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Forecast of Commodity Energy Consumption and Structure of Rural Households in Sichuan Province

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ABSTRACT

With the growth in energy consumption, problems such as environmental pollution and resource depletion are becoming more and more prominent, and the sustainable use of energy resources and sustainable economic and social development can be achieved only through scientific forecasting and effective management. Forecasting the changing trend of energy consumption structure can guide the government and society to take corresponding measures for environmental protection and sustainable development, and reduce the negative impact of energy consumption on the environment. Based on the current development situation of commodity energy in rural households in Sichuan Province and related consumption data, this paper uses the grey prediction model and Markov model to predict the consumption and consumption structure of commodity energy in rural households in Sichuan Province. It is found that among the four types of commodity energy consumed by rural households in Sichuan Province, the consumption of electricity shows exponential and growth, and it is expected that the consumption of electricity by rural households in Sichuan Province from 2022 to 2025 will be 3,316,166, 3,582,203, 3,886,622, and 4,216,240 tonnes of standard coal, respectively. Meanwhile, using Markov chain to predict the consumption structure, it is found that under the no-planning constraint scenario, the share of energy consumption of electricity and natural gas is increasing, while the share of energy consumption of coal and liquefied petroleum gas (LPG) will be decreasing, and the shares of energy consumption of coal, electricity, natural gas, and LPG will be 1.97 per cent, 75.82 per cent, 26.36 per cent, and 0.02 per cent, respectively, by 2030.

KEYWORDS

Commodity Energy; Rural Areas; Consumption and Structure.

1. INTRODUCTION

In December 2021, the National Energy Administration, the Ministry of Rural Agriculture and the National Rural Revitalization Administration jointly issued a notice on the "Implementation Opinions on Accelerating Rural Energy Transformation and Development to Help Rural Revitalization", pointing out that the green energy transformation and development in rural areas is of great significance to promoting rural revitalization and achieving the goals of carbon peak and carbon neutrality. In March 2022, the Sichuan Provincial People's Government issued the "14th Five-Year Plan for Energy Development in Sichuan Province", which provides a path for the development of rural clean energy in rural areas of Sichuan Province and the promotion of green energy transformation and development. As an important part of rural social and economic development, rural household energy consumption is not only related to the quality of life of farmers, but also directly affects the protection and sustainable development of the rural ecological environment. With the acceleration of rural modernization, the energy consumption structure of rural households is undergoing profound changes, and the transformation from traditional biomass energy to clean and efficient modern energy is not only an inevitable trend of rural development, but also the only way to achieve rural revitalization.

As a large agricultural province, Sichuan has a vast rural area, with a rural population accounting for more than 40% of the province's total population, and a huge rural household energy consumption base. In addition, with the continuous improvement of infrastructure in rural areas of Sichuan and the increase of rural household income, the energy consumption structure of rural households in Sichuan has been continuously optimized. Between 2015 and 2021, the consumption of clean energy such as electricity and natural gas by rural households in Sichuan continued to increase, and the consumption of coal and liquefied petroleum gas (LPG) declined, until in 2021, coal consumption was only 651,100 tons of standard coal, 1,927,100 tons less than in 2015. However, rural household energy consumption also faces many challenges. On the one hand, due to the relatively weak energy infrastructure in rural areas, the stability and security of energy supply still need to be improved. On the other hand, farmers' awareness and acceptance of new energy are limited, which hinders the promotion and application of new energy in rural areas. At the same time, because the proportion of energy consumption in rural areas of China in total primary energy consumption has been lower than that in urban areas for a long time, the problem of rural energy is often ignored [1]. Therefore, it is of great significance to predict the development trend of energy consumption and consumption structure in rural areas of Sichuan Province for scientific planning of rural energy development, ensuring the security of rural energy supply, promoting rural ecological environmental protection and promoting the sustainable development of rural economy and society.

2. LITERATURE REVIEW

Household energy consumption has become an important issue in China's energy consumption, but also an important unit of China's clean energy transition [2], is always a hot spot of energy research [3]. In the process of studying rural household energy consumption, domestic for scholars from the characteristics of energy consumption of household residents, household energy consumption influencing factors, household energy use efficiency and energy consumption structure and other perspectives for in-depth discussion.

With regard to the influencing factors of rural household energy consumption, scholars at home and abroad have analysed them from the aspects of income, geographic environment, characteristics of household residence and demographic characteristics. For example, Galvin pointed out that income inequality is a determinant of household energy consumption [4].Chung et al. found that the increase in the number of households and the improvement of energy efficiency are the main reasons affecting household energy consumption, and that the final use of energy per household is decreasing in government rental subsidised housing (flats) [5].Jiang et al. concluded that the demographic effect is one of the leading factors leading to the decline of energy consumption in China's rural areas [6]. one of the dominant factors in the decline of energy consumption [6]. There are significant differences between different regions in terms of the characteristics of energy consumed by rural households and their consumption structure.Joyeux et al. pointed out that household energy consumption serves as an important indicator of the quality of life of the population [7].Miah et al. found through a stratified random sample of 120 households in Bangladeshi villages that 92 per cent of households used biomass, 28 per cent of liquefied petroleum gas (LPG), 89 per cent of paraffin, 78 per cent of of electricity and 27% of candles as fuel types [8].San et al. found through their survey that in Kampong Chhnang municipality, Cambodia, about 96% of the sampled households relied on fuelwood as the main source of cooking, boiling water, preparing animal fodder, and protecting livestock from insects [9].Lekveishvili's data from his research in the state of Georgia in the United States shows that the difference in rural and townships have similar total energy consumption, but commodity energy consumption in towns is much higher than in rural areas [10].Zhang and Guo studied China's rural commodity energy consumption and found that the average annual growth rate of rural commodity energy consumption was 2.15 per cent from 1991 to 2010 [11]. By summarising and analysing official statistics and literature, Cong Hongbin et al. pointed out that rural commodity energy accounted for 51.6% in 2014 [12].L Jiang et al. found that the structure of household energy consumption had shifted from traditional biomass to a combination of coal and other energy sources through a comprehensive survey of farming households in farming and animal husbandry areas of Qinghai Province, and that households with different cultural backgrounds had different patterns of energy consumption [13].

By combing the existing literature, it can be found that scholars at home and abroad have conducted extensive and in-depth research on household energy consumption from different perspectives, and the research mainly focuses on the structure, characteristics, trends, and existing problems and challenges of household energy consumption. Foreign research on household energy consumption started earlier, and the research content is richer and deeper. They not only pay attention to the structure and trend of household energy consumption, but also focus on analysing the influencing factors of household energy consumption behaviour, as well as the correlation between household energy consumption and global issues such as environmental protection and climate change. China's rural household energy consumption research started late, but has now also achieved more fruitful results [14], but there are relatively few studies on the differences in household energy consumption in different regions and at different income levels. Therefore, based on the existing research, this paper adopts the grey prediction model and Markov chain to predict the consumption and consumption structure of rural household commodity energy in Sichuan Province, so as to provide a basis for scientific planning of rural energy development, promote the security of rural energy supply and promote the sustainable development of rural economy and society.

3. MODEL CONSTRUCTION

Scientific prediction of household energy consumption and structural changes in rural areas of Sichuan Province is of great significance for the future transformation of rural energy system development. In predicting the future physical energy consumption and energy structure of rural households, the GM(1,1) model and Markov chain are used to carry out the prediction analysis respectively.As a kind of grey prediction model, the GM(1,1) model has a unique advantage in dealing with the uncertain system with small samples and little information. It reveals the intrinsic patterns and future trends of data series through cumulative generation and cumulative reduction of the original data. Markov chain, on the other hand, is a probabilistic prediction method based on state transfer, which speculates the trend of future state change based on the state transfer probability of historical data. The combined use of these two prediction methods enables us to more accurately grasp the dynamic changes and future direction of energy consumption in rural areas of Sichuan Province.

3.1. Principle and Construction of GM(1,1) Model

In the rapid development of modern society, energy, as an important cornerstone to promote economic and social progress, the prediction of its consumption trend is of far-reaching significance for the formulation of national energy strategy, market decision-making of enterprises and even life planning of individuals. Among many forecasting methods, GM(1,1) model, as a typical grey forecasting method, not only can adapt to the complex environment of small sample data, incomplete information and nonlinear system, but also can effectively reveal the inner law hidden behind the data, which is a powerful tool to reveal the future trend of energy consumption.GM(1,1) model generates new data series by accumulating the original data, and establishes the one-time The cumulative data growth trend model is used for prediction, and the reverse operation recovers the original data series to get the prediction results. The steps of model construction and prediction are as follows:

3.1.1. Original Data and First-order Cumulative Series

The original series is the physical energy consumption data of rural households in Sichuan Province, which is a non-negative time series.

$$X_0 = \left(x_{(0)}(1), x_{(0)}(2), \cdots, x_{(0)}(n)\right) \tag{1}$$

The raw energy consumption data is added up once, and the raw data is transformed into:

$$X_1 = \left(x_{(1)}(1), x_{(1)}(2), \cdots, x_{(1)}(n)\right) \tag{2}$$

Thereinto, $X_1(i) = \sum_{j=0}^{i} x_{(0)}(j), (i = 1, \cdots, n)$.

3.1.2. Modeling Feasibility Analysis

Before constructing the GM(1,1) model, it is necessary to test the raw data and the first-order cumulative data, including the quasi-smoothness test, the quasi-exponential law test, and the step test, and if the correlation test is passed, the differential equation can be used to describe and construct a prediction model [15].

Quasi-smoothness test: $0 < x_{(0)}(k) / x_{(1)}(k-1) < 1, (k = 2, \cdots, n)$,then pass the test;

Quasi-exponential law test: $1 \le x_{(1)}(k) / x_{(1)}(k-1) \le 1.5, (k = 2, \cdots, n)$, then pass the test;

Grade test: $e^{-\frac{2}{n+1}} \le x_{(0)}(k) / x_{(1)}(k-1) \le e^{\frac{2}{n+1}}, (k = 2, \cdots, n)$, then pass the test.

3.1.3. GM(1,1) Model Construction

The specific form of the GM(1,1) model is:

$$\frac{dx}{dt} + ax = b \tag{3}$$

where a is the development coefficient and b is the endogenous control ash number, which can be calculated by the least squares method.

$$\begin{pmatrix} a \\ b \end{pmatrix} = (B^T B)^{-1} B^T y \tag{4}$$

thereinto $y=\left(x_{(0)}\left(2\right),x_{(0)}\left(3\right),\cdots,x_{(0)}\left(n\right)\right)^T$,

$$B=\begin{pmatrix} -z_{(1)}(2),1 \\ -z_{(1)}(3),1 \\ \cdots \\ -z_{(1)}(n),1 \end{pmatrix},\quad z_{(1)}(k)=0.5x_{(1)}(k-1)+0.5x_{(1)}(k),k=2,\cdots,n$$

From this, the discrete response formula for the GM(1,1) model is obtained:

$$\hat{x}_{(1)}\left(k\right)=\left(x_{(0)}\left(1\right)-\frac{b}{a}\right)e^{-a(k)}+\frac{b}{a},k=1,2,\cdots,n \tag{5}$$

Reducing the forecast values yields energy consumption forecasts:

$$\hat{x}_{(0)}\left(k\right)=\hat{x}_{(1)}\left(k\right)-\hat{x}_{(1)}\left(k-1\right),k=2,\cdots,n \tag{6}$$

When k <=n, it is the analog value of the original data; When k >n, it is called the predicted value of the model.

3.1.4. Model Accuracy Test

In the GM(1,1) model, the commonly used accuracy tests include "residual test", "posterior difference test", "gray correlation test", "step deviation test", "relative error size" and other methods. In this paper, the relative error size and residuals are used to verify the simulation accuracy of the model.

3.2. Markov Chain Model

3.2.1. The Basic Principle and Construction of Markov Chain

The basic principle of Markov forecasting is to predict future states using the current situation and trends of variables. When the state at time t is i and the state at the next moment is j, the formula for conditional probability can be expressed as:

$$P(X_{t+1}=j\mid X_t=i)=p_{ij} \tag{7}$$

where Pij is the one-step transition probability from state i to state j, referred to as the transition probability. When the Markov transition probability is independent of time t, then the Markov process is homogeneous and denoted as P=pij. For n random states, the transition matrix is:

$$P=(P_{ij})=\begin{bmatrix} p_{11} & p_{12} & p_{13} & \cdots \\ p_{21} & p_{22} & p_{23} & \cdots \\ p_{31} & p_{32} & p_{33} & \cdots \\ \vdots & \vdots & \vdots & \ddots \end{bmatrix} \tag{8}$$

thereinto , $p_{ij} \geq 0,(i,j=1,2,\cdots,n),\sum_{i=1}^{n} p_{ij}=1(i=1,2,\cdots,n)$.

The conditional probability $p_{ij}^{(k)}=P\{X_{t+k}=j \mid X_t=i\}$ is the k-step transition probability of the Markov chain, which refers to the probability of the system transitioning from i to state j after passing k steps, and $P^{(k)}=\left[p_{ij}^{(k)}\right]$ is the k-step transition matrix, when k=1, $p_{ij}^{(1)}=p_{ij}, P^{(1)}=P$.

3.2.2. Markov Chain Model of Rural Energy Consumption in Sichuan

The state of rural energy consumption structure at time t is $S_t=\left\{s_1(t), s_2(t), \cdots, s_n(t)\right\}$. Among them, $s_1(t), s_2(t), \cdots, s_n(t)$ indicates the proportion of N-class energy in the physical energy consumption of rural Sichuan at time t.Let us assume that the probability matrix of the one-step transfer of China's rural household energy consumption structure from time t to time t+1 is as follows:

$$P(t)=\begin{bmatrix} p_{1\to 1}(t) & p_{1\to 2}(t) & \cdots & p_{1\to n}(t) \\ p_{2\to 1}(t) & p_{2\to 2}(t) & \cdots & p_{2\to n}(t) \\ \vdots & \vdots & \vdots & \vdots \\ p_{n\to 1}(t) & p_{n\to 2}(t) & \cdots & p_{n\to n}(t) \end{bmatrix} \tag{9}$$

In $P(t)$, the main diagonal value represents the retention probability of the same energy source from time t to time t+1. With the exception of the main diagonal, the values on the rows represent the probability of the transfer of energy consumption from one type of energy to another, and the values on the columns represent the probability of the transfer of other energy sources to that type of energy. Since the Markov model assumes that the future state of the system depends only on the current state, it has nothing to do with the past state. Therefore, firstly, the one-step transfer matrix of energy structure in adjacent years is calculated, and the average transfer matrix is the average of multiple one-step transfer matrices, and then the average transfer matrix is used to predict the future energy structure. The steps to calculate the transition matrix of the energy consumption structure are as follows:

First, calculate the value of the energy retention probability: from time t to time t+1, if the share of a certain energy source increases, the retention probability is 1, and if the share decreases, the retention probability = the share of t+1 tick / the share of time t.

Second, calculate the value of other elements in a row with a retention probability of 1 for an energy source: retention probability = 1, then it is not transferred to other energy sources, and the transfer probability of other elements in the row is 0.

Third, calculate the value of other column elements with a certain energy retention probability less than 1: the retention probability is less than 1, and other energy sources have not been transferred to it, so the value of other column elements in the same column is 0.

Fourth, calculate the value of a non-zero element in the row where the probability of energy retention is less than 1. It is calculated as follows:

$$p_{x\to y}(t)=\frac{[1-p_{x\to x}(t)]\cdot[s_x(t+1)-s_x(t)]}{\sum_{i=1}^{x-1}[s_i(t+1)-s_i(t)]+\sum_{i=x+1}^{n}[s_i(t+1)-s_i(t)]} \tag{10}$$

where , $p_{x \to y}(t)$ indicates the proportion of X energy to Y energy (where the retention probability of X energy is less than 1, and the difference between Y energy at time T+1 and time T is not negative). $\sum_{i=1}^{x-1}[s_i(t+1)-s_i(t)]+\sum_{i=x+1}^{n}[s_i(t+1)-s_i(t)]$ represents the sum of the non-negative share difference between the non-negative shares of energy sources other than x at time T+1 and T time.

After calculating the one-step transfer matrix of energy structure in adjacent years, the mean value of multiple one-step transfer matrices is obtained to the average transfer matrix, and the future energy consumption structure is predicted by using it. The prediction formula is as follows:

$$S_{t+m} = S_t \cdot P^m \tag{11}$$

4. FORECAST OF COMMODITY ENERGY CONSUMPTION AND STRUCTURE OF RURAL HOUSEHOLDS IN SICHUAN

4.1. Forecast of Rural Electricity Consumption in Sichuan

At present, the commodity energy consumed by rural households in China includes coal, oil, natural gas, and LPG [3]. In this paper, the relevant data are collected through the China Energy Statistical Yearbook, and the data unit is unified into 10,000 tons of standard coal according to the reference coefficient of energy conversion to standard coal. The specific data is as follows:

Table 1. Commodity energy consumption of rural households in Sichuan Province from 2015 to 2021

year	coal	electricity	Natural gas	Liquefied Petroleum Gas	Energy Consumption
2015	257.82	172.65	59.98	9.09	499.54
2016	184.20	198.62	58.12	8.57	449.51
2017	105.90	219.01	55.59	9.26	389.76
2018	101.39	244.63	65.17	2.74	413.94
2019	71.93	255.05	75.94	2.93	405.86
2020	67.63	288.14	91.90	1.54	449.21
2021	65.11	299.03	111.45	0.79	476.38

Source: China Energy Statistical Yearbook.

It can be seen from Table 1 that the total rural commodity energy consumption in Sichuan Province did not show a continuous trend of change after 2015, but the electricity consumption showed a continuous downward trend, and the development trend was consistent, so the power consumption data from 2015~2021 was selected to construct the original energy consumption time series, and the data were processed and analyzed by PyCharm.

First, analyze the feasibility of the data. The GM(1,1) model was constructed for the electricity consumption of rural households, and the step ratio test was first carried out to judge the applicability of the data series for model construction. The grade ratio is the data of the previous period/the current period. The results showed that the test values of the scale were all within the standard range range [0.779, 1.284], which means that the data were suitable for the construction of GM(1,1) model.

Table 2. Model construction results

Development coefficient a	grey action b	posterior difference ratio c value	small error probability p value
-0.0815	180.2515	0.0121	1

Second, model building. As shown in Table 2, the development coefficient is a=-0.0815, and the endogenous control ash effect is b=180.2515. A posteriori error ratio of 0.012<0.35 means that the accuracy level of the model is very good. In addition, a small error probability p-value of 1.000>0.95 means that the model accuracy is good.

Table 3. GM(1,1) model test table

Year	Raw Value	Forecast Value	Residuals	Relative Error	Residual Grade Deviation
2015	172.65	172.65	0	0.00%	-
2016	198.62	202.463	-3.843	1.94%	0.057
2017	219.01	219.656	-0.646	0.30%	0.016
2018	244.63	238.309	6.321	2.58%	0.029
2019	255.05	258.546	-3.496	1.37%	-0.041
2020	288.14	280.502	7.638	2.65%	0.04
2021	299.03	304.322	-5.292	1.77%	-0.045

Thirdly, the relative error size and residuals verify the simulation accuracy of the model. As can be seen from Table 3, the maximum relative error value of the model is 0.027<0.1, which means that the fitting effect of the model meets the high requirements. For the grade deviation value, the value less than 0.2 means that the requirements are met, if it is less than 0.1, it means that the higher requirements are met, and the maximum value of the relative error value of the model is 0.057<0.1, which means that the fitting effect of the model meets the high requirements.

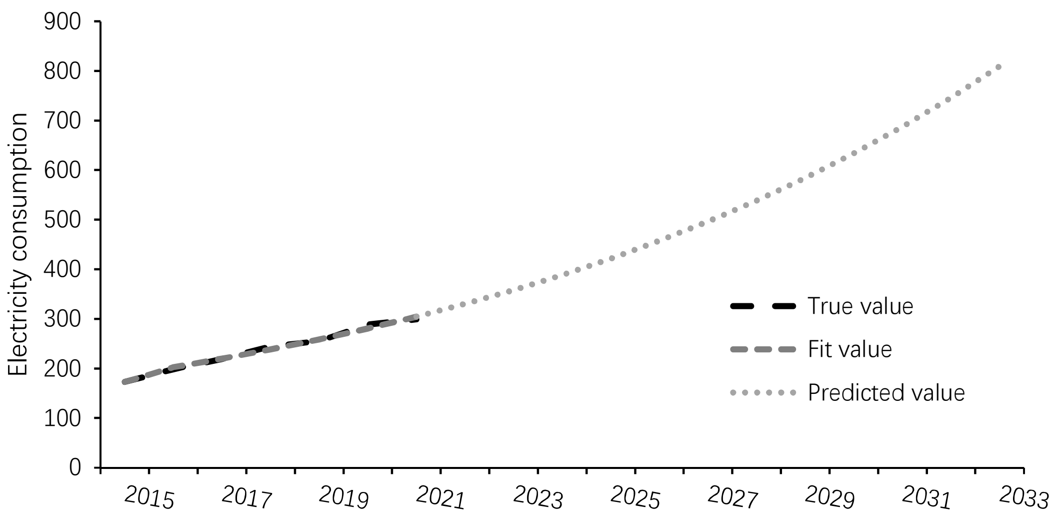

Figure 1. Electricity consumption model

Fourth, electricity consumption forecasting. As can be seen from Figure 1, the future electricity consumption data of rural households in Sichuan is predicted by using the tested model, and the electricity consumption is expected to continue to increase, and the predicted rural electricity energy consumption in Sichuan from 2022~2025 will be 330.166, 358.203, 388.622, 4.21624 million tons of standard coal, respectively.

4.2. Energy Structure Forecasting without Planning Constraints

According to the basic principle of Markov chain and the corresponding formula, the RyCharm editor was used to obtain the transfer probability matrix and average transfer probability matrix of each step of rural household commodity energy consumption in Sichuan from 2015 to 2021. The average transition probability matrix from 2015 to 2021 is shown in Table 4, which contains information on changes in the energy structure:

Table 4. Average transfer probability matrix of commodity energy consumption structure of rural households in Sichuan from 2015 to 2021 (%)

	Coal	Electricity	Natural gas	liquefied petroleum gas
Coal	80.66	25.09	2.89	0.12
Electricity	0.00	99.64	0.16	0.00
Natural gas	0.00	0.00	100.00	0.00
liquefied petroleum gas	0.00	20.99	25.36	70.61

The main diagonal represents the retention probability of energy for the 4 categories of commodities. Among them, the retention probability of natural gas is 100%, indicating that the energy share of natural gas continued to increase from 2015 to 2021. The retention probability of coal, electricity and liquefied petroleum gas is less than 100%, and the retention probability of electricity is the highest, which is 99.64%, indicating that with the improvement of residents' living standards, the number of cars and household appliances increases, and the corresponding electricity consumption increases year by year. The lowest is liquefied petroleum gas, with a retention probability of 70.61%.

Table 5. Forecast of commodity energy structure of rural households in Sichuan without planning constraints (%)

Year	Coal	Electricity	Natural gas	liquefied petroleum gas
2022	11.02	66.01	23.93	0.13
2023	8.89	68.57	24.39	0.11
2024	7.17	70.58	24.79	0.09
2025	5.78	72.15	25.13	0.07
2026	4.67	73.36	25.43	0.06
2027	3.76	74.28	25.70	0.05
2028	3.04	74.97	25.94	0.04
2029	2.45	75.47	26.16	0.03
2030	1.97	75.82	26.36	0.02

The first line of the average probability transfer matrix is the probability of coal retention and the probability of transfer to other energy sources. The probabilities of coal to electricity, natural gas and LPG were 25.09%, 2.89% and 0.12%, respectively, indicating that electricity contributed the most to the reduction of coal consumption. For the fourth row, there is the probability of retention of LPG and the probability of transfer to other energy sources, of which LPG has the largest share of electricity consumption, reaching 20.99%. In general, electricity consumption has the highest share of absorption of other energy sources, and electricity is convenient and efficient, can be used for all purposes, and is easier to replace other energy sources.

Based on the current situation of the energy structure and the average transfer probability matrix in 2021, the formula is used to predict the future commodity energy consumption structure of rural households in Sichuan, and the future commodity energy consumption structure of rural households in Sichuan is shown in Table 5.

Under the scenario without planning constraints, the share of electricity and natural gas energy consumption will increase, while the proportion of coal and liquefied petroleum gas will continue to decrease. From 2022 to 2030, the share of electricity consumption will grow from 66.01% to 75.82% at an average annual growth rate of 1.09%, and the share of natural gas consumption will grow from 23.93% to 20.36% at an average annual growth rate of 0.27%. The share of LPG consumption will fall below 0.1% in 2024, at 0.09%. At the same time, the share of coal consumption will drop to 1.97% in 2023, a decrease of 9.05% in nine years. In 2030 compared to 2021, the status quo of electricity as one of the dominant energy sources for household commodity energy consumption remains unchanged.

5. CONCLUSION AND PROSPECTS

Based on the development status and related consumption data of rural household commodity energy in Sichuan Province, this paper uses the gray prediction model and Markov model to predict the consumption and consumption structure of rural household commodity energy in Sichuan Province. It is estimated that in 2022~2025, the electricity consumption of rural households in Sichuan will be 330.166, 358.203, 388.622, 4.21624 million tons of standard coal, respectively. At the same time, the Markov chain is used to predict the consumption structure, and it is found that under the scenario of no planning constraints, the share of electricity and natural gas energy consumption will continue to increase, while the proportion of coal and liquefied petroleum gas will continue to decrease, and by 2030, the energy consumption shares of coal, electricity, natural gas and liquefied petroleum gas will be 1.97%, 75.82%, 26.36% and 0.02% respectively.

With the increase of energy consumption and structural changes, it is necessary to pay attention to environmental protection and sustainable development. Measures should be taken to reduce the environmental impact of energy consumption, such as promoting energy-saving technologies, strengthening pollution control and developing renewable energy. Government departments should formulate relevant policies to guide rural households to use energy rationally and promote the structural adjustment and optimization of energy consumption. At the same time, it is necessary to strengthen the supervision and management of energy consumption to ensure the effective use and equitable distribution of energy resources. In order to promote the sustainable development of rural household energy consumption, it is necessary to strengthen social and economic development, improve people's living standards, and strengthen education and publicity on energy consumption, and enhance public awareness and action on energy conservation and emission reduction.

REFERENCES

[1] ZHANG L X, WANG C B, BAHJ A S. Carbon emissions from rural energy in China [J/OL]. Renewable Energy, 2014, 66:641-649.

[2] JIANG L, XING R, CHEN X, et al. A survey-based investigation of greenhouse gas and pollutant emissions from household energy consumption on the Tibetan Plateau, China[J/OL]. Energy and Buildings, 2021, 235:110753.

[3] Hong ZG. Assessment of energy saving potential of household energy consumption and clean renewable energy in rural China [D/OL]. Lanzhou University, 2021 [2024-05-04].

[4] GALVIN R, SUNIKKA-BLANK M. Economic Inequality and Household Energy Consumption in High-income Countries: Challenges for Social Science-based Energy Research [J/OL]. Ecological Economics, 2018, 153:78-88.

[5] CHUNG W, KAM M S, IP C Y. A study of residential energy use in Hong Kong by decomposition analysis, 1990-2007 [J/OL]. Applied Energy, 2011, 88(12): 5180-5187.

[6] JIANG Zh, DAI Yu, LUO Xu, et al. Bioenergy development potential for rural household energy consumption and its environmental impact assessment: a case study in Shandong, China[J/OL]. Renewable and Sustainable Energy Reviews, 2017, 67: 1153-1161.

[7] JOYEUX R, RIPPLE R D. Household energy consumption versus income and relative standard of living: a panel approach[J/OL]. [7] JOYEUX RIPPLE R D. Household energy consumption versus income and relative standard of living: a panel approach[J/OL].

[8] MIAH Md D, KABIR R R M S, KOIKE M, et al. Rural household energy consumption patterns in neglected villages of Bangladesh [J/OL]. Energy Policy, 2010, 38(2): 997-1003.

[9] San V, Spoann V, Ly D, et al. Fuelwood consumption patterns in Chumriey Hill, Kampong Chhnang Province, Cambodia [J/OL]. Energy, 2012, 44(1): 335-346.

[10] LEKVEISHVILI G. Data on household energy consumption in small urban & rural settlements of Georgia[J/OL]. Data in Brief, 2019, 24: 103859.

[11] ZHANG M, GUO F. Analysis of rural residential commercial energy consumption in China[J/OL]. Energy, 2013, 52: 222-229.

[12] Cong Hongbin, Zhao Lixin, Wang Jiuchen, et al. Analysis of the current situation and development demand of energy production and consumption in rural China [J]. Transactions of the CSAE, 2017, 33(17): 224-231.

[13] JIANG L, XUE B, XING R, ET AL. Rural household energy consumption of farmers and herders in the Qinghai-Tibet Plateau[J/OL]. Energy, 2020, 192: 116649.

[14] Wang Fang, Li Xia, Chen Jianfei, et al. Spatial optimization decision of intensive utilization of farmland biomass energy[J]. Transactions of the CSAE, 2009, 25(9): 232-236.

[15] Wang Huilei. Application Example of Prediction Method Based on MATLAB and GM(1,1) Model[J]. Modern Computer(Professional Edition), 2015(5): 44-47.