Congo River by 2040

Power Transmission Schemes by 2050

Focus will be put on four DC projects, Inga-South Africa, Inga-Morocco, Pioka-Guinea, Pioka-Ethiopia. The total number of inter-regional DC transmission projects will be nine, with a total transmission capacity of 65GW.

The Inga-South African DC project will send the Inga hydropower to Cape Town in South Africa, to supply power to the petrochemical and mechanical manufacturing industrial parks and meet the demands after the gradual decommissioning of the coal-fired generating units. The length of the ±800 kV UHV DC line is about 3800 km, with a transmission capacity of about 8GW, and an annual transmission capacity of about 48 TWh.

The Inga-Morocco DC transmission project will send the Inga hydropower to Zag in Morocco. The length of the ±1100 kV UHV DC line is about 6500 km, with a transmission capacity of about 10GW. Among them, 2GW is for local demands in Morocco, and the rest 8 GW will mix with the power of solar power base in North Africa through Morocco-Spain, and Algeria-France-Germany DC channels.

The Pioka-Guinea DC transmission project will send Pioka hydropower to Boke in Guinea, to supply power for electrolytic aluminum industrial parks in Boke, to meet Guinea's production needs of 40 million tons of alumina and 6 million tons of electrolytic aluminum. The length of the ±800 kV UHV DC line is about 4,500 km, with a transmission capacity of about 8 GW, and an annual transmission capacity of about 48 TWh.

The Pioka-Ethiopia DC transmission project will send Pioka hydropower to Addis Ababa in Ethiopia through the 765 kV vertical transmission channel in East Africa. The benefits of hydropower in the downstream of the Congo River are brought into full play to meet the long-term demands of manufacturing industry in East Africa and improve the utilization efficiency of the built transmission channels in East Africa. The length of the ±800 kV UHV DC line is about 4000 km, with a transmission capacity of about 8GW, and an annual transmission capacity of about 48 TWh. The hydropower transmission projects in the downstream of Congo River by 2050 are shown in Fig 4.22.

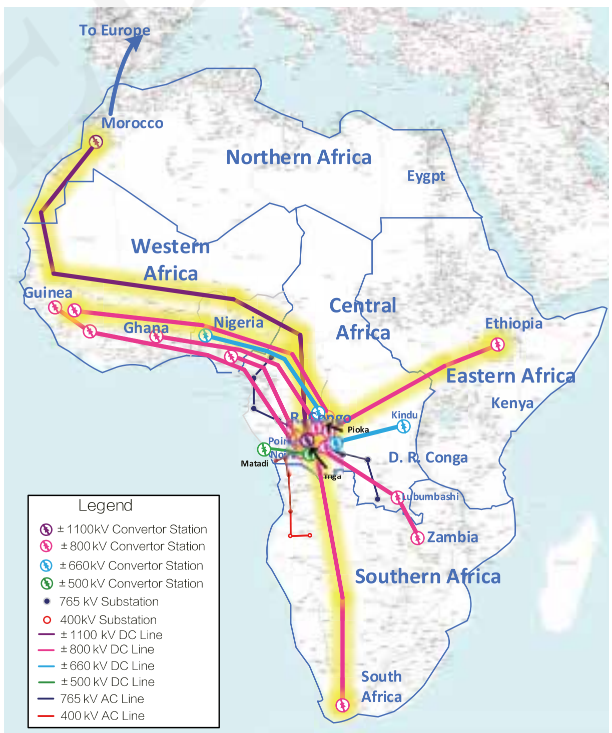


Fig. 4.22 The Hydropower Transmission Projects in the Downstream of Congo River by 2050

Power Transmission Schemes by 2060

Focus will be put on two DC projects, Matadi-Egypt and Matadi-Kenya. The total number of inter-regional DC transmission projects will be eleven, with a total transmission capacity of 83GW.

The Matadi-Egypt DC transmission project will send Matadi hydropower to Minya in Egypt, to complement with the power of solar power bases in Minya and Aswan across time and space, so as to meet the demands of Egypt's long-term development. The length of the ±1,100 kV UHV DC line is about 5,500 km, with a transmission capacity of about 10 GW, and an annual transmission capacity of about 60 TWh.

The Matadi-Kenya DC transmission project will send Matadi hydropower to Nairobi in Kenya through the 765/400 kV grid in East Africa, providing power security for the long-term development of Kenya and Tanzania. The length of the ±800 kV UHV DC line is about 3,100 km, with a transmission capacity of about 8 GW, and an annual transmission capacity of about 48 TWh. The hydropower transmission projects in the downstream of Congo River by 2060 are shown in Fig 4.23.

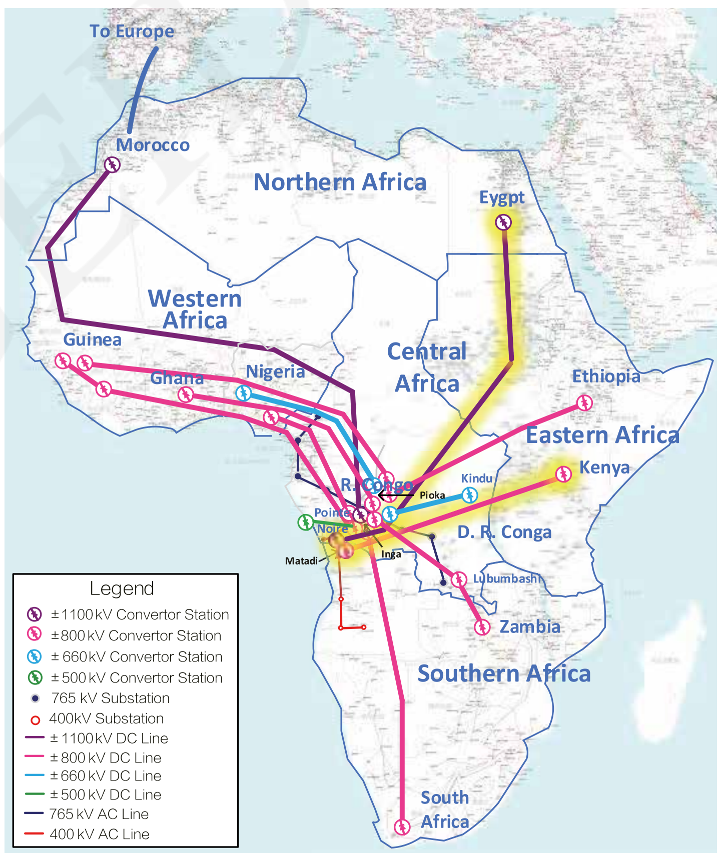
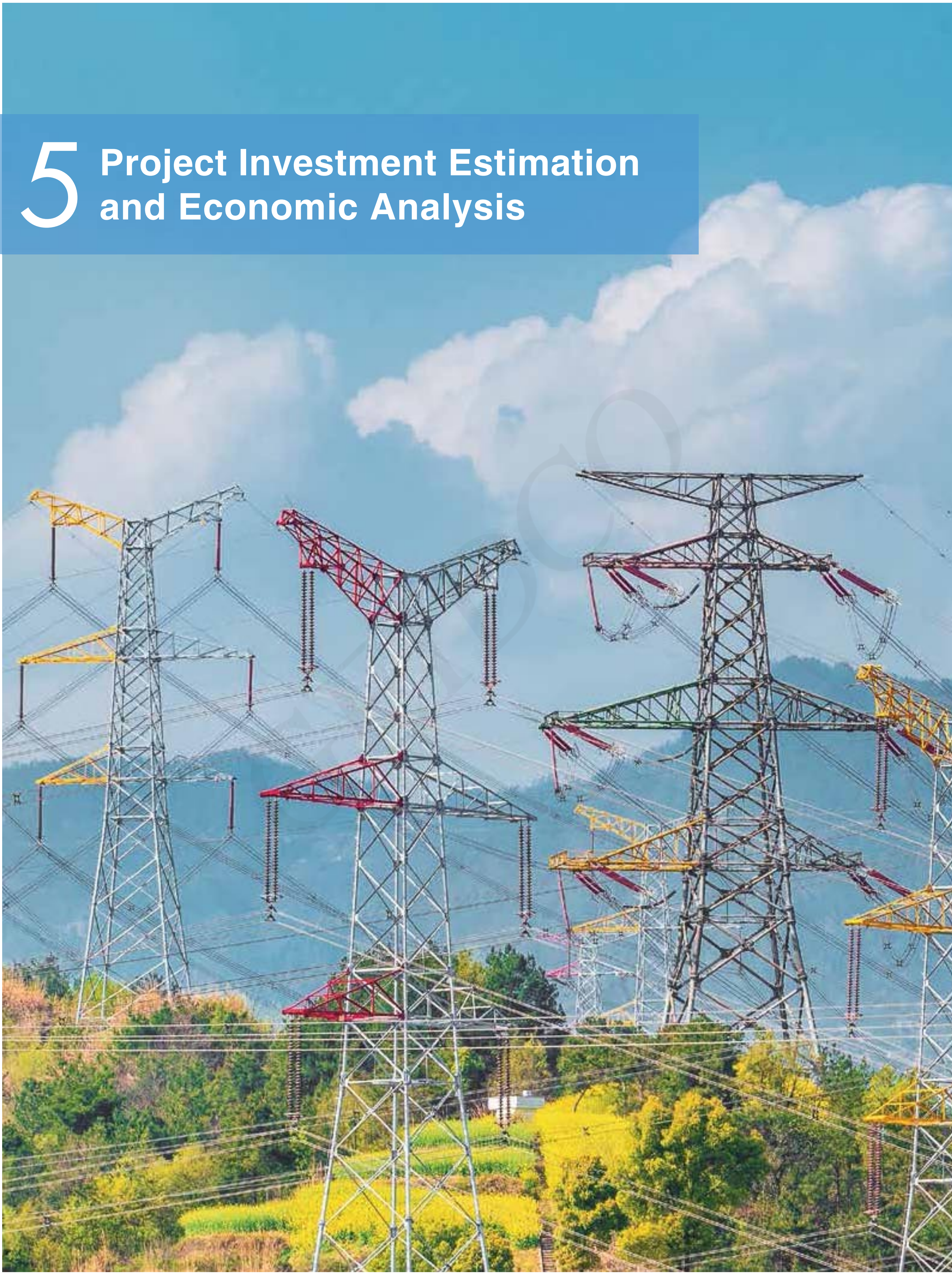


Fig. 4.23 The Hydropower Transmission Projects in the Downstream of Congo River by 2060

5 Project Investment Estimation and Economic Analysis



5.1

Investment Estimation

Investment in hydropower generation and corresponding transmission projects in the lower reaches of Congo River includes investment in power station and the corresponding transmission lines. A preliminary analysis of the investment scale and economic benefits were carried out regarding the installation of 35 GW of the Pioka hydropower station, 60 GW of the Grand Inga hydropower station and 15 GW of the Matadi hydropower station.

Hydropower station investment

Investment estimation will consider factors including geological situation, project scope, system layout, etc. The estimation will take local projects and projects in China as reference. Since project scope, geological situation and layout have great impact on the investment, the investment estimation in this report only provide the rough cost range.

Transmission investment

Regarding investment estimation of UHV projects, the cost of similar projects in China and Brazil are taken as reference. EHV and HV projects investment estimation makes appropriate adjustments to similar project cost in Africa and neighboring countries.

Table 5.1 Cost Parameters for UHVDC and HVDC Transmission Projects

Unit：USD/kW、thousand USD/km

Voltage Level	Converter Station	Transmission Line
±660 kV DC	119	520
±800 kV DC	126	900
±1100 kV DC	108	1110

The cost estimation shows the downstream hydropower development of Congo River with the related transmission projects will cost around 219~246 billion USD. The hydropower generation will cost 140~167 billion USD, accounting for 65% of the total cost. The transmission project will cost 79 billion USD, accounting for 35% of the total cost.

Table 5.2 Investment Estimation of Cascaded Hydropower Projects of the Lower Congo River

Project	Capacity (GW)	Generation Investment (Billion USD)	Transmission Investment (Billion USD)	Total Investment (Billion USD)
Pioka	35	55~70	23.5	78.5~93.5
Grand Inga	60	58~64	38.5	96.5~102.5
Matadi	15	27~33	17.0	44.0~50.0
Total	110	140~167	79.0	219.0~246.0

5.2 Pricing Evaluation

5.2.1 Feed-in Tariff

In order to fix a suitable feed-in tariff for the hydropower generation, the generation cost, maintenance and operation cost, local federal tax policy, as well as suitable amount of capital investment, rate of profit return, loan interest, etc., shall be taken into consideration. The key parameters involved can be seen in table 5.3.

Table 5.3 Key Parameters for Calculation of the Feed-in Tariff for the Cascaded Hydropower Projects in Lower Congo River

Parameters		Unit	Value	Note
Generation	Water Abandonment Rate	%	2	Considering the Market Space
	Percentage of Self-Using Electricity	%	2	
Cost of Operation	Depreciation Period	Year	30	
	Repair Cost	%	0.5	Accounting for Total Investment
	Insurance	%	0.25	Accounting for Total Investment
	Others	USD/kW	5	
Financing	Capital Ratio	%	20	
	Long-Term Loan Interest Rate	%	6	Key Influencing Factor，Low Interest Loan Should Be Sought for
Tax	Vat Rate	%	5	Key Influencing Factor，Preferential Tax Policy Should Be Provided for Key Projects
	Income Tax Rate	%	10	
Profit	IRR	%	12	Average Level of International Hydropower Projects

Feed-in Tariff Evaluation Results:

Pioka Hydropower Station

Installed Capacity of 35 GW，Static Investment of 55~70 Billion USD，Feed-in Tariff of 4.2~5.2 US cents/kWh.

Grand Inga Hydropower Station

Installed Capacity of 60 GW, Static Investment of 58~64 Billion USD，Feed-in Tariff of 3~3.5 US cents/kWh.

Matadi Hydropower Station

Installed Capacity of 15 GW，Static Investment of 27~33 Billion USD，Feed-in Tariff of 4.8~5.7 US cents/kWh.

Table 5.4 Main Economic Indicators of the Cascaded Hydropower Stations in Lower Congo River

Stations	Installed Capacity (GW)	Static Investment (Billion USD)	Per kW Cost (USD/kW)	Per kWh Cost (USD/kWh)	Feed-in Tariff (US Cents/kWh)
Pioka	35	55~70	1530~1940	0.246~0.314	4.2~5.2
Grand Inga	60	58~64	970~1070	0.150~0.166	3~3.5
Matadi	15	27~33	1800~2200	0.295~0.360	4.8~5.7

5.2.2 Transmission Price

The price of the transmission projects is evaluated with the parameters shown in Table 5.5.

Table 5.5 Parameters of Transmission Price Estimation for Hydropower Transmission in Lower Congo River

Parameters	Value
Project Annual Utilization Hours	6200 hrs
Operation Period	30 yrs
Capital Investment Ratio	20%
Loan Ratio	6.0%
IRR	15%

Transmission Price Evaluation Results：

The transmission price of delivering the downstream hydropower bases of Congo River to West Africa is about 1.3~2.5 US cents/kWh，and the price of delivering the hydropower to South Africa is about 1.5~2.0 US cents/kWh，and the price of delivering to East Africa is about 1.7~2.1 US cents/kWh，and to North Africa is about 2.3~2.6 US cents/kWh.

Table 5.6 Estimation of Transmission Price of Hydropower Transmission Projects in the Lower Reaches of the Congo River

Unit：kV、km、billion USD、US cents/kWh

Project	Voltage Level	Transmission Length	Investment	Year To Complete	Price
Grand Inga-Kerouane-Linsan（Guinea）	±800	4500	8.7	2030	2.5
Grand Inga-Lubumbashi-Lusaka（Zambia）	±800	2200	5.7	2030	1.5
Grand Inga-Benin City（Nigeria）	±800	2000	4.9	2040	1.3
Grand Inga-Cape Town（Rsa）	±800	3800	7.0	2050	2.0
Grand Inga-Zag（Morocco）	±1100	6500	12.2	2050	2.6
Pioka-Lagos（Nigeria）	±660	2000	2.6	2030	1.4
Pioka-Kumasi（Ghana）	±800	2800	5.9	2040	1.6
Pioka-Addis Ababa（Ethiopia）	±800	4000	7.2	2050	2.1
Pioka-Boke（Guinea）	±800	4500	7.8	2050	2.3
Matadi-Minya（Egypt）	±1100	5500	10.8	2060	2.3
Matadi-Nairobi（Kenya）	±800	3100	6.2	2060	1.7

5.3 Competitiveness Analysis

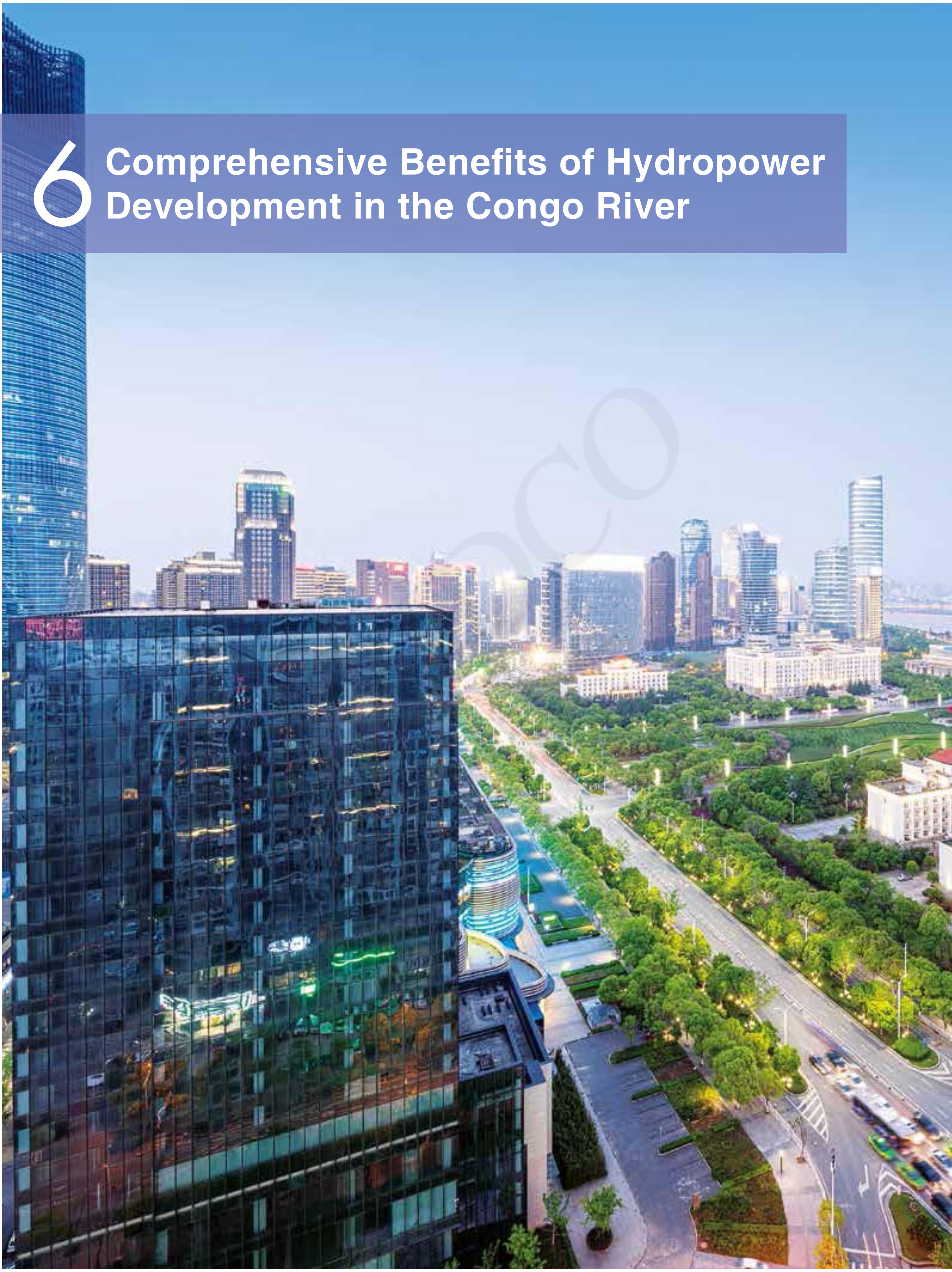
According to the feed-in tariff and transmission price evaluation, the price at the receiving end is calculated and compared with the local market average price to evaluate the competitiveness of the hydropower transmission.

Large-scale development of the downstream hydropower of Congo River, could fully take use of the resource advantages of the Congo River and reduce the life cycle investment, construction and operation cost. Low feed-in tariff and high utilization hours of transmission will make the project competitive. The price at the receiving end will be 2~5 US cents/kWh lower compared to local market price.

The price at the receiving end in West Africa is about 4.1~7.7 US cents/kWh，and the price gap is 2~6 US cents/kWh. Taking Grand Inga-Kerouane-Linsan UHVDC project as an example, the feed-in tariff of Grand Inga hydropower station is about 3.3 US cents/kWh，transmission price is about 2.5 US cents/kWh，and the price at receiving end is about 5.8 US cents/kWh. Considering the local generation feed-in tariff is about 10 US cents/kWh in average，the price gap is over 4 US cents/kWh.

The price at the receiving end in South Africa is about 4.3~5.3 US cents/kWh，and the price gap is about 2~5 US cents/kWh；The price at the receiving end in East Africa is about 5.9~7.4 US cents/kWh，and the price gap is about 2~5 US cents/kWh；The price at the receiving end in North Africa is about 5.4~8 US cents/kWh，and the price gap is about 2~5 US cents/kWh.

6 Comprehensive Benefits of Hydropower Development in the Congo River



6.1

Economic Benefits

Achieving clean, sustainable and reliable energy and power supply. The Congo River is rich in hydropower resources, with a theoretical reserve of 2500 TWh/year. Especially the development conditions of the downstream hydropower base are superior. After the completion of the project, the annual power generation capacity will reach 690 TWh, which is the total electricity consumption of Africa in 2016. By 2050, the hydropower base of the lower reaches of Congo River will generate about 600 TWh of electricity per year, accounting for 14% of Africa's total electricity generation and 21% of Africa's total clean energy generation. Accelerating the large-scale and high-efficiency development of hydropower in the lower reaches of the Congo River, will play the role of hydropower "regulator" to support the safe operation of high proportion wind power and solar power generation, and will also achieve the energy clean energy complementary, which will meet Africa's energy and electricity demand of economic and social development in a clean and green way, to help Africa to get rid of dependence on fossil fuels and achieve a clean and sustainable supply of energy.

Stimulating economic growth. Hydropower development in the Congo River Basin and the delivery of downstream hydropower bases will effectively stimulate the development of industries such as electricity, mining, smelting, processing, and international trade, and create a new engine for economic growth in Africa. The total investment in the development and delivery of hydropower bases in the lower reaches of the Congo River will be approximately USD 219-246 billion, which will effectively boost regional economic growth. Under the guarantee of sufficient electric energy, the output of electrolytic aluminum in Africa can reach 25 million tons, the output of steel can reach 400 million tons, and the total output value of the mineral processing industry will exceed 480 billion US dollars, which will help Africa to achieve industrialization.

Reducing development costs. The advantages of large-scale and intensive development of hydropower in the Congo River Basin are obvious, which can effectively reduce the average power supply cost in Africa. The on-grid electricity price of hydropower in the lower reaches of the Congo River is 3~5.7 cents/kWh, of which the British-Indian hydropower is only 3~3.5 cents/kWh, and the cross-regional delivery price is 2~5 cents/kW lower than the target market power price. Thus, the annual electricity cost can be reduced by more than USD 20 billion, and the benefits are very significant.

Increasing foreign exchange earnings. The scale of power import and export trade will be significantly expanded, while the hydropower in the lower reaches of the Congo River is exported through transnational, inter-regional and inter-continental transmission channels. By 2050, Africa's electricity import and export trade will earn more than USD 170 billion. Relying on the co-development model of "electricity, mining, metallurgy, manufacturing and trade", the cheap and reliable hydropower in the lower reaches of the Congo River will help African countries gradually reduce the export of raw ore and greatly increase the export of manufactured products such as electrolytic aluminum, aluminum profiles and stainless steel. By 2050, total exports of manufactured minerals in African will exceed USD100 billion.

6.2 Social Benefits

Making electricity available to all persons. At present, Africa's electricity access rate is only 52%, there are still 600 million people without electricity, and D.R. Congo has the third largest number of people without electricity in the world. With the large-scale development of hydropower in the Congo River Basin and the sharp drop in average electricity prices, by 2050, electricity will be available to nearly all persons, and the power penetration rate will increase to over 95%. In the future, everyone in Africa can use and afford green, clean, low-cost, reliable power, can enjoy the achievements of modern power civilization, thereby the problem of energy poverty canbe fundamentally solved.

Improving health. Sulfur dioxide, nitrogen oxides and fine particulate matter are the main air pollutants. The vast majority of these pollutants come from energy production and use, mainly from fossil fuels and biomass burning. The large-scale development and delivery of hydropower in the lower reaches of the Congo River will effectively reduce the pollution problems caused by fossil energy production and use, and significantly reduce the number of diseases and deaths caused by energy pollution.

Promoting employment. The large-scale development and delivery of hydropower in the Congo River Basin involves many fields such as hydropower development, power grid construction, electrical equipment, electric energy replacement, intelligent technology, new materials, information and communication, etc. At the same time, it supports the development of large-scale industries such as mining, smelting and processing, and can effectively promote employment. By 2050, more than 15 million new jobs will be created.

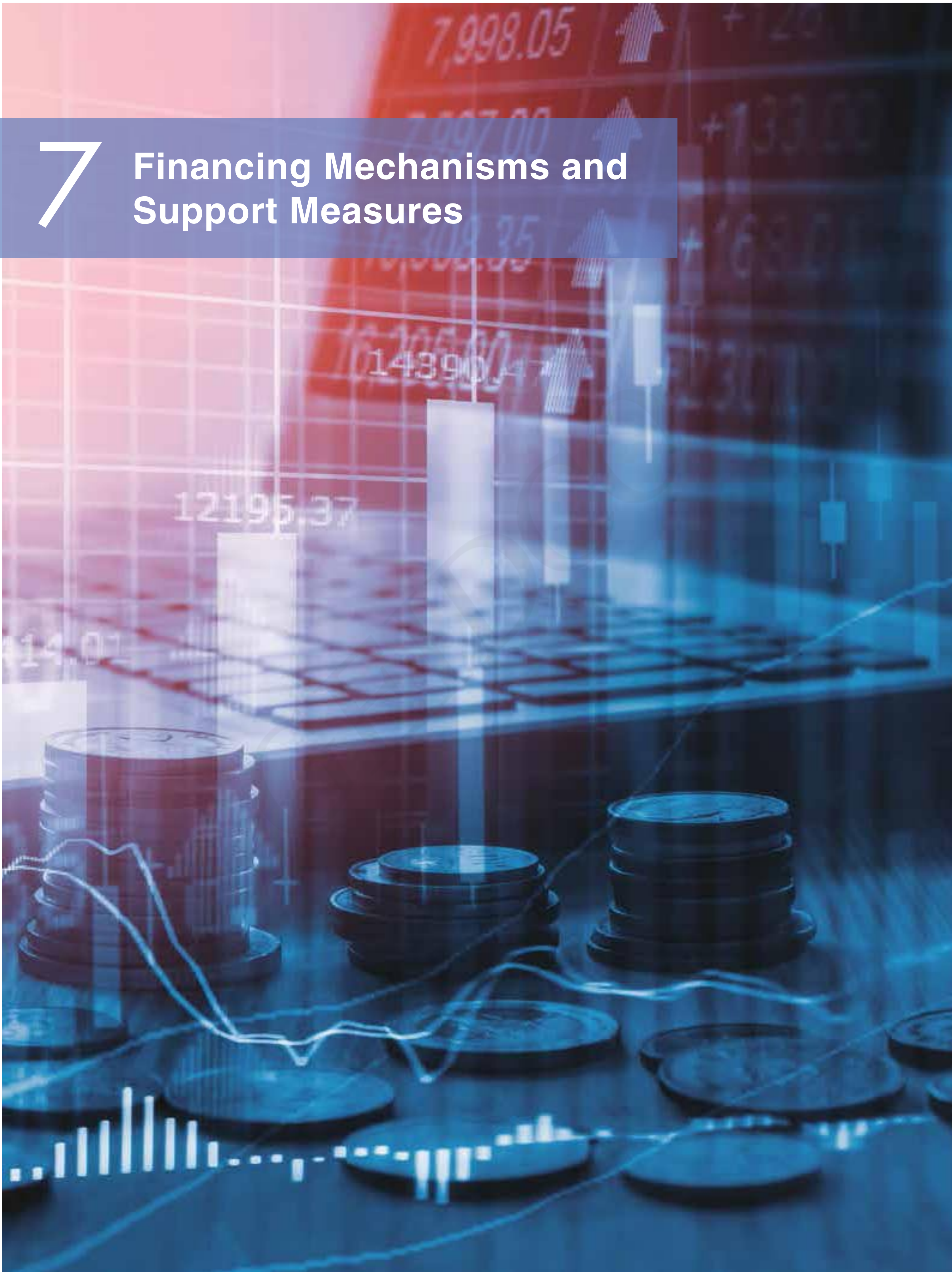
Getting rid of poverty. The economic development of the Congo River Basin countries is relatively lagging behind. The construction of hydropower projects in the Congo River Basin can not only transform the advantages of hydropower resources into economic advantages and effectively promote economic development, but also play a role in flood control and disaster mitigation; the development of irrigation, tourism, fisheries and so on can realize the increase of residents' economic income and the improvement of ecological environment, and fundamentally solve the problems of economic development imbalance and poverty.

6.3 Environmental Benefits

Reducing environmental pollution. With the sharp decline in the scale of fossil energy development and utilization, air and groundwater pollution, geological damage, land and marine ecological damage caused by mining, processing, transportation, storage, combustion, etc. will be increasingly reduced. Sulfur dioxide, nitrogen oxides and fine particles emissions can be reduced by 1.8 million. 2 million and 400,000 tons respectively, and the ecological environment will be protected and restored.

Reducing greenhouse gas (GHG) emissions. Hydropower development in the Congo River Basin will significantly reduce greenhouse gas emissions from fossil fuels. By 2050, the hydropower base downstream of the Congo River will generate 600 TWh/year, equivalent to 550 million tons of carbon dioxide emissions per year.

7 Financing Mechanisms and Support Measures



Hydropower Development and delivery projects in Congo River Basin are characterized by large-scale investment, more participating countries, long-term construction and significant socio-economic benefits. Because of the shortage of credit and guarantee, it has long been difficult to finance and start infrastructure construction in Africa. Under the new model of "electricity, mining, metallurgy, manufacturing and trade", guided by unified planning, supported by the cooperation of relevant countries, and coordinated resources by multilateral institutions, a multi-level investment and financing structure will be established and the joint participation of multi-subjects such as energy and financial enterprises in the implementation of the project will be promoted.

7.1 Financing Mechanisms

The development of "electricity, mining, metallurgy, manufacturing and trade" is beneficial to form the industrial project clusters, covering power generation and transmission, mining and metallurgy, industrial parks, trade, which is featured by internationalization and commercialization.

Power generation projects can use the public-private partnership model to integrate the design, construction, financing, and operation, which can obtain power sales revenue.

Power transmission projects can also use the public-private partnership model, such as BOT, BOOT, BOO, etc., which can get the transmission tariff.

Mining and metallurgy projects are operated through the franchising license from the government to carry out mining, roughing and other activities, and mainly receive the local sales and export revenue.

For the industrial park, it can take advantage of the labor and land in Africa to ore dressing and deep processing, and gradually improve the local industrial system. Processing primary mineral products into industrial products, to obtain additional value income.

For the trade, it will gradually upgrade the current situation of Africa from raw material export to industrial products export, greatly enhance the profitability of Africa's industrial enterprises and the ability to earn foreign exchange through exports, and promote industrial upgrading and reinvestment. The participants include the governments, power generation and transmission enterprises, engineering construction companies, mining and metallurgical enterprises, industrial enterprises, investment institutions, trading companies, etc.

On the basis of the “electricity, mining, metallurgy, manufacturing and trade” model, the hydropower development and delivery projects in the Congo River Basin are characterized by internationalization and commercialization, which can mostly rely on the market-oriented financing. Given full play to the initiative of governments and enterprises, it would scale up both the public and private investment. The project risks would be allocated reasonably among participants through the effective risk management; By promoting diversified sources of participation, optimizing financing structures, and the rational using of capital market tools, the financing mechanisms can be well improved and it will make big sense for the projects financing.

7.1.1 Diversified Sources of Participation

The hydropower development and delivery projects in the Congo River basin have huge socio-economic benefits. Projects development requires the joint participation of government departments, public institutions, and industrial organizations, as well as multilateral development financial institutions and commercial investment entities, making use of their advantages to maximize the effectiveness in each phase of the project.

During the project planning phase, the project developers and the investors jointly design the project financing structures.By discussing with government departments and the development financial institutions to apply supports, such as government policy support; Through the signing of completion agreements, power purchase agreements and other commercial contracts with the contractor and electricity users, to ensure the quality of the project and the purchase and sale of electricity.

During the project development phase, the project developers, development financial institutions and commercial investment institutions jointly participate in the project financing evaluation and risk assessment, confirm a reasonable financing structure, and fix the financing close. The comprehensive using of policy/development financial institutions supports the investment of commercial institutions and improves the level of project income.

During the project construction and operation phase, project developers and operators participate in project construction management and review, analyze and evaluate the operation plan, system scale and workflow by establishing long-term and stable relationships with government agencies. The project investment institutions should be deeply involved in the implementation, and carry out the funds recovery, refinancing and cost structure adjustment based on the current project process and in accordance with the contracts.

7.1.2 Optimization of Financing Structures

The hydropower development and delivery projects in Congo River basin need to set up comprehensive financing structures, which mainly includes equity, subordinated debt, senior debt. The risk level is reduced in turn. Due to the differences in financing cost, risk preference and tenors among different financing sources, the financing structure optimization needs to fully consider the characteristics of financing source, project cycle, expected return, credit guarantee mechanism, etc. Besides, it makes big sense to pay much attention to the combination of public financing and market-oriented financing.

The project developer invests a certain percentage of capital and participates as a shareholder with the public utilities and other investors. Policy/development financial institutions participate in investments, share income and share risks through the provision of concessional loans, convertible bonds, etc. The Syndication, which is composed of commercial banks and other market-oriented financial institutions, participates in the investment by means of commercial loans.

7.1.3 Application of Capital Market Tools

Specific capital market tools such as bonds and Asset Backed Securities are now widely used in mature capital markets. Hydropower Development and distribution projects in the Congo River Basin could explore the application of such tools to unlock large-scale finances.

Regarding to the long-term investment, the project bonds could be considered in the project financing, which rely on the project's own profitability for credit support. And the priority is given to issuing green bonds, which has low costs. During the maturity stage of the project, considering the refinancing and capital flow, asset securitization tools can be used to flexibly circulate in the capital market based on the future stable cash flow of the project. It can also provide exit channels for early stage investors, and greatly enhance project financing capabilities.

7.2 Support Measures

The development of the power industry, investment and financing policies, and the cooperation mechanisms are main concerns to the participants of the hydropower development and delivery projects in the downstream of Congo River. Governments, multilateral agencies and project entities should establish and improve relevant support measures to promote the projects.

7.2.1 Government

Optimizing domestic industrial planning and policies

The first is to combine the domestic industrial development plan with the overall plan for hydropower development in the downstream of Congo River, such as the merge the hydropower development and delivery plan of the downstream of Congo River into the strategic development plan of the government of Democratic Republic of Congo. The second is to further open up the electricity market, reduce the threshold for investment, promote electricity price reform, optimize electricity price structure, and design specific reform principles and methods. It is also needed to encourage private sector investment to develop and support long-term power purchase policies, and introduce active land, immigration and construction protection policies. By improving power development policies such as the on-grid tariff subsidy mechanism, the efficient cooperation between all parties is promoted.

Improving financial investment policies

It is an important way to optimize government credit enhancement or guarantee mechanisms and innovate government financing methods. Improving the tax structure, introducing tax incentives, and achieving structural tax cuts in the power industry are also needed. It is better to build an efficient and stable foreign exchange system by reducing foreign exchange controls, and improve the cooperation mechanism for project development such as public-private partnerships to provide institutional guarantee for the cooperative development of government, state-owned enterprises and private investors.

Improving investment protection mechanisms

It is important to establish and improve investor protection laws to effectively protect the assets of entities, improve the international investment and financing legal arbitration mechanism to solve the investment disputes of multinational projects, and establish the international investment insurance system gradually.

7.2.2 Multilateral agencies

Coordinating the construction of regional cooperation mechanisms

In order to promote hydropower development and delivery projects in the downstream of Congo River, multilateral institutions can use commercial mechanisms to coordinate the formulation of unified trade and customs tariffs, and promote the free flow of people, assets, labor, and capital. Multilateral agencies should improve investment protection and dispute resolution mechanisms, strengthen project risk assessment and risk warning, establish investment debt default assistance mechanisms, promote anti-corruption and anti-commercial bribery, and improve the openness of credit information in the region.

Promoting the establishment of the "Take-or-Pay" mechanism

This mechanism is adopted for important contracts such as long-term power purchase agreements, which can enhance the income stability of the transmission projects, ensure the efficiency of electricity usage in the mining projects, improve the predictability of costs, and promote the smooth implementation of the project.

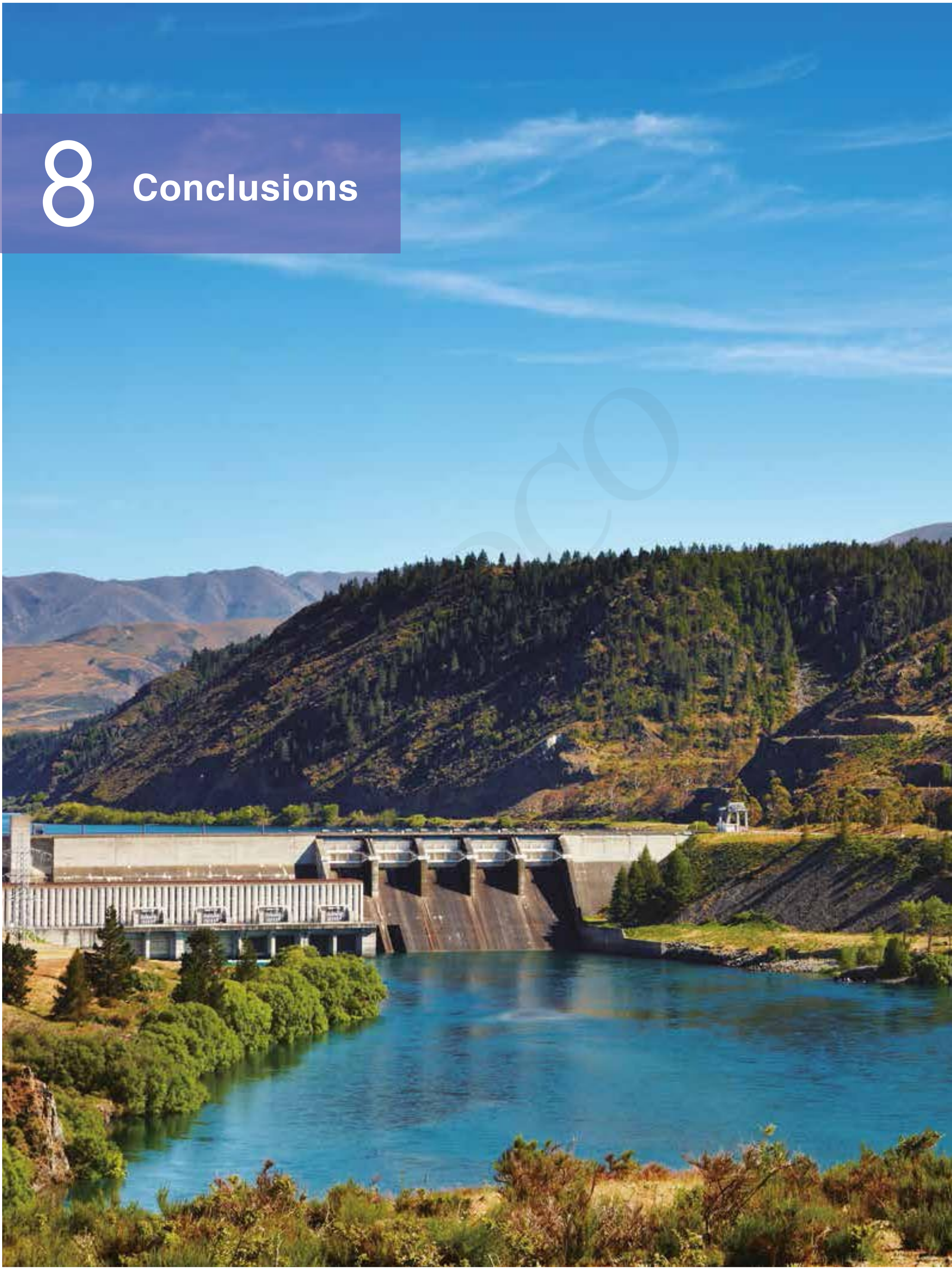
Unifying regional investment and financing policies

Multilateral institutions coordinate countries use or optimize international general rules, such as international financial accounting standards, investment protection and international investment arbitration, Basel Accord on banking supervision, etc., which can guide project investment or project financing. When the general rules do not correspond to local conditions, the multilateral agencies may initiate new policies.

Enriching policy-based financial instruments

Multilateral organizations use technology, financial assistance, project preparation funds, policy loans or other innovative financial instruments to promote project development, improve project financing performance, and attract capital from private sector.

8 Conclusions



The report aims to achieve large-scale development, optimization and efficient use of hydropower in the Congo River Basin. The hydropower resource is evaluated and the cascade hydropower station development plan in the downstream Congo River is analyzed. On this basis, the hydropower consumption market, power delivery direction and the transmission scheme are proposed. And the investment estimation and economic analysis is conducted. The project financing model and policy recommendations are also discussed. The main conclusions are as follows.

1 — **Taking the development of hydropower in the Congo River Basin as the driving force, accelerating the construction of the Africa Energy Interconnection and realizing the joint development of "electricity-mining-metallurgy-manufacturing-trade" is of great significance for achieving sustainable development in Africa.** Relying on abundant mineral and clean energy resources, Africa is welcoming new opportunities for sustainable development characterized by industrialization, urbanization and regional integration. It puts higher requirements on the development of energy and power. In particular, the development potential of mineral smelting and processing industry in some countries is huge, driving the rapid growth of electricity consumption, which will be dozens of times more than the current. African hydropower resources have obvious advantages with theoretical reserves of 4.4 PWh/year, of which Congo River Basin alone accounts for half of the total. Relying on the "electricity-mining-metallurgy-manufacturing-trade" co-development mode and grid interconnection, accelerating the large-scale development, optimization and efficient utilization of hydropower will provide safe, economical and clean energy for the industrialization in Africa. It will inject new impetus into Africa's economic development and help achieve the "2063 Agenda" targets.

2 — **The Congo River Basin is rich in water energy resources with very limited development currently. There is an urgent need for unified planning and accelerated development.** The theoretical hydropower potential of the Congo River basin is 2500 TWh/year, of which 52% are concentrated in the mainstream, and the left bank and right bank tributaries account for 29% and 19% respectively. The eastern and southern parts of the Congo River Basin are plateaus, and the central part is the Congo Basin. The main drops are concentrated in the up-stream, the transition zone between the left bank plateau and the basin, and the mainstreamdownstream. The Kinshasa-Matadi seaction of the downstream Congo River is the well-known Livingstone waterfalls. It is the most concentrated area of African hydropower resources, with a theoretical annual power generation of 850 TWh. At present, the installed hydropower capacity of the entire basin is only 2.86 GW, and the development ratio is less than 2%. Through the research of topography and hydrological characteristics, the area with favorable development conditions are the Congo River mainstream, the left bank tributaries and the right bank tributary Ubangi River. Among them, the development focus of the mainstream is located in the up-stream and downstream. The development focus of left bank tributaries is mainly located on the Lualaba River, the Kasai River and the up-stream of the

Ubangi River. The technical feasibly hydropower potential of the whole basin is about 150 GW.

3 — **Hydropower in the downstream Congo River needs to be unified planned and can be coordinated developed in a manner of three cascades, namely, Pioka, Grand Inga and Matadi. The total installed capacity is about 105 to 110 GW.** The development plan is mainly affected by factors such as river topography, hydro energy utilization, reservoir resettlement, and migration of Zongo II Hydropower Station. Through comprehensive analysis and cascade modeling operation on the hydropower digital planning research platform, a three-cascade development plan is proposed. The total reservoir capacity is about 13 billion cubic meters, which basically enables the daily adjustment. The total installed capacity is about 105 to 110 GW. The annual power generation is about 660~690 TWh, with utilization hours of about 6,200 and the water utilization rate of 99%. From the perspective of economics, the Grand Inga project is better than the other two cascades, and priority should be given to its development. The upstream Pioka and the downstream Matadi projects will be developed successively.

4 — **The scale of hydropower in the Congo River Basin is so huge that the local countries have limited market space to consume. It is necessary to make overall plans, expand the market, and optimize the electricity allocation in a wider range in Africa.** Taking full consideration of factors such as exploitation conditions, scales and timing, the delivery market and power transmission capacity of hydropower in the Congo River Basin is analyzed comprehensively. **Hdropower in the upstream of the mainstream and the tributaries** is better to be consumed locally because of the moderate exploitation scale, relatively high cost and short distance to the mining area. Electricity from these hydropower stations is mainly to meet local demands within 300~500 km, including loads in D.R. Congo, R. Congo, Central Africa, Cameroon etc.. Industries of Mining and agricultural product processing will be powered to develop in these countries, as well as the population without access to electricity. **Centralized and large-scale exploitation of hydropower in the downstream Congo River** will bring obvious advantage in scale with an annual utilization hour of 6,200. These characteristics are highly matched with industrial loads such as electrolytic aluminum and steel making. Under the premise of meeting local demands with a scale of 25GW, the rest 85GW hydropower could be delivered inter-regionally to the West, Southern, East, and North Africa. The electricity can support co-development of “electricity, mining, metallurgy, manufacturing and trade” throughout the whole Africa. Moreover, hydropower from the Congo River can also be transmitted inter-continentally to Europe and West Asia.

5 — **The hydropower in the Congo River Basin transmits electricity to the load centers in D. R. Congo, R. Congo and neighboring countries through EHV AC power grids and DC channels, and transmits through 11 EHV/UHV DC channels inter-regionally.** Considering the distance and capacity of transmission, while taking into account the grid interconnection needs, load centers within the

regions and in neighboring countries. **Hydropower of the upper reaches of the mainstream and the Lualaba River** are mainly transmitted to southern special economic zones, such as Katanga Province. It is firstly converged with 400 kV transmission channels and then integrate into the 765 kV main grid in the south of the D.R. Congo. **Hydropower of the Kasai River and its tributaries** mainly meets the power demands of the central special economic zones such as the Western Kasai Province and the Eastern Kasai Province. It is advisable to use 220 kV transmission channels to directly transmit power to large cities and towns such as Kananga and Kiwete. **Hydropower of the Sangha River and its tributaries** mainly meets the demands of the Ouesso Special Economic Zone in the north of R. Congo and southern Cameroon. The 400 kV AC transmission channel between R. Congo and Cameroon can be built via the development of Chollet hydropower station, and hydropower of small-sized and middle-sized station can be converged in 110 kV AC transmission channels. **The Oubangui River hydropower** mainly meets the demands of the northern D.R. Congo and the Central African Republic. After converging in 110 kV transmission channel, they can be transmitted to large cities and towns such as Bangui. **Hydropower in the downstream of Congo River** is directly transmitted intra-regionally and inter-regionally, to large load centers in Africa, such as mineral smelting and processing load centers, mainly relying on UHV DC technology. 11 EHV/UHV channels will be built by 2060, including 5 channels to West Africa with a capacity of 36 GW, 2 channels to Southern Africa with a capacity of 11 GW, 2 channels to East Africa with a capacity of 16 GW, and 2 channels to North Africa with a capacity of 20 GW.

6 — **Hydropower in the downstream Congo River has significant competitiveness in electricity price.** The total investment of three-cascade hydropower stations and their transmission projects in the lower Congo River is in the range of 219~246 billion USD, of which the hydropower station investment is 140~167 billion USD, accounting for about 65%. The price of Grand Inga, Pioka and Matadi hydropower is about 3~3.5, 4.2~5.2, 4.8~5.7 US cents/kWh, respectively. The total investment of transmission lines is around 79 billion USD, accounting for about 35%. The transmission tariff of the DC channels to various regions of Africa is between 1.3 and 2.6 US cents/kWh, and the arrival cost is about 2~5 US cents/kWh, which is lower than the average electricity price of receiving-end countries.

7 — **Accelerating the development and transmission of hydropower in the Congo River Basin will bring comprehensive economic, social and environmental benefits. In terms of economics,** it will meet the energy and power needs of Africa in a clean, green and sustainable way, stimulate economic growth, and vigorously drive the development of sectors such as power system, mining, smelting, processing, and international trade, becoming a new driving force of regional and African economies. Meanwhile, the development cost will be largely reduced since the arrival price of the Congo River hydropower is lower than that of the target market, saving more than 20 billion USD per year for African countries. In addition, the export of clean electricity will significantly expand

foreign exchange earnings of D.R. Congo and R. Congo, which will reach more than 17 billion USD in 2050. **In terms of social development,** the Congo River basin hydropower development will enhence electricity accessiblity. By 2050, accessibility to electricity will reach nearly 100%. The health of African people will improve, due to the effective reduction of pollution caused by energy production and utilization. The employment will also be promoted, adding more than 15 million new jobs. **In terms of environment**, as the demand of fossil fuel being greatly reduced, the air and groundwater pollution, the geological and ecological damage caused by the production, processing, storage, transportation and utilization of fossil energy will be increasingly reduced. Finally, it will contribute to reduce greenhouse gas emissions, which will reduce the carbon dioxide emissions by 550 million tons per year.

8 — **Relying on the internationalized and commercialized project clusters such as electric transmission, mining, metallurgy, industrial parks and trade, with strong legal guarantee and multilateral coordination mechanism, the projects cooperation will be guaranteed through agreement, and the profitability of the whole projects package will be improved.** All aspects of the industrial chain will be smoothly promoted as a whole, and the project financing performance will be enhanced. Given valuable project opportunity, the structure of investment and financing will be optimized; capital market financial instruments will be rationally used; project risk management will be effectively implemented; governments, enterprises, or other entities can enhance the initiative of participation. The Participants should establish and improve support measures. The government should promote the optimization of industrial policies, improve investment and financing policies, and promote effective cooperation between countries. Multilateral institutions should strengthen coordination and cooperation mechanisms, promote the establishment of the "Take-or-Pay" mechanism, unify regional investment and financing rules and enrich policy-based financial instruments; the project entity should have close communication with the government, strengthens coordination among enterprises, conducts due diligence, as well as economic and technological assessment before investment.