Research on the factors influencing the growth of residential electricity consumption

Qing Liu[1], Haifeng Zheng[1,a], Xiang Wang[1], Guoqiang Ji[1], Shanshan Wu[1], Xiandong Tan[1], Kaiyue Qu[2]

[1]State Grid Energy Research Institute, Beijing, China

[2]North China Electric Power University, Baoding, China

[a] Corresponding author e-mail: zhenghaifeng@sgeri.sgcc.com.cn

Abstract. Influenced by the continuous economic and social development and frequent occurrence of extreme weather, the factors influencing the growth of residential domestic electricity consumption in China are increasing, the mechanism of influence is more complex and the trend judgment is more difficult to judge. To this end, this paper studies the influence mechanism of residential domestic electricity consumption growth, researches the driving force of residential domestic electricity consumption growth, carries out correlation and regression analysis of factors influencing residential domestic electricity consumption growth, and draws the following conclusions: the number of air conditioners per 100 households has the strongest influence on per capita residential domestic electricity consumption, followed by the influence of per capita disposable income, and the influence of urbanization rate and population is relatively weak.

Keywords: Residential living and electricity consumption; Growth; Influencing factors; mechanism.

1. Introduction

At present, the centennial changes are intertwined with the epidemic situation of the century, the economic globalization is encountering a countercurrent, and a new round of scientific and technological revolution and industrial reform is deepening. In the face of the complex international environment and the more severe impact of climate change, China has proposed the "double carbon" goal, which requires accelerating the comprehensive green transformation of economic and social development[1]. In this context, the factors that affect the growth of power consumption in China are increasing, such as "double carbon" constraints, new urbanization, rural revitalization, electrification, digitalization, new power system, power market, etc., which lead to more complex mechanisms for the growth of power consumption, and it is difficult to accurately grasp the changes in the impact of power consumption factors.[2]

The spatio-temporal evolution system of the influencing factors of electricity consumption can reflect the changing characteristics of the influencing mechanism of electricity consumption from the time and space dimensions[3]. In the time evolution system, it can not only reflect the difference of the influence of different factors on power consumption in the same period of time, but also reflect the change of the influence of the same factors on power consumption in different periods of time, and also reflect which factors have influence on power consumption from nothing to something; In the spatial evolution system, the country is divided into four major regions, namely, the east, the middle, the west and the northeast[4]. In addition to reflecting the time evolution characteristics of the influencing factors in each region, it can also reflect the differences in the impact of the same factors on power consumption in different regions during the same period[5].

For this reason, this section adopts a combination of quantitative and qualitative methods to build a time-space evolution system of factors affecting power consumption. The following methods are used for analysis nationwide and in all regions. First, carry out quantitative analysis, and build a multiple regression analysis model between the influencing factors and power consumption in Section 2.1 by time period (before 2010 and since 2010), in which each factor is represented by representative indicators and standardized per unit, and power consumption is represented by the electricity consumption of the whole society. If the regression coefficient of a factor increases in

different periods, it indicates that the influence of this factor on power consumption is increasing; If the regression coefficient of a factor in the same period is the largest, it indicates that the factor has the strongest impact on power consumption. Then carry out qualitative analysis. For the influencing factors that are difficult to be characterized by specific indicators, difficult to obtain historical data, difficult to pass various tests and have no obvious impact on the power consumption of the whole society, it is difficult to analyze their impact on power consumption through quantitative methods. Therefore, qualitative methods are mainly used to analyze their impact on the power consumption of the whole society. Finally, a spatio-temporal evolution system is established, which, combined with quantitative and qualitative correlation analysis, can represent the degree of influence of various factors on power consumption in the same period of time across the country and in different regions, which is greater or lesser, which factors in different periods have an impact on power consumption from nothing to something, which are from weak to strong, and which factors have different degrees of influence in different regions. Based on this, a schematic diagram of the spatio-temporal evolution system of power consumption influencing factors is drawn.

2. Analysis on the Impact Mechanism and Driving Force of Residential Electricity Growth

2.1 Analysis of Impact Mechanism

From the perspective of scale factor, household electricity consumption is mainly affected by population; In terms of intensity factors (per capita domestic electricity consumption), residents' domestic electricity consumption is mainly affected by income level, urbanization rate, household electrical equipment (such as air conditioners, electric vehicles, etc.), climate and temperature, electricity price, etc.
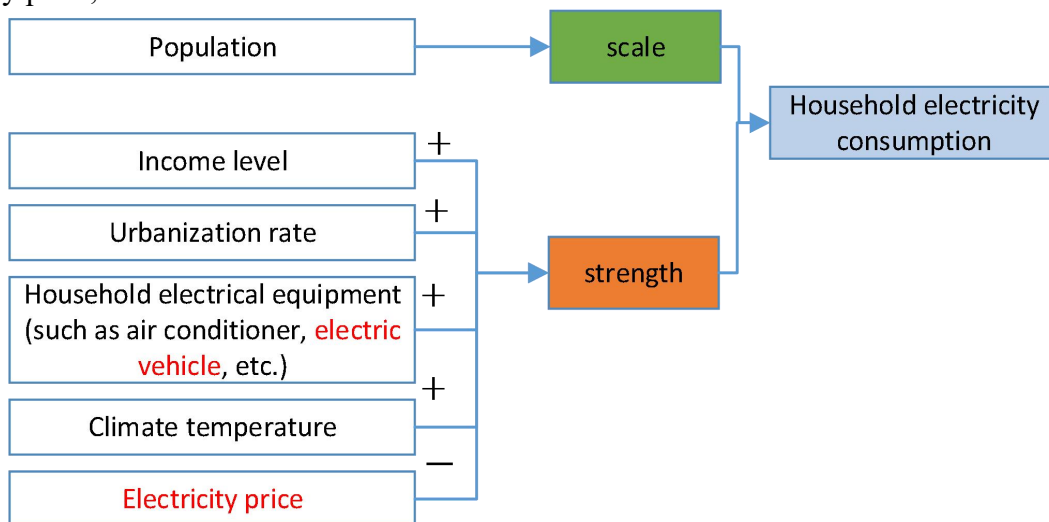

Figure 1.　Conduction logic diagram of various factors and their impacts on household electricity consumption (the red characters represent the influencing factors that need to be focused on in the near future and in the future).

2.2 Analysis on Driving Force of Power Consumption Growth

From 1990 to 2021, domestic electricity consumption in China increased from 46.1 billion kWh to 1174.3 billion kWh, with an average annual growth of 11.0%. From time to time, the growth rate of domestic electricity consumption of residents generally showed a downward trend. The average growth rate was 16.9% in 1991-1995, and dropped to 8.3% in 2016-2021. According to the LMDI index decomposition calculation, due to the slowing population growth and other factors, the driving effect of scale factors on household electricity consumption continues to weaken. From 2016 to 2021, scale factors drove the growth of electricity consumption by 0.4 percentage points,

0.9 percentage points lower than 1991-1995; Influenced by the increase of income level, urbanization rate and the number of household electrical equipment such as air conditioners and electric vehicles, the pulling effect of intensity factors on household electricity consumption has gradually increased in recent years. From 2016 to 2021, intensity factors have driven the growth of household electricity consumption by 7.9 percentage points, 1.4 percentage points higher than 2011-2015.
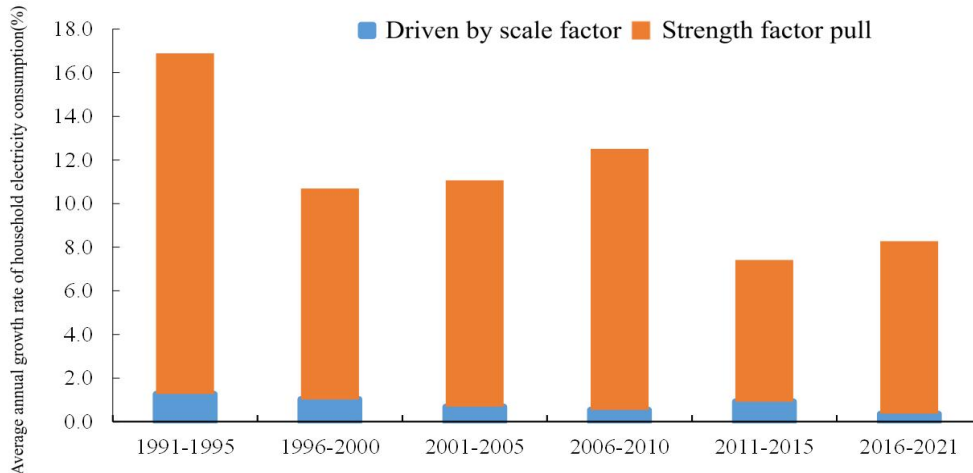

Figure 2.   Changes of scale and intensity factors on residents' life movies.

3.   Correlation and Regression Analysis of Influencing Factors of Residential Electricity Consumption Growth

3.1 Population

The more the population, the more the family units, the more the number and area of houses, the more the number of household appliances, and thus the increase of household electricity consumption. From 1990 to 2021, China's total population increased from 1.14 billion to 1.41 billion, with an average annual growth of 0.7%; During the same period, the average annual growth of household electricity consumption was 12.5%, with a large gap in growth. Through correlation analysis, the correlation coefficient between residential electricity consumption and population is 0.918.
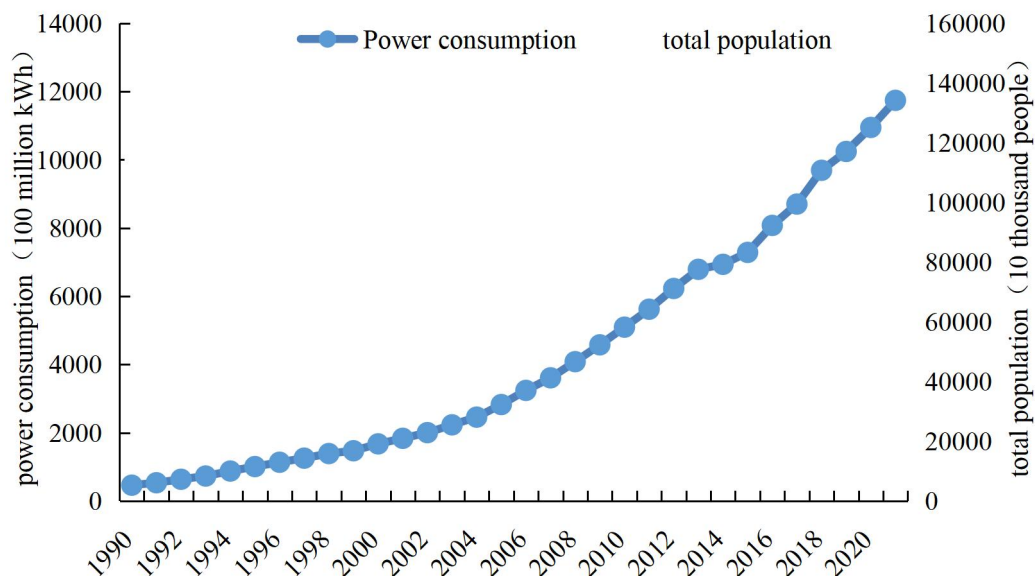

Figure 3.   Comparison of annual changes of household electricity consumption and total population.

3.2 Income Level

The increase of income means that the ability to purchase houses and appliances is improved, and then the variety and quantity of household appliances are increased, and the household electricity consumption is increased. From 1990 to 2021, China's per capita disposable income increased from 904 yuan to 35128 yuan, with an average annual growth of 11.0%; In the same period, the household electricity consumption increased from 46.1 billion kWh to 1174.3 billion kWh, with an average annual growth rate of 12.5%. The average annual growth rate of per capita disposable income was close to that of household electricity consumption, with a difference of only 1.5 percentage points. Through correlation analysis, the household electricity consumption is closely related to the per capita disposable income, and the correlation coefficient is as high as 0.997.
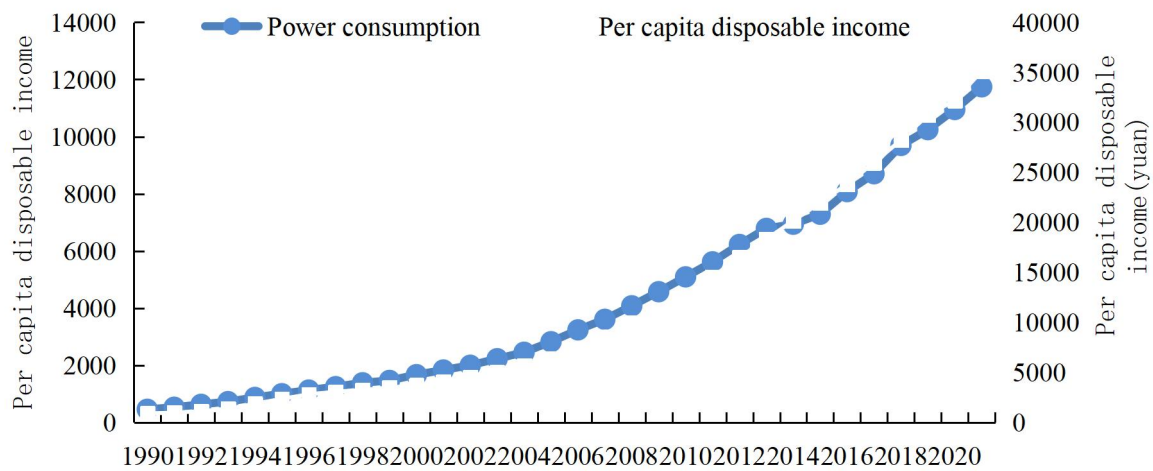

Figure 4.   Comparison of annual changes in household electricity consumption and per capita disposable income.

3.3 Urbanization Rate

In the process of economic development, the urban and rural structure has changed significantly, the rural population has migrated to the city on a large scale, and the level of urbanization has been continuously improved, leading to the change of people's lifestyle and family structure, thus increasing the household electricity consumption. From 1990 to 2021, China's urbanization rate increased from 26.4% to 64.7%. Through correlation analysis, the correlation coefficient between residential electricity consumption and urbanization rate is 0.968, which is relatively strong.

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3.4 Quantity and Type of Household Electrical Equipment

In recent years, residents' demand for electricity tends to be diversified, recreational electricity and decorative electrical equipment gradually increase, and residents' living electricity consumption continues to increase. Among the household electrical equipment, the power consumption of air conditioners and electric vehicles is relatively large, and has increased rapidly in recent years. From 2013 to 2020, the number of air conditioners per 100 households in China increased from 70.4 to 117.7, with an average annual growth of 7.6%; The number of electric vehicles per 100 households in China has increased from 39.5 in 2013 to 66.7 in 2020, with an average annual growth of 7.8%; In the same period, the average annual growth rate of residential electricity consumption is 7.1%,

which is close to the aforementioned electrical appliances. According to the correlation analysis, the correlation coefficients of residential electricity consumption and air conditioning ownership, residential electricity consumption and electric vehicle ownership are 0.990 and 0.978 respectively, which are relatively strong.

3.5 Climate and Temperature

Changes in meteorological conditions will affect people's household electricity use behavior. For example, changes in temperature will affect the use of air conditioners and electric heating equipment, changes in humidity will affect the use of humidifiers, and changes in air quality will affect the use of air purifiers. As the power consumption of air conditioning and electric heating equipment in household electrical equipment is relatively large, the impact of temperature on household electricity consumption is mainly studied. From the perspective of summer temperature, as the number of air conditioners continues to increase, power consumption becomes more sensitive to temperature changes. Summer temperature changes have a very obvious impact on the fluctuation of power consumption growth, especially since 2014, the trend of summer temperature and residential power consumption growth is completely consistent; From the perspective of winter temperature, the consistency of winter temperature fluctuation on the fluctuation of power consumption growth rate is relatively weak. However, since 2020, with the continuous promotion and popularization of electric heating equipment, the impact of winter temperature on power consumption is becoming increasingly significant, and the trend of winter temperature and residential power consumption growth rate is constantly approaching.

3.6 Electricity Price Mechanism

The guiding role of electricity price on electricity consumption will be gradually strengthened. According to the price theory, generally speaking, the rise in commodity prices or the decline in the prices of other substitutes will eventually lead to a decrease in the supply and demand of products. At present, in order to ensure people's quality of life, China has implemented cross subsidy policy, which has greatly weakened the regulatory role of the price mechanism. Last year, the National Development and Reform Commission said that "the next step is to improve the tiered electricity price system for residents, gradually ease the cross subsidy of electricity prices, so that electricity prices can better reflect the cost of power supply, restore the commodity attribute of electricity, and form a residential electricity price mechanism that more fully reflects the cost of electricity, the relationship between supply and demand, and the degree of resource scarcity". In the future, the adjustment of residential electricity price policy will encourage people to improve their awareness of electricity conservation and choose more energy-saving and consumption reducing electrical products, It will reduce household electricity consumption to a certain extent and change the characteristics of household electricity load.

3.7 Emergency

During the epidemic, the epidemic prevention and control measures required residents to isolate at home, and the extended use of household appliances increased the domestic electricity consumption, leading to a counter trend increase in the domestic electricity consumption of residents. Combined with the relationship between the historical epidemic data and the growth rate of household electricity consumption, calculate the impact of the epidemic on the growth rate of household life. In March 2020, affected by the epidemic situation in Wuhan and other places, the growth rate of domestic electricity consumption in the company's business area reached 6.1%, of which the epidemic situation increased the growth rate of electricity consumption by about 0.5 percentage points; In April 2022, affected by the epidemic situation in Shanghai, Jilin and other places, the growth rate of household electricity consumption in the company's business area will reach 5.7%, of which the epidemic situation will increase the growth rate of electricity consumption by about 0.5 percentage point. Throughout the year, in 2020 and 2021, the epidemic will increase

the growth rate of residential electricity consumption in the company's business area by 0.7 and 0.3 percentage points.

3.8 Comprehensive Analysis

Combined with the analysis of the impact mechanism of residential electricity consumption and related factors, considering the fitting effect of the regression equation, F test, T test, etc., a standardized multiple regression model of residential electricity consumption Z and population Z1, per capita disposable income Z2, urbanization rate Z3, and air conditioning ownership Z4 per 100 households is finally built. The regression of the model has passed the test of main statistics, and the regression equation can explain 99% of the changes in household electricity consumption. By comparing the coefficient of the first term of the regression equation, it can be seen that the ownership of air conditioners per 100 households has the strongest impact on the domestic electricity consumption of residents, followed by the per capita disposable income, and the urbanization rate and population are relatively weak.

Table 1. Multivariate regression equation between domestic electricity consumption and influencing factors in China1

Project	content
Multiple regression equation	$Z=0.12Z1+0.33Z2+0.11Z3+0.54Z4$
Goodness of fit	Decision coefficient $R2=0.996$, greater than 0.8
F-test	F value=2853, far greater than the critical value 6.7E-30
t-test	The P-values of Z1, Z2, Z3 and Z4 are 0.06, 0.003, 0.0005 and 0.008 respectively, all less than 0.1

4. Conclusion

This paper studies the impact mechanism of residential electricity consumption growth, the driving force of residential electricity consumption growth, and carries out correlation and regression analysis on the influencing factors of residential electricity consumption growth. The following conclusions are drawn:

1) From the perspective of scale and unit consumption, due to the slowing down of population growth and other factors, the pulling effect of scale factors on household electricity consumption is weakening; Influenced by the increase of income level, urbanization rate and the number of household electrical equipment such as air conditioners and electric vehicles, the pulling effect of intensity factors on household electricity consumption has gradually increased in recent years.

2) From the perspective of specific influencing factors, the ownership of air conditioners per 100 households has the strongest impact on household electricity consumption, followed by per capita disposable income, and the urbanization rate and population have relatively weak impact.

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