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Promoting Shared Development in Southwest China Through Energy Revolution

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Abstract: Southwest China is a key area for winning the battle against poverty and pollution. Southwest China is rich in hydropower and natural gas resources; the region is crucial for supporting the West-to-East Power Transmission and West-to-East Natural Gas Transmission projects. The energy resources among the five provinces of the region are varied and complement each other; therefore, shared development is important for the energy revolution. This study combines this with the regional development strategy of the area and analyzes the connotation of promoting shared development through the revolution. The strategic positioning and objectives of the energy revolution in Southwest China are discussed. The measures for the shared development include improving nature gas infrastructure, promoting efficient development and clean utilization of coal, optimizing the development sequence of hydropower, and encouraging diversified development and utilization of wind, solar, and hydropower. Furthermore, several policy suggestions are proposed, including improving the hydropower consumption mechanism, breaking regional barriers, implementing preferential fiscal and tax policies, paying equal attention to resource and capital diversification, promoting environmental protection, and strengthening the construction of high-end think tanks and talent introduction.

Keywords: energy revolution; Southwest China; shared development; clean energy consumption

1 Introduction

As one of China's seven geographical regions, Southwest China covers Sichuan Province, Chongqing Municipality, Yunnan Province, Guizhou Province, and the Tibet Autonomous Region, and contributes 26%, 14%, and 11% to the country's territory, population, and gross domestic product (GDP), respectively [1]. Due to a significantly lower economic and social development as well as per capita income compared to more developed regions, it struggles with poverty. Additionally, Southwest China's wastewater discharge and SO_2 emissions per unit of GDP are 1.2 and 1.8 times the national average, respectively, indicating increasing ecological and environmental constraints. However, the region boasts abundant hydropower and natural gas resources. For example, the combined installed hydropower capacity of Sichuan and Yunnan accounts, and basic reserves of natural gas in Sichuan and Chongqing account are over 40% and 30% of the national total, respectively. Through national strategic arrangements such as the West-to-East Power Transmission Project and the West-to-East Natural Gas Transmission Project, Southwest China has fueled the development of the eastern region through abundant clean energy.

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The area has notable differences between energy supply and demand and obvious complementary advantages. (1) The overall energy resources in Sichuan Province include: rich water and conventional/unconventional natural gas, limited coal, scarce wind energy, and concentrated solar energy in some parts. The electricity and natural gas proportions delivered to other parts of the country are 44.4% and 47.3%, respectively. (2) Chongqing Municipality is generally poor in energy resources, especially primary energy, and is characterized by "scarce coal and water, rich gas but no oil"; 16.4% of natural gas is transferred to other localities, but 55.8% of electricity comes from other parts of China. (3) The energy structure of Yunnan Province is dominated by water, coal, solar, and wind, with rich hydropower, wind, and photovoltaic (PV) power resources but relatively limited coal, oil, and gas resources; 52.3% of electricity is transferred to other parts. (4) Guizhou Province has abundant coal and certain hydropower resources, but the latter have been developed and coal production is declining; 33.5% of coal and 78.2% of electricity are transferred to other parts [2]. (5) The Tibet Autonomous Region has abundant hydropower and PV power resources, but it is relatively difficult to develop and utilize clean energy resources due to geographical constraints such as high mountains and deep valleys, and the high-standard environmental protection. Regarding optimal allocation of resources, coordinated development and utilization of energy resources will cost less, but produce more comprehensive benefits than the independent development of a single characteristic resource in a relevant province, and will also play a stronger role in driving regional energy structure optimization, as well as economic and social development.

The area is not only a key region in the development strategy of China's western region, but is also important to tackle poverty and pollution, and an integral part of the Yangtze River Economic Belt development strategy. Therefore, it is necessary to comprehensively analyze the energy revolution path, considering coordinated economic, social, and environmental development. Starting with the basic characteristics and problems of energy, economy, and environment in Southwest China, this study explores the strategic measures and policy suggestions for promoting shared development through the energy revolution.

2 Basic characteristics of energy, economy, and environment in Southwest China

2.1 Southwest China is rich in clean energy resources, which present differences in the distribution

Southwest China is rich in hydropower resources, which, with 4.2×10^8 kW available technologically, are concentrated in Sichuan Province, Yunnan Province, and the Tibet Autonomous Region. Reserves of natural gas resources account for 29% of the national total, mainly found in Sichuan Province and Chongqing Municipality; coal reserves account for 10%, mainly distributed in Guizhou Province. The region has oil shortages, with the reserves accounting for merely 0.3% of the national total. Solar energy resources are abundant only in some parts, and there is generally a shortage of wind energy resources in the region, excluding Yunnan Province.

2.2 Clean energy production occupies a large share, but the end-use energy consumption structure is not optimized

In 2017, electricity generated from primary energy (non-fossil) and natural gas accounted for 64% and 13% of the primary energy production in Southwest China (excluding the Tibet Autonomous Region) respectively, significantly higher than the national levels (16.8% and 5.2%). The primary energy consumption structure was clean, with the ratio of coal, oil, and gas, and non-fossil energy being 42:26:32, better than the national average (60:26:14) [3]. The end-use energy consumption structure was yet to be optimized, as coal accounted for 47% and 40% of the end-use energy consumption in industry and the accommodation and catering industry respectively, both below the national averages (38% and 23%).

2.3 There is a significant difference in energy self-sufficiency, but the general gap is small

In Southwest China, the comprehensive energy self-sufficiency rate is 88.4%; electricity and natural gas are transferred to other parts of China, with self-sufficiency rates of 126% and 114% respectively. Oil consumption depends on transfer from other localities and coal production is equal to consumption, with self-sufficiency rates of 0.1% and 94%, respectively. According to the 13th Five-Year Plans of relevant provinces and municipalities for energy development, the comprehensive energy self-sufficiency rates of Sichuan is 82%, which transfers electricity and natural gas to other localities but brings in coal and oil, Chongqing's is 45%, demanding transfer of coal, oil, natural gas, and electricity from other localities, Yunnan's is 109%, transferring electricity to other localities but taking in coal, oil, and a small amount of natural gas and Guizhou's is 139%, sending out coal and electricity and bringing in oil and some natural gas.

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2.4 Southwest China is generally underdeveloped, with environmental constraints gradually increasing

From 2010 to 2018, the GDP in Southwest China grew from 3.7 trillion CNY to 9.5 trillion CNY, representing an annual average growth rate of up to 2.4%, above the national average (10.3%) [3,4]. However, in comparison to other provinces and municipalities in terms of GDP (Fig. 1), southwestern provinces are last on the list, except for Sichuan Province (ranking the 6th nationwide). The region is still underdeveloped with a large number of poor people, a lower per capita income than the national average, and a laggard process of industrialization. It boasts a generally good ecological environment, especially in Yunnan Province; but air, water, soil, and other environmental pollution problems tend to emerge, and some parts have fragile ecosystems, frequent natural disasters, water loss, soil erosion, rocky desertification, declining forest coverage, and unmitigated pollution in mining areas.

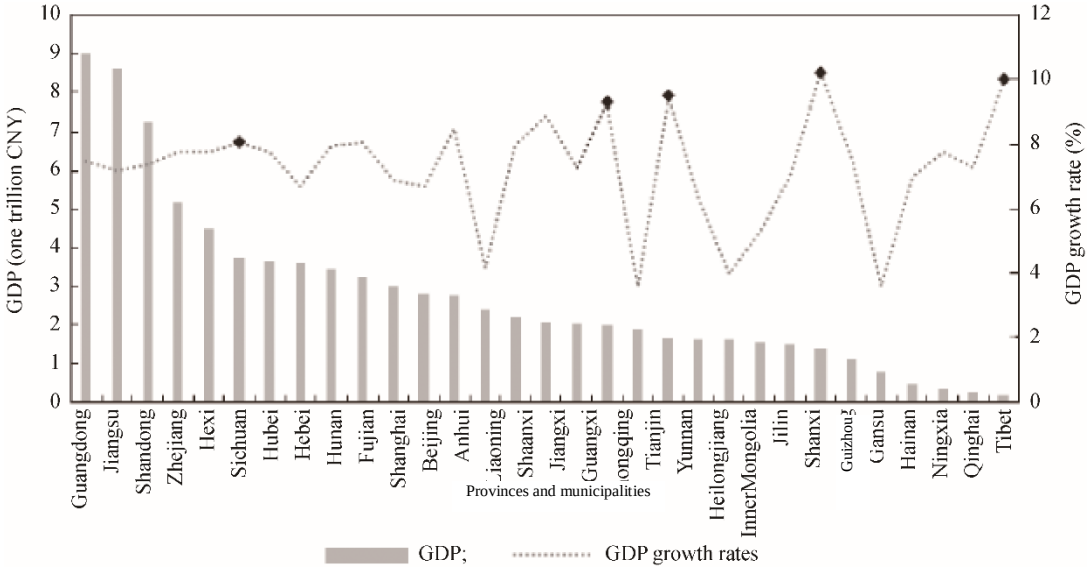

Fig. 1. Comparison of GDP and GDP growth rates in different provinces and municipalities across China (2017).

3 The necessity of promoting energy revolution in Southwest China

3.1 Many structural problems in the energy system are prominent

As energy consumption in Southwest China is mainly observed in energy-intensive industries with low added value, its structure needs to be adjusted. For example, during the 12th Five-Year Plan period, energy consumption by the six energy-intensive industries in Yunnan Province accounted for 70% of the provincial total. In some areas, the contradiction between the excess production capacity of traditional energy resources and strong investment demand is severe. For instance, hydropower production has urgent structural problems and the construction of leading reservoirs with regulation capacity is delayed; except for Xiaowan, Nuozhadu, and other hydropower stations built with regulation capacity for many years, Yunnan Province lacks hydropower regulation capacity [3]. The coal industry is less intensive, with a considerable number of small coal mines, and the construction of intelligent and information-based coal mining is behind schedule. New coal chemical industries such as coal-to-olefin conversion and coal conversion into clean fuels evolve slowly, and the structure of clean use needs diversification.

3.2 The operation of the energy system is problematic, and the overall efficiency needs to be improved

The extensive use of energy in Southwest China has not changed fundamentally. The comprehensive efficiency of energy processing and conversion, storage and transportation, and end use is low. Different energy supply systems such as electricity, heat, and fuel gas can seldom be integrated, complemented, or used in cascade. Demand-side energy saving or user response mechanism has not been established. Electricity coordination and scheduling are inefficient, with a significant difference between peak and valley electric operations. The power grid requires a high reserve capacity, and hydropower transmission lines are long-distance, with high line loss and an insufficient number of utilization hours. The region is experiencing huge peak load regulation pressure due to a shortage of natural gas storage facilities, and an imbalance between peak and valley gas uses.

3.3 Clean energy absorption is faced with dual challenges

Increasing hydropower absorption is important in achieving China's CO_2 emission reduction target, but clean energy absorption remains a challenge in the southwest region. Low willingness to accept clean energy and insufficient capacity of cross-regional power transmission channels in receiving areas are key factors. During the 13th Five-Year Plan period, the region witnessed serious hydropower curtailments. For example, the hydropower curtailment in Sichuan was theoretically 4.19×10^{10} kW·h, which was over 5.0×10^{10} kW·h given the incoming water in 2017, with the curtailment in peak load regulation reaching 1.4×10^{10} kW·h (Fig. 2). In Yunnan Province, it was 1.75×10^{10} kW·h in 2018 which improved after 2019. This was because receiving provinces built power projects locally to meet their economic development needs and the interests of local enterprises amidst the economic downturn, causing the saturation of the local power supply market and the reluctance to accept external hydropower. However, the capacity of cross-regional power transmission channels restricted the amount of hydropower transferred to other localities, as such channels could not be put into operation as scheduled because of large power transmission projects often cover a vast territory, exert extensive influence, and involve complicated interests, and their planning and construction concern numerous organizations.

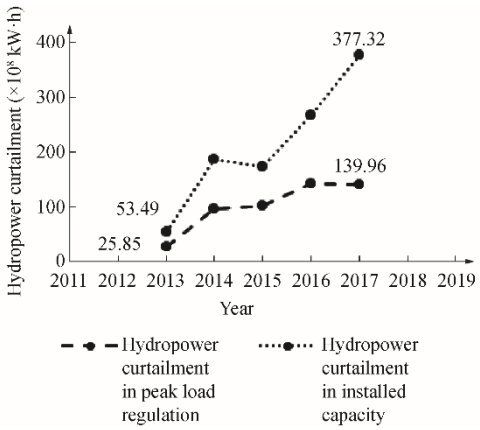

Fig. 2. Annual hydropower curtailment variation trend in Sichuan Province.

3.4 The contradiction between rising hydropower development costs and declining electricity price expectations is increasingly apparent

Although the West-to-East Power Transmission Project is a national strategy, the overall planning, coordination, and regulation at the national level are not strengthened, and the policy system for cross-regional allocation of clean energy resources needs improvement. Average feed-in tariffs for hydropower units in Sichuan Province and Yunnan Province are significantly lower than those for coal-fired and gas-fired units in receiving provinces and municipalities (Fig. 3). Subsequent hydropower development in Southwest China faces many challenges: increasing construction costs, technically difficult engineering construction, rising resettlement and other costs, and growing environmental constraints, which will further increase subsequent hydropower development costs. Moreover, the increasing demand for lower electricity prices in the power consumption market poses a serious challenge to subsequent hydropower development and transmission.

3.5 Regional barriers still restrict the comprehensive development and utilization of energy resources

Southwestern provinces are not fully coordinated, and have developed energy and power planning regarding their respective conditions. Cross-provincial resources are seldom shared, indirectly causing underutilization of abundant clean hydropower and natural gas resources. If there is relative excess power supply, the provinces hope to reduce the power consumption costs by enterprises and promote local economic growth through market-oriented power trading. The root cause of regional barriers is poor systems and mechanisms, and hence, the holistic layout of the

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national energy system should be deepened and power market construction promoted at a higher level, thus seeking more room for hydropower and natural gas absorption in other parts of the country.

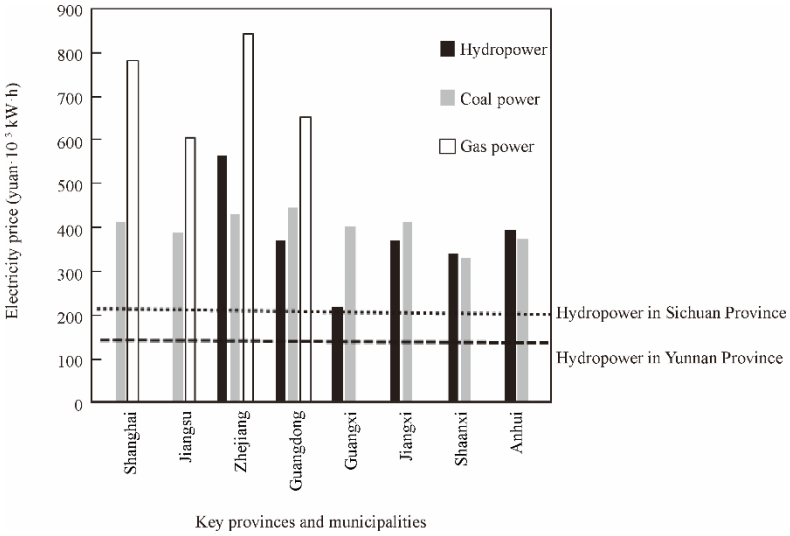

Fig. 3. Comparison of average feed-in tariffs among power generation enterprises in key provinces and municipalities in 2017.

4 The strategy of promoting shared development in Southwest China through the energy revolution

4.1 The connotation of promoting shared development in Southwest China through energy revolution

An analysis of the energy supply and demand status and the necessity of promoting energy revolution in Southwest China indicates that the provinces are highly complementary regarding energy resources. Concerning national strategic arrangements, the region is playing a crucial role in outputting clean power and transferring natural gas. As the economy grows, the energy demand there will increase and the amount of clean energy delivered to other localities will gradually drop.

In promoting shared development in Southwest China through energy revolution, the priority is the sharing of clean energy resources, which will drive sustainable economic, social, and environmental development and ensure that the benefits are fully shared. For this, a phased approach should be adopted to promote cross-regional optimal allocation of clean energy resources, considering the differences in long-term energy demand among different provinces. Regarding sharing of economic and social development benefits, the development of clean energy should be leveraged to drive relevant industries to the region and promote employment growth, tax increases, poverty improvement, and infrastructure upgrading, and achieve balanced economic and social development. Regarding clean energy sharing, the reduction of pollutant and greenhouse gas (GHG) emissions should be aligned to clean and low-carbon services in the region and the ecological civilization construction nationwide.

Specifically, shared development in Southwest China is two-fold: (1) when sharing within the region, optimal allocation of energy resources, including hydropower, wind power, PV power, and natural gas, should be advanced in stages, and energy reciprocity should be achieved through intra-region sharing; (2) when sharing on a national scale, optimal allocation of advantageous energy resources in Southwest China should be carried out at the national level, and the benefits of national economic development should be shared to drive high-quality development and common prosperity in the southwestern region.

4.2 Strategic positioning and objectives of the energy revolution in Southwest China

4.2.1 Strategic positioning of the energy revolution in Southwest China

Efforts will be to build Southwest China into: demonstration zone for the high consumption of clean energy, national clean energy base, pioneer in clean and low-carbon energy development, important supporter of low-carbon transformation of other regions, pacesetter for regionally coordinated energy sharing, and new energy technology innovation and industry incubation center.

4.2.2 Objectives of the energy revolution in Southwest China

The energy consumption structure will be further upgraded. Energy resources will be cleaner and more low-carbon, and the consumption ratio of coal, oil, and gas, and non-fossil energy will develop from 4:3:3 in 2020, to 3:3:4 in 2035 and then to 2:3:5 in 2050.

Healthy economic and social development will continue. By 2035, China will be a socialist modern country, with the per capita GDP reaching the 2018 levels of first-tier cities such as Beijing and Shanghai. The proportion of middle-income groups will significantly increase, as well as the gap between urban and rural development and the gap in people's living standards will be significantly narrowed. By 2050, China will be built into a socialist modern country, with improved economic and social development and an established pattern of common prosperity for all residents.

Pollutant and GHG emissions will be significantly reduced. By 2035, NO*x* and SO_2 emissions will be down 10% and 20% respectively from the 2017 levels, and the GHG emissions will peak around 2030. As an important contributor to national clean and low-carbon development, Southwest China will contribute 10% of China's total CO_2 emissions in 2020, to the national CO_2 emission reductions in 2035.

4.3 Key measures for promoting shared development in Southwest China through the energy revolution

4.3.1 Promoting the construction of natural gas infrastructure and its sharing between Sichuan Province and Chongqing Municipality

The southwestern natural gas pipeline network centered around Sichuan Province and Chongqing Municipality will be perfected, with construction of facilities for natural gas transmission from the Yunnan and Chongqing to Guizhou Province. A support system for natural gas allocation will be established, construction of its storage and transportation infrastructure will be sped up, and the building of underground gas storages by using abandoned coal mines in Guizhou Province will be explored. Channels for natural gas transmission from Southwest China will be made unobstructed, and a large gas transmission pipeline project will be built to connect the area with the central region and the Yangtze River Delta.

4.3.2 Advancing efficient development and clean utilization of coal

Efficiency development and clean utilization of coal, intelligent coal mining, and the development of technology-intensive industries will be promoted. Biomass co-firing will be gradually implemented in coal-fired power plants to reduce carbon emissions from coal power, maximize the role of original coal power equipment and increase fuel efficiency, while retaining the technical advantages of coal power, such as reliability, stability, and flexibility.

4.3.3 Optimizing the development sequence of hydropower and exploring power transmission from Tibet

A reasonable hydropower development sequence will be developed, with accelerated construction of a 1×10^7 kW clean energy base in the upper Lancang, and study of the technical feasibility of power transmission from Tibet. Before 2030, the focus will be on transmitting hydropower from the upper Jinsha and Lancang to Central and South China through high-voltage direct current power transmission systems. After 2030, it will shift to the development of the "Daguaiwan (Great Bend)," a large hydropower project in the Yarlung Zangbo River as the succeeding power source of the West-to-East Power Transmission Project.

4.3.4 Facilitating diversified development and utilization of "wind, PV and hydropower" and increasing the proportion of clean energy absorption

The advancement of hydropower development will occur with planning and construction of wind and PV power generation bases to form a hybrid modern power system. The overall hydropower regulation performance in the river basin will enhance the ability of the power grid to absorb wind and PV power. Facilities for hydrogen production from water electrolysis based on renewable energy and for energy storage will be developed to upgrade the energy industry in Southwest China.

5 Policy suggestions

5.1 Improving the hydropower absorption mechanism and highlighting the value of hydropower as a clean and low-carbon resource

It is recommended to explore and establish mechanisms for sharing hydropower development benefits, such as regulating function compensation of leading reservoirs, asset income support, and development funds setup, pay attention to coordinated economic development of southwestern provinces, and pull people in the region out of

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poverty through hydropower development. The construction of leading reservoirs should be supported and quickened in a market-oriented manner, reasonable compensation methods and adjustable storage capacity established, and coordinated scheduling of cascade power stations in a river basin advanced synchronously. The on-grid hydropower pricing mechanism should be perfected in the southwestern region. An electricity pricing mechanism that can be accepted by the market and power grids, be afforded by power generation enterprises, accelerate hydropower growth, and benefit regional development should be integrated into the pricing model of "government + market" and "costs + social/ecological benefits" to better reflect the clean energy value.

5.2 Breaking regional barriers to promote clean energy sharing and absorption

It is recommended to strengthen policy guidance at the national level, reasonably optimize economic and social development appraisal mechanisms in Southwest China, advocate the concept of green GDP and increase the willingness of provinces to actively absorb clean energy. As the five provinces are supported by two power grid companies, physical connection, unification of settlement, and trading mechanisms may be promoted between them to break the inter-grid and inter-provincial traditional self-development thinking, optimize the allocation of resources under the umbrella of the national energy system, and effectively promote shared development. The national energy planning and layout should be optimized, a regional energy scheduling center established, and an energy scheduling management mechanism explored to ensure unobstructed management boundaries between southwestern provinces and facilitate the optimal allocation of energy resources.

5.3 Implementing targeted fiscal and tax policies and encouraging absorption of clean energy in different ways

It is recommended to advance decentralized utilization of coal in Southwest China, levy pollutant emission fees on backward production capacity in traditional energy-intensive industries, and provide high-tech enterprises implementing coal-to-electricity and coal-to-gas projects with tax breaks, fiscal and tax subsidies, and rewards. Policies that support the upgrading and transformation of industrial fuels in Southwest China should be studied and developed, and enterprises that have applied natural gas in coal-fired boilers and furnaces should be granted concessional loans and land revenue returns. Enterprises engaged in the development of electric vehicles and liquefied natural gas ships in Southwest China should be encouraged to construct charging piles and gas stations, and subsidies and tax preference should be given to them for the construction and operation of the charging piles and gas stations according to policies that support clean energy vehicles.

5.4 Attaching equal importance to resource and capital diversification, and expanding the scale development and utilization of shale gas

It is recommended to guide resource enterprises and other social capital in Southwest China to invest in the upstream areas of oil and gas development, encourage the diversification of investors, and support social and private capital to enter oil and gas exploration and development. The concept of "production increases before storage increases" for unconventional natural gas should be practiced under the guidance of the *Shale Gas Development Plan (2016–2020)* of the National Energy Administration. Policy support, technological advances, and mechanism reforms should be leveraged to accelerate the development of core technologies for shale gas exploration and development, to lay a solid resource, technological and equipment foundation for the development of the industry, and scale development and utilization should be steadily implemented.

5.5 Intensifying environmental protection, and improving environmental pollution

It is recommended to build an atmospheric pollution prevention and control system with air quality improvement at its core, and fulfill energy conservation and emission reduction obligations and duties of governments at all levels and pollutant emitters in Southwest China. Science-based pollutant emission control standards should be developed and strictly enforced for the energy industry in Southwest China. Stricter standards for the release of "the three wastes" should be implemented in energy-intensive and high-emission industries in areas with more serious atmospheric pollution. Management systems for the trading of coal consumption rights and pollution emission permits should be practiced and promoted, and contingency plans should be developed for heavy pollution weather.

5.6 Strengthening the construction of high-end think tanks and professionals in clean energy

It is recommended to set up high-end think tanks for the development of clean energy in Southwest China, thereby providing scientific and technological support and development basis to advance the energy revolution and develop this region into a national clean energy base. Several national and provincial key scientific research and industrial development bases should be set up, talent cultivation and innovative team construction should be emphasized, and the talent cultivation model and incentive mechanism for energy innovation should be improved to provide solid intellectual support for promoting the development of Southwest China through energy revolution.

References

[1] National Bureau of Statistics of China. China statistical yearbook 2019 [M]. Beijing: China Statistics Press, 2019. Chinese.
[2] Department of Energy Statistics, National Bureau of Statistics of China. China energy statistical yearbook 2016 [M]. Beijing: China Statistics Press, 2017. Chinese.
[3] Department of Energy Statistics, National Bureau of Statistics of China. China energy statistical yearbook 2019 [M]. Beijing: China Statistics Press, 2019. Chinese.
[4] National Bureau of Statistics of China. China statistical yearbook 2011 [M]. Beijing: China Statistics Press, 2011. Chinese.