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Research On Target And Path Planning Of Regional Carbon Peaking And Carbon Neutrality

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ABSTRACT

To achieve peak carbon neutrality is a broad and profound economic and social systemic change. At present, the economic and social development of our country has entered the stage of accelerating green and low-carbon high-quality development. In this paper, under no less than three scenarios, the regional dual carbon target is associated with the time node of carbon peak and carbon neutrality, and is associated with the improvement of energy efficiency and the increase of the proportion of non-fossil energy consumption. In various scenarios, if the GDP in 2035 doubles over the base period and quadruples in 2060, the method of calculating carbon emissions is found. If the carbon absorption amount of ecological carbon sink in 2060 is 10% of the carbon emissions of the base period, the calculation method of carbon emissions at this time is found; To find the targets and paths that can determine the GDP, population, energy consumption, energy efficiency and non-fossil energy consumption in 2025, 2030, 2035, 2050 and 2060, and finally complete the qualitative and quantitative analysis of the four major projects.

KEYWORDS

Carbon peaking carbon neutrality; Carbon emissions; Qualitative and quantitative analysis

1. INTRODUCTION

In the context of global climate change, the goal of carbon peaking and carbon neutrality has become a major challenge for China and even the whole world. With the continuous development of economy and the continuous growth of energy demand, how to effectively promote carbon emission reduction, optimize the energy structure, and promote green and low-carbon development has become an important issue in front of us.

In recent years, many scholars have conducted in-depth studies on the "dual carbon" goal, exploring the path to enhance carbon emission reduction effect and regional green and low-carbon development strategies. Based on the fsQCA method, Zhang Jiangang and other scholars conducted a study on the configuration effect of the enhancement path of carbon emission reduction effect, providing a scientific basis for policy formulation. Yin Taotao et al. took the Chengdu-Chongqing dual-city economic circle as an example to discuss the territorial spatial planning path and governance mechanism of urban agglomerations, providing new ideas for regional coordinated development. In addition, Sheng Yanchao et al. focused on urban energy development planning and proposed an energy development strategy based on the "dual carbon" goal. Zhou Maochun et al. took Liaoning Province as an example to study the path of regional green and low-carbon development.

In this paper, economic development, population and social factors, non-fossil energy supply, and industrial structure upgrading are selected as key indicators as variables, and combined with carbon emissions. According to different conditions, we set three different constraints and construct the objective function. We then used the ant colony algorithm to accurately calculate carbon emissions in the three scenarios. Through the in-depth analysis of these data, we have come to the goal and path to achieve carbon peak and carbon neutrality. Finally, we conduct in-depth quantitative and qualitative analysis of energy efficiency improvements, industry and product upgrades, energy decarbonization, and energy consumption electrification.

2. REGIONAL DUAL OBJECTIVE PROGRAMMING MODEL

In at least three different contexts, there is a need to explore how regional dual-carbon targets are related to the timing of carbon peaking and carbon neutrality, taking into account the impact of energy efficiency improvements and the increasing share of non-fossil energy consumption. Under different scenarios, if GDP doubles relative to the base period in 2035 and doubles again in 2060, we need to determine how to calculate carbon emissions at this time. At the same time, under the assumption that the carbon absorption of ecological carbon sinks in 2060 reaches 10% of the carbon emissions of the base period, it is necessary to explore the calculation method of carbon emissions at this time. In addition, it is necessary to establish targets and paths for GDP, population and energy consumption in 2025, 2030, 2035, 2050 and 2060, while considering how to improve energy efficiency and the share of non-fossil energy consumption.

2.1. Problem Assumptions

Suppose 1: GDP doubles over the base period (2020) in 2015; By 2060, the base period is quadrupled;

Suppose 2: The carbon absorption of ecological carbon sinks in 1960 is 10% of the carbon emissions in the base period;

Suppose 3: The amount of carbon absorbed by the carbon sink or carbon trading of the project in 1960 is 10% of the carbon emission in the base period.

2.2. Mathematical Model

The following mathematical models are established for three scenarios: natural scenario without human intervention, benchmark scenario of carbon peak on time and carbon neutral, and ambitious scenario of carbon peak and carbon neutral first.

(1) Natural scenarios without human intervention

The objective functions (1-1) and (1-2) are shown as follows:

$$\min C_{peak}(t) \tag{1-1}$$

$$\min C_{peak}(t) \tag{1-2}$$

The constraints for this scenario are shown in formula (1-3):

$$\begin{cases} Pgdp(2035) \geq 2 \times Pgdp(2020) \\ Pgdp(2060) \geq 4 \times Pgdp(2020) \\ NUM(t) \geq 0,\ Pgdp(t) \geq 0,\ EN(t) \geq 0,\ W_1(t) \geq 0,\ W_2(t) \geq 0,\ W_3(t) \geq 0 \end{cases} \tag{1-3}$$

(2) Baseline scenario of carbon peak and carbon neutrality on time

Objective functions (1-4) and (1-5) are shown as follows:

$$\min C_{peak}(t) \tag{1-4}$$

$$\min C_{peak}(t) \tag{1-5}$$

The constraints for this scenario are shown in equation (1-6):

$$\begin{cases} Pgdp(2035) \geq 2 \times Pgdp(2020) \\ Pgdp(2060) \geq 4 \times Pgdp(2020) \\ E(2060) \leq E(2020) \times 10\% \\ NUM(t) \geq 0,\ Pgdp(t) \geq 0,\ EN(t) \geq 0,\ W_1(t) \geq 0,\ W_2(t) \geq 0,\ W_3(t) \geq 0 \end{cases} \tag{1-6}$$

(3) Take the lead in ambitious scenarios of carbon peak and carbon neutrality

Objective functions (1-7) and (1-8) are shown as follows:

$$\min C_{peak}(t) \tag{1-7}$$

$$\min C_{peak}(t) \tag{1-8}$$

The constraints for this scenario are shown in equation (1-9):

$$\begin{cases} Pgdp(2035) \geq 2 \times Pgdp(2020) \\ Pgdp(2060) \geq 4 \times Pgdp(2020) \\ E(2060) \leq E(2020) \times 10\% \\ Z(2060) \leq Z(2020) \times 10\% \\ D(2060) \leq D(2020) \times 10\% \\ NUM(t) \geq 0,\ Pgdp(t) \geq 0,\ EN(t) \geq 0,\ W_1(t) \geq 0,\ W_2(t) \geq 0,\ W_3(t) \geq 0 \end{cases} \tag{1-9}$$

(4) Dual-objective programming model modeling under multiple scenarios

The two objective functions are shown in equations (1-10) and (1-11):

$$\min C_{peak}(t) \tag{1-10}$$

$$\min C_{peak}(t) \tag{1-11}$$

The constraints are as follows:

$$Pgdp(2035) \geq 2 \times Pgdp(2020)$$

$$Pgdp(2060) \geq 4 \times Pgdp(2020)$$

Decision variables:

$$NUM(t) \geq 0,\ Pgdp(t) \geq 0,\ EN(t) \geq 0,\ W_1(t) \geq 0,\ W_2(t) \geq 0,\ W_3(t) \geq 0$$

Among them:

$$C_{peak}(t) = \rho \cdot \sum_{j=1}^{4} C_j(t) \tag{1-12}$$

$$C_{neutral}(t) = \rho \cdot \sum_{j=1}^{4} C_j(t) \tag{1-13}$$

$$C_1(t) = NUM(t) \cdot \varepsilon \tag{1-14}$$

$$C_2(t) = Pgdp(t) \cdot Cgdp(t) \tag{1-15}$$

$$C_3(t) = EN(t) \cdot Z(t) \cdot D(t) \tag{1-16}$$

$$C_4(t) = [W_1(t) \cdot F_1(t) + W_2(t) \cdot F_2(t) + W_3(t) \cdot F_3(t)] / (1-\varepsilon) \tag{1-17}$$

Formula (1-14) represents the carbon emissions generated by the number of population. According to the kaya model, total carbon emissions = population * carbon emission factor; Formula (1-15) represents the carbon emissions generated by per capita GDP, total carbon emissions = per capita GDP* carbon emission factor; Formula (1-16) represents the carbon emissions generated by non-fossil energy consumption, and formula (1-17) represents the carbon emissions generated by the added value of the three major industries. Energy consumption per unit of GDP = (weight of value added of primary industry) * Energy consumption per unit of value added of primary industry + weight of value added of second generation * Increased consumption per unit of secondary industry + weight of value added of tertiary industry * Energy consumption per unit of value added of tertiary industry)/(1- proportion of household energy consumption).

The above model takes the period of carbon peak and carbon neutrality as the target, and takes into account the core factors such as economic development, population and social factors, non-fossil energy supply, and industrial structure upgrading.

3. ALGORITHM MODEL

Ant Colony Optimization (ACO), first proposed by M. Dorigo, draws on the behavior characteristics of ants during the foraging process to form a bionic evolutionary algorithm that iteratively solves complex combinatorial optimization problems (especially discrete optimization problems) through continuous search. In essence, it is a heuristic global optimization algorithm. The ant search path diagram is shown in Figure 1.

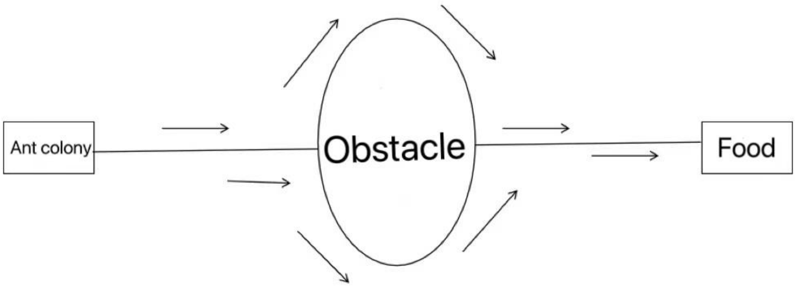

Figure 1. The process of ants finding their way

The main solving steps and processes of ant colony algorithm are shown in Figure 2

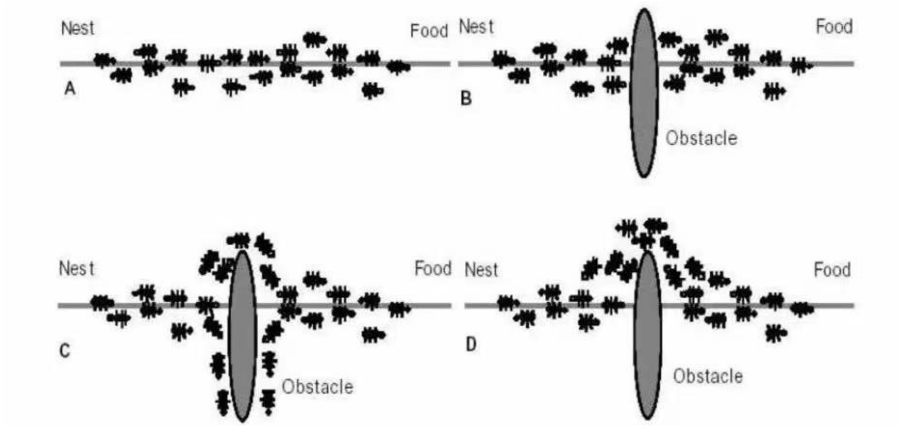

Figure 2. Ant colony algorithm flow chart

Step 1 Initialization

- Set the number of ants
- Initialize the pheromone matrix
- Initialize the path for each ant

Step 2 Construct Paths

- For each ant:
- Move from one node to another based on pheromone levels and heuristic information
- Update the ant's path

Step 3 Evaluate Paths

- Calculate the cost (or quality) of each ant's path

Step 4 Update Pheromones

- Evaporate pheromone from all paths
- Deposit pheromone on the best paths
- Optionally, apply local pheromone update rules

Step 5 Termination Criterion

- Check if the termination condition is met (e.g., maximum iterations, no improvement for a certain number of iterations)

Step 6 Output Result

- Output the best path found

4. DOUBLE CARBON TARGET RESULTS

Using historical data and trends in economic growth, population growth, and energy consumption, various economic and statistical models can be used to predict future GDP, population, and energy consumption. By forecasting the target values of GDP, population and energy consumption in 2025, 2030, 2035, 2050 and 2060, the target and path of carbon peaking and carbon neutrality are further identified. Forecast future data based on past trends in economic growth, population growth, and energy consumption. By analyzing past data, long-term and short-term trends can be identified, which helps build models. The relationship among GDP, population and energy consumption is shown in Table 1, and the forecast trend chart is shown in Figure 3.

Table 1. Projected GDP, population, and energy consumption

	GDP	Population	Energy consumption
2025	115004.30	82694551.36	34689.48
2030	139544.45	84796623.38	38799.98
2035	164084.59	85934956.56	42910.48
2050	237705.03	94482530.65	55241.99
2060	286785.31	101241135.72	63463.00

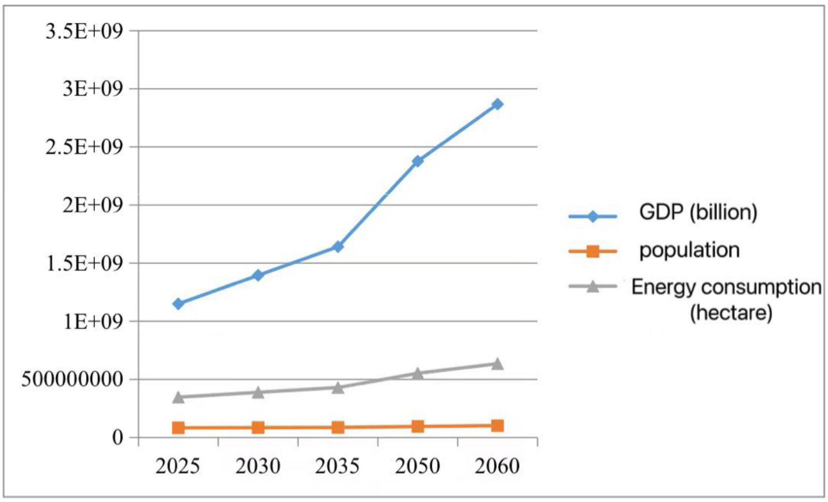

Figure 3. Forecast trend chart

5. DATA ANALYSIS AND CONCLUSION

5.1. Quantitative Analysis

To understand the evolution of energy consumption over the years and its potential impact, we need to do a quantitative analysis and present it in a chart to show the data more clearly, as shown in Figure 4. This chart will clearly show the trend of projected carbon emissions. By comparing the data from one year to the next, it can be seen whether consumption has changed dramatically or increased gradually. So we can judge whether the demand for energy is growing steadily.

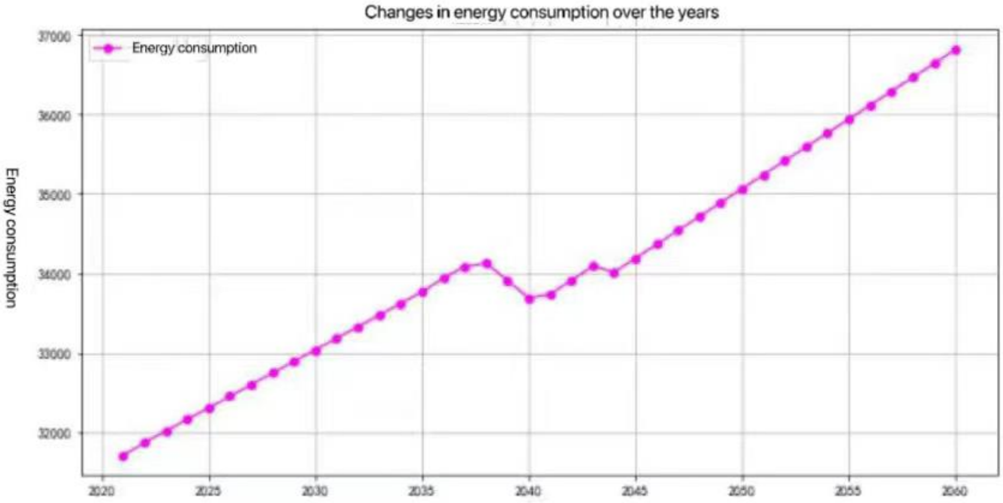

Figure 4. Changes In Energy Consumption

To understand the relationship between energy consumption and carbon emissions, we need to conduct a quantitative analysis. The relationship between energy consumption and carbon emissions is shown in Figure 5, in which we can see how energy consumption directly leads to changes in carbon emissions. By analyzing the data of energy consumption and carbon emissions over many years, we can determine the trend and correlation between them. This can see if there is a strong positive correlation, that is, whether an increase in energy consumption leads to an increase in carbon emissions. By comparing data at different points in time, we can understand whether energy consumption is increasing or decreasing, as well as its growth rate and changing trend.

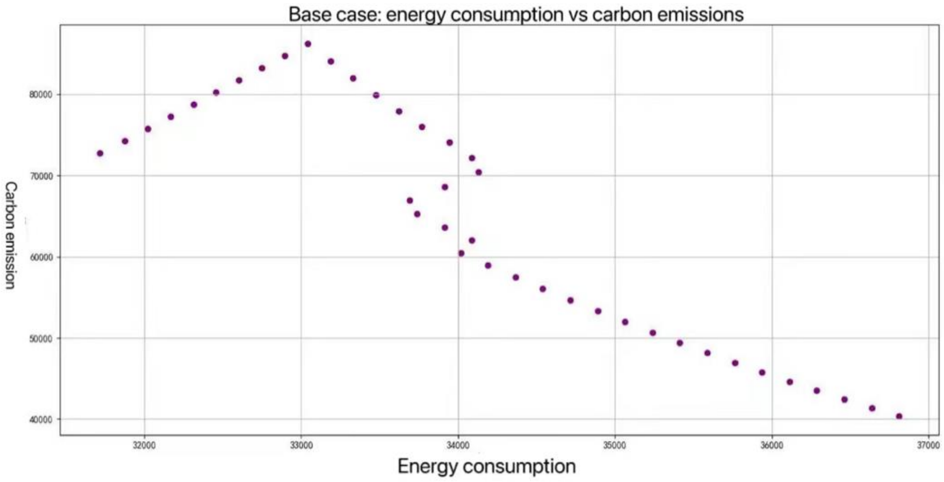

Figure 5. Relationship Between Energy Consumption And Carbon Emissions

The Energy efficiency Improvement Index (EEI) in the biobjective function is usually associated with energy efficiency improvement. When energy efficiency is improved, it means less carbon emissions per unit of energy consumed. This is because greater energy efficiency means less exhaust gas and waste generated during production and energy use, thereby reducing carbon emissions.

Therefore, if the Energy efficiency Improvement index (EEI) is added to the biobjective function, carbon emissions can be expected to decrease. This reduction could have a positive impact in terms of carbon peaking and carbon neutrality, as greater energy efficiency can help lower energy-related carbon emissions and advance both goals. Overall, improving energy efficiency is one of the key strategies for achieving carbon reduction targets.

Industrial upgrading usually involves the adoption of more advanced and environmentally friendly production technologies and methods to improve production efficiency and reduce resource consumption. This upgrade can have a multifaceted impact on carbon emissions, depending on the specific measures implemented and the nature of the industry. Here are some possible scenarios:

(1) Carbon emission reduction: Industrial upgrading may lead to a reduction in carbon emissions. For example, more efficient production processes and the adoption of clean energy can reduce energy consumption and greenhouse gas emissions. In addition, using fewer resources, such as raw materials and energy, can also reduce carbon emissions.

(2) Increased carbon emissions: In some cases, industrial upgrading may lead to an increase in carbon emissions in the short term. This may be because new production technologies require more energy or resources, or because the industrial upgrading phase requires large-scale construction projects that may release carbon.

(3) Unchanged carbon emissions: In other cases, industrial upgrading may have a relatively small impact on carbon emissions, especially if the upgrading is mainly focused on improving production efficiency rather than reducing carbon emissions.

Therefore, the impact of industrial upgrading on carbon emissions depends on a number of factors, including the nature of the upgrading, the measures implemented, and whether it is accompanied by energy efficiency improvements, clean energy adoption, and carbon emission management measures. In order to more accurately understand the changes in carbon emissions after industrial upgrading, each industry and scenario needs to be analyzed specifically, taking into account sustainability and environmental goals. In most cases, rational industrial upgrading should be aimed at reducing carbon emissions to promote sustainable development and combat climate change.

5.2. Qualitative Analysis

Policy plays an important role in improving energy efficiency, carbon emissions, industrial upgrading, energy decarbonization, and energy consumption electrification. The following is a qualitative analysis of these aspects, exploring how policy affects them:

(1) Energy efficiency: Policies can encourage businesses and individuals to adopt more energy-efficient practices. For example, governments could issue regulations requiring the building industry to adopt energy efficiency standards, encourage automakers to produce more fuel-efficient vehicles, or provide incentive programs to encourage industrial sectors to improve production processes. These policies drive energy efficiency, reduce energy consumption, and reduce energy waste.

(2) Carbon emissions: Policies have great potential to reduce carbon emissions. Policies such as carbon pricing, carbon quota systems, and carbon taxes can force companies to reduce emissions and facilitate the transition to low - and zero-carbon energy sources. In addition, governments can support renewable energy projects, provide subsidies and incentive programs to encourage the adoption of greener technologies and production methods and reduce carbon emissions.

(3) Industrial upgrading: Policies can promote industrial upgrading and make enterprises more competitive and sustainable. This includes policies to train workers to adapt to new technologies, support R&D and innovation, improve infrastructure, and reduce costs for businesses. Governments can also develop industrial policies that focus on supporting the development of key industries in the future, fostering innovation and job growth.

(4) Energy decarbonization: Energy decarbonization is a key goal in addressing climate change. Governments can adopt a range of policies to achieve this, such as providing subsidies to support clean energy projects, setting carbon emission targets, pushing the power sector to switch to green energy, and supporting research and development of carbon capture and storage technologies. Policies can also encourage energy efficiency improvements and reduce reliance on high-carbon energy sources.

Energy consumption electrification: Energy consumption electrification policies aim to make the energy system more intelligent, efficient and renewable. Governments can create policies to encourage the development and adoption of electric vehicles, support the construction of smart grids, and provide incentives for energy storage and distribution. These policies help reduce dependence on fossil fuels, improve the stability of the power system, and promote the use of renewable energy sources.

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