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Study on the Strategic Path of Carbon Peaking in the Building Sector--based case study of Shaanxi, China

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ABSTRACT

China's carbon emissions from the building sector have exceeded 50% of the national total emissions. Energy saving and carbon reduction in the building sector is of great significance to China's "double-carbon" strategy. In this study, the future development of the building sector in Shaanxi Province is divided into a baseline scenario (BAS), a low-carbon peak scenario (LCS), and an enhanced low-carbon scenario (ELS), using static forecasts and Monte Carlo simulations. The results show that the probability of BAS peaking before 2030 is only 19.9%; the peak time of LCS is around 2030, and its probability of peaking before 2030 is 65.05%; and in ELS, the probability of peaking is 2026, and the probability of peaking before 2030 is 99.9%. The peaks of BAS, LCS and ELS are 101.97 million tons, 97.97 million tons and 91.28 million tons, respectively, indicating that the enhanced energy conservation measures and the adjustment of the energy-use structure have an obvious effect on the control of carbon emissions. The results of the thesis provide a reference for the formulation and implementation of energy conservation and emission reduction policies and measures in the building sector, and provide suggestions for the path to carbon peaking in the building sector.

Keywords: building sector, carbon emissions, scenario analysis, Shaanxi Province

NONMENCLATURE

Abbreviations	
BAS	Baseline Scenario
LCS	Low-Carbon Scenario
ELS	Enhanced Low-carbon Scenario
Symbols	
i	Type of energy

1. INTRODUCTION

Energy is a basic resource for the development of human society and productive social life. The massive use of energy, especially fossil energy, has long caused serious environmental problems, and the increase in carbon dioxide emissions in particular has had a significant impact on the global environment. As an important developing country, China has made a solemn commitment to the world to achieve the "dual-carbon" goal, which has been incorporated into the major strategies of national development and has become an indispensable part of the country's vision and sustainable development.

The building sector, an important production sector of the national economy, has huge carbon emissions. The Global Status Report on Buildings and Building 2021 states that building-related energy demand will account for 36% of global energy demand and 37% of energy-related CO_2 emissions in 2020[1]. The China Building Energy Efficiency Association has also pointed out in its report that in 2019, the energy consumption of the whole life cycle of the nation's buildings accounted for as much as 45.8% of the country's total energy consumption [2]. Therefore, the study of "dual-carbon" strategy in the building sector is of great significance and urgent.

The research on the factors affecting carbon emissions mainly includes social, economic and technological factors. Yuan et al constructed a model for calculating carbon emissions from civil buildings according to the statistical method of IPCC, and used the Energy Statistical Yearbook to calculate the total carbon emissions in the field of civil buildings from 2005 to 2016[3]. Lu selected five categories of factors affecting carbon emissions in the building sector. Scenario analysis is widely used in the prediction research of carbon emissions, which describes various scenarios in the future through parameter settings in various models [4]. Xu set up different scenarios based on the degree of difficulty of each type of technology, and set up six pre-set technological paths to arrive at low-carbon development path through the measurement of carbon emissions in different scenarios [5].

This study focusing on the goals and paths of China's "dual-carbon" strategy in the building sector, builds a variety of scenarios for analyzing carbon emissions from the building sector in Shaanxi Province based on basic macro data and policy guidelines. The study estimates the intensity and total amount of carbon emissions from the building sector in Shaanxi Province, predicts the time of the peak of carbon emissions from the building sector and the peak value, which provides data support for the building of key tasks and targets for emission reduction in the building sector.

2. METIRIALS AND METHODS

2.1 Data source

The availability of data is mainly to analyze whether the indicator can be accessed through statistical yearbooks, information, etc., and the year in which the specific data values can be obtained. Or it can be converted through other indicators to obtain the specific value of the time dimension, which is convenient for the quantitative analysis of the subsequent research.

2.2 Accounting boundary and calculation model

From the perspective of the life cycle of a building, its energy consumption and carbon emissions can be divided into the production of building materials, building construction, building operation and maintenance, and building demolition. In this study, taking into account that the energy consumption of building materials belongs to the industry, and the scope covered by the housing and construction industry involves mainly the construction industry, building energy efficiency, urban construction, city management, village and town construction. Therefore, in this study, the construction field is based on the current development of the industry, and the carbon emissions in the construction field covers the construction and operation of new buildings, the renewal and reconstruction of old urban buildings, and the construction of villages and towns, i.e., the two phases of the construction of buildings and the operation of civil buildings related to the industry.

According to the IPCC emission factor inventory calculation method, carbon emissions are equal to the consumption of categorized energy sources multiplied by the corresponding carbon emissions factor. In the subsequent factor analysis study of the research, the integrated carbon emissions factor is an important driving factor, which is calculated by the energy consumption structure and the carbon emissions factor of each type of energy, and the specific calculation formula is shown in Eq.(1):

$$C_E = \sum_{i=1}^{n} \frac{E_i}{E} \times \frac{C_i}{E_i} \qquad (1)$$

where: C_E is integrated carbon emissions factor for energy, $\frac{E_i}{E}$ is the share of the i-th energy consumption in the total consumption, $\frac{C_i}{E_i}$ is carbon emissions factor of the i-th energy source.

2.3 Scenario design and parameter setting

Based on the historical and current development trends of Shaanxi Province's building sector and the standards, policies and technologies adopted for building energy conservation and emission reduction, three scenarios of future changes in Shaanxi Province's carbon emissions from the building sector are set up: BAS, LCS and ELS. Each scenario is based on the implementation of policies related to energy-saving technologies in the building sector, energy-saving renovation technologies for existing buildings, the promotion of green buildings, the promotion of renewable energy, and the magnitude of changes in the indicators of each influencing factor.

2.4 Monte Carlo dynamic prediction

For each of the influencing factors related to carbon emissions, a positive distribution is assumed, where the middle most value is the one with the highest probability value, and the values on both sides show a symmetrical distribution and should cover the minimum and maximum of the range of potential future changes for each variable in the scenario.

3. RESULTS

3.1 Historical status of carbon emissions

Carbon emissions in the field of construction at various stages from 2001 to 2020, the specific emission status is shown in Figure 1.

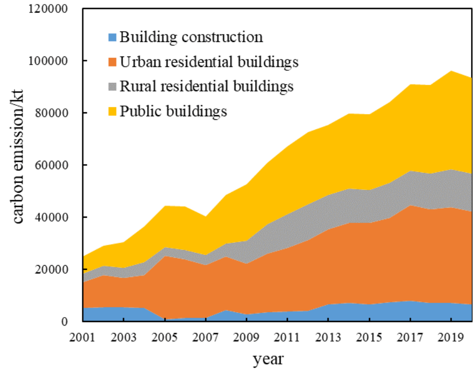

Fig. 1 Carbon emissions from Construction in Shaanxi

It can be seen that the carbon emissions in the construction field is still in the stage of continuous rise, and has not yet appeared the inflection. And the parts of which the operation stage is also in the same period of growth of carbon emissions, has not appeared peak inflection point. Carbon emissions from building construction have shown a downward trend since 2014. Overall, carbon emissions from the building sector rose by 68.32 million tons of carbon emissions value from 2001 to 2020, an increase of 2.75 times. It shows that the building sector still faces great pressure to reduce emissions and needs further control and optimization.

3.2 Static prediction

The year-by-year carbon emissions under the three scenarios, the results are shown in Figure 2.

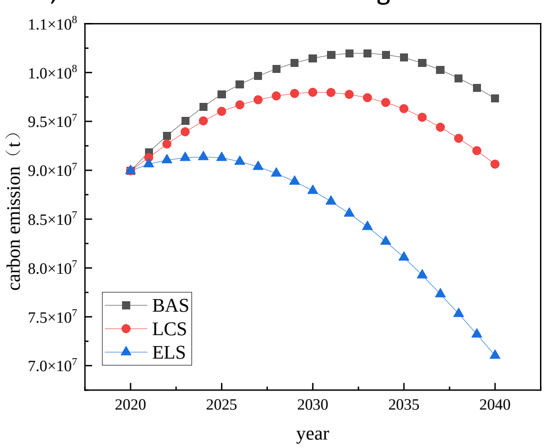

Fig. 2 Static Scenario Analysis Forecast

It can be seen that in BAS, the total carbon emissions show a trend of growth and then decline, and reach the peak of carbon emissions in 2033, with the peak carbon emissions of 101.97 million tons. Compared with BAS, LCS shows a decrease in total carbon emissions, which also shows a trend of growth and then decline, and reaches the peak of total carbon emissions in 2030, with a maximum value of 97.97 million tons of carbon dioxide. The ELS shows a significant reduction in total carbon emissions compared to the previous two scenarios, with the overall trend showing a slight increase followed by a downward trend, and the peak of carbon emissions occurring around 2025, with a maximum value of 91.28 million tons of carbon dioxide.

3.3 Monte Carlo prediction

Based on the stochastic parameter trends of the influencing factors under the static scenario and 100,000 Monte Carlo simulations, the peak carbon emissions from the building sector under each scenario are finally determined.

The peak and year distribution in BAS is shown in Figure 3.

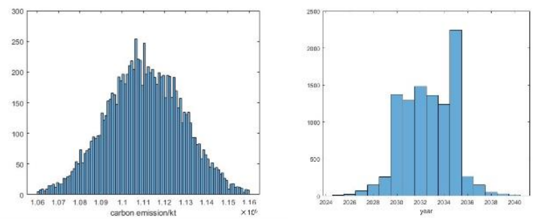

Fig. 3 *Peak and Year Distribution in BAS*

In the dynamic simulation of BAS, the peak distribution of carbon peaks in the building sector in Shaanxi Province and the peak year interval are shown in Figures 3. According to the trend in the figures, the peak value and peak year of carbon peak in the building sector under the baseline scenario show a positive distribution after fitting. In which the peak value of carbon peak attainment is taken in the range of 10594.62-11618.00 million tons, and the average peak value is taken as 111,063,100 tons of carbon dioxide. The peak year of carbon peak is taken in the range of 2025-2040, while the average peak is taken in 2033, and the probability of reaching the peak before 2030 is 19.9%. This suggests that it will be difficult to achieve the peak carbon target between 2030 in BAS.

The peak and year distribution in LCS is shown in Figure 4.

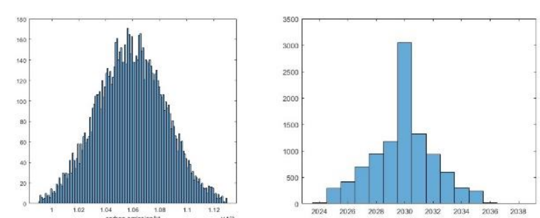

Fig. 4 *Peak and Year Distribution in LCS*

In the dynamic simulation of LCS, the peak value and peak year of carbon peak in the building sector in LCS show a positive distribution after fitting, in which the peak value of carbon peak is taken in the range of 98,725,400 tons to 113,098,000 tons, and the average peak value is 105,902,600 tons of carbon dioxide; and the peak year of carbon peak is taken in the range of 2024-2036. The average peak value is taken in the range of 2030, and the average peak value is taken in 2030, and the average peak value is taken in 2030. 2030, and the probability of reaching the peak before 2030 is 65.05%, indicating that the development according to LCS has a high probability of realizing the carbon peak target between 2030.

The peak and year distribution in ELS is shown in Figure 5.

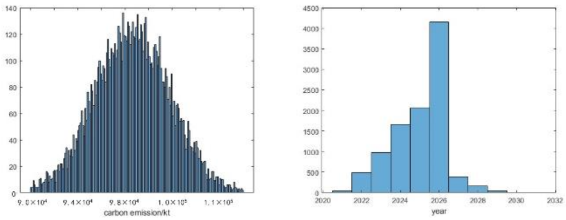

Fig. 5 *Peak and Year Distribution in ELS*

In the dynamic simulation of ELS, the peak value of the carbon peak is taken in the range of 89,575,200 tons to 107,673,300 tons, and the average peak value is taken as 98,621,300 tons of carbon dioxide. The peak year of carbon peak does not show a positive distribution after fitting, but the peak year is taken in the range of 2021-2031, the maximum probability of peak value is taken in 2026, and the probability of peak value before 2030 is 99.9%. This indicates that the development in accordance with ELS can achieve the goal of carbon peaking between 2030.

4. DISCUSSION

4.1 Peaking situation of carbon emissions

If no measures are taken, the carbon emissions in 2030 will be 133.63 million tons based on the energy intensity and carbon emissions factors in 2020, while the carbon emissions in each scenario are expected to be reduced by 32.17 million tons in 2030 in the baseline scenario, 35.66 million tons in the low-carbon peak scenario, and 45.73 million tons in the enhanced scenario.

Shaanxi Province will not be able to achieve the goal of carbon peaking by 2030 if it does not take new emission reduction measures and develops only on the basis of the current inertia trend. Therefore, it is necessary for the government to further strengthen its interventions and take a low-carbon development path, with further optimization of the energy structure and further upgrading of energy-saving technologies to achieve low-carbon peaking. Under this scenario, the energy intensity per unit of completed area needs to be reduced by 50% from 2021 to 2040, the energy intensity per unit of area of urban residential buildings needs to be reduced by 10%, the energy consumption per unit of area of public buildings needs to be reduced by 10%, and the energy consumption per unit of area of rural residential buildings needs to be controlled to increase by 25% or less.

4.2 Sensitivity Analysis

The most significant influence degree of each influencing factor of total carbon emissions are carbon emissions factor of rural residential buildings, public building area per capita, energy consumption per unit area of public buildings, carbon emissions factor of the construction industry, and energy consumption per unit area of urban residential buildings, with sensitivities of -19.10%, 17%, 15.40%, -14.40%, and 10.50%.

This result shows that: urban residential buildings should focus on their energy intensity per unit area when controlling total carbon emissions. Rural residential buildings should pay attention to the energy consumption structure in rural areas and improve the electrification degree when controlling the total carbon emissions. Public buildings should control the per capita public building area and the intensity of energy consumption per unit area when controlling the total carbon emissions, and pay attention to the renovation of existing public buildings as well as improve the requirements and implementation of energy-saving standards. At the building construction stage, it is necessary to pay attention to the carbon emissions factors of the construction industry, reduce the use of coal energy and promote the consumption of green electricity.

4.3 Carbon Reduction Policy Recommendations

According to the results of the carbon peak scenario, in order to realize the goal of carbon peak before 2030 in the building sector in Shaanxi Province, the reasonable path of "double carbon" should be implemented as follows: i) Reasonably control the area scale of the building sector. ii) Emphasize on upgrading the technical energy-saving level of various types of buildings. iii) Reasonably optimize the structure of energy consumption in the building sector.

In addition to focusing on the innovation and promotion of technology, it is also necessary to actively promote the concept of low carbon at the policy level, and to establish and improve the laws, regulations and standard policies related to energy saving and low carbon. It is also necessary to actively build a system for collecting and analyzing data on energy consumption and carbon emissions, so as to build a low-carbon development path for the construction field in Shaanxi Province in a multifaceted and coordinated manner.

5. CONCLUSIONS

This study takes the building sector in Shaanxi Province as the main body of research, with the goal of rationally planning future emission reduction paths. The study focuses on carbon emissions data from 2001 to 2020, presetting future scenarios, identifying three types of possible technology development modes, accounting for emission reductions according to type as well as giving macro-level recommendations for reaching the peak. The main research conclusions are as follows:

(1) Carbon emissions from the building sector in Shaanxi Province will be 93.19 million tons in 2020, and the total amount will rise by 68.32 million tons in 20 years. The building sector still faces great pressure to reduce emissions and needs further control and optimization.

(2) The results of static analysis show that in BAS, LCS, and ELS, the building sector in Shaanxi Province will reach its peak in 2033, 2030, and 2025, and the peaks of carbon emissions will be 101.97 million tons, 97.97 million tons, and 91.28 million tons. The Monte Carlo simulation results show that the peak value of BAS is mainly in the range of 105,946,200-116,180,000 tons, and the value of the peak year is taken in the range of 2025-2040. The peak value of LCS is in the range of 98,725,400-113,098,000 tons, and the peak year is in the interval of 2024-2036, and the probability of peaking before 2030 is 65.05%. And the peak value of ELS takes the range of 89,575,200-107,673,000 tons, and the interval of the peak year is in 2021-2031, and the probability of reaching the peak before 2030 is 99.9%.

(3) The implementation of the technical special work of energy conservation and emission reduction in Shaanxi Province is carried out from controlling the area scale of the building field, upgrading the level of technical energy conservation of all kinds of buildings and optimizing the structure of energy use in the building field. The government should also pay attention to guiding the whole society to cultivate low-carbon concepts, improve the construction of laws and regulations and policy systems, build a shared data platform for building carbon emissions, and strongly support technological innovation and breakthroughs.

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