

# ***The Optimization of the Path to Energy Transformation in Areas of Weak New Energy Resources under the Double Carbon Background***

## ***---Taking Anhui Province of China as an Example***

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**Abstract:** “Double Carbon” is the abbreviation for emission peak and carbon neutrality. In September 2020, China proposed to strive to achieve an "emission peak" by 2030 and "carbon neutrality" by 2060. In this context, the process of energy transformation and new energy substitution is accelerating. And those areas with weak new energy resources urgently need to solve the transformation problems caused by limited local resources. Taking Anhui Province of China as an example, this essay studies the trend of energy development and changes, and compares Anhui with Jiangxi Province, which shares similar resource endowments, in order to explore energy transformation plans that are in line with provincially local conditions. The consumption of typical fossil fuels and the development conditions of new energy sources in Anhui Province are analyzed by using the methods of statistical and qualitative analysis. Based on the experience of transformation in neighboring Jiangxi Province and fully considering the functional orientation of Anhui Province in energy and economic fields in East China, this paper concludes that in Anhui Province, the efficient and safe utilization of local new energy resources should be given priority, along with actively promoting the technology of new energy generation and storage. Anhui Province should also strive to transfer existing rich new energy resources and promote cooperation in new energy supply with other provinces to improve the capability of energy guarantee, which may inject new impetus into economic development.

**Keywords:** carbon neutrality, emission peak, new energy transformation, Anhui Province of China

## **1. Introduction**

Energy is closely related to the stability and development of the socio-economic system. Under the background of “Double Carbon”, energy transformation has become an inevitable trend, and new energy will have an important role to play in addressing climate change and promoting economic growth. However, the quality distribution of new energy sources such as solar energy, wind energy, and biomass energy is uneven, which hinders the energy transition in resource-deficient areas. Taking Anhui Province as an example, this essay will firstly analyze the current energy consumption situation

from the perspective of three major industries, and evaluates energy consumption and industry development based on the total carbon emissions. Following this, it will explore the distribution, utilization and restrictive development factors of new energy in Anhui Province. Using the case study method, this paper will take Jiangxi, a neighboring province of Anhui in East China, as an example to study the characteristics and relevant experiences of the energy transition. Finally, the Energy Transformation Plan of Anhui Province under the "Double Carbon" target will be proposed, considering the endowment difference, economic cost, and policy orientation of this province.

After the proposal of the "dual carbon" target, Wang Jipeng believed that many areas with weak new energy resources in China are facing new challenges in energy transformation, including energy security, social benefits, economic benefits, industrial transition and so on [1]. This type of area has mostly relied on fossil fuels for production and daily energy supply for decades, facing the pressure from the contradiction between economic growth and environmental protection. This paper will study a suitable energy transformation path for this type of area, which is also helpful to promote the reform and innovation of energy supply, realize green transformation of energy and resources industry, and ultimately achieve harmonious and green development of society.

## 2. Energy consumption and industrial development status in Anhui Province

### 2.1. Analysis of energy consumption in Anhui Province

According to the Anhui Statistical Yearbook, energy consumption in the province has increased year by year, as shown in Figure 1 [2]. It increased from 130.5187 million tons of standard coal in 2017 to 153.4263 million tons of standard coal in 2021, with an average annual growth rate of 3.29%. Among them, the growth rate in 2019 reached 5.80%, which was the fastest.

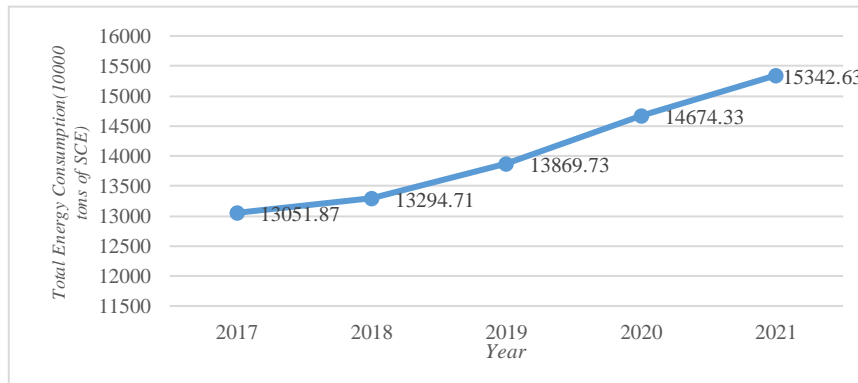


Figure 1: Trend of total energy consumption in Anhui Province from 2017 to 2021.

The elasticity ratio of energy consumption reflects the proportional relationship between the average growth rate of energy consumption and the average growth rate of the national economy. The elasticity ratios of energy consumption in Anhui Province in 2017 and 2018 were 0.33 and 0.26, respectively [2]. The gap between the growth rate of energy consumption and that of the national economy has widened further, which means that Anhui Province realizes sustained and rapid economic growth with less energy consumption.

Table 1: Elasticity ratios of energy consumption of Anhui Province from 2017 to 2021 [2].

	2017	2018	2019	2020	2021
<i>Elasticity Ratio of Energy Consumption</i>	0.33	0.26	0.58	1.55	0.53

According to China's National Economic Industry Classification, the three industries in China are the primary industry (agriculture, forestry, animal husbandry and fishery), the secondary industry (industry and construction) and the tertiary industry (service industry) [3]. From 2017 to 2021, the energy consumption of the secondary industry in Anhui Province was the largest, accounting for 77% to 78% of the total consumption, and it had increased year by year, as shown in Figure 2. The total energy consumption of the tertiary industry was on the rise, at 20% -21% of the total. Total energy consumption of the primary industry remained stable at the level of 2%.

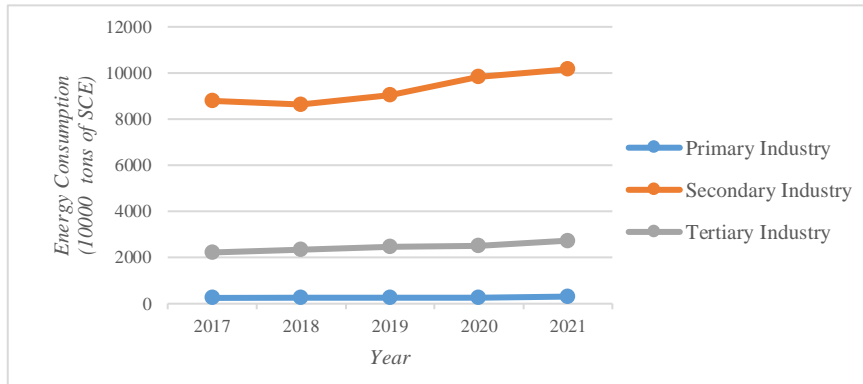


Figure 2: Energy consumption of three industries in Anhui Province from 2017 to 2021 [2].

## 2.2. Analysis of carbon emissions from energy consumption in Anhui Province

According to the IPCC 2006 National Greenhouse Gas Inventory Guidelines 2019 Revised Edition, based on the availability of energy statistics data of Anhui Province, eight major energy products shown in Table 2 were selected to calculate their separate carbon emissions [4]. The formula is as follows:

$$E(\text{CO}_2) = \sum_{i=1}^8 \omega_i \times N_i$$

In the formula,  $N_i$  is the consumption of energy  $i$ , calculated based on standard coal,  $10^4\text{t}$ ;  $\omega_i$  is the carbon emission coefficient of energy  $i$ ;  $i$  represents the type of energy. And the carbon emission coefficients of the eight selected energy products are shown in Table 2.

Table 2: Carbon emission coefficients of eight energy products [4].

The Type of Energy	Raw Coal	Washed and Refined Coal	Coke	Crude Oil	Gasoline	Kerosene	Diesel Oil	Natural Gas
Carbon Emission Coefficients	0.7559	0.7559	0.8550	0.5857	0.5538	0.5714	0.6185	0.5921

Since 2017, the total carbon emissions caused by energy consumption in Anhui Province have increased from 267.4442 million tons in 2017 to 275.1185 million tons in 2019, with an annual average growth rate of 0.94%.

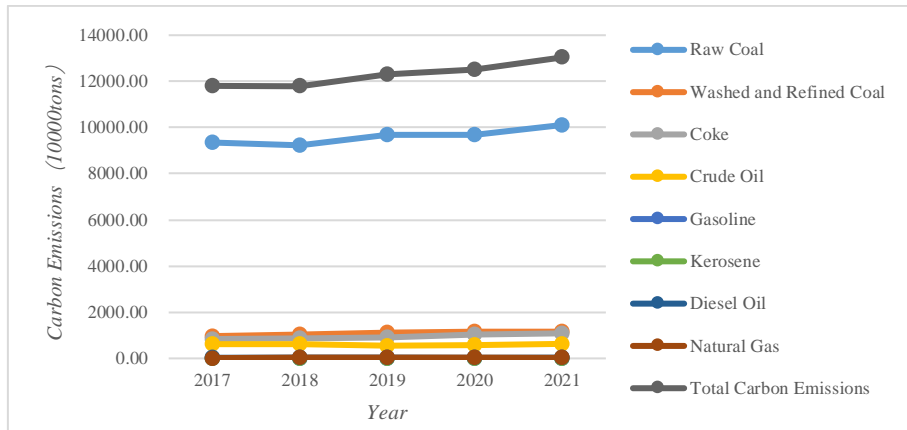


Figure 3: Carbon emissions of eight types of energy products from industrial enterprises in Anhui Province from 2017 to 2021.

As shown in Figure 3, the total carbon emissions of industrial enterprises increased from 118.2431 million tons of standard coal in 2017 to 130.3713 million tons of standard coal in 2021, indicating a high energy consumption in the industrial sector. Carbon emissions from raw coal were the largest, accounting for approximately 78% of the total emissions, with a clear upward trend after 2018. It can be seen that the industrial sector was an important driver for economic growth in Anhui Province. Therefore, in the background of "dual carbon", promoting the comprehensive energy transformation of Anhui Province is of great significance.

### 3. Natural resource and exploitation status of new energy in Anhui Province

The availability of new energy resources within a region largely depends on the natural resource endowment. This chapter will analyze the main natural resources in Anhui Province and explore the limiting factors for the development of new energy at present.

#### 3.1. Natural resource conditions in Anhui Province

The natural resources which are available for the exploitation of new energy in Anhui Province are generally acceptable. Referring to the Atlas of Solar Energy Resources by Province in China, Anhui Province has an annual average total solar radiation of 4540-5460 MJ/m<sup>2</sup>, which is regarded as a medium-sized solar energy resource area according to the China Renewable Energy Society. The annual average solar radiation is the largest in the northern part of Anhui, approximately at the level of 5400 MJ/m<sup>2</sup>. And the area around the city called Mount Huang is the lowest in the province [5].

As far as wind energy is concerned, Anhui Province is located in a monsoon region. The annual average wind speeds in the area of Chao Lake and the peak of Mount Huang can reach 3.3 m per second and 3.8 m per second, respectively, where wind resources are superior. But the annual average wind speed in river valley area is only 1.3 meters per second. From the seasonal point, the wind speed is higher in winter and spring, and that is lower in summer and autumn.

Additionally, as a major agricultural province, Anhui has great potential for biomass energy exploitation. About 48 million tons of crop straw are collected annually, and the total amount of waste from livestock and poultry is about 56 million tons. However, this waste is still treated by traditional methods, such as composting and returning to the field. What's more, with the improvement of residents' living standards and the acceleration of urbanization, the amount of municipal solid waste in Anhui Province will also increase.

### 3.2. Current situation and restrictive factors of new energy development

Since 2021, the government of Anhui Province has accelerated a revolution in energy consumption in five major fields: industrial production, building heating, transportation, agricultural production and people's lives. Therefore, the proportion of new energy power installation projects has significantly increased. By the end of January 2022, the installed capacity of new energy was 30.0314 million kilowatts, accounting for 35.46% of total capacity, with a large share of photovoltaic power, as illustrated in Figure 4.

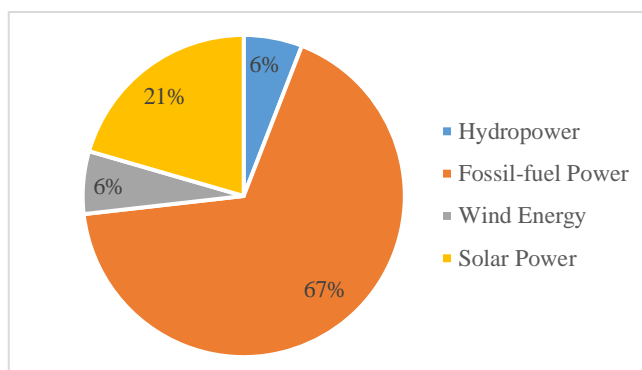


Figure 4: The proportion of installed power capacity of main energy sources in Anhui province.

At present, technological challenges have led to the high costs and limited usage of new energy resources. In addition, Li Enping pointed out that the opportunity costs of solar and wind energy exploitation are fairly high because these facilities for power generation require a large number of vacant land [6]. Most of the high-quality solar and wind energy resources in Anhui Province are in intensive farming areas, and the ground space is occupied by economically valuable agricultural land, woodland, lakes, and reservoirs, making it difficult to achieve large-scale exploitation [6]. Moreover, large-scale access to new energy power will also be affected by channels, peak shaving, energy storage, the power system, and various other factors.

## 4. An analysis of the transition plan of a similar resource region in China: a case study of Jiangxi Province

Jiangxi Province, located in East China, is adjacent to Anhui Province, and also has plain, mountainous and hilly. From the perspective of new energy development, Jiangxi and Anhui Province are both China's Class III solar energy resource area and Class IV wind energy resource area, with decent potential of development. Hilly and mountainous areas have relatively abundant new energy resources. In 2017, energy supply in Jiangxi Province faced big problems such as inadequate energy self-sufficiency, a coal-dominated energy consumption structure, and weak infrastructure, requiring an energy transition to achieve low-carbon development.

### 4.1. Energy transformation plan

In order to alleviate the difficulties in development, the Jiangxi provincial government has formulated a series of policies and measures to promote a revolution in energy production and consumption to build a clean, low-carbon and efficient energy system.

In response to the limiting capacity of energy and insufficient potential for new energy, the Jiangxi provincial government has accelerated the innovation of technology, encouraging the application of mature technologies and guiding breakthroughs in core cutting-edge technologies to improve the working efficiency of existing energy. Furthermore, efforts have been made to strengthen

infrastructure, such as the construction of power grids and oil and natural gas pipelines. The Government has also carried out model projects for solar power generation and special wind farms with low wind speed to make up for the lack of resources [7].

In view of the problem that the high proportion of coal in the energy consumption structure, the administrator of the Jiangxi provincial government has chosen a mode called "multi-energy complementation" to make a scientific plan for the exploitation and utilization of coal, oil, gas, and diverse new energy. It focused on the utilization of photovoltaic power by comprehensive power stations, such as the floating photovoltaic plant integrated with fishery. This mode also focused on the development of wind power in high-mountain wind farms so as to steadily increase the proportion of wind, solar, and biomass power generation [7]. Furthermore, the government has taken active measures to encourage residents to practice energy conservation in their daily lives.

In response to the reform of the energy market, the management department of the government and industry association actively cooperated with each other on formulating public policies and regulations and exploring market-oriented trading mechanisms. The government established a special fund to support financial needs to accelerate the transformation of current enterprises and cultivate new companies.

#### **4.2. Current Situation of Energy Utilization**

Thanks to the effectiveness of the above – mentioned policies, the total energy supply and the proportion of new energy power generation has gradually increased in Jiangxi Province. In 2022, 156,858 million kilowatt-hours of industrial power were generated in Jiangxi province. The proportion of hydropower increased by 27.9%, while the proportion of wind and solar power increased by 16.5% and 21.6% respectively. The proportion of new energy generation such as hydropower, wind and solar power accounted for 16.2% of the total electricity generation, a rise of 4 percentage on 2019. The production of raw coal decreased, with 1.946 million tons of industrial raw coal produced, a year-on-year decrease of 8.3%.

Secondly, energy savings and consumption reduction have achieved significant results. In 2022, the energy consumption per unit of industrial added value in Jiangxi Province decreased by 3.4% year on year, and the overall efficiency of industrial conversion was 62.9%, which increased by 1.4 percentage points in 2021 [8].

### **5. Discussion on the path of energy transformation in Anhui Province**

*The 14th Five – year Plan for Energy Development in Anhui Province* points out that although Anhui Province is traditionally viewed as a major energy province, it is relatively rich in coal resources. And conventional hydropower resources have already been developed. Wind and solar energy resources are relatively common in China, and there is a lack of conditions for nuclear power construction. Oil and gas mainly rely on imports from other provinces, while there are also shortcomings in the diversification of gas supply and transportation capacity [9]. In 2020, coal accounted for 69.8% of primary energy consumption of Anhui Province, 13 percentage points higher than the national level, while natural gas and non-fossil energy consumption accounted for 3.6 percentage points lower than the national level. The coal-dominated situation of energy structure, which is similar to Jiangxi Province, has not changed. Therefore, the pressure on low-carbon transformation will remain high.

#### **5.1. To make Full use of new energy resources in Anhui Province**

Between 2017 and 2021, non-fossil energy consumption grew at an annual average rate of 29.3%, much faster than 1.5% increase in coal consumption. This indicates that the proportion of fossil energy consumption was further decreasing, while the application of new energy was accelerating. In

terms of electricity installation, the proportion of solar, hydro and wind power generation can reach 7.68%, which was conducive to environmental protection. *The 14th Five Year Plan for Energy Development in Anhui Province* predicts that 25% of the province's electricity will come from renewable sources by 2025, which is equivalent to an annual reduction in carbon dioxide emissions of about 69 million tons or more, and in sulfur dioxide and nitrogen oxide emissions of above 13000 tons and 16000 tons respectively [9].

In order to achieve these goals, the first step is to vigorously develop photovoltaic power generation and adhere to both centralized and distributed power generation plans. It is advised to fully utilize barren mountains, existing coal mining subsidence areas, idle water surface and other unused land to construct centralized solar power plants tailored to local conditions. The distributed application of photovoltaic power generation should be promoted on roofs of industrial parks, public buildings, residential buildings and other constructions. According to the suggestion of Lu Yufa, the vice president of the Anhui New Energy Association, the mode of complementary agriculture and solar energy is generally preferred in mining areas with medium or mild subsidence. For those areas where mining subsidence is less severe and the land is prepared for reclamation in the future, the combination of photovoltaic and ecological management mode may be adopted. For areas with permanent water logging, the mode of floating photovoltaic plant integrated with fishery had better be applied. At the end of 2022, 140,000 mu of water accumulated perennially in coal-mining subsidence areas in Huainan City, Anhui Province. And it is expected that the total area of surface subsidence will be 370,000 mu by 2030. However, it is also estimated that the installed capacity of photovoltaics on water surface in the Huainan mining area would reach over 18 million kilowatts by 2030, close to the capacity of the Yangtze River Three Gorges (18.2 million kilowatts).

Then the government should consider promoting the sustainable development of wind power. It is suggested that both centralized and scattered wind farms ought to be constructed. For example, the construction of large-scale wind power plants should be promoted in the North Plain, Anhui Province, based on different terrain conditions. And the measures for encouraging innovation in business mode of scattered wind power had better be carried out also by learning from the experience of building high mountain wind power projects in Jiangxi Province. In July 2023, the first distributed wind power project in Anhui Province, the Leida Cement Green Energy Project in Wuwei City, was launched, whose wind power generation can reach 13.65 MW. It is planned to form a distributed power generation system consisting of three wind turbines with a single unit capacity of 4550 kW and three 4550 kVA/0.69 kV transformer boxes to directly deliver electricity to the enterprise electricity distribution room, providing green power energy for the Leida Cement Company.

To efficiently utilize biomass energy, the government ought to promote the construction of agricultural and forestry biomass heating and power supply projects and reasonably plan household waste incineration to generate power. It is recommended that the utilization of biomass energy would be expanded as well. In rural areas in Anhui, villagers and companies are encouraged to develop and apply industrial biogas and bio-natural gas, which may use crop straw and organic household waste. Various enterprises should strengthen their cooperation to innovate the multi-production technology of bio-natural gas, carbon dioxide, and organic fertilizer", actively promoting the establishment of multi-production projects in the northern region of Anhui Province.

From a macro perspective, it is still necessary to accelerate the development of the new energy industry and enhance the modernization level of the industry and supply chain. New energy business should also complement the shortcomings of the industry and supply chains with strengthening the production capacity of crucial process and equipment components. Promoting the recycling industry of waste batteries, photovoltaic modules could be probable to achieve closed-loop green development throughout the entire life cycle of new energy industry.

During the construction process of new energy projects, negative environmental impacts should be prevented and reduced. Companies in the new energy industry ought to pay attention to former research and environmental arguments about the probability of power stations and formulate scientific and effective environmental protection measures to avoid damage to the region's native vegetation. The plan of roads for maintaining wind power stations in mountainous areas should be reasonably selected. What's more, biomass and garbage power generation projects not only need to be located in proper areas, but also to use advanced environmental protection equipment and energy-saving technology.

Finally, promoting cooperation between domestic and international corporations in the new energy industry is a significant measure for development. The government should fairly encourage leading enterprises in new energy industry, such as photovoltaic, wind power, and energy storage in Anhui Province, to actively participate in the division of production and the formulation of industry standard in both domestic and international markets. Relying on platforms such as universities and research institutes in Anhui Province to gather innovative technology and knowledge in energy field, the new energy industry in Anhui would carry out in-depth cooperation in international research and technology absorption.

## **5.2. Construction of cross-regional channels for new energy power generation transmission**

Anhui Province not only needs to scientifically utilize the local new energy resources, but also to actively promote the transfer of existing affluent new energy from other provinces and areas. The 14th Five-Year Plan for Energy Development in Anhui Province calls for the need to strengthen cooperation with resource-rich regions, support energy enterprises in Anhui to leverage their comprehensive advantages, and develop energy resources outside the Anhui Province [9].

Detailedly speaking, the government should encourage enterprises in Anhui Province to give full play to their advantages in technology, equipment, talent and standards to Inner Mongolia, Shanxi, Gansu, Qinghai, Xinjiang and other resource-rich provinces to exploit renewable energy. It is suggested that Anhui Province should enhance energy and electricity cooperation with western provinces in China. For instance, the  $\pm 1100$  kV high-voltage direct current transmission project from Changji to Guquan can be accelerated to realize a full transmission capacity as soon as possible, which may continuously transfer Xinjiang's abundant electricity to Eastern China. To strengthen the coordinated planning and construction of transmission projects in new energy resource-rich areas would do a favor in meeting the requirement for new energy grid connections.

One of the most useful measures is to speed up the overall optimization of the energy system with the purpose of improving equipment utilization and system efficiency. Yao Xin pointed out that governments should pay attention to the changing trend of natural factors, such as wind, sunlight, topography and woodland to make reasonable predictions of new energy electricity production to dynamically optimize the allocation of new energy electricity [10]. And it is positive to achieve the complementary operation of traditional fossil fuels and new energy sources [10]. The government may also support the innovation of ultra-high voltage, high voltage, low voltage and other power transportation technologies and allocate electricity effectively based on the actual transmission situation.

The government of Anhui Province should also make efforts to reduce local protection barriers within the province to promote the coordinated operation of cross-regional green power trading. Yao Xin also hold a view that much attention should be paid to the design of incentive mechanisms for the transmission of green electricity, with scientifically deciding the cost of green electricity transmission, to motivate green electricity transmission into Anhui from other provinces [10].

The related administrators would be told to emphasize safety management. Furthermore, high-voltage converter stations and dense transmission channels should be necessary for their work



responsibilities to strengthen the safety protection of hub substations. For example, their management could pay more attention to the safety control of energy storage facilities and charging stations, improving the manufacturing standards of products to further upgrade the level of safety management.

## 6. Conclusion

Energy is an important foundation for the national economy and social development. This essay uses statistical analysis methods and a case study to analyze and research the energy transformation in Anhui Province. And the conclusions are as follows:

Firstly, as for energy consumption, the total energy consumption in Anhui Province has been increasing in recent years, showing an upward trend. Among the three major industries, the secondary industry has the largest amount of energy consumption, with raw coal as the main energy source. Then, regarding the exploitation conditions of new energy, Anhui Province has abundant solar energy resources, uneven distribution of wind energy and great potential for biomass energy. At present, the application of new energy in Anhui Province is mainly solar and wind power generation. And the development of new energy is still limited by the high cost and weak technology. However, by promoting technological revolution and innovation, making reasonable plans for traditional fossil fuels and new energy development and actively improving policies and regulations, the proportion of new energy consumption in Jiangxi Province has continuously increased, achieving great results in low-carbon development. Lastly, based on the excellent experience of Jiangxi and the actual situation of Anhui, this paper summarizes measures that can be referenced for energy transformation in Anhui Province. It will be achieved by vigorously developing solar photovoltaic and wind power generation, efficiently making use of biomass energy, improving the modernization of the industry chain of new energy and promoting domestic and international cooperation in the new energy areas.

The development and application of new energy is a long and complex process, involving many fields such as politics, economy, environment, etc. Limited by the author's cognitive level of things, there are still some shortcomings in this study. Although the Anhui and Jiangxi Province share similarities in geographical terrain, energy consumption structure and new energy resource reserves, they are not necessarily at the same stage of lifecycle in energy development. Therefore, it is better to be flexible when exploring experience at a deep level. Additionally, due to the availability of data, this paper does not conduct an input-output analysis on new energy resources.

## References

- [1] Wang, J.P. (2023) *Research on the path of promoting green and low-carbon energy transformation in Yangquan city under the double carbon target.* <https://kns.cnki.net/KCS/detail/detail.aspx?dbname=CMFDTEMP&filename=1023508149.nh>
- [2] Guo, J.S, Gao B.Z, Xiao Z.Y. (2020, 2021, 2022) *Anhui Statistical Yearbook.* China Statistics Press, The Hefei.
- [3] National Bureau of Statistics. (2017) *Industrial classification for national economic activities.* <http://www.stats.gov.cn/sj/tjbz/gmjhyfl/202302/P020230213400314380798.pdf>
- [4] IPCC. (2019) *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.* <https://www.ipcc.ch/report/2019-refinement-to-the-2006-ipcc-guidelines-for-national-greenhouse-gas-inventories/>
- [5] Zhu, R.Z. (2006) *Atlas of Solar Energy Resources by Province in China.* <https://www.doc88.com/p-9418921594576.html>
- [6] Li, E.P. (2022) *The strategic choice of energy transformation in the weak resource area of solar and wind energy under the background of "double carbon": a case study of Jiangxi Province.* *J. Qiye Jingji*, 12: 22-30.
- [7] People's Government of Jiangxi Province. (2017) *Energy development plan of Jiangxi Province during the 13th five – year plan.* [http://www.jiangxi.gov.cn/art/2017/7/12/art\\_4968\\_212681.html](http://www.jiangxi.gov.cn/art/2017/7/12/art_4968_212681.html)
- [8] People's Government of Jiangxi Province. (2022) *Interpretation: energy data of Jiangxi Province in the first quarter of 2022.* [http://www.jiangxi.gov.cn/art/2022/4/26/art\\_423\\_3937596.html](http://www.jiangxi.gov.cn/art/2022/4/26/art_423_3937596.html)

- [9] People's Government of Anhui Province. (2022) *The 14th five – year plan for energy development in Anhui Province*. <https://www.ah.gov.cn/public/1681/554156461.html>
- [10] Yao, X, Sun, Y,P. (2022) *Trans-regional power transmission under the target of “double carbon”: prominent problems and countermeasures*. *J. Governance*, 18: 34-37.