

Analysis of carbon emission status in Gansu Province and suggestions on electric power transformation under the goal of "dual carbon"

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Abstract: As an important transmission corridor of "West-east power transmission" and the central hub of the power grid in northwest China and has obvious resource advantages in the power and location of the country. And it will accelerate the construction of a new power system to adapt to the gradual increase in the proportion of new energy, from the traditional energy consumption structure dominated by coal power to the new energy consumption structure, new energy will enter the stage of high-quality leapfrog development, in order to achieve the "double carbon" goal as soon as possible. Based on the analysis of carbon emissions in Gansu province, especially in the power industry, this paper demonstrates the overall situation of carbon emissions in Gansu province, and points out the status of new energy in Gansu province combined with the latest energy resources and the existing regional development situation, and puts forward relevant suggestions to adapt to the development of new energy in Gansu province under the "dual carbon" goal.

1. Introduction

Scientists point out that climate change will interact with global trends such as excessive consumption of natural resources, rapid urbanization, social inequality and loss and damage caused by extreme events and pandemics, endangering future development [1-3]. In September 2020, at the 75th session of the United Nations General Assembly, China proposed that "it will increase the intensity of its nationally determined contributions, adopt more powerful policies and measures, strive to reach the peak of CO₂ emissions before 2030, and strive to achieve carbon neutrality by 2060" [4-6]. To achieve the "double carbon" goal as soon as possible, China will accelerate the construction of a new power system to adapt to the gradual increase in the proportion of new energy [7-8]. As an essential ecological security barrier in the west of the country and the central hub of the Northwest power grid, Gansu Province plays a pivotal role in the country's environmental security [9-11]. The realization of the goal of carbon neutrality requires the joint efforts of various industries and departments in each province [12-13].

As an important new energy base in western China, the power industry in Gansu Province has great emission reduction potential and is the key to achieving the dual-carbon goal [14]. Some scholars have carried out phased accounting of carbon dioxide emissions in the power industry of Gansu Province, and further studied the driving factors and effect intensity of carbon emissions in different stages of power generation. The results show

that the carbon emissions generated in the power production stage of Gansu Province account for the largest proportion in the whole power life cycle. From the perspective of cumulative contribution rate, electricity consumption and electricity trading promote carbon emissions in the power production stage. Power structure, power efficiency and fuel structure have opposite effects [15-17].

Based on the analysis of carbon emissions in Gansu Province from 2001 to 2022, especially in the power industry, this paper demonstrates the overall situation and peak of regional carbon emissions, and combines it with the actual development of regional new energy, and puts forward new energy development suggestions to adapt to the energy transformation and sustainable development of Gansu Province.

2. General situation of Gansu electric power production

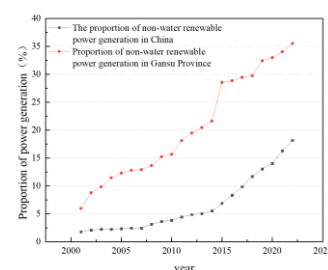


Fig. 1. The proportion of non-fossil energy power generation in China and Gansu Province from 2001 to 2022

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From the perspective of power production structure, the proportion of non-water renewable energy generation in Gansu Province has increased yearly (Fig.1). From 4.471 billion kWh in 2001 to 65.622 billion kWh in 2022, from 9.82% to 33% in 2022, the degree of electricity cleanliness has significantly improved. It is always higher than the national average level of electricity cleanliness. Prior to 2016, Gansu's thermal power generation was mainly through the burning and consumption of fossil resources, mainly coal, which accounted for more than 50%. By 2017, coal combustion will account for 47% of electricity generation in Gansu Province, and non-polluting clean energy will account for 53%, which for the first time realized that the proportion of clean energy power generation exceeded that of thermal power (Fig. 2). As of May 2023, the province's installed power generation capacity reached 70.71 million kilowatts, of which new energy installed capacity accounted for 53.8%, becoming the largest power source in the province. At the same time, from the overall level of electricity consumption in Gansu Province, the supply exceeds the demand, which belongs to the power output province.

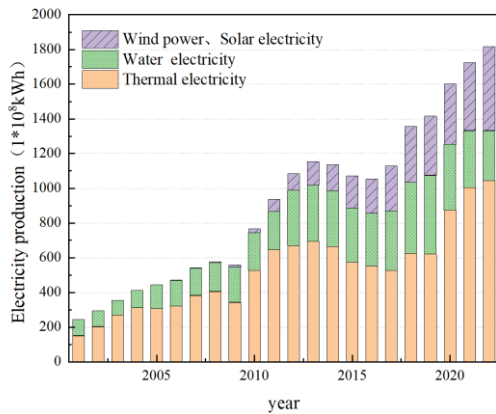


Fig. 2. Power production structure of Gansu Province from 2001 to 2022

3. Analysis of carbon emission and the overall situation of the power industry in Gansu Province

3.1 CO₂ carbon emissions

In this paper, the National IPCC Greenhouse Gas Listing Guidelines are used to calculate CO₂ emissions from the electricity production side of the power sector in Gansu Province [20]. The specific calculation formula is as follows:

$$CEP = \sum_{k=1}^m ef_k \cdot fm_k \quad (1)$$

Where ef_k is the carbon dioxide emission factor of the k fuel, fm_k is the amount of the k fuel used in the power generation stage, and m is the type of power generation fuel.

Gansu power grid has always undertaken the task of inter-provincial power exchange in the five provinces (autonomous regions) in Northwest China. To a certain extent, power flow detour between different voltage levels and provinces cannot be avoided, resulting in a large

amount of power loss in the transmission process between Gansu Province and some provinces. This part of power loss is mainly line loss, that is, in the transmission and distribution lines, the resistance heat loss, induced electromagnetic wave loss and capacitance current loss caused by the current passing through the wire. The phenomenon that results in the loss of electrical energy during transmission. Line loss is an important index to measure the running quality of power system [18-19]. The corresponding amount of carbon dioxide in this part of the network loss is defined as the carbon dioxide emissions in the power transmission stage, which can be calculated by the following formula:

$$CET = \sum_{n=1}^q ef_n \cdot fl_n \quad (2)$$

Where ef_n is the carbon emission coefficient of coal-fired power plants in Gansu Province in the n th year, fl_n is the electricity lost by transformers and transmission lines of different voltage levels in the power transmission process of Gansu power grid in the n th year, collectively referred to as network loss, and q is the year.

The grid carbon emission factor ef_n is determined by the following formula, the meanings of specific parameters are shown in Table 1.

$$ef_n = \frac{FC_{i,y} \times NCV_{i,y} \times EF_{i,y}}{EG_y} \quad (3)$$

Table 1 The specific meanings of each factor in Formula (3)

divisor	Specific meaning
EG_y	Total net power generation in year y of Gansu Province (MWh)
$FC_{i,y}$	Total consumption of fuel i by generator set in year y (mass unit)
$NCV_{i,y}$	Average low calorific value of fuel i in year y (GJ/ mass unit)
$EF_{i,y}$	CO ₂ emission factor of Fuel i for Year y (tCO ₂ /GJ)
i	Types of fossil fuels consumed by power generation in Gansu in year y
y	year

The total carbon emissions of Gansu Province have shown a gradual upward trend since 2000 (Fig. 3). In 2000, Gansu's carbon emissions were 5,430 mt, of which 1,425 mt of carbon dioxide was emitted by coal-fired power plants. In 2013, Gansu Province produced 65.66 million tons of carbon dioxide directly for power generation. To a certain extent, the rapid development of new energy in Gansu Province has slowed down the growth rate of total carbon dioxide emissions.

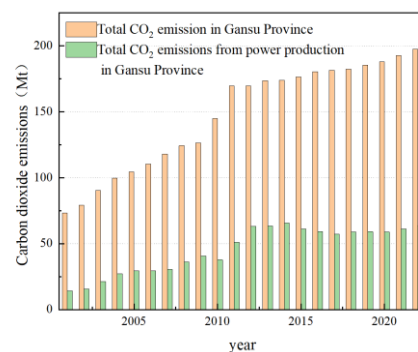


Fig. 3. Total carbon emissions and direct carbon emissions from electricity in Gansu Province from 2001 to 2019

3.2 Carbon emission intensity analysis

The electric power carbon emission intensity in Gansu Province showed a trend of first increasing and then decreasing (Fig. 4). The carbon emission intensity (carbon dioxide emission per 1 kWh of electricity production) of Gansu Province increased from 0.51kg/kWh in 2001 to 0.77kg/kWh in 2003, which was the same as the trend of carbon emission on the power production side at the same stage. From 2003 to 2009, the power carbon emission intensity continued to decrease, and from 2009 to 2011, it showed an increasing trend, and then continued to decline from 0.67kg/kWh in 2011 to 0.42kg/kWh in 2022. During this period, carbon emission from the power production side has increased. It shows that the power production of Gansu Province is increasing year by year, and the proportion of clean power is gradually increasing. The change of power carbon emission intensity indicates that the clean power production in Gansu Province is getting higher and higher.

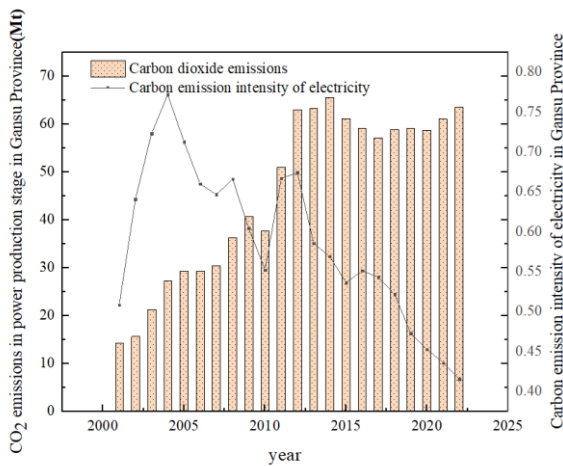


Fig.4. Carbon emission intensity of electricity production in Gansu Province from 2001 to 2022

3.3 Judgment on the overall situation of carbon emission

From the perspective of carbon emissions, the total carbon emissions of Gansu Province, especially the carbon emissions of the power industry, are still growing in a volatile manner. From the perspective of carbon emission intensity, the carbon emission intensity of Gansu Province and the carbon emission intensity of the power industry have decreased significantly. However, there is still a certain gap with the 30 provinces in China (excluding Tibet). Gansu's carbon emission has not reached its peak, and the peak trend of the power industry is faster than the overall development. Therefore, under the "dual carbon" goal, Gansu Province's carbon peak pressure is greater, the industrial structure and energy consumption structure still need to be further optimized and adjusted, and the high-quality sustainable development of new energy needs is urgent.

4. New energy development situation and situation of Gansu Province

4.1 Landscape resources and wind power photovoltaic development status

Gansu Province is rich in wind energy and light energy resources, with effective reserves of 237 million kilowatts and more than 100 million kilowatts, ranking fifth and third in China, respectively, with superior conditions for base, scale, and integrated development. However, due to the low degree of economic development, and the characteristics of new energy development stages and discontinuity, new energy investment has been limited to a certain extent. As of April 30, 2023, Gansu's installed power generation capacity reached 70.71 million kilowatts, of which new energy installed capacity accounted for 53.8%, becoming the largest power source in the province. At the same time, by increasing the power transmission, Gansu and 20 provinces and cities carried out inter-provincial power transmission, and the pattern of large-scale transmission grid was initially formed.

4.2 New energy consumption

In 2022, Gansu will be connected to the grid with 6.22 million kW of new energy, generating 53.8 billion KWH of new energy, ranking second in the country. Among them, the province consumed 29.8 billion kWh of new energy, an increase of 10.0%; 24 billion kWh of new energy was exported across provinces, up 37.4% year on year. Gansu's green electricity has been transmitted to 21 provinces, and the proportion of new energy market electricity ranks first in the country.

4.3 The situation facing the development of new energy

In the process of energy consumption growth from high speed to medium and low speed, affected by factors such as the reduction of consumption level in internal and external markets, the uncertain factors in achieving stable energy development are increasing. The inherent intermittency and volatility of wind power and photovoltaic power generation bring challenges to the stable operation of the power system. The shortage of peak load balancing capacity is prominent, and the flexibility of the power system needs to be improved. The relationship between large-scale new energy development and power grid security, transmission, and consumption needs to be further coordinated, and the power grid's transmission and distribution capacity and intelligent level need to be improved. The problem of unbalanced coal supply and demand still exists. The shortage of coal in the Hexi area coexists with the poor export channel of coal in Longdong. The shortage of coal supply in the time period has not been fundamentally solved; Insufficient investment in exploration and development of oil and gas resources and insufficient ability to ensure natural gas in winter.

5. Results and discussion

Based on the analysis of the overall situation of carbon emissions in Gansu Province, it is found that regional carbon emissions have not reached their peak, the power industry has reached its peak faster than the overall development, the regional industrial structure and energy consumption structure still need to be further optimized and adjusted, and there is an urgent need for high-quality sustainable development of new energy.

As an essential clean energy base for China to achieve the goal of "double carbon", Gansu Province has relatively rich wind and light resources. The high-quality development of new energy in Gansu Province also faces many challenges, such as the traditional positioning adjustment of thermal power and new energy, the increasing demand for flexible resources in the power system, and the low matching degree between resources and demands.

6. Suggestions for adapting to new energy development in Gansu Province

6.1 Optimize the carbon emission accounting system of the power industry and strengthen cross-regional environmental supervision

Carbon emission tracking accounting is a necessary condition for inter-regional environmental responsibility allocation. With the continuous increase of inter-provincial power trading in China, the carbon emission of the power industry is not only affected by the direct carbon emission level of its production side, but also by the indirect carbon emission reflected in cross-border power transmission. For Gansu Province, the electricity transaction volume has increased rapidly in recent years, and most of it is the electricity output to multiple provinces and cities. If only carbon emissions related to production are considered, its environmental responsibility will be overestimated, and carbon leakage will be caused. Based on this, the government needs to optimize and promote an accounting framework or emission guidelines that include indirect carbon emissions from the power supply side and the consumption side, accurately track indirect carbon emissions generated by transmission and consumption of the power industry and lay a solid data foundation for emission reduction responsibility sharing and carbon emission trading market. At the same time, in order to ensure the fairness of carbon emission accounting and responsibility sharing, it is necessary to establish trans-regional environmental regulatory agencies to promote the equality of environmental responsibility in different regions of China.

6.2 Intensify the development of new energy and build a comprehensive energy development pattern

In recent years, the adjustment of the power generation structure of the power industry in Gansu Province has

achieved great results. The new energy generation continues to rise, and in the long run, the power structure has a relatively obvious inhibition effect on the carbon emissions of the power production side. However, at the same time, there are still problems to be solved and critical problems to be overcome. The contradiction between economic development and environmental protection is still prominent, such as: The development and utilization of hydropower generation will cause serious ecological damage, and wind power generation and photovoltaic power generation are difficult to be connected to the grid on a large scale because of their unstable characteristics. Therefore, Gansu Province should focus on promoting the construction of a new power system with new energy as the main body, play to the role of the grid resource optimization allocation platform, and promote clean and low-carbon energy supply, efficient energy consumption, and electrification.

6.3 Accelerate the construction of power transmission channels and continue to promote "green power transmission".

In the "14th Five-Year Plan" plan, in order to meet the demand for electricity in areas with little power and lack of power, Gansu Province will become an important transmission corridor of China's west-east power transmission strategy and bear the power needs of many provinces. Therefore, Gansu Province should speed up the construction of the transmission grid, fully promote the construction of UHV, actively serve the development of new energy, constantly improve the comprehensive regulation capacity of the power system, promote the consumption and utilization of new energy, accelerate the transformation of Gansu Province's energy resources, power grid, location, energy storage, and industrial advantages into development advantages and competitive advantages, and further promote the green transformation of Gansu Province

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