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Research on energy policies of Jiangxi province under the dual-carbon constraints

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As a region with a good ecological foundation and a strong carrying capacity of resources and environment, Jiangxi Province of China was included in the first batch of unified and standardized national ecological civilization experimental zones as early as 2016. How to realize carbon neutrality and carbon peak was the long-term key task of Jiangxi Province and the energy policy was the main effective means for Jiangxi Province to achieve high-quality economic and social development during the 14th Five-Year Plan period. Therefore, based on Bayesian Nash equilibrium theory, a carbon game analysis between enterprises and government under double carbon constraints was established. Besides, by relying on the current situation of energy consumption and carbon emission in Jiangxi Province of China, the goal path of achieving carbon neutrality and carbon peak in Jiangxi Province was tested. According to the research, with lack of natural resources and energetic development of low-carbon economy, enterprises and governments should make transpositional consideration to balance interests and realize common development amid cooperation, thus achieving the harmonious development of society. It is necessary to deepen the understanding of peak carbon dioxide emissions and carbon neutrality, analyze how Jiangxi Province solves the challenges and realization pathways under the goal of peak carbon dioxide emissions and carbon neutrality and discuss policy demands, which are of vital significance for the realization of low-carbon transformation and upgrading of China's economy and society.

KEYWORDS
low-carbon economy, energy policy of Jiangxi province, China, innovation, the path to study

Introduction

Impediments to address the challenges for obtaining the sustainable development that are linked to excessive biodiversity loss, climate change and carbon emission are hot topic in environmental economics and among policymakers (Alvarado et al., 2021). Several empirical studies have concluded that the major causes of deterioration in the quality of environment are constant increase in per capita income and excessive exploitation of natural resource rents (Ma and Stern, 2008). Although the historical accumulation of greenhouse gas concentrations in the atmosphere is a major cause of warming, the enormous increase in current emissions in developing countries has also exposed these countries to increasing pressure for abatement (Shi, 2012). In the range of response options aimed at reducing carbon emissions caused by human activities."low-carbon" development model, has been generally recognized in the world, and has become the goals of human development in the new era (Yang, 2012). To achieve the long-term goals outlined in the Paris Agreement that address climate change, many countries have committed to carbon neutrality targets (Chen H et al., 2021). China signed the Copenhagen Climate Agreement as early as 2010 and it is also an advocator and defender of the Kyoto Protocol. China has made a lot of efforts in realizing energy conservation and emission reduction and promoting sustainable development (Gao, 2021). In response to the scarcity of resources and the deterioration of the global environment, Chinese President Xi Jinping set a "dual-carbon" target in 2020, with carbon emissions peaked in 2030 and eventually neutralized in 2060, urging China to contribute to environmental conservation. In January 2022, he re-emphasized the importance of the carbon-reduction process. The key to reaching the "dual carbon" goal is the establishment of a low-carbon economy. Developing a low-carbon economy requires a shift in China's development model, which now includes not only pursuing economic growth but also pursuing economic development while considering the environment. China's development of a low-carbon economy will have a major impact on the world's ecological and economic fields as the world's second-biggest economy and largest carbon emitter. To achieve President Xi Jinping's goal of a low-carbon and efficient Chinese economy as soon as possible, the Chinese government should formulate a reasonable development plan based on a combination of its own national conditions and relevant low-carbon economy conditions (Cheng et al., 2020; Chen Y et al., 2021; Du et al., 2021; Meng et al., 2021).

The development of low-carbon economy is also a global game (Tang and Tian, 2022). Throughout the world, a total of 54 countries have achieved the goal of peak carbon dioxide emissions, accounting for 40% of the total global carbon emissions. According to statistics, among the top 15 carbon-emitting countries in the world, the United States, Japan, Russia, South Korea, the United Kingdom, Indonesia, Brazil, France, Germany, Canada, and other countries have achieved this goal as of 2020 (Liu and Ma, 2021). It has become urgent for China to achieve this goal. "Taking steps towards the goals of peak carbon dioxide emissions and carbon neutrality" have been included in the eight key tasks for 2021 determined since the 2020 Central Economic Work Conference (Guo and Wan, 2021). Each locality is required to formulate an action plan for peak carbon dioxide emissions till 2030 according to their actual conditions and support will be given to the areas that have satisfied the conditions for achieving this goal early. In January 2021, Shanghai announced that it would fully achieve the goal of peak carbon dioxide emissions by 2025 and become the first city to reach this goal. Afterwards, Jiangsu, Guangdong, Hainan and other regions also proposed to strive to become leaders in achieving the same goal in China (Yu and Zhang., 2021). Achieving the goals of peak carbon dioxide emissions and carbon neutrality are two inseparable stages, with the former being the key basis and important precondition for the latter (Wang et al., 2018). When we can achieve the goal of peak carbon dioxide emissions and the size of the peak will produce a direct impact on the difficulty and specific duration of the work required to achieve the goal of carbon neutrality (Wiryadinata et al., 2018).

No widely recognized and used methods have been found to judge carbon peak in current research. However, some scholars have made attempts. According to urban historical carbon emission data, some scholars judged whether the carbon emissions realized the peak by using conditional judgment function and Mann-Kendall trend analysis test method. Some scholars predicted and researched the time and peak value of carbon peak with scenario analysis method and a series of economic models. They held that China could achieve carbon peak in about 2030, and the peak value could be controlled at about 12 billion tons (Lu et al., 2021). Simultaneously, a unidirectional positive linkage emerged from non-renewable energy use intensity to environmental emissions index (Ahmad al., 2021a). The most optimistic solutions for sustainable development and emission reduction involve switching from conventional technologies to environmentally friendly technologies (EFTs) (Adedoyin et al., 2021; Dogan et al., 2021; Fatima, et al., 2022).

It can be found after reorganizing the literature that main research fields of carbon peak and carbon neutrality include three aspects: factors that influence carbon peak and carbon neutrality, realization path of carbon peak and carbon neutrality, and challenges and opportunities under the objective of carbon peak and carbon neutrality. The factors that influence carbon peak and carbon neutrality are mainly energy, technology and economy. The realization path of carbon peak and carbon neutrality is mainly to change energy structure, develop technology and innovate thoughts ideas.

On the whole, the existing research on carbon peak and carbon neutrality mainly focuses on the macro level concerning energy, technology, economy and industry, while there is rare research at micro level concerning specific provinces, cities, counties and individuals. In view of this fact, based on the current energy and environmental issues facing Jiangxi Province, this paper takes the achievement of the dual carbon goals as an important basis and takes full account into the interactions between the government and economic entities. It provides a useful reference for the dual-carbon policies to smoothly transform from the administrative type to the market-oriented type, the pathways for dual-carbon goals to be optimized, decision-making departments to formulate more reasonable low-carbon policies and the state to further improve the strategies for green, low-carbon development.

Government-enterprise game analysis under double Carbon constraints

The market mechanism is often compared to an "invisible hand", and the government's role a "visible hand". With development of low-carbon economy, enterprises need to increase additional costs. Environmental protection, safe production and other issues will often be neglected if supervision and restraint of government agencies are lacking. Once the government supervises the production behavior of enterprises, enterprises and the government will certainly face the problem of carbon game.

Construction of government-enterprise Carbon game model

As the maker and propagandist of low-carbon innovation policy, the government is also the first actor in the game process. Enterprises select their own strategies according to the low-carbon innovation encouragement policy formulated by the government. Above analysis indicates that the government can choose two strategies: action and inaction, namely, whether the government provides capital and technology and other assistance and support for low-carbon innovation of enterprises. Besides, enterprises have two strategies available: one is to pursue low-carbon innovation and apply the results of low-carbon innovation during production and operation process, thus realizing the objective of energy conservation and emission reduction with the technical level improved. The other is to adopt traditional technological innovation instead of low-carbon innovation. Moreover, the government is entitled to supervise whether enterprises discharge pollutants according to the regulations or standards, and also has the right to punish them if the discharged pollutants exceed the standard.

Above circumstance is abstracted and the following assumption is made:

1) When enterprises take non-low-carbon innovation strategy, the input is I and the income is Q. If enterprises take low-carbon innovation behavior, additional input is ΔI and additional income is ΔQ.
2) If enterprises select non-low-carbon innovation strategy, the government's input is N, and the government's income is P. To encourage enterprises to carry out low-carbon innovation, the government implements policies such as tax reduction and exemption, R&D subsidy, patent protection, etc., with additional input of ΔN. Due to low-carbon innovation of enterprises, the increased income of government is ΔP.
3) The government can select whether to make punishment according to different strategies taken by enterprises. The cost of inspection by the government for enterprise emissions beyond the standard is C and the penalty obtained by the government for punishing violating enterprises is f.

Therefore, the government-enterprise carbon game income matrix can be established, as shown in Table 1.

Analysis of game evolution process

During the game process, if the government selects "action" strategy and supports enterprises to carry out low-carbon innovation, enterprises need to make choice between two strategies, namely "low-carbon innovation" and "non-low-carbon innovation". According to strategies selected by enterprises, the government makes "punishment" or "no punishment". When enterprises select "low-carbon innovation" strategy, the maximum income of the government is:

$$\begin{aligned} Y_1 &= max\,(T_1, T_2) \\ &= max\left(P + \Delta P + f - N - \Delta N - C, P + \Delta P - N - \Delta N\right) \end{aligned} \tag{1}$$

Similarly, when enterprises select "non-low-carbon innovation" strategy, the maximum income of the government is Y_2. For the government, selection of "punishment" or "no punishment" strategies should be decided according to the size relationship between f and C, P and N, $\triangle P$ and $\triangle N$. When $f > C$, $P > N$, $\triangle P > \triangle N$ and when $f > C$, $P > N$, $\triangle P < \triangle N$, the government will select "punishment" strategy. At this time, Y_1 and Y_2 are respectively:

$$Y_1 = P + \Delta P + f - N - \Delta N - C \tag{2}$$

$$Y_2 = P + \Delta P + f - N - C \tag{3}$$

Similarly, when $f < C$, $P > N$, $\triangle P > \triangle N$ and when $f < C$, $P > N$, $\triangle P < \triangle N$, with income of supervision and inspection by the government for enterprise emission less than sum of all costs paid, the government will select "no punishment". From the perspective of enterprises, when the government selects "punishment" strategy, the maximum income of enterprises is:

$$\begin{aligned} W_1 &= max\,\{t_1\ ,\ t_3\} \\ &= max\{Q + \Delta Q + N + \Delta N - I - \Delta I - f, Q + N - I - f\} \end{aligned} \tag{4}$$

When the government selects "no punishment" strategy, the maximum income of enterprises W_2 can be obtained. When $\Delta Q + \Delta N > \Delta I$, enterprise profits increase. Hence, regardless of "punishment" or "no punishment" strategy taken by the government, enterprises will take low-carbon innovation technology for energy conservation and emission

TABLE 1 Enterprise-government carbon game income matrix.

Government-enterprise	Low-carbon innovation	Non-low-carbon innovation
(action, punishment)	$(P+\Delta P+f-N-\Delta N-C, Q+\Delta Q+N+\Delta N-I-\Delta I-f)$	$(P+f-N-C, Q+N-I-f)$
(action, no punishment)	$(P+\Delta P-N-\Delta N, Q+\Delta Q+N+\Delta N-I-\Delta I)$	$(P-N, Q+N-I)$
(inaction, punishment)	$(P+\Delta P+f-N-C, Q+\Delta Q+N-I-\Delta I-f)$	$(P+f-N-C, Q+N-I-f)$
(inaction, no punishment)	$(P+\Delta P-N, Q+\Delta Q+N-I-\Delta I)$	$(P-N, Q+N-I)$

reduction. When $\Delta Q + \Delta N < \Delta I$, regardless of "punishment" strategy taken by the government, enterprises will select "non-low-carbon innovation strategy" for the purpose of guaranteeing that their interests will not be reduced.

If the government selects "inaction" strategy during the game process, enterprises can also select "low-carbon innovation" and "non-low-carbon innovation" strategies. Then the government will make "punishment" or "no punishment" according to enterprise performance. When enterprises select "low-carbon innovation" strategy, the maximum income of the government is:

$$Y_3 = max\{T_5 \ , \ T_6\} = max\{P + \Delta P + f - N - C, P + \Delta P - N\} \tag{5}$$

When enterprises select "non-low-carbon innovation" strategy, the maximum income of the government Y_4 can be obtained. The government will decide whether to take "punishment" strategy according to the size relationship between f and C on the basis of income matrix. Only when the income is greater than the cost regarding inspection and supervision by the government for low-carbon innovation results of enterprises, namely $f > C$, $Y_3 > Y_4$, will the government select "punishment" strategy. On the contrary, if $f < C$, $Y_3 < Y_4$, namely with the income less than the cost regarding inspection and supervision by the government for low-carbon innovation results of enterprises, the government will select "no punishment" strategy. For enterprises, when the government selects "punishment" strategy, the maximum income of enterprises is:

$$\begin{aligned} W_3 &= max\{t_5 \ , \ t_7\} \\ &= max\{Q + \Delta Q + N + \Delta N - I - \Delta I - f, Q + N - I - f\} \end{aligned} \tag{6}$$

When the government selects "no punishment" strategy, the maximum income of enterprises is W_4. If $\Delta Q > \Delta I$, the optimal strategy selection for enterprises is to implement "low-carbon innovation". Under this condition, after pursuing low-carbon innovation, enterprise income increases are higher than input increases when the innovation begins. On the contrary, if $\Delta Q < \Delta I$, the optimal selection of enterprises is to implement "non-low-carbon innovation". On the whole, when $f > C$, $P > N$, $\Delta P > \Delta C$, $\Delta Q + \Delta N > \Delta I$ with conditions satisfied,{(action, punishment), low-carbon innovation} is the equilibrium solution of game. When $\Delta P > \Delta C$, $\Delta Q > \Delta I$ with conditions satisfied, {(inaction, punishment), low-carbon innovation } is the equilibrium solution of game.

Analysis of optimal government-enterprise relationship from the perspective of game theory

During development of low-carbon economy, a key issue that must be correctly and properly handled is how to establish the optimal government-enterprise relationship. Theoretically speaking, firstly, for the low-carbon economy, the government and enterprises should have an equal relationship based on law. Secondly, with social services provided for enterprises, the government also supervises the behavior of enterprises and it is the foundation of the modern government-enterprise relationship. As tax payers, enterprises are entitled to supervise and restrict government actions within the scope of the legal system, and should play a more active role in the process of building the government-enterprise relationship. Such equal relationship of mutual service, mutual supervision and mutual restriction should be the basis for establishing the optimal government-enterprise relationship in low-carbon economy.

Enterprises and the government make strategic choices on the basis of considering their own interests under the environment of low-carbon economy. To a certain degree, the implementation of their strategies is mutually influenced. The best outcome of the game is to maximize the interests of both parties. However, with lack of natural resources and energetic development of low-carbon economy, the ideal state is difficult to exist. If enterprises and the government both only consider their own interests and do their own thing, various conflicts and contradictions will be stimulated. Hence, the two sides should make transpositional consideration to realize balanced interests and common development in cooperation, thus achieving harmonious development of society. We can also find through the research of game theory that both sides of the game often have fluky psychology in one-off game owing to information asymmetry. In practice, the government collects taxes without any action, and the enterprises obtain illegal profits, harming interests of other groups in the market. Therefore, through the

TABLE 2 Energy consumption data of Jiangxi Province, China from 2016 to 2020.

Year	Total energy consumption (10^4tce)	Proportion of each type of consumption in total energy consumption (%)				Energy consumption per unit of GDP (tce*(10,000 yuan) $^{-1}$)
		Oil	Non-fossil energy	Coal	Natural gas	
2016	8971.89	17.60	13.6	65.32	3.05	0.49
2017	9285.69	18.13	13.0	64.39	3.10	0.46
2018	9666.16	18.54	12.4	64.38	3.46	0.44
2019	9808.58	18.67	13.6	62.43	3.43	0.42
2020	8971.89	16.92	16.46	62.86	3.76	0.39

TABLE 3 Breakdown of high-quality leap-forward development of new energy industry in Jiangxi Province, China.

No.	Administrative area	Main operating income in 2023 (100 million yuan)
	The whole province	2000
1	Nanchang	40
2	Jiujiang	50
3	Jingdezhen	5
4	Pingxiang	15
5	Xinyu	300
6	Yingtan	10
7	Ganzhou	300
8	Yichun	400
9	Shangrao	600
10	Ji'an	200
11	Fuzhou	40
12	Ganjiang New Area	40

repeated game, both sides can weigh the advantages and disadvantages in the game and conjecture each other's psychology, a win–win strategy can be followed by increasing the economic growth and environmental quality simultaneously with incentives to use renewable resources in tourism, as well as in other sectors (Işik et al., 2020).

Energy consumption and energy policies in Jiangxi province, China

Energy consumption and CO_2 emission in Jiangxi province

According to statistics, Jiangxi Province had a GDP of 2,475.75 billion yuan in 2019 and its energy consumption grew by 4.1 percent, contributing 8 percent to the total GDP of the province. Currently, this province stands at the forefront in terms of GDP growth in China. It has maintained a medium-to-high growth in local economic indicators, ranking among the first in this respect nationwide. The per capita GDP of the province has hit more than US$ 7,000 and the ratio of its primary, secondary and tertiary industries is 8.3:44.2:47.5. Among the total energy consumption of 96.6515 million tce of the province in 2019, coal consumption accounted for 62.42 percent, oil consumption 18.66 percent, natural gas consumption 3.42 percent, and non-fossil energy consumption 13.5 percent, significantly lower than the national average. The energy consumption per unit of GDP was 0.42 tce/10,000 yuan (see Table 2); the electricity consumption of the whole society reached 153.570 billion kWh; and the proportion of renewable energy in Jiangxi arrived at 25.5 percent (Fang et al., 2021).

According to the specific calculating method for CO_2 emissions in the *Guideline for the Preparation of the Action Plan for Provincial Peak Carbon Dioxide Emissions*, CO_2 emissions caused by energy activities and the indirect emissions contained in the transfer of electricity were calculated. It was found that the total CO_2 emissions of Jiangxi Province have gradually increased in the past 5 years. (Han et al., 2018). The year 2019 saw a total CO_2 emissions of 252.47 million tons, representing a growth rate of 10.9 percent compared with the figure 5 years ago (see Figure 1), carbon emission intensity of 0.88 t/10,000 yuan, a decrease of 20.3 percent compared with the figure 5 years ago, and per capita carbon emissions of 4.35 t. The carbon emission intensity and per capita carbon emissions of Jiangxi Province were significantly lower than the national average. (see Figure 2). This means that rising government spending (through the AC hypothesis) increases real GDP per capita (RGDPPC) and, consequently, increases in RGDPPC (through the EKC hypothesis) increase CO2emissions (Işik et al., 2022). Besides, CO2emissions produced a neutral influence on the aggregate economic output in the short run, whereas it put forward the aggregate economic output hampering influence in the long run. (Ahmad et al., 2021b).

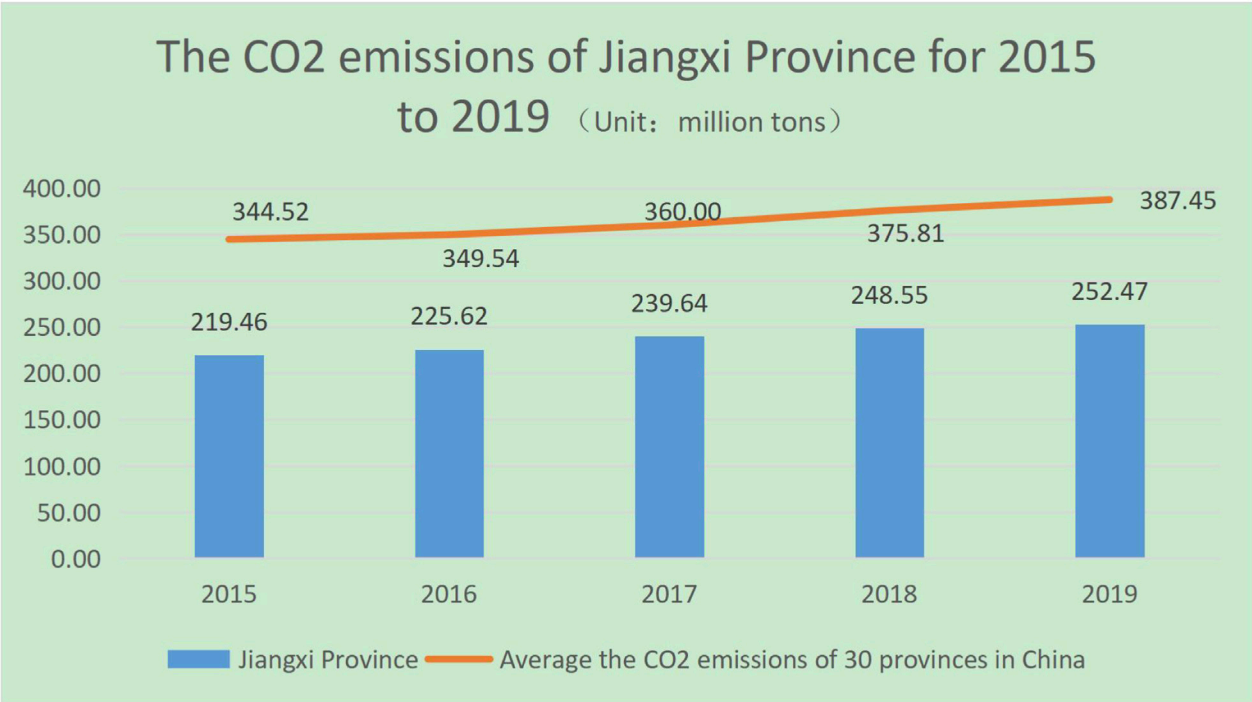

FIGURE 1
The CO2 emissions of Jiangxi Province for 2015 to 2019.

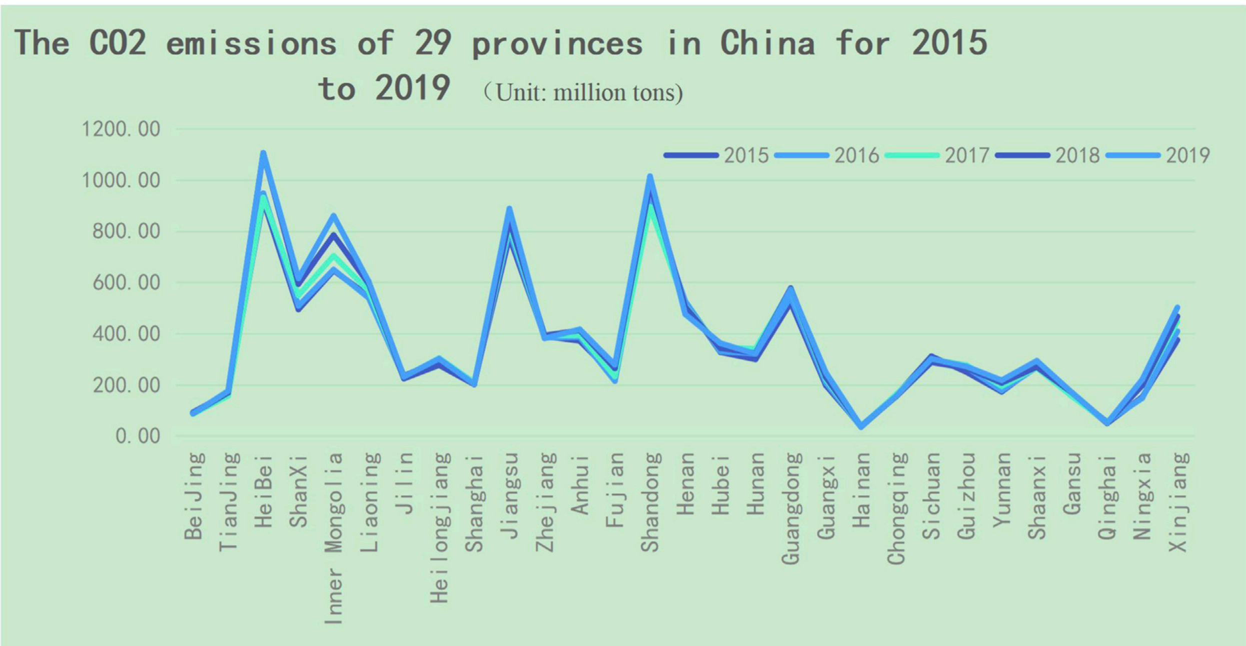

FIGURE 2
The CO2 emissions of 29 provinces in China for2015 to 2019.

Energy policies of Jiangxi province

1) The *Action Plan for the High-quality Leapfrog Development of New Energy Industry in Jiangxi Province* was issued by the Department of Industry and Information Technology of Jiangxi Province in 2019. This scheme is intended to realize three objectives. Firstly, it is to achieve a rapid growth in industrial scale. After efforts of 4 years, the income from the main business of new energy industries such as photovoltaic and lithium batteries in the province will exceed RMB 200 billion. Secondly, it is to steadily improve the comprehensive strength, cultivate two to three ten-billion-level new energy leading enterprises with international first-class level and 10–15 industry backbone enterprises with an income over RMB two billion. Thirdly, it is to further increase input in R&D. The R&D input ratio of leading backbone enterprises will be over 3%, and a series of invention patents will be obtained in some key technical fields.

2) The *Administrative Measures for the Development and Trading of Forestry Carbon Sinks in Jiangxi Province (Trial)* was issued by the Department of Ecology and Environment of Jiangxi Province in 2021. These measures apply to the development, declaration, review, trading and other work of forestry carbon sink projects within the administrative region of Jiangxi Province. Management responsibilities of all departments are clarified in the measures and related provisions are made for the management of forestry carbon sink trades and the third party audit, supervision and management.

3) The *Statistical Statement System of the Department of Response to Climate Change in Jiangxi Province* was formulated to improve the statistical accounting system for response to climate change. Third-party and fourth-party review systems for data of key emission units were mainly improved and the data verification of key emission units in eight industries was completed with high quality.

4) The *Carbon Emission Trading Quota Pre-allocation Plan of Jiangxi Province* was promulgated to regulate the data verification and quota pre-allocation of key emission units and their stable and orderly access to the national carbon market. The research of carbon peak and peak-reaching road map of 11 prefecture-level cities is completed in the scheme, with the tracking mechanism of carbon peak and peak path in the whole province established. In addition, the peak-reaching progress is updated in a real time way and tracked dynamically in the big data platform. Carbon neutrality, near-zero carbon emission demonstration zones, low-carbon tourism demonstration scenic spots, low-carbon counties and other pilot demonstrations are implemented for the purpose of exploring the peak-reaching paths in key areas and key fields.

5) The *Interim Measures for the Management of Forestry Carbon Sink Projects of Jiangxi Province*, the *Rules for Forestry Carbon Sink Trading of Jiangxi Province*, and the *Methodology on the Carbon Sink Projects of Forest Management in Jiangxi Province* were formulated to regulate the forestry carbon sink management system in the whole province.

6) A carbon trading work coordination group across 16 provincial departments was established in Jiangxi Province to strengthen safeguard measures with systematic thinking.

Ecological carrying capacity determines the limits of ecological loss, and thus determines the scale of a economy. So, “eco-loss quotas” is a key of construction of ecological civilization (Zhong, 2014). Under the joint effort of the Jiangxi Provincial People’s Government and enterprises in this province, Jiangxi has become the first in issuing the *Guiding Opinions on Promoting Carbon Neutrality in Large-scale Events*. In large-scale events such as the Fifth World Green Development Investment and Trade Expo and the Seventh National Low-carbon Day, a total of 10 carbon neutrality events were organized and 5,900 tons of carbon emissions were offset by forestry carbon sinks in Jiangxi Province. Counties with abundant forestry resources and concentrated poor populations were selected in the former Central Soviet Area such as southern Gansu for piloting carbon sink project development and establishing a model of forestry carbon sinks’ participation in carbon trading featuring “poor village development—consumption in large-scale events”, making forestry carbon sinks play an active role in ecological value conversion and poverty alleviation through ecology.

(7) In April 2022, the Jiangxi Provincial Committee of the CPC, and the Jiangxi Provincial People’s Government jointly issued the *Opinions on Completely, Accurately and Comprehensively Implementing the New Development Concept and Doing a Good Job of Peak Carbon Dioxide Emissions and Carbon Neutrality*, which proposes the goal of developing new energy in Jiangxi Province (see Table 3).

In the *Opinions on Completely, Accurately and Comprehensively Implementing the New Development Concept and Doing a Good Job of Peak Carbon Dioxide Emissions and Carbon Neutrality*, Jiangxi sets its goal as follows: By 2030, the province will become a leader in comprehensive green transformation of economic and social development throughout the country; its key energy-consuming industries will reach the domestic advanced level; and the proportion of non-fossil energy consumption will see a steady increase. Regional energy consumption per unit of GDP will continue to decline; regional carbon dioxide emissions per unit of GDP will ensure the targets set by the state to be reached; the stock of living trees will reach 900 million cubic meters and the carbon dioxide emissions will peak and achieve a steady decline. Zou Wenjie thinks under the national common Frontier the innovation efficiency level of the eastern region’s high-tech industry is the highest, while that of the western region is the lowest (Zou et al., 2022). By 2060, advanced, efficient energy conservation and carbon neutrality pathways will be fully implemented; the province will lead the world in energy utilization efficiency; the proportion of non-fossil energy consumption will be 80 percent or above; the goal of carbon neutrality will be successfully realized to create a new environment featuring harmonious coexistence between man and nature.

Challenge against peak Carbon dioxide emissions and Carbon neutrality in Jiangxi province

Tight schedule for realizing the goal of peak Carbon dioxide emissions

Environmental sustainability is the prime concern of global economies to avoid climatic adversities in the future (Yasir et al., 2022). In the international community, when pursuing economic development, some countries have achieved the goal of peak carbon dioxide emissions early in the 1990s and continue to promote carbon neutrality in the subsequent 60 years. As an undeveloped region in China, Jiangxi has slow economic growth and low total carbon emissions. Now, the province is undergoing a period of rapid growth and the new development pattern of the "dual cycle". The industries transferred from the eastern coastal regions will be further accelerated and the rigid demand for energy will increase year by year. So, there should be a strong dependence on energy in order to enable Jiangxi to achieve rapid growth and the need to face extremely heavy tasks within a short period of time in order to achieve the goal of peak carbon dioxide emissions by 2030 and the goal of carbon neutrality by 2060. In addition, the *14th Five-Year Plan for Ecological and Environmental Protection (Draft for Comment)* emphasizes that sufficient support should be given to some areas if conditions permit, and enable them to achieve the goal of peak carbon dioxide emissions first and the Beijing-Tianjin-Hebei Region, the Yangtze River Delta, Hong Kong, Guangdong and Macao, the National Ecological Civilization Pilot Zone, and relevant eco-friendly provinces should all stand at the forefront of peak carbon dioxide emissions. If Jiangxi Province wants to reach the goal as stipulated in the draft plan, the remaining time for the province will be less than 5 years, which means the province will face more severe challenges.

Limited space for CO_2 emission increment

According to the 7 percent GDP growth plan for Jiangxi Province during the 14th Five-Year Plan period and the 19 percent binding index for the reduction of carbon emission intensity, Jiangxi Province should control the increase in CO_2 emissions within the range of 2,700 t in the next 5 years. As seen from the special report issued by the Jiangxi Provincial Development and Reform Commission in November 2020, there will be 79 projects to be put into production in the first 3 years of this period, and the energy consumption to reach production capacity will exceed 50,000 tce. The new energy consumption will be about 18 million tce, and the calculated CO_2 emissions about 47.88 million t. During the same period, the CO_2 emissions in Jiangxi Province will tend to gradually increase, forming an extreme contradiction with the constraints of carbon emission intensity.

Difficulty in energy consumption structure adjustment

The need to improve national competitiveness and implement climate and energy strategies means that an energy-consuming country like China must rapidly enhance its green energy efficiency (GEE) and energy consumption structure (Ma and Co et al., 2022). Jiangxi Province must strictly control the consumption of coal and increase the utilization rate of new energy and the proportion of non-fossil energy if it wants to achieve the goal of carbon neutrality. However, this province features a relatively high external dependence due to its shortage of primary energy and insufficient energy supply. This is shown in the 90 percent external dependence for coal and 100 percent external dependence for oil and natural gas. The province mainly consumes traditional fossil energy such as oil and coal, resulting in a still high annual coal consumption percentage. According to statistics, the figure remained higher than the national average in 2019. The development of water resources, which has reached the upper limit, and the wind energy and solar energy resources, which development is lower than the national average, reflect the urgency of this province to adjust the energy consumption structure. Despite the abundant biomass reserves of the province, the available scale of biomass here is small and the province faces an unclear nuclear power construction situation, making it uncertain to achieve its goal of carbon neutrality. It is still difficult to fundamentally improve the energy supply situation and energy consumption structure within the short term if the province relies on the adjustment of its own energy structure only.

The urgent need of industrial institutions for low-carbon transformation

Peak carbon dioxide emissions represent the entry of the local economy into a period of high-quality development. Beijing is now the city that is closest to the goal of peak carbon dioxide emissions in China. In 2019, the ratio of the city's primary to secondary to tertiary industries was 0.3:16.2:83.5. It was found that the share of the secondary industry in Jiangxi was almost 30 percent higher than that in Beijing but the share of the tertiary industry in Jiangxi was 36 percent lower than that in Beijing. So, Jiangxi remains to have a large space for improvement compared with Beijing in terms of the structure of the three industries. Industrial output is one of the sources of CO_2 emission. The proportion of CO_2 emissions in the industrial output of Jiangxi Province was as high as 81%. Currently, in terms of industrial structure, Jiangxi shows a very high proportion in the industrial structure and a relatively high proportion of energy consumption within the industry. In 2019, the energy consumption of the six segments with the highest energy consumption accounted for 87 percent and their added value was nearly 38.8 percent of the industry. Compared with the average industrial development, the proportion of added energy consumption in segments with high energy consumption was more than doubled. Jiangxi invests too much in industries with high energy consumption when pursuing economic growth, with a low energy utilization rate, though. So, Jiangxi needs to face great pressure to improve industrial energy efficiency when achieving the goal of peak carbon dioxide emissions.

Large difficulty in achieving Carbon neutrality

Jiangxi Province has a forest coverage rate of 63.1 percent, ranking second in China. However, it is still low in total carbon sinks. According to the results of the *2010 Report on the Greenhouse Gas List of Jiangxi Province*, the total carbon sinks of the province were approximately 22 million tons, accounting for 14 percent of the total carbon dioxide emissions. Excluding the existing garden land, arable land and urban and rural buildings in the province, there is very limited space for carbon sink growth. It is unrealistic for Jiangxi to achieve the goal of carbon neutrality by relying on the province's forest carbon sinks only. As of 2019, among the 3,782 kW of total installed capacity of electricity in Jiangxi Province, the installed capacity of thermal power reached 22.05 million kW and that of wind power and photovoltaic power even did not reach 10 million kW. Plus the limited total area of unused land, it will be still difficult to adopt centralized new energy in the future local economic development of Jiangxi Province. Distributed wind power and distributed photovoltaic power can also increase the installed capacity of new energy in the province to a certain extent. However, it is also unrealistic for the province to achieve the goal of carbon neutrality only by relying on new energy. During the 14th Five-Year Plan Period, Jiangxi Province still has the 7.32 million kW coal-fired units to be built. This installed capacity plan will further add the overall difficulty in achieving the dual carbon goals in the future.

Practice for realizing the dual Carbon goals in Jiangxi province

Accelerating industrial restructuring and upgrading

In order to promote the upgrading and restructuring of the energy industry structure in Jiangxi Province, it is necessary to optionally eliminate and resolve backward and excess types, optimize stock capacity, and strictly control industries with high energy consumption. The province should focus on competitive new energy industries, such as aviation, new materials, electronic information and technology, energy conservation and environmental protection, equipment guidance, etc. And implement the "2 + 6+N" industry high-quality leap-forward development action. Jiangxi should adjust its product structure plan, continue to improve production technology, implement the long-term industrial chain system, and strengthen and supplement the industrial chain to increase the added value of the industry. The province should develop towards the modern service industry, shift its development direction from production service to high-end value chain, ensure diversified and high-quality upgrading and development of life services, promote the further integration of advanced manufacturing industry and modern service industry, increase the share of the service industry in the tertiary industry of the province, and advance the deep integration of digital industrialization and the real economy.

Making every effort to build a green, low-carbon energy system

The total energy consumption should be strictly controlled in order to promote the transformation and development of the low-carbon energy structure in Jiangxi Province. The "dual-control" system may be implemented for coal consumption projects and strict examination and approval regulations may be formulated. In particular, for new coal-fired power plant projects, it is stipulated that low-efficiency coal-fired power units below 600,000 kW may not be put into production, thereby effectively reducing the proportion of coal consumption. It is necessary to push the transformation and upgrading of the existing power plant units, promote energy-saving and innovative production technologies, shorten the gap from the international advanced production technology, and reduce coal consumption for power supply. The "coal-to-gas conversion, coal-to-electricity conversion" projects should be carried out to increase the utilization of residual pressure and residual heat and the construction of clean energy, such as solar, hydro, wind, biomass, etc. The application of "PV+" power generation innovation technology should be explored so that wind power and energy storage can be combined with photovoltaic power generation. With reference to China's overall strategic deployment plan for peak carbon dioxide emissions and carbon neutrality, Jiangxi will start in good time the construction of the Jiujiang Pengze Nuclear Power Project in Jiangxi Province. By 2030, the proportion of primary energy consumption in non-fossil energy consumption will account for about 25 percent.

Continuing to improve the utilization rate of energy resources

Jiangxi Province should accelerate the upgrading and transformation of low-carbon technologies in traditional industries such as cement, steel and chemistry in Jiangxi Province, improve production technologies and management, and promote the development of industries with high emissions and high energy consumption, such as cement, steel, petrochemical and non-ferrous industries so as to achieve the goal of peak carbon dioxide emissions early by 2025. Energy-saving technologies should be promoted in Jiangxi Province and the promotion and application of energy-saving technologies in the industry should be expanded to improve the overall energy efficiency. The province should implement a strict energy consumption access system and conduct energy conservation assessment and carbon emission assessment of fixed asset investments, striving to control carbon dioxide emissions from the source and the total CO_2 emissions. Jiangxi should also establish strict energy consumption standards and carbon emission systems, striving to achieve energy conservation and emission reduction in an all-round way and improve the low-carbon level of regional enterprises. Additionally, it is also necessary for the province to develop a green circular economy, promote the application of new energy technologies and utilize resources that can be recycled for the production of waste gas materials. The industrial sector can adoptsthe Best Available Technologies (BAT) by the International Energy Agency (IEA) tosave energy and reduce carbon emissions. (Lu and Zhu., 2013).In this way, the application of products with high conversion rates will be promoted and industrial restructuring and upgrading will be promoted in the province through the construction of technologically advanced new energy projects.

Establishing an energy policy framework for peak Carbon dioxide emissions and Carbon neutrality in Jiangxi province

1) Identifying government functions. Peak carbon dioxide emissions and carbon neutrality fall within the scope of the strategic goal of addressing global warming concerns and are closely related to all aspects of national social and economic development. The implementation of the carbon emission reduction target is bound by international conventions and involves many issues such as international integration, international negotiation, and the implementation of conventions, carbon emission reduction and control of other greenhouse gases. In order to cope with climate change and achieve the strategic goals of peak carbon dioxide emissions and carbon neutrality, it is necessary to systematically change the original policy framework for responding to climate change, which is different from the previous work on climate change. So, the focus of the reform is to give full play to the role of the government in macro planning. The government occupies a pioneering, priority and dominant position in the low-carbon transformation and development of society. Thus, the specific functions of government departments and agencies in achieving the goals of peak carbon dioxide emissions and carbon neutrality should be regarded as the core of the reform.

First of all, targeted adjustments should be made in light of the functions of governments in Jiangxi Province and they are to adjust the economic structure in essence. It is necessary to adjust the economic structure before the leading role of relevant government departments and agencies is played. During the process of realizing its dual carbon goals, Jiangxi should adjust its original energy conservation and emission reduction related systems and the functions of its government departments, form a correct awareness of the importance of the rule of law, strictly implement each legal regulation, and govern the country strictly for realizing strategic goals. Secondly, it is of particular importance to issue laws and regulations for achieving the dual carbon goals and addressing climate change. Nevertheless, legal regulations are based on legal systems only. So, the overall framework for the government's governance work should be clearly identified to improve the legal systems and guarantee the smooth implementation of each legal system. Otherwise, even if legal systems are promulgated, it is impossible for them to be implemented in the governance practice of the governments of Jiangxi. So, it is especially necessary to identify the specific functions of the government departments in achieving the dual carbon goals.

2) Strengthening top-level policy design. It is suggested that Jiangxi should issue top-level policy documents and regard high-level work deployment as the guide to achieving the dual carbon goals so as to fully reflect the important guiding role of this province in addressing climate change. In the top-level policy documents, the guiding work needs to include: overall work requirements, work ideas, implementing principles and ultimate objectives for achieving the dual carbon goals; the bottom principle lines that cannot be touched in practice; adjusting the economic structure of industries in Jiangxi Province, with a focus on the low-carbon transformation of industrial structures for energy, industry and transportation; vigorously developing

TABLE 4 High-quality new energy development evaluation indicator system.

Primary indicator	Secondary indictor	Content
High-quality new energy development	Development	New energy penetration rate, proportions of electricity and electric quality in power generation
	Utilization	Capacity factor, utilization rate of new energy power generation, weight of consumption responsibility
	Operation safety	New energy power penetration rate, electric quantity regulation index, peak factor
	Policy mechanism	Current policy improvement index, participation in new energy power plant construction
	Technical affordability	New energy power generation index

new business formats, and adjusting the consumption structure; and the responsibility of the central government and local governments of Jiangxi as main participants to establish the work system and policy guarantee for achieving the dual carbon goals. It can be understood that in the governance work, the governments of Jiangxi Province should supplement the deficiencies for achieving the dual carbon goals, adjust unreasonable systems and mechanisms and identify the guiding thought for coping with climate change. For Jiangxi, whether to achieve the short-term peak carbon dioxide emissions goal or to achieve the long-term carbon neutrality goal, it is necessary to guarantee the linkage between the two goals and adopt a combination of a tough battle and a protracted battle. The tasks should be implemented steadily rather than being accomplished in one stroke.

3) Improving the indicator system. Jiangxi should establish a multi-level indicator system on the path to achieving the dual carbon goals. In the contents of the system, some are binding and some are instructive. First of all, it is necessary to further understand and correlate the indicators related to peak carbon dioxide emissions and carbon neutrality given in international conventions and classify these indicators into target, measures and guarantee indicators. Secondly, it is necessary to further refine related indicators in international conventions. NDC is subject to certain constraints in the formulation of indicators due to the different conditions of all localities. In this way, the guiding role of indicators in international conventions can be played. In combination with the actual conditions of Jiangxi Province, the existing indicators for energy conservation and emission reduction measures should be analyzed and studied. On top of that, new indicators should be formulated to replace the original replaceable indicators or integrate and establish a new indicator system. However, when improving the system for peak carbon dioxide emissions and carbon neutrality, Jiangxi should avoid the transitional correlation of individual indicators so as to effectively reduce the utilization costs. Take the high-quality new energy development evaluation indicator as an example. There is no need to give priority to measuring the utilization rate of power generation; instead, it is necessary to establish a comprehensive evaluation indicator system (see Table 4). According to the table below, the high-quality development of new energy in this province can be refined into multi-dimensional evaluation to help new energy develop in a sustainable and sound way. This indicator represents a comprehensive consideration of the progress of Jiangxi's realization of the dual carbon goals by 2025, 2030, 2035, 2050 and 2060, with a focus on 5-year and 10-year goals. That is because it is necessary to ensure the formulation of various indicators has the actual conditions as the basis with the progress of social development. Besides, the formulation of international conventions should also keep pace with the times. In particular, long-term goals should not be excessively detailed.

4) Scientifically calculating emissions. It is necessary to scientifically calculate the CO_2 emissions, take into account and calculate the CO_2 emissions of countries, regions, industries and enterprises, whether the peak and neutrality have been reached, and whether to calculate man-caused emissions and removals so as to complete the calculation of the net value of CO_2 emissions. Due to the difference between direct CO_2 emission and indirect emission, it is necessary to guarantee the scientificness and authority of the method used when calculating CO_2 emissions. Care must be taken to avoid omissions or duplication of calculation. Additionally, attention should be paid to whether there will be a "punitive" default value due to insufficient parameters related to the actual measurement of CO_2 emissions during the calculation process, which would affect the accuracy of the calculation results due to human factors. It is necessary to strictly refer to the calculation requirements proposed in the Paris Agreement, such as transparency, integrity, consistency and accuracy, when calculating CO_2 in Jiangxi Province.

5) Building a low-carbon transportation system. Buses should be given priority to when promoting the low-carbon construction of public transportation infrastructure in Jiangxi Province. Urban walking and cycling transportation systems may be established to increase the sharing rate of travel. A green travel system of "public transport + cycling/walking" may be listed as a priority for improvement. The CO_2 emissions from locomotive fuels should be effectively controlled. Clean power vehicles should be fully popularized in Jiangxi Province. A new energy vehicle development policy system should be built and the promotion and implementation of this policy system should be expanded. Great efforts should be made to build fast charging piles and centralized charging piles. Intelligent transportation

should also be developed to improve the management of modern transportation services in Jiangxi Province and further optimize and improve the existing transportation network. The proportions of water transportation and railway transportation may be increased. The publicity and promotion of green, low-carbon travel should be expanded. Local residents of Jiangxi should be encouraged to adopt low-carbon travel and reduce CO_2 emissions from the source.

6) Selecting the optimal path for peak carbon dioxide emissions and carbon neutrality. When the pressure that Jiangxi Province can face for achieving the dual carbon goals is considered only, the sooner the goal of peak carbon dioxide emissions is reached and the lower the peak is, the faster the decline will reach. Accordingly, the pressure to realize the goal of carbon neutrality will be lowered. So, the optimal path to achieving the goal of carbon neutrality is to find the optimal path by considering multiple factors. Technological innovation represents a decisive factor for identifying such an optional path. The continuous innovation of science and technology has been followed by reduced energy transformation costs. Technological transformation will affect the trend of carbon prices to a large extent. On the one hand, prices will rise due to the requirements for an increase in emission reduction but drop under the impact of carbon emission reduction technologies. So, prices will tend to fluctuate dynamically. Full integration of upstream and downstream industrial chains in Jiangxi Province should be made by encouraging further linkage among new energy manufacturers and realizing. Also, industry alliances should be established to help create a highland for the new energy industry. It is necessary to strengthen cooperation, establish a supporting cooperation model, increase the proportion of applications for new energy technologies, and successfully build a new energy system.

Conclusion

In conclusion, making steps in peak carbon dioxide emissions and carbon neutrality in the new era is one of the important tasks of Jiangxi Province at present and in the future and also the main driver for vigorously lifting the economic level of the province and realizing the high-quality transformation of its society during the 14th Five-Year Plan Period. When realizing the strategic dual carbon goals, it is necessary to realize that this is a project with a long timeline and involves various aspects of social development. The overall layout of the concept of ecological civilization should be clarified under the guidance of the overall national strategic goal. It is essential to deploy the actions towards the goal of peak carbon dioxide emissions, properly formulate the ideas for achieving the dual carbon goals, accelerate industrial transformation and upgrading, make every effort to build a green, low-carbon energy system, continue to improve the utilization rate of energy resources and solve the challenges against the achievement of the dual carbon goals. The challenges include a tight schedule for achieving the goal of peak carbon dioxide emissions, limited CO_2 emissions increment space, difficulty in adjusting the energy consumption structure, urgent need for low-carbon transformation of industrial institutions and large difficulty in carbon neutrality. Also, it is necessary to establish an energy policy framework that applies to Jiangxi, identify government functions, strengthen top-level policy design, improve the indicator system, scientifically calculate emissions and jointly promote the province to achieve the dual carbon goals. The method path proposed in the Paper is a rough framework, and further refinement of rules is needed for the execution and implementation of policies. Future research direction of the Paper is to explore how to satisfy the overall completeness and mutual exclusion between individuals, further refine relevant policies and put specific policies into practice, verify the feasibility of views. However, this can be addressed by the future research, and can thus be taken as the limitation of this study.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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