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The long-term forecast of and energy demand with leap model Based on Scenario Analysis: A case of Beijing

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Abstract

As the capital city of China, the energy demand prediction of energy consumption departments has been a topic of concern in recent years. In terms of population growth and dwindling fossil fuel resources, energy demand forecasts are the most closely watched in history. In this paper, the demand for electricity, natural gas, oil, coal and heat for all economic sectors in Beijing is forecasted. Two energy demand forecasting methods were used, namely the Holt-Winters exponential smoothing method and the LEAP model. Estimates for each method were compared using annual energy demand data. The results of this study show that compared with the Holt-Winter model, the comprehensive electric energy replacement scenario set in LEAP is more suitable for the energy demand prediction of Beijing.

Keywords

Holt-Winters exponential smoothing method, Energy forecast, Long Range Energy Alternative Program,The Beijing municipal.

1. Introduction

China's new era and its journey require China's energy industry to accelerate the energy production and consumption revolution deeply, to build clean low-carbon, safe and efficient energy system. To this end, the Chinese government has introduced a number of relevant policies, including environmental protection law, renewable energy law, energy conservation law, etc., as a powerful support for the energy production and consumption revolution. Since the reform and opening up, China's energy consumption has been rising along with the economic growth. In 2010, China became the world's largest energy consumer. Energy consumption has been controlled and sustained decline due to policies such as energy conservation, emission reduction and environmental protection, but energy demand is still large. In particular, China is still in the process of urbanization, energy demand may be further rebound, which directly affect the pace of China's energy structure adjustment. Therefore, energy demand is still the focus of our country's focus areas, and energy demand forecast has become a key point.

Beijing has a total area of 16,410.54 square kilometers and is located in the northern part of the North China Plain, backed by Yanshan and close to Tianjin and Hebei provinces. It is the lifeblood of China's economic, political and cultural development. In recent years,the resident population of Beijing has gained a certain degree of growth. The resident population of Beijing in 1978 was 8.715 million, and by 2017 it had grown to 21.707 million. Since the 1980s, family planning has always been a basic national policy. In the face of continued population pressure, a new round of planning for Beijing in 2035 has put forward a strict requirement of 23 million people on the population scale.

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Beijing's economy has developed rapidly over the past 30 years. The regional GDP of Beijing as of 2017 is 280.04 billion yuan, and the per capita GDP is 129,000 yuan. The primary industry accounted for 0.4%, the secondary industry accounted for 19.0%, and the tertiary industry accounted for 80.6%. Since 2010, Beijing's GDP growth rate has remained at around 7%. In order to support this development, a large and growing amount of energy is being consumed.

Beijing's energy use faces dual pressures of economic growth and environmental protection [1], but its energy efficiency ranks first in the country and steadily increases. On the one hand, the continuous drastic decline in industrial energy consumption directly inhibits the growth of energy consumption. On the other hand, the implementation of the Clean Air Action Plan has improved the efficiency of energy use. Beijing's clean and low-carbon energy consumption structure has taken shape. The ratio of traditional energy consumption such as coal has declined significantly, and the proportion of clean energy has continued to rise.

During the period of "Twelfth Five-Year Plan", the balance contradiction of energy region still exists under the influence of national economic development on the sustained growth of energy demand. Although energy supply basically meets Beijing's energy development needs, some energy varieties will also suffer from tight supply due to factors such as source production capacity, extreme climate, and market changes [2018-2025 China Beijing Energy Industry Development Status Survey And Development Trend Analysis Report]. Therefore, energy supply also needs to be forecasted based on factors such as market changes in order to make real-time adjustments.

The realistic forecast of energy demand may be the first key step for governments to formulate appropriate strategic plans and allocate appropriate resources for various activities to meet future energy demand [2]. Energy planning needs to understand past, present, and future energy consumption [3], and it needs good predictive measures to support it. This paper describes the current situation and recent trend of energy supply and demand in Beijing, constructs two scenarios, forecasts the long-term energy demand of Beijing with the help of leap model, compares and analyzes the prediction results of the two models, and finally draws a conclusion.

2. Beijing's energy situation

2.1. Energy demand

Energy consumption has increased significantly in recent years, but different energy categories show a variety of trends. According to the Beijing Statistical Yearbook issued by the Beijing Municipal Bureau of Statistics, the share of coal products in total energy consumption fell from 29.59% in 2010 to 9.81% in 2016. The consumption of specific energy categories is shown in Table 1.

Table 1: Energy consumption by fuel group(units: 10,000 tons), 2010-2016
Source: Beijing Municipal Bureau of Statistics, Survey Office of the National Bureau of Statistics in Beijing: Beijing Statistical Yearbook

Energy category/ Year	2010	2011	2012	2013	2014	2015	2016
Raw coal	2415.41	2358.98	2264.79	2011.71	1728.25	1153.57	841.81
Cleaned coal	220.52	13.17	14.34	12.34	10.05	8.71	0.02
Coal products	34.62	29.73	27.25	22.23	17.75	17.08	6.22

Coke	220.45	33.28	32.27	0.79	0.64	0.44	0.21
Crude oil	1116.29	1105.08	1075.77	870.92	1034.62	991.54	821.00
Gasoline	371.53	389.79	415.90	423.61	440.62	462.75	470.37
Kerosene	392.63	419.88	443.33	477.06	507.58	544.38	594.27
Diesel	237.42	241.12	215.82	193.90	196.46	182.35	172.69
Fuel oil	66.69	74.64	78.16	8.30	5.63	4.91	4.64
Naphtha	188.52	191.25	176.08	127.95	130.01	156.55	202.87
Lubricating oil	1.61	25.20	25.22	1.37	1.24	0.97	1.21
Paraffin	0.12	0.14	0.18	0.77	0.38	0.23	0.21
Solvent oil	0.03	0.08	0.10	0.35	0.08	0.09	0.05
Asphalt	23.26	21.93	19.52	25.37	19.15	15.00	15.80
Petroleum coke	31.13	29.04	25.84	23.20	25.77	19.50	21.47
LPG	46.21	48.64	45.67	45.23	50.37	51.15	49.47
Refinery dry gas	74.16	74.33	79.12	65.33	58.12	76.41	69.01
Natural gas	598.32	588.48	736.56	790.48	909.60	1162.96	1282.40
LNG						10.91	14.60
Electricity	1021.18	1049.17	1120.77	1116.79	1147.16	1169.09	1253.89

The total energy consumption of Beijing's energy consumption sector in 2010 was 63,594,900 tons of standard coal, and it increased to 69.617 million tons of standard coal in 2016. The total energy consumption by energy category in 2010-2016 (Table 2) shows that 30% of the energy demand is provided by oil products, and the trend of proportion is relatively stable, with the second largest share of primary power. However, the declining trend of coal product is obvious, which originates from China's policy of restricting coal products in recent years.

Table 2: Total energy consumption by energy category, 2010-2016

Year	Total energy consumption (10,000 tons of standard coal)	Share of total energy consumption (%)					
		Coal products	Oil products	natural gas	primary power	Net power transfer (+) and call-out (-)	Other energy
2010	6359.49	29.59	30.94	14.58	0.45	24.35	0.09
2011	6397.30	26.66	32.92	14.02	0.45	25.62	0.33
2012	6564.10	25.22	31.61	17.11	0.42	25.38	0.26
2013	6723.90	23.31	32.19	18.20	0.35	24.99	0.96
2014	6831.23	20.37	32.56	21.09	0.41	24.03	1.54
2015	6852.55	13.68	33.54	28.97	0.40	21.55	1.86
2016	6961.70	9.81	32.93	31.68	0.66	23.20	1.72

In all sectors, the industrial sector has always occupied the largest proportion, and the energy demand of different industrial sub-sectors will also be affected by economic conditions. The

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agricultural sector accounts for the smallest share, only a few percent. Due to the increase in national income, the development of public transportation networks and the popularity of automobiles, the energy demand of the transport sector has increased. At the same time, with the improvement of the national standard of living and the rapid development of the tertiary industry, the energy demand in the residential and commercial sectors has increased dramatically. The structure of Beijing's energy demand by sector in 2016 shows that the current energy demand of various sectors.

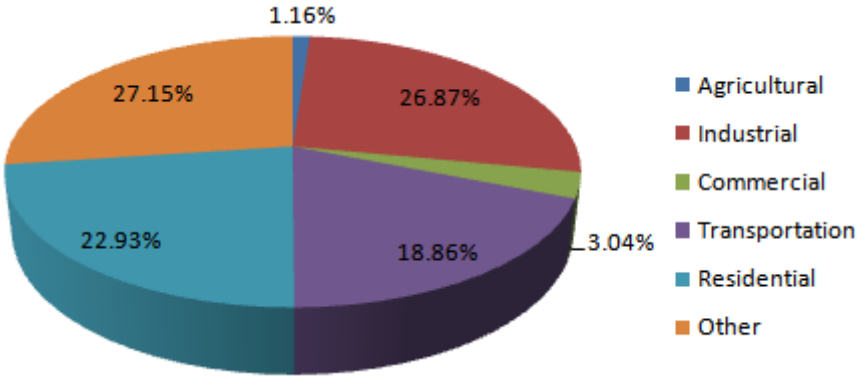

Figure 1: The structure of Beijing's energy demand by sector, 2016

2.2. Energy supply

In recent ten years, the primary energy supply of Beijing gradually decreased from 6.796 million tons of standard coal in 2005 to 4.458 million tons of standard coal in 2016, among which the raw coal supply decreased from 9.452 million tons to 317.6 million tons. The main channel of energy supply is heating, accounting for nearly 70%. The supply of secondary energy showed an overall upward trend, but fell slightly during the period, which was largely attributed to the implementation of the government's energy conservation and emission reduction policies. The variation trend of specific energy supply is shown in Figure 2.

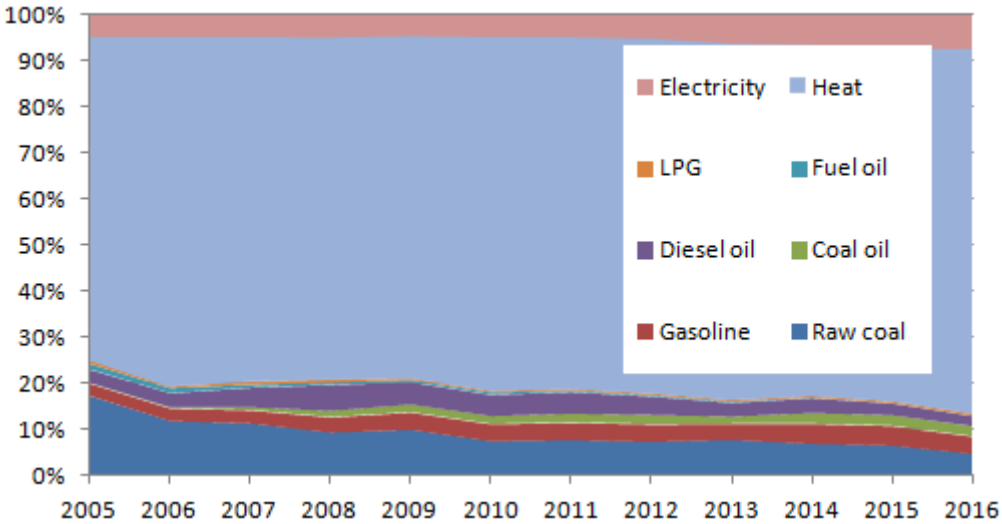

Figure 2: Changes trends in main energy supply, 2005-2016

2.3. Economic growth and energy consumption

The energy consumption of a country is related to its economic development stage and energy development model. There is a close positive correlation between energy consumption and economic development. As China's energy key development center, the related relationship of Beijing is even more pronounced. Therefore, it is very important to analyze the trend of

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economic development and energy consumption in Beijing to forecast the change of China's energy structure.

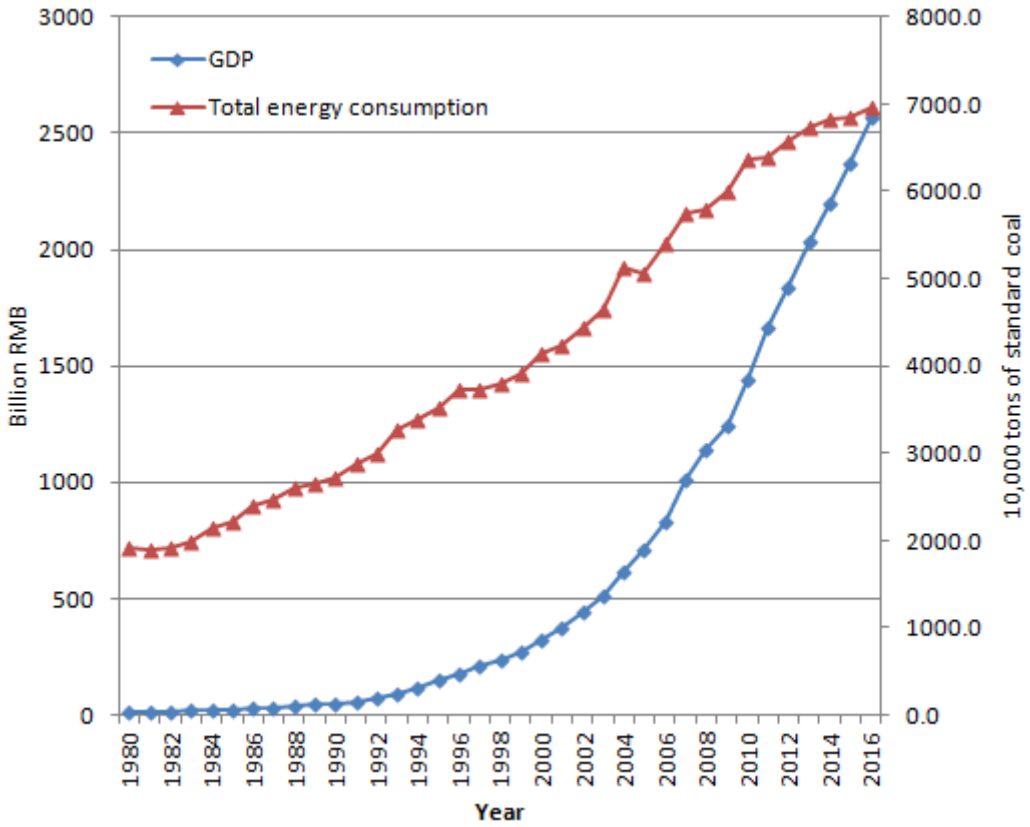

Figure 3: Plot of GDP and energy consumption.

As shown in Figure 3, Beijing's overall GDP remained stable during 1980-1994, and the growth rate of energy consumption also remained stable. In 2004, economic growth slowed down, leading to negative growth of energy consumption. After 2005, economic growth continued to heat up, and energy consumption also continued to grow.

In order to prove the relationship between economic development and energy consumption, many scholars have conducted in-depth research. Guo [4], Kose et.al [5], Zhang [6], Payne and Taylor [7], Aboagye [8] and others have made a detailed explanation of the relationship between economic growth and energy consumption by using Cobb Douglas production function method based on ECM, grey correlation analysis, state space model, neoclassical production function method, etc.

In addition, there is also a correlation between energy demand and economic development. Turkey [9], Malaysia [10], Bangladesh [11] and other countries respectively use genetic algorithm energy demand model (GAEDM), expanded production function method and maximum entropy guidance method to verify the close relationship between economic growth and energy demand.

3. Methods and scenarios

3.1. The LEAP model

LEAP, the Long-range Energy Alternatives Planning System, is a widely-used software tool for energy policy analysis and climate change mitigation assessment. Many scholars previously used LEAP for energy research. In the analysis of energy system planning, many countries and regions have conducted the research,such as the United States National Research Program (USCS) [12], Mexico [13], China [14], Taiwan [15], Turkey [16], Rawalpindi and Islamabad [17].

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In the analysis of various industry sectors, there have been advances in studies of power generation [18], transportation [19], industry [20], and residential [21]. In the analysis of energy demand forecasting, Nigeria [22], Pakistan [23], Iran [24], India [25], Philippines [26] and other countries combined national policies and energy development to make future energy demand forecasts.

We use the LEAP model to predict future energy demand in Beijing and discuss the implications of national energy policies. The data used in the model were all public data, reports and statistical yearbooks in Beijing, and were supplemented according to the analysis structure of the LEAP model. The main energy sectors involved in this model are: residential, industrial, transportation, commercial and agricultural. In the set of LEAP models, we create different scenarios to highlight the difference in energy policy.

3.1.1. Structure of the LEAP model

In order to improve the reliability of the prediction results, 2015 with comprehensive data is selected as the base year, and the energy demand module of leap model is used to predict and analyze the energy demand of Beijing under different scenarios. According to the current general division of energy consumption sector, the energy consumption sector is divided into four sectors: the first industry, the second industry, the third industry and residents' life. Beijing's leap model takes 2016 as the base year and 2017-2035 as the forecast period, covering all sectors of energy terminal demand, processing conversion and resource supply, forming a closed and balanced energy system. Among them, the demand module includes the variety and quantity of energy demand of each end consumer sector in the national economic system; the conversion module includes the intermediate links of energy processing, conversion, transportation, storage and distribution; the resource module includes primary and secondary energy supply [27]. The specific leap model structure of Beijing is shown in Figure 4.

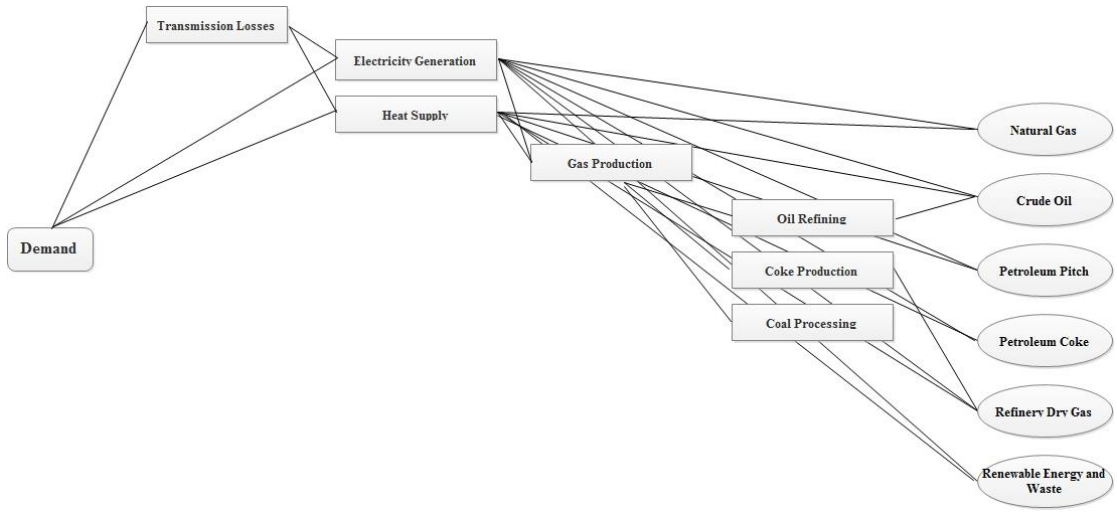

Figure 4:The structure of leap model in Beijing

3.1.2. Calculations

The total terminal energy demand is the sum of the energy demand of each department, which is obtained by multiplying the activity level of each department with the energy intensity. The specific formula is as follows.

$$ED(t) = \sum_i ED_i(t) \quad (1)$$

$$ED_i(t) = \sum_j AL_i(t) EI_i(t) \quad (2)$$

Where, $ED(t)$ is the terminal energy demand in year t. $AL_i(t)$is the production activity level of the i-th sector in year t or the population of Beijing in year t. $ED_i(t)$is the energy intensity of the i-th sector in year t, that is, the energy demand per unit activity level [28].

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3.2. Alternative scenarios

3.2.1. BAU: Business As Usual scenario for Beijing

The Business As Usual (BAU) analyzes how Beijing's energy demand will evolve (to 2035) in the absence of significant new policies. The BAU scenario includes historical energy consumption and production from 1980 to 2010 and is projected to 2035.

In this paper, we make the following assumptions: Based on the overall assumption of the economic growth level of Beijing and with the increase of income level, the activity level of each consumption sector (industry, housing, agriculture, transportation) can be predicted in priority.In this case, basic assumptions about population and per capita disposable income are required. According to the historical experience and the prediction of multi-level algorithm, the change trend of population and per capita disposable income in the next 20 years can be predicted (Figure 5).

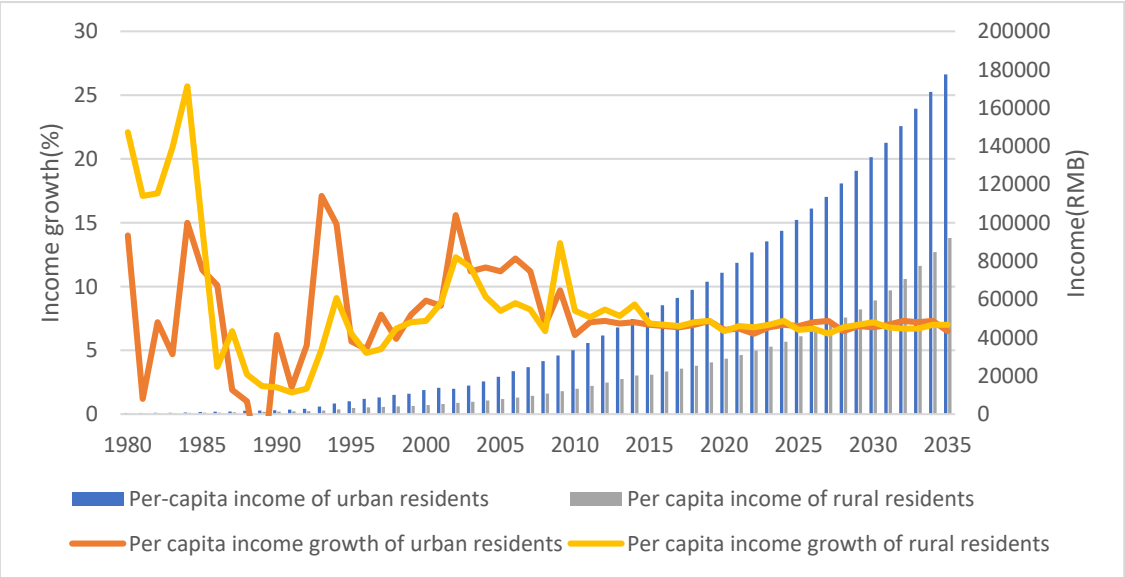

Figure 5:Trend of population and per capita disposable income from 1980 to 2035

As can be seen from Figure 5, the growth rate of disposable income of urban residents and rural residents gradually tends to be stable, and the level of disposable income will continue to grow rapidly.

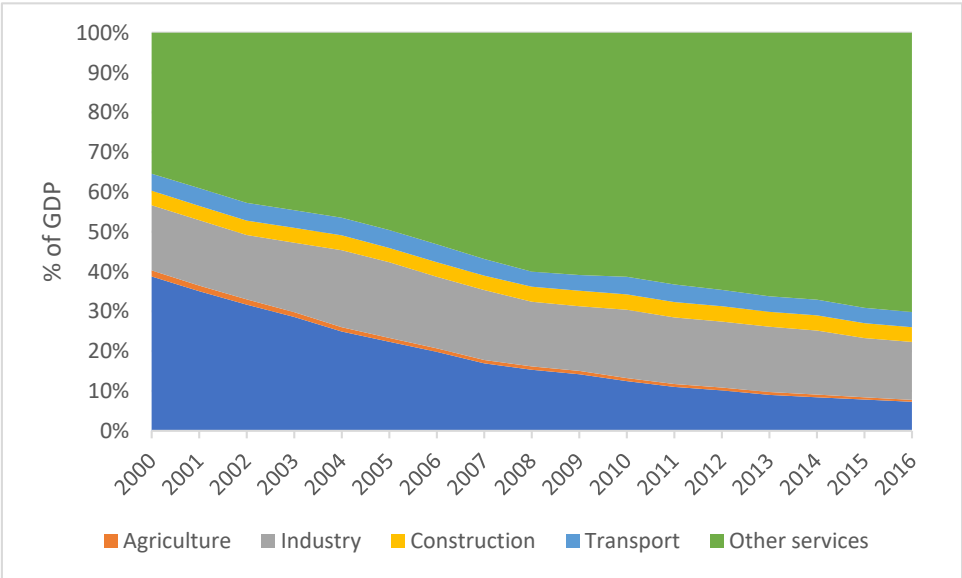

Figure 6:Proportion of GDP of various industries in Beijing from 2000 to 2016

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According to the proportion of the GDP of various industries in Beijing from 2000 to 2016 (Figure 6), it can be seen that the proportion of the share of agriculture in GDP under the BAU scenario is low and on a downward trend, and the trend is expected to remain unchanged in the next 20 years. The trend of change of industry share is not obvious, still account for a large proportion. However, as an emerging industry, the service industry has a good momentum of development and is on the rise as a whole. These data are used to calculate the GDP share of the major sectors so that the GDP estimates can be distributed among the energy consumption sectors. However, this estimate is not certain, and the GDP share of the three industries may change, which still needs further study.

As can be seen from Table 3, the proportion of energy consumption in the agricultural sector in 2016 was very low, with only 1.16%. The industrial sector still accounts for a large proportion, and the service industry, as an emerging industry, has greatly improved compared with the previous years. Life consumption is still an important consumption sector of energy consumption. With the increase of vehicle ownership in recent years, the energy consumption of the transportation sector is also gradually increasing.

Table 3: The proportion of energy consumption sectors

Sectors	Sub-sector	BAU consumption share(%)
Agriculture, forestry, animal husbandry and fishery	Agriculture, forestry, animal husbandry and fishery	1.16
Industry	Mining	0.21
	Agricultural and sideline products processing industry	0.33
	Food manufacturing	0.42
	Wine, beverage and refined tea manufacturing	0.36
	Textile industry	0.05
	Textile and clothing industry	0.17
	Leather, fur, feather and their products and shoemaking industry	0.02
	Wood processing and wood, bamboo, rattan, palm and grass manufacturing	0.04
	Furniture manufacturing industry	0.11
	Paper and paper products industry	0.14
	Printing and recording media reproduction industry	0.32
	Culture and education, arts and crafts, sports and entertainment products manufacturing industry	0.05
	Petroleum processing, coking and nuclear fuel processing industries	5.95
	Chemical raw materials and chemical products manufacturing	1.29

	Pharmaceutical manufacturing	0.51
	Chemical fiber manufacturing industry	0.02
	Rubber and plastic products industry	0.32
	Non metallic mineral products industry	1.85
	Ferrous metal smelting and calendering industry	0.30
	Nonferrous metal smelting and calendering industry	0.08
	Metal products industry	0.43
	General equipment manufacturing	0.41
	Special equipment manufacturing industry	0.31
	Automobile manufacturing industry	1.67
	Railway, shipping, aerospace and other transportation equipment manufacturing industry	0.23
	Electrical machinery and equipment manufacturing industry	0.30
	Computer, communication and other electronic equipment manufacturing industry	1.19
	Computer, communication and other electronic equipment and instrument manufacturing industry	0.11
	Other manufacturing industries	0.10
	Comprehensive utilization of waste resources	0.02
	Metal products, machinery and equipment repair industry	0.06
	Production and supply of electricity, gas and water	7.75
	Power and heat production and supply	5.58
	Gas production and supply	1.50
	Water production and supply	0.66
	Construction industry	1.72
Service industry	Wholesale and retail	3.04
	Accommodation and catering	4.02
	Information transmission, software and information technology services	2.60
	Information transmission, software and it Finance	0.93
	Real estate industry	5.52
	Leasing and business services	2.95
	Scientific research and technology services	2.75

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	Water conservancy, environment and public facilities management	0.90
	Residential services, repair and other services	0.45
	Public administration, social security and social organizations	1.59
	Other	5.45
Living consumption	Town	19.27
	Countryside	3.66
Communications and transportation industry	Transportation, storage and postal services	18.86

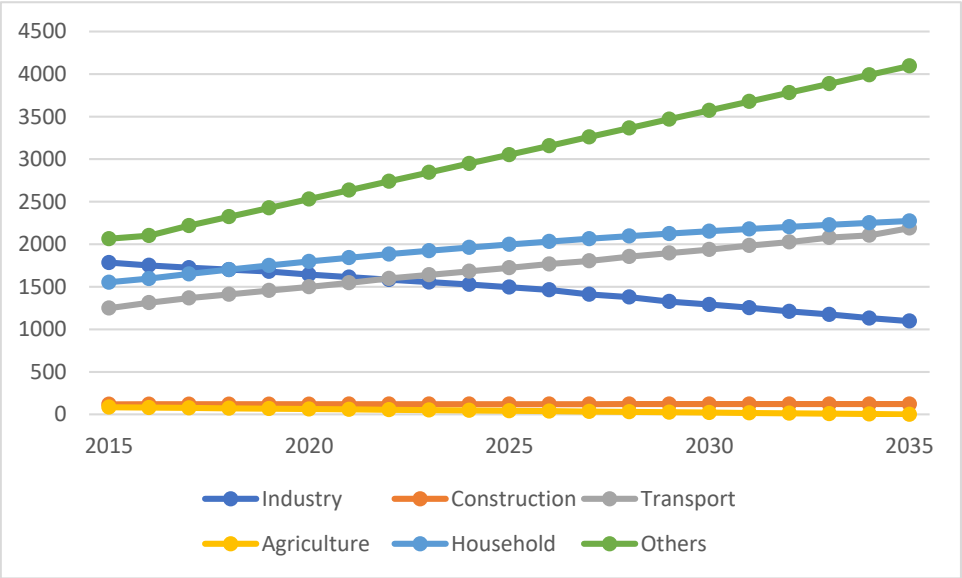

Figure 7: Final energy demand by sector in the BAU scenario.

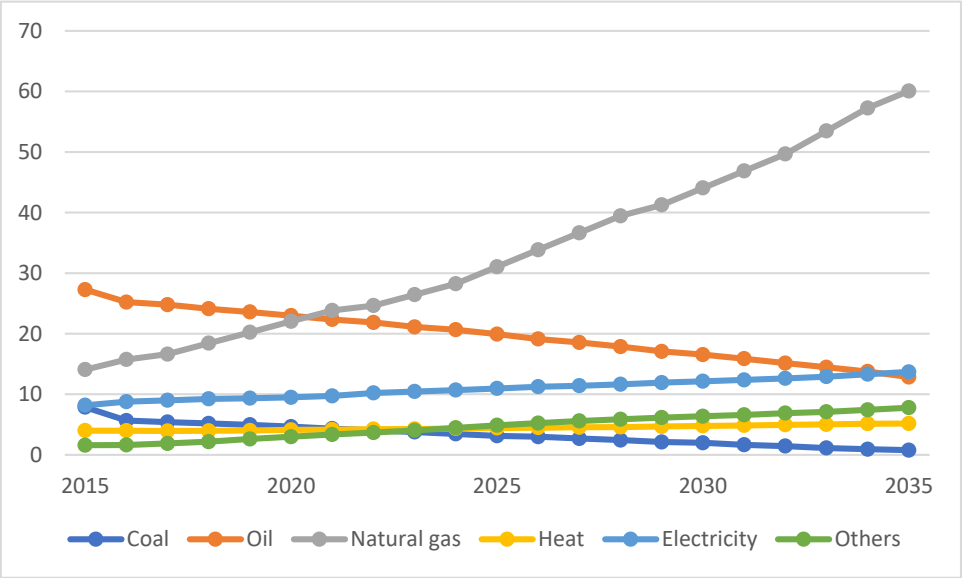

Figure 8: Final energy demand by fuel in the BAU scenario

Figure 7 and Figure 8 summarize the final energy demand under the baseline scenario, showing the projected energy demand data for the entire industry and fuel in Beijing, broken down into

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key sectors. Noting the growing importance of natural gas and electricity products, as well as the continued decline in oil products, the continued dominance of the industrial sector and the rapid growth of the transport sector.

3.2.2. ES: Electricity substitution scenario for Beijing

Electric energy substitution is in the terminal energy consumption link, the use of electric energy to replace coal, oil products of energy consumption.Due to the advantages of clean, safe and convenient electric energy, and the central position of electric energy in the energy system, the terminal energy consumption can be replaced by electric energy.Therefore, the implementation of electric energy substitution is of great significance to promote the revolution of energy consumption, implement the national energy strategy, and promote the clean development of energy. Therefore, many policies put forward new requirements for electric energy substitution.Starting from the high requirements of promoting the coordinated development of Beijing, Tianjin and Hebei and controlling air pollution, Beijing State Grid implements the development strategy of national electric energy substitution, speeds up the pace of replacing coal and oil with electricity, and provides clean energy supply for Beijing from new energy installation to grid connection of distributed generation, so as to help the work of energy conservation and emission reduction.

(1)Replacing Coal with Electricity(RCE)

China's air pollution is serious. Due to the large use of coal products and high emission intensity per unit, it is the consensus of the whole society to strengthen the control of coal products and vigorously promote the substitution of electricity for coal. The serious haze in China in recent years is mainly caused by the rapid growth of total energy consumption, the coal based energy consumption structure, the continuous expansion of thermal power scale in eastern and central China, the increase in the number of motor vehicles and other factors. In essence, it is the problem of energy development mode and the result of the concentrated exposure of deep-seated structural spear shield.

In the scenario of RCE, the consumption of coal products is gradually reduced, and the consumption of electricity is gradually increased. By 2035, the consumption of coal products will be greatly reduced, and the consumption of electricity will become the mainstream, and the air pollution will be effectively improved.

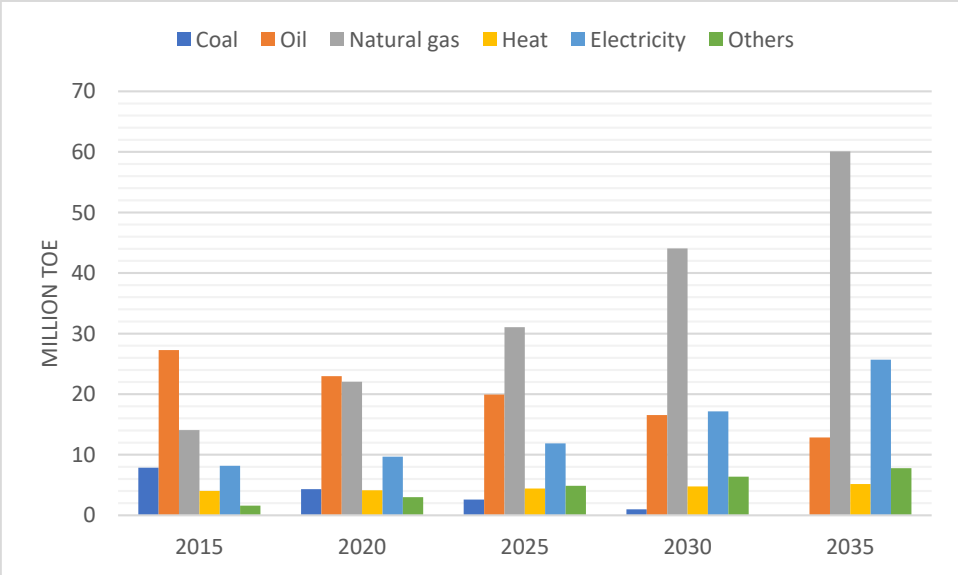

Figure 9: Forecast results of energy demand by fuel under RCE scenario

(2) Replacing Petroleum with Electricity(RPE)

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Replacing oil with electricity in the fields of railway, urban rail transit and automobile transportation, improving the level of transportation electrification can reduce oil consumption, adjust the energy consumption structure, promote the efficient utilization of energy in the transportation industry and reduce environmental pollution. It can be seen from Figure 10 that the decrease of oil product year by year translates into the increase of electricity consumption.

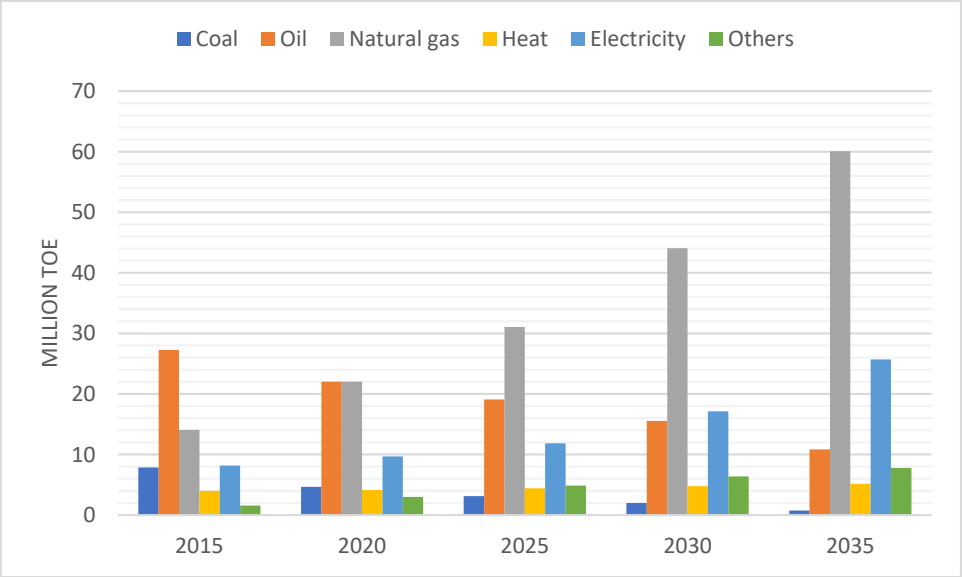

Figure 10: Forecast results of energy demand by fuel under RPE scenario

(3) Comprehensive Electricity Substitution (CES)

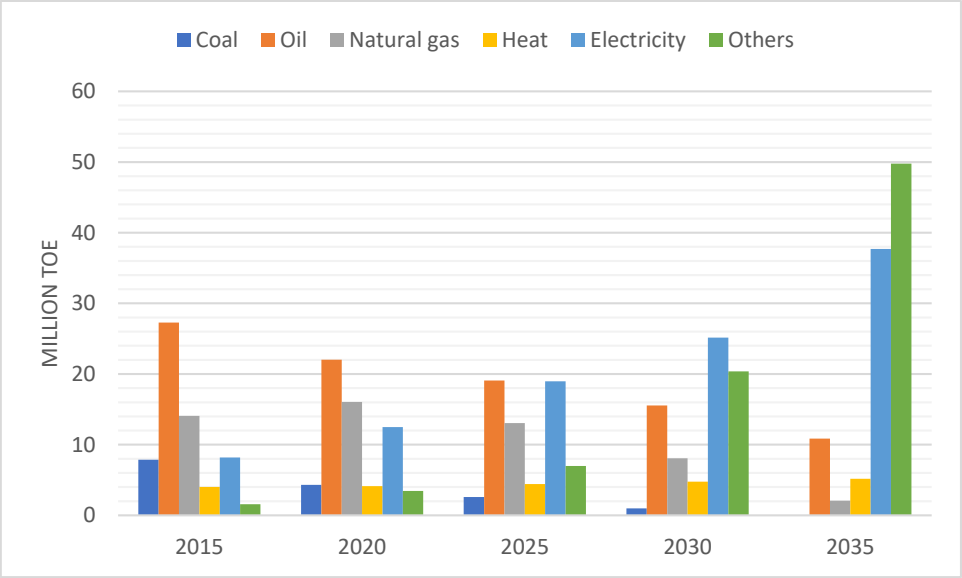

Figure 11: Energy demand forecast results by fuel under CES scenario

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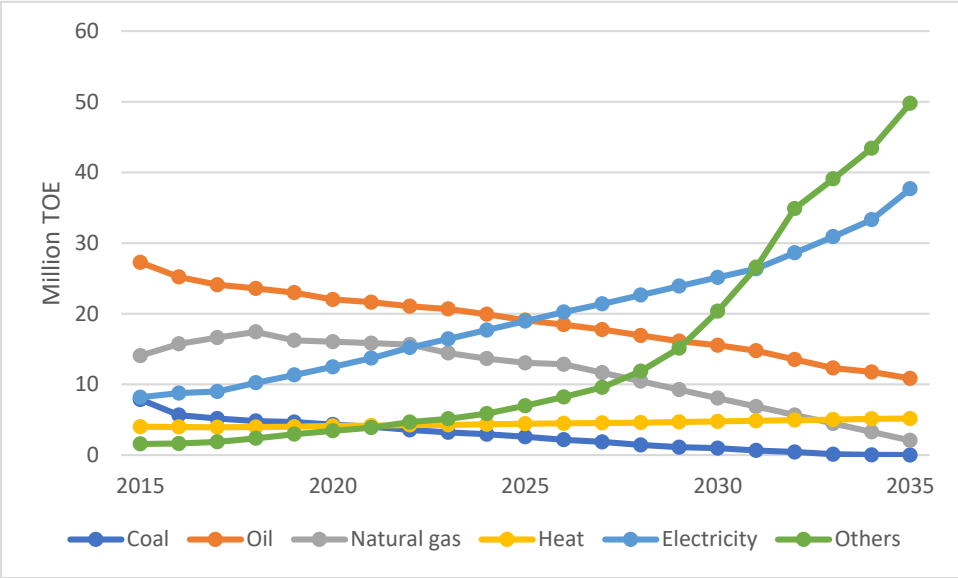

Figure 12: Energy demand forecast trend by fuel under CES scenario

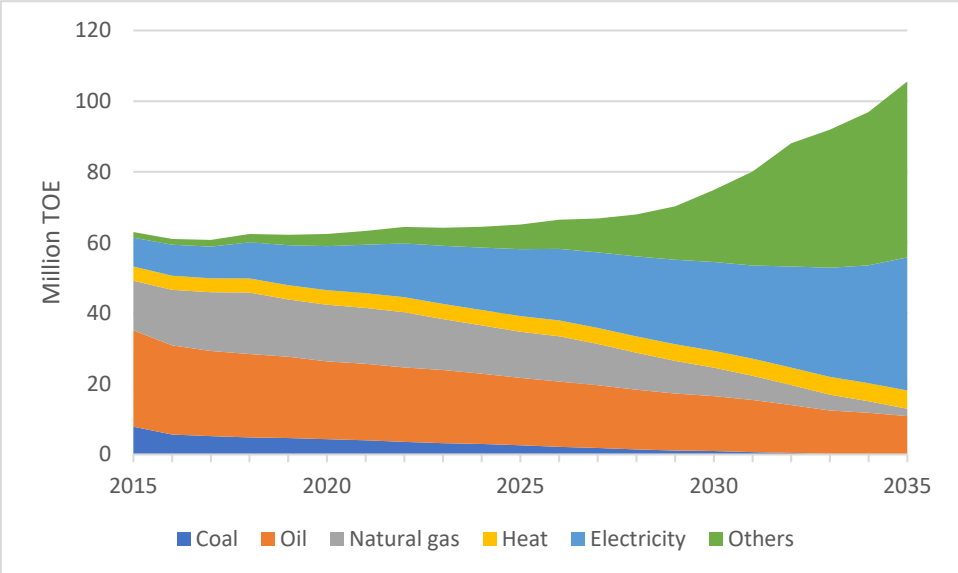

Figure 13: Energy demand ratio by fuel under CES scenario

As can be seen from the above figures, with the implementation of the electricity substitution policy, the energy demand of coal, oil and natural gas decreases while the demand of electricity increases. The three figures can clearly show the development trend of each energy source.

4. Holt Exponential Smoothing Approach

According to the Yearbook of Beijing Municipal Bureau of Statistics, Holt-Winter method was used to make the prediction. HOLT exponential smoothing method is a time series forecasting method with increasing or decreasing trend and no seasonally additive model. Holt exponential smoothing method can estimate the level of the current time and the slope, the smooth level is controlled by two parameters, namely, α and β. α is used to estimate the current level of β is used to estimate the current trend of a part of the slope, both parameters between 0 and 1. When the parameters of the closer to 0, the most recent observations of weights will be smaller. If the parameter is close to 1, the weight of much of the recent observations will be larger. Generally, Holt exponential smoothing method has three equations [29].

$$\text{Level: } a_t = \alpha Y_t + (1-\alpha)(a_{t-1} + b_{t-1}) \quad (3)$$

$$\text{Trend: } b_t = \beta(a_t - a_{t-1}) + (1-\beta)b_{t-1} \quad (4)$$

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$$\text{Prediction: } Y_{t+h} = a_t + b_t(h) \tag{5}$$

Holt-Winter index smoothing method is a short-term forecasting method with trend and seasonal pattern [30], which requires three smoothing components, namely horizontal component, trend component and seasonal component [31]. Its basic equation is as follows.

$$a_t = \alpha(Y_t - s_{t-p}) + (1-\alpha)(a_{t-1} + b_{t-1}) \tag{6}$$

$$b_t = \beta(a_t - a_{t-1}) + (1-\beta)b_{t-1} \tag{7}$$

$$s_t = \gamma(Y_t - a_t) + (1-\gamma)s_{t-p} \tag{8}$$

Where, α, β and γ is the smoothing parameter, a_t is the smoothing level at time t, b_t is the change of trend at time t, s_t is the seasonal smoothing at time t, and p is the number of seasons each year. We use the above formula to calculate the predicted value of Holt-winter. Therefore, the prediction formula for the time period t+h is as follows.

$$Y_{t+h} = a_t + hb_t + s_{t-p+h} \tag{9}$$

Figure 14 and Figure 15 show the proportion of energy demand in each sector. It can be seen that the energy demand in the sector of living consumption keeps a small range and continues to increase. The energy demand of the transportation and agricultural sectors remained stable, but its proportion gradually decreased. The energy demand of industry and construction industry gradually decreases, while the demand of other sectors gradually increases, which is reflected in the continuous increase of energy demand of tertiary industry due to the rise of new service industry.

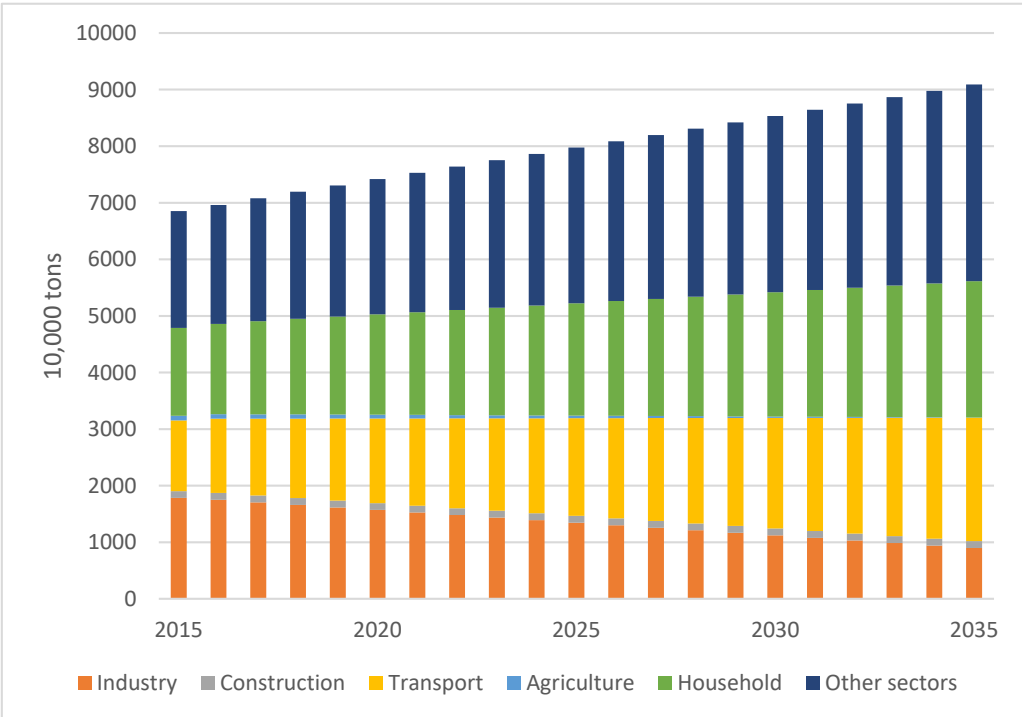

Figure 14: Smooth forecast results of the Holt-Winters Index (percentage of energy demand by sector)

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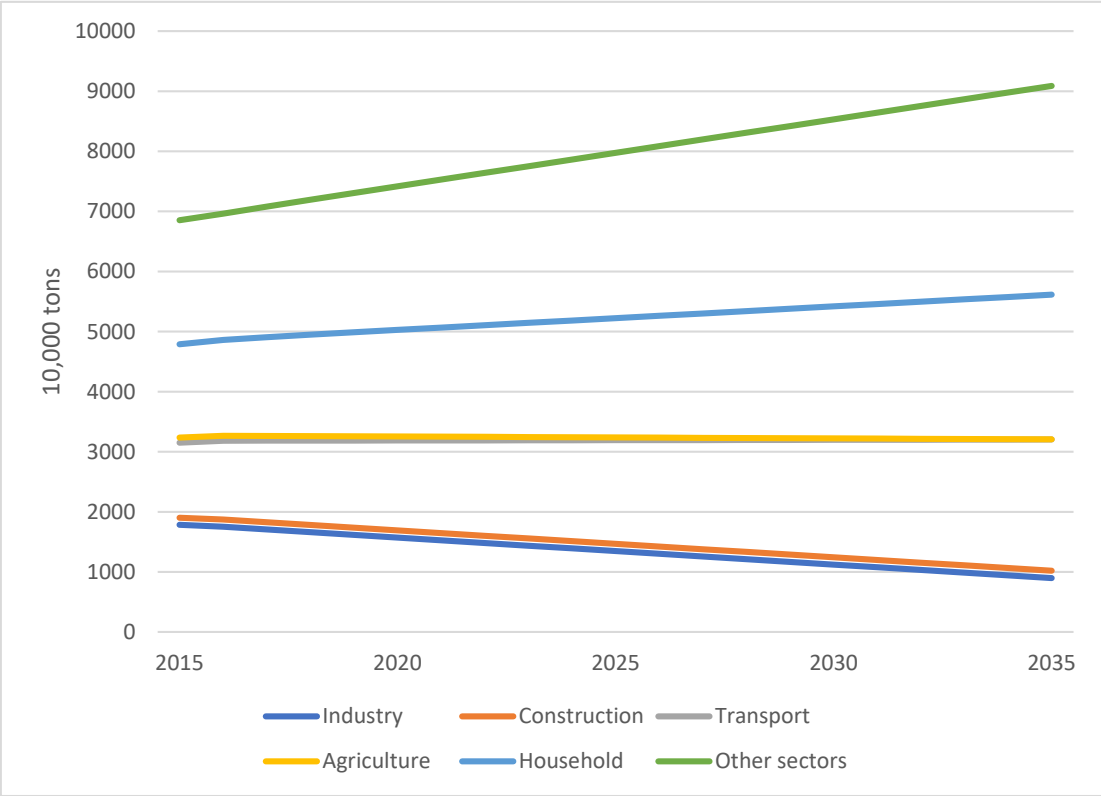

Figure 15: Smooth forecast results of the Holt-Winters Index (Energy Demand Trends by Sector)

5. Discussions

In this paper, we use the Holt-Winter and Leap models to forecast energy demand for the period 2017-2035. First, the results of the Holt-Winters model are analyzed. The results show that the energy demand of transportation industry has increased significantly, which is due to the increasing number of motor vehicles in China. Although the industrial sector has declined somewhat, it still accounts for a large proportion.

Table 4: Holt-Winters Model Energy Demand Forecasting Results by Sector

Year	Industrial	Construction	Transportation	Agricultural	Housing industry	Other
2015	1784.4	118.3	1249.4	84.6	1552.7	2064.1
2020	1571.3	120.1	1495.9	67.5	1772.7	2390.5
2025	1346.8	120.7	1725.0	45.9	1984.9	2751.7
2030	1122.3	121.3	1954.1	24.3	2197.3	3112.9
2035	897.8	121.9	2183.1	2.8	2409.6	3474.0

Table 5: Comparison of prediction results between the Holt-Winters model and the Leap model

Fuels/Year		2015	2020	2025	2030	2035
Coal	Holt-Winters	7.86	-1.81	-11.26	-20.71	-30.16
	RPE	7.86	4.65	3.13	1.98	0.76
	RCE	7.86	4.32	2.59	0.98	0.01

	CES	7.86	4.32	2.59	0.98	0.01
Oil	Holt-Winters	27.27	22.75	19.35	15.95	12.55
	RPE	27.27	22.02	19.09	15.54	10.85
	RCE	27.27	22.98	19.93	16.54	12.85
	CES	27.27	22.02	19.09	15.54	10.85
Natural Gas	Holt-Winters	14.07	27.04	41.05	55.06	69.08
	RPE	14.07	22.04	31.05	44.06	60.08
	RCE	14.07	22.04	31.05	44.06	60.08
	CES	14.07	16.04	13.05	8.06	2.08
Heat	Holt-Winters	4.01	4.02	4.16	4.29	4.43
	RPE	4.01	4.12	4.43	4.77	5.17
	RCE	4.01	4.12	4.43	4.77	5.17
	CES	4.01	4.12	4.43	4.77	5.17
Electricity	Holt-Winters	8.18	9.48	10.68	11.88	13.07
	RPE	8.18	9.67	11.86	17.15	25.69
	RCE	8.18	9.67	11.86	17.15	25.69
	CES	8.18	12.48	18.96	25.15	37.69
Others	Holt-Winters	1.58	2.4	3.45	4.5	5.55
	RPE	1.58	2.99	4.87	6.37	7.78
	RCE	1.58	2.99	4.87	6.37	7.78
	CES	1.58	3.44	6.98	20.37	49.78

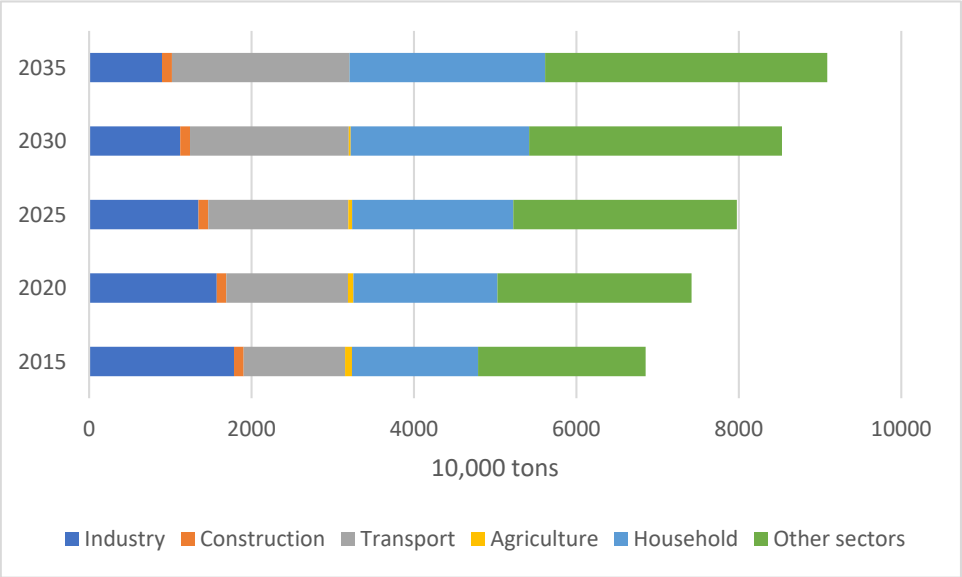

Figure 16: Energy demand forecasts by sector for the Holt-Winters model

We can see from the comparison table of the results of the two forecasting models that the energy demand for electricity is increasing, and it is observed that the results under the CES scenario are closest to the results under the policy background.

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6. Conclusion

As the capital city of China, Beijing faces dual demographic and socio-economic challenges and basically needs to provide sustainable energy supplies for all its economic sectors. Therefore, energy demand forecasts are important for the development of long-term plans and policies to achieve this goal. However, forecasting research requires that data based on energy and economic data, particularly on sub-sectors, are often missing or unreliable. Nevertheless, we used the Holt-Winters and Leap models for demand forecasting. Demand forecasting analysis covers different sectors of the economy, namely industry, agriculture, construction, residential, transportation and other sectors, and forecasts the actual demand for various energy commodities such as electricity, natural gas, oil products, coal and heat. The models in this paper all use historical data on energy consumption from 1980 to 2016 to predict energy demand for the study period (2017-2035).

Although there are a variety of energy demand forecasting models, these models have always existed in the literature and have certain limits and limitations on data and other modeling parameters. Therefore, the prediction technique used in this paper aims to compare the results to get the most consistent forecast results. Analysis of the predicted results showed that the Holt-Winters model was the most appropriate and similar to the model in other literature. However, the negative results of demand projections need to be carefully considered, and it is appropriate to use the LEAP model to analyze these estimates. In light of the findings of this study, it is critical that governments take the initiative to develop long-term plans and policies to ensure that future energy supplies can meet growing demand. Finally, it is strongly recommended that the government strengthen energy-related institutions, narrow the gap between academia, industry and policy-making bodies, and formulate energy plans and policies based on solid research to promote energy security and sustainability.

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