

Analysis of energy consumption structure in China, the United States and Germany based on forecasting models

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Abstract. This study analyzes and models the energy consumption structure of China, the United States and Germany, and reveals the characteristics, trends and influencing factors of energy consumption by comparing the energy consumption of different countries. The grey GM(1,1), ARIMA, LSTM and GLVM models are used to model and forecast energy consumption, and the model results are evaluated. It is found that there are significant differences in the structure, transformation speed and influencing factors of energy consumption in different countries, which has important implications for formulating energy policies and promoting sustainable development.

Keywords: Energy consumption structure, Grey model, Time series analysis, Sustainable development.

1. Introduction

With the development of the global economy and the growth of the population, the issue of energy consumption has attracted increasing attention. Energy is an important foundation to support economic development and social progress, and its consumption structure and trend have an important impact on the development of the country and the region. China, the United States and Germany are among the largest energy consumers in the world, and their energy consumption directly affects the global energy market and environment. Therefore, an in-depth study of the energy consumption structure, transition trends and influencing factors in different countries is of great significance for formulating sustainable development strategies and promoting energy transition. This study aims to reveal the characteristics and future development trends of energy consumption in China, the United States and Germany through modeling analysis, so as to provide scientific basis for relevant decisions.

Energy is an important material basis for developing social production and improving people's living standards, and a powerful driving force for promoting national economic development. Its importance has prompted scholars to devote themselves to the construction of accurate energy consumption prediction models.

In terms of statistical methods, it mainly focuses on linear regression model, ARIMA, elastic elasticity coefficient method and elastic decoupling index. Payne[1] uses Toda-Yamamoto causality test to show that there is no Granger causality relationship between real GDP and renewable resources and non-renewable resources. Bianco[2] used a linear regression model for the long-term prediction of non-residential natural gas demand in Italy, taking into account the impact of economic and environmental changes. Yukseltan[3] added Fourier series expansion and modulation of seasonal harmonics into the linear model to solve the electricity prediction of Turkey. Nichiforov[4] established seasonal forecasting model (ARIMA) to predict energy consumption. Yuan[6] used ARIMA for the first time to predict China's energy economic consumption, and took primary energy consumption as the primary measurement factor of energy economic consumption.

In terms of machine learning methods, it mainly focuses on EWF-attention-LSTM, echo state network, quantile regression, decision tree, ANN and HW-ELM. Peng proposed empirical wavelet change and attention-mechanism based LSTM(EWT-attention-LS) for structural analysis and trend prediction of energy demand TM). Wang[7] proposed a new method for predicting periodic energy

consumption based on LSTM. Nsangou[8] used fractional bit, decision tree and artificial neural network methods in estimating the driving factors of energy consumption demand. Liu[9]proposed a hybrid model using Holt-Winters method and extreme learning machine network (HW-ELM), in which electricity data are decomposed into smooth linear and fluctuating nonlinear components using moving average filters.

As far as grey prediction methods are concerned, they mainly focus on unbiased nonlinear grey thin effort model, flexible grey multivariate model, MNMG-ARIMA and adaptive grey model with time power structure. In 1982, grey prediction model was proposed by Deng Julong [10] to solve the lack of information in prediction and decision making under the condition of information uncertainty. Shaikh[11], considering the complexity of the model in the real situation, used Verhulst and gray thin effort prediction model to analyze and forecast the current situation of natural gas in China. Zhang[12]established a flexible grey multivariate model to solve the problem of energy structural analysis and prediction in China's provinces with huge energy consumption. Wang[[13]established MNGM-ARIMA for US shale and shale oil production, and combined the fractional accumulation and rolling mechanism to improve the accuracy. Ding[14]established an adaptive gray prediction model with time power structure in the face of the nuclear energy consumption problem between China and the United States.

There is a correlation between GDP and carbon emissions to a certain extent, and there is a long-term and short-term cointegration relationship within them, and the overall performance is one-way Granger causality [15]. Energy not only promotes economic development, but also drives the exponential growth of China's per capita carbon emission contribution [16]. However, economic development has a significantly negative impact on carbon emissions from energy consumption, and the continuous contradiction between economic growth and carbon emissions from traditional fossil energy shows an "inverted U" curve [17]. Qiu Lixin et al. [18]adopted the Tapio model to analyze the carbon emissions of typical cities in China, and found that there is overall strong decoupling in typical cities with carbon emissions in China. It also concludes that carbon emissions and economic growth have nonlinear characteristics and autocorrelation characteristics. Sun and Liupredicted CO2 emissions of three major industries and residential consumption. Wang et al. introduced a nonlinear correction term: power exponential term and gray action to improve the GM(1,n) model for the nonlinear relationship between fossil energy carbon emissions and GDP.

2. Analysis of energy consumption structure

Primary energy consumption is an important indicator to reflect the energy consumption of an enterprise, a country or a region. The United States reached a peak in 2007 (97.44EJ) and continued to increase after that, with a continued rise in 2023. India's primary energy consumption is growing rapidly, peaking in 2022 (111.48EJ). In recent years, the energy consumption of various countries fluctuated and rose due to the impact of COVID-19 and the Russian-Ukraine war, but with the epidemic control and government policy support, energy consumption gradually picked up. Primary energy consumption will grow 7.1 per cent in China and 5.3 per cent in the US in 2022, and 2.6 per cent in Germany.

In the world's primary consumption energy consumption structure in 2022, oil consumption will account for 40.67%, natural gas consumption for 26.68%, coal consumption for 29.77%, and nuclear energy consumption for 5.5%. The consumption of coal in China's primary energy consumption accounts for a relatively high 52.04%, but the consumption of oil and natural gas is far lower than the proportion of world energy consumption, showing a "top-heavy" situation, which is caused by the domestic energy resource mix structure, while the oil and natural gas account for a relatively high proportion in the United States and Germany, which are 79.8% and 57.8% respectively. For non-fossil energy, the proportion of fossil energy in the United States is 46.13%, while that in Germany is 57.77%. This shows that China still has a long way to go to achieve the "dual carbon" development goal and realize the transformation and upgrading of energy consumption system.

3. Case study

In this section, different models are used to model the energy consumption structure of relevant countries. By comparing the relevant data in 2022, the top several countries with the highest energy consumption and the fastest development of renewable energy are selected as representative countries.

Grey GM (1,1), ARIMA model, OLS least squares estimation, Lotka-Volterra model for different types of energy consumption in China were analyzed in detail. MAPE and RMSE indicators are used to evaluate the predicted value of the model, and the best model is selected for analysis.

3.1. Data collection and description

In this study, the data of energy consumption and renewable energy development speed of each country in 2022 are combined to select representative countries selected for quantitative analysis. The three countries with the highest total energy consumption in 2023: the United States, China and Germany are selected for analysis. Source :BP Statistical Review of World Energy [1](missing data for some countries). Its thermal map is shown in Figure 1:

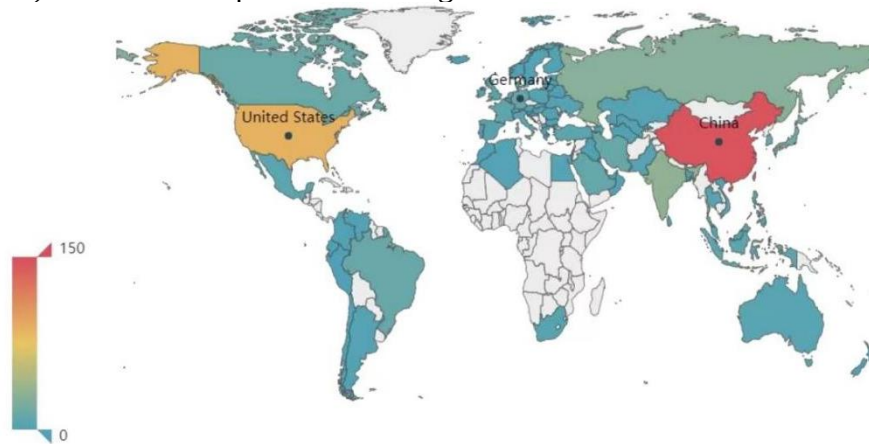


Figure 1 Thermal map of world energy consumption

As for the statistical indicators of energy consumption, different countries adopt different statistical methods, caliber and conversion methods. It is also due to the fact that countries are in different energy transition periods and the extent of energy consumption is different. It is necessary to process the relevant data to maintain the same dimension, and then analyze the relationship between different consumables, while ensuring the accuracy of data prediction results. According to the classification of energy investment, the difference between fossil energy and non-fossil energy combined with the current situation of energy consumption transition in different countries, the energy consumption system is divided. Since the relevant yearbooks and institutions use different caliber to make statistics on the data, it is necessary to process the relevant data to maintain the same dimension, and then analyze the relationship between different consumables, and ensure the accuracy of the data prediction results. According to the classification of energy investment, the difference between fossil energy and non-fossil energy combined with the current situation of energy consumption transition in different countries, the energy consumption system is divided.

The original data of US energy consumption (2012-2022) come from the US Energy Information Administration (EIA), as shown in Figure 2.1(b). Due to the impact of the COVID-19 pandemic in 2019, the United States began to see a consumption downgrade in 2020, with its internal energy structure corresponding to a decline in oil energy use accompanied by an increase in renewable energy consumption; As shown in Figure 2.1(c), China's energy consumption data (2012-2022) are from China Statistical Yearbook. China's energy consumption generally shows an increasing trend. Before 2012, China's energy structure was mainly driven by coal consumption, but after 2020, China's energy consumption level gradually moved closer to new energy. As shown in Figure 2.1(d), India's energy consumption data remain less volatile in aggregate terms. In its internal energy mix, coal consumption is declining, while consumption of oil and renewable resources is increasing. Since 2012, oil has

gradually replaced coal as the driving factor of China's energy driving structure in China's internal energy structure, along with the gradual growth of many clean energy consumption.

3.2. Modeling results and discussion of China's energy consumption system

China is a country with coal as the main energy source, and coal has an absolute advantage in the world. In recent years, the consumption of coal has been increasing, from 70.26% in 2011 to 56.7% in 2020, 13.56% less than the same period last year. The main reason for such a large decline is that China's crude oil and natural gas are highly dependent on imports, and there is no way to ensure China's energy security; Moreover, China's new energy sources such as: The consumption of hydropower, nuclear power and wind power has shown an increasing trend year by year in recent years. According to the research report, compared with 4.6% and 8.4% in 2011, the consumption of hydropower, nuclear power and wind power has reached 8.4% and 15.9% in 2020 respectively, up 3.6% and 7.5% year-on-year, with a large growth rate. This shows that China's energy consumption has changed from the traditional energy consumption to the consumption mode with new energy as the main and other energy as the auxiliary. It is intended to explore the sustainable development path of energy economic structure transformation through total energy consumption and energy consumption structure. The model analysis data are shown in Table 1:

Table 1 Model analysis table

Type of	predictive model	fit component		Forecasting component	
		MAPE(%)	RMSE	MAPE(%)	RMSE
Fossil energy consumption	GM(1,1)	12.0433	23987.85	29.4578	833560.97
	ARIMA	2.4407	28012.02	0.6980	2054.59
	LSTM	13.2300	33694.03	10.9169	31659.14
	GLVM	3.6118	7267.73	4.4321	13066.86
	GM(1,1)	3.6227	1816.07	6.0194	8532.55
	ARIMA	2.2782	4515.88	3.1054	4795.04
	LSTM	17.8735	11997.52	12.6989	18381.29
	GLVM	2.3166	1643.44	2.0334	3276.93
Nuclear power consumption	GM(1,1)	8.6880	1736.88	1.9060	1558.14
	ARIMA	6.7637	6444.28	2.0393	1953.03
Renewable energy consumption	LSTM	28.6209	8672.03	26.1279	20061.55
	GLVM	5.1190	1315.12	1.2309	1049.11

From the values of the parameters of China's energy consumption model shown in the above table, the GLVM model of US energy consumption is obtained as follows:

$$\begin{cases} \frac{dx}{dt} = (0.0200 - 0.0559x + 0.1353y - 0.0504w)x \\ \frac{dy}{dt} = (0.0666 + 0.0154y - 0.0067x - 0.0058w)y \\ \frac{dw}{dt} = (0.0880 - 0.0019w + 0.0059x + 0.0007y)w \end{cases} \quad (1)$$

(Note: x- coal consumption in China; y- Consumption of oil and natural gas in the PRC; w- Non-fossil energy consumption in China)

Table 2 GLVM parameters in China

Parameters of	Numerical value	Parameters of	Numerical value
r_1	0.0202	λ_1	1.0202
a_1	0.0557	α_1	0.0567
b_1	-0.1355	β_1	-0.1369
c_1	0.0506	γ_1	0.0509
r_2	0.0668	λ_2	1.0689
a_2	-0.0154	α_2	-0.0159
b_2	0.0067	β_2	0.0069
c_2	0.0058	γ_2	0.0062
r_3	0.0882	λ_3	1.0922
a_3	0.0019	α_3	0.0022
b_3	-0.0059	β_3	-0.0063
c_3	-0.009	γ_3	-0.0009

As shown in Table 2, the competition factor between China's oil and gas consumption and coal is negative 0.1353, while the competition factor between coal consumption and oil and gas consumption is 0.0067, indicating that there is a substitution relationship between the two. As oil and gas consumption rises, coal consumption rises and oil and gas consumption falls. Clean transformation and gasification of coal are gradually replacing traditional oil and gas consumption to ensure energy security and reduce dependence on coal. At the same time, non-mineral fuels are gradually replacing coal, which is manifested by the change of competitive factors between the two. Oil and gas consumption will be gradually replaced by non-mineral energy, which is of great significance to deal with climate change, energy security and environmental pollution. China's energy structure is gradually being optimized and diversified. Promoting the wide application of renewable energy is of great significance to reduce energy shortage, protect the environment and ensure national energy security.

3.3. Modeling results and discussion of the US energy consumption system

The United States is the world's largest energy producer and consumer. Energy consumption is dominated by fossil energy, with non-fossil energy accounting for more than 60%. Since the 1950s, the United States has mainly used coal as fuel, and coal production and consumption have continued to grow and improve utilization efficiency. However, since the 1990s, oil consumption has begun to grow rapidly, and non-fossil energy consumption has gradually surpassed coal to become the main energy structure. Coal production and consumption have risen since 1991, but have declined since 2001, affected by coal restrictions and the development of alternative energy sources. The government has taken measures to encourage the development of clean energy technologies, such as wind, solar, geothermal and hydrogen, to cope with energy demand and environmental pressure. In the analysis of energy consumption, fossil, nuclear and renewable energy sources dominate. The study shows that the GLVM model has higher accuracy and prediction precision compared to other models in predicting energy consumption. The model analysis data are shown in Table 3:

Table 3 Model analysis table

Type of	Prediction model	Part of fit		The forecasting part	
		MAPE(%)	RMSE	MAPE(%)	RMSE
Fossil energy consumption	GM(1,1)	3.9029	3.55	7.0653	6.43
	ARIMA	1.8293	3.30	6.8944	6.40
	LSTM	3.4581	3.24	6.6222	6.16
	GLVM	1.8545	1.85	5.7025	5.09
	GM(1,1)	4.2715	0.36	7.5626	0.65
	ARIMA	2.2773	0.37	2.9018	0.28
	LSTM	4.4098	0.44	4.4985	0.40
	GLVM	2.0395	0.20	1.1804	0.10
Nuclear power consumption	GM(1,1)	10.7587	0.82	5.4139	0.63
	ARIMA	4.8889	0.82	1.3684	0.17
Renewable energy consumption	LSTM	10.9352	0.98	12.7446	1.46
	GLVM	3.9821	0.36	4.6362	0.54

From the values of the parameters of the US energy consumption model shown in the table above, the GLVM model of US energy consumption is obtained as follows:

$$\begin{cases} \frac{dx}{dt} = (-0.0484 + 0.0025x - 0.0248y + 0.0060w)x \\ \frac{dy}{dt} = (0.0260 - 0.0164y + 0.0014x - 0.0001w)y \\ \frac{dw}{dt} = (0.3729 - 0.0121w - 0.0098x + 0.0680y)w \end{cases} \quad (2)$$

(Note: x- coal consumption in China; y- Consumption of oil and natural gas in the PRC; w- Non-fossil energy consumption in China)

As shown in Table 4 In the United States, the consumption of nuclear power and renewable resources increased from 1990 to 2018 as the United States implemented an independent energy policy. However, from 1990 to 2018, the consumption of mineral resources in the United States did not increase continuously, and its consumption of mineral energy was still high compared with the consumption of nuclear power and renewable resources. Mineral fuel consumption, nuclear energy consumption and new energy consumption are negative 0.0484, 0.0260 and 0.3729, respectively. The results show that from 1985 to 2018, the consumption of nuclear energy and new energy in China shows a great development trend, and the use rate of new energy is slightly higher than that of nuclear energy. At the same time, fossil fuel consumption is declining.

Table 4 Parameters of GLVM in the United States

Parameters of	Numerical value	Parameters of	Numerical value
r_1	-0.0485	λ_1	0.9528
a_1	-0.0026	α_1	-0.0025
b_1	0.0249	β_1	0.0243
c_1	-0.0062	γ_1	-0.0058
r_2	0.0262	λ_2	1.0265
a_2	0.0165	α_2	0.0167
b_2	-0.0015	β_2	-0.0015
c_2	0.0002	γ_2	0.0002
r_3	0.3728	λ_3	1.4518
a_3	0.0122	α_3	0.0148
b_3	0.0099	β_3	0.0118
c_3	-0.0681	γ_3	-0.0825

By fitting the electricity consumption model for the US regions, the correlation between the two different types of electricity consumption is obtained to be greater than zero. It can be seen that the current situation of using nuclear energy and new energy has slowed down the use of nuclear energy and new energy to some extent. However, the self-interaction factor of fossil energy is 0, which indicates that there is a positive internal competition within the system. The United States now faces this situation, mainly because it is the world's largest oil and gas producer, and its oil consumption has risen as a result, mainly due to its internal reforms. However, fossil energy consumption is set to decline further as U.S. energy consumption moves toward a low-carbon and cleaner environment.

The competitive factor between energy consumption and nuclear energy consumption in the United States. $0.02 < 0$, indicating that the two have the effect of mutual substitution. The consumption of nuclear energy has played a role in hindering the development of China's petrochemical energy, while the consumption of nuclear energy has played a role in promoting the development of nuclear energy, and the consumption of nuclear power has gradually replaced the high carbon dioxide emissions in fossil energy.

In renewable energy consumption, the competition factors of fossil fuel consumption and renewable energy are all higher than 0, showing an inhibitory effect on renewable energy. The results show that the two different types of energy consumption have different degrees of mutual substitution. The fundamental reason is the American First Energy Progress promoted by President Trump, which repealed the Obama Clean Energy and Security Act, re-promoted the development of conventional mineral resources, reduced the consumption of renewable energy, and stimulated the consumption of fossil fuels.

The competition coefficient of nuclear power and new energy $c_2 > 0, c_3 < 0$, There is a mutual substitution relationship between nuclear power and new energy. It is characterized by the fact that the consumption of renewable energy promotes the development of nuclear power to some extent; With the safe use of nuclear power and the falling electricity price of renewable energy consumption, new energy is gradually replacing nuclear power.

Overall, U.S. oil consumption remained stable and natural gas and renewable resource consumption continued to grow. Under the national regulation, the composition of energy investment in the United States has been constantly optimized, showing a trend of low-carbon and clean development. The relationship between various types of energy consumption in different regions of the United States is complex, and there is a certain balance between energy consumption in different regions.

3.4. Modeling results and discussion of the German energy consumption system

Germany has a lack of resources and high dependence on foreign countries, but it has achieved a green transformation of its energy structure through the Renewable Energy Law. In 2020, Germany's primary energy consumption reached 810,354.74 MW, mainly from oil and natural gas (34.91%), natural gas (26.76%), new energy and biomass fuels (8.94%), and electricity (21.31%). Germany, a leader in new energy, plans to close all its nuclear plants by 2022. Its energy conversion scheme is dominated by renewable energy sources. Germany is the world's second-largest energy investor. In the study, grey model, statistical model, deep neural network model and Lotka-Volterra model were used to predict energy consumption. The Lotka-Volterra model has high accuracy and consistency and is better than the traditional model in predicting various types of energy consumption in Germany. The model analysis data are shown in Table 5:

Table 5 Model analysis table

Type of	Prediction model	Part of fit		The forecasting part	
		MAPE(%)	RMSE	MAPE(%)	RMSE
Fossil energy consumption	GM(1,1)	3.3555	156970.41	7.2133	244663.00
	ARIMA	2.8693	179148.38	1.8845	79802.90
	LSTM	6.7345	303310.84	2.4599	96079.83 126319.33
	GLVM	2.6760	138266.27	2.9661	69896.38
	GM(1,1)	5.9551	144361.46	3.1224	86474.68
	ARIMA	3.9437	135440.61	3.8180	
	LSTM	5.6037	139643.26	1.8661	43679.71
	GLVM	3.2134	90300.73	0.2116	6472.41
Nuclear power consumption	GM(1,1)	5.1500	151667.78	13.7245	403088.59
	ARIMA	2.1911	156115.13	3.7135	116258.14
	LSTM	4.9760	201728.70	8.1832	244071.86
Renewable energy consumption	GLVM	2.6385	103444.25	6.1809	185232.37

From the values of the parameters of the US energy consumption model shown in

$$\begin{cases} \frac{dx}{dt} = (0.0982 - 0.1002x + 0.0019y - 0.0384w)x \\ \frac{dy}{dt} = (0.7061 - 0.1935y - 0.2505x - 0.2029w)y \\ \frac{dw}{dt} = (-0.3531 + 0.0230w + 0.1275x + 0.1783y)w \end{cases} \quad (3)$$

Table 5, the GLVM model of US energy consumption is obtained as follows:

(Note: x- coal consumption in China; y- Consumption of oil and natural gas in the PRC; w- Non-fossil energy consumption in China)

As a result of Germany's Renewable Energy Law, coal and crude oil consumption declined between 1990 and 2020, while the consumption of natural gas and other fossil free fuels increased. From the perspective of vector vector regression, the endogenous growth rate of coal is 0.0982, the endogeneity of crude oil is 0.7061, and the endogeneity of other fuels is -0.3531. Data show rapid growth in German oil consumption between 1990 and 2018.

Table 6 German GLVM parameters

German GLVM parameters			
r_1	0.0983	λ_1	1.1032
a_1	0.1003	α_1	0.1052
b_1	-0.0018	β_1	-0.0021
c_1	0.0385	γ_1	0.0405
r_2	0.7062	λ_2	2.0263
a_2	0.1936	α_2	0.2814
b_2	0.2504	β_2	0.3641
c_2	0.2028	γ_2	0.2948
r_3	-0.3532	λ_3	0.7024
a_3	-0.0231	α_3	-0.0195
b_3	-0.1276	β_3	-0.1075
c_3	-0.1782	γ_3	-0.1504

As shown in Table 6, After fitting the German energy consumption pattern, the self-influence coefficients of German energy consumption are all above 0, such as coal, crude oil and natural gas. It can be seen from this that the consumption rate of coal, oil and gas in China has slowed down at present. However, the coefficient of natural influence of non-mineral resources is 0, indicating that China's oil and gas market is actively competitive. This shows that the consumption of non-mineral energy in our country has entered a good period of development.

Competition coefficients for coal, oil and gas in Germany $b_1 < 0, b_2 > 0$, It indicates that there is a substitution relationship between the consumption of coal, oil and natural gas. Specifically, the consumption of coal and oil has promoted the energy consumption of our country to a certain extent; As a clean energy source, natural gas has replaced coal, oil and other high greenhouse gas emissions. Competition coefficients for coal, oil and non-mineral energy consumption $c_1 > 0, b_3 < 0$, It shows that the two have a mutual substitution relationship. This indicates that energy consumption, which is dominated by coal and oil, is gradually shifting from coal to oil. Competitive coefficients of natural gas and non-fossil energy consumption $c_2 > 0, c_3 < 0$, It shows that the two have a certain substitution effect. It can be seen that the position of natural gas in China's energy consumption is increasingly important.

Germany has decided to abandon nuclear power for domestic policy reasons and intends to completely eliminate nuclear power by 2022. In recent years, with the gradual decline in the proportion of nuclear power, the natural growth rate of non-fossil energy resources in China has converged to zero. In order to meet the needs of the domestic "energy transition", Germany imported a lot of gas from Russia as a "stable" energy mix, while also promoting the development of new domestic energy sources across the country. The "non-nuclear" strategy implemented by Germany has enabled Germany to gradually replace Germany and develop sustainable new energy sources around the world. Germany has been constantly optimizing its own energy structure, and constantly changing and improving its system and institutions, so as to achieve control over its energy conversion costs. Then, around the German energy system, with its flexibility as the center, it will be digitized and intelligent, so that its energy consumption can achieve clean and clean. It is shown that Lotka-Volterra model can describe multiple nonlinear correlations of energy consumption system more accurately than other control models, thus improving the prediction accuracy. At the same time, this new analysis method is also suitable for the quantitative analysis of various types of energy consumption, which has certain practicability. This new forecast is highly accurate and the forecast accuracy is high.

4. Conclusion

This project establishes a nonlinear grey Lotka-Volterra model that comprehensively considers the interaction between multiple energy categories, evaluates and forecasts its energy consumption, and performs numerical multiplication transformation on it. The empirical analysis of energy consumption in China, the United States and Germany shows that the energy consumption level of these three countries is higher than that of other countries. Compared with the traditional method, OLS support vector machine can more accurately describe the nonlinear correlation in the energy consumption system, thus improving the prediction accuracy of the measured data. In addition, the model can also be used to quantitatively study the interaction between various energy consumption, which is an effective method.

Like developing countries such as China, China's energy consumption is mainly petrochemical energy, which is of great significance to ensure China's energy security, and the alternative ways represented by non-mineral energy are of great significance to reduce emissions. We should properly solve the problem of ensuring energy supply and medium - and long-term "low-carbon" transformation, and promote the development of China's energy structure in the direction of diversification, cleanliness and low-carbon. Some large countries, such as the United States, aim to achieve "energy independence". On this basis, a new development strategy is proposed, and a new, sustainable, sustainable and sustainable development strategy is proposed. Countries such as Germany relied

heavily on external sources until renewable sources became mainstream. Developing countries should gradually develop renewable resources on the premise of ensuring their own energy security.

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