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

Research on Global Electricity Development Index

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Preface

The widespread consensus on addressing climate change and accelerating energy transition has been formed globally. The dynamics of energy allocation, supply structure, utilization techniques, technological advancements, and industrial ecology are evolving rapidly. Key aspects of energy development, such as "cleanliness, electrification, networking, and intelligence," are gaining increasing prominence. Electricity ensures the provision of safe, cost-effective, green and inclusive energy services to citizens and industries. Given its foundational and leading role in national economies, electricity holds a central position within the energy landscape. Against the backdrop of global efforts towards carbon emissions peak and carbon neutrality, the role and importance of electricity development in driving greener and low-carbon energy transition and ensuring energy security have become more pronounced. The establishment of a global electricity development index (GEDI) allows for the scientific assessment of electricity development effectiveness across different regions and major countries worldwide. This index leads the development and technological innovation within the electricity sector, facilitates the transformation and upgrading of electricity and related industries, creates a favorable environment, and fosters electricity cooperation and exchange among nations, which holds great significance and far-reaching influence.

The trajectory and progression of electricity development are shaped by diverse factors including economic and social elements, industrial frameworks, technological infrastructures, policy landscapes, and institutional mechanisms. The establishment of GEDI aims to evaluate regional and national electricity development on various dimensions to provide reference for decision makers, investors, electricity industry practitioners and people concerned about the industry development. Confronted with emerging demands for secure electricity supply, green and low-carbon development, economic efficiency, and technological innovation amidst the global energy transition, the Global Energy Interconnection Development and Cooperation Organization (GEIDCO) has compiled the *Research on Global Electricity Development Index (2024)* to objectively, impartially, and scientifically evaluate the state of electricity development across various regions and countries worldwide.

Building upon global energy transition trends and recognizing electricity's pivotal role in this transition, this report introduces a comprehensive index and a two-tier, four-dimensional evaluation framework for global electricity development. The report delves into the specifics of evaluation principles and procedures, indicator framework and selection, and calculation methodologies. It conducts electricity development index calculations and rankings for 100 representative countries from diverse continents worldwide.

This report consists of five chapters:

The first chapter expounds the purpose and significance of the research on GEDI.

The second chapter introduces the principles and evaluation process for index construction, proposes the index evaluation indicator system and index calculation method, and explains the basic data collection and country selection.

The third chapter calculates the global and continental electricity development indexes, analyzes them from the overall perspective, by dimensions and regions, and releases country rankings.

The fourth chapter analyzes the electricity development and related experience of leading countries in the electricity development index on all continents.

The fifth chapter summarizes the report and presents the outlook.

Electricity serves as the core and crucial component in constructing a clean, low-carbon, safe, and efficient energy system. It holds paramount importance in achieving sustainable energy development and addressing climate change. The research on GEDI aims to provide scientific guidance for the global transformation of electricity sector, foster broad international cooperation in energy and electricity, promote universal access to sustainable and affordable electricity, and help to build a community with a shared future for mankind. This report aims to provide reference for government departments, international organizations, energy enterprises, financial institutions, research institutes, universities and relevant personnel in policy formulation, strategic research and international cooperation. Constraints in data availability and research time frame may cause defects in the content. Your constructive advises and feedback are highly appreciated.

The report refers to publications from institutions such as the United Nations for the names and geographical delineations of countries in China. The report takes no stance on territorial sovereignty, international boundary demarcation, or the naming of any territory, city, or region.

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1 Research Background

1.1 The Dominant Role of Electricity in Energy Transition

Electricity serves as the core and crucial component in constructing a clean, low-carbon, safe, and efficient energy system. It is the primary means for developing and utilizing clean energy, enabling flexible and efficient conversion among various energy sources. Electricity stands as a primary choice for replacing fossil fuels at the end-user level. The power system integrates clean primary energy sources such as hydroenergy, wind energy, and solar energy with secondary energy sources like heat and hydrogen. It acts as a pivotal hub and platform for efficient energy allocation. In the global context of “carbon emissions peak” and “carbon neutrality”, the significance and role of electricity development in driving energy transition and ensuring energy security are increasingly highlighted. This development holds crucial importance in achieving sustainable energy supply and addressing climate change.

(I) Green and low-carbon transformation of electricity is the core driver for decarbonization in the energy sector

Energy activities are the key source of carbon emissions. According to the International Energy Agency’s (IEA) report *CO_2 Emissions in 2022* [1], energy-related CO_2 emissions reached a historical high of 36.8 $GtCO_2$ in 2022, contributing to 83% of global carbon emissions. Specifically, the electricity sector emitted 14.7 $GtCO_2$, accounting for 40% of carbon emissions in the energy sector, and twice the number of the second largest emitter, the industry sector. The main reason behind this is the significant carbon intensity of traditional power systems dominated by fossil fuel combustion, coupled with the continuously growing electricity demand, leading to substantial carbon emissions. The progression of the green and low-carbon development in the electricity sector will directly influence the effectiveness of decarbonization efforts in the energy sector. Moreover, as electricity stands as a critical substitute for fossil fuels in industries and other energy sectors, its decarbonization plays a crucial role in driving decarbonization in these sectors.

[1] https://www.iea.org/reports/co2-emissions-in-2022

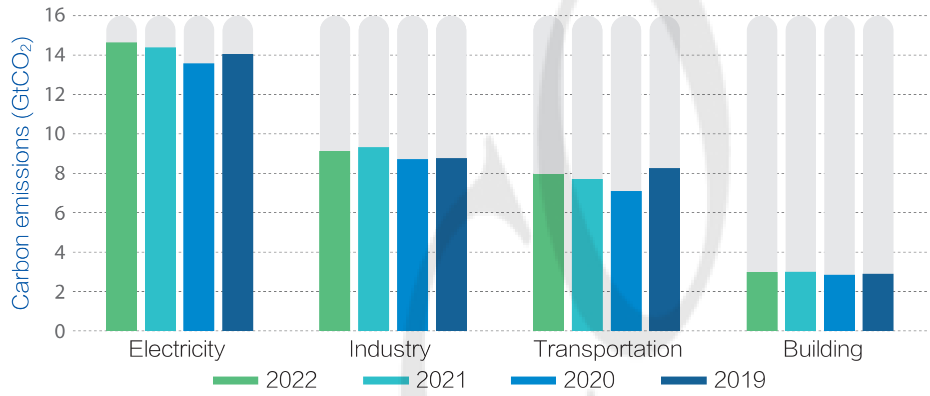


Figure 1-1 Global CO_2 Emissions by Sector from 2019 to 2022

In 2023, global electricity sector's carbon emissions were at **13.58** $GtCO_2$

With the rapid growth of wind and solar power generation, the share of fossil fuel-based power generation has been gradually declining, leading to a structural decarbonization in the global electricity sector. In 2023, global electricity sector's carbon emissions were at 13.58 $GtCO_2$[1], with an average annual growth rate declining to 0.9%. Global carbon emissions per unit of electricity consumption continue to decrease, dropping to about 0.49 kg CO_2/kWh in 2023, dropping by 8 percentage points over the past five years.

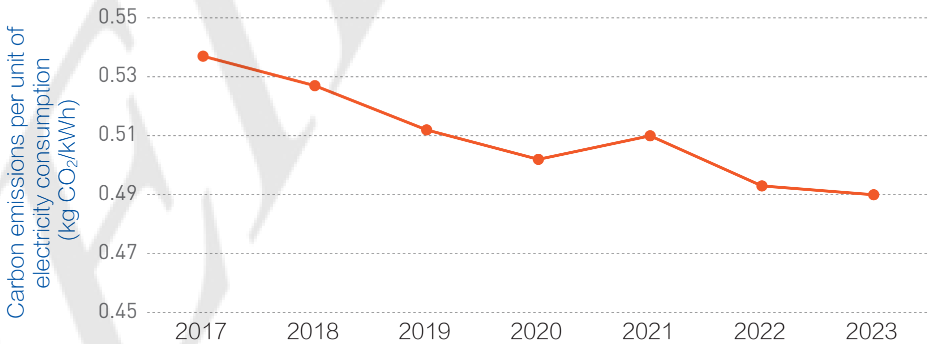


Figure 1-2 Change in Global Carbon Emissions per Unit of Electricity Consumption

(II) Electricity generation is the main way to utilize clean energies on the supply side

Renewable energy sources such as wind and solar energy are abundant, easily accessible, and widely distributed. Electricity generation serves as a key technological pathway for the large-scale development and efficient utilization of various renewable energy sources. Replacing fossil fuels with clean energy on the supply side helps ensure energy security and accelerate energy transition. In recent years, the rapid expansion of global development of renewable energy has emerged as the major driving force for the accelerated transformation of energy mix.

[1] Data source: IEA's report *Electricity 2024*

In 2023, the total installed power capacity reached **8.96** TW

Clean energy-based installed capacity and electricity generation have been steadily increasing, leading to continuous optimization of the electricity supply structure. In 2023, the total installed power capacity reached 8.96 TW[1], with clean energy accounting for approximately 4.2 TW[2], representing around 47% share, marking a growth of 7.6 percentage points over the past five years. Total electricity generation reached 29,700 TWh[3], with clean energy generation accounting for 39.3%, seeing a 3.3 percentage point growth over the last five years.

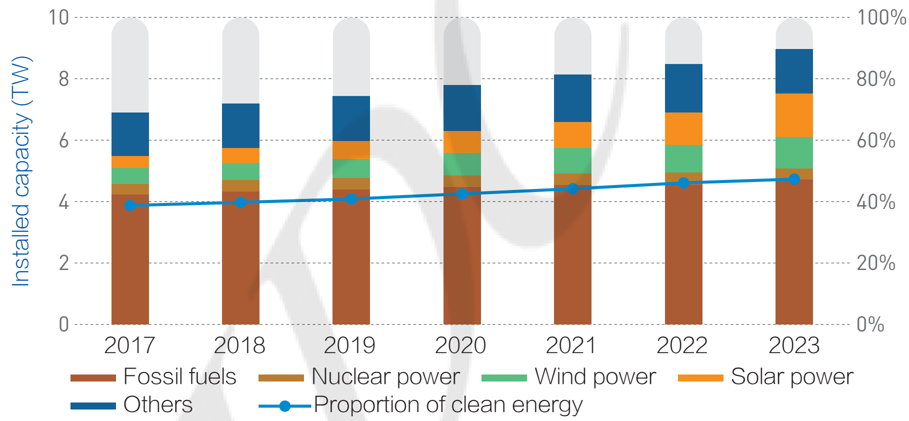


Figure 1-3 Changes in Global Installed Power Capacity by Power Source

In 2023, the global installed capacities of wind and solar power reached **1.02** TW and **1.42** TW respectively

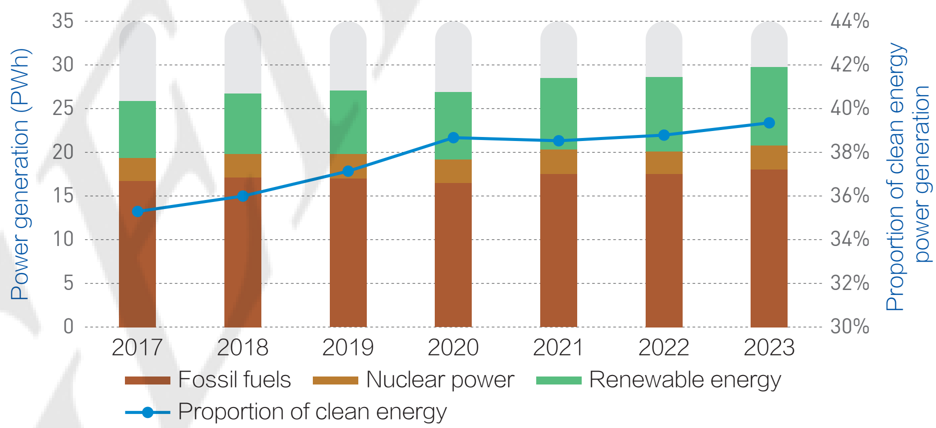


Figure 1-4 Changes in Global Power Generation by Power Source

New energy power has entered an exponential growth phase. With the continuous decrease in the generation costs of wind and solar power, the global installed capacity of wind and solar power is rapidly increasing. In 2023, the global installed capacities of wind and solar power reached 1.02 TW and 1.42 TW respectively[4], accounting for 27% of the total installed capacity, an increase of 12 percentage points compared to 2018, with the total capacities being 2.3 times that of 2018. Since 2018, the annual average added capacity of new energy installations globally has reached 280 GW.

1. Data source: calculated according to IRENA's report *Renewable capacity statistics 2024*
2. Data source: IRENA's report *Renewable capacity statistics 2024*, IEA's report *Electricity 2024*
3. Data source: IEA's report *Electricity 2024*
4. Data source: IRENA's report *Renewable capacity statistics 2024*

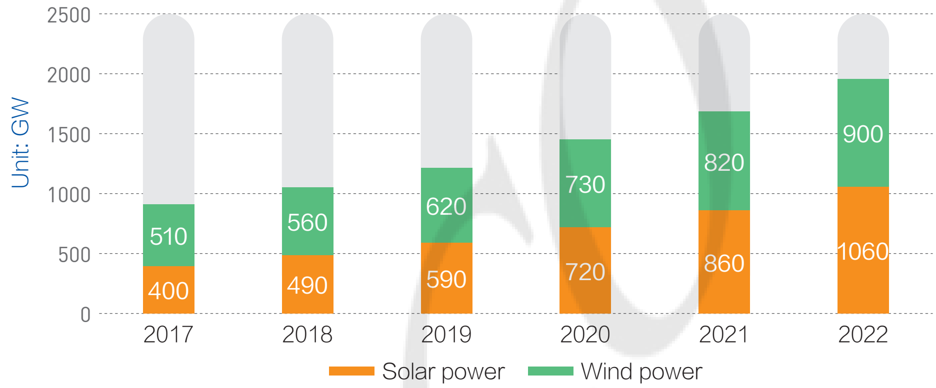


Figure 1-5 Changes in Global Installed Capacity of New Energy by Power Source

(III) Energy interconnection supports the building of a digital, intelligent and robust power grid on the allocation side

Interconnection is an inherent requirement for the clean and low-carbon transition of global energy, which will drive the transition of traditional energy systems to interconnected energy networks. Global clean energy resources are abundant but are often distributed in areas with few human activities like deserts, gobi and oceans. The imbalance in the distribution and consumption of clean energy resources necessitates global energy and electricity transformation. It entails further developing various clean energy resources and leveraging the enormous advantages of power grids and other energy networks in efficient energy conversion, optimal allocation, and demand-supply coordination. This systematic approach can address challenges such as flexible allocation of clean energy, efficient consumption, and secure energy supply.

The electricity transformation imposes higher demands on the allocation capability of various innovative elements and resources, with the power system manifesting a trend towards intelligence and digitalization. The transformation of the power system is based on digitalization, facilitated by intelligence, and oriented towards sustainability. With modern information technologies such as "big data, cloud computing, internet of things (IoT), mobile internet, artificial intelligence (AI) and blockchain", this development leverages the deep coupling between the digital industries and the energy and electricity sectors. This encourages information sharing and capability complementation among various entities across the entire spectrum of generation, grid, load and storage, and stimulates interconnection among resources and innovative elements. In 2023, the number of digital and intelligent projects and collaborations in the electricity sector doubled compared to 2022[1]. Key focus areas include new energy generation forecasting, online monitoring and automatic control of power grids, electricity marketing and market services.

[1] Source: BloombergNEF's report *AI Joins the Front Lines in Battle to Clean Up Power Grids*

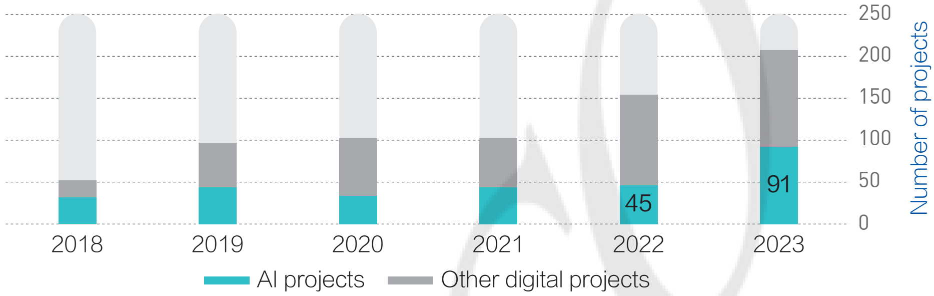


Figure 1-6 Changes in Digital and Intelligent Projects and Collaborations in the Global Electricity Sector

The digital, intelligent and robust power grid serves as a crucial platform supporting energy allocation platforms. The power grid serves as the primary carrier for the extensive interconnection of energy networks. This transition efficiently harnesses time zone differences, seasonal variations, resource disparities, and price differentials among various clean energy resources, and achieves optimal allocation and efficient utilization of clean energy. It also leads to synergy of "wind power, solar power, hydropower, thermal power and nuclear power", interconnection of "electricity, hydrogen, cooling, heating and gas", and coordination of "generation, grid, load and storage", thus integrating various energy sources and segments. Incorporating UHV and EHV backbone grids at various levels and integrating modern information technologies like "big data, cloud computing, IoT, mobile internet, AI and blockchain", the digital, intelligent and robust power grid network significantly enhances the long-range transmission and in-depth utilization of renewable energy.

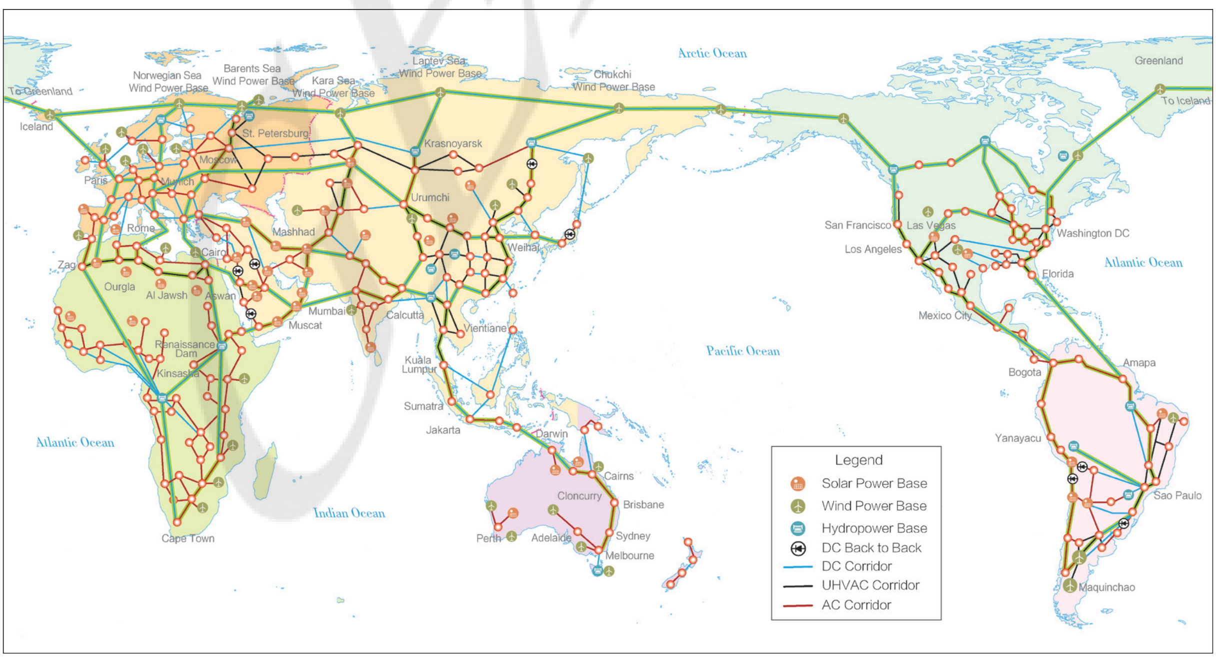


Figure 1-7 Backbone Grids of Global Energy Interconnection

(IV) Electricity replacement is the key to improve electrification level on the consumption side

Accelerating electricity replacement and improving the electrification level are crucial for optimizing the energy consumption structure. Electricity, as a high-quality and efficient secondary energy source, holds economic value equivalent to 17.3 times that of coal and 3.2 times that of oil. Every one percent increase in electricity consumption in the final energy mix leads to a 3.7% decrease in energy intensity. Accelerating electricity replacement on the consumption side and propelling the replacement of coal, oil, gas and firewood with electricity, this transition will establish an energy consumption pattern dominated by electricity. Implementing clean replacement on the supply side and meeting new electricity demand with renewable energy, this transition will significantly improve energy efficiency levels of all nations and elevate cleanliness levels of energy consumption structures, thereby ensuring the smooth progression of energy transition.

In 2023, global electricity demand came to 27,700 TWh[1], showing consistent growth since 2020. Notably, China, India, and Indonesia exhibited growth rates of 6.4%, 7%, and 7% respectively, significantly higher than the global average. Emerging economies and developing countries have emerged as major drivers of global electricity demand growth. For three consecutive years, the share of electricity in global final energy mix has remained above 20%. Electrification has emerged as a key pathway for major countries to drive decarbonization in traditional industries, catalyze the development of emerging industries, and improve electricity accessibility.

In 2023, global electricity demand came to **27,700** TWh

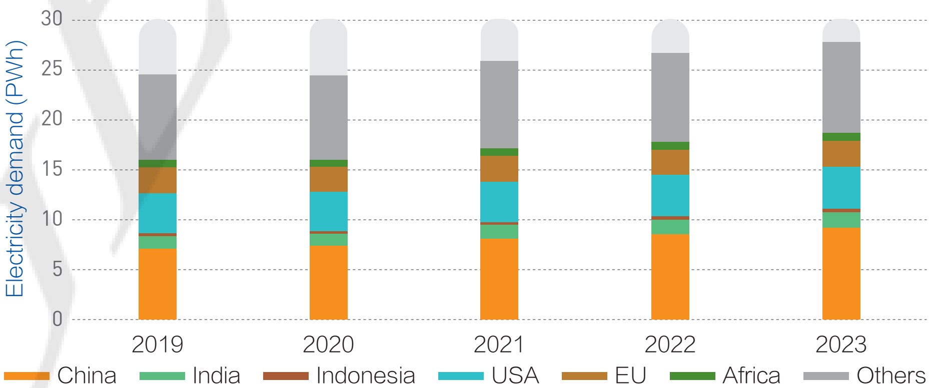


Figure 1-8 Changes in Electricity Demand in Major Countries and Regions

[1] Data source: IEA's report *Electricity 2024*

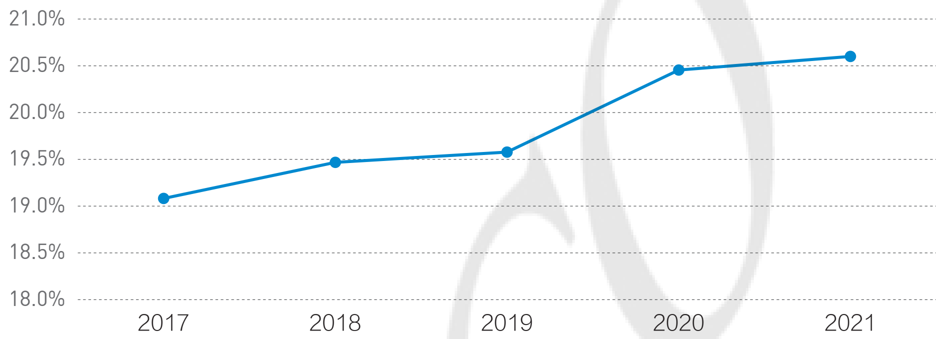


Figure 1-9 Changes in Global Electrification Level

The electrification of transportation sectors such as electric vehicles (EVs) and emerging industries such as data centers, AI computing power, and new energy equipment manufacturing have become new driving forces for global electricity demand growth. In 2023, the global ownership of EVs[1] reached 40 million, with a total electricity consumption of 130 TWh[2], accounting for 0.5% of global electricity demand. This is equivalent to 1% of the sum of electricity consumption in China and the EU and approximately equal to Norway's national electricity consumption. The global EV industry has made salient progress, especially in China, with increasing production capacity. The global electricity demand of EVs is expected to increase rapidly, to surpass 1000 TWh by 2030. Data centers, AI, and new energy equipment manufacturing have become significant drivers of electricity demand growth in many regions. More than 8,000 data centers are in operation worldwide, with more than half located in the USA (33%), Europe (16%) and China (10%). In 2022, the total electricity consumption of global data centers was about 460 TWh[3], accounting for 2% of global electricity consumption. It is projected that by 2026, this figure may exceed 1000 TWh, which is equivalent to Japan's national electricity consumption.

In 2023, the global ownership of EVs reached **40** million

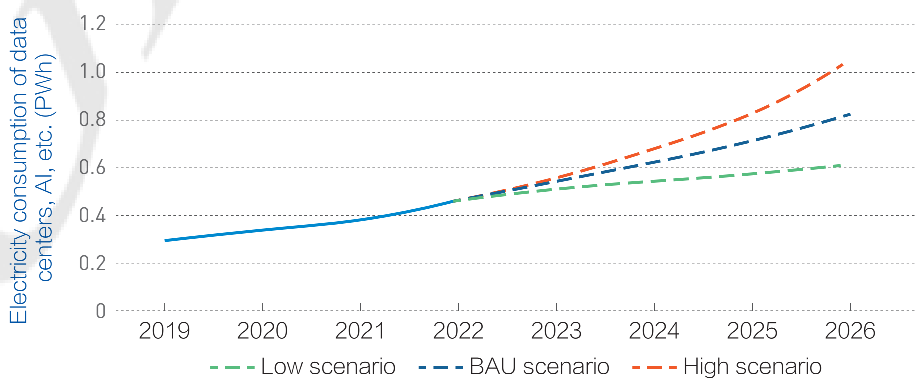


Figure 1-10 Changes and Forecasts of Global Electricity Demand of Data Centers and AI

1. Sum of BEVs and PHEVs.
2. Data source: IEA's report *Global EV Outlook 2024*
3. Data source: IEA's report *Electricity 2024*

1.2 Purpose and Significance of Electricity Development Index Research

Given its foundational and leading role in national economies, electricity holds a central position within the energy landscape. The establishment of GEDI aims to scientifically assess the electricity development in various regions and major countries, and uncover advantages and potentials. This endeavor also seeks to guide innovative transformations and technological advancements of electricity sector, drive industrial transformation and upgrading, expedite mutual learning and collaboration, and ensure sustainable and affordable access to electricity for all.

(I) Assessing electricity development and uncovering advantages and potentials

The trajectory and progression of electricity development are shaped by diverse factors including economic and social status, industrial structure, technological infrastructures, policy landscapes, and institutional mechanisms. Across different continents, regions and countries, disparities exist in many aspects such as development stages and resource endowments. Through systematic assessments of levels and effectiveness of electricity development in various regions and countries based on local conditions and changing circumstances, it becomes imperative to scientifically identify electricity development orientations, tap strengths and potentials, rectify weaknesses, and catalyze the innovative and sustainable development of electricity sector. Currently, only institutions such as the World Bank have published evaluation indicators for access to electricity and other single dimensions. These indicators fall short in offering a comprehensive and systematic reflection of the recent electricity development status, achievements and trends in countries worldwide, especially in emerging economies and developing countries.

(II) Guiding innovative transformations and leading technological advancements

By introducing the electricity development index, comprehensive evaluations of electricity development levels across regions and countries on various dimensions provide guidance for policymakers and decision-makers regarding industry transformation trends and technological innovation pathways. This facilitates the alignment of national resources, industrial structures, technological foundations, and policy environments to bridge development gaps, navigate innovation investments, and pinpoint key areas for technological breakthroughs. Through horizontal comparisons among regions and countries, adjusting industry-related policies and refining market mechanisms can create a policy and market environment for green, low-carbon and cost-effective transformation of energy and electricity.

(III) Driving industrial upgrading and improving efficiency

Assessing capabilities in electricity technological innovation, infrastructure development levels, market potentials, and development trends serves as a guiding compass for industrial upgrades, driving investments in the electricity sector and related new industries. Leveraging industrial transformation and upgrading can facilitate the optimization of productivity factors, foster new formats, modes and driving forces in industry development, promote resource sharing and advantage complementation, and improve investment efficiency and benefits.

(IV) Creating a collaboration-friendly environment

Systematically evaluating electricity development levels, supply guarantee capabilities, service levels, and transformation processes worldwide cultivates an environment conducive to mutual exchange and learning. Such an environment facilitates the experience sharing in electricity infrastructure construction, operational services, technological innovation, market reform, and environmental protection, fostering cooperative efforts between countries at various development stages and resource allocations. This cooperation is imperative in ensuring universal access to sustainable and affordable electricity for all.

2 Electricity Development Index Evaluation Model

2.1 Principles and Evaluation Process for Index Construction

(I) Connotation of electricity development index

GEDI (Global Electricity Development Index) is positioned as a comprehensive global index that tracks and evaluates the electricity development at regional and national levels. It covers various aspects of electricity production, consumption and allocation, aiming to establish a multidimensional evaluation system focusing on safety, reliability, green and low-carbon development, economic efficiency, as well as technology, policies, and market dynamics. GEDI also aims to provide reference for decision makers, investors, electricity industry practitioners and people concerned about the industry development.

(II) Principles of indicator system construction

Systematic and Comprehensive

The establishment of GEDI should meet the new requirements for global energy and electricity development, including aspects such as secure electricity supply, green and low-carbon development, economic efficiency, and technological innovation. The indicator system construction and indicator selection should highlight the leading role and impact of electricity development in the global energy transition, portraying a comprehensive and scientific overview of electricity development levels, characteristics, and trends across different countries and regions worldwide. The electricity development index should strive to cover key indicators in various phases of electricity production, transmission, allocation and consumption, providing a comprehensive reflection of a country or region's electricity development. The indicator system should encompass aspects like secure electricity supply, green and low-carbon development, economic efficiency, and technological innovation.

Objective and Fair

The indicator selection should consider both the connotation of the indicators and data availability. The index calculation method should predominantly rely on quantifiable, comparable and continuous statistical data as indicator sources to minimize subjective judgment effects, with quantitative analysis as the main method and qualitative analysis as the auxiliary method. Instead of aggregate indicators, only per capita indicators are selected to reduce the impact of country size on the evaluation results, thus ensuring the objectivity of the index calculation results. Acknowledging the differences in development status, characteristics, and data availability among different countries, objective and fair principles are crucial to establish a balanced indicator system for countries at different locations, and development stages.

Universal and Open

In the process of index calculation, the standardization of basic data and the adoption of universal indicator weighting methods ensure that the evaluation methods are applicable to all countries. Considering the complexity of the electricity industry environment, the design and weighting selection of evaluation indicators should be more open, allowing flexibility according to specific needs. This approach allows for different emphases, subsequently yielding adjusted calculation and ranking results that are easy for people to understand and accept.

Development-centered and Inclusive

The GEDI should fully demonstrate the electricity development levels and growth potential of each country, incorporating current status indicators and growth rate indicators that reflect recent development effectiveness. The indicator design should take into account the economic, cultural, and environmental diversities of different regions and countries in an inclusive way, especially for developing countries.

(III) Basic process of index calculation

The calculation and analysis of GEDI is a complex and systematic undertaking involving multiple key steps, including meticulously constructing the indicator system, rigorously selecting data, scientifically allocating weights, accurately calculating scores, and carrying out global assessments and comparisons.

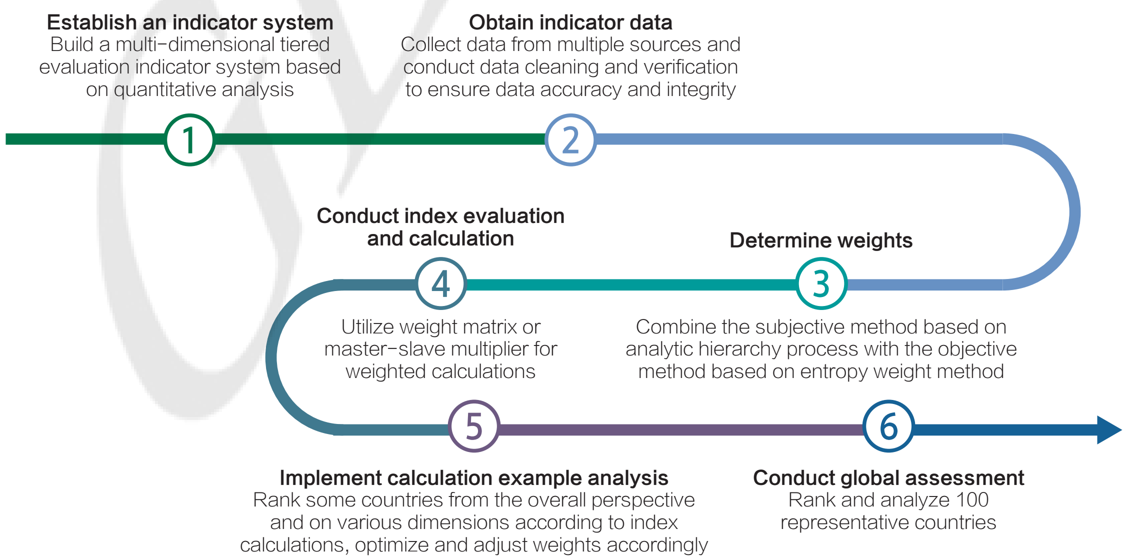


Figure 2-1　Calculation Process of GEDI

Step 1 involves the meticulous construction of a comprehensive, objective, and scientific indicator system, which is foundational and critical. The indicator system should encompass various aspects of electricity production, consumption, services, policies and markets, as well as multiple dimensions such as safety, economy, and environmental protection to provide a holistic and objective reflection of each country's electricity development level.

Step 2 involves the accurate acquisition of relevant indicator data from each country, followed by stringent organization and selection processes to ensure the objectivity and comparability of calculation results. Extensive data collection, meticulous data screening, and error correction are essential to guarantee the accuracy and reliability of calculation results.

Step 3 involves a scientific weight allocation to each indicator to reflect their relative importance in electricity development. This process requires in-depth research and expert consultation to ensure fair and reasonable weight settings.

After completing the basic data collection and weight allocation, a selection of representative countries is used for index calculation. The indicator data of each country is standardized and combined with weights to calculate the electricity development index scores for each country. Based on the results of the electricity development index calculations for representative countries, adjustments are made to optimize the indicator weight settings. Sensitivity analysis of the weight settings is conducted to assess the degree of impact on calculation results, allowing a better understanding of index trends and uncertainties, and providing comprehensive references for decision-making.

Step 4 a global-scale analysis of the electricity development index is carried out to comprehensively evaluate the electricity development levels of various countries. Through comparative analysis of the comprehensive scores and individual indicator scores of each region and country, the overall trends in regional electricity development and differences between countries are examined to assess the current status and future trends of electricity development worldwide.

2.2 Indicator System of GEDI

(I) Theoretical foundation

In 1987, the World Commission on Environment and Development published the report *Our Common Future*, which first introduced the concept of sustainable development. This was widely recognized and accepted at the 1992 United Nations Conference on Environment and Development, emphasizing sustainable development as a global collective action.

Sustainable development refers to the development that meets the needs of the present without compromising the ability of future generations to meet their own needs. In 2013, Chinese President Xi Jinping proposed the Belt and Road Initiative during visits to Central Asia and Southeast Asian countries. In 2015, in a significant speech at the General Debate of the 70th Session of the UN General Assembly, he advocated for fostering a global community of shared future, contributing Chinese wisdom and strength to achieving the UN's sustainable development goals by 2030.

Energy, as the foundation of human society's sustainable development, has become a crucial topic of the United Nations in recent years. The key to achieving sustainable energy development lies in balancing the relationships between energy, economy, and environment. It involves meeting the demands of the economy, environment, and society during energy development and utilization, ensuring sustainable resource use for future generations' benefit. The core of sustainable energy development involves promoting the use of renewable energy, advocating energy conservation, enhancing energy efficiency, meeting society's energy demands, and reducing negative environmental and social impacts.

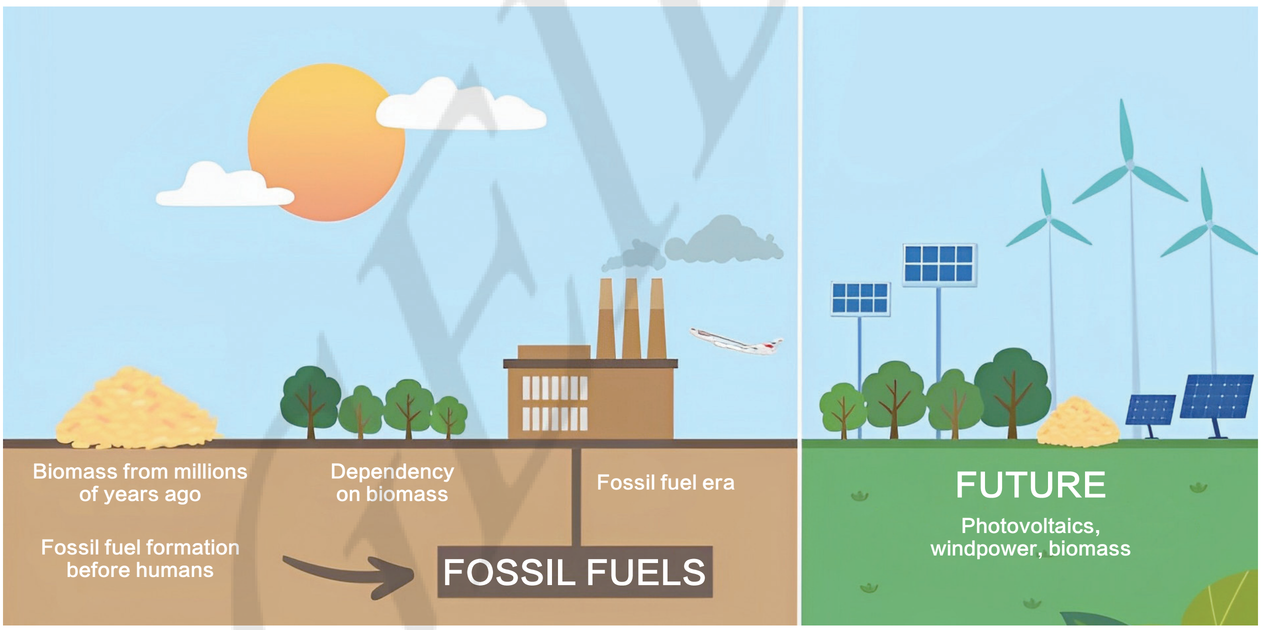


Figure 2-2 Sustainable Development Direction of Energy[1]

Electricity, as a critical component of energy systems, requires a balanced relationship between electricity, economy, environment, and society to achieve sustainable development. As a public infrastructure, the power system directly influences a country's economic and social development and the daily lives of its citizens. Thus, **a secure and reliable electricity supply is fundamental and crucial for electricity development, with quality and efficient electricity consumption services as important objectives.**

[1] Picture source: https://green.org/2024/01/30/sustainable-energy-transition-a-thought-leaders-blueprint/

Advancing sustainable electricity development **relies on technological innovation and progress.**

Firstly we should develop clean energy generation technologies to meet the sustainable supply needs.

Secondly we should accelerate the research and application of smart grid technologies, enhance the digitization and intelligence of the grid, enhance electricity allocation capabilities, improve the stability and security of electricity systems, and provide users with convenient and efficient electricity services.

Thirdly we should develop and popularize advanced electricity transmission and storage technologies to improve electricity allocation efficiency.

Lastly we should promote electricity replacement and intelligent electricity utilization technologies, such as EVs, charging infrastructure, and electrofuels, to improve electrification levels, reduce fossil fuel consumption, and protect the environment.

Green and low-carbon development are the directions for electricity industry transformation and sustainable development. Carbon emissions from electricity systems are a major contributor to global emissions. Reducing fossil fuel-based power generation and carbon emissions is crucial to address climate change. Additionally, renewable energy resources are widely distributed, abundant and sustainable, with decreasing costs of renewable energy generation. Replacing fossil fuels with renewable energy in power generation ensures secure energy supply and reduces energy utilization costs. Green and low-carbon development provides an important solution for sustainable electricity development.

Drawing upon energy and sustainable development theories, and the requirements posed by economic, social, and environmental sustainability for electricity development, such as security, reliability, economic efficiency, green and low-carbon development, and technological innovation, research efforts have culminated in the construction of a **four-dimensional GEDI model.** The model incorporates dimensions such as supply guarantee, consumption services, technological innovation, and green and low-carbon development. Among them, the **supply guarantee** dimension measures a country's electricity infrastructure and supply guarantee capability. The **consumption services** dimension measures a country's electricity consumption level, service quality, and service efficiency. The **green and low-carbon development** dimension measures a country's level and speed of electricity industry transformation. The **technological innovation** dimension measures a country's potential and driving force in electricity development.

Figure 2-3 4D Model of Electricity Development Index

(II) Indicator system

To comprehensively, accurately, thoroughly, and objectively characterize the electricity development levels of different countries, a two-tier, four-dimensional indicator system has been established, covering technical-economic indicators in dimensions of supply guarantee, consumption services, technological innovation, and green and low-carbon development. The system includes clear interpretations and calculation methods for each level of indicators.

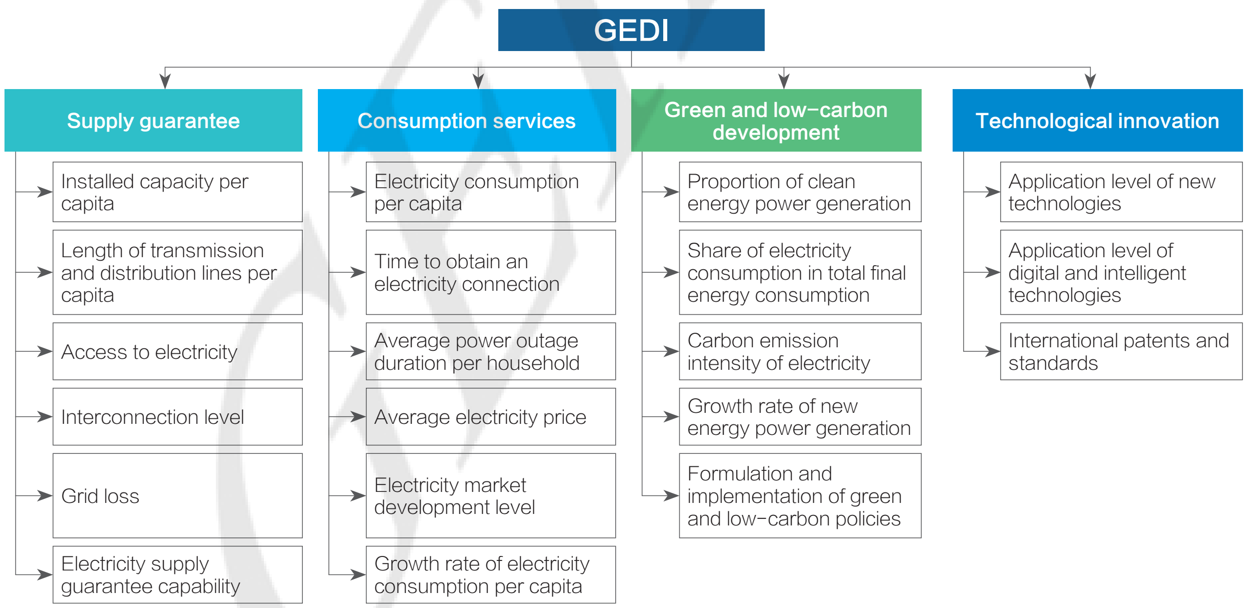


Figure 2-4 Two-tier System of Global Electricity Development Index

The supply guarantee dimension measures whether a country's basic electricity production and supply capacity can meet the needs of economic and social development, safety, reliability, and economic efficiency. Six secondary indicators are selected to measure a country's electricity supply guarantee capability from different aspects. Among them, the installed capacity per capita and length of transmission and distribution lines per capita measure a country's electricity production capacity and grid operation capacity respectively. The access to electricity represents electricity accessibility. The interconnection level reflects the interconnection level of power grids in different regions. The grid loss reflects the operation efficiency of transmission and distribution networks. The electricity supply guarantee capability reflects whether a country's electricity production and supply capacity can meet the needs of economic and social development.

Table 2-1 Connotation and Calculation Method of Secondary Indicators of Supply Guarantee

Primary Indicator	Secondary Indicator	Connotation	Calculation Method
Supply guarantee	Installed capacity per capita	Electricity production capacity	Total installed capacity/total population
	Length of transmission and distribution lines per capita	Grid operation capacity	Total length of transmission and distribution lines/total population
	Access to electricity	Electricity accessibility	1-Population without access to electricity/total population, which measures the coverage of electricity supply
	Interconnection level	Mutual support capacity of power grids	According to the inter-regional power exchange capacity, the grid structure is scored qualitatively and quantitatively
	Grid loss	Grid operation efficiency	Transmission and distribution network loss/electricity supply, which measures the grid operation efficiency
	Electricity supply guarantee capability	Whether the electricity supply can meet economic and social needs	① Effective installed capacity/peak load -1 (reserve ratio) ② number and scope of large-scale power outages/rationing

The consumption services dimension measures a country's electricity consumption level and potential and whether the power system can provide users with high-quality, economical and efficient power supply services. Six secondary indicators are selected to measure a country's electricity consumption service level from different aspects. Among them, the electricity consumption per capita measures a country's electricity consumption level. The time to obtain an electricity connection reflects a country's service efficiency of electricity access. The average power outage duration per household reflects the reliability of consumption services. The average electricity price reflects the affordability of electricity service. The electricity market development level reflects the development level and progress of electricity markets. The growth rate of electricity consumption per capita reflects a country's development potential of electricity consumption.

Table 2-2 Connotation and Calculation Method of Secondary Indicators of Consumption Services

Primary Indicator	Secondary Indicator	Connotation	Calculation Method
Consumption services	Electricity consumption per capita	Electricity consumption level	Total electricity consumption/ total population
	Time to obtain an electricity connection	Service efficiency of electricity access	Average time to obtain an electricity connection
	Average power outage duration per household	Electricity supply reliability	Total outage duration/total number of households
	Average electricity price	Electricity affordability	Weighted average electricity price for industrial, commercial and residential uses/per capita disposable income
	Electricity market development level	Development progress of electricity markets	① Proportion of electricity in market-oriented transactions ② construction progress of electricity markets
	Growth rate of electricity consumption per capita	Development potential of electricity consumption	Average annual growth rate of electricity consumption per capita in the past five years

The green and low-carbon development dimension

measures a country's effect and potential of electricity industry transformation. Five secondary indicators are selected to evaluate the green and low-carbon development level and potential of electricity. Among them, the proportion of clean energy power generation measures a country's clean electricity production level. The share of electricity consumption in total final energy consumption reflects a country's electrification level. The carbon emission intensity of electricity reflects a country's low-carbon electricity consumption level. The growth rate of new energy power generation reflects a country's efforts and achievements in the green and low-carbon transformation. The formulation and implementation of green and low-carbon policies reflect a country's determination, support and guarantee for the green and low-carbon transformation.

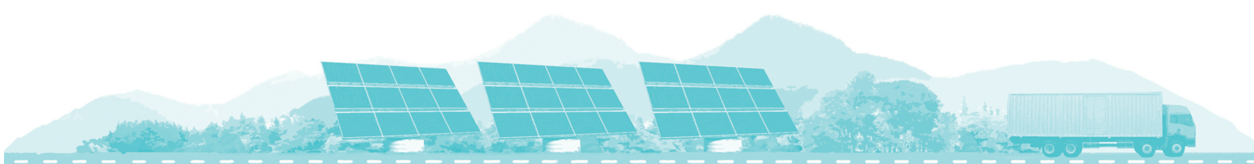


Table 2-3 Connotation and Calculation Method of Secondary Indicators of Green and Low-carbon Development

Primary Indicator	Secondary Indicator	Connotation	Calculation Method
Green and low-carbon development	Proportion of clean energy power generation	Clean electricity production	Clean energy power generation/total power generation
	Share of electricity consumption in total final energy consumption	Electrification level	Electricity consumption/total final energy consumption
	Carbon emission intensity of electricity	Low-carbon electricity consumption	Total carbon emissions from electricity/total electricity consumption
	Growth rate of new energy power generation	Speed of green transition and new energy development	Growth rate of new energy power generation in the past five years
	Formulation and implementation of green and low-carbon policies	Policy guarantee	Scoring qualitatively and quantitatively according to the formulation, implementation and enforcement of green and low-carbon policies

The technological innovation dimension

measures a country's technological innovation level in electricity development. Three secondary indicators are selected, including the application level of new technologies, application level of digital and intelligent technologies, international patents, standards and other innovation achievements. Among them, the application level of new technologies is scored according to the application of new technologies in various aspects of a country's power system, for example, building transmission networks at a higher voltage level or applying advanced energy storage equipment. The application level of digital and intelligent technologies measures a country's efforts in new digital and intelligent technologies, which is represented by the proportion of digital and intelligent technology services in total services. International patents and standards refer to the relevant documents prepared by a country in the target year.

Table 2-4 Connotation and Calculation Method of Secondary Indicators of Technological Innovation

Primary Indicator	Secondary Indicator	Connotation	Calculation Method
Technological innovation	Application level of new technologies	Application of new technologies	Scoring qualitatively and quantitatively according to the application of new technologies in various aspects of a country's power system
	Application level of digital and intelligent technologies	Digitization and intelligence levels	Volume of digital and intelligent technology services/total volume of services
	International patents and standards	Innovation achievements	Scoring qualitatively and quantitatively according to the promulgation of international patents and standards in electricity

2.3 Index Calculation Method

(I) Basic data collection

The collection, processing, and aggregation of basic data required for index calculation are crucial to data accuracy. A combined online and offline approach is employed for data collection in this study. For 13 quantitative indicators such as electricity consumption per capita, installed capacity per capita, grid loss, length of transmission and distribution lines per capita, Share of electricity consumption in total final energy consumption, time to obtain an electricity connection, access to electricity, average power outage duration per household, proportion of clean energy power generation, carbon emission intensity of electricity, growth rate of electricity consumption per capita, growth rate of new energy power generation, and average electricity price, GEIDCO collects data online from public sources such as national statistics bureaus, energy authority websites, and international organizations like the UN, World Bank and IEA.

For three quantitative indicators including electricity supply guarantee capability, interconnection level, international patents and standards, which cannot be directly obtained, a mix of online and offline research methods are used to collect basic data and calculate the index. Evaluation of electricity supply guarantee capability involves gathering data on effective installed capacity, peak load, number, scale and scope of large-scale power outages/rationing across various countries. Evaluation of interconnection level involves researching and collecting information on the grid structures of different countries to determine inter-regional power exchange capacities. Evaluation of international patents and standards entails researching international patents in the electricity sector from international patent databases and collecting information on countries' participation in international standard setting from relevant international organizations such as IEEE, CIGRE, and IEC.

Experts were invited to assess four qualitative indicators of electricity market development level, application level of new technologies, application level of digital and intelligent technologies, formulation and implementation of green and low-carbon policies according to the actual situations in various countries. The electricity market development level is evaluated comprehensively based on the proportion of electricity in market-oriented transactions and construction progress of electricity markets. This includes the evaluation of construction progress of spot markets and ancillary service markets in different countries. Regarding the application level of new technologies, experts consider the application of new technologies in various aspects of the electricity system, such as generation, grid, load and storage. This evaluation encompasses scenarios like the initial use of higher voltage levels or flexible DC transmission technology in the transmission network, introduction of virtual power plant (VPP) technology in the distribution network, and the initial grid connection of offshore wind power. The evaluation of application level of digital and intelligent technologies is based on the provision of digital and intelligent technology services in different countries, including the use of platforms for electricity information management and transaction and the application of smart meters. Lastly, the scoring for the formulation and implementation of green and low-carbon policies is determined by each country's formulation, implementation and enforcement of green and low-carbon policies.

(II) Data standardization methods

Significant variations exist in the raw data of different countries across indicators. Taking electricity consumption per capita as an example, in 2022, Iceland had the highest consumption at 55,000 kWh per year, followed by Norway at 23,000 kWh per year, with the global average of only 3324 kWh per year. Most African countries fell below 1000 kWh per year. In this case, simple normalization will impact the fairness and rationality of calculation results.

The study employs the concept of normal distribution quintiles to standardize all raw data of the indicators. The data are divided into five grades based on ranking: Grade A for the top 20%, Grade B for the 20%-40% range, Grade C for the 40%-60% range, Grade D for the 60%-80% range, and Grade E for the bottom 20%.

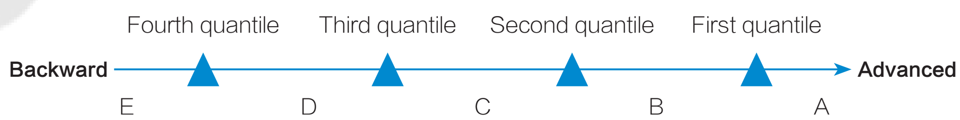


Figure 2-5 Quintile Method

Taking annual per capita electricity consumption as an example

100 countries are divided into five grades: those consuming over 6960 kWh per year are in Grade A, 4440–6960 kWh in Grade B, 2320–4440 kWh in Grade C, 860–2320 kWh in Grade D, and below 860 kWh in Grade E.

Taking installed capacity per capita as an example

100 countries are categorized into five grades: those with installations exceeding 2.36 kWh are in Grade A, 1.55–2.36 kWh in Grade B, 0.8–1.55 kWh in Grade C, 0.23–0.8 kWh in Grade D, and below 0.23 kWh in Grade E.

(III) Weight design method

The weight design method plays a crucial role in the calculation and ranking results of the electricity development index, with the magnitude of indicator weights indicating the influence of the indicators on the final index calculation. This study employs a combined subjective and objective method to comprehensively calculate the weights of primary and secondary indicators in the two-tier indicator model of GEDI.

The subjective–objective weighting method first utilizes the analytic hierarchy process (AHP) to calculate the subjective weights of the indicators and then applies the entropy weight method (EWM) to derive the objective weights of the indicators. Finally, the subjective and objective weights are combined through weighted coupling to obtain the final indicator weights, as depicted in Figure 2–6.

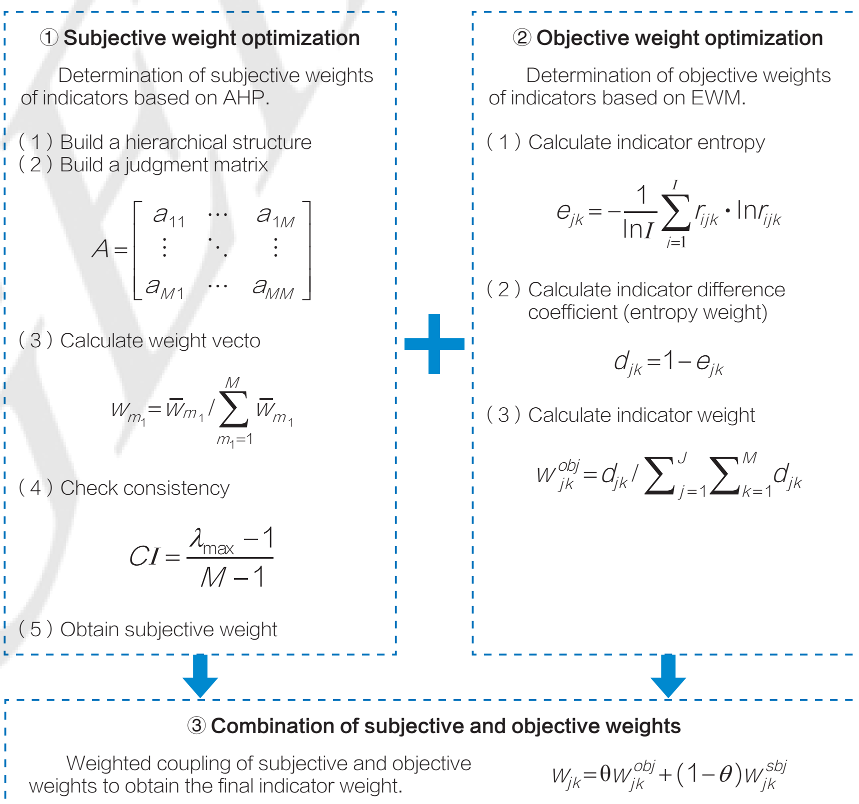


Figure 2-6 Weight Design Method

1. Calculation method of subjective weight

Step 1 Build a hierarchical structure of the indicator system. Based on the established indicator system, a hierarchical structure is formed in which the evaluation purposes are regarded as the goal level, the primary indicators as the criterion level and the secondary indicators as the scheme level.

Step 2 Build a judgment matrix. For indicators of the same level, a scale of 1–9 is used for pairwise comparison to determine the relative importance between indicators and obtain the judgment matrix $\boldsymbol{A}$, which is expressed as follows:

$$\boldsymbol{A}=\left(a_{m_1,m_2}\right)_{M\times M} \tag{2-1}$$

Where: a_{m_1,m_2} represents the importance of the sub-indicator m_1 relative to the sub-indicator m_2 under the same parent indicator; M is the number of indicators.

Step 3 Calculate the indicator weight. The weight of each indicator is calculated as follows:

$$\begin{cases} Q_{m_1}=\prod_{m_2=1}^{M} a_{m_1,m_2} \\ \bar{W}_{m_1}=\sqrt[M]{Q_{m_1}} \\ W_{m_1}=\bar{W}_{m_1}/\sum_{m_1=1}^{M}\bar{W}_{m_1} \end{cases} \tag{2-2}$$

Where: Q_{m_1} is the product of elements in row m_1 of matrix **A**; $\bar{W}_{m_1}$ is Q_{m_1} raised to the power of 1/M; w_{m_1} is the weight of the indicator m_1.

The indicator weight vector W can be expressed as: $W^T=\left[w_1 \cdots w_{m_1} \cdots w_M\right]$.

Step 4 Check the consistency of the judgment matrix. **First,** the maximum eigenvalue λ_{max} of the judgment matrix **A** is calculated as follows:

$$\lambda_{max}=\sum_{m_1=1}^{M}\frac{(\boldsymbol{A}\cdot\boldsymbol{W})_{m_1}}{Mw_{m_1}} \tag{2-3}$$

Where: $(\boldsymbol{A}\cdot\boldsymbol{W})_{m_1}$ represents the No. m_1 element of a new matrix obtained by multiplying matrices $\boldsymbol{A}$ and $\boldsymbol{W}$.

Then, the consistency indicator CI and random consistency ratio CR of the judgment matrix are calculated as follows:

$$\begin{cases} CI=\dfrac{\lambda_{max}-1}{M-1} \\ CR=CI/RI \end{cases} \tag{2-4}$$

Where: RI is the average random consistency indicator, obtained by looking up the table.

When the random consistency ratio CR < 0.01, it is considered that the consistency requirements are met. When CR > 0.01, the judgment matrix needs to be adjusted until it is consistent.

Step 5 Obtain the subjective weight. From Step 1 to Step 4, the weight of each indicator at the criterion level and scheme level is obtained. Through weighted multiplication, the subjective weight of secondary indicators is obtained as follows:

$$w_{jk}^{sbj} = w_j^{PR} \times w_{jk} \tag{2-5}$$

Where: w_{jk}^{sbj} is the final subjective weight of the tertiary indicator k under the secondary indicator j; w_j^{PR} is the subjective weight of the secondary indicator j; w_{jk} is the process value of the subjective weight of the tertiary indicator k under the secondary indicator j.

2. Calculation method of objective weight

The pre-processed sample data matrix $\mathbf{X} = (x'_{ijk})_{I \times J \times M}$ is transformed into a data matrix $\mathbf{R} = (r_{ijk})_{I \times J \times M}$, where: I, J and M are respectively the number of evaluation objects, the number of primary indicators and the number of secondary indicators. It is transformed as follows:

$$r_{ijk} = x'_{ijk} / \sum_{i=1}^{I} x'_{ijk} \tag{2-6}$$

Then, the entropy value e_{jk} of each indicator is calculated as follows:

$$e_{jk} = -\frac{1}{\ln I} \sum_{i=1}^{I} r_{ijk} \cdot \ln r_{ijk} \tag{2-7}$$

The difference coefficient d_{jk} is calculated as follows:

$$d_{jk} = 1 - e_{jk} \tag{2-8}$$

The objective weight w_{jk}^{obj} of the tertiary indicator k is obtained by normalizing d_{jk}:

$$w_{jk}^{obj} = d_{jk} / \sum_{j=1}^{J} \sum_{k=1}^{M} d_{jk} \tag{2-9}$$

3. Combination of subjective and objective weights of secondary indicators

The calculated subjective weight and objective weight are combined to obtain the final weight:

$$W_{jk}=\theta W_{jk}^{obj}+(1-\theta)W_{jk}^{sbj} \tag{2-10}$$

Where: W_{jk} is the final weight value of the secondary indicator j; θ is the objective coefficient, taken as 0.5.

4. Weight calculation of primary indicators

The weight of the primary indicator is obtained by summing the weights of the secondary indicators included:

$$W_j=\sum_{k\in L_j} W_{jk} \tag{2-11}$$

Where: L_j is the set of primary indicator j containing secondary indicators.

Based on the weight calculation results, some countries are selected for a preliminary assessment and ranking of the comprehensive electricity development index, followed by improvement and adjustment of the weight design according to the ranking results.

This study aims to provide a tool for comprehensive assessment of electricity development level, allowing flexibility in weight selection. Different researchers can set weights for indicators at various levels according to their preferences and needs, reflecting different emphases, leading to corresponding variations in calculation and ranking results.

(IV) Country selection

As the first release of GEDI, evaluating the electricity development index for over 190 countries and regions poses significant challenges due to limited access to timely electricity development data in many countries. Considering this, 100 countries are selected for the calculation and ranking of the electricity development index. To represent the global and regional electricity development situations, a certain number of countries from each continent are selected. The total electricity demand of the selected countries should not be less than 95% of the global total electricity demand, with the total electricity demand of selected countries from each continent not falling below 90% of that continent's total electricity demand.

In Asia

34 countries including China, Japan, South Korea and Mongolia are selected, where the combined electricity consumption of the selected countries accounted for **97.2%** of Asia's total electricity consumption, with an installed capacity share of **97.4%** in 2022. Countries with smaller electricity scales or difficult data accesses are excluded from the selection.

Figure 2-7 Asian Countries Included in Electricity Development Index Calculation

In Europe

30 countries including the UK, Germany, Norway and Sweden are selected, where the combined electricity consumption of the selected countries represented **98.3%** of Europe's total electricity consumption, with an installed capacity share of **98.4%** in 2022.

In these maps, all green zebra-striped cells indicate countries or regions that have not been selected for electricity index calculation.

Figure 2-8 European Countries Included in Electricity Development Index Calculation

In Africa

17 countries including South Africa, Egypt, Algeria and Morocco are selected, where the combined electricity consumption of the selected countries accounted for **90.3%** of Africa's total electricity consumption, with an installed capacity share of **90.0%** in 2022.

Figure 2-9 African Countries Included in Electricity Development Index Calculation

In Central and South America (South America and the Caribbean)

14 countries including Brazil, Chile, Argentina and Dominican Republic are selected, where the combined electricity consumption of the selected countries made up **94.1%** of Central and South America's total electricity consumption, with an installed capacity share of **93.4%** in 2022.

Figure 2-10 Central and South American Countries Included in Electricity Development Index Calculation

In North America

Canada, the USA and Mexico are selected.

Figure 2-11 North American Countries Included in Electricity Development Index Calculation

In Oceania

Australia and New Zealand are selected, where the combined electricity consumption of the selected countries represented **91.7%** of Oceania's total electricity consumption, with an installed capacity share of **97.0%** in 2022.

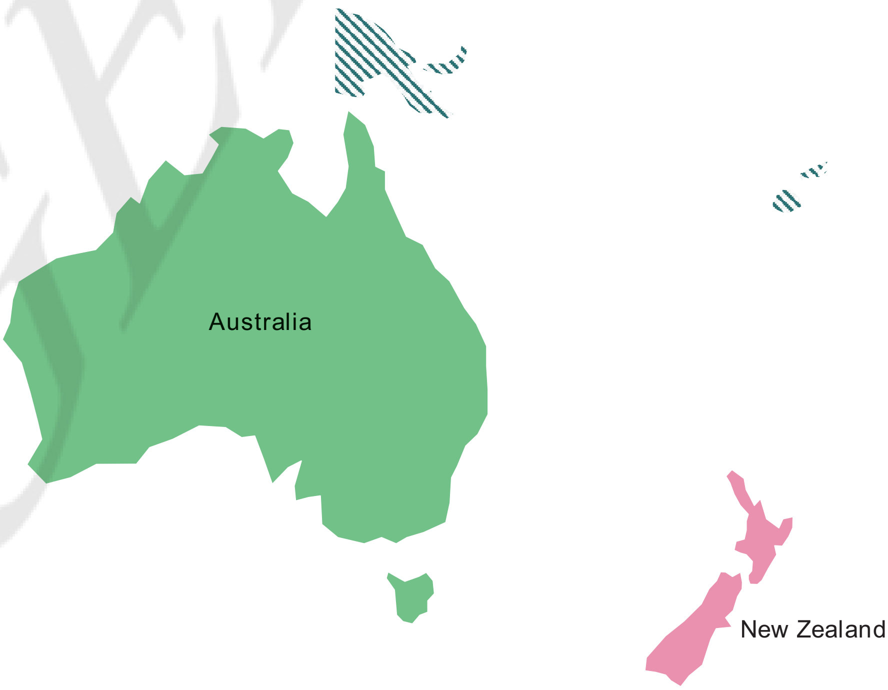


Figure 2-12 Oceanian Countries Included in Electricity Development Index Calculation

3 Analysis and Evaluation of Global Electricity Development Index

3.1 Analysis of Global Electricity Development Index

In this section, the comprehensive electricity development indexes of the world and various continents, alongside specific indicators and secondary indicators, are calculated and horizontally compared. Additionally, the characteristics, advantages, and disadvantages of electricity development across various continents are analyzed through multiple dimensions. These include overall electricity industry development, supply guarantee, consumption services, green and low-carbon development, and technological innovation.

(I) Global electricity development comprehensive index

According to the calculation results of comprehensive electricity development indexes of all continents and special electricity development indexes across different dimensions, **the global comprehensive electricity development index stands at about 73.9 points.** This indicates a robust electricity development foundation, which provides strong support for the steady recovery of the global economy.

By dimension

electricity development is relatively balanced across all dimensions, with green and low-carbon development and technological innovation indexes scoring lower. In recent years, the prolonged and complex Russia-Ukraine conflict has had a huge impact on the global energy system and energy security. The increase in the global average energy price led to the slowing phase-out of traditional energy sources such as coal power, which has affected the global energy and power transition process. Countries should continue to enhance technological innovations in areas such as development and utilization of new energy sources, electricity substitution, and promote sustainable development of electricity.

By region

the comprehensive electricity development indexes in Europe and North America are significantly higher than the global average. Europe boasts the highest comprehensive index, demonstrating well-balanced electricity development across various dimensions. It leads other regions in technological innovation and supply guarantee. Europe is followed by Asia, Central and South America, and Oceania. Comparatively, Africa falls behind across various dimensions. It can be seen that the characteristics of electricity development indexes in various regions are highly related to these regions' economic development levels and development stages.

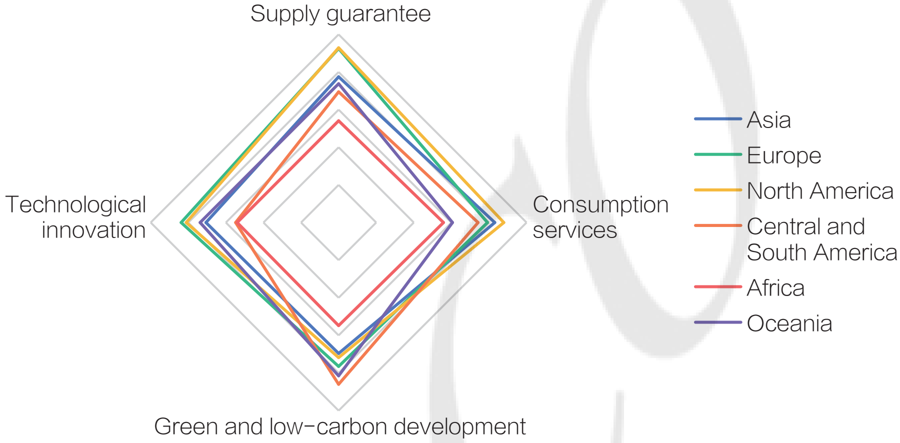


Figure 3-1 Comparison of Electricity Development in Various Dimensions across Various Continents

Table 3-1 Comparison of Calculation Results of Various Indicators in the World and Various Continents by Dimension

Indicator	World	Asia	Europe	North America	Central and South America	Africa	Oceania
Supply guarantee	75.2	77.5	92.5	92.9	69.5	54.1	73.8
Consumption services	77.3	83.1	79.2	87.9	74.2	55.8	60.6
Green and low-carbon development	69.0	69.6	76.5	71.8	86.0	54.8	81.5
Technological innovation	68.6	70.6	83.8	81.1	54.8	54.0	73.7
Comprehensive index	73.9	76.9	84.4	86.0	72.7	54.7	71.4

(II) Special index of supply guarantee

Table 3-2 Comparison of Calculation Results of Secondary Indicators in Electricity Supply Guarantee Dimension across Various Continents

Indicator\Region	World	Asia	Europe	North America	Central and South America	Africa	Oceania
Installed capacity per capita (kW)	1.02	0.91	2.04	2.87	0.80	0.17	2.50
Access to electricity	90.5%	98.8%	100%	100%	98.3%	54.8%	81.4%
Grid loss	7.7%	7.0%	8.3%	5.5%	17.2%	16.9%	4.8%
Power grid length per capita (m)	7.7	4.7	21.5	29.2	9.2	2.7	29.1
Electricity supply guarantee capability	3	3	4	3.5	3.5	1	3
Interconnection level	2	2	5	1.5	2	2.5	0
Special index of supply guarantee	75.2	77.5	92.5	92.9	69.5	54.1	73.8

The special index of global electricity supply guarantee is 75.2 points, with North America scoring the highest and Africa the lowest.

In terms of installed capacity per capita, the global average is 1.02 kW. The figure in North America is the highest, reaching 2.87 kW while that in Africa is the lowest, merely 0.17 kW; In terms of access to electricity, the global average is approximately 90.5%. The percentages in Europe and North America reach 100%, while that in Africa is only 54.8%. There are still about 600 million people without access to electricity; Regarding power transmission and distribution network losses, the global average is about 7.7%. The loss rates in Central and South America and Africa are the highest, up to about 17%. The main reason lies in the exclusion of electricity consumed through illegal connections from the sales statistics, leading to inflated loss figures. The loss rate in Oceania is the lowest, only 4.81%. This is due to the concentration of electrical load in major cities and the proximity of the energy sources to these load areas; In terms of the length of transmission and distribution lines per capita, the global average is about 7.7m. The figures in North America and Oceania are the highest, approaching 30m, mainly due to their expansive land areas and well-developed distribution networks. The figures in Asia, Africa, and Central and South America are shorter, all below 10m.

In terms of electricity supply guarantee capability, Europe scores the highest, mainly due to complete electricity infrastructure, a relatively slow load growth rate, and no large-scale power outages or rationing under extreme heat in the summer of 2022. Consequently, the region enjoys a high level of electricity supply reliability. Africa scores the lowest. The electricity infrastructure in many Sub-Saharan African countries is inadequate, failing to meet their economic and social needs. Countries such as Nigeria, South Africa, and Zimbabwe have experienced large-scale power outages and rationing, with some areas experiencing daily power outages lasting 6-12 hours during peak periods, demonstrating an insufficient electricity supply guarantee capability; In terms of interconnection, Europe ranks highest. With the efforts of the EU and ENTSO-E, the region has preliminarily established a transnational AC interconnected power grid, leading the world in transnational and inter-regional electricity exchange. North America and Central and South America follow closely. Guided by the regional electricity markets, these regions have developed large-scale inter-regional and transnational AC interconnected power grids, and exhibit relatively closer power grid interconnections. Africa scores the lowest. Many countries in the region have limited internal grid coverage and a small scale of inter-regional and transnational power interconnection. Only some countries there such as South Africa and Egypt have achieved higher levels of power interconnections.

(III) Special index of consumer services

Table 3-3 Comparison of Calculation Results of Secondary Indicators in Electricity Consumption Services Dimension across Various Continents

Indicator\Region	World	Asia	Europe	North America	Central and South America	Africa	Oceania
Electricity consumption per capita (kWh/year)	3324	3190	5481	9920	2201	528	6844
Average power outage duration per household (min)	1400	587	322	65	404	6500	13880
Average electricity price (US cent/kWh)	14	10.7	22.5	16.3	14.5	8.1	24.0
Time to obtain an electricity connection (day)	42	25	41	34	36	47	53
Electricity market development level	2.5	1	4	3.5	2.5	2.5	3.5
Growth rate of electricity consumption per capita	1.7%	3.5%	1.6%	0.6%	0.5%	-1.4%	-1.3%
Special index of consumer services	77.3	83.1	79.2	87.9	74.2	55.8	60.6

The special index of global electricity consumption services is 77.3 points, with North America scoring the highest and Africa the lowest.

Regarding electricity consumption per capita, the global average is about 3,324 kWh/year. North America reports the highest consumption at about 9,920 kWh/year while Africa has the lowest at only 528 kWh/year; As for the average power outage duration per household, the global average stands at about 1,400 minutes. North America experiences the shortest outages, averaging 65 minutes, while Oceania faces the highest, up to 13,880 minutes. The main reason lies in the occurrences of natural disasters such as widespread wildfires and floods affected by global warming in Oceania in 2022, causing damage to electricity infrastructure and large-scale power outages in countries such as Australia; In terms of average electricity price, the global average is about 14 US cents/kWh. The prices in Oceania and Europe are the highest, exceeding 22 US cents/kWh. In comparison, the price in Africa is the lowest, only 8.1 US cents/kWh, largely attributed to the high subsidies for electricity consumption provided by many African governments; As for the time to obtain an electricity connection, the global level averages 42 days or so. Oceania experiences the longest time, reaching about 53 days. In contrast, Asia boasts the shortest time, merely 25 days, thanks to the high efficiency of power access in East Asian and Gulf countries.

In terms of electricity market development level, Europe scores the highest while Asia sees the lowest. The electricity markets in European countries started early, with a high degree of marketization, rich transaction varieties, and complete transaction strategies. Due to significant variations in resource endowments among Northern Europe, Southern Europe, Eastern Europe, and Western Europe, the scale of market-oriented electricity transactions is relatively large in the region. Globally, the electricity market in Europe takes the lead. The electricity market in Asia is relatively underdeveloped. Many countries in the region have yet to establish electricity markets and many that have carried out electricity market reforms feature limited electricity transaction varieties. Additionally, some countries and sub-regions have not yet established electricity spot markets. Overall, the transnational power interconnection level in Asia is low, and various countries still manage their electricity supply and demand independently; In terms of the growth rate of electricity consumption per capita, the global average stays at 1.7% or so. The growth rate in Asia is the highest, reaching 3.5%. By contrast, the growth rate in Africa is the lowest, at -1.4%. The main reason lies in the lower-than-expected economic recovery and a significant reduction in electricity demand from 2021 to 2022.

(IV) Special index of green and low-carbon development

Table 3-4 Comparison of Calculation Results of Secondary Indicators in Green and Low-carbon Transformation Dimension across Various Continents

Indicator\Region	World	Asia	Europe	North America	Central and South America	Africa	Oceania
Proportion of clean energy power generation	38.6%	29.6%	54.7%	45.8%	67.9%	24.7%	37.5%
Share of electricity consumption in total final energy consumption	20.6%	23.4%	18.8%	21.9%	20.6%	10.3%	23.8%
Carbon emission intensity of electricity (kg CO_2/kWh)	0.49	0.62	0.30	0.35	0.19	0.61	0.49
Growth rate of new energy power generation	16.6%	24.9%	11.0%	13.9%	28.1%	25.2%	25.4%
Formulation and implementation of green and low-carbon policies	2.5	3	4	2.5	2	1	3
Special index of green and low-carbon development	69.0	69.6	76.5	71.8	86.0	54.8	81.5

The special index of global green and low-carbon development is 69.0 points, with Central and South America scoring the highest and Africa the lowest.

In terms of the proportion of clean energy power generation, the global average stands at approximately 38.6%. Central and South America leads with a high of 67.9%, followed by Europe at about 54.7%. Africa sees the lowest at 24.7%; In terms of the rate of electricity consumption in total final energy consumption, the global average is around 20.6%. Oceania reports the highest at 23.8%, while Africa has the lowest at 10.3%. Given its early stages of urbanization and industrialization, Africa's energy consumption is predominantly characterized by biomass energy, including firewood, which accounts for a significant portion of its final energy consumption; With regard to the carbon emission intensity of electricity, the global average is 0.49

kg CO_2/kWh. Asia and Africa have the highest levels, both surpassing 0.6 kg CO_2/kWh. This is primarily because fossil fuel-based power generation still plays an absolutely dominant role in the energy source structures of many Asian and African countries. Central and South America sees the lowest level, only 0.19 kg CO_2/kWh, thanks largely to abundant hydropower resources; As to the average annual growth rate of new energy power generation, the global average is about 16.6%. Central and South America exhibits the highest growth rate of 28.1%, while Europe has the lowest growth rate of 11%. This is mainly because new energy power generation was developed early in Europe, which means that the proportion of new energy power generation there is already quite high. Additionally, the retirement of coal-fired thermal power units in recent years, coupled with the challenges in new energy consumption, has slowed down the development speed of new energy.

In regard to the formulation and implementation of green and low-carbon policies, Europe is the leading region. Most European countries including France and Germany have set clear development goals at the legal level to achieve carbon neutrality by 2050 and developed plans to shut down coal-fired units. Africa and Central and South America have lower scores. Economic strain and policy changes have led several countries in these regions to suspend subsidies for new energy power generation projects or delay the development plans of new energy projects. Moreover, some countries have revised their new energy development goals.

(V) Special index of technological innovation

Table 3-5 Comparison of Calculation Results of Secondary Indicators in Dimension of Technological Innovation of Electricity across Various Continents

Indicator\Region	World	Asia	Europe	North America	Central and South America	Africa	Oceania
Application level of new technologies	3.2	3	4.5	2.5	2	3	2
Application level of digital and intelligent technologies	2.5	2	4	2.5	2	1	4
International patents and standards	4	4	4.5	4	1.5	0.5	2
Special index of technological innovation	68.6	70.6	83.8	81.1	54.8	54.0	73.7

The special index of technological innovation of global electricity is 68.6 points, with Europe scoring the highest and Africa the lowest.

In terms of the application of new electricity technologies, Europe ranks the highest and Oceania ranks the lowest. Europe has applied new technologies in many fields, including flexible DC transmission, coordinated electricity-hydrogen development, and VPPs. In comparison, Oceania has employed fewer such technologies; Regarding the application of digital and intelligent technologies, Europe and Oceania perform the best, thanks to the popularization and application of intelligent meters and the deep integration of digital and information technologies with power systems. Africa falls behind other regions in this area, with sluggish electricity development and limited application of digital and intelligent technologies in most businesses; As for international patents and standards in the electricity sector, Europe also stands out as a leader. The region is home to influential international organizations, including the International Electrotechnical Commission (IEC) and the International Council on Large Electric Systems (CIGRE). Developed countries such as France, Germany, Spain, Portugal, and Italy have taken the lead in formulating many international standards in the electricity sector. Internationally renowned power equipment enterprises such as Siemens and ABB have possessed a significant number of international patents in the industry. Africa scores the lowest. Except for countries such as South Africa and Egypt, most African countries show low participation in international patent applications and standards in the electricity sector.

3.2 Analysis of Electricity Development Index in Various Continents

(I) Asia

Table 3-6 Basic Data of Economic, Social and Electricity Development in Asia

Economy and Society	Data	Electricity Development	Data
Area (million km^2)	31.22	Total installed capacity (GW)	4220
Population (million)	4650	Total electricity consumption (PWh)	14.8
GDP (USD 1 trillion)	37.4	Installed capacity per capita (kW)	0.91
GDP per capita (USD)	8054	Electricity consumption per capita (kWh)	3190
Share of electricity consumption in total final energy consumption	23.4%	Access to electricity	98.8%
Proportion of clean energy power generation	29.5%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.62

Asia is the world's largest continent in terms of area, population, and economic volume. It stands as a crucial engine for global economic development. Most countries within the region are developing nations, possessing great development potential. In recent years, Asia has experienced a consistent rise in electricity demand. The region has significantly expanded its installed electric power capacity and continuously enlarged its power grid. Additionally, the share of electricity consumption in total final energy consumption has continuously risen, signaling robust electricity development.

From 2017 to 2022, the total electricity consumption in Asia rose from **11,800** TWh to **14,800** TWh, with an average annual growth rate of **3.5%**

From 2017 to 2022, the total electricity consumption in Asia rose from 11,800 TWh to 14,800 TWh, with an average annual growth rate of 3.5%. The total installed capacity increased from 3,360 GW to 4,220 GW, with an average annual growth rate of 4.65%. The electricity production capacity and consumption level illustrated steady improvement. In 2022, the electricity consumption per capita and installed capacity per capita in Asia reached 3,190 kWh and 0.91 kW respectively, slightly lower than the global average. Some countries and regions in South Asia and Southeast Asia fell behind in electricity development. By 2022, 98% of Asia's population had access to electricity, with most countries in the region achieving universal electricity access for all households.

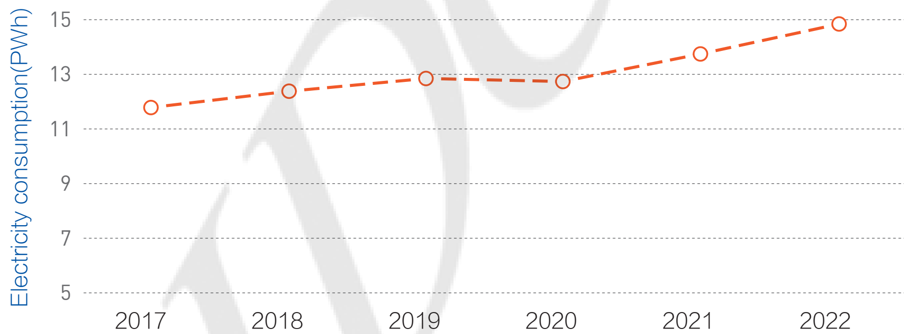


Figure 3-2 Growth and Change Trend of Electricity Consumption in Asia

From 2017 to 2022, the proportion of clean energy power generation in Asia increased from **23.3%** to **29.5%**

From 2017 to 2022, the proportion of clean energy power generation in Asia increased from 23.3% to 29.5%, with a peak value of 32.6% in 2021. In general, Asia continues to make progress in increasing the portion of clean and low-carbon electricity. However, coal-fired thermal power remains the predominant source in the region's power generation structure, indicating a challenging clean and low-carbon transformation task. In 2022, the share of electricity consumption in total final energy consumption was 23.4% in Asia, and electricity was gradually developing into an important source of final energy consumption.

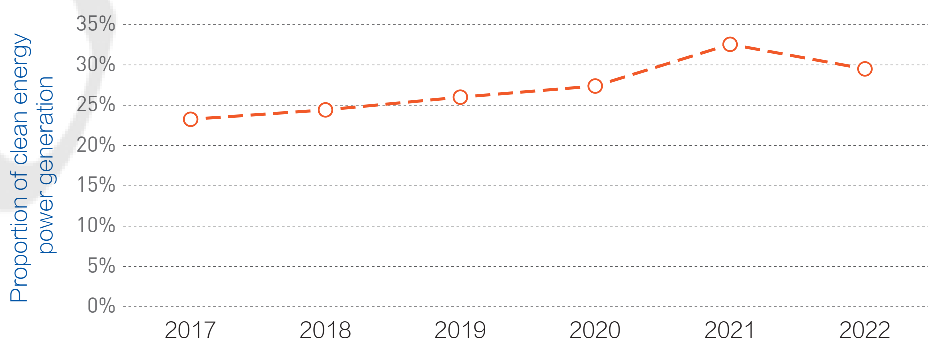


Figure 3-3 Trend of Proportion of Clean Energy Power Generation in Asia

Asia's comprehensive electricity development index is 76.9 points, slightly higher than the global comprehensive index.

According to the calculation results of electricity development index, the special index of consumption services is higher than the global average, while the special index of green and low-carbon development is relatively lower. Among the 34 Asian countries included in the electricity development index evaluation, the top three are China, South Korea, and Japan, which are also currently the largest economies in Asia.

Figure 3-4 Electricity Development Level of Asia in Different Dimensions

In the future, **the electricity development level should be enhanced in Asia. First,** it is necessary to further promote the development and utilization of clean energy, reduce fossil fuel-based power generation, and accelerate the transition to clean and low-carbon electricity; **Second,** economies with rapid electricity development such as China, Japan, and South Korea are encouraged to proactively provide technological support for countries that lag behind in this regard, aiming to narrow the gap in electricity development among countries within the region; **Third,** digital and intelligent technologies should be utilized to further strengthen the climate resilience of the electricity system under extreme weather conditions and improve its ability to consume intermittent and fluctuating new energy, thereby comprehensively enhancing the electricity supply guarantee capability.

Table 3-7 Ranking and Scores of 34 Asian Countries in Electricity Development Index

Ranking	Country	Score	Ranking	Country	Score
1	China	90.8	9	Kuwait	78.7
2	South Korea	86.3	10	Qatar	78.4
3	Singapore	85.5	11	Bahrain	76.9
4	Japan	85.1	12	Laos	73.2
5	Kazakhstan	82.3	13	Oman	72.6
6	United Arab Emirates	80.9	14	Malaysia	72.2
7	Israel	79.9	15	Uzbekistan	71.5
8	Saudi Arabia	79.8	16	Vietnam	71.5

Continued Table

Ranking	Country	Score	Ranking	Country	Score
17	Indonesia	70.1	26	Mongolia	64.9
18	Azerbaijan	69.8	27	The Philippines	64.1
19	Thailand	69.2	28	Pakistan	64.1
20	Kyrgyzstan	69.2	29	Nepal	60.9
21	Georgia	69.1	30	Sri Lanka	60.8
22	Jordan	68.3	31	Bangladesh	59.1
23	Iran	67.9	32	Cambodia	58.8
24	India	65.6	33	Myanmar	54.7
25	Tajikistan	65.0	34	Iraq	52.0

(II) Europe

Table 3-8 Basic Data of Economic, Social and Electricity Development in Europe

Economy and Society	Data	Electricity Development	Data
Area (million km^2)	23.78	Total installed capacity (GW)	1690
Population (million)	830	Total electricity consumption (PWh)	4.5
GDP (USD 1 trillion)	23.8	Installed capacity per capita (kW)	2.0
GDP per capita (1,000 USD)	28.8	Electricity consumption per capita (kWh)	5481
Share of electricity consumption in total final energy consumption	18.8%	Access to electricity	100%
Proportion of clean energy power generation	54.7%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.3

With a developed economy and society, Europe takes the lead in the world in promoting clean energy development, coping with climate change, and advancing regional integration. Overall, Europe boasts complete electricity infrastructure, a robust electricity supply capacity, and a high electricity consumption level. In the last century, the region already realized transnational and inter-regional power grid interconnections and enabled all of its population to have access to electricity. Europe began the transition to clean and low-carbon electricity early, spearheading global technological innovation in the field. In recent years, due to the impact of the energy supply crisis caused by the Russia-Ukraine conflict and other factors, combined with a continuous decline in the total population and a continuous improvement of the energy efficiency level, the growth of electricity consumption in Europe has generally shown a downward trend.

From 2017 to 2022, Europe's total electricity consumption decreased from 4,640 TWh to 4,530 TWh, with an average annual growth rate of −0.5%

From 2017 to 2022, Europe's total electricity consumption decreased from 4,640 TWh to 4,530 TWh, with an average annual growth rate of −0.5%. Its total installed capacity increased from 1,530 GW to 1,690 GW, with an average annual growth rate of 1.93%. In 2022, Europe's electricity consumption per capita and installed capacity per capita reached 5,481 kWh and 2.04 kW respectively, nearly twice the global average.

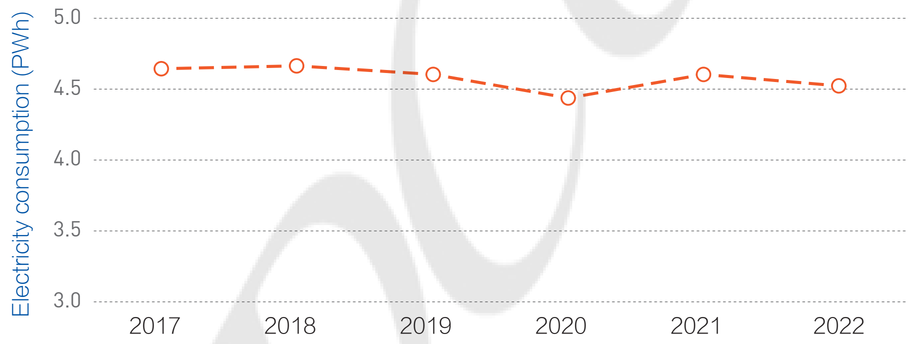


Figure 3-5　Growth Trend of Electricity Consumption in Europe

From 2017 to 2022, the proportion of clean energy power generation in Europe increased from 50.8% to 54.7%, with a peak value of 57.5% in 2020

From 2017 to 2022, the proportion of clean energy power generation in Europe increased from 50.8% to 54.7%, with a peak value of 57.5% in 2020, indicating a relatively high clean and low-carbon development level. In 2022, Europe's share of electricity consumption in total final energy consumption was 18.8%, lower than the global average. Russia, Belarus, Greece, and some other countries reported relatively low proportions.

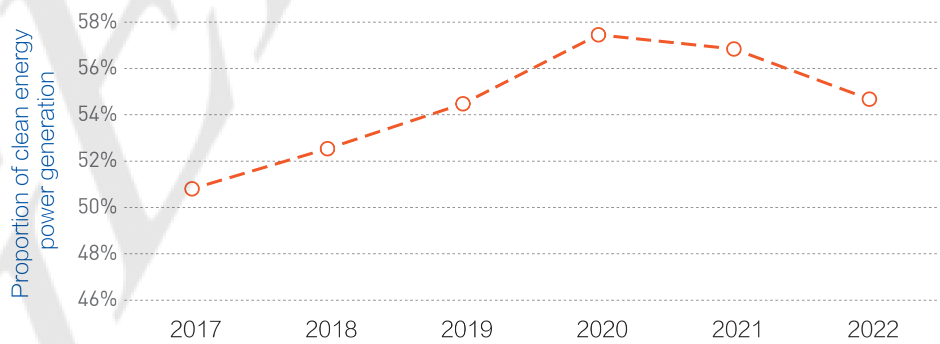


Figure 3-6　Trend of Proportion of Clean Energy Power Generation in Europe

According to the calculation results of electricity development index, Europe's comprehensive electricity development index is 84.4 points, positioning it as the leading region in this aspect.

The electricity supply guarantee and technological innovation indexes score the highest. Among the 30 European countries included in the electricity development index evaluation, the top three are Sweden, Norway, and Switzerland, which also rank among the top 100 countries globally in terms of electricity development index.

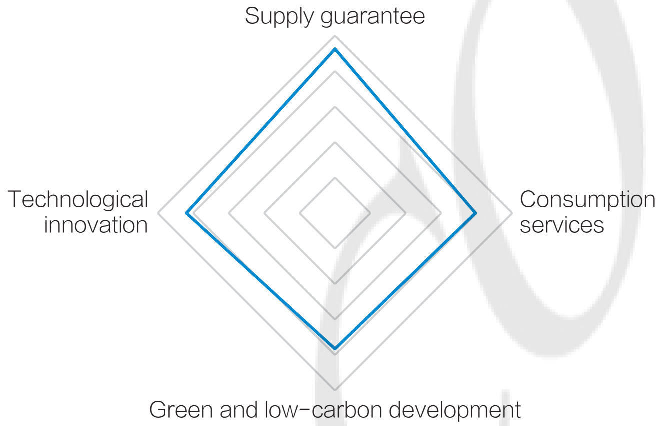


Figure 3-7 Electricity Development Level of Europe in Different Dimensions

In the future, **the electricity development level should be further enhanced in Europe**. **First,** there is a need to further expand the scale of new energy development, which will help bridge the gap between electricity supply and demand as thermal power is gradually phased out; **second,** some countries should further shorten the time to obtain an electricity connection and improve the electricity services; **third,** countries with high fossil fuel consumption need to strengthen electricity replacement and improve electrification level.

Table 3-9 Ranking and Scores of 30 European Countries in Electricity Development Index

Ranking	Country	Score	Ranking	Country	Score
1	Sweden	93.9	16	Belgium	81.1
2	Norway	92.8	17	Russia	80.2
3	Switzerland	91.5	18	Greece	77.1
4	Denmark	91.4	19	Slovakia	76.9
5	France	91.0	20	Slovenia	76.7
6	Iceland	86.7	21	Bulgaria	76.0
7	Portugal	86.3	22	Czech Republic	75.8
8	Germany	86.3	23	Belarus	75.7
9	Austria	85.7	24	Türkiye	75.2
10	Spain	85.0	25	Poland	75.1
11	Finland	84.4	26	Hungary	74.7
12	The Netherlands	83.9	27	Ukraine	74.2
13	Italy	83.3	28	Croatia	73.3
14	UK	83.2	29	Serbia	71.4
15	Ireland	82.9	30	Romania	68.3

(III) Africa

Table 3-10 Basic Data of Economic, Social and Electricity Development in Africa

Economy and Society	Data	Electricity Development	Data
Area (million km^2)	30.03	Total installed capacity (GW)	246
Population (million)	1440	Total electricity consumption (PWh)	0.76
GDP (USD 1 trillion)	2.9	Installed capacity per capita (kW)	0.17
GDP per capita (USD)	2011	Electricity consumption per capita (kWh)	528
Share of electricity consumption in total final energy consumption	10.3%	Access to electricity	54.8%
Proportion of clean energy power generation	24.7%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.61

Africa is the continent with the largest number of developing countries in the world, and a region with the greatest development potential. In recent years, with increasingly stable political situation, continuous release of demographic dividend and improved business environment, African countries have become an important growth pole of the world economy. They are ushering in a new era characterized by industrialization, urbanization and regional integration. However, African countries are facing severe challenges such as weak development foundations, lagging infrastructure construction, and urgent need to improve their capabilities to guarantee energy and electricity supply and to address climate change. Nearly half of Africa's population still has no access to electricity while only 54.8% has access to electricity.

From 2017 to 2022, Africa's total electricity consumption increased from 710 TWh to 760 TWh, with an average annual growth rate of 1.3%

From 2017 to 2022, Africa's total electricity consumption increased from 710 TWh to 760 TWh, with an average annual growth rate of 1.3%, and its total installed capacity increased from 209 GW to 246 GW, with an average annual growth rate of 3.26%. In 2022, Africa's electricity consumption per capita and installed capacity per capita reached 528 kWh and 0.17 kW respectively, about one-sixth of the global average.

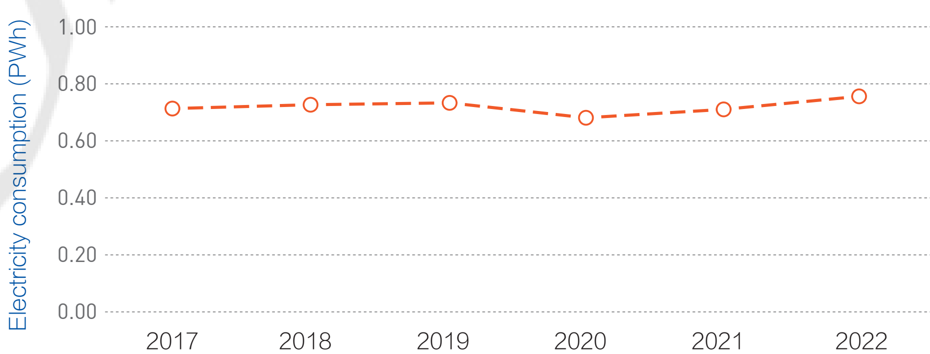


Figure 3-8 Growth and Change Trend of Electricity Consumption in Africa

From 2017 to 2022, Africa's proportion of clean energy power generation increased from **20.2%** to **24.7%**

From 2017 to 2022, Africa's proportion of clean energy power generation increased from 20.2% to 24.7%, with a good momentum for the transition towards clean and low-carbon electricity. In 2022, Africa's share of electricity consumption in total final energy consumption was only 10.3%, half of the global average.

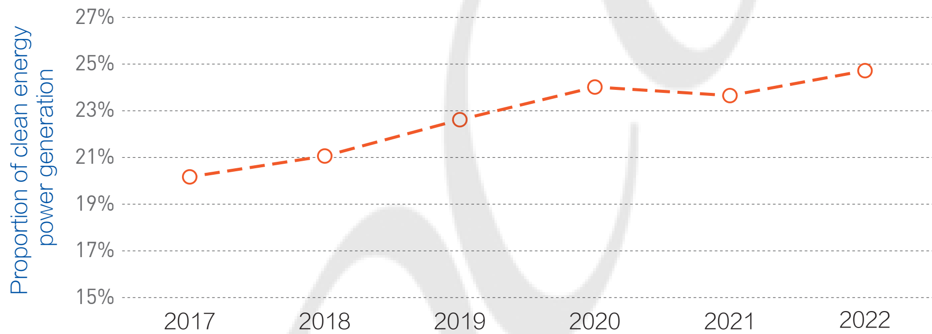


Figure 3-9 Trend of Proportion of Clean Energy Power Generation in Africa

Africa's comprehensive electricity development index is 54.7 points, which is far lower than the level of the global comprehensive index.

According to the calculation results of the electricity development index, Africa's scores in all dimensions are among the lower in the world. Among the 17 African countries included in electricity development index calculation, only Egypt ranks among the top 50.

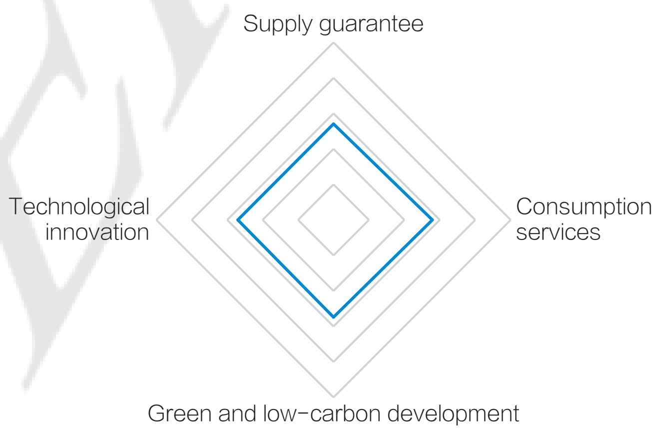


Figure 3-10 Electricity Development Level of Africa in Different Dimensions

In order to improve the electricity development level, it is crucial for Africa to speed up the construction of electricity infrastructure, increase access to electricity, accelerate clean energy development, increase the share of electricity consumption in total final energy consumption, build a sustainable electricity system, and guarantee electricity supply for economic and social development.

Table 3-11 Ranking and Scores of 17 African Countries in Electricity Development Index

Ranking	Country	Score	Ranking	Country	Score
1	Egypt	73.0	10	Senegal	57.7
2	Morocco	70.1	11	Cameroon	56.0
3	Algeria	69.2	12	Angola	55.1
4	South Africa	68.2	13	Nigeria	55.1
5	Libya	67.3	14	Zambia	54.7
6	Tunisia	63.1	15	Uganda	53.9
7	Ghana	58.3	16	Tanzania	53.7
8	Côte d'Ivoire	58.1	17	Ethiopia	52.9
9	Kenya	57.9			

(IV) Central and South America

Table 3-12 Basic Data of Economic, Social and Electricity Development in Central and South America

Economy and Society	Data	Electricity Development	Data
Area (million km^2)	18.57	Total installed capacity (GW)	430
Population (million)	535	Total electricity consumption (PWh)	1.18
GDP (USD 1 trillion)	5.1	Installed capacity per capita (kW)	0.8
GDP per capita (USD)	9520	Electricity consumption per capita (kWh)	2201
Share of electricity consumption in total final energy consumption	20.6%	Access to electricity	98.3%
Proportion of clean energy power generation	67.9%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.19

Composed of emerging market countries and developing economies, Central and South America boasts rich natural resources, a sound foundation for industry, human resources and regional integration, and significant advantages in sustainable development, but its capabilities to allocate energy and electricity and address climate change are facing severe challenges. At present, 98.3% of Central and South America's population has access to electricity, and some still have no access to electricity.

From 2017 to 2022, Central and South America's total electricity consumption increased from 1,100 TWh to 1,180 TWh, with an average annual growth rate of 1.3%

From 2017 to 2022, Central and South America's total electricity consumption increased from 1,100 TWh to 1,180 TWh, with an average annual growth rate of 1.3%; its total installed capacity increased from 374 GW to 428 GW, with an average annual growth rate of 2.73%. In 2022, Central and South America's electricity consumption per capita and installed capacity per capita reached 2,201 kWh and 0.8 kW respectively, about 30% lower than the global average.

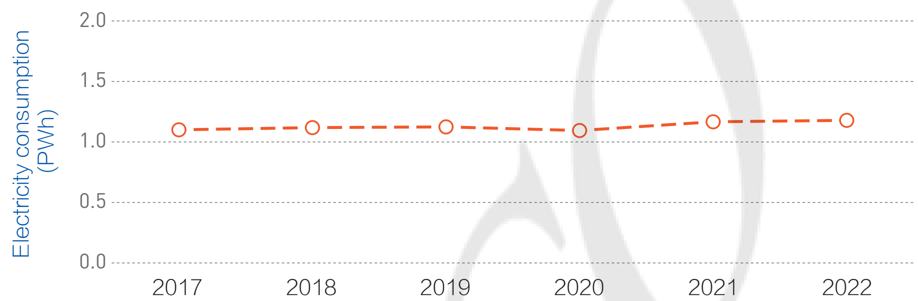


Figure 3-11 Growth and Change Trend of Electricity Consumption in Central and South America

From 2017 to 2022, Central and South America's proportion of clean energy generation increased from **65.9%** to **67.9%**

From 2017 to 2022, Central and South America's proportion of clean energy power generation increased from 65.9% to 67.9%, with a peak value of 70.1% in 2020. Thanks to sufficient hydropower resources, Central and South America's proportion of clean energy power generation is far ahead of other regions in the world. In 2022, Central and South America's share of electricity consumption in total final energy consumption reached 20.55%, which is the global average.

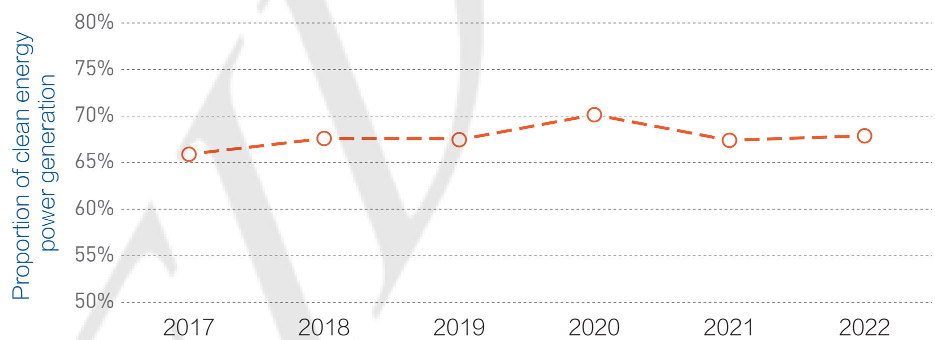


Figure 3-12 Trend of Proportion of Clean Energy Power Generation in Central and South America

Central and South America's comprehensive electricity development index is 72.7 points, which is slightly lower than the global comprehensive index.

According to the calculation results of the electricity development index, the score in the green and low-carbon development index is at the global leading level. Among the 14 countries in Central and South America included in electricity development index calculation, Chile, Brazil, Uruguay and Argentina rank higher.

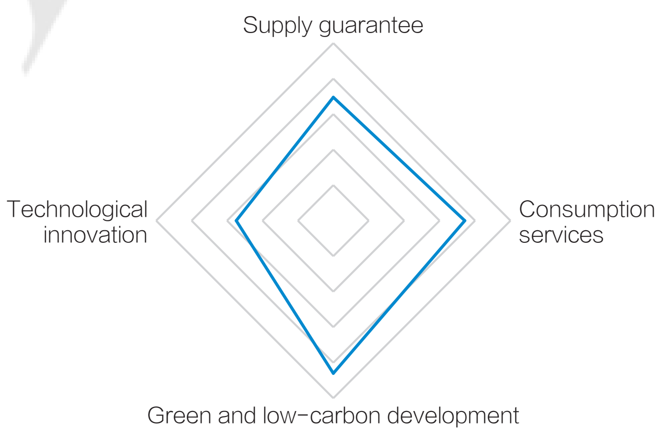


Figure 3-13 Electricity Development Level of Central and South America in Different Dimensions

In order to improve the electricity development level, Central and South America should make the following efforts. **First,** enhance the capability to guarantee electricity supply and strengthen the capability of electricity supply to support economic and social development. **Second,** strengthen technological innovation and build a digital intelligent electricity system to serve the larger-scale development and consumption of new energy and the safe and stable operation of the electricity system.

Table 3-13 Ranking and Scores of 14 Central and South American Countries in Electricity Development Index

Ranking	Country	Score	Ranking	Country	Score
1	Chile	82.7	8	Peru	71.7
2	Brazil	76.1	9	Ecuador	69.4
3	Uruguay	76.0	10	Venezuela	66.4
4	Argentina	74.8	11	Puerto Rico	65.8
5	Panama	72.8	12	Dominican Republic	62.9
6	Colombia	72.5	13	Bolivia	61.5
7	Costa Rica	72.0	14	Cuba	61.3

(V) North America

Table 3-14 Basic Data of Economic, Social and Electricity Development in North America

Economy and Society	Data	Electricity Development	Data
Area (million km^2)	23.96	Total installed capacity (GW)	1440
Population (million)	502	Total electricity consumption (PWh)	4.98
GDP (USD 1 trillion)	29.07	Installed capacity per capita (kW)	2.87
GDP per capita (USD)	57882	Electricity consumption per capita (kWh)	9920
Share of electricity consumption in total final energy consumption	21.9%	Access to electricity	100%
Proportion of clean energy power generation	45.7%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.35

With a developed economy and society, North America has close regional cooperation, a high level of free trade and economic integration, leading technological innovation, a good business environment, large energy resource reserves and complete energy and electricity infrastructure. At the same time, it faces problems such as old infrastructure, high fossil fuel consumption and large carbon emissions. In 2022, the carbon emissions per capita in the electricity industry was 3.52 tonnes, twice higher than the global average. In North America, the electricity development started early. In the last century, transnational and inter-regional electricity interconnection had been realized, and 100% of its population has access to electricity.

From 2017 to 2022, North America's total electricity consumption increased from **4,720** TWh to **4,980** TWh, with an average annual growth rate of **1.08%**

From 2017 to 2022, North America's total electricity consumption increased from 4,720 TWh to 4,980 TWh, with an average annual growth rate of 1.08%; its total installed capacity increased from 1,327 GW to 1,440 GW, with an average annual growth rate of 1.64%. In 2022, North America's electricity consumption per capita and installed capacity per capita reached 9,920 kWh and 2.87 kW respectively, nearly three times the global average.

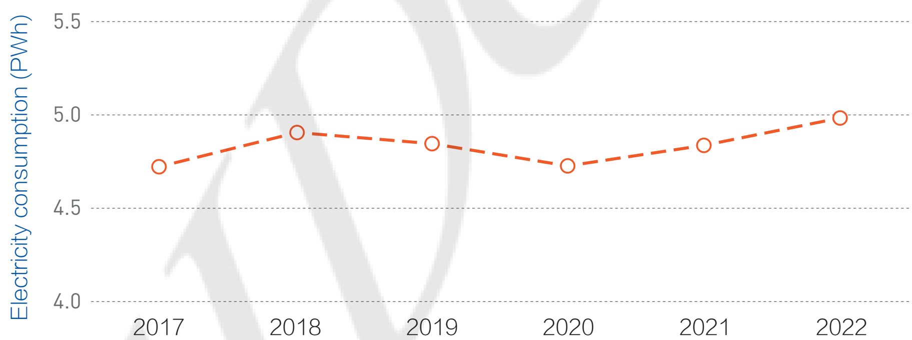


Figure 3-14 Growth and Change Trend of Electricity Consumption in North America

From 2017 to 2022, North America's proportion of clean energy power generation increased from **42.1%** to **45.7%**

From 2017 to 2022, North America's proportion of clean energy power generation increased from 42.1% to 45.7%, showing a good momentum for the transition towards green and low-carbon electricity. In 2022, North America's share of electricity consumption in total final energy consumption reached 21.9%, slightly higher than the global average. The USA's was 21.4%, the lowest, and Mexico's 25.7%, the highest.

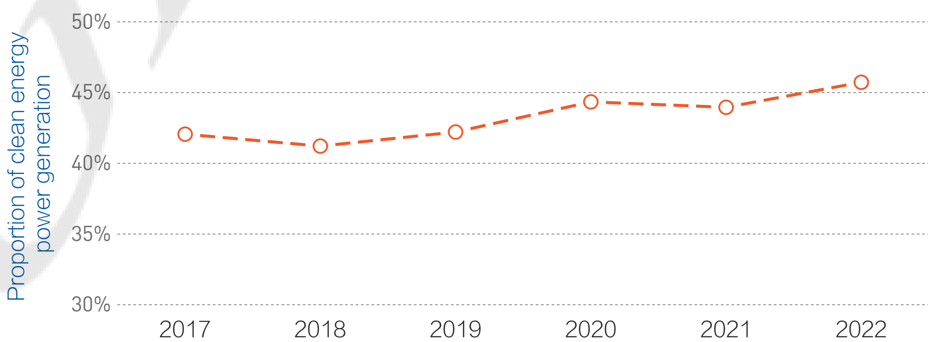


Figure 3-15 Trend of Proportion of Clean Energy Power Generation in North America

North America's comprehensive electricity development index is 86.0 points, which is higher than the level of the global comprehensive index.

According to the calculation results of the electricity development index, it is at the global leading level in the electricity supply guarantee and consumption services indexes, and there is still room for improvement in green and low-carbon development, and technological innovation. Among the three North American countries included in electricity development index calculation, Canada and the USA rank among the top in the world.

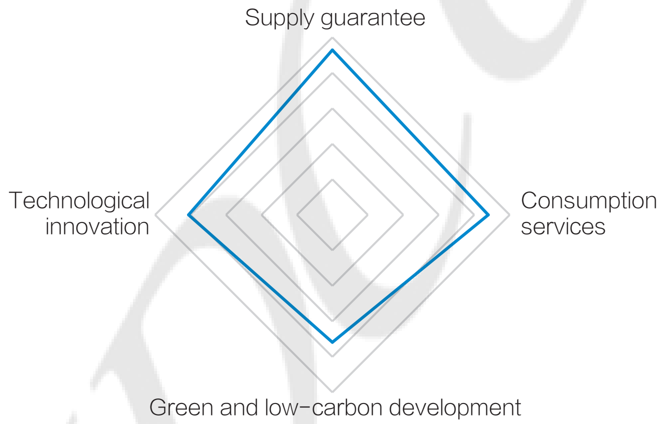


Figure 3-16 Electricity Development Level of North America in Different Dimensions

In order to further improve the electricity development level, North America should make the following efforts. **First,** vigorously develop new energy power generation, reduce dependence on fossil fuel power generation and bring down carbon emissions in the electricity industry. **Second,** strengthen technological innovation and application and carry out technological transformation and upgrading of old infrastructure.

Table 3-15 Ranking and Scores of Three North American Countries in Electricity Development Index

Ranking	Country	Score	Ranking	Country	Score
1	Canada	91.7	3	Mexico	74.8
2	USA	84.0	–		

(VI) Oceania

Table 3-16 Basic Data of Economic, Social and Electricity Development in Oceania

Economy and Society	Data	Electricity Development	Data
Area (million km^2)	8.51	Total installed capacity (GW)	110
Population (million)	44	Total electricity consumption (PWh)	0.3
GDP (USD 1 trillion)	2.0	Installed capacity per capita (kW)	2.5
GDP per capita (USD)	45283	Electricity consumption per capita (kWh)	6844

Continued Table

Economy and Society	Data	Electricity Development	Data
Share of electricity consumption in total final energy consumption	23.8%	Access to electricity	81.4%
Proportion of clean energy power generation	37.5%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.49

Oceania is rich in natural and mineral resources. The electricity development level of Australia and New Zealand ranks among the top in the world. Some Pacific island countries have backward electricity infrastructure, and there are still many people without access to electricity. At present, 81.4% of Oceania's population has access to electricity. Due to their special geographical location and complex and fragile environment, Pacific island countries are the most vulnerable to climate change in the world. Oceanian countries attach great importance to climate change and actively participate in global climate governance.

From 2017 to 2022, Oceania's total electricity consumption remained at about 300 TWh

From 2017 to 2022, Oceania's total electricity consumption remained at about 300 TWh, and its total installed capacity increased from 87 GW to 110 GW, with an average annual growth rate of 4.75%. In 2022, Oceania's electricity consumption per capita and installed capacity per capita reached 6,844 kWh and 2.5 kW respectively, more than twice the global average.

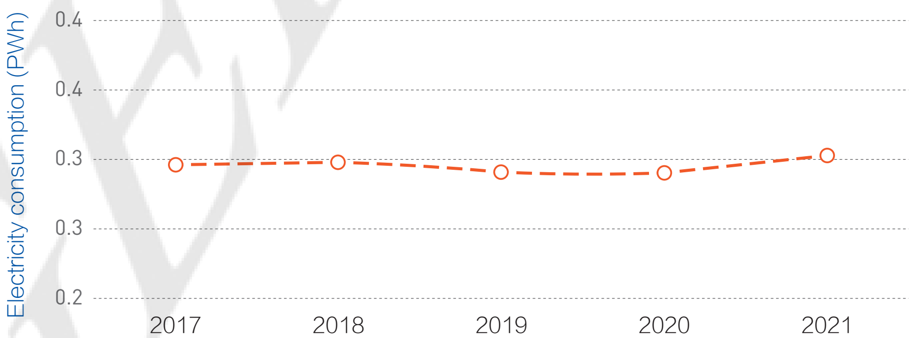


Figure 3-17 Growth and Change Trend of Electricity Consumption in Oceania

From 2017 to 2022, Oceania's proportion of clean energy power generation increased from 25.3% to 37.5%

From 2017 to 2022, Oceania's proportion of clean energy power generation increased from 25.3% to 37.5%, making it the fastest-growing continent in the world. In 2022, Oceania's share of electricity consumption in total final energy consumption was 23.8%, 3 percentage points higher than the global average.

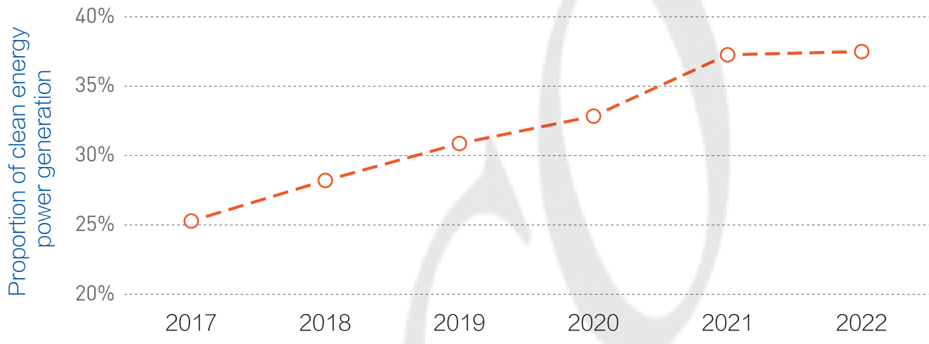


Figure 3-18 Trend of Proportion of Clean Energy Power Generation in Oceania

Oceania's comprehensive electricity development index is 71.4 points, which is lower than the level of the global comprehensive index.

According to the calculation results of the electricity development index, it is at the global leading level in the green and low-carbon development index, while its scores in supply guarantee and consumption services are relatively low. Australia and New Zealand are both among the top 20 in the global electricity development index, leading the world in terms of electricity development level.

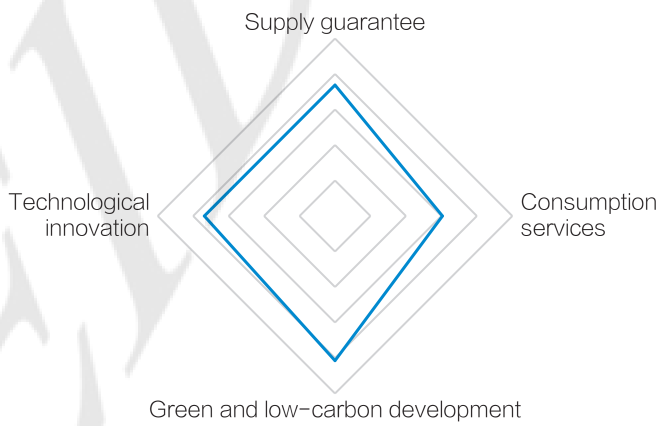


Figure 3-19 Electricity Development Level of Oceania in Different Dimensions

In order to further improve the electricity development level, Oceania should make the following efforts. **First,** enhance the electricity supply guarantee capability, especially the resilience of the electricity system to cope with extreme weather. **Second,** improve consumption services, reduce electricity costs, shorten the time to obtain an electricity connection, and elevate electricity supply reliability. **Third,** improve the construction of electricity infrastructure in small island countries.

Table 3-17 Ranking and Scores of Two Oceanian Countries in Electricity Development Index

Ranking	Country	Score	Ranking	Country	Score
1	New Zealand	85.1	2	Australia	84.0

3.3 Country Ranking Analysis

(I) Overall ranking

The comprehensive electricity development index of 100 selected representative countries on 6 continents in the world is calculated and ranked. Based on the collected basic data of electricity development in those countries, the two-tier index model of the global electricity development index is used to calculate and rank their comprehensive electricity development index and four special indexes of supply guarantee, consumption services, green and low-carbon development, and technological innovation. The overall ranking and scores of every country, as well as their scores in special indexes are shown in Annex 2.

The top 20 countries

According to the calculation and ranking results of the index, except China, all the other top 20 countries in the comprehensive electricity development index are developed countries. The common characteristics of those countries with the highest electricity development level include relatively complete electricity infrastructure, a high level of installed capacity per capita and electricity consumption per capita, a high level of electricity supply guarantee and services, clear willingness and goals for energy and power transition, and emphasis on clean energy development and the application of new technologies. There are small differences in those countries' scores in the comprehensive electricity development index.

Countries ranking 21-50

Countries ranking 21–50 are mainly European Asian, and Central and South American countries. Africa only has Egypt among the top 50, indicating that its overall development level is relatively backward. Their common characteristic is uneven electricity development, with high scores only in some specific indicators, which affects the overall rating. For example, Bahrain's electricity consumption per capita and installed capacity per capita are as high as 19,445 kWh and 3.93 kW respectively, ranking the third and eighth in the world, about 6 times and 4 times the global average respectively. However, its green and low-carbon development level is relatively low, almost all power generation comes from oil and gas, and technological innovation is slightly insufficient.

Countries ranking 51-80

Countries ranking 51–80 are mainly Asian, African, and Central and South American countries. Their common characteristics include a certain foundation for the development of electricity infrastructure, but a relatively low level of installed capacity per capita and electricity consumption per capita. Some countries are at the global leading level in a special index.

The last 20 countries

The last 20 countries are mainly African and Asian countries. Their common characteristics are relatively backward development of electricity infrastructure, a low level of installed capacity per capita and electricity consumption per capita, a large number of people without access to electricity, a poor electricity supply guarantee capability and a low service level, and insufficient electricity development for the needs of economic and social development.

Table 3-18 Ranking of Countries in Global Electricity Development Index

Ranking	Country	Ranking	Country	Ranking	Country	Ranking	Country
1	Sweden	26	Belgium	51	Panama	76	Tajikistan
2	Norway	27	United Arab Emirates	52	Oman	77	Mongolia
3	Canada	28	Russia	53	Columbia	78	The Philippines
4	Switzerland	29	Israel	54	Malaysia	79	Pakistan
5	Denmark	30	Saudi Arabia	55	Costa Rica	80	Tunisia
6	France	31	Kuwait	56	Peru	81	Dominican Republic
7	China	32	Qatar	57	Uzbekistan	82	Bolivia
8	Iceland	33	Greece	58	Vietnam	83	Cuba
9	Portugal	34	Bahrain	59	Serbia	84	Nepal
10	South Korea	35	Slovakia	60	Morocco	85	Sri Lanka
11	Germany	36	Slovenia	61	Indonesia	86	Bangladesh
12	Austria	37	Brazil	62	Azerbaijan	87	Cambodia
13	Singapore	38	Uruguay	63	Ecuador	88	Ghana
14	Japan	39	Bulgaria	64	Thailand	89	Cote d'Ivoire
15	New Zealand	40	Czech Republic	65	Algeria	90	Kenya
16	Spain	41	Belarus	66	Kyrgyzstan	91	Senegal
17	Finland	42	Türkiye	67	Georgia	92	Cameroon
18	Australia	43	Poland	68	Jordan	93	Angola
19	USA	44	Mexico	69	Romania	94	Nigeria
20	The Netherlands	45	Argentina	70	South Africa	95	Myanmar
21	Italy	46	Hungary	71	Iran	96	Zambia
22	UK	47	Ukraine	72	Libya	97	Uganda
23	Ireland	48	Croatia	73	Venezuela	98	Tanzania
24	Chile	49	Laos	74	Puerto Rico	99	Ethiopia
25	Kazakhstan	50	Egypt	75	India	100	Iraq

(II) Ranking by Dimension

On the basis of the overall ranking, the top 20 countries in each special index are ranked, which is conducive to mutual learning among countries, and experience exchanges and cooperation in inter-regional and transnational electricity development. The top 20 countries in special indexes of supply guarantee, consumption services, green and low-carbon development and technological innovation are shown in the table below.

Table 3-19 Top 20 Countries in Special Indexes of Global Electricity Development

Special index	Top 20 Countries
Supply guarantee	Denmark, Norway, Canada, Sweden, Iceland, Singapore, China, Finland, Austria, France, The Netherlands, Japan, Switzerland, Belgium, Portugal, Germany, Spain, Australia, New Zealand, Kuwait
Consumption services	UAE, The Netherlands, South Korea, China, Sweden, Switzerland, Qatar, Saudi Araibia, Kuwait, Bahrain, Ireland, Canada, UK, Singapore, Norway, Portugal, France, USA, Denmark, Kazakhstan
Green and low-carbon development	Norway, Switzerland, France, Sweden, Brazil, New Zealand, Denmark, Finland, Malaysia, Canada, Peru, Uganda, Tajikistan, Iceland, Kyrgyzstan, Slovakia, Portugal, Slovenia, China, Hungary
Technological innovation	Germany, China, USA, France, Denmark, Sweden, the Netherlands, UK, Norway, Japan, Australia, Brazil, Canada, Italy, Portugal, Switzerland, Ireland, Kazakhstan, Spain, India

The top-ranking countries in supply guarantee are mainly developed countries and China. Their common characteristics include higher installed capacity per capita and strong electricity supply guarantee capacity, which can support the needs of economic and social development.

The top-ranking countries in consumption services are mainly Northern European and Asian countries. Their common characteristics include high electricity supply reliability, short time to obtain an electricity connection, strong price competitiveness, and high level of electricity consumption per capita.

The top-ranking countries in green and low-carbon development are mainly European, Central and South American and African countries. Their common characteristics include a high proportion of clean energy electricity, low carbon emission intensity of electricity, and rapid development of new energy.

The top-ranking countries in technological innovation are mainly developed countries and large countries in Asia, and Central and South America, such as China, Brazil, Kazakhstan and India. These countries have a high level in the application of new technologies and the input and output of electricity technology R&D.

(III) Ranking of OECD Countries

Among the 100 countries, 34 are OECD members. Except for Colombia and Costa Rica in Central and South America, they all rank among the top 50 in the world in the electricity development index, of which 18 rank in top 20. On the whole, OECD countries have a higher level of electricity development, largely because most have a good economic foundation, a high GDP per capita, relatively complete electricity infrastructure, and a high level of electricity production and consumption.

Among OECD countries, the top 5 in the electricity development index are Sweden, Norway, Canada, Switzerland and Denmark, while the last 5 are Poland, Mexico, Hungary, Colombia and Costa Rica.

Table 3-20 Ranking of OECD Countries in Electricity Development Index

Ranking	Country	Ranking	Country	Ranking	Country
1	Sweden	13	New Zealand	25	Greece
2	Norway	14	Spain	26	Slovakia
3	Canada	15	Finland	27	Slovenia
4	Switzerland	16	Australia	28	Czech Republic
5	Denmark	17	USA	29	Türkiye
6	France	18	The Netherlands	30	Poland
7	Iceland	19	Italy	31	Mexico
8	Portugal	20	UK	32	Hungary
9	South Korea	21	Ireland	33	Colombia
10	Germany	22	Chile	34	Costa Rica
11	Austria	23	Belgium		
12	Japan	24	Israel		

(IV) Ranking of Developing Countries

According to the latest standards of the World Bank, those with GNI per capita less than USD 12,696 are developing countries. Among the 100 countries, 54 are developing countries. China is the only developing country in top 20. In addition to China, others among the top 50 countries include Kazakhstan, Egypt, Brazil, Belarus, Türkiye, Mexico, and Laos.

Developing countries generally rank low in the electricity development index. Many countries have a GDP per capita of less than USD 1,000, and their electricity infrastructure is seriously insufficient. There are still a large number of people without access to electricity in some African, South Asian and Southeast Asian countries. Strengthening the construction of electricity infrastructure and achieving universal access to electricity is the most effective way for these countries to improve their electricity development level.

Table 3-21 Ranking of Developing Countries in Electricity Development Index

Ranking	Country	Ranking	Country	Ranking	Country
1	China	19	Ecuador	37	Cuba
2	Kazakhstan	20	Thailand	38	Nepal
3	Brazil	21	Algeria	39	Sri Lanka
4	Belarus	22	Kyrgyzstan	40	Bangladesh
5	Türkiye	23	Georgia	41	Cambodia
6	Mexico	24	Jordan	42	Ghana
7	Ukraine	25	South Africa	43	Côte d'Ivoire
8	Laos	26	Iran	44	Kenya
9	Morocco	27	Lybia	45	Senegal
10	Colombia	28	Venezuela	46	Cameroon
11	Malaysia	29	India	47	Angola
12	Peru	30	Tajikistan	48	Nigeria
13	Uzbekistan	31	Mongolia	49	Myammar
14	Vietnam	32	The Philippines	50	Zambia
15	Serbia	33	Pakistan	51	Uganda
16	Egypt	34	Tunisia	52	Tanzania
17	Indonesia	35	Dominican Republic	53	Ethiopia
18	Azerbaijan	36	Bolivia	54	Iraq

4 Electricity Development Index Analysis of Some Countries

4.1 Asia

(I) China

China has the largest land area, the largest economic size, and the second largest population in Asia. It is the only developing country ranked in top 20 for electricity development. An in-depth analysis of various dimensions of China's electricity development helps provide references and models for other developing countries to enhance their electricity development levels.

1. Basic overview of electricity development

Table 4-1 Basic Data of Economic, Social and Electricity Development in China

Economy and Society	Data	Electricity Development	Data
Land area (1,000 km^2)	9597	Total installed capacity (GW)	2594
Population (million)	1453	Total electricity consumption (PWh)	8.54
GDP (USD 1 trillion)	18.3	Installed capacity per capita (kW)	1.78
GDP per capita (1,000 USD)	12.6	Electricity consumption per capita (kWh)	5877
Share of electricity consumption in total final energy consumption	28.14%	Access to electricity	100%
Proportion of clean energy power generation	35.1%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.61

In 2022, China's total installed capacity was **2,594** GW, accounting for **30.6%** of the world's total

China has built the world's largest electricity system, ranking first globally in installed power capacity, power transmission and distribution networks, and scale of electricity consumption. In 2022, China's total installed capacity was 2,594 GW, accounting for 30.6% of the world's total and exceeding that of G7 countries. The total electricity consumption was 8,540 TWh, representing 32.1% of the world's total and close to one-third of global electricity demand. Transmission lines at 35 kV or above were 2.26 million km long.

The secure electricity supply provides a strong guarantee for economic and social development. In the past five years, China's GDP has grown at an average annual rate of about 5.3%, 2.2 times the global average; electricity demand has increased at an average annual rate of 6.2%, 2.3 times the

In 2022, China's electricity consumption per capita and installed capacity per capita reached 5,877 kWh and 1.8 kW respectively, 1.7 and 1.8 times the global average

global average; installed capacity has risen at an average annual rate of 7.7%, 1.8 times the global average. In 2022, China's electricity consumption per capita and installed capacity per capita reached 5,877 kWh and 1.8 kW respectively, 1.7 and 1.8 times the global average. The Chinese government and power enterprises have coordinated development with safety, as well as supply assurance and transformation. The collaborative efforts from the power generation side and the power grid side ensure a reliable and secure electricity supply, providing strong support for economic and social development.

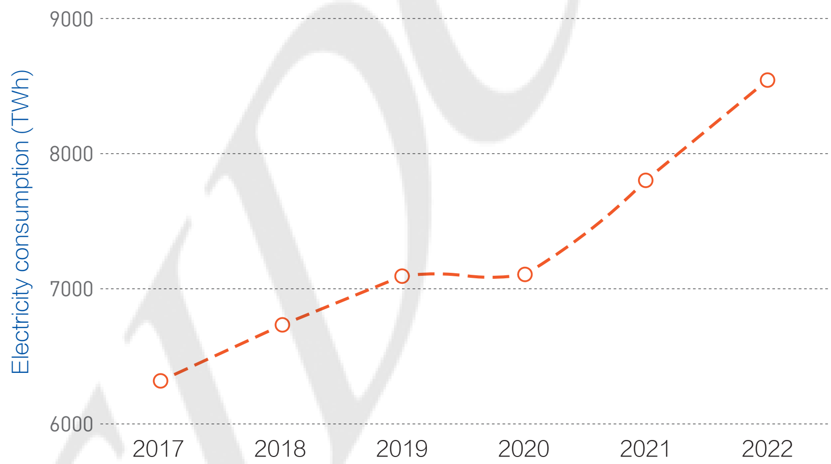


Figure 4-1 Changes in Electricity Consumption in China over the Past 5 Years

China has achieved universal access to electricity.

To address the issue of populations without electricity in remote areas, China combined the extension of the large power grid with a localized electricity supply through decentralized energy sources. This approach enabled all households to have access to electricity in 2015, improving electricity consumption services across the nation.

Emphasizing the technological innovation and development of electricity, China has leveraged ultra-high voltage (UHV) power transmission technology to achieve power grid interconnection.

UHV power transmission technology stands as a major innovation in China's power sector, effectively addressing the challenges posed by the uneven distribution of power resources and loads. As of April 2024, China has commissioned 38 UHV projects (18 AC and 20 DC), with the scale of "power transmission from West to East" nearing 350 GW. This significant advancement has greatly enhanced the level of power grid interconnection, as well as the capability for resource allocation.

China has played a significant role in driving the global transition towards green and low-carbon electricity.

From 2017 to 2022, China's clean energy installed capacity scale grew by 561 GW, accounting for 45.4% of the global clean energy installed capacity increase of 1,235 GW. The proportion of clean energy power generation rose from 28.5% to 35.1%, an increase of 6.6 percentage points, while the proportion of clean energy installed capacity climbed from 38.2% to 48.6%, representing a growth of over 10 percentage points. In 2022, China's share of electricity consumption in total final energy consumption reached 28.14%, surpassing the global average by 7.5 percentage points and leading the world in this aspect, also exceeding the majority of OECD countries.

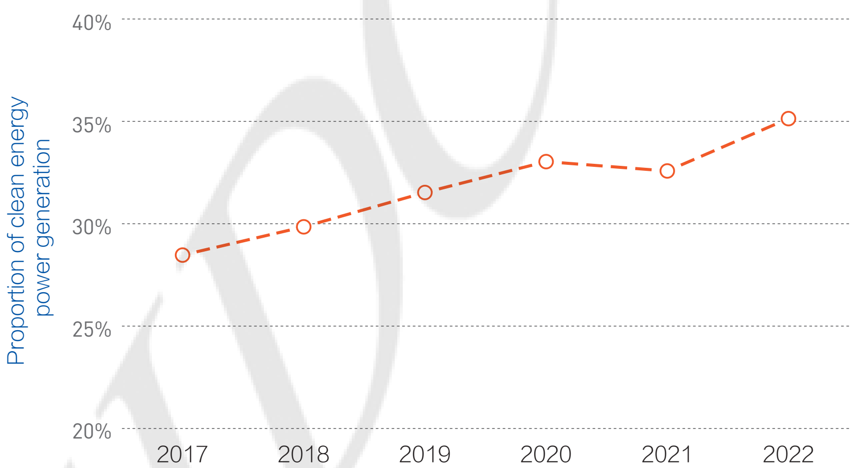


Figure 4-2 Changes in Proportion of Clean Energy Power Generation in China over the Past 5 Years

2. Calculation and analysis of electricity development index

According to the calculation results of the electricity development index, China's comprehensive electricity development index is 90.8 points. **China's electricity development scores high in technological innovation, placing it at the global forefront. In terms of electricity supply guarantee and electricity consumption services, China also leads globally.** However, due to the relatively low proportion of hydropower and nuclear power generation, despite rapid growth in wind and solar power, the overall proportion of clean energy power generation is not very high. This factor affects the score for the green and low-carbon transition.

In the future, to further enhance China's electricity development level, several key steps should be taken.

First it is necessary to continue to vigorously develop new energy power generation, continuously promote the green and low-carbon transition of electricity, reduce fossil fuel-based power generation, and lower carbon emissions from electricity generation.

Second it is required to accelerate the deployment of flexible resources such as pumped storage, new types of energy storage, virtual power plants, and V2G, optimize mechanisms in the ancillary services market, strengthen power grid interconnection, and further enhance the new energy consumption.

Third it is essential to keep building and improving the electricity market, expand the coverage of the spot market, diversify market trading products, and encourage electricity-carbon market integration.

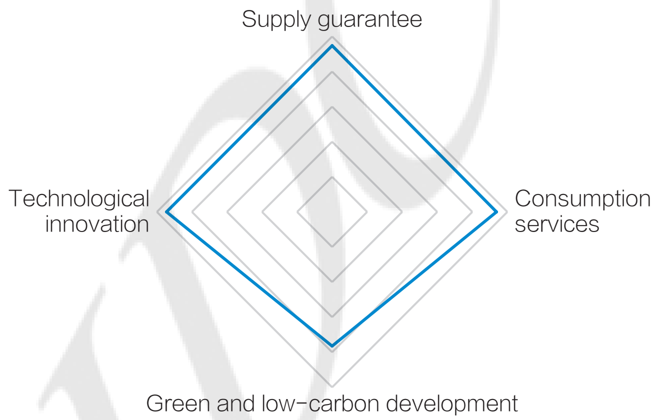


Figure 4-3 Electricity Development Level of China in Different Dimensions

3. Experience in electricity development

China is at the forefront globally in various areas such as new energy power generation, UHV power transmission, flexible DC transmission, and the digitization and intellectualization of electricity systems. The country has constructed a series of demonstration projects, providing the world with experience and practices in electricity innovation.

The new energy base project in the Kubuqi Desert and the central and northern Ordos jointly built by China Three Gorges Corporation and Inner Mongolia Energy Group is the world's largest wind power and PV base project developed and constructed in the desert and Gobi region. It is also the first 10 GW-level new energy mega-base project under construction in China. The project is designed with an overall installed capacity of 16 GW, including 8 GW of PV, 4 GW of wind power, and the expansion and renovation of an additional 4 GW of advanced and efficient coal power capacity. The construction of the project was officially started in December 2022. Once completed, it will be capable of supplying approximately 40 TWh of electricity annually to the Beijing-Tianjin-Hebei region, of which clean energy accounts for more than 50%, equivalent to saving about 6 million tonnes of standard coal and reducing carbon emissions by about 16 million tonnes.

it will be capable of supplying approximately **40** TWh of electricity annually to the Beijing-Tianjin-Hebei region, of which clean energy accounts for more than **50%**, equivalent to saving about **6** million tonnes of standard coal and reducing carbon emissions by about **16** million tonnes

Figure 4-4 Kubuqi Desert Large-scale Wind Power and PV Base

The Changji-Guquan ±1,100 kV UHVDC Demonstration Project invested and constructed by SGCC is the first ±1,100 kV DC transmission project in the world. It is known for being the "Four Superlatives" project with the highest voltage level, largest transmission capacity, longest power transmission distance, and most advanced technology. The project's transmission line stretches 3,293.1 km, with a rated transmission capacity of 12 GW. It had a total investment of RMB 40.7 billion and was commissioned in 2019. The project can transmit 66 TWh of electricity to East China every year, meeting the electricity demand of 50 million households there and reducing the transportation of coal by 30.24 million tonnes. This reduction results in a decrease of 24,000 tonnes of particulate matter, 149,000 tonnes of SO_2, and 157,000 tonnes of nitrogen oxides per year.

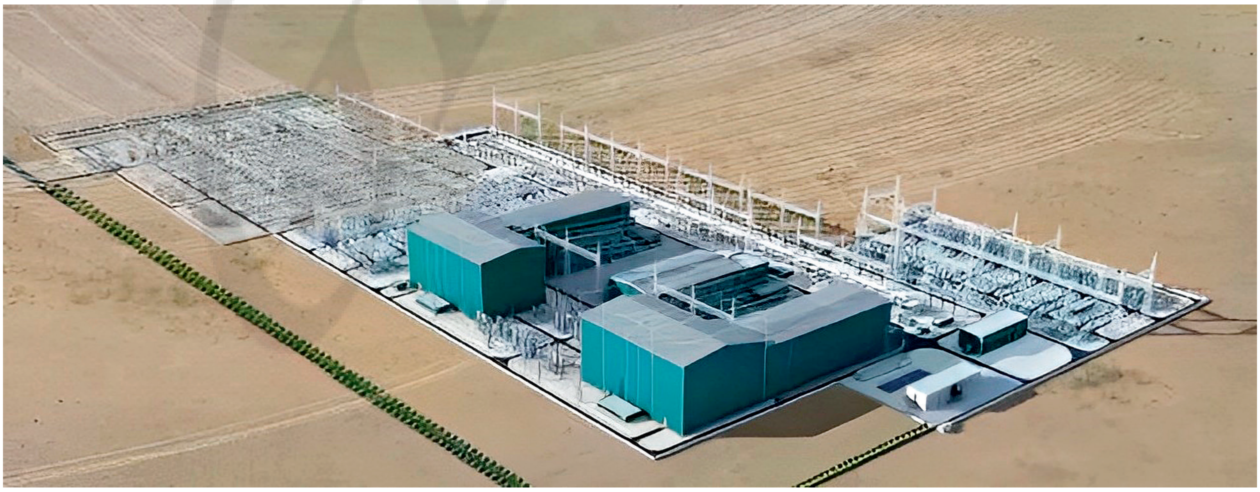


Figure 4-5 Panorama of Changji Convertor Station of Changji-Guquan ±1,100 kV UHVDC Transmission Project

The Multi-terminal UHVDC Demonstration Project from Wudongde Power Station to Guangdong and Guangxi, or Kunbei-Liubei-Longmen DC Project for short, was constructed by China Southern Power Grid Company with core equipment provided by NR Electric Co., Ltd. It is the world's largest multi-terminal UHVDC power transmission project, the first hybrid multi-terminal UHVDC project, the first UHV flexible DC convertor station project, and the first flexible DC transmission project with the capability of DC fault self-clearing on overhead lines. This project operates at a voltage level of ±800 kV and spans a total length of 1,452 km, crossing Yunnan, Guizhou, Guangxi, and Guangdong provinces, with a total transmission capacity of 8 GW. Commissioned in 2020, it delivers 33 TWh of green and clean hydropower annually from Yunnan to the power load centers in Guangxi and the Guangdong-Hong Kong-Macau Greater Bay Area.

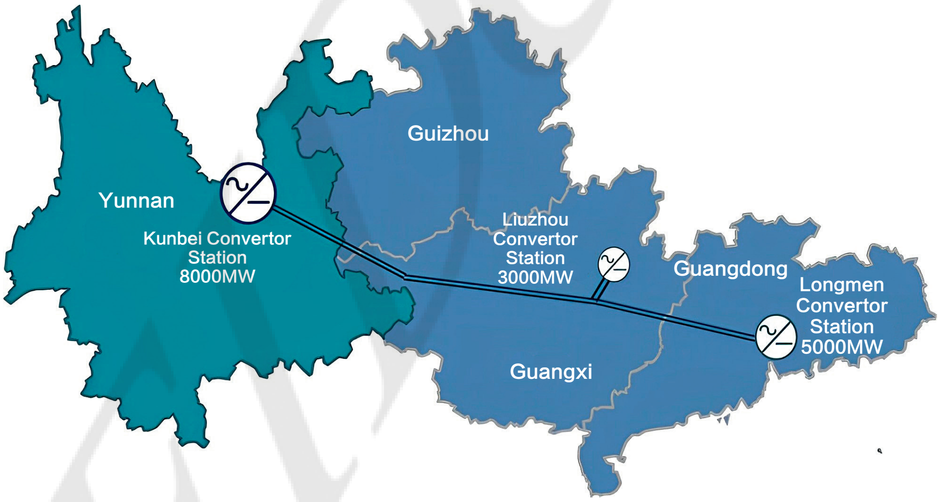


Figure 4-6 Kunbei-Liubei-Longmen Flexible DC Transmission Project

The "New Energy Cloud" platform developed by SGCC is the world's largest new energy information monitoring and consulting service system. It has innovatively established a visual online management mode of "Metro Map", offering one-stop full-process online services to connect energy source projects to the grid and providing full-process, all-stage, and all-scenario data and professional services for new energy planning, construction, grid connection, and production and manufacturing. The platform was officially launched in April 2021, presenting operation monitoring and information consulting services for all new energy stations within SGCC's operation area, encompassing over 3.3 million sites with a total installed capacity of 600 GW. The New Energy Cloud has also developed four application systems of Carbon Public Trust, Carbon Value, Carbon Research, and Carbon Ecology and introduced application scenarios such as Carbon Efficiency Code, Carbon Finance, Carbon Justice, Carbon Storage Certificate, and Carbon Measurement. It was awarded the Typical Case of Integrated and Innovative Application of Industrial Internet at the 4th Global Industrial Internet Conference in 2022.

Figure 4-7 Large Screen Display of State Grid New Energy Cloud Platform

(II) South Korea

As a developed Asian country, South Korea boasts well-developed electricity infrastructure and high levels of electricity production and consumption services. In recent years, it has prioritized the transition towards green and low-carbon electricity along with technological innovation, leading to it being positioned at the forefront of global electricity development.

1. Basic overview of electricity development

Table 4-2 Basic Data of Economic, Social and Electricity Development in South Korea

Economy and Society	Data	Electricity Development	Data
Land area (1,000 km^2)	100.2	Total installed capacity (GW)	147
Population (million)	51.7	Total electricity consumption (TWh)	586.8
GDP (USD 1 trillion)	1.67	Installed capacity per capita (kW)	2.83
GDP per capita (USD 1,000)	32.3	Electricity consumption per capita (MWh)	11.3
Share of electricity consumption in total final energy consumption	25.36%	Access to electricity	100%
Proportion of clean energy power generation	34.9%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.46

From 2017 to 2022, the total electricity consumption in South Korea increased from **558.5** TWh to **586.8** TWh, with an average annual growth rate of **1.91%**

South Korea features generally high levels of electricity production and consumption. From 2017 to 2022, the total electricity consumption in South Korea increased from 558.5 TWh to 586.8 TWh, with an average annual growth rate of 1.91%. The total installed capacity increased from 125 GW to 147 GW, with an average annual growth rate of 3.2%. Following the COVID-19 pandemic, with economic recovery, electricity production and consumption have resumed growth. In 2022, the electricity consumption per capita and installed capacity per capita in South Korea reached 11.3 MWh and 2.83 kW respectively, about three times the global average.

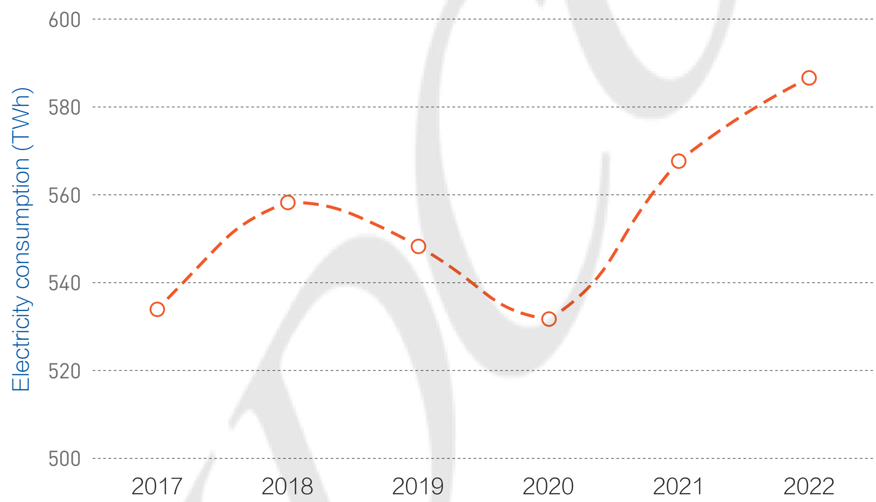


Figure 4-8 Changes in Electricity Consumption in South Korea over the Past 5 Years

From 2017 to 2022, the proportion of clean energy power generation in South Korea increased from **28.8%** to **34.9%**, representing a growth of **6** percentage points

South Korea has been actively engaged in the transition towards green and low-carbon electricity. From 2017 to 2022, the proportion of clean energy power generation in South Korea increased from 28.8% to 34.9%, representing a growth of 6 percentage points. The proportion of clean energy installed capacity also rose from 30.9% to 38.5%, marking an increase of 7.6 percentage points during the same period. In 2022, South Korea's share of electricity consumption in total final energy consumption registered 25.4%, surpassing the global average by 5 percentage points.

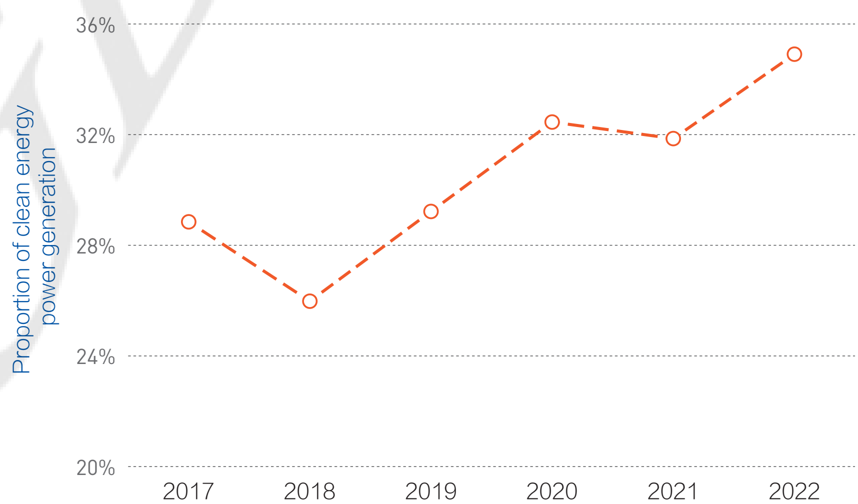


Figure 4-9 Changes in Proportion of Clean Energy Power Generation in South Korea over the Past 5 Years

2. Calculation and analysis of electricity development index

According to the calculation results of the electricity development index, **South Korea's comprehensive electricity development index is 86.3 points, with relatively balanced development across all dimensions. It ranks among the top in the world in terms of electricity supply guarantee, consumption services, and technological innovation. To further improve the level of electricity development in South Korea, the focus should be on** promoting the transition towards low-carbon electricity. This includes increasing the development and utilization of new energy, continuing to reduce the proportion of fossil fuel-based power generation, and decreasing carbon emissions from the electricity industry.

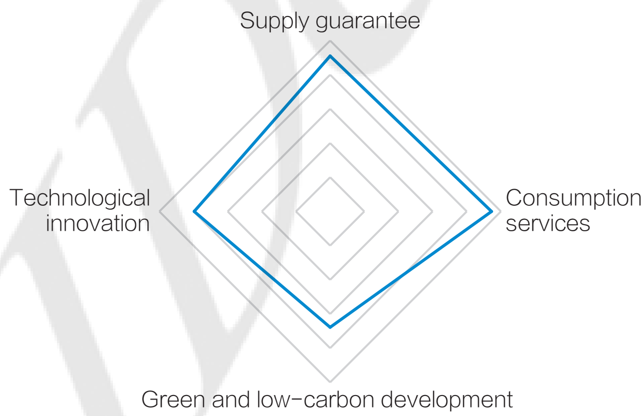


Figure 4-10 Electricity Development Level of South Korea in Different Dimensions

3. Experience in electricity development

The country's electricity system operating regulations specify a standard reserve margin of 22%, which is considered relatively high on a global scale

South Korea places significant emphasis on electricity supply security, and its relevant measures hold valuable insights for others. The country's electricity system operating regulations specify a standard reserve margin of 22%, which is considered relatively high on a global scale. To cope with the impact of new energy volatility on the safe operation of the power grid, South Korea plans to invest KRW 29~45 trillion before 2036 in building a new reserve margin of 26.3 GW.

According to the *10th Basic Plan for Long-Term Electricity Supply and Demand* ("New Plan" for short) issued by the government of South Korea, to ensure sufficient and secure electricity supply, there have been adjustments compared to the Old Plan announced in 2020. The New Plan involves restarting the construction of new nuclear power projects, slowing down the decommissioning of coal power plants, increasing gas power stations, adjusting the development ratios of wind power and solar energy, and boosting wind power development. As per the New Plan, by 2036, the installed capacity of nuclear power in South Korea will increase from 24.7 GW in 2022 to 31.7 GW, that of coal power will decrease from 38.1 GW to 27.1 GW, that of gas power will rise from 41.3 GW to 64.6 GW, and that of renewable energy will grow from 29.2 GW to 108 GW.

4.2 Europe

(I) Sweden

Sweden is not only the country with the highest ranking in the electricity development index in Europe but also a leader in the global electricity development index rankings. Across dimensions of electricity development such as supply guarantee, consumption services, green and low-carbon development, and technological innovation, Sweden excels at a global level. Therefore, it is selected as a representative country in Europe to analyze its electricity development status, offering valuable insights and references to countries in both Europe and other parts of the world.

1. Basic overview of electricity development

Table 4-3 Basic Data of Economic, Social and Electricity Development in Sweden

Economy and Society	Data	Electricity Development	Data
Land area (1,000 km^2)	450.3	Total installed capacity (GW)	52.71
Population (million)	10.07	Total electricity consumption (TWh)	129.9
GDP (USD billion)	591.2	Installed capacity per capita (kW)	5.1
GDP per capita (USD 1,000)	57.2	Electricity consumption per capita (MWh)	12.6
Share of electricity consumption in total final energy consumption	33.45%	Access to electricity	100%
Proportion of clean energy power generation	99%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.012

Sweden, as a developed country in Northern Europe, has well-developed and mature energy and electricity infrastructure. Due to its geographical location and climatic conditions, Sweden leads globally in electricity consumption per capita and installed capacity per capita and boasts high levels of electricity supply guarantee and consumption services. The country is abundant with clean energy resources such as hydropower and wind power, has a high proportion of clean energy installed capacity, and is home to globally leading companies in the power sector like ABB. It stands out in the transition towards green and low-carbon electricity, as well as technological innovation.

From 2017 to 2022, Sweden's total electricity consumption decreased from **133** TWh to **129.9** TWh, with an average annual growth rate of **-0.5%**

From 2017 to 2022, Sweden's total electricity consumption decreased from 133 TWh to 129.9 TWh, with an average annual growth rate of −0.5%. Multiple factors such as weak industrial performance, energy efficiency enhancement, and climate warming led to the decline in electricity demand. The total installed capacity increased from 44.25 GW to 52.71 GW, with an average annual growth rate of 3.6%, slightly lower than the global average. In 2022, Sweden's electricity consumption per capita and installed capacity per capita reached 12.6 MWh and 5.1 kW respectively, about four times the global average.

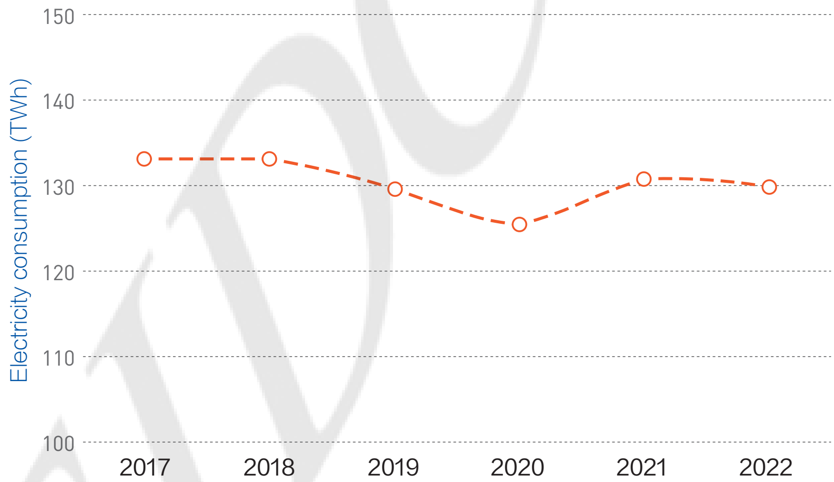


Figure 4-11 Changes in Electricity Consumption in Sweden over the Past 5 Years

Sweden's proportion of clean energy power generation is close to 100%.

From 2017 to 2022, the country's proportion of clean energy power generation further increased from 98.5% to nearly 99%, basically realizing a 100% clean energy electricity system. This achievement was mainly attributed to hydropower, nuclear power, and wind power, with the proportions of power generation standing at approximately 42%, 29%, and 19%, respectively. Together, these three sources accounted for 90% of Sweden's total power generation. The proportion of clean energy installed capacity also rose from 83.2% to 85.3%, marking an increase of around 2 percentage points. In 2022, Sweden's share of electricity consumption in total final energy consumption reached 33.5%, surpassing the global average by 13 percentage points and placing the country at a leading position globally, ahead of many OECD countries.

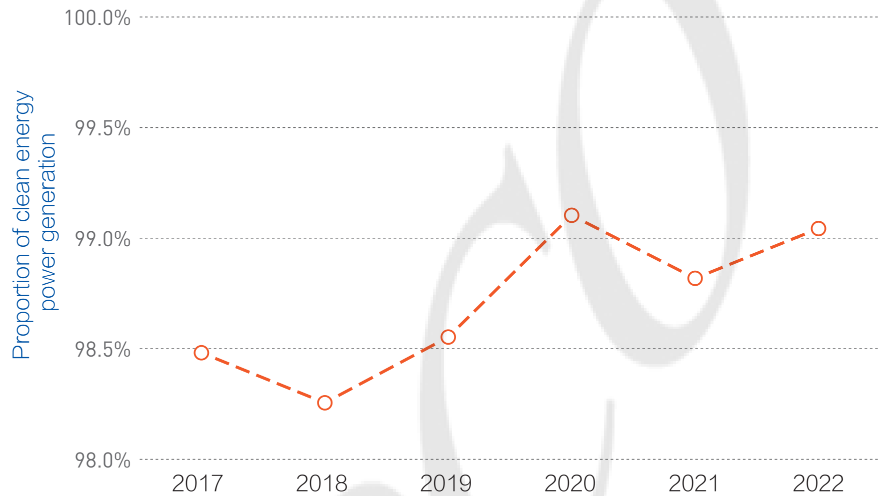


Figure 4-12 Changes in Proportion of Clean Energy Power Generation in Sweden over the Past 5 Years

Sweden highly values the development of power grid interconnection and has established interconnections with multiple countries in Northern and Western Europe.

Sweden has been interconnected with countries such as Norway, Denmark, and Finland in Northern Europe and achieved transnational power grid interconnection with Germany, Poland, and Lithuania in Western Europe. Through power grid interconnection, the country has made transnational power mutual complementarity and support reality and supplied electricity to load centers in Germany.

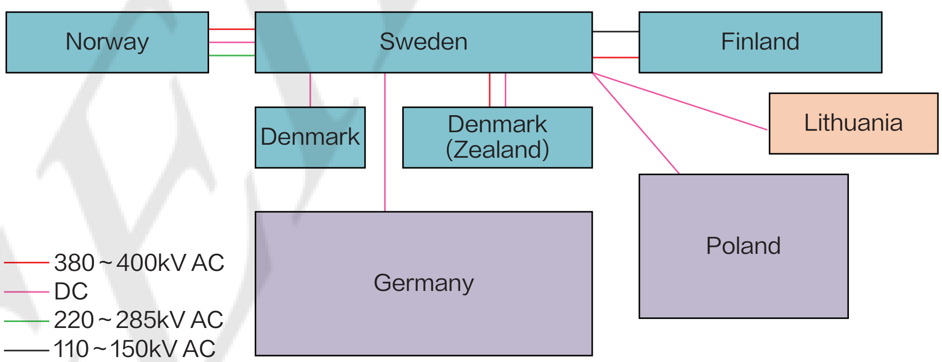


Figure 4-13 Transnational Power Grid Interconnection in Sweden

2. Calculation and analysis of electricity development index

According to the calculation results of the electricity development index, **Sweden's comprehensive electricity development index is 93.9 points, with well-balanced scores across various special indices, all ranking among the top globally.** The two most outstanding indices are the proportion of clean energy power generation and the formulation and implementation of green and low-carbon policies. **In the future, to further enhance Sweden's electricity development level, there should be a focus on** improving electricity consumption services, such as reducing the time to obtain an electricity connection and lowering electricity costs.

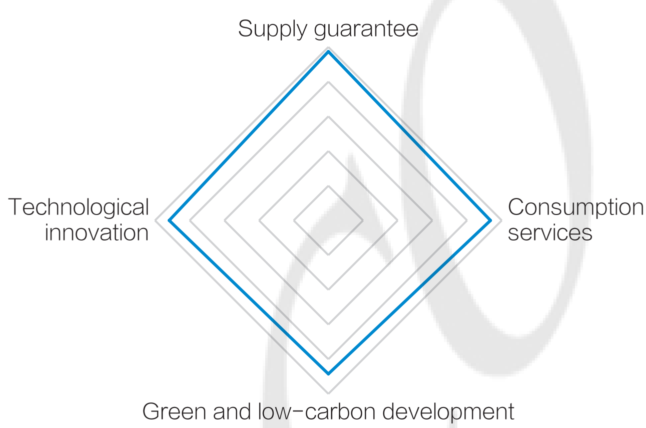


Figure 4-14 Electricity Development Level of Sweden in Different Dimensions

3. Experience in electricity development

Sweden has accumulated a wealth of advanced experience in the transition towards green and low-carbon electricity as well as technological innovation, which can serve as valuable references and sources of inspiration for other countries worldwide.

Legislation first is a prominent feature of Sweden's green and low-carbon transition and development of energy and electricity

As early as the 1970s, the Swedish government promulgated a series of mandatory laws and regulations to guide energy conservation and carbon reduction. In 1991, Sweden began to impose a carbon tax, with the current price being the highest in Europe at around SEK 1.15/kg (approximately RMB 0.88/kg). In 2009, the Swedish government adopted the *Integrated Climate and Energy Policy*, which set targets for renewable energy to account for no less than 50% and a 40% reduction in greenhouse gas emissions by 2020. Sweden achieved these goals ahead of schedule in 2016. To address climate change and achieve carbon emission reduction, Sweden has established more ambitious development goals. It plans to build a 100% renewable energy electricity system by 2040, achieve net zero greenhouse gas emissions by 2045, and become the world's first fossil fuel-free nation by 2050.

Nuclear power plays a crucial role for Sweden to achieve its goal of net zero greenhouse gas emissions

In November 2023, the Swedish government released a roadmap for nuclear power development, outlining plans to construct 10 large nuclear reactors by 2045. Additionally, revisions were made to nuclear-related laws, allowing for the construction of nuclear reactors at new sites.

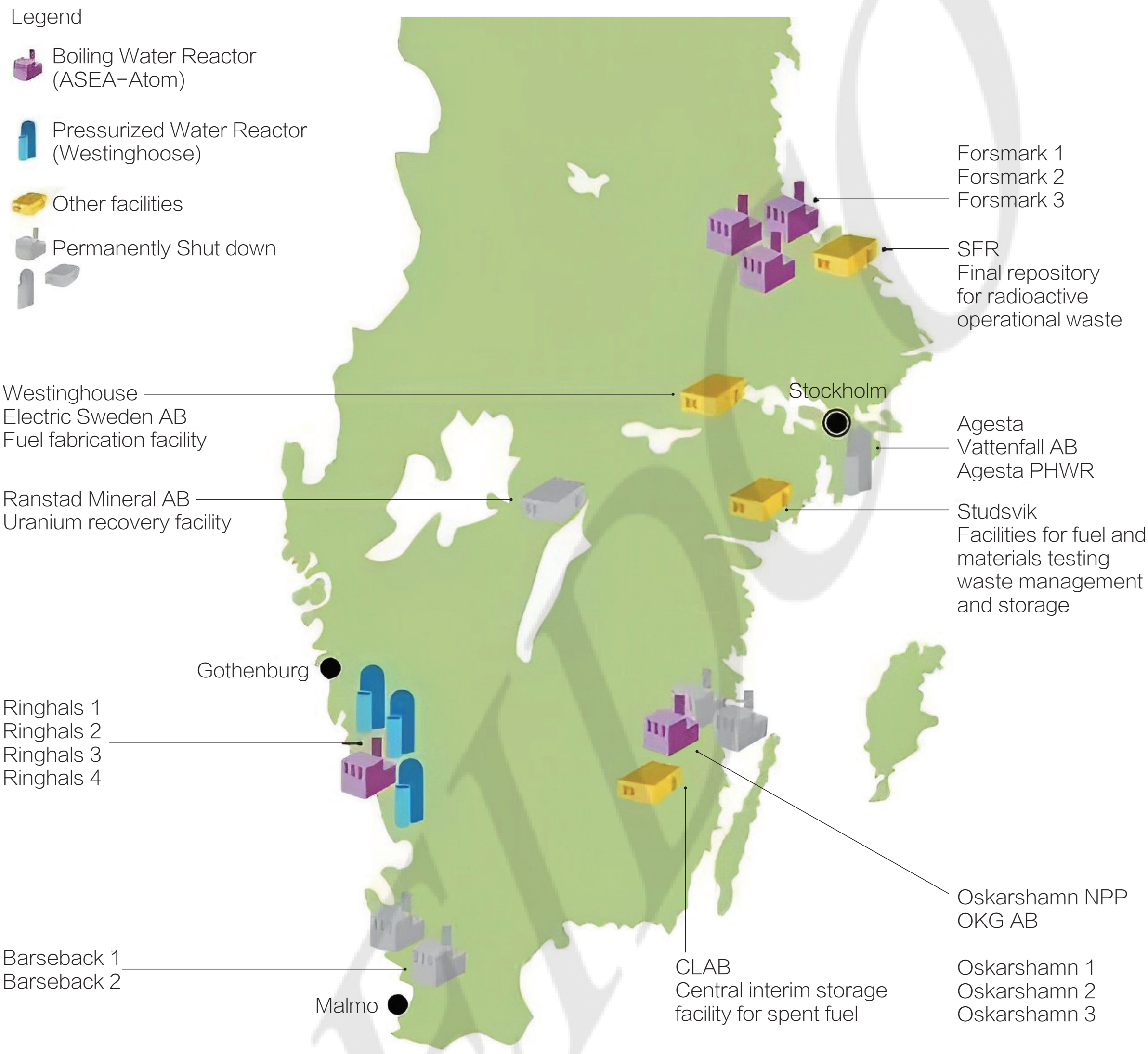


Figure 4-15 Distribution of Nuclear Power Infrastructure in Sweden[1]

To achieve the ambitious goal of building a 100% renewable energy electricity system by 2040, the Swedish Energy Agency, in collaboration with the International Renewable Energy Agency (IRENA), has conducted joint research and proposed four innovative solutions. First, it is necessary to strengthen technological innovation, mainly including large-scale grid-side energy storage, energy interconnection, AI and big data, blockchain, super interconnected power grids, and P2X. Second, it is expected to optimize market mechanisms, including increasing transaction frequency, innovating the ancillary services market, refining time-of-use electricity price, and integrating distributed energy sources markets. Third, it is planned to improve the system operation control capability, including introducing more advanced new energy output prediction models, distributed energy source operators, and virtual transmission lines as well as strengthening cooperation between transmission and distribution system operators. Fourth, it is required to innovate business models, mainly including introducing integrators.

[1] https://www-pub.iaea.org/MTCD/publications/PDF/cnpp2020/countryprofiles/Sweden/Sweden. htm

(II) France

France is a global leader in nuclear power technology and also a frontrunner in Europe and the world in terms of electricity development level. Its comprehensive electricity development index ranks among the top globally.

1. Basic overview of electricity development

Table 4-4　Basic Data of Economic, Social and Electricity Development in France

Economy and Society	Data	Electricity Development	Data
Land area (1,000 km^2)	551.7	Total installed capacity (GW)	135
Population (million)	67.6	Total electricity consumption (TWh)	4260
GDP (USD 1 trillion)	2.78	Installed capacity per capita (kW)	2.2
GDP per capita (USD 1,000)	41	Electricity consumption per capita (kWh)	6302
Share of electricity consumption in total final energy consumption	24.67%	Access to electricity	100%
Proportion of clean energy power generation	87.9%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.07

From 2017 to 2022, its total electricity consumption decreased from **4,570** TWh to **4,260** TWh, with an average annual growth rate of **−1.4%**

France's overall electricity production and consumption levels are relatively high. From 2017 to 2022, its total electricity consumption decreased from 4,570 TWh to 4,260 TWh, with an average annual growth rate of −1.4%. The continuous decline in electricity demand was attributed to reductions in industrial capacity and the impact of rising electricity prices due to energy crises. The total installed capacity climbed from 134 GW to 135 GW, basically remaining unchanged. In 2022, France's electricity consumption per capita and installed capacity per capita reached 6,302 kWh and 2.2 kW respectively, approximately twice the global average.

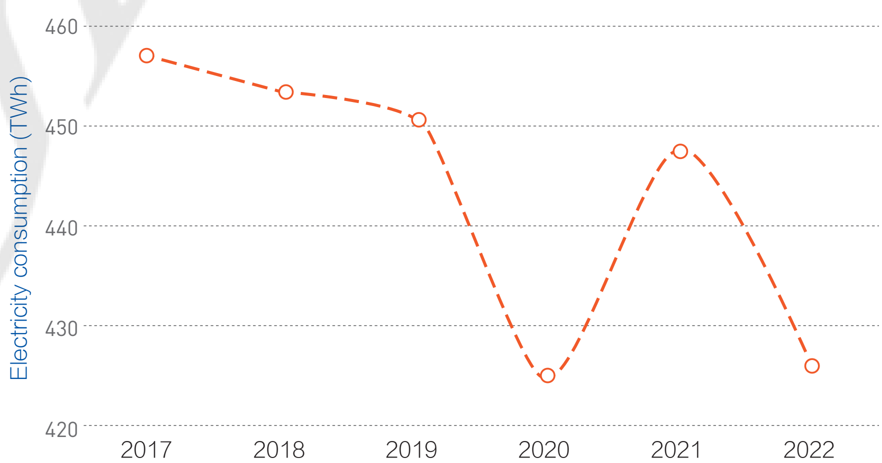


Figure 4-16　Changes in Electricity Consumption in France over the Past 5 Years

In 2022, France's rate of electricity consumption in total final energy consumption reached **24.7%**, **4** percentage points higher than the global average

France's energy source structure is predominated by nuclear power, leading to an overall high level of clean electricity production. From 2017 to 2022, the proportion of clean energy power generation in France peaked at 91% in 2021 but dropped to 87.9% in 2022, with nuclear power contributing 62.5% of power generation. The proportion of clean energy installed capacity increased from 83.7% to 86.3%, primarily driven by the installed capacity of new energy such as wind and solar power. In 2022, France's share of electricity consumption in total final energy consumption reached 24.7%, 4 percentage points higher than the global average.

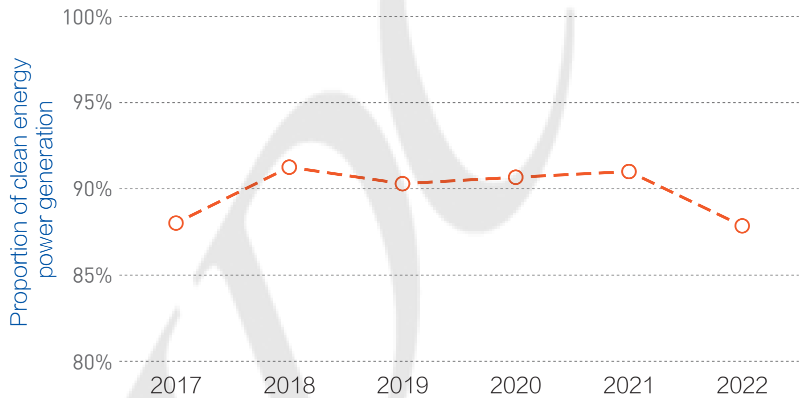


Figure 4-17 Changes in Proportion of Clean Energy Power Generation in France over the Past 5 Years

France is the largest electricity exporter in Europe. Relying on abundant nuclear power, the country has long been the leading European country in terms of electricity exports. Through transnational interconnections, it has supplied surplus electricity to neighboring countries like the UK, Germany, Switzerland, and Italy. Towards the end of 2021, stress corrosion cracking was discovered at several nuclear reactors, resulting in a historic decline in electricity exports in 2022. However, by 2023, France reclaimed its position as the largest electricity exporter in Europe.

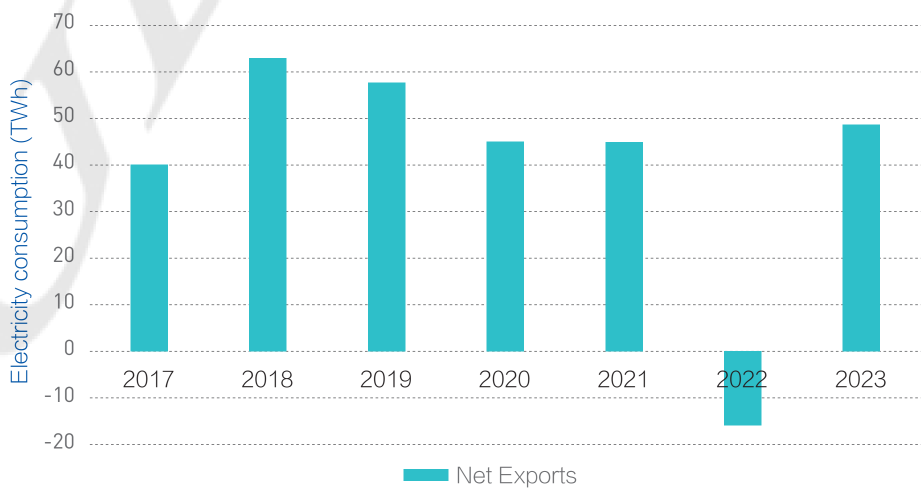


Figure 4-18 Net Electricity Exports of France

2. Calculation and analysis of electricity development index

According to the calculation results of the electricity development index, **France's comprehensive electricity development index is 91.0 points. The country is a global leader in electricity technological innovation, with a high level of electricity supply guarantee and green and low-carbon development.**

To further improve electricity development in France,

Firstly it is necessary to upgrade electricity consumption services, to shorten the time to obtain an electricity connection and lower the cost of electricity;

Secondly it is required to continue to vigorously develop new energy power generation, to make electricity cleaner and lower the cost of electricity;

Thirdly it is essential to strengthen electricity replacement in industry and transportation sectors, to increase the Share of electricity consumption in total final energy consumption.

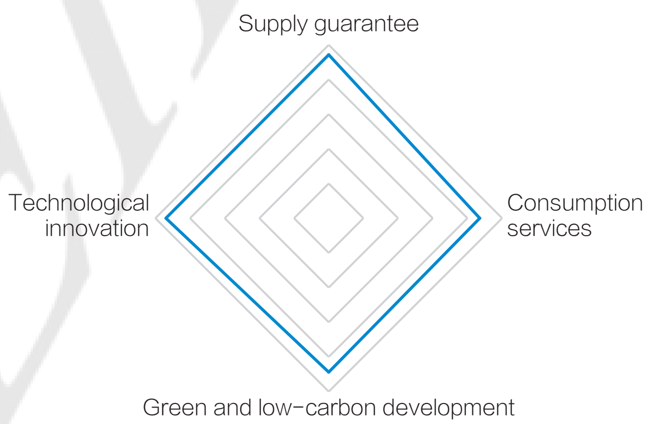


Figure 4-19 Electricity Development Level of France in Different Dimensions

3. Experience in electricity development

France is one of the most mature countries in nuclear power development worldwide, with advanced technology in this field that leads globally.

In 2022, nuclear power generation in France accounted for 63%, providing the country with clean, low-carbon, and stable electricity supply. In response to energy and climate crises, the French government decided to extend the lifespan of all nuclear reactors and to construct 6 to 14 new-generation nuclear reactors by 2050. These new reactors will be the improved version developed by the EDF Group, called EPR2, and are expected to cost around EUR 50 billion each to build. France is also the only country in the world that practices nuclear waste recycling and reuse. By recycling nuclear waste, it can save 30% of natural uranium resources, reduce nuclear waste production by 20%, and increase the utilization rate of nuclear energy.

France attaches great importance to the digital and intelligent development of its electricity system.

The EDF Group has been vigorously promoting intelligent meters, of which the number exceeded 40 million in 2022, a growth of over a hundredfold compared to a decade ago. On the one hand, massive data will facilitate analysis, risk control, and preventive maintenance, enabling precise distribution network investments. On the other hand, it will assist in fault detection, analysis and diagnosis, self-recovery, and manual processing of distribution networks and help balance supply and demand for electricity sales, fostering a more dynamic and flexible supply-demand matching between producers and consumers.

4.3 Africa

(I) Egypt

Egypt, as the second largest economy in Africa, has a strong foundation in electricity development with 100% access to electricity. It ranks highest in the electricity development index within the African region and is the only African country to enter the top 50 in the global electricity development index rankings. In recent years, Egypt has prioritized the development and utilization of new energy and the technological innovation and development of electricity, showing good momentum for the transition towards green and low-carbon electricity. Choosing Egypt as a representative country for analyzing its electricity development can serve as a reference and provide insights for other African nations.

1. Basic overview of electricity development

Table 4-5 Basic Data of Economic, Social and Electricity Development in Egypt

Economy and Society	Data	Electricity Development	Data
Land area (1,000 km^2)	1001	Total installed capacity (GW)	59.25
Population (million)	107	Total electricity consumption (TWh)	176.7
GDP (USD billion)	476.8	Installed capacity per capita (kW)	0.55
GDP per capita (USD)	4464	Electricity consumption per capita (kWh)	1655
Share of electricity consumption in total final energy consumption	22.8%	Access to electricity	100%
Proportion of clean energy power generation	11.5%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.53

Egypt's electricity infrastructure is relatively well-developed, but the electricity production and consumption per capita level is relatively low.

From 2017 to 2022, Egypt's total electricity consumption increased from 162.5 TWh to 176.7 TWh, with an average annual growth rate of 1.7%, showing faster growth after the COVID-19 pandemic. The total installed capacity rose from 47.17 GW to 59.25 GW, with an average annual growth rate of 4.7%, slightly higher than the global average. In 2022, Egypt's electricity consumption per capita and installed capacity per capita reached 16.55 GWh and 0.55 kW respectively, about half of the global average.

From 2017 to 2022, Egypt's total electricity consumption increased from **162.5** TWh to **176.7** TWh, with an average annual growth rate of **1.7%**

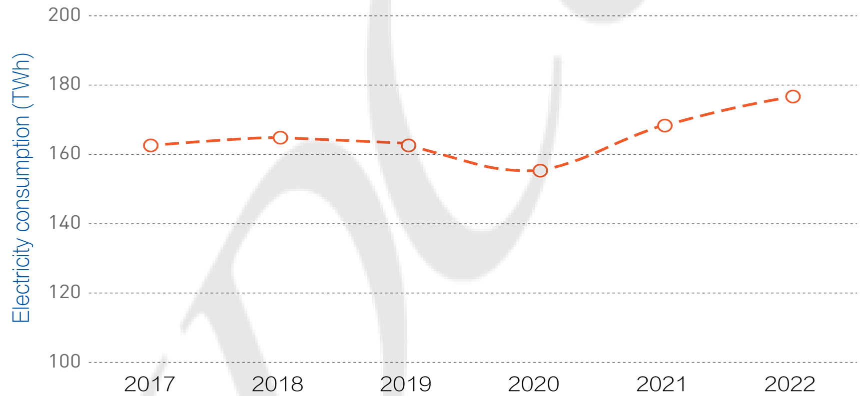


Figure 4-20 Changes in Electricity Consumption in Egypt over the Past 5 Years

In Egypt, thermal power generation holds a high proportion in the energy source structure, while the development of clean energy is still in its infancy.

From 2017 to 2022, the proportion of clean energy power generation in Egypt increased from 8% to 11.5%, with natural gas power generation still dominating the energy source structure. The proportion of clean energy installed capacity climbed from 8.1% to 10.6%, with the growth rate of clean energy power generation and installed capacity being lower than the global average. In 2022, Egypt's share of electricity consumption in total final energy consumption reached 22.8%, 2 percentage points higher than the global average and more than twice that of Africa.

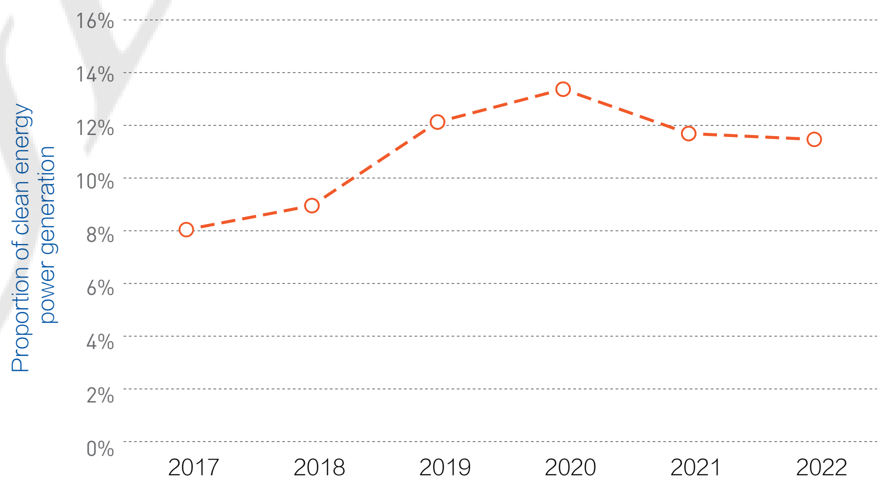


Figure 4-21 Changes in Proportion of Clean Energy Power Generation in Egypt over the Past 5 Years

2. Calculation and analysis of electricity development index

According to the calculation results of the electricity development index, **Egypt's comprehensive electricity development index is 73.0 points, roughly equivalent to the global average, with a relatively high score in technological innovation.** Gas-fired power generation occupies an absolutely dominant position in the energy source structure, with a relatively low electricity consumption per capita and lower scores for consumption services and green and low-carbon development. **In the future, to enhance Egypt's electricity development level,** the focus should be placed on improving electricity consumption services and accelerating the clean and low-carbon transition of electricity. **First,** efforts are needed to improve electricity consumption levels for low- and middle-income populations in remote areas. **Second,** there is a need to expedite electricity replacement in industry and transportation sectors, to increase the level of electrification and reduce fossil fuel consumption. **Third,** efforts should be increased to develop new energy, to accelerate the clean and low-carbon transition of electricity.

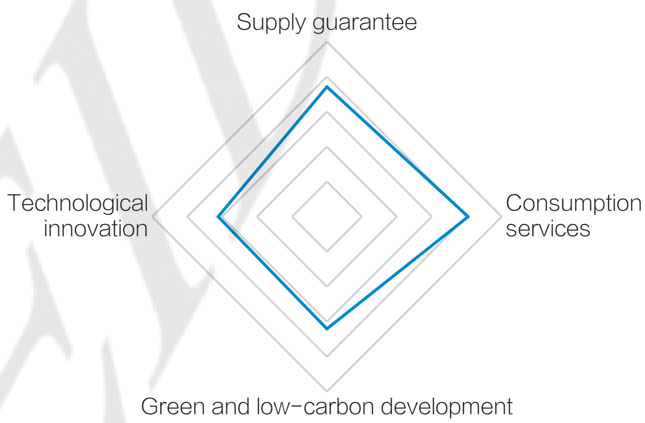


Figure 4-22 Electricity Development Level of Egypt in Different Dimensions

3. Experience in electricity development

Egypt values electricity supply guarantee, implementing multiple measures to stabilize the electricity supply. In recent years, Egypt has issued several policies and measures to improve the level of electricity supply guarantee and alleviate electricity shortage. Its level of electricity supply guarantee now stands at an absolute leading position in Africa. Egypt's measures to improve its electricity supply guarantee capability include building new transmission lines, establishing and developing distribution network control centers, transforming rural power grids, building, renovating and expanding power plants, and promoting the digital transformation of power grids. Egypt has also promulgated the *Renewable Energy Law* and amended the *Electricity Law* to encourage the development of solar energy and wind power.

the average power outage duration in Egypt is **119.4** minutes, about one twentieth of the average level in Africa

According to the World Bank's latest statistics of "Access to electricity", the average power outage duration in Egypt is 119.4 minutes, about one twentieth of the average level in Africa.

Figure 4-23　EETC 500 kV Transmission Line Crossing the Gobi in Egypt under China-Egypt Energy Cooperation

Attaching great importance to innovation in energy and electricity technologies, Egypt is vigorously promoting the coordinated development of electricity and hydrogen. Egypt aims to develop into a green electricity and green hydrogen production center in West Asia and North Africa. At the 27th session of the Conference of the Parties of the United Nations Framework Convention on Climate Change (COP 27), Egypt, as the host, released the *National Green Hydrogen Strategy* prepared in cooperation with the European Bank for Reconstruction and Development (EBRD), issued the *Joint Statement on the EU-Egypt Renewable Hydrogen Partnership*, and signed more than ten memorandums of understanding with several countries to build green hydrogen plants in the Suez Canal Economic Zone (SCZONE). Egypt's Minister of Electricity and Renewable Energy declared 2022 as "The Year of Green Hydrogen" in Egypt. To meet the needs of electricity supply produced by green hydrogen in the SCZONE, Egypt plans to build large-scale wind and solar power generation bases along both sides of the Nile River, and use HVDC or flexible DC transmission technology to transmit new energy power from central and southern regions to the Suez load center.

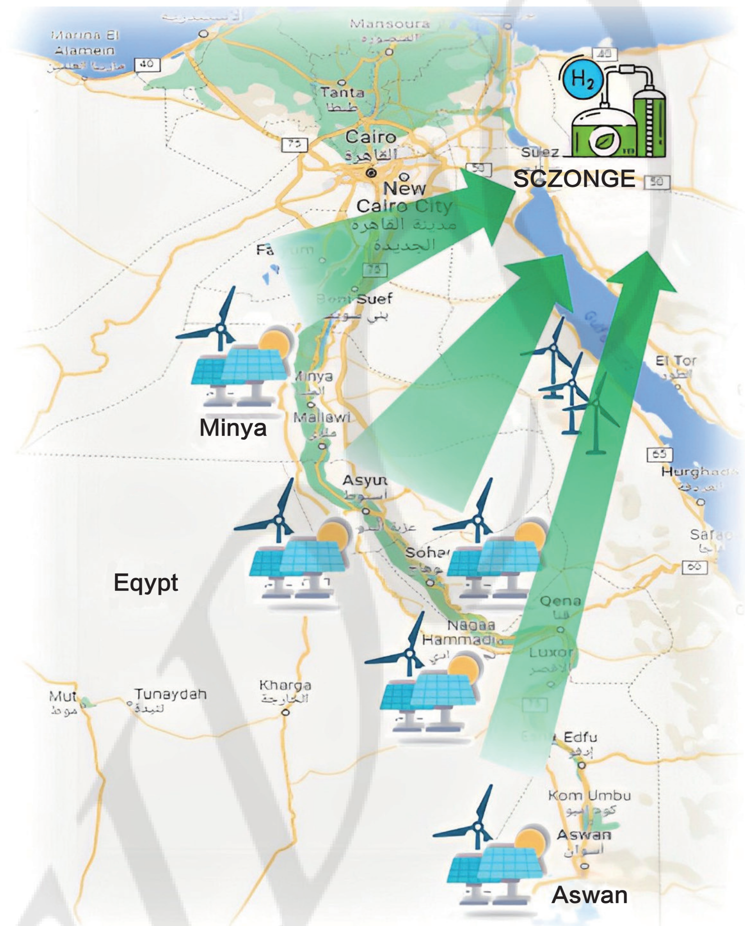


Figure 4-24 “Green Corridor” for Electricity Supply from Egypt to Suez Green Hydrogen Industrial Park

(II) South Africa

South Africa is the third largest economy and the most economically developed country in Africa, with the GDP per capita of USD 6,460, nearly twice the global average. Its electricity development is at a leading level in Africa.

1. Basic overview of electricity development

Table 4-6 Basic Data of Economic, Social and Electricity Development in South Africa

Economy and Society	Data	Electricity Development	Data
Land area (1,000 km^2)	1219	Total installed capacity (GW)	63.41
Population (million)	62.74	Total electricity consumption (TWh)	200.6
GDP (USD billion)	405.3	Installed capacity per capita (kW)	1.01
GDP per capita (USD)	6460	Electricity consumption per capita (kWh)	3197
Share of electricity consumption in total final energy consumption	26.99%	Access to electricity	89.3%
Proportion of clean energy power generation	12.2%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.95

The electricity production and consumption per capita of South Africa are leading in Africa; however, the electricity supply has not provided adequate support for economic and social development in recent years.

From 2017 to 2022, the total electricity consumption in South Africa decreased from **221.9** TWh to **200.6** TWh, with an average annual growth rate of **−2.0%**

From 2017 to 2022, the total electricity consumption in South Africa decreased from 221.9 TWh to 200.6 TWh, with an average annual growth rate of −2.0%. The main reasons for the decline in electricity demand lie in the old coal-fired thermal power units and low reliable output of energy sources, which resulted in an insufficient electricity supply capacity and poor electricity supply reliability; the total installed capacity increased from 53.75 GW to 63.41 GW, with an average annual growth rate of 3.4%. In 2022, the electricity consumption per capita and installed capacity per capita in South Africa reached 3,197 kWh and 1.01 kW respectively, slightly lower than the global average. South Africa's GDP per capita is twice the global average, but its electricity production capacity and consumption level are lower than the global average. Its electricity production capacity is insufficient to meet the demands of economic and social development.

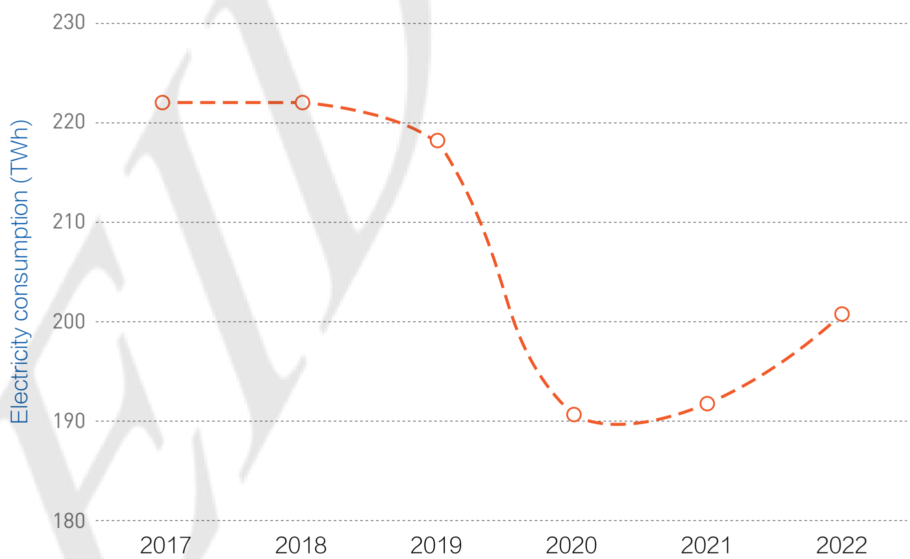


Figure 4-25 Changes in Electricity Consumption in South Africa over the Past 5 Years

Coal power still plays a dominant role in the energy source structure of South Africa.

From 2017 to 2022, the proportion of clean energy power generation in South Africa grew from 9.4% to 12.2%, with an increase of less than 3 percentage points; the proportion of clean energy installed capacity rose from 20.7% to 23.7%, up by 3 percentage points. In 2022, South Africa's Share of electricity consumption in total final energy consumption reached 27%, 6.4 percentage points higher than the global average and 2.5 times that of the African average. This placed South Africa ahead of the rest of Africa.

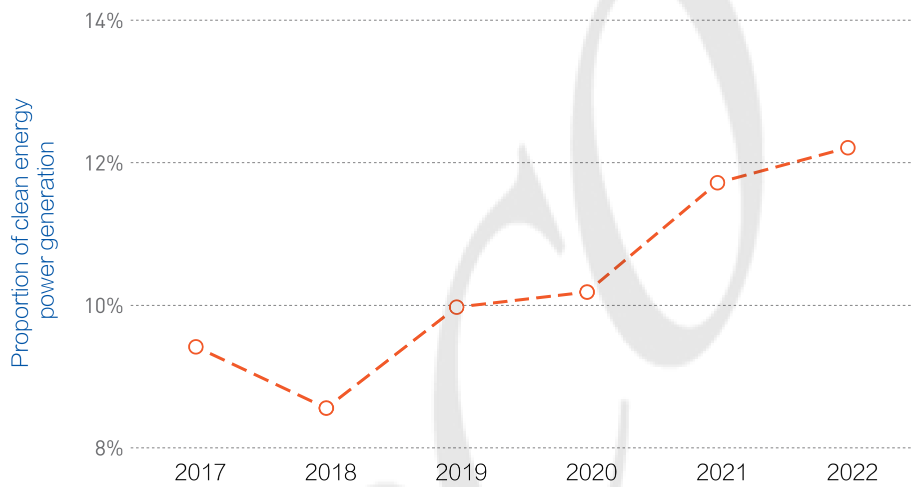


Figure 4-26 Changes in Proportion of Clean Energy Power Generation in South Africa over the Past 5 Years

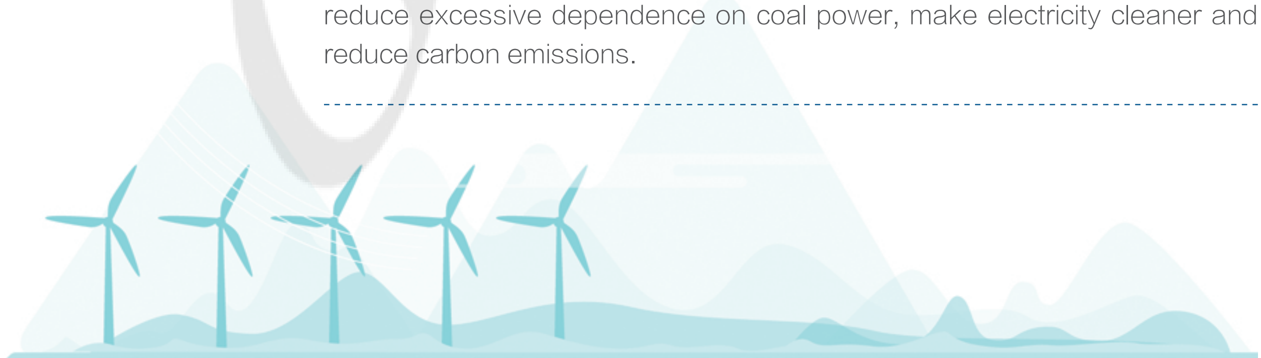
2. Calculation and analysis of electricity development index

According to the calculation results of the electricity development index, **South Africa's comprehensive electricity development index is 68.2 points.** Due to the old power generation equipment with frequent failures and low effective output, the score in electricity supply guarantee is relatively low. The energy source structure is still dominated by coal power, with a relatively low score in green and low carbon development.

In the future, it is necessary to further improve the electricity development level in South Africa.

Firstly it should vigorously enhance the electricity supply and guarantee capability, take multiple measures to alleviate the tension of electricity supply, increase the transformation of old units, and speed up the construction of new energy sources and transmission lines;

secondly it needs to vigorously develop new energy power generation, reduce excessive dependence on coal power, make electricity cleaner and reduce carbon emissions.



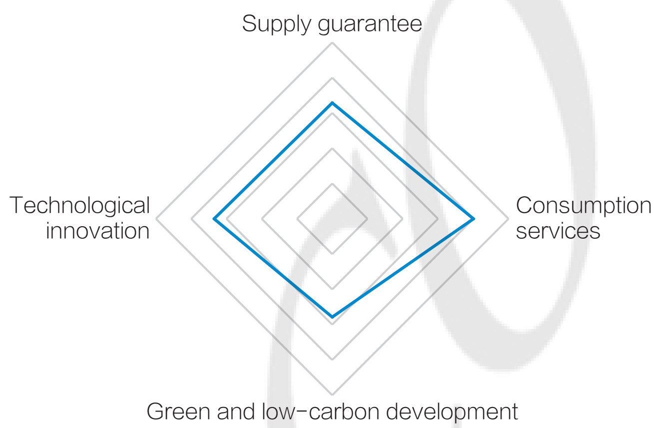


Figure 4-27 Electricity Development Level of South Africa in Different Dimensions

3. Experience and enlightenment of electricity development

In recent years, South Africa faced serious power outages and rationing accidents, drawing global attention. The government of South Africa formulated a series of measures to alleviate the pressure on electricity supply guarantee. In 2022, affected by factors such as the aging of electricity supply infrastructure, unplanned power outages and rationing across South Africa reached 18 GW, resulting in direct economic losses up to ZAR 125 million (USD 7 million). To solve the problem of insufficient electricity supply guarantee capability in South Africa, the Ministry of Electricity of South Africa has set up a special action team to upgrade and renovate the power generation equipment of the electricity company Eskom, add new installed capacity and strengthen demand-side management.

4.4 Central and South America

(I) Chile

As one of the developed countries in Central and South America, Chile has relatively complete electricity infrastructure and attaches great importance to the green and low-carbon electricity transformation and development. It ranks 1st in the electricity development index in Central and South America, where its installed capacity per capita and electricity consumption per capita are second only to Puerto Rico. Analysis of the electricity development in Chile, as a representative country of Central and South America, can offer valuable insights and guidance for the electricity development in other countries of the region.

1. Basic overview of electricity development

Table 4-7 Basic Data of Economic, Social and Electricity Development in Chile

Economy and Society	Data	Electricity Development	Data
Land area (1,000 km^2)	756	Total installed capacity (GW)	35.6
Population (million)	19.5	Total electricity consumption (TWh)	86.6
GDP (USD billion)	301	Installed capacity per capita (kW)	1.83
GDP per capita (USD 1,000)	15.4	Electricity consumption per capita (kWh)	4442
Share of electricity consumption in total final energy consumption	23.9%	Access to electricity	100%
Proportion of clean energy power generation	56.6%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.33

From 2017 to 2022, Chile's total electricity consumption grew from **74.7** TWh to **86.6** TWh, with an average annual growth rate of **3.0%**

Chile's electricity production and consumption levels are higher than the global average. From 2017 to 2022, Chile's total electricity consumption grew from 74.7 TWh to 86.6 TWh, with an average annual growth rate of 3.0%; the total installed capacity rose from 26.73 GW to 35.6 GW, with an average annual growth rate of 5.9%, which was higher than the global average. In 2022, Chile's electricity consumption per capita and installed capacity per capita reached 4,442 kWh and 1.83 kW respectively, 1.3 to 1.7 times the global average.

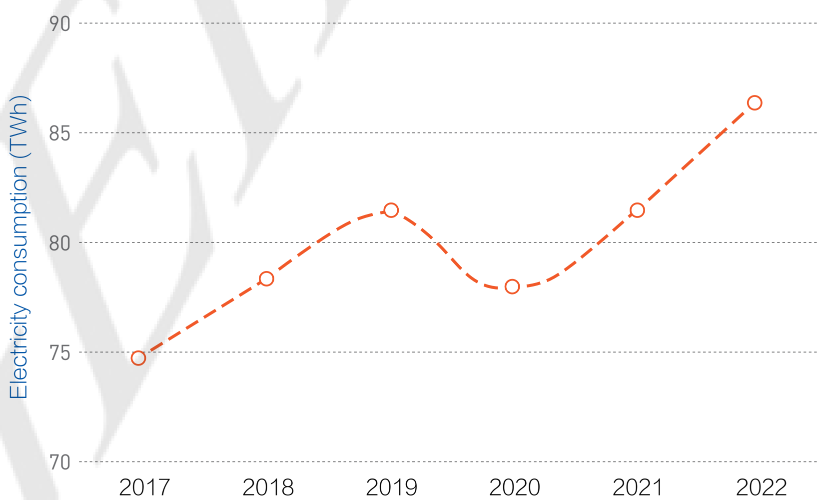


Figure 4-28 Changes in Electricity Consumption in Chile over the Past 5 Years

In 2022, Chile's share of electricity consumption in total final energy consumption reached **23.9%**, **3.3** percentage points higher than the global average

Chile has formed an energy source structure dominated by clean energy. From 2017 to 2022, the proportion of clean energy power generation in Chile increased from 43.5% to 56.6%, up by 13 percentage points; the proportion of clean energy installed capacity grew from 38.3% to 50.1%, with an increase of nearly 12 percentage points. In 2022, Chile's share of electricity consumption in total final energy consumption reached 23.9%, 3.3 percentage points higher than the global average.

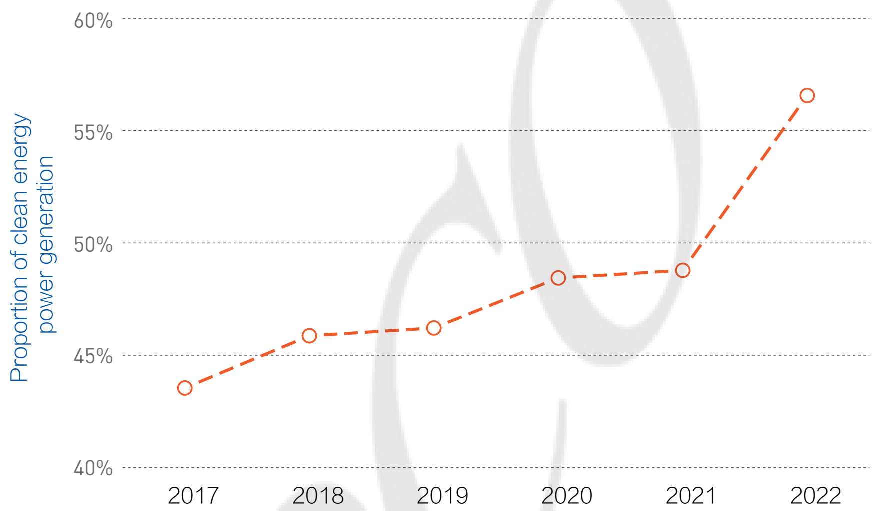


Figure 4-29 Changes in Proportion of Clean Energy Power Generation in Chile over the Past 5 Years

2. Calculation and analysis of electricity development index

According to the calculation results of the electricity development index, **Chile's comprehensive electricity development index is 82.7 points, with relatively high scores in technological innovation and green and low-carbon development.** The high electricity prices, long average power outage duration per household and relatively large grid losses have led to a lower score in consumption services. **In the future, Chile should further improve its electricity development level. First,** it needs to accelerate electricity replacement in industry, transportation, residential life and other fields to reduce the consumption and utilization of fossil fuels and improve the electricity consumption level; **second,** it should continue to promote the development of new energy resources such as solar and wind power to further reduce carbon emissions from the electricity industry.

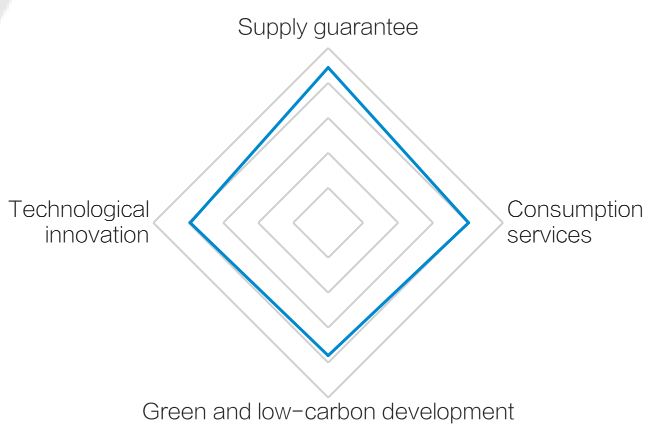


Figure 4-30 Electricity Development Level of Chile in Different Dimensions

3. Experience in electricity development

Chile attaches great importance to the development of new energy. It is the first country in Central and South America to develop large-scale new energy bases in desertification areas. In June 2022, Chile's electricity company AME and its French counterpart EDF jointly built the CEME1 PV Power Plant in Atacama Desert, northern Chile. The project was undertaken by POWERCHINA HUADONG ENGINEERING CORPORATION LIMITED. It covers an area of 435 hectares, with a total installed capacity of 480 MW. Since it was put into operation in January 2024, this project has become the largest solar power plant in Chile.

Figure 4-31 CEME1 PV Power Plant in Atacama Desert, Chile

(II) Brazil

Brazil is the largest economy in Central and South America, with the largest territorial area and population in the region. Its electricity development level ranks among top 50 in the world.

1. Basic overview of electricity development

Table 4-8 Basic Data of Economic, Social and Electricity Development in Brazil

Economy and Society	Data	Electricity Development	Data
Land area (1,000 km^2)	8516	Total installed capacity (GW)	220
Population (million)	216	Total electricity consumption (TWh)	583.2
GDP (USD 1 trillion)	1.92	Installed capacity per capita (kW)	1.02
GDP per capita (USD)	8872	Electricity consumption per capita (kWh)	2695
Share of electricity consumption in total final energy consumption	20.39%	Access to electricity	99.5%
Proportion of clean energy power generation	90.1%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.06

From 2017 to 2022, Brazil's total electricity consumption increased from **533.4** TWh to **583.2** TWh, with an average annual growth rate of **1.8%**

Brazil's electricity production and consumption show a continuous upward trend. From 2017 to 2022, Brazil's total electricity consumption increased from 533.4 TWh to 583.2 TWh, with an average annual growth rate of 1.8%. The total installed capacity rose from 172 GW to 220 GW, with an average annual growth rate of 5.1%, exceeding the global average level. Its electricity production and consumption have grown steadily after the COVID-19 pandemic. In 2022, Brazil's electricity consumption per capita and installed capacity per capita reached 2,695 kWh and 1.02 kW respectively, slightly lower than the global average.

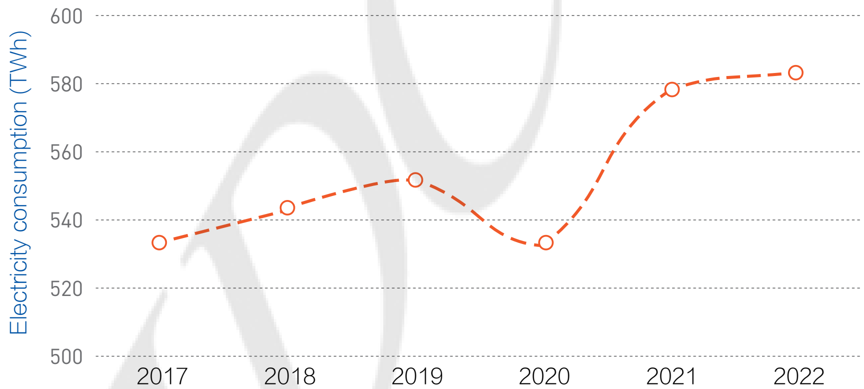


Figure 4-32 Changes in Electricity Consumption in Brazil over the Past 5 Years

Brazil is rich in hydropower resources, and hydropower plays a leading role in the energy source structure. From 2017 to 2022, the proportion of clean energy power generation in Brazil grew from 81.4% to 90.1%, with an increase of nearly 10 percentage points; the proportions of hydropower, wind power and solar power generation in Brazil were 63.3%, 12.1% and 4.0% respectively; the proportion of clean energy installed capacity rose from 75.7% to 80.4%, with an increase of nearly 5 percentage points. In 2022, Brazil's share of electricity consumption in total final energy consumption reached 20.4%, roughly equal to the global average level.

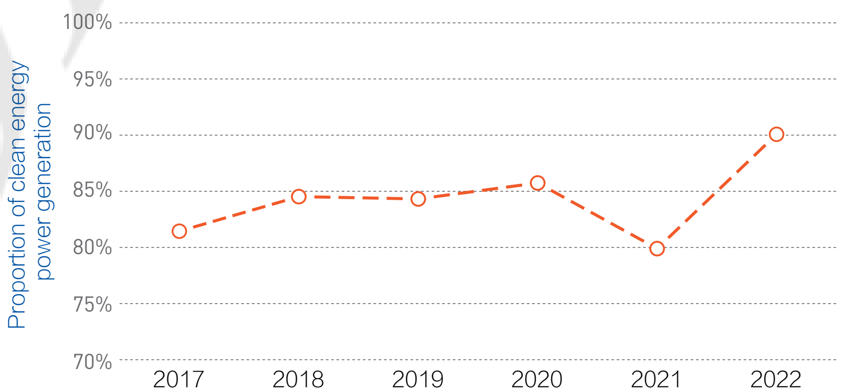


Figure 4-33 Changes in Proportion of Clean Energy Power Generation in Brazil over the Past 5 Years

Brazil has built nationwide interconnected power grids and formed a long-distance large-capacity electricity transmission pattern from north to south. Brazil's transmission network consists of the National Interconnected System (SIN) and several independent small grids. SIN is responsible for transmitting electricity to 99.9% of users in the country, with a voltage level of 138 kV to 750 kV and an electricity transmission capacity of 180 GW. As of 2022, the total length of SIN's transmission lines reached 183,000 km, of which 230 kV and 500 kV lines accounted for 37.44% and 39.06% respectively. The coastal area in southeast Brazil is the most densely populated region in the country and also a power load center. Brazil has built a multi-circuit DC transmission channel to transmit hydropower from the Amazon Basin in the north to load centers such as Sao Paulo and Rio de Janeiro in the southeast.

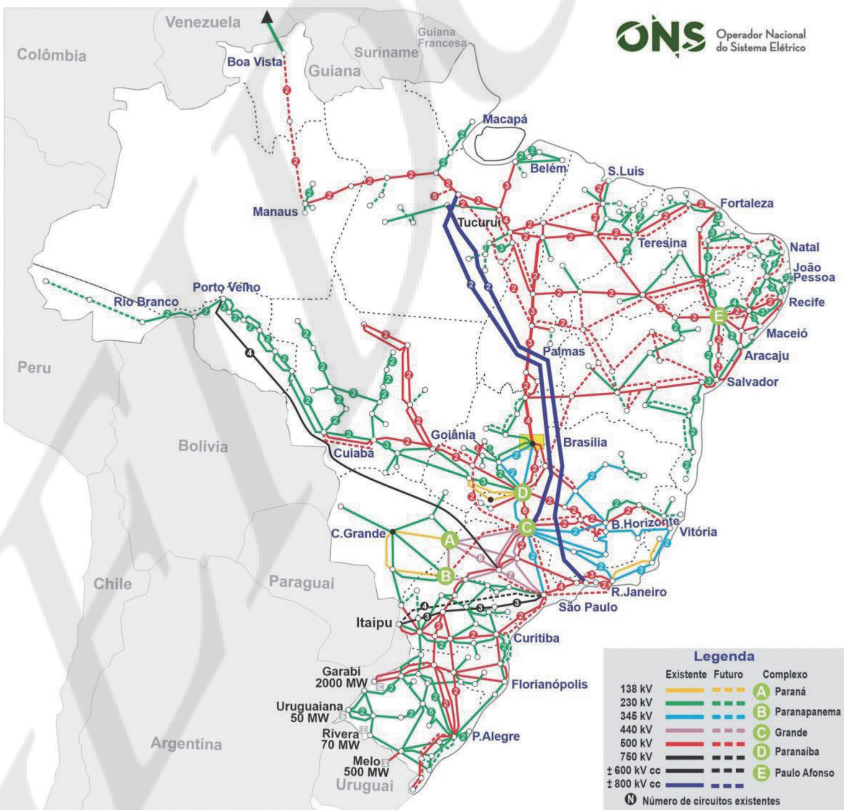


Figure 4-34 Transmission Network in Brazil[1]

[1] Picture source: https://ri.taesa.com.br/en/taesa/transmission-sector/

2. Calculation and analysis of electricity development index

According to the calculation results of the electricity development index, **Brazil's comprehensive electricity development index is 76.1 points, with relatively high scores in technological innovation and green and low-carbon development.** In 2022, 180,000 households in southern Brazil suffered from power outages due to strong wind and rainfall. Brazil's installed capacity per capita was lower than the global average, resulting in a low score in supply guarantee; Brazil's high electricity prices, long time to obtain an electricity connection and long average power outage duration per household led to a relatively low score in consumption services. **In the future, the country needs to further improve its electricity development level. First,** it is urgent to strengthen the construction of energy sources and grid infrastructure and improve the electricity supply guarantee capability and residential electricity consumption level; **second,** it is necessary to shorten the time to obtain an electricity connection, improve the electricity supply reliability and enhance the level of electricity supply services; **third,** it is crucial to strengthen the electricity replacement in the industry and transportation sectors, increase the Share of electricity consumption in total final energy consumption, and further reduce fossil fuel consumption.

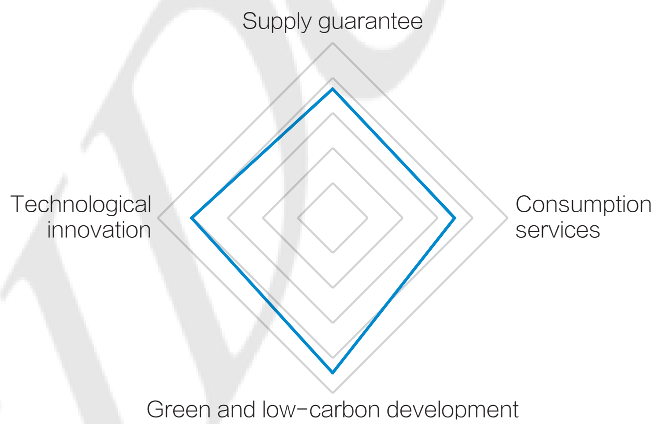


Figure 4-35 Electricity Development Level of Brazil in Different Dimensions

3. Experience in electricity development

Brazil has a vast territory and spans more than 2,000 km from north to south, with 80% of its power load concentrated in the developed areas in the south and southeast. However, the energy source center is located in the Amazon Basin in the north. To solve the problem of large-scale long-distance electricity transmission, Brazil is committed to the innovative application of electricity transmission technology. It has introduced UHV electricity transmission technology independently developed by China and built a “electricity expressway” to transmit large-scale hydropower in the north to load centers in the south and southeast.

Belo Monte Hydropower Station is the second largest hydropower plant in Brazil, with a total installed capacity of 11 GW. The State Grid Corporation of China has built two UHVDC transmission lines for the power delivery, with a length of 2,084 km and 2,539 km respectively. The total transmission capacity is 8 GW, meeting the electricity demand of 22 million people in core areas such as Sao Paulo and Rio de Janeiro. Besides, 25,000 jobs have been created for Brazil, strongly driving its economic and social development.

Belo Monte Hydropower Station is the second largest hydropower plant in Brazil, with a total installed capacity of 11 GW

Figure 4-36 Phase I and Phase II UHV Transmission Projects of Belo Monte Hydropower Plant (solid line indicates Phase I, dotted line indicates Phase II)

4.5 North America

Canada not only leads North America in clean electricity production but also boasts the highest installed power generation capacity per capita and electricity consumption per capita among all countries in the region. Analysis of the electricity development in Canada, as a representative country in North America, can provide valuable insights and guidance for the electricity development in other countries of the region or other parts of the world.

1. Basic overview of electricity development

Table 4-9 Basic Data of Economic, Social and Electricity Development in Canada

Economy and Society	Data	Electricity Development	Data
Land area (1,000 km^2)	9985	Total installed capacity (GW)	159
Population (million)	38.12	Total electricity consumption (TWh)	553.3
GDP (USD million)	214	Installed capacity per capita (kW)	4.17
GDP per capita (USD 1,000)	56.1	Electricity consumption per capita (MWh)	14.5
Share of electricity consumption in total final energy consumption	23.6%	Access to electricity	100%
Proportion of clean energy power generation	82.8%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.13

From 2017 to 2022, Canada's total electricity consumption increased from **551.2** TWh to **553.3** TWh, with an average annual growth rate of only **0.1%**

Canada leads the world in electricity production and consumption. From 2017 to 2022, Canada's total electricity consumption increased from 551.2 TWh to 553.3 TWh, with an average annual growth rate of only 0.1%; the total installed capacity grew from 150 GW to 159 GW, with an average annual growth rate of 1.2%. In 2022, Canada's electricity consumption per capita and installed capacity per capita reached 14.5 MWh and 4.17 kW respectively, about four times the global average.

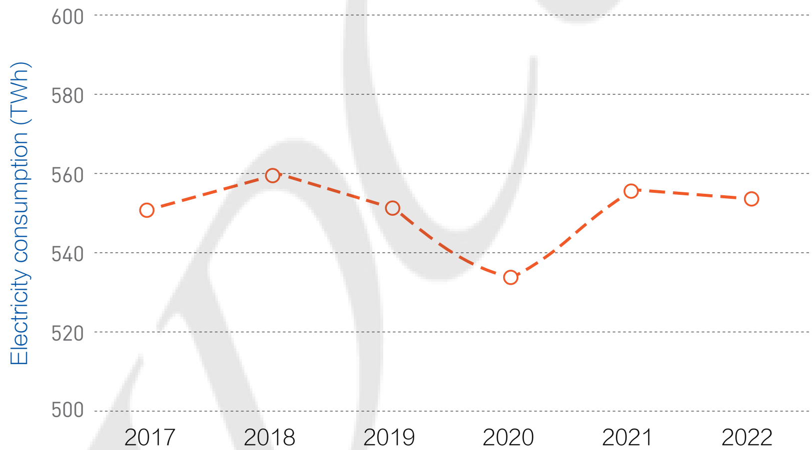


Figure 4-37 Changes in Electricity Consumption in Canada over the Past 5 Years

In 2022, Canada's share of electricity consumption in total final energy consumption reached **23.6%**, **3** percentage points higher than the global average

Canada has built a power system dominated by clean energy. From 2017 to 2022, the proportion of clean energy power generation in Canada further rose from 82.1% to 82.8%, with hydropower, nuclear power and wind power representing 62%, 13%, and 6% respectively, collectively contributing to 81% of Canada's total power generation; the proportion of clean energy installed capacity rose slightly from 75.1% to 75.2%. In 2022, Canada's share of electricity consumption in total final energy consumption reached 23.6%, 3 percentage points higher than the global average.

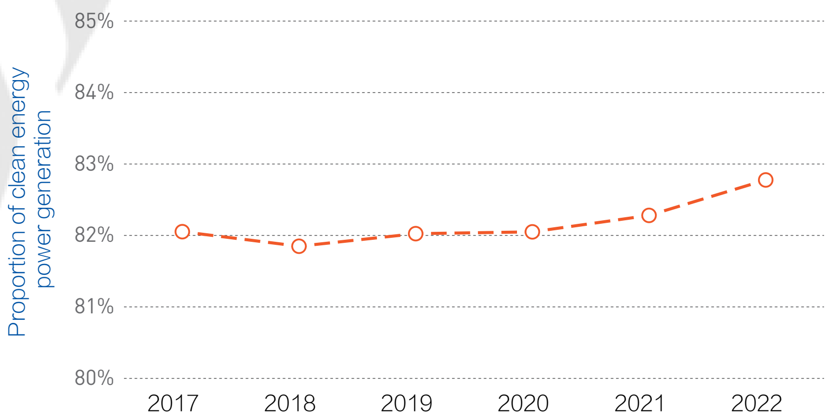


Figure 4-38 Changes in Proportion of Clean Energy Power Generation in Canada over the Past 5 Years

Canada attaches great importance to transnational power grid interconnection. It has built North American interconnected grids with the USA. There are more than 100 north-south lines between the USA and Canada's New Brunswick, Quebec, Ontario, Manitoba, Saskatchewan and British Columbia, with an electricity exchange capacity of 20 GW.

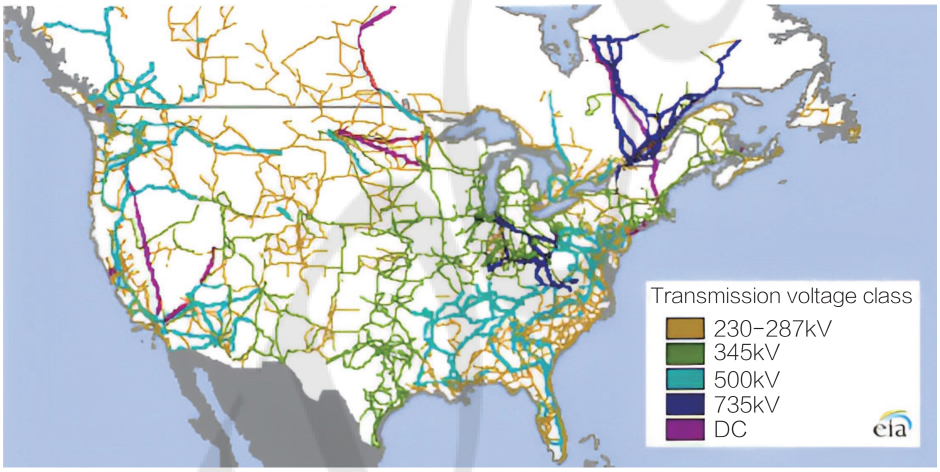


Figure 4-39 Power Grid Interconnection between Canada and the USA[1]

[1] Picture source: https://www.eia.gov/todayinenergy/detail.php? id=8930

2. Calculation and analysis of electricity development index

According to the calculation results of the electricity development index, **Canada's comprehensive electricity development index is 91.7 points, and the scores of various specific indexes are also among the top in the world.**

In the future, it is necessary to further improve Canada's electricity development level.

First it should continue to increase the development of new energy sources such as wind power to replace the remaining fossil fuels for power generation;

second it needs to increase the share of electricity consumption in total final energy consumption, reduce fossil fuel consumption and facilitate the low-carbon transformation of the energy system.

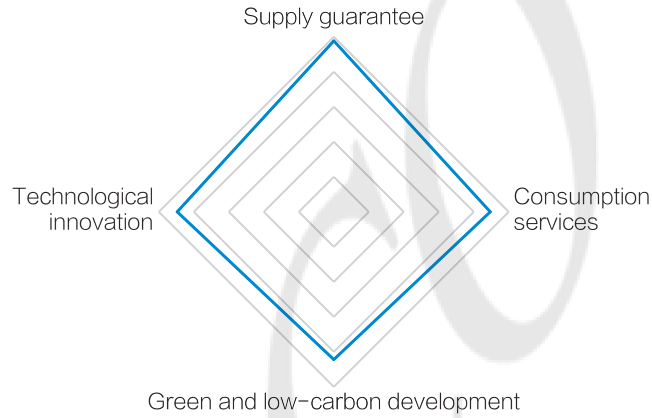


Figure 4-40 Electricity Development Level of Canada in Different Dimensions

3. Experience in electricity development

Canada attaches importance to the green and low-carbon transformation and development of energy and electricity, and plans to vigorously develop wind power to supplement the electricity demand gap caused by decommissioning of coal power equipment.

In 2021, a total of 31 wind power projects were planned in Canada. The largest one is Yarmouth Offshore Wind Farm with a planned installed capacity of 5 GW. It is 20 km away from the Yarmouth coast in Nova Scotia, with a depth of 44–60 m and a wind speed of 10 m/s. The project is expected to be tendered in 2025. Nova Scotia also announced the construction of Canada's first offshore wind power project in 2023. This project, with a total installed capacity of 400,000 kW, is about 20–30 km away from the Goldberg coast in Nova Scotia.

Figure 4-41 Offshore Wind Power in Nova Scotia

Relying on power grid interconnection, Canada has realized large-scale optimal allocation of power resources.

Canada's energy source structure is dominated by hydropower, with the highest load occurring in winter. The USA's energy source structure is dominated by coal-fired thermal power, with the highest load occurring in summer. Canada's abundant hydropower resources complement well with the large amount of coal-fired thermal power in the USA. Canada relies on the power grid interconnection channel with the USA. It imports cheap coal power from the USA during the trough of electricity consumption (at night) to save hydropower resources, and exports low-cost hydropower to the USA at the peak of electricity consumption.

4.6 Oceania

Australia is the largest, most populous and most economically developed country in Oceania, with relatively complete electricity infrastructure. It attaches importance to technological innovation of electricity and green and low-carbon electricity transformation, and plays a vital role in electricity development and cooperation in the Asia-Pacific region. Australia features high-level electricity development. Analysis of the electricity development in Australia, as a representative country in Oceania, can provide valuable insights and guidance for the electricity development in other countries of the region or other parts of the world.

1. Basic overview of electricity development

Table 4-10 Basic Data of Economic, Social and Electricity Development in Australia

Economy and Society	Data	Electricity Development	Data
Land area (1,000 km^2)	7692	Total installed capacity (GW)	101
Population (million)	25.8	Total electricity consumption (TWh)	250
GDP (USD 1 trillion)	1.69	Installed capacity per capita (kW)	3.93
GDP per capita (USD 1,000)	65.5	Electricity consumption per capita (kWh)	9690
Share of electricity consumption in total final energy consumption	23.6%	Access to electricity	100%
Proportion of clean energy power generation	34.5%	Carbon emissions per unit of electricity consumption (kg CO_2/kWh)	0.56

Australia has complete electricity infrastructure and high-level electricity production and consumption per capita.

From 2017 to 2022, Australia's total electricity consumption increased from 243.7 TWh to 250 TWh, which remained basically constant; the total installed capacity increased from 74.32 GW to 101 GW, with an average annual growth rate of 6.4%, higher than the global average. In 2022, Australia's electricity consumption per capita and installed capacity per capita reached 9,690 kWh and 3.93 kW respectively, about three times the global average.

From 2017 to 2022, Australia's total electricity consumption increased from 243.7 TWh to 250 TWh, which remained basically constant

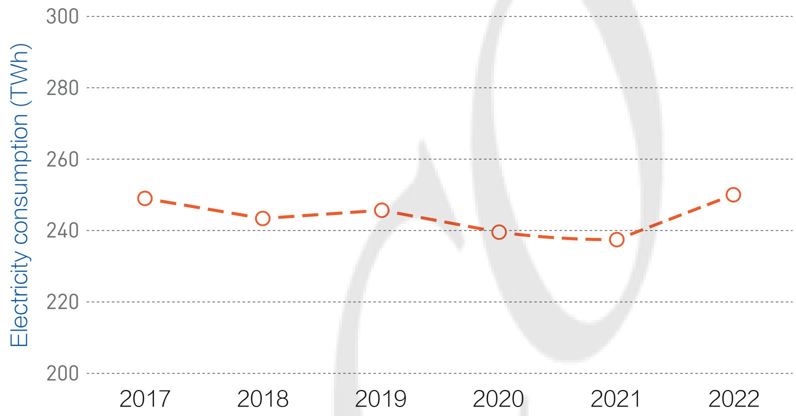


Figure 4-42 Changes in Electricity Consumption in Australia over the Past 5 Years

Australia's clean energy power generation develops rapidly.

From 2017 to 2022, the proportion of clean energy power generation in Australia expanded from 16% to 34.5%, more than doubled; the proportion of clean energy installed capacity rose from 31.1% to 47.5%, up by 16 percentage points. In 2022, Australia's share of electricity consumption in total final energy consumption reached 23.6%, 3 percentage points higher than the global average.

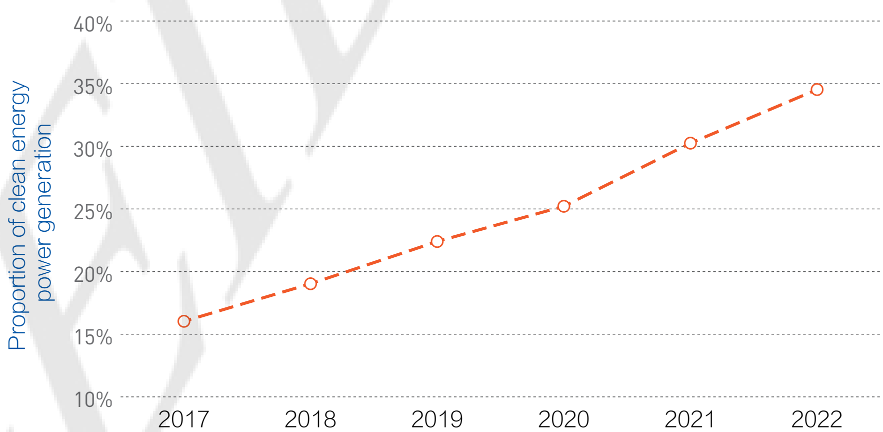


Figure 4-43 Changes in Proportion of Clean Energy Power Generation in Australia over the Past 5 Years

2. Calculation and analysis of electricity development index

According to the calculation results of the electricity development index, **Australia's comprehensive electricity development index is 84.0 points, with relatively high scores in technological innovation and supply guarantee.** Due to Australia's relatively limited hydropower resources, despite the rapid development of new energy sources, especially PV, the proportion of clean energy electricity is still lower than that of New Zealand and many countries in Central and South America, North Europe, and North America. That is why Australia does not score high in green and low-carbon development.

In the future, Australia should further raise its electricity development level.

First it should continue to vigorously develop solar and wind power and accelerate the clean and low-carbon electricity transformation;

Second it needs to shorten the time to obtain an electricity connection, reduce the electricity cost, improve the electricity supply reliability, and take multiple measures to improve the level of electricity consumption services;

Third it has to accelerate the research on new technologies to improve the resilience of power grids under extreme weather conditions such as mountain fires and rainstorms, so as to further enhance the level of electricity supply guarantee.

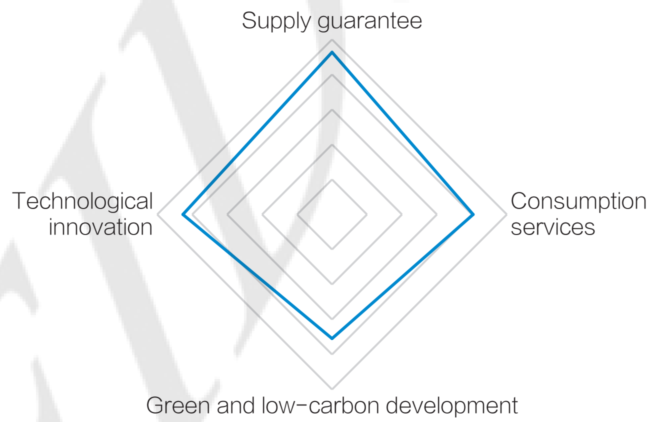


Figure 4-44 Electricity Development Level of Australia in Different Dimensions

3. Experience in electricity development

Solar power generation in Australia develops rapidly.

In 2022, the centralized and distributed PV installed capacity in Australia reached 11 GW and 20 GW respectively, accounting for 13% of power generation, surpassing wind power. It is currently the third largest energy source in Australia. Australia's distributed PV is mainly rooftop PV, and all state governments in Australia have introduced corresponding preferential policies. By the end of 2022, nearly one-third of households in Australia had installed rooftop PV panels, and rooftop PV for commercial buildings was also growing rapidly. At present, the unit cost of rooftop PV in Australia has dropped to less than USD 1,000/kW.

Figure 4-45 Roof PV in Australia

Australia actively explores the application of innovative electricity technologies, aiming to improve the consumption capacity of new energy power and assist in achieving carbon neutrality.

In 2020, the Australian government proposed to invest USD 13 billion in technological innovation of electricity by 2030. Electricity innovation related technologies that Australia currently focuses on include green hydrogen, energy storage and carbon capture and storage (CCS).

Australia attaches great importance to the application of the energy storage technology in the power system.

At the end of 2022, there were 19 large-scale grid-side energy storage projects under construction in Australia, with an energy storage capacity of up to 1.4 GW/2 GWh. In 2023, there were 27 large-scale energy storage projects, with the capacity hitting a record to reach 5 GW/11 GWh. Australia's largest energy storage project is the Waratah Super Battery project in New South Wales, with an energy storage capacity of 850 MW/1.68 GWh and a total investment of AUD 100 million. It is planned to be put into operation in 2025.

Figure 4-46 Rendering of Waratah Super Battery Energy Storage System in New South Wales

5 Conclusion

Against the backdrop of "carbon emissions peak and carbon neutrality", the global energy allocation pattern, supply structure, utilization mode, technological innovation and industrial ecology are rapidly evolving. Electricity holds a central position and plays an increasingly crucial role in advancing energy transformation and guaranteeing energy security. The research on the global electricity development index (GEDI) aims to provide scientific guidance for global electricity transformation, promote exchanges and mutual learning among countries, create a friendly environment for electricity innovation and cooperation, and enable sustainable and affordable electricity for all.

Countries and regions vary significantly in economy, society and environment among countries. This report proposes a comprehensive index model and analysis method for evaluating electricity development, and establishes an open assessment indicator system of the index to provide reference for policy makers, investors, electricity industry practitioners and people concerned. The index calculation is affected by factors such as data integrity and weight design limitations, and thus the calculation results in this report are for readers' reference only.

The global energy and electricity industry is in a period of accelerated transformation, with numerous technological innovations emerging. The research on the electricity development index needs to keep pace with the times by continuously deepening the research model and method, optimizing and improving the indicator system, and making the evaluation of the electricity development index more scientific. GEIDCO is willing to exchange ideas and cooperate with individuals and institutes engaged in the industry, and contribute together to the sustainable development of global energy and power.

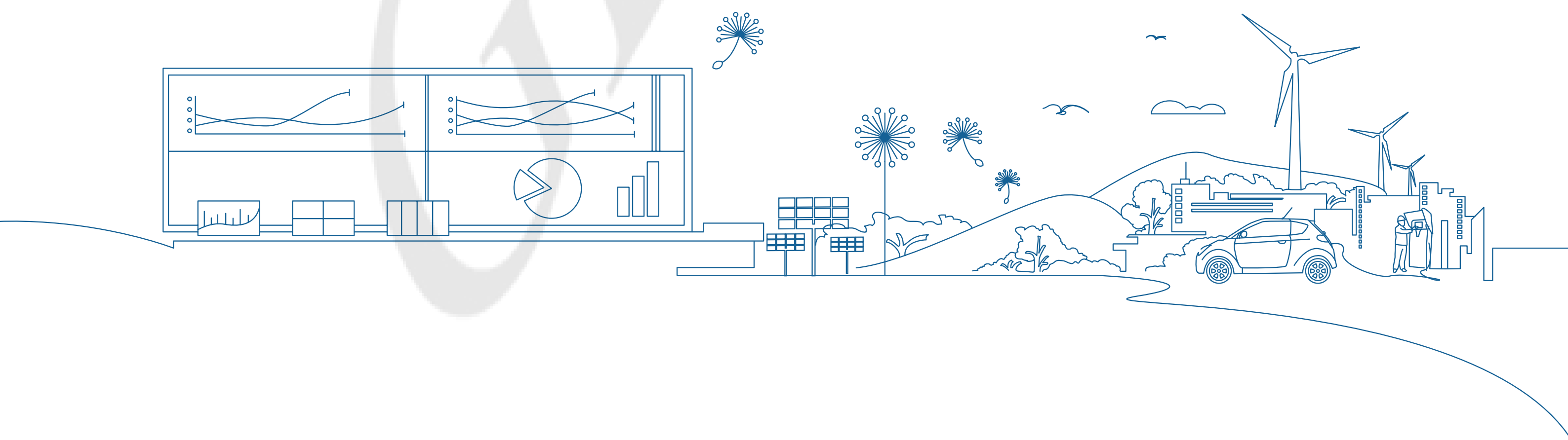
Appendix

(I) List of Figures

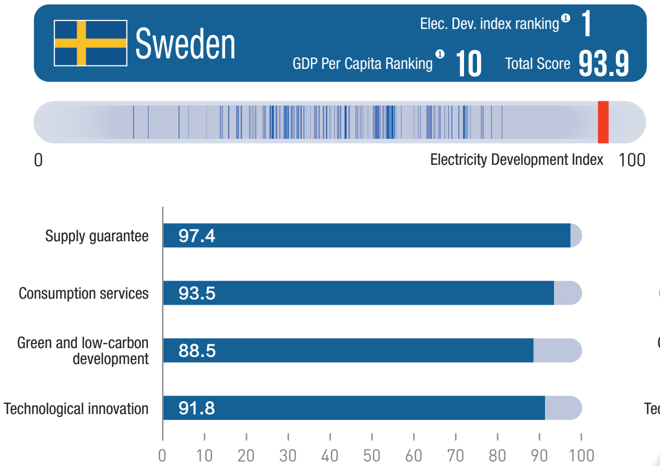
(II) List of Tables

Annexed table 1 List of Countries chosen for Global Electricity Development Index Assessment

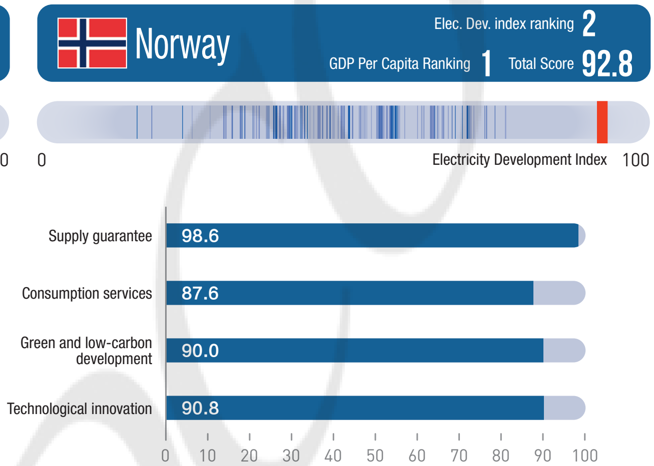
Continent	Country
Asia	China, Japan, South Korea, Mongolia, Cambodia, Laos, Myanmar, Thailand, Vietnam, Indonesia, the Philippines, Malaysia, Singapore, India, Bangladesh, Nepal, Sri Lanka, Pakistan, Uzbekistan, Kyrgyzstan, Kazakhstan, Iran, Israel, Jordan, Iraq, Kuwait, Saudi Arabia, Oman, United Arab Emirates, Qatar, Bahrain, Azerbaijan, Georgia, Tajikistan
Europe	UK, Ireland, Norway, Sweden, Finland, Denmark, Iceland, France, the Netherlands, Belgium, Spain, Portugal, Germany, Austria, Switzerland, Italy, Slovenia, Serbia, Greece, Croatia, Poland, Czech Republic, Slovakia, Hungary, Romania, Bulgaria, Türkiye, Russia, Belarus, Ukraine
Africa	South Africa, Egypt, Algeria, Morocco, Libya, Nigeria, Ghana, Tunisia, Angola, Zambia, Ethiopia, Kenya, Cote d'Ivoire, Tanzania, Cameroon, Senegal, Uganda
North America	Canada, USA, Mexico
Central and South America	Brazil, Chile, Argentina, Dominican Republic, Uruguay, Venezuela, Colombia, Ecuador, Peru, Costa Rica, Panama, Cuba, Puerto Rico, Bolivia
Oceania	Australia, New Zealand



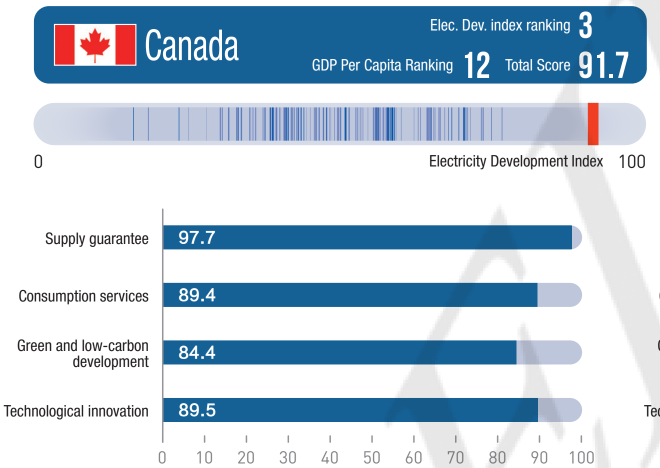
Annex 2 Assessment Results of Global Electricity Development Index



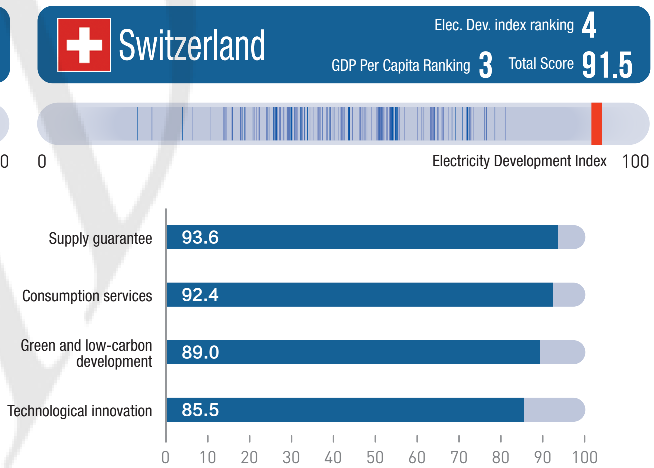
Evaluation Results of Sweden Electricity Development Index



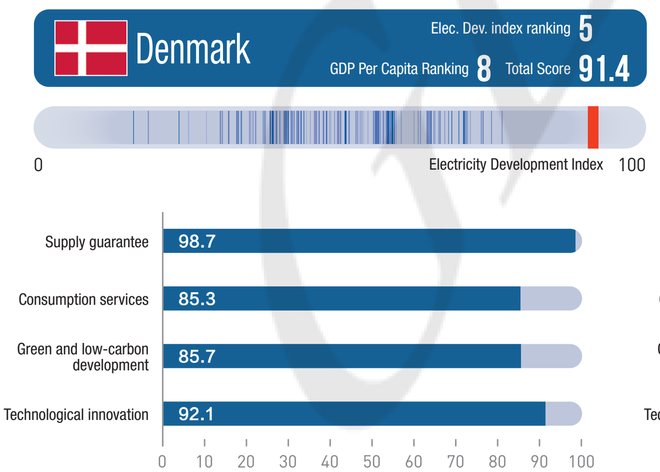
Evaluation Results of Norway Electricity Development Index



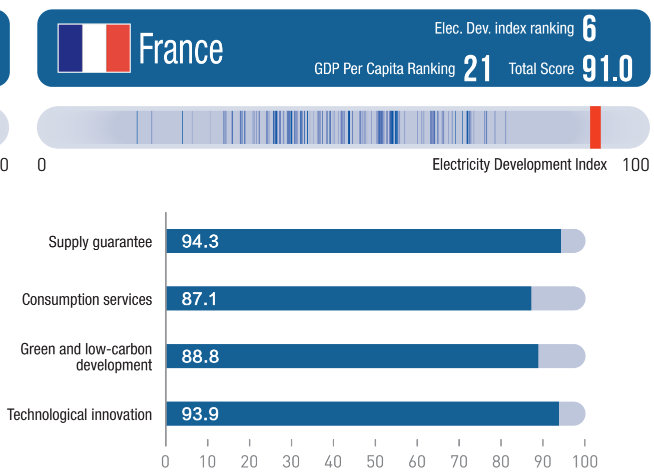
Evaluation Results of Canada Electricity Development Index



Evaluation Results of Switzerland Electricity Development Index

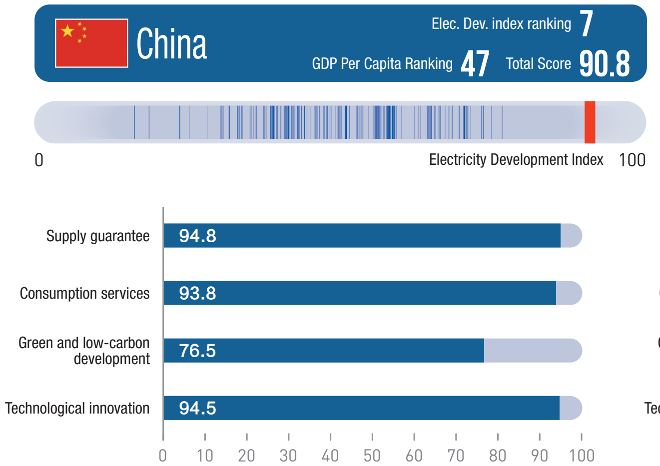


Evaluation Results of Denamrk Electricity Development Index

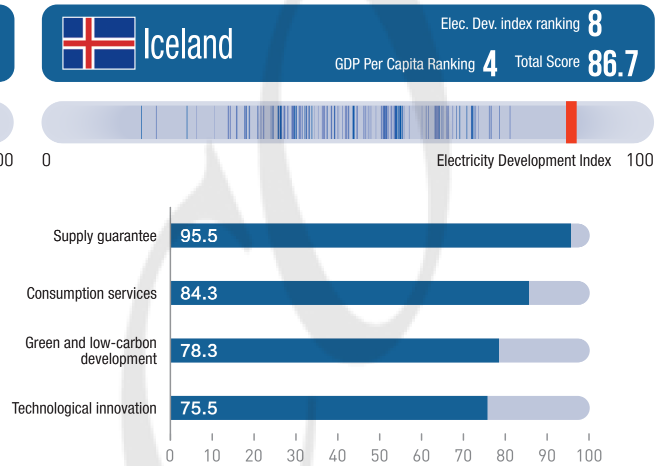


Evaluation Results of France Electricity Development Index

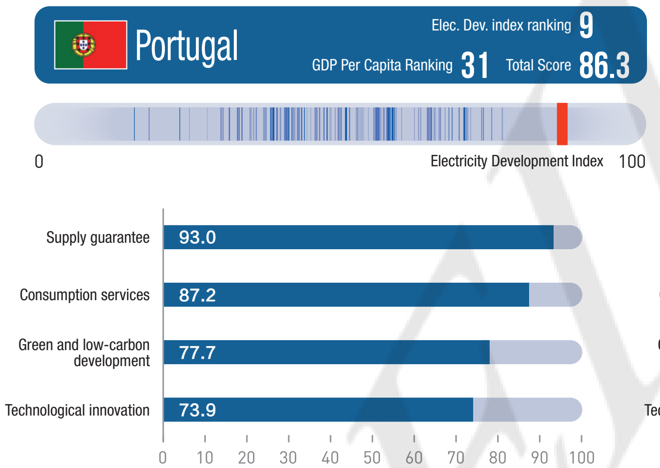
[1] The rankings of the Electricity Development Index and per capita GDP correspond to the relative ranking of the country among the 100 countries chosen for calculating the Electricity Development Index, not among all countries globally.



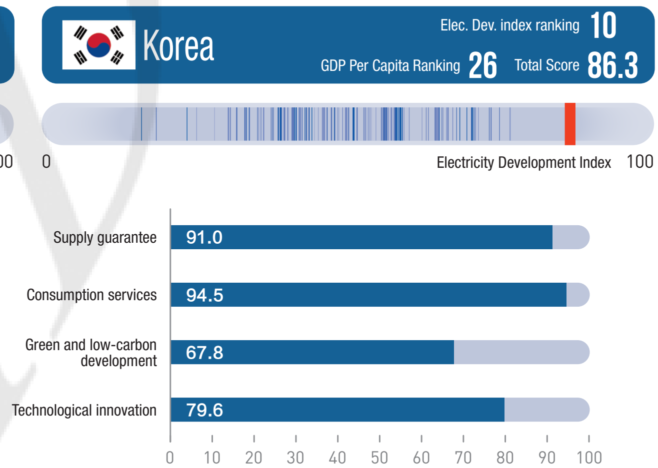
Evaluation Results of China Electricity Development Index



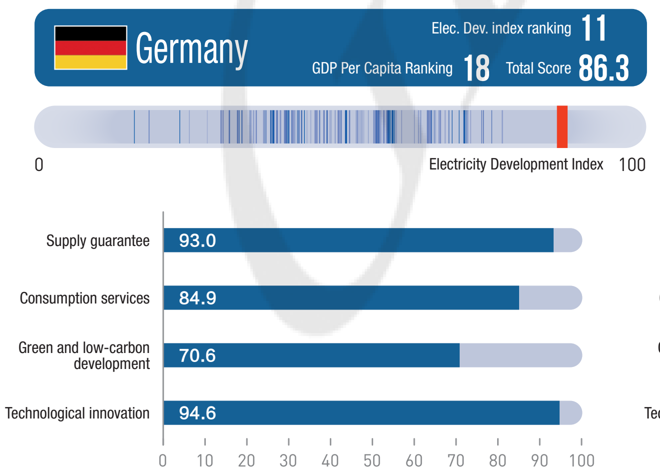
Evaluation Results of Iceland Electricity Development Index



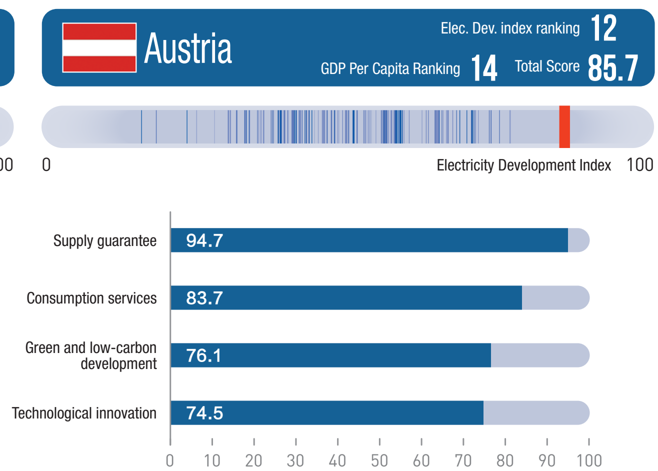
Evaluation Results of the Portugal Electricity Development Index



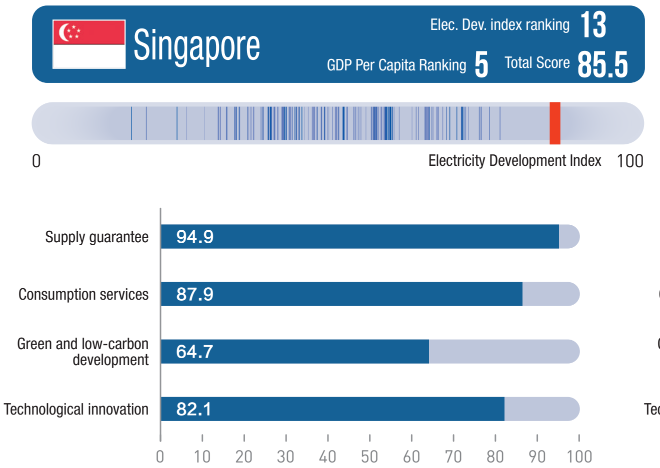
Evaluation Results of South Korea Electricity Development Index



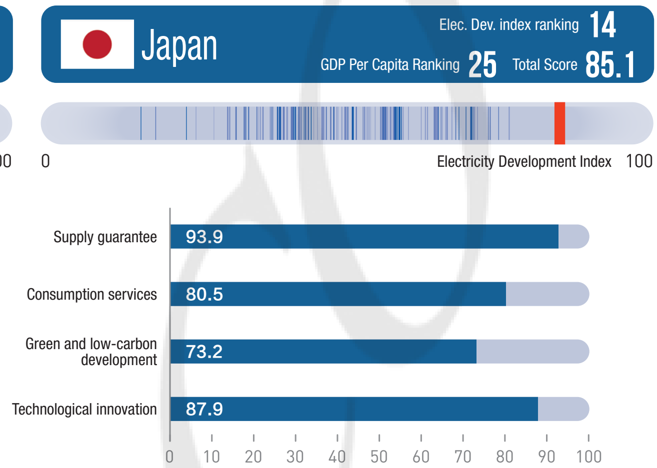
Evaluation Results of Germany electricity development Index



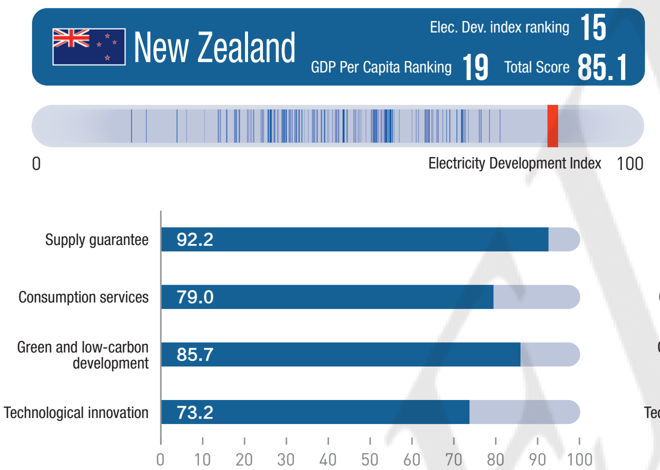
Evaluation Results of Austria Electricity Development Index



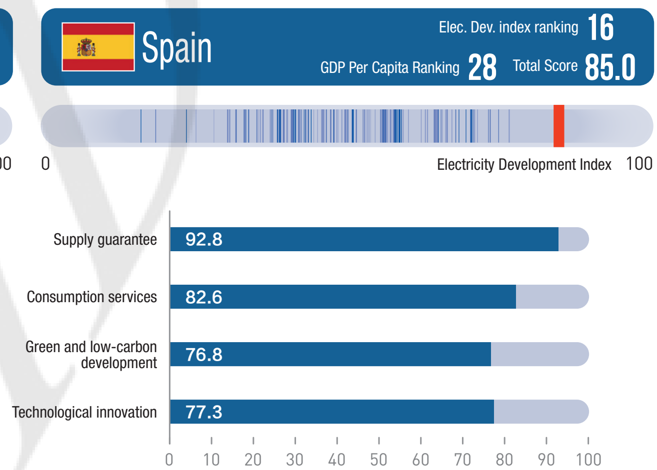
Evaluation Results of Singapore Electricity Development Index



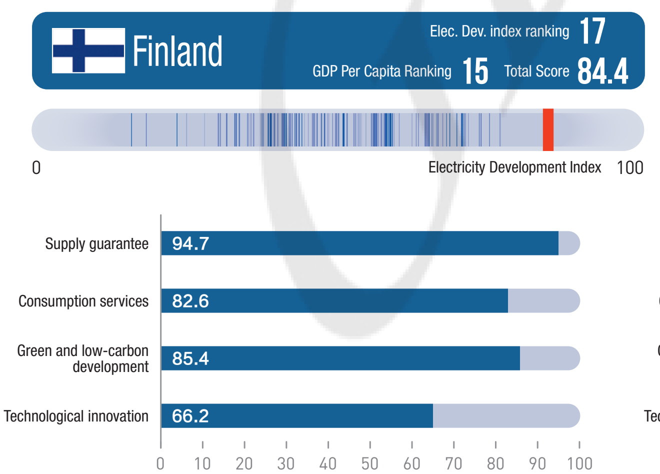
Evaluation Results of Japan Electricity Development Index



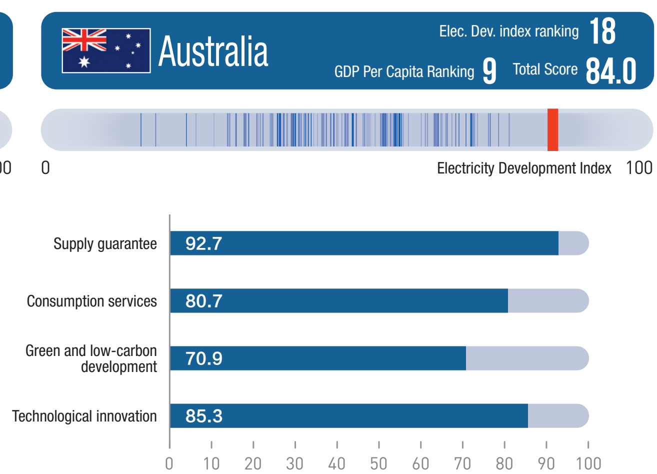
Evaluation Results of New Zealand Electricity Development Index



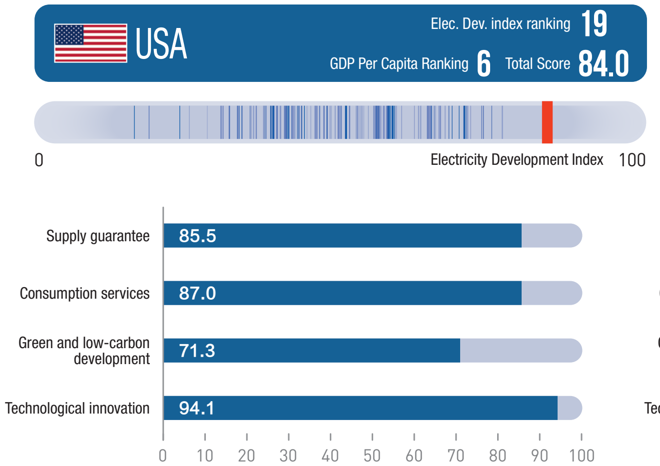
Evaluation Results of Spain Electricity Development Index



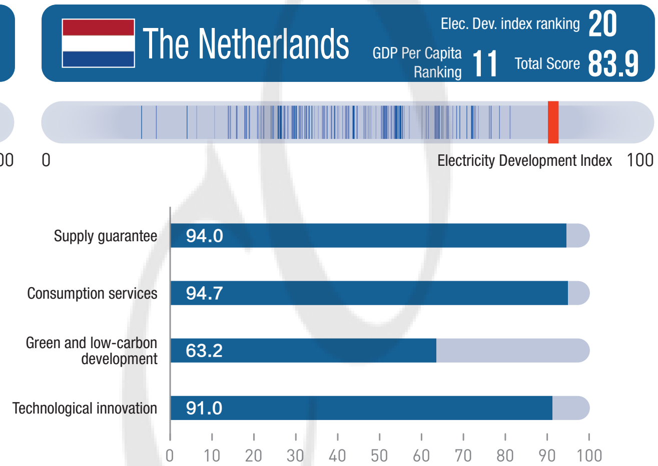
Evaluation Results of Finland Electricity Development Index



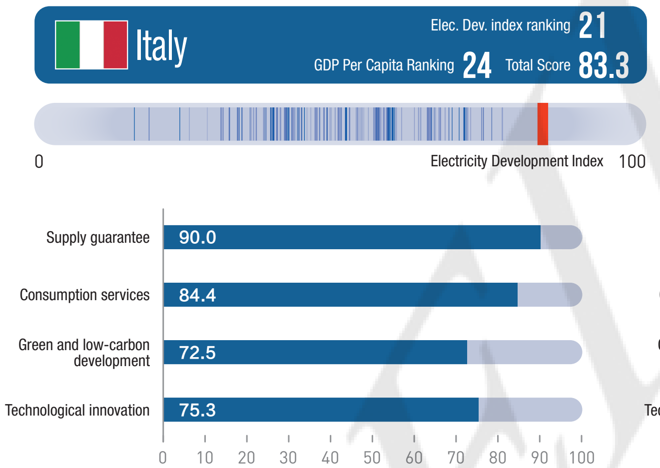
Evaluation Results of Australia Electricity Development Index



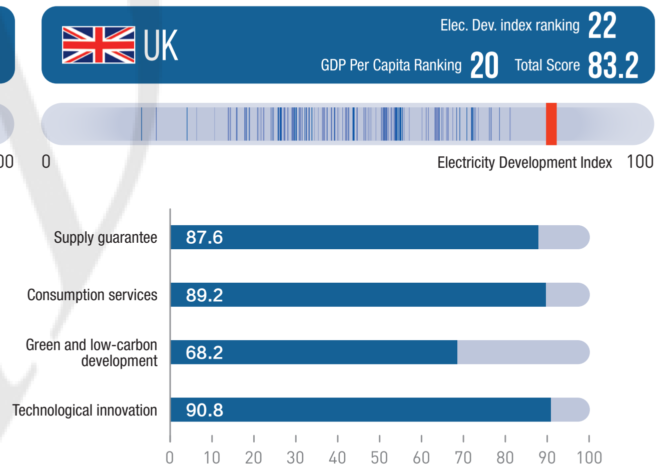
Evaluation Results of USA Electricity Development Index



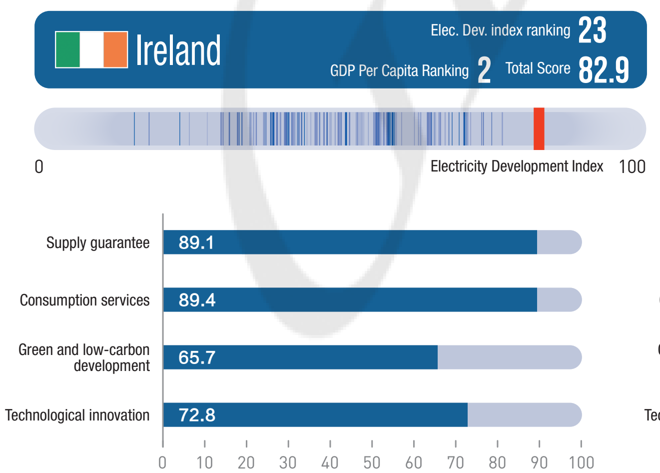
Evaluation Results of The Netherlands Electricity Development Index



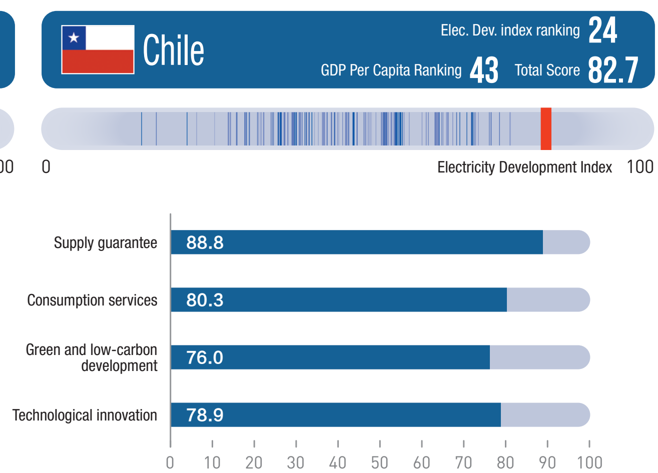
Evaluation Results of Italy Electricity Development Index



Evaluation Results of UK Electricity Development Index



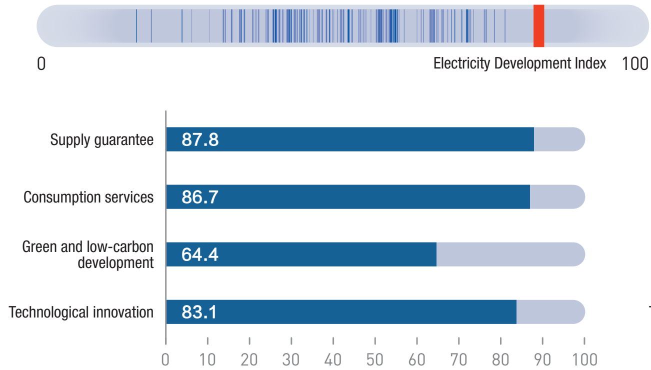
Evaluation Results of Ireland Electricity Development Index



Evaluation Results of Chile Electricity Development Index

Kazakhstan

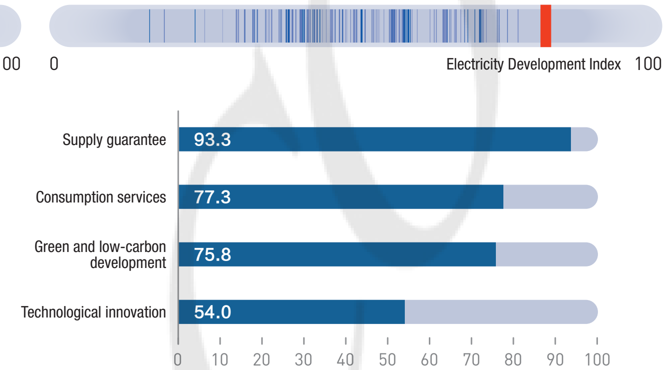
Elec. Dev. index ranking 25
GDP Per Capita Ranking 49 Total Score 82.3



Evaluation Results of Kazakhstan Electricity Development Index

Belgium

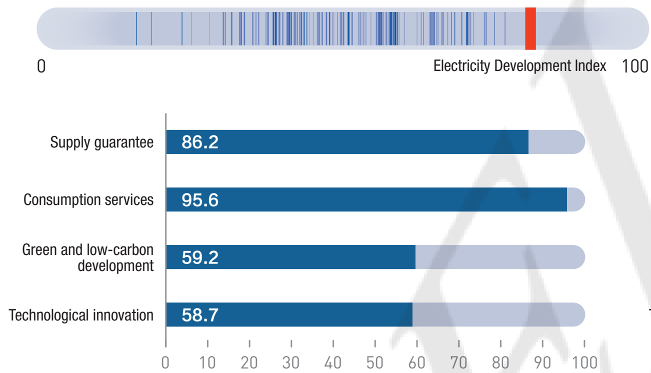
Elec. Dev. index ranking 26
GDP Per Capita Ranking 16 Total Score 81.1



Evaluation Results of Belgium Electricity Development Index

United Arab Emirates

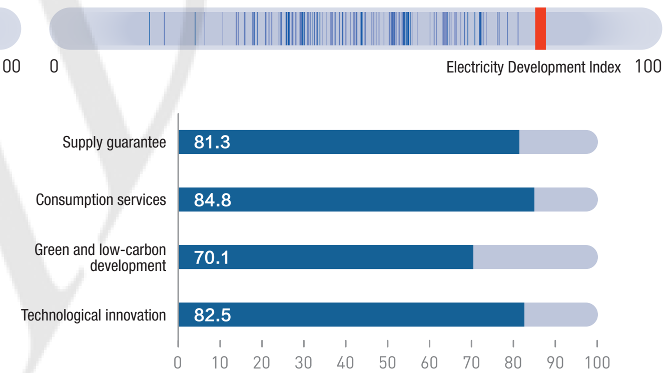
Elec. Dev. index ranking 27
GDP Per Capita Ranking 17 Total Score 80.9



Evaluation Results of United Arab Emirates Electricity Development Index

Russia

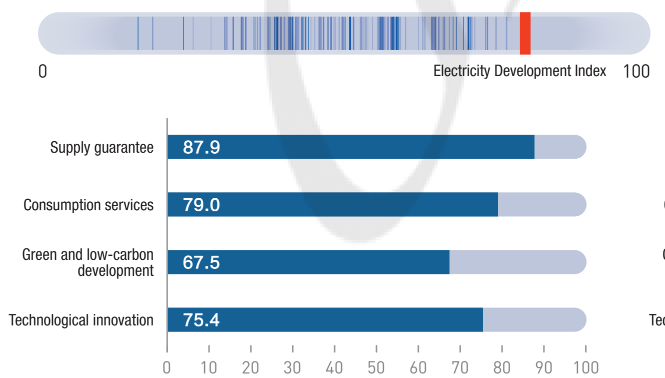
Elec. Dev. index ranking 28
GDP Per Capita Ranking 42 Total Score 80.2



Evaluation Results of Russia Electricity Development Index

Israel

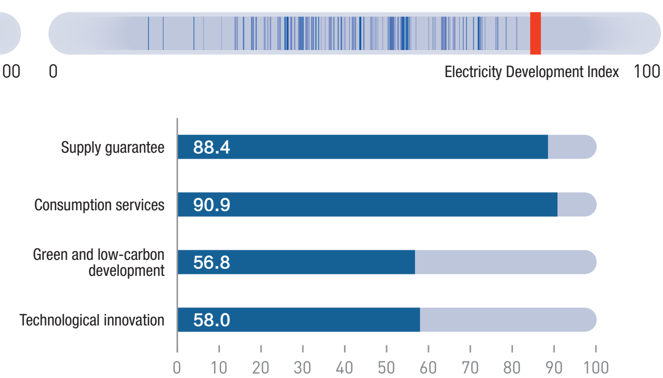
Elec. Dev. index ranking 29
GDP Per Capita Ranking 13 Total Score 79.9



Evaluation Results of Israel Electricity Development Index

Saudi Arabia

Elec. Dev. index ranking 30
GDP Per Capita Ranking 27 Total Score 79.8



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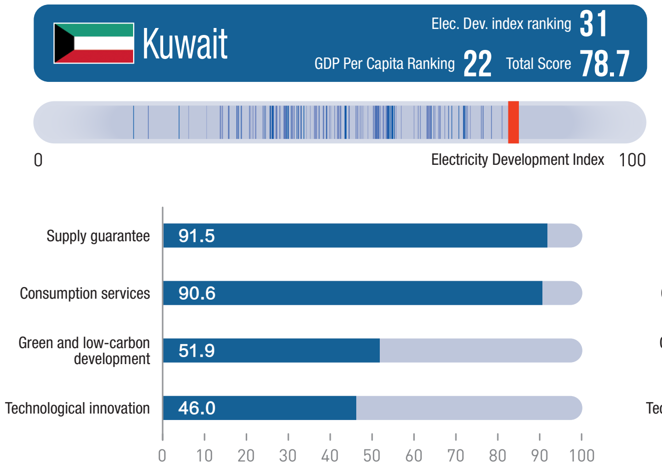

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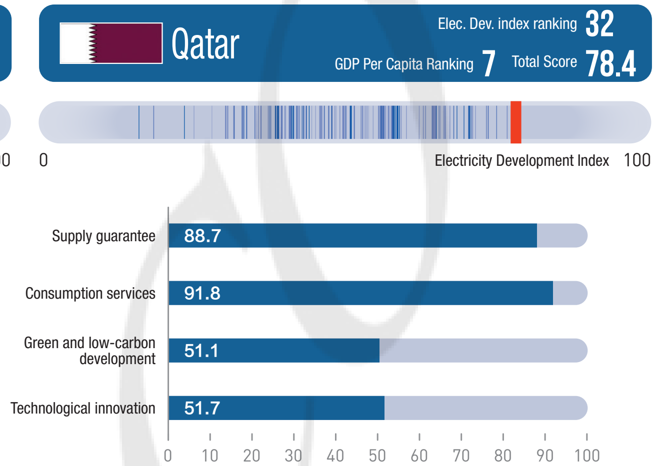

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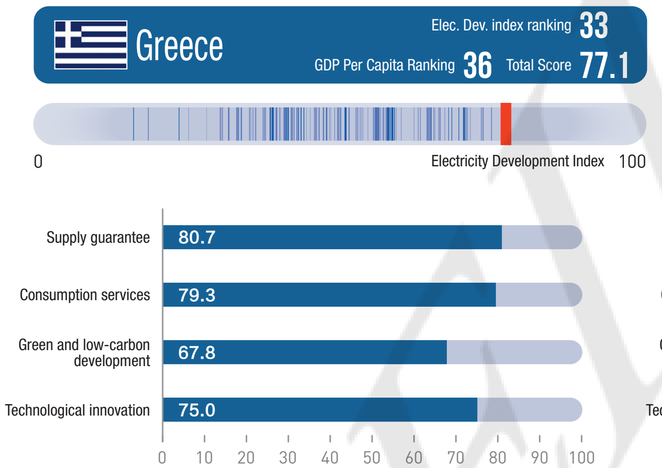

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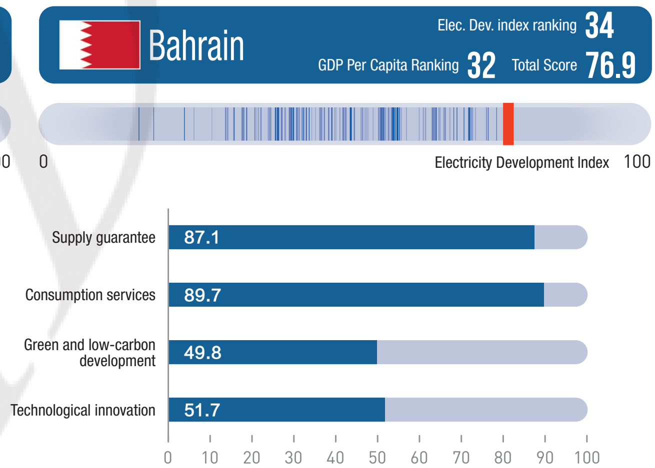
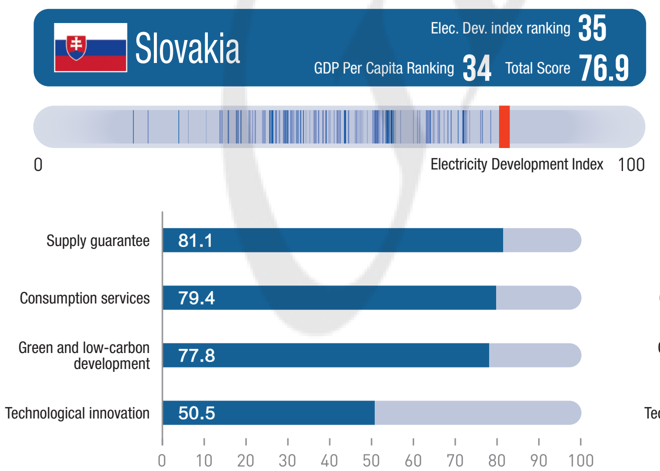


Evaluation Results of Bahrain Electricity Development Index



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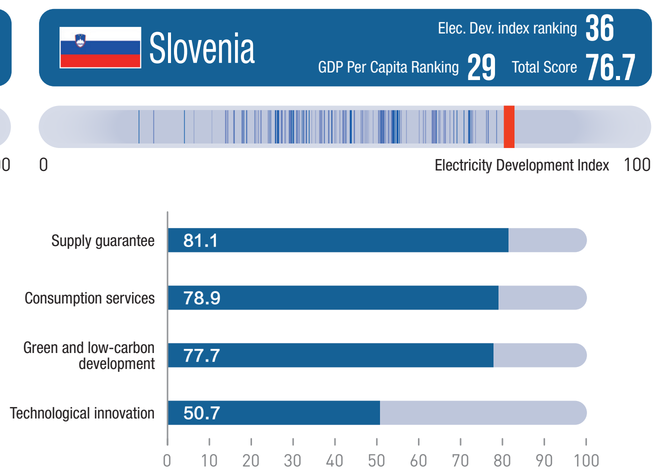
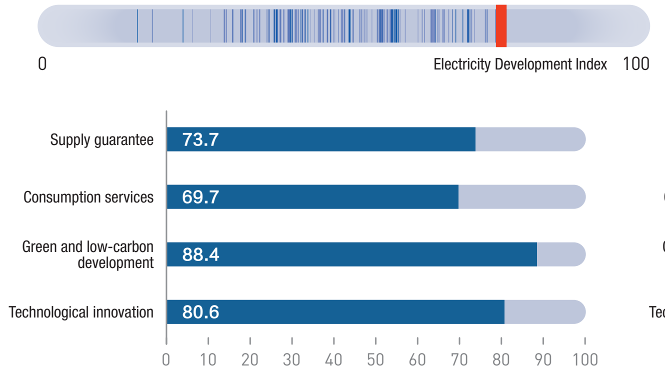


Evaluation Results of Slovenia Electricity Development Index

Brazil

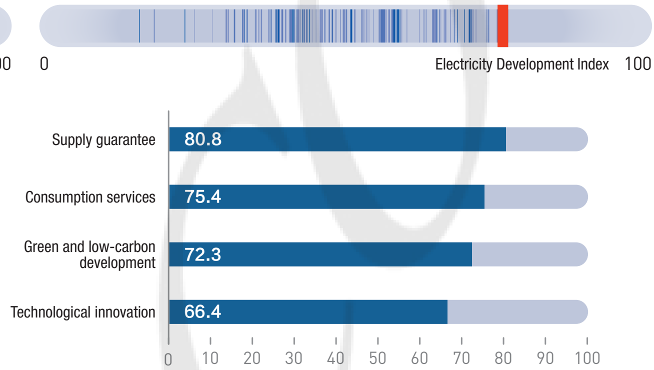
Elec. Dev. index ranking **37**
GDP Per Capita Ranking **55** Total Score **76.1**



Evaluation Results of Brazil Electricity Development Index

Uruguay

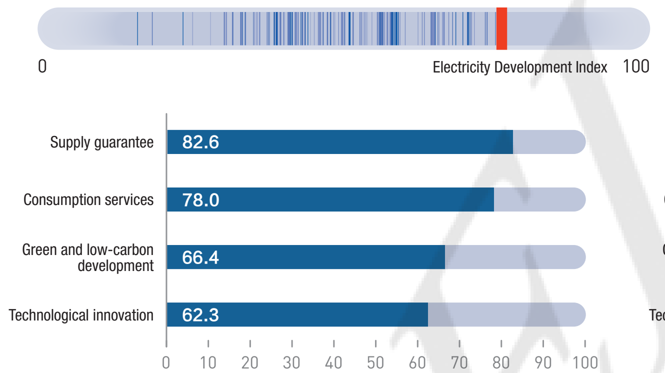
Elec. Dev. index ranking **38**
GDP Per Capita Ranking **35** Total Score **76.0**



Evaluation Results of Uruguay Electricity Development Index

Bulgaria

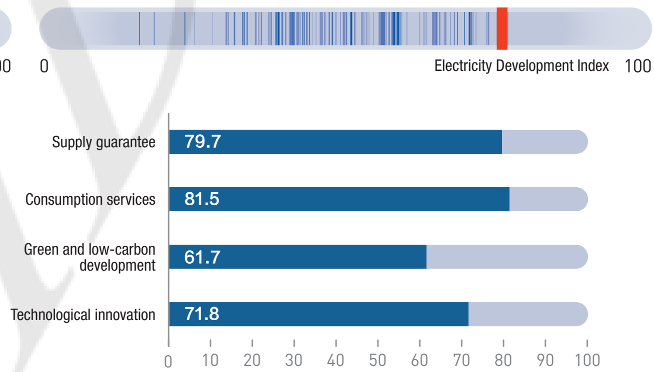
Elec. Dev. index ranking **39**
GDP Per Capita Ranking **45** Total Score **76.0**



Evaluation Results of Bulgaria Electricity Development Index

Czech Republic

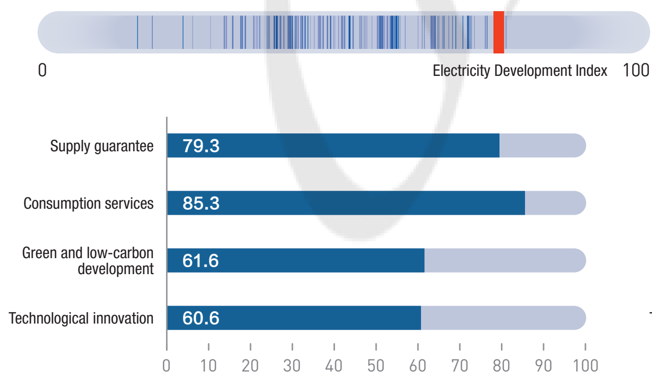
Elec. Dev. index ranking **40**
GDP Per Capita Ranking **30** Total Score **75.8**



Evaluation Results of Czech Republic Electricity Development Index

Belarus

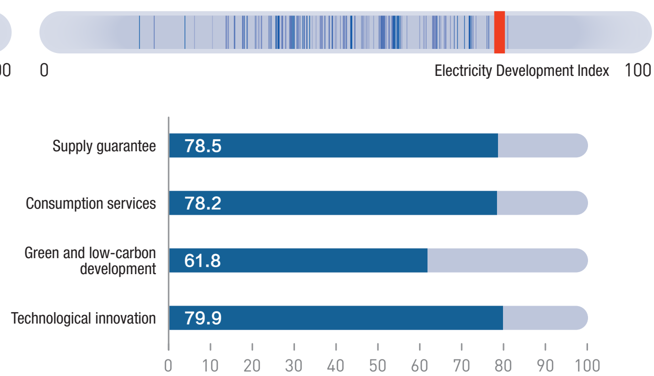
Elec. Dev. index ranking **41**
GDP Per Capita Ranking **56** Total Score **75.7**



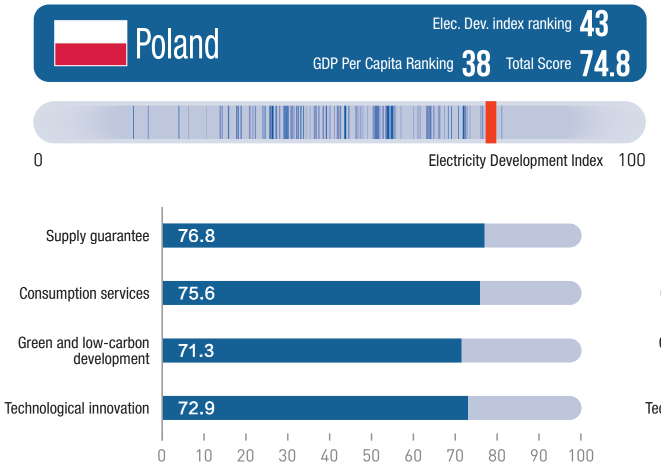
Evaluation Results of Belarus Electricity Development Index

Türkiye

Elec. Dev. index ranking **42**
GDP Per Capita Ranking **51** Total Score **75.2**



Evaluation Results of Türkiye Electricity Development Index



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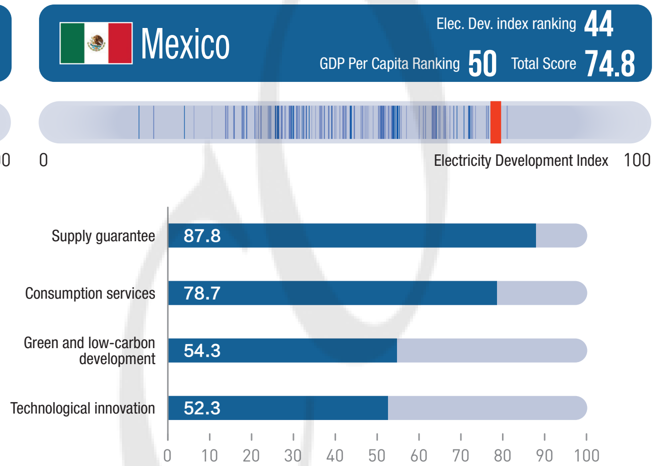
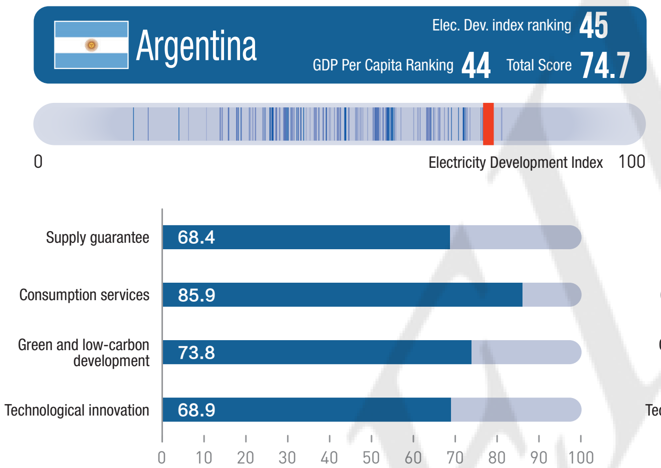


Evaluation Results of Mexico Electricity Development Index



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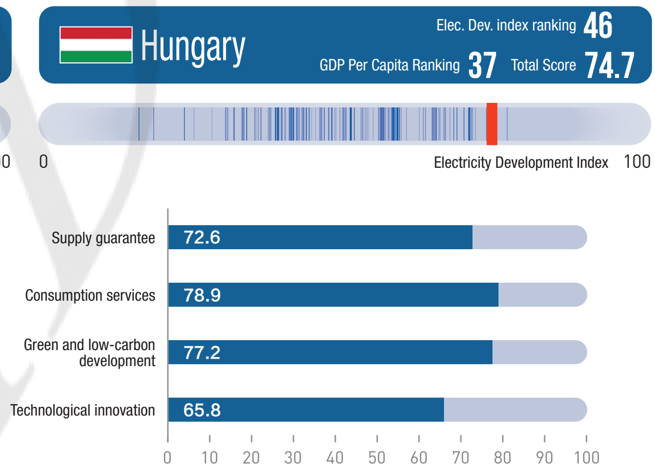
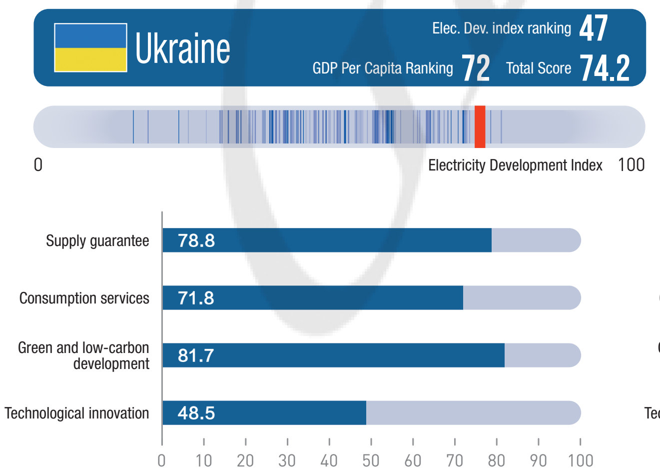
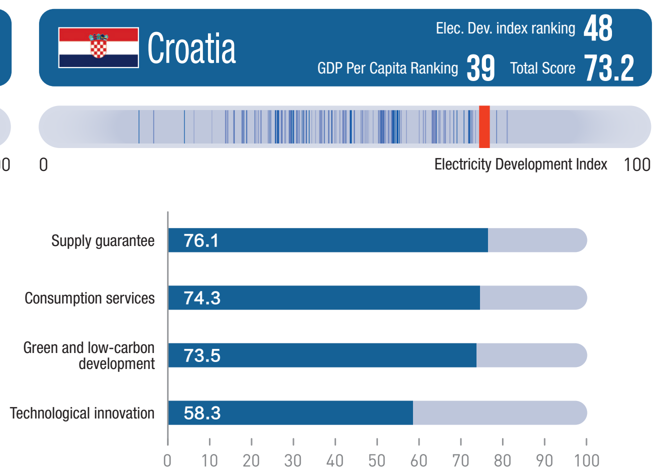


Evaluation Results of Hungary Electricity Development Index



Evaluation Results of Ukraine Electricity Development Index



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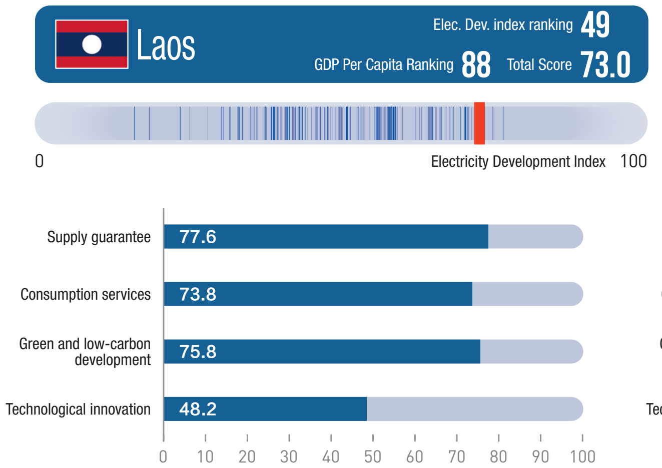

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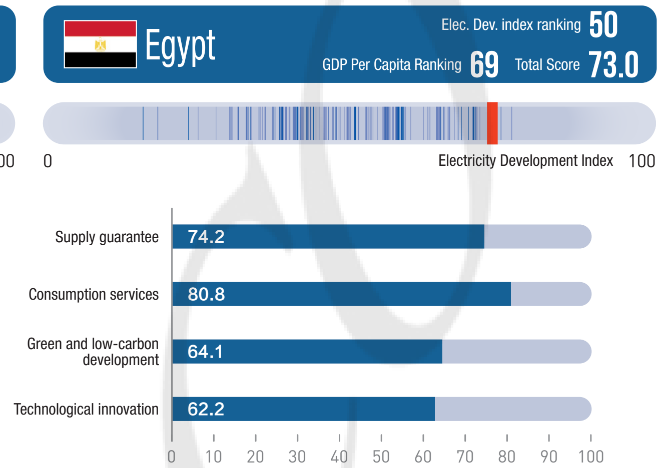

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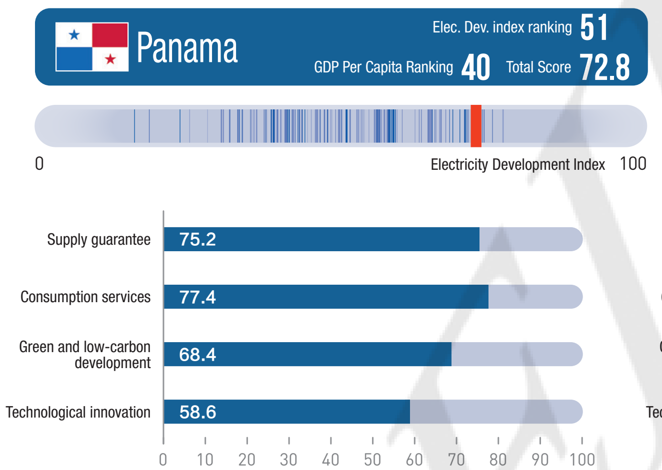

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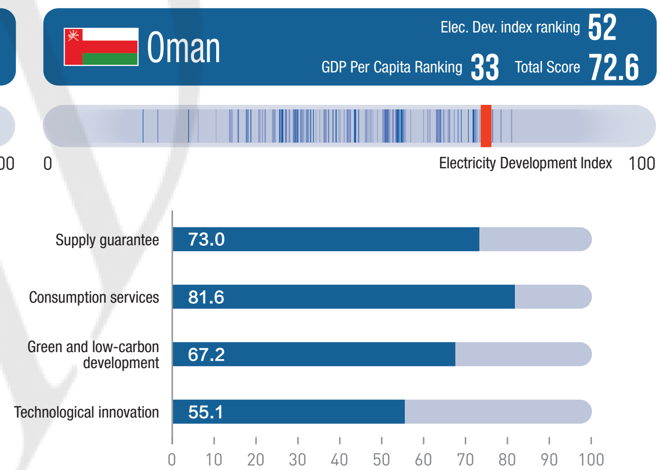

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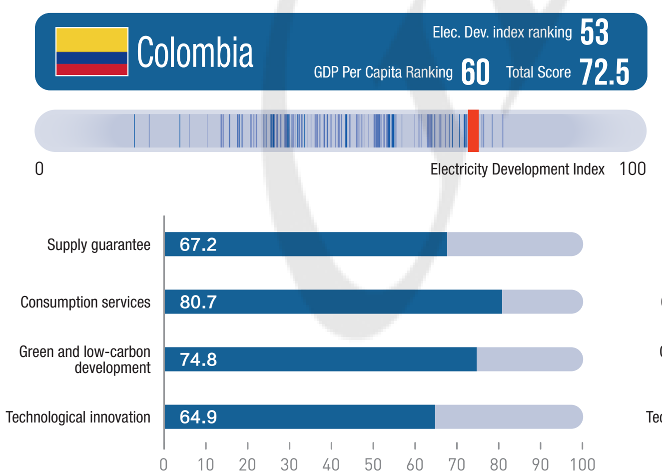

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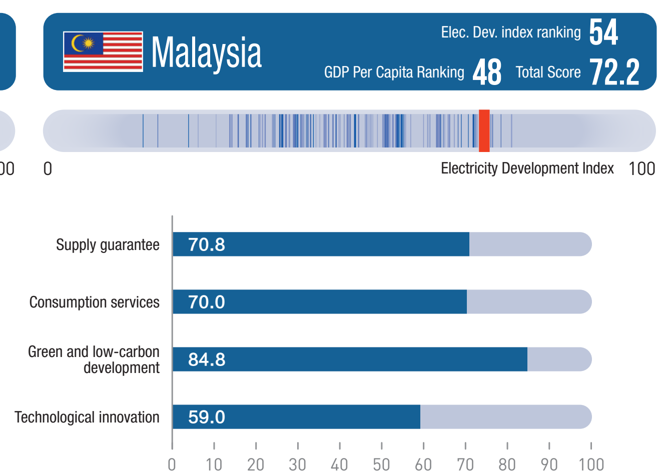

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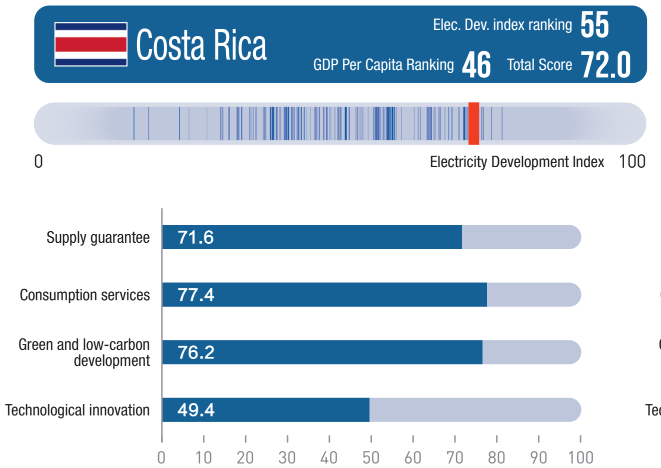

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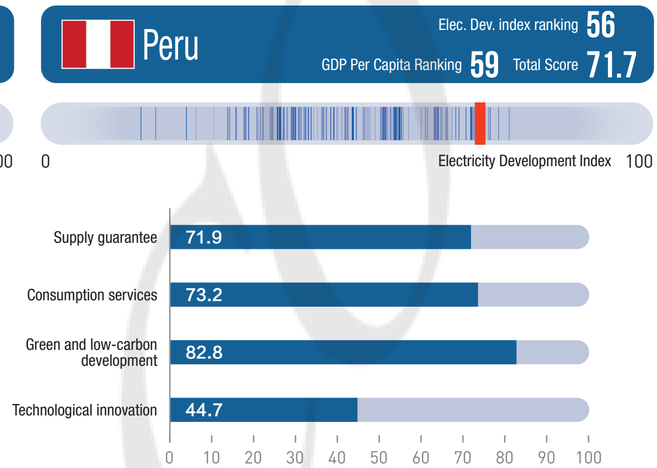

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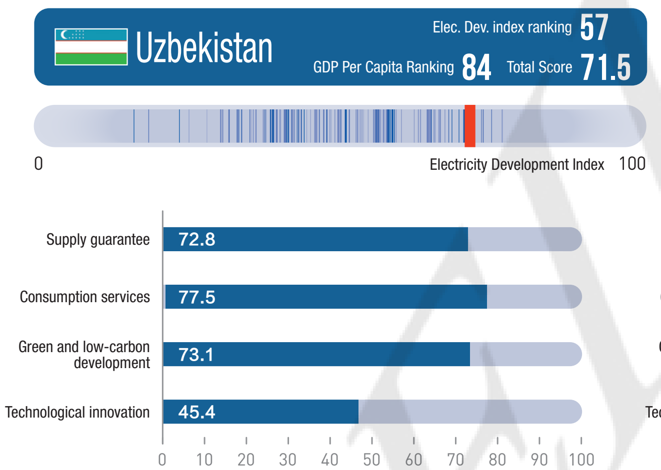

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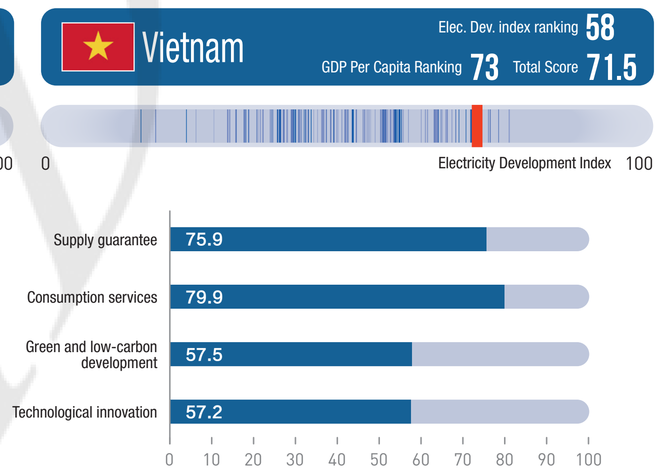

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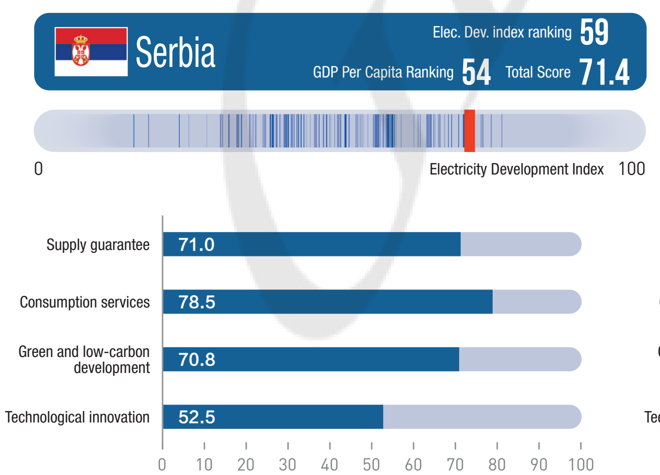

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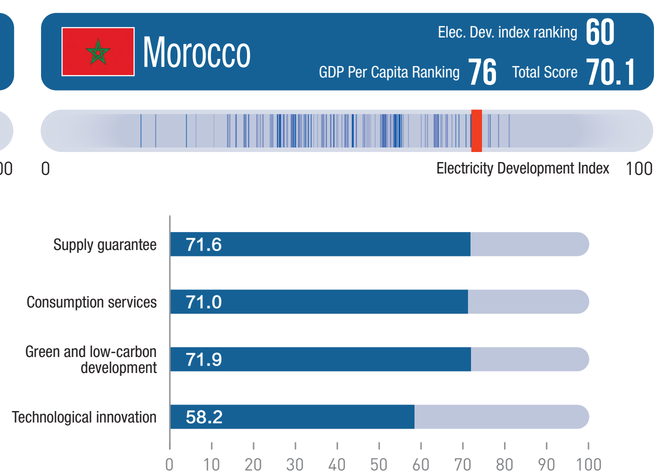

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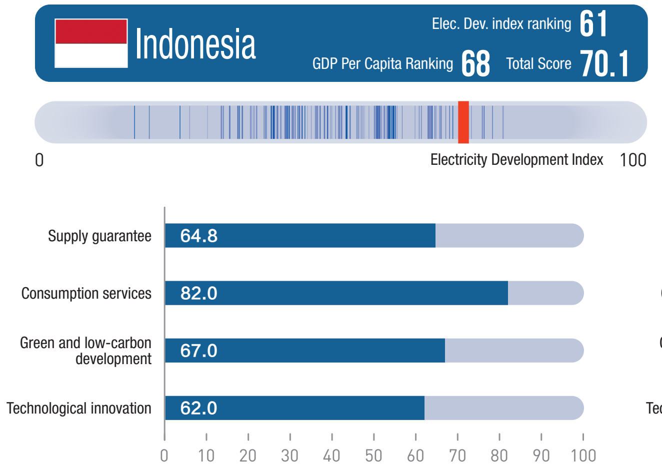
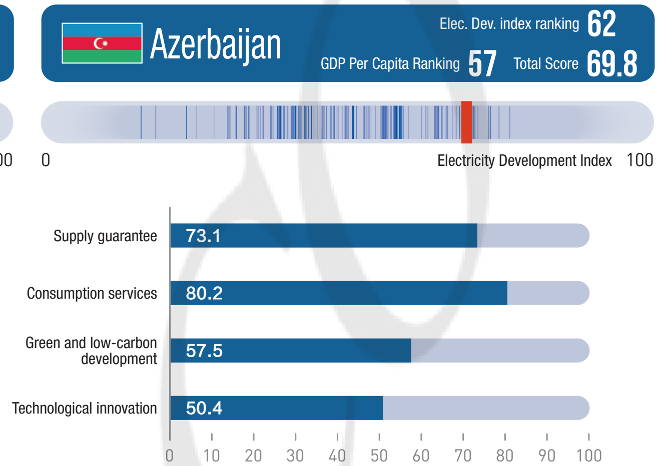


Evaluation Results of Indonesia Electricity Development Index



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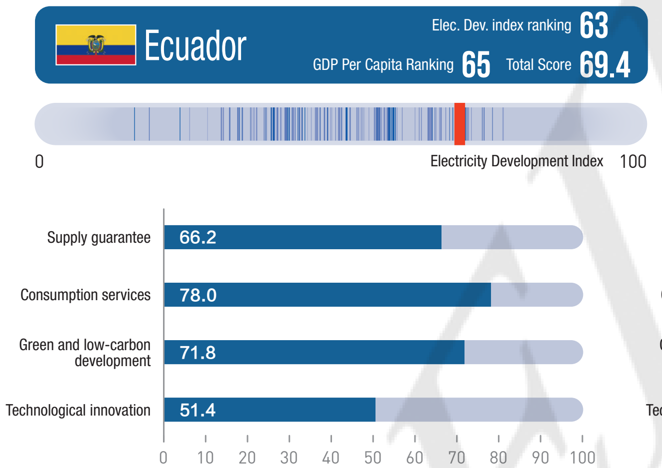

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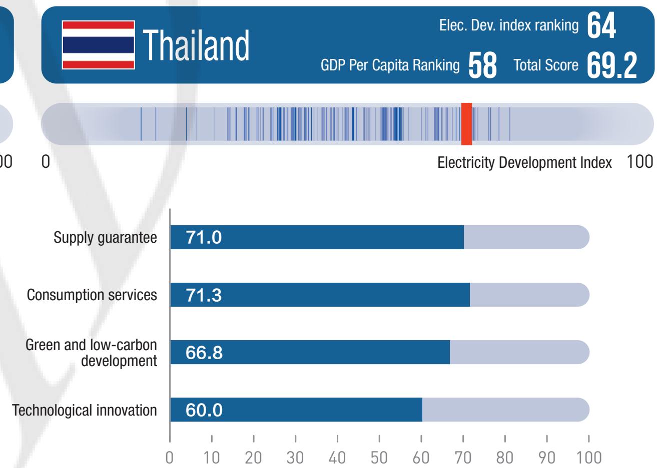

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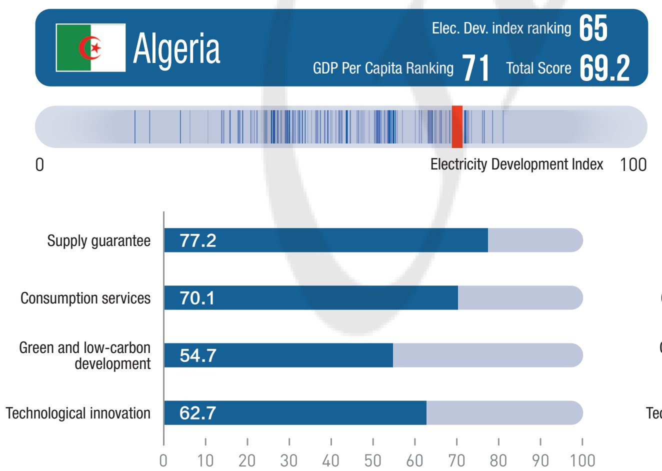
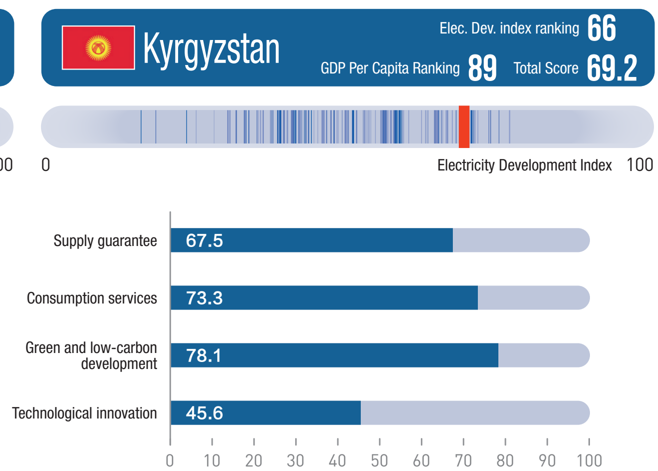


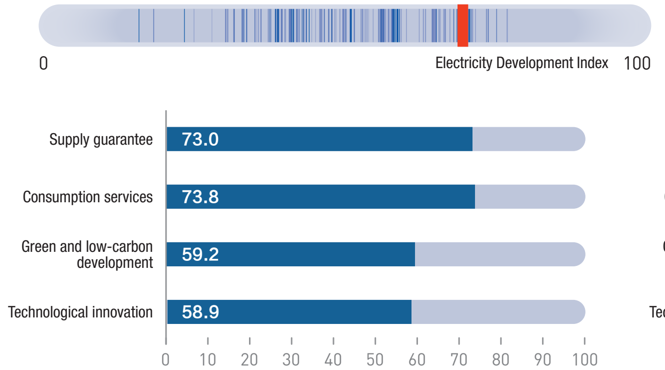
Evaluation Results of Algeria Electricity Development Index



Evaluation Results of Kyrgyzstan Electricity Development Index

Georgia

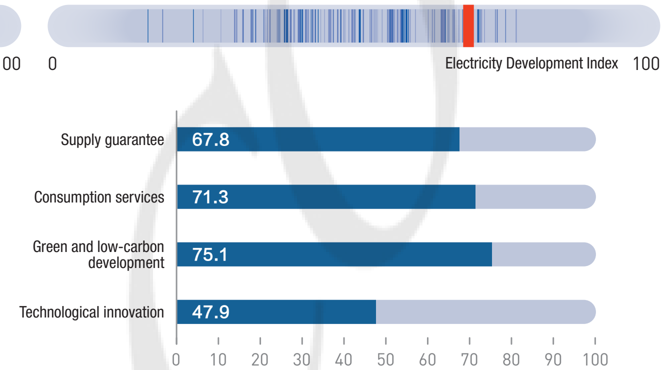
Elec. Dev. index ranking **67**
GDP Per Capita Ranking **63** Total Score **69.1**



Evaluation Results of Congo Electricity Development Index

Jordan

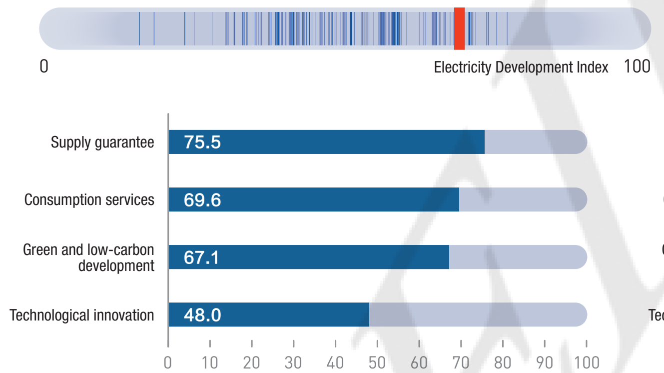
Elec. Dev. index ranking **68**
GDP Per Capita Ranking **70** Total Score **68.3**



Evaluation Results of Jordan electricity development index

Romania

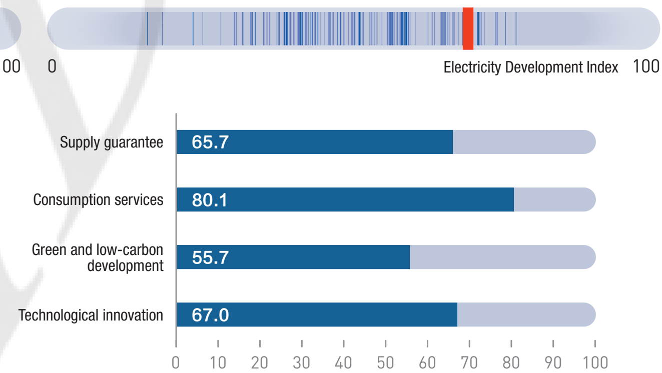
Elec. Dev. index ranking **69**
GDP Per Capita Ranking **41** Total Score **68.3**



Evaluation Results of Romania electricity development index

South Africa

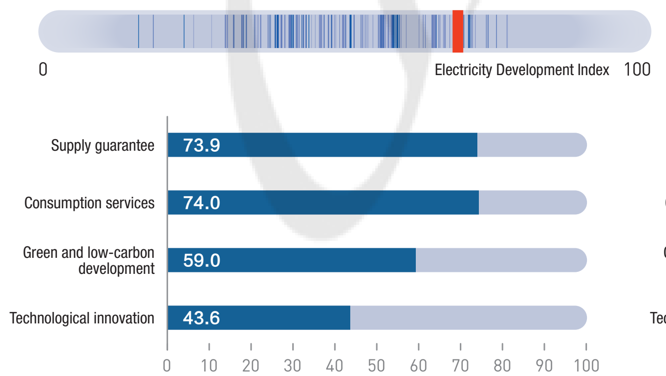
Elec. Dev. index ranking **70**
GDP Per Capita Ranking **61** Total Score **68.2**



Evaluation Results of South Africa Electricity Development Index

Iran

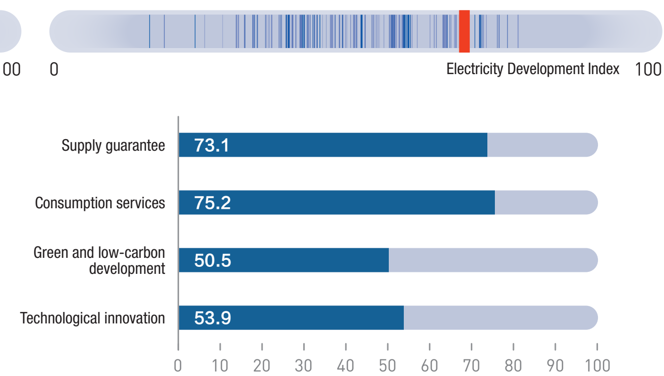
Elec. Dev. index ranking **71**
GDP Per Capita Ranking **67** Total Score **67.3**



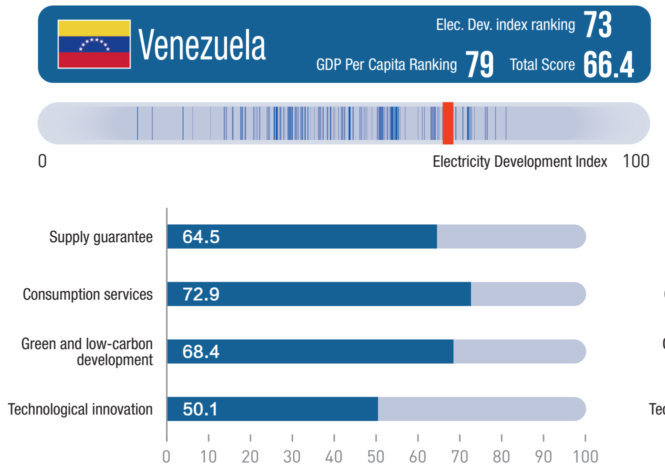
Evaluation Results of Iran electricity development index

Libya

Elec. Dev. index ranking **72**
GDP Per Capita Ranking **64** Total Score **67.3**



Evaluation Results of Libyan electricity development index



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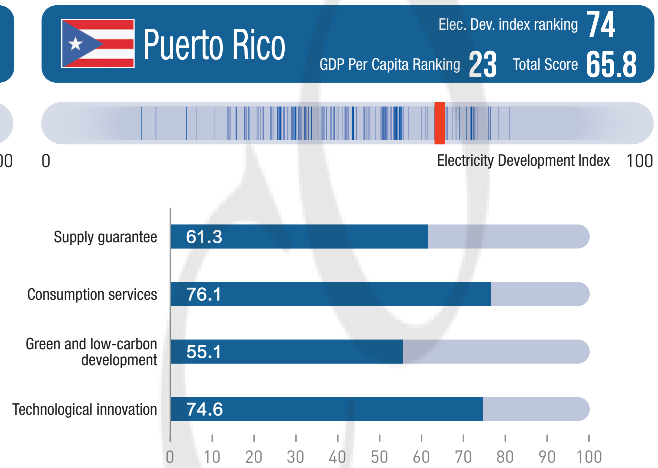
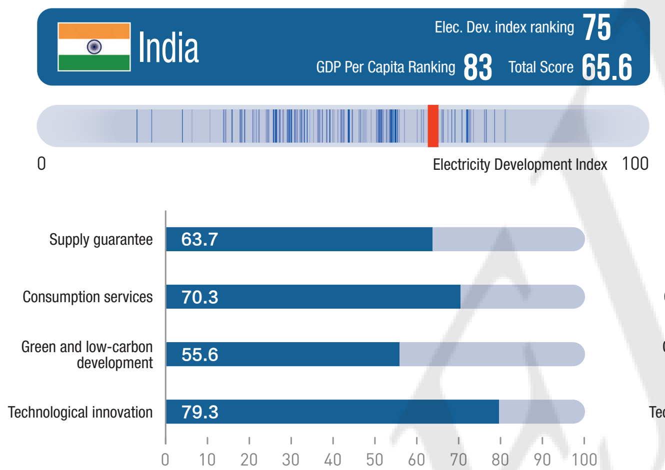
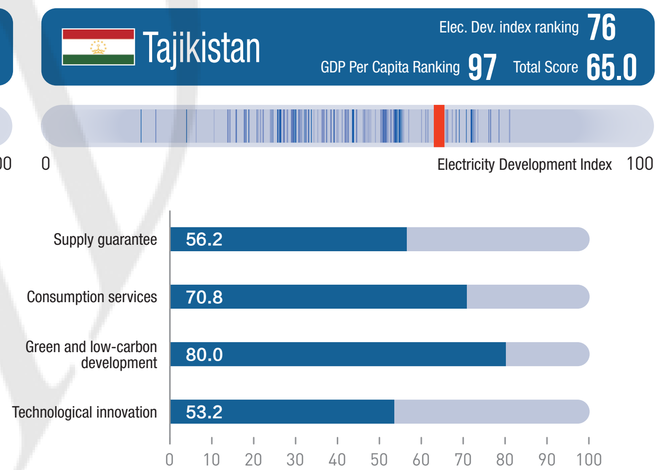


Evaluation Results of Puerto Rico Electricity Development Index



Evaluation Results of India Electricity Development Index



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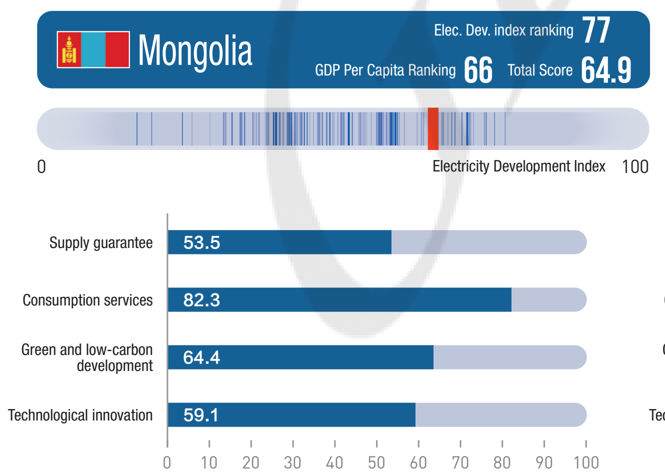

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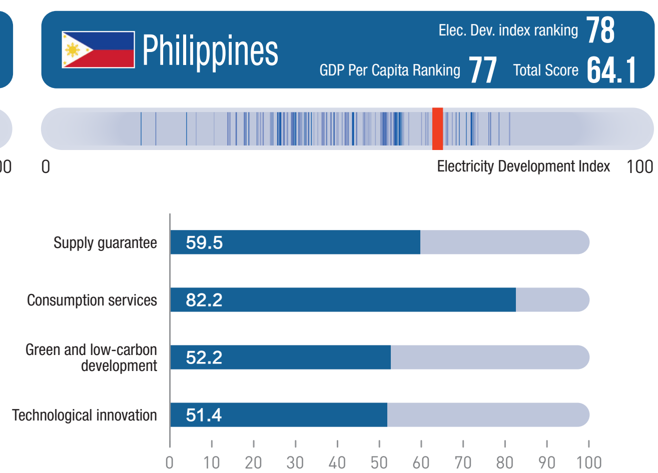

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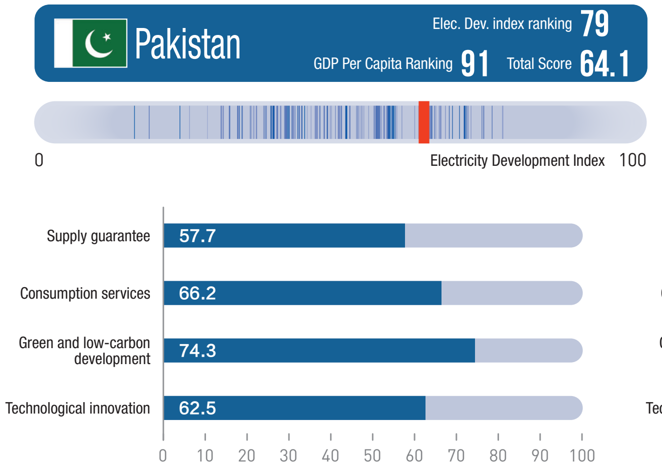
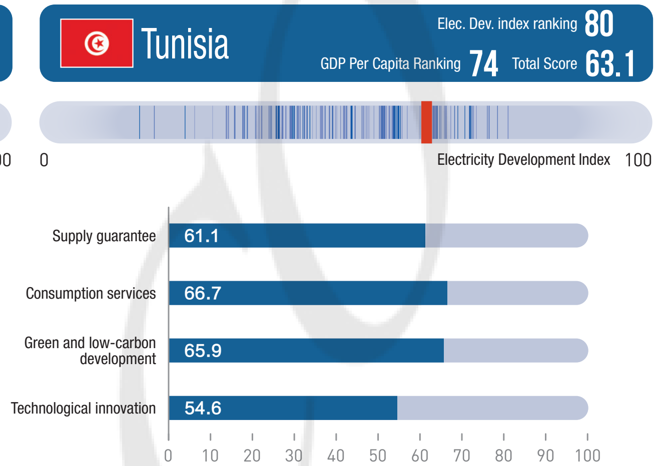


Evaluation Results of Pakistan Electricity Development Index



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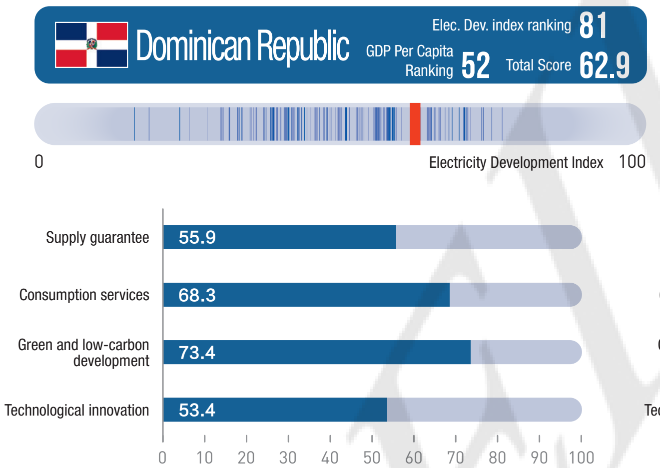
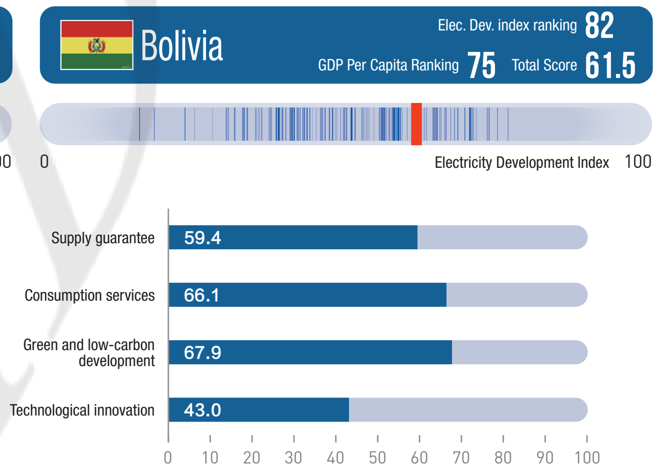
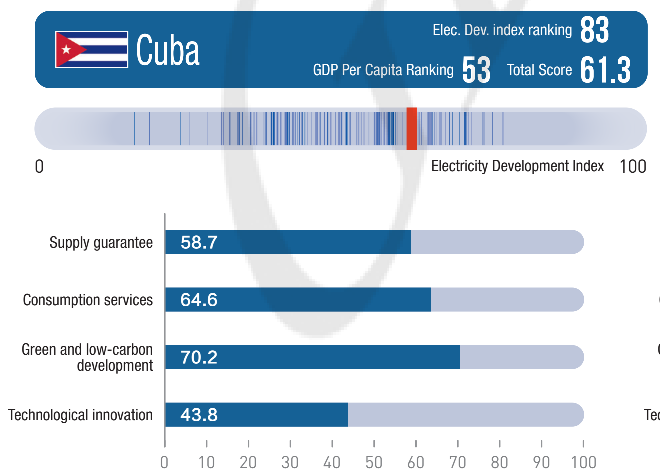


Evaluation Results of Dominican Republic Electricity Development Index



Evaluation Results of Bolivia Electricity Development Index



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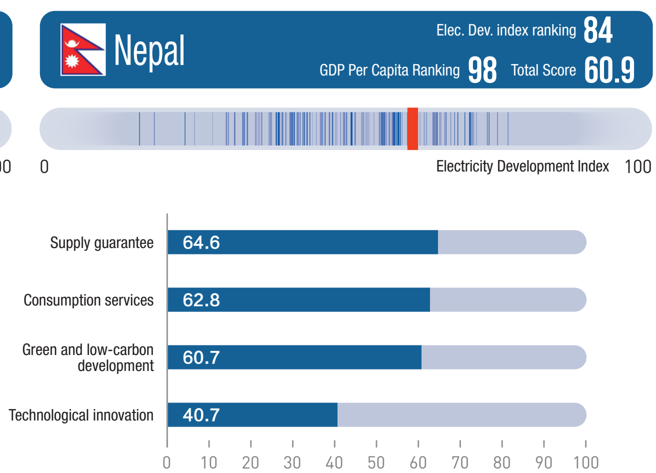

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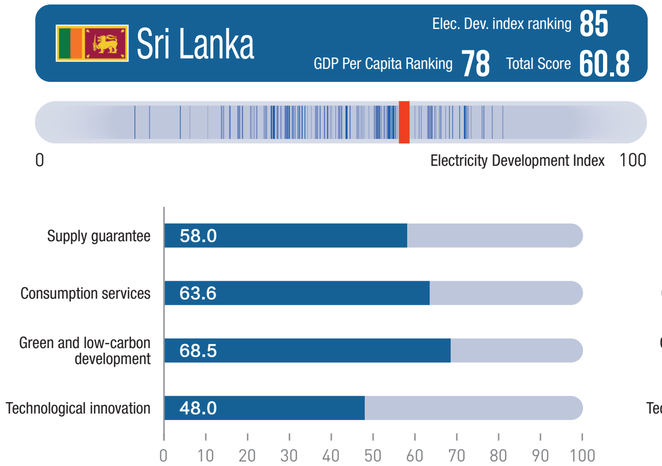

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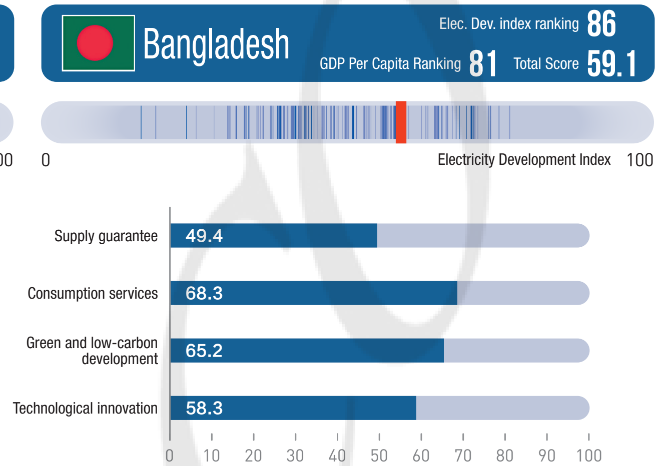

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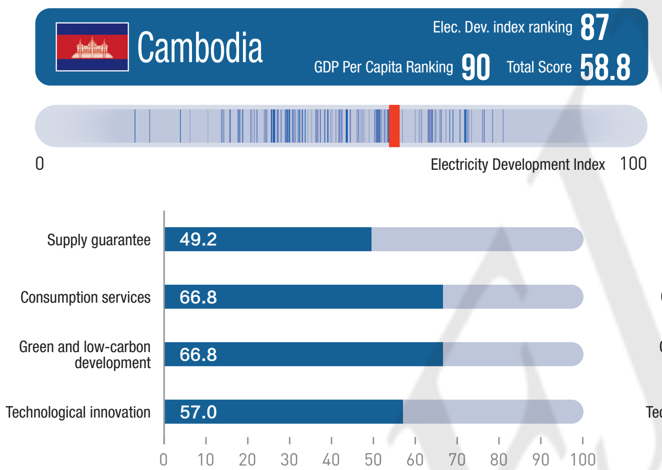

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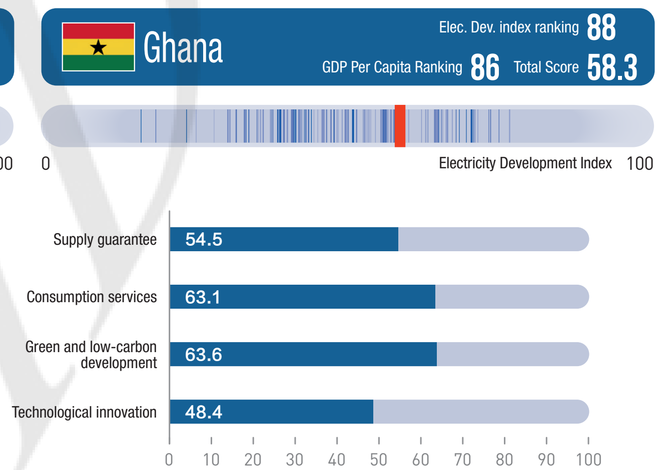

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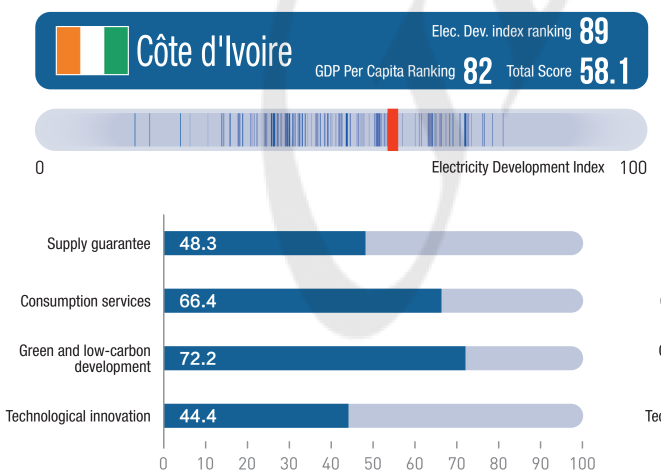
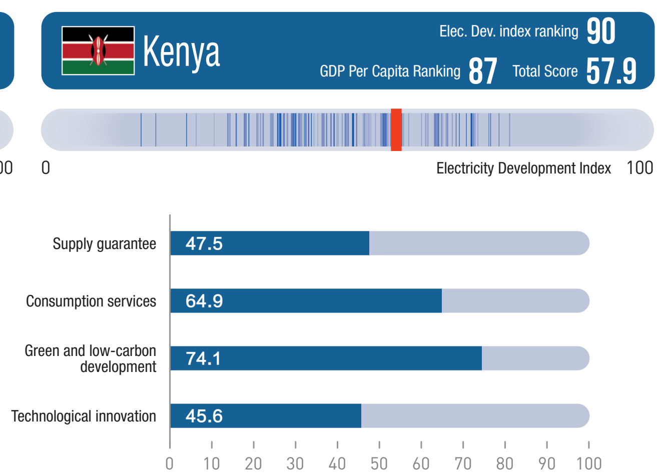


Evaluation Results of Côte d'Ivoire Electricity Development Index



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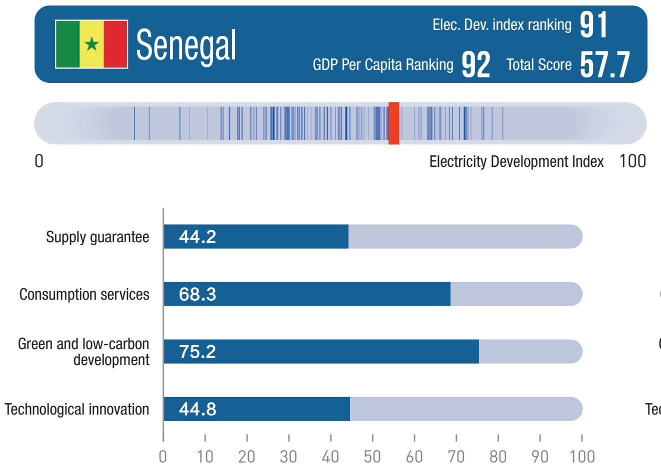

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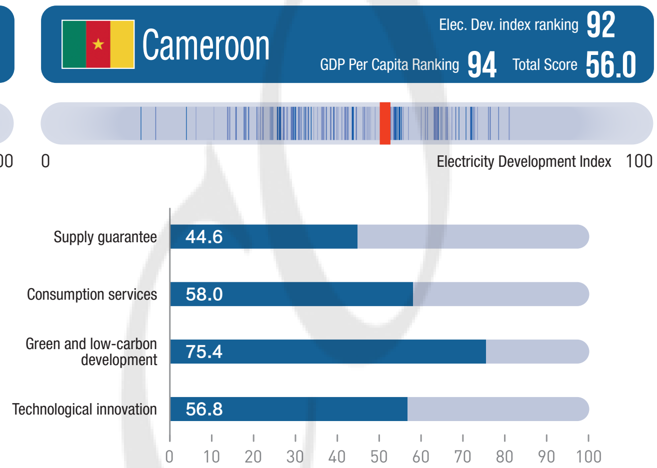
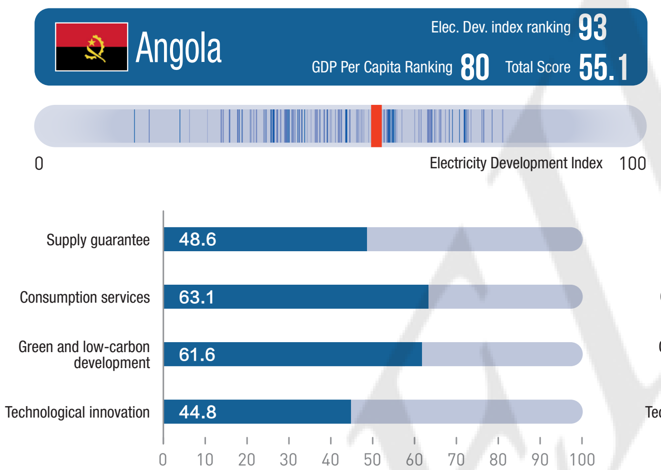
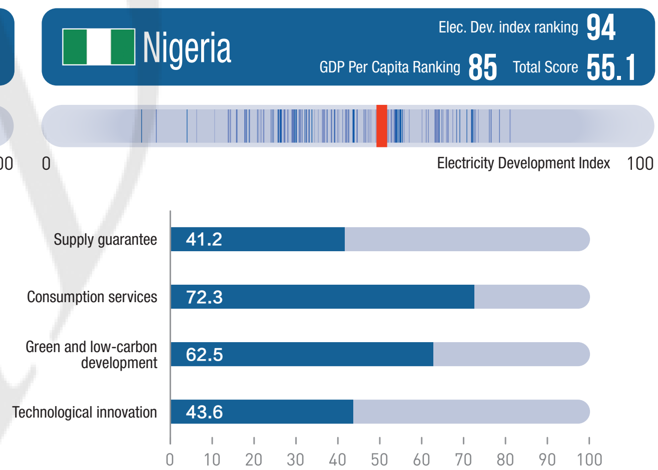


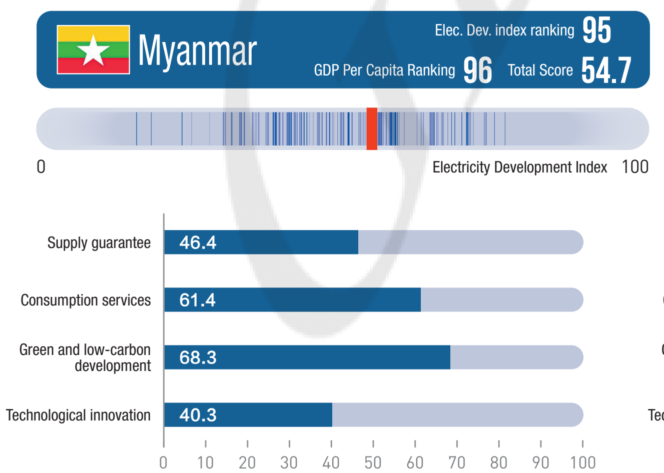
Evaluation Results of Cameroon Electricity Development Index



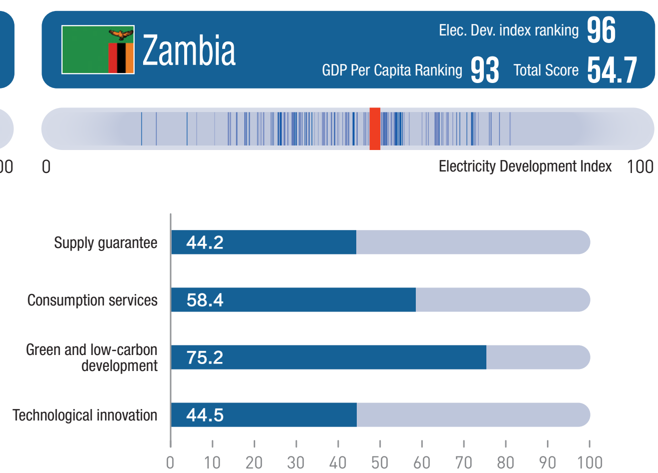
Evaluation Results of Angola Electricity Development Index



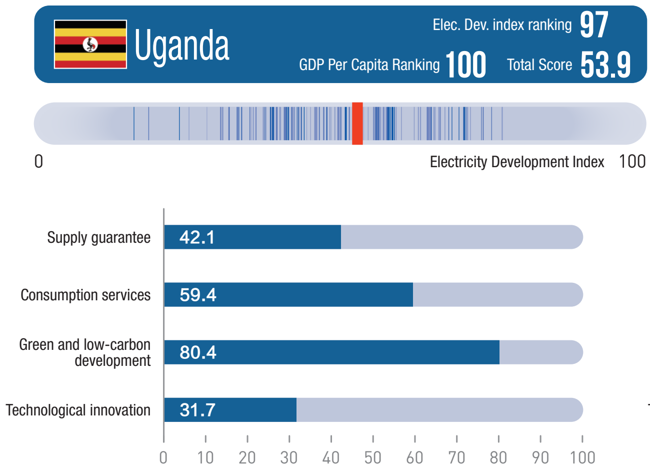
Evaluation Results of Nigeria Electricity Development Index



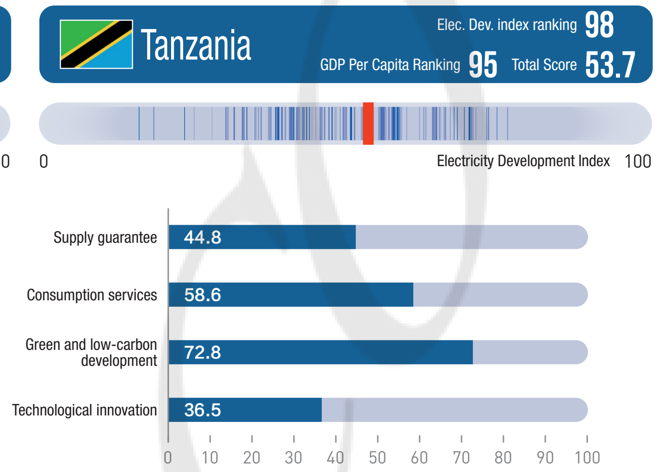
Evaluation Results of Myanmar Electricity Development Index



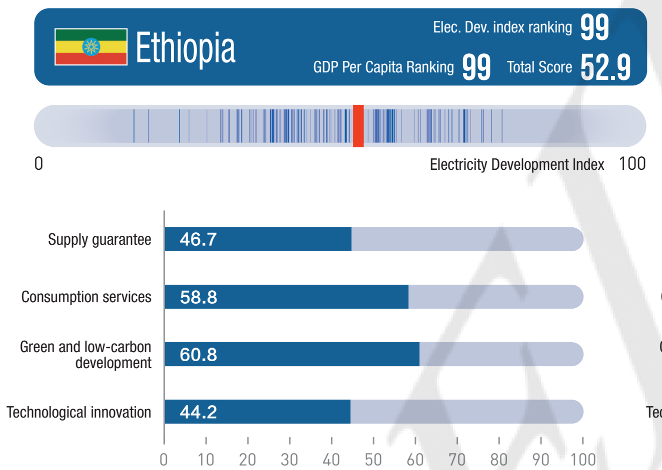
Evaluation Results of Zambia Electricity Development Index



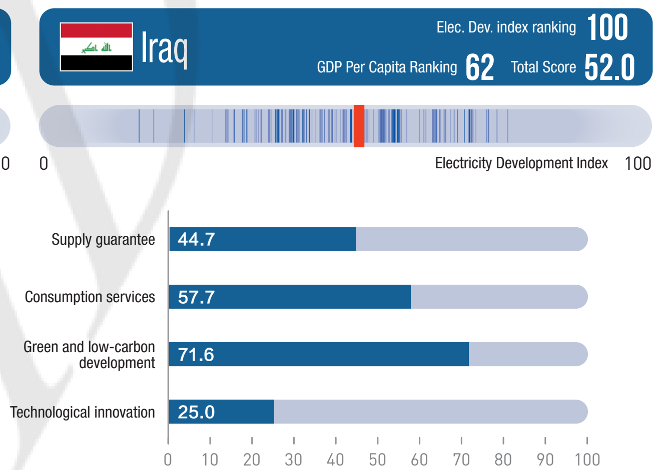
Evaluation Results of Uganda Electricity Development Index



Evaluation Results of Tanzania Electricity Development Index



Evaluation Results of Ethiopia Electricity Development Index



Evaluation Results of Iraq Electricity Development Index

Annexed table 3 Basic Data for Assessment of Global Electricity Development Index

No.	Country	Installed capacity per capita (kW)	Access to Electricity (%)	Grid Loss	Length of Transmission and Distribution Lines Per Capita (m)	Electricity consumption per capita (kWh/year)	Time to obtain an electricity connection (day)	Average power outage duration per household (min)	Average Electricity Price (US cent)	Growth rate of electricity consumption per capita	Proportion of clean energy power generation	Share of Electricity Consumption in Total Final Energy Consumption	Carbon Emission Intensity of Electricity (kg CO_2/kWh)	Growth rate of new energy power generation
1	China	1.78	100	3.8%	5.6	5877	6.9	53.76	9	6.2%	35.1%	28.1%	0.61	23.3%
2	India	0.34	99.6	20.3%	2.9	1032	22.8	222.948	13	4.5%	23.9%	16.4%	0.84	17.1%
3	Japan	2.78	100	5.5%	12.7	7455	18.9	86	22.5	−1.7%	28.3%	30.0%	0.52	11.3%
4	South Korea	2.83	100	3.4%	9.8	11349	15	10	12.6	1.9%	34.9%	25.4%	0.46	27.6%
5	Saudi Arabia	2.29	100	9.8%	0.9	11231	5.5	118.8	13	2.5%	0.3%	17.4%	0.75	79.0%
6	Iran	0.95	100	11.9%	18.1	3698	30	420	4	3.3%	6.5%	11.0%	0.52	28.9%
7	Indonesia	0.25	99.2	8.2%	4.6	1134	6	130.8	9	5.3%	20.1%	16.1%	0.73	86.8%
8	Vietnam	0.84	100	6.8%	0.7	2491	18.5	124.2	11	6.6%	43.2%	27.7%	0.52	147.9%
9	Thailand	0.81	100	7.2%	7.7	2819	27.9	22.8	16	0.6%	17.9%	17.4%	0.42	7.4%
10	Malaysia	1.10	100	6.8%	8.1	5502	34.4	28.8	9.5	3.6%	18.6%	23.8%	0.65	46.2%
11	United Arab Emirates	3.98	100	4.6%	5.1	16157	30	15	8.2	5.1%	15.4%	19.7%	0.40	55.4%
12	Pakistan	0.19	94.9	15.8%	2.8	653	20	4898.4	8.5	5.9%	37.5%	10.9%	0.50	8.3%
13	The Philippines	0.23	97.5	9.9%	2.3	869	18.6	214.2	20	3.6%	21.8%	21.4%	0.72	4.4%
14	Kazakhstan	1.33	100	9.0%	8.4	5522	18.1	54.6	5	3.3%	11.0%	17.3%	0.78	47.5%
15	Bangladesh	0.13	99	11.1%	3.3	586	88.9	3000	12	7.4%	1.3%	23.8%	0.63	15.8%

Continued Table

No.	Country	Installed capacity per capita (kW)	Access to Electricity (%)	Grid Loss	Length of Transmission and Distribution Lines Per Capita (m)	Electricity consumption per capita (kWh/year)	Time to obtain an electricity connection (day)	Average power outage duration per household (min)	Average Electricity Price (US cent)	Growth rate of electricity consumption per capita	Proportion of clean energy power generation	Share of Electricity Consumption in Total Final Energy Consumption	Carbon Emission Intensity of Electricity (kg CO_2/kWh)	Growth rate of new energy power generation
16	Israel	2.36	100	5.4%	8.3	6962	55.3	122.4	19	2.0%	9.9%	34.4%	0.59	34.8%
17	Kuwait	4.40	100	9.8%	1.8	17109	30	6	14	3.5%	0.2%	27.3%	0.78	39.3%
18	Uzbekistan	0.49	99.9	15.8%	7.1	1977	9.3	13.2	3.5	6.1%	6.7%	14.1%	0.48	10.4%
19	Iraq	0.67	100	128.5%	6.5	1274	18.6	6000	7	6.3%	2.3%	16.4%	1.35	0.0%
20	Singapore	2.13	100	1.2%	2.5	9684	20	3.6	19	2.0%	5.3%	24.5%	0.44	47.9%
21	Qatar	3.65	100	5.8%	2.9	16319	40	4.2	3	3.5%	0.3%	17.7%	0.46	−0.1%
22	Oman	1.77	100	10.4%	4.1	7546	40	106.2	3	3.5%	0.6%	12.9%	0.50	76.3%
23	Bahrain	3.93	100	3.1%	1.7	19445	40	52.8	3	3.8%	0.0%	0.0%	0.45	8.0%
24	Azerbaijan	0.75	100	9.4%	8.6	2320	4.6	57.6	5	2.8%	6.4%	15.2%	0.50	19.5%
25	Myanmar	0.12	72.5	23.2%	5.1	276	50	1816.8	10	−1.6%	49.4%	7.8%	0.37	9.0%
26	Jordan	0.61	99.9	12.2%	2.4	1757	3.8	142.8	9	0.9%	22.9%	28.4%	0.40	29.7%
27	Sri Lanka	0.23	100	15.6%	1.4	469	42.4	240	10	−5.9%	52.6%	13.8%	0.52	23.0%
28	Kyrgyzstan	0.67	99.7	20.3%	2.9	2034	24.4	714	8	3.5%	85.9%	31.9%	0.13	0.0%
29	Cambodia	0.19	82.5	12.5%	1.3	637	7.9	1246.8	20	9.6%	50.8%	13.5%	0.38	63.9%
30	Nepal	0.08	89.9	18.6%	1.5	305	21.3	3000	10	10.3%	100.0%	5.0%	0.00	11.6%
31	Mongolia	0.49	100	12.0%	6.7	2607	17.8	3720	6	4.9%	11.1%	15.2%	0.77	36.9%
32	Laos	1.63	100	38.2%	3.9	1177	14.7	237.6	7	14.9%	73.0%	25.2%	1.33	44.8%

Continued Table

No.	Country	Installed capacity per capita (kW)	Access to Electricity (%)	Grid Loss	Length of Transmission and Distribution Lines Per Capita (m)	Electricity consumption per capita (kWh/year)	Time to obtain an electricity connection (day)	Average power outage duration per household (min)	Average Electricity Price (US cent)	Growth rate of electricity consumption per capita	Proportion of clean energy power generation	Share of Electricity Consumption in Total Final Energy Consumption	Carbon Emission Intensity of Electricity (kg CO_2/kWh)	Growth rate of new energy power generation
33	Georgia	1.05	100	6.5%	7.7	3520	20.9	281.4	9.9	4.1%	76.2%	23.0%	0.11	−0.2%
34	Tajikistan	0.63	99.6	30.7%	10.0	1512	8.9	130.2	4.1	0.6%	89.3%	38.5%	0.14	0.0%
35	Russia	2.08	100	9.3%	25.6	7087	8.1	10.92	9	1.4%	39.7%	12.8%	0.38	50.7%
36	Germany	3.15	100	5.2%	21.0	6111	30.3	15	40	−1.7%	51.1%	18.9%	0.41	4.9%
37	France	2.20	100	8.5%	20.7	6302	40	21	28	−1.4%	87.9%	24.7%	0.07	11.2%
38	Türkiye	1.24	100	10.9%	14.9	3355	6.9	2681.4	17	1.6%	41.8%	21.1%	0.47	19.4%
39	UK	1.64	100	9.1%	22.3	4254	30	16.8	40	−1.9%	58.5%	20.6%	0.21	9.1%
40	Italy	2.04	100	6.3%	23.9	4939	10.2	78	33	−0.8%	36.3%	21.3%	0.30	2.7%
41	Spain	2.49	100	11.2%	26.2	4908	32.1	30.6	28	−1.6%	62.2%	23.7%	0.24	8.8%
42	Poland	1.55	100	5.5%	12.4	4128	24.3	67.8	18	−0.6%	21.6%	15.6%	0.75	12.5%
43	Ukraine	1.54	100	11.1%	12.6	2623	51.5	162.6	8	−5.2%	67.4%	20.8%	0.29	31.1%
44	Sweden	5.10	100	8.4%	25.8	12578	17.5	36.6	10	−0.5%	99.0%	33.4%	0.01	14.0%
45	Norway	7.55	100	7.3%	49.0	22709	40	90	12	−0.4%	99.5%	47.5%	0.01	39.4%
46	The Netherlands	3.19	100	4.3%	11.7	6226	59.6	46.8	28	−0.3%	44.7%	16.5%	0.34	24.9%
47	Belgium	2.29	100	4.2%	13.7	6948	76.6	24.6	34	−1.6%	71.0%	17.3%	0.15	14.2%
48	Finland	4.45	100	3.8%	92.6	14367	32.4	12	20	−0.9%	90.1%	27.7%	0.07	20.3%
49	Austria	3.35	100	5.0%	24.7	7322	22.8	37.8	27	−1.0%	74.9%	19.7%	0.11	5.2%

Continued Table

No.	Country	Installed capacity per capita (kW)	Access to Electricity (%)	Grid Loss	Length of Transmission and Distribution Lines Per Capita (m)	Electricity consumption per capita (kWh/year)	Time to obtain an electricity connection (day)	Average power outage duration per household (min)	Average Electricity Price (US cent)	Growth rate of electricity consumption per capita	Proportion of clean energy power generation	Share of Electricity Consumption in Total Final Energy Consumption	Carbon Emission Intensity of Electricity (kg CO_2/kWh)	Growth rate of new energy power generation
50	Czech Republic	2.04	100	5.5%	15.9	5775	151.5	28.8	19	−0.7%	51.6%	18.5%	0.54	2.3%
51	Switzerland	2.75	100	8.2%	15.7	6557	15	12	22	0.3%	99.1%	27.6%	0.00	16.8%
52	Romania	1.00	100	12.5%	19.1	2608	32.8	184.8	20	−1.2%	60.9%	15.1%	0.30	−1.1%
53	Portugal	2.31	100	9.0%	25.7	4976	10.4	32.4	22	0.4%	57.9%	25.1%	0.18	4.7%
54	Greece	2.09	100	11.3%	15.7	4419	11.6	94.2	25	−4.1%	46.6%	10.2%	0.33	13.6%
55	Hungary	1.24	100	6.5%	21.2	4452	144.2	153.6	17	1.0%	66.9%	17.1%	0.15	36.8%
56	Denmark	3.35	100	5.9%	30.4	5700	35.3	30	24	−0.1%	88.8%	20.3%	0.09	6.4%
57	Belarus	1.22	100	7.6%	29.3	3755	21.4	30.6	8	0.7%	15.5%	14.6%	0.44	14.3%
58	Bulgaria	1.75	99.8	7.4%	18.4	5139	24.8	369	17	0.3%	51.4%	25.3%	0.62	3.8%
59	Serbia	1.17	100	14.7%	22.6	4440	113.6	231	12	−0.9%	31.2%	25.3%	0.67	73.3%
60	Ireland	2.26	100	8.0%	36.9	6027	49.3	48	28	2.2%	41.8%	22.6%	0.34	9.9%
61	Slovakia	1.47	100	4.7%	10.3	4841	21.5	52.8	20	−1.1%	82.2%	18.7%	0.12	5.0%
62	Iceland	8.56	100	2.9%	64.1	54975	55	37.8	12	0.9%	100.0%	50.6%	0.00	0.0%
63	Croatia	1.35	100	10.1%	20.5	4272	20.9	198	18	0.6%	63.6%	19.5%	0.18	13.9%
64	Slovenia	2.09	100	6.4%	14.0	6319	56.9	7.8	19	−1.6%	73.3%	23.8%	0.22	13.4%
65	USA	3.61	100	5.0%	34.9	12397	45	76.8	17	1.2%	40.5%	21.4%	0.37	14.0%
66	Canada	4.17	100	6.1%	40.9	14514	40	58.8	14.3	0.1%	82.8%	23.6%	0.13	4.8%

Continued Table

No.	Country	Installed capacity per capita (kW)	Access to Electricity (%)	Grid Loss	Length of Transmission and Distribution Lines Per Capita (m)	Electricity consumption per capita (kWh/year)	Time to obtain an electricity connection (day)	Average power outage duration per household (min)	Average Electricity Price (US cent)	Growth rate of electricity consumption per capita	Proportion of clean energy power generation	Share of Electricity Consumption in Total Final Energy Consumption	Carbon Emission Intensity of Electricity (kg CO_2/kWh)	Growth rate of new energy power generation
67	Mexico	0.80	100	13.2%	11.3	2277	17.1	35.046	11	1.3%	25.0%	25.7%	0.50	23.8%
68	Brazil	1.02	99.5	17.8%	9.4	2695	27.7	398.4	16	1.8%	90.1%	20.4%	0.06	20.3%
69	Argentina	1.01	100	23.3%	19.8	2763	53.5	270.6	10	−0.8%	34.7%	19.0%	0.40	93.6%
70	Chile	1.83	100	5.0%	9.4	4442	21.1	174	16	3.0%	56.6%	23.9%	0.33	25.9%
71	Colombia	0.37	100	5.8%	7.2	1569	59.6	270	15	2.1%	71.9%	19.2%	0.18	86.1%
72	Venezuela	1.23	100	49.1%	6.9	2006	13.9	1200	8	−4.2%	77.7%	38.9%	0.21	0.5%
73	Peru	0.44	95.6	13.4%	2.6	1458	79	383.4	15	1.5%	61.4%	22.3%	0.20	14.1%
74	Ecuador	0.45	100	17.3%	7.4	1497	18.1	127.2	10	2.8%	81.0%	18.7%	0.21	−1.5%
75	Puerto Rico	1.99	100	6.8%	14.2	5468	40	861	21	3.3%	2.6%	0.0%	0.90	7.3%
76	Cuba	0.68	100	25.3%	3.7	1292	60	900	5	−3.5%	4.6%	21.8%	1.21	23.8%
77	Dominican Republic	0.49	100	12.8%	4.0	1683	16.7	34.8	13.5	2.7%	14.2%	21.7%	0.73	28.8%
78	Uruguay	1.54	100	10.8%	14.0	3384	34.2	600	14	1.1%	90.9%	20.1%	0.12	5.5%
79	Costa Rica	0.69	100	10.7%	9.3	1976	39	32.4	15	1.1%	100.0%	23.4%	0.00	1.7%
80	Panama	1.03	95.3	11.3%	4.2	2691	1.8	469.2	19	4.6%	78.2%	26.8%	0.17	12.8%
81	Bolivia	0.34	98.6	9.0%	12.7	865	30	477.6	19	3.9%	35.0%	8.4%	0.32	64.4%
82	South Africa	1.01	89.3	12.6%	10.0	3197	11.9	1831.8	10	−2.0%	12.2%	27.0%	0.95	12.4%
83	Egypt	0.55	100	21.3%	3.2	1655	76.9	119.4	6	1.7%	11.5%	22.8%	0.53	30.6%

Continued Table

No.	Country	Installed capacity per capita (kW)	Access to Electricity (%)	Grid Loss	Length of Transmission and Distribution Lines Per Capita (m)	Electricity consumption per capita (kWh/year)	Time to obtain an electricity connection (day)	Average power outage duration per household (min)	Average Electricity Price (US cent)	Growth rate of electricity consumption per capita	Proportion of clean energy power generation	Share of Electricity Consumption in Total Final Energy Consumption	Carbon Emission Intensity of Electricity (kg CO_2/kWh)	Growth rate of new energy power generation
84	Algeria	0.48	99.8	11.9%	6.7	1732	49.1	254.4	10	3.7%	0.8%	12.9%	0.49	3.0%
85	Morocco	0.37	100	20.9%	5.3	912	9.8	29.4	10	2.2%	17.9%	17.6%	0.91	14.5%
86	Libya	1.44	70.2	26.2%	7.5	3380	70	1200	1	−1.7%	0.0%	17.4%	0.76	2.4%
87	Nigeria	0.06	59.5	17.1%	2.5	150	9.4	3600	4	2.9%	21.7%	1.7%	0.40	12.6%
88	Ghana	0.16	86.3	8.5%	5.6	571	44.7	3356.4	12	8.8%	34.0%	16.4%	0.36	36.4%
89	Tunisia	0.54	99.9	24.8%	3.3	1615	128.3	152.4	7	2.5%	3.1%	18.0%	0.47	2.0%
90	Angola	0.20	48.2	13.0%	4.3	402	7.7	767.4	4	9.3%	75.0%	10.5%	0.23	0.7%
91	Zambia	0.19	46.7	16.0%	0.7	748	61.7	3073.2	8	3.5%	88.9%	12.0%	0.14	272.3%
92	Ethiopia	0.05	54.2	29.8%	1.5	85	194.3	12000	4	3.9%	100.0%	2.2%	0.00	2.5%
93	Kenya	0.06	76.5	30.6%	1.2	150	78.9	720	4	1.1%	92.0%	5.1%	0.11	79.9%
94	Côte d'Ivoire	0.08	71.1	20.3%	0.6	308	39.8	865.2	16	5.7%	31.1%	9.6%	0.38	20.8%
95	Tanzania	0.03	42.7	15.6%	1.0	124	52.6	1254	9	5.6%	32.6%	2.7%	0.34	3.3%
96	Cameroon	0.06	65.4	28.7%	1.2	205	16.2	6000	15	0.0%	62.4%	6.3%	0.28	5.4%
97	Senegal	0.10	68	15.0%	0.6	418	24.8	1042.8	17	9.9%	25.7%	14.4%	0.87	76.9%
98	Uganda	0.05	45.2	27.7%	0.7	84	18.1	3702	16.6	10.3%	99.0%	1.8%	0.02	16.5%
99	Australia	3.93	100	4.6%	38.6	9690	56	60	25	0.1%	34.5%	23.6%	0.56	26.2%
100	New Zealand	2.05	100	6.5%	38.1	8179	50	226.2	18	0.3%	86.8%	25.0%	0.07	7.6%