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LEAP Model-Based Carbon Emission Peak Projections for Zhanjiang City

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Abstract: As society develops, the quality of life improves, but at the same time the rate of consumption of all types of energy increases. As the highest energy consumer, the transport sector brings great convenience to people's lives, but it also consumes a great deal of energy and emits large amounts of carbon dioxide and pollutants. As a result, the global greenhouse effect is increasing and human activities are being restricted, reducing greenhouse gas emissions has become a hot topic worldwide. The main objective of this paper is to investigate the prediction of carbon emissions (CE) and carbon peaking in Zhanjiang City based on the LEAP model. The paper first analyses the CE forecasting methods, detailing the reasons for choosing the LEAP model and its advantages; then introduces the characteristics of the LEAP model, analyses the calculation methods of EC and emissions, then analyses the CE factors of energy, builds the relevant forecasting model and sets the parameters. In the comparative analysis of energy consumption (EC), it is found that the LEAP model is more detailed than the EC elasticity factor method, and the modular calculation makes the LEAP model calculation results more accurate than the EC elasticity factor method.

1. Introduction

In order to achieve the goals of carbon peaking by 2030 and carbon neutrality by 2060, China has opened a carbon trading platform and set the corresponding emission reduction targets. At the same time, China has introduced green and low-carbon development as a major part of accelerating economic transformation and structural adjustment in order to promote ecological civilisation. However, as one of the major contributors to China's economic development, Zhanjiang's economy is growing and its demand for energy is increasing, accompanied by a rapid increase in CEs. Therefore, studying the trends of ECACE in Zhanjiang City and exploring the timing and magnitude of its peak CE is one of the important tasks at present, as well as a primary task in order to find CE reduction strategies that are in line with the current situation of Zhanjiang City [1-2].

In a related study, Anusooya et al. mentioned that predicting peak time loads between data centres and distributing the loads would minimise the use of power consumption and minimise CEs from data centres [3]. Reducing CEs by reducing EC in data centres will have an impact on the environment and thus reduce the carbon footprint. The proposed Water Bath Model (WSM) using

Cyclic Peak Time Service (CPTS) has reduced the execution time to 10 ms in comparison with the cyclic algorithm. The load is shared between data centres by predicting the type of request from the user as a read-only request (ROR) or a read-write request (RWR).Carmona et al. use mean-field control and mean-field game models to analyse and inform decisions on how much renewable energy should be used by electricity producers in the presence of a carbon tax [4]. A non-standard system of forward-backward stochastic differential equations describing Nash equilibrium and social optimality is first presented. These equations are then used to prove that both problems have unique solutions. The behaviour of producers in each scenario is then illustrated using numerical experiments. The impact of regulators in controlling carbon tax policies is further presented and analysed, and the resulting Starkberg equilibrium in the producer domain is investigated.

The paper addresses ECACE in Zhanjiang, which includes a discussion of past trends and future scenarios to reduce future emissions. This paper briefly introduces the current status of economic development and EC in Zhanjiang City in terms of total EC, EC structure, and energy emission intensity, and accounts for the total CEs in Zhanjiang City through the CE factor method. The LEAP model is used to construct a framework for predicting energy consumption and carbon emissions (ECACE) in Zhanjiang, and four scenarios, namely, baseline (BS), energy efficiency (ES), energy efficiency and low carbon (ELCS) and low carbon (LCS), are set up to make predictions using a comparative approach. The four scenarios are used to predict ECACE under the influence of factors such as GDP, energy structure, energy intensity, and energy and CE factors.

2. Design Research

2.1. CE Projection Methods

Along with the continuous strengthening of China's economy, human demand and consumption of various energy sources are increasing, and although people's living standards have improved significantly, this has also caused an increase in EC. The consumption of fossil energy is not the only a source of pressure on the energy supply, but it also has a significant impact on the environment due to the large amount of pollutants emitted in the process of energy use. The clean use of energy and the reduction of pollutant emissions are therefore one of the main concerns of the world today [5-6].

Predicting and solving CE problems is a complex scientific task. There are various methods available for energy forecasting, with different classification criteria and different results, as shown in Table 1. The classification method used in this paper is the predictive classification method [7-8].

Table 1: Forecast Classification

Classification criteria	Classification results
Prediction method	LEAP model, econometric model, grey system theory, artificial neural network, combined forecasting, etc
Forecast content	Demand forecast, supply forecast, energy environment forecast, economic energy environment forecast, etc
Forecast period	Short term forecast (0-5 years), medium-term forecast (5-10 years), long-term forecast (more than 10 years), etc
Forecast range	Enterprise energy forecast, regional energy forecast, national energy forecast, global energy forecast, etc
Other standards	Single variable prediction, multi variable prediction, machine learning prediction, structure prediction, total amount prediction, etc

Based on statistics and mathematics, econometric models use time series data and panel data to study the interaction between various factors in human activities. According to the econometric models used in the current research, the main econometric models applicable to the field of energy forecasting include STIRPAT model, IPAT model, regression model, and elasticity analysis. As the relevant theories of measurement models have developed maturely and are relatively simple to use, their use for energy prediction has been recognized by experts and scholars in the field [9-10].

In 1982, the theory of grey system model was put forward. Scholars used this theory to develop grey prediction models, which were widely used in the fields of economy and ecological environment. Among them, GM (1,1) model has the best accuracy and applicability. However, for the first short-term CE prediction in China, there are relatively few experts and scholars who have used the gray CE prediction model to study and analyze CEs, but the gray CE prediction model also has certain characteristics and advantages. It does not require too much calculation and samples when modeling, and has relatively low requirements for the number and regularity of samples, it saves a lot of time and computation and has relatively high market adaptability.

With the continuous progress and innovation of electronic information technology, the current artificial intelligence technology and neural network computing model are gradually used in the energy environment, mainly for the prediction and research of energy demand and pollutant emissions.

With the deepening of research, some scholars found that the use of a single prediction model can no longer meet the current research needs. Because each of the models currently used has its own advantages and disadvantages, its applicability varies according to different research issues, and the use of models usually requires a lot of time for research. Therefore, some scholars proposed a combined model to mix multiple models to improve the accuracy of the current prediction results and the applicability of the model.

Each of the above analysis methods has its own advantages and disadvantages. This paper focuses on the CEs and terminal EC under the energy demand of Zhanjiang City. It is difficult to collect and analyze data. The LEAP model has a strong structure and can be combined with the traditional econometric analysis model and the modern scenario economic analysis model to calculate the CEs and terminal EC of Zhanjiang under different scenarios. We can directly judge and determine the direct impact of the factors in each method on the energy CEs of Zhanjiang through a single factor comprehensive analysis method, therefore, this paper selects the LEAP model to analyze and predict the impact of CEs and terminal EC of Zhanjiang's EC [11-12].

2.2. LEAP Model

The characteristics of LEAP model are as follows:

(1) The data of various scenarios can be generated and assessed by analyzing and comparing their future energy demand, environmental impact, future social use, costs, and economic benefits.

(2) A large number of initial data, emission data in the base year, and emission data in the next few years are required, and interpolation, extrapolation or growth rate and other calculation methods are used to estimate future energy demand and air pollutant emissions in other years.

(3) It has low requirements for initial data, flexible and simple structure, and can simulate the impact of policies to build different energy systems. So far, it has been applied by thousands of organizations in more than 190 countries around the world in the medium and long-term energy and environmental planning of cities.

Today, LEAP model has been widely used in provincial and municipal industrial structure and CEs, CEs scenario prediction, carbon tracking and collection, etc. This study mainly uses LEAP model to predict the impact of Zhanjiang's future EC and future CE development [13-14].

The main module structure of LEAP model is shown in Figure 1.

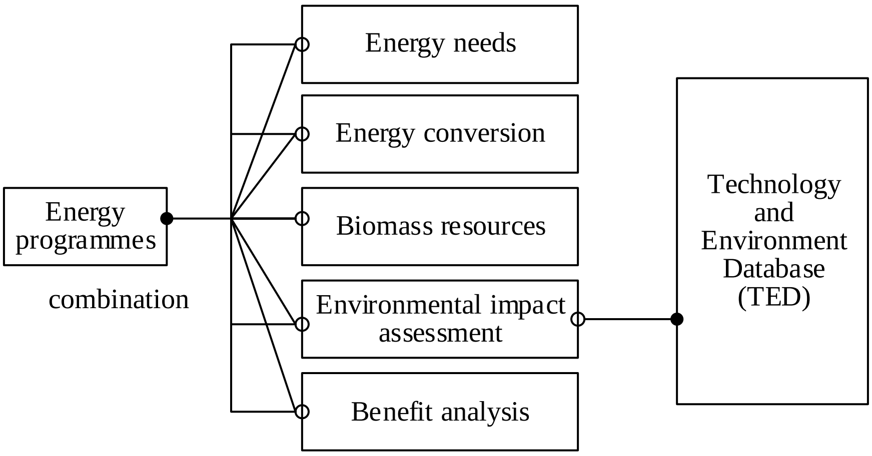

Figure 1: LEAP model module structure

2.3. Calculation Method

The established data structure is input into the LEAP model and the total end-use EC and total end-use EC CEs can be calculated according to the following process. This paper adopts the calculation formulae as in Equation 1 and Equation 2.

$$\sum E(t) = \sum S_i(t) \times \sum SKT_i(t) \times F_i(t) \times EF_i(t) \tag{1}$$

Where: E(t) - total EC.

Si(t), SKTi(t), Fi(t) have the same meaning as in Equation 1.

EFi(t) - is the pollutant emission factor.

$$C = \sum_n \sum_k I \times P \times E \times U \times f \tag{2}$$

where: C - represents total CEs.

n - represents individual sectors.

k - represents individual energy types.

I - represents the value added.

P - represents the ratio of value added to the value added for each sector (%).

E - the energy intensity of each sector (tonnes of standard coal per million).

U - represents the share of consumption of each energy source in each sector (%).

f - represents the CE factor for each energy source.

3. Experimental Study

3.1. CE Factors for Energy

In this study, the statistical results of EC as well as CEs in Zhanjiang City are calculated from the number of end-use ECS in the energy balance sheets in the statistical yearbooks of previous years. After reviewing the relevant literature, EC was divided into direct EC (fossil EC) and indirect EC (electricity consumption).

(1) CE factor for fossil EC

$$I = \sum_j NCV_j \times CC_j \times O_j \times 44/12 \tag{3}$$

Where: I is the direct CE factor; j is the different fossil energy types; NCVj is the average low level heat content; CCj is the carbon content per unit calorific value; Oj is the carbon oxidation rate of energy j; 44/12 is the conversion factor, which are shown in Table 2.

Table 2: Correlation coefficient of main fossil energy

Energy name	Average low calorific value (kJ/kg)	Carbon content per unit calorific value (ton carbon/TJ)	Carbon oxidation rate (%)
raw coal	20908	26.37	0.94
crude oil	41816	20.1	0.98
gasoline	43070	18.9	0.98
kerosene	43070	19.6	0.98
diesel oil	42652	20.2	0.98
fuel oil	41816	21.1	0.98
natural gas	38931	15.3	0.99

(2) CE factors for electricity consumption

Electricity energy is the most widely used secondary energy source and is expressed in energy balance sheets in both equivalent and equivalence terms. Since electricity can be converted into heat, the equivalent value is the amount of standard coal converted into the current amount of heat that can be generated from electricity. The equivalent value of electricity is therefore 1.229t of standard coal per 10,000 kw h of electricity. The relevant departments in China as well as energy statistics stipulate that the calculation of electricity needs to be expressed in terms of the equivalent value of EC, i.e., the amount of energy consumed in the current production of one degree of electricity. In this study, the equivalent calculation is used to calculate the amount of electrical energy consumed in Yangtze River shipping and the CEs it produces. However, there are discrepancies in the values of electricity generation, electricity consumption, and electricity end-use EC in the energy balance sheet due to the existence of electricity imports and the fact that electricity consumes more energy in both production and transportation, which indirectly generates carbon dioxide emissions. Combined with the above analysis, the formula for calculating the CE factor for electricity consumption is shown in 4.

$$EE_t = T\frac{EE_t}{EP_t} \times \frac{EC_t}{EC_{et}} \tag{4}$$

Where EEt is the electricity consumption CE factor in year t; TEt is the CE of thermal power generation in year t; EPt is the total electricity generation in year t; ECt is the total electricity consumption in year t; and ECet is the total electricity terminal EC in year t.

3.2. Model Construction and Parameter Setting

(1) Model construction

The model of EC elasticity coefficient method consists of four parts: economic data, energy data, CEs, and parameter settings. The economic data consists of GDP (constant price, same below) and industry composition, the energy data consists of coal, oil, natural gas, and electricity (some of which are green electricity) consumption, the CEs are calculated by the model, and the parameter settings consist of preset values for each model parameter. The model prediction period is from 2021 to 2025, and the model outputs are GDP, the composition of the three industries, EC by species, and CEs for each year.

(2) Parameter settings

The model parameters include GDP growth rate, population growth rate, value-added growth rate of the three industries, and the growth rate of EC of each species. The EC elasticity coefficient method is consistent with the LEAP model, with two scenarios: the baseline scenario (BS) and the peak scenario (ER). The EC parameters of species are set as follows:

1) Coal

Baseline scenario: According to the relevant plan of Zhanjiang City, coal consumption will reach its peak during the 14th Five-Year Plan period, and the average annual growth rate of coal consumption during the 14th Five-Year Plan period is set at 0%. Peak scenario: Coal consumption in Zhanjiang City reaches its peak in 2021, and coal consumption continues to be reduced from 2022 onwards, with a growth rate of -2% during the 14th Five-Year Plan period.

2) Oil products

Baseline scenario: The growth rate of oil consumption is set at 20% in 2021, with a lower growth rate from 2022 to the end of the 14th Five-Year Plan. Peak scenario: compared to the baseline scenario, the growth rate of oil consumption decreases during the 14th Five-Year Plan period, with a growth rate set at 1%.

3) Natural gas

Baseline scenario: Higher growth rate of natural gas consumption in 2021 is due to resilient economic growth, with electrification advancing, so that natural gas consumption in Zhanjiang remains at a lower growth rate during the 14th Five-Year Plan period, with the average annual growth rate decreasing over the years. Peak scenario: compared to the baseline scenario, the growth rate of natural gas consumption slows down during the 14th Five-Year Plan period.

4) Electricity

Baseline scenario: By correlating Zhanjiang's historical GDP growth rate with the growth rate of electricity consumption, it is found that the ratio of electricity consumption growth rate to GDP growth rate is maintained between 1.2 and 2.2, and the average value of 1.5 is taken for the historical years. The share of green electricity (non-fossil self-generation) increases from 3% in 2021 to 10% in 2025.

Peak scenario: The growth rate of electricity consumption remains consistent with the baseline scenario, but the share of green electricity increases compared to each year of the baseline scenario, from 5% in 2021 to 25% in 2025.

4. Comparative Experimental Analysis of Model Results

The prediction results of the LEAP model and the EC elasticity coefficient method were compared and analysed to explore the differences and consistency of the results calculated by the two models.

4.1. Comparative Analysis of EC

Table 3: Comparison of EC between the two models

	1	2	3	4	5
LEAP Model BS	4700	4800	4900	5000	5100
LEAP model ER	4550	4600	4650	4675	4700
Elasticity coefficient method of EC BS	4810	5200	5320	5440	5660
Elasticity coefficient method of EC ER	4810	5100	5200	5300	5400

The specific results are shown in Table 3.

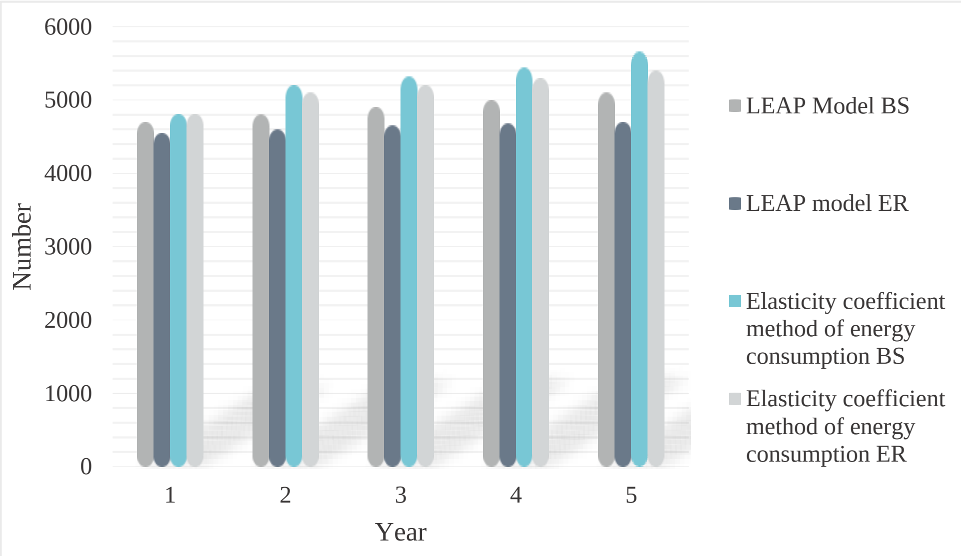

Figure 2: Comparison and Analysis of EC of Two Models

As can be seen from Figure 2, there is a similar pattern between the prediction results of the two models, with the EC curve showing an upward trend in general, and the results of the peak scenario in both models are generally smaller than those of the baseline scenario. The LEAP model is more detailed than the EC elasticity method, and the modularity of the calculation makes the results of the LEAP model more accurate than the EC elasticity method.

4.2 Comparative Analysis of CEs

The specific results are shown in Table 4.

Table 4: Comparison of CEs of two models

	1	2	3	4	5
LEAP Model BS	11000	11250	11500	11750	12000
LEAP model ER	10600	10700	10725	10750	10800
Elasticity coefficient method of EC BS	11150	11750	12150	12500	12850
Elasticity coefficient method of EC ER	11100	11500	11600	11700	11800

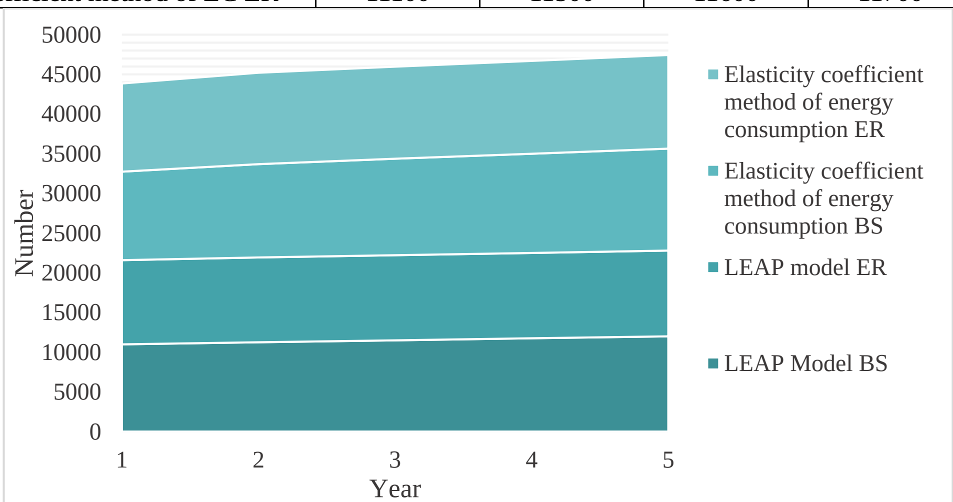

Figure 3: Comparison and Analysis of CEs of Two Models

In the comparison of CE prediction results, it is found that the EC curve and CE curve of the two models have the same law. Under the same scenario, the curve rules of the prediction results of different models are almost the same, but the same as the results of EC, the CE results of the EC elasticity coefficient method are generally large, the difference between the CE results of the two models is about 10 million tons of CO2e, and the CE in the peak scenario (ER) of the EC elasticity coefficient method is higher than the results of the LEAP model base scenario (BS) in the first three years of the "14th Five Year Plan", as shown in Figure 3.

5. Conclusions

At present, the main material basis for the development of human society is energy, which can not only promote the development of social productivity, but also promote social change and social and economic change through the change of use forms. It can be said that the history of the use of energy and the transformation of the way of energy use is the history of the development of human social productivity. After the completion of policy adjustment, China's demand for energy will further increase, and there will be a V-shaped rebound in energy security. Energy security is closely related to national security. If there is a shortage of oil and natural gas supply due to the reduction of energy supply, or the current phenomenon of excessive dependence on imports of energy, it will have a serious impact on the social stability and political stability of the country. At present, we are faced with the problem of how to use energy efficiently and cleanly.

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