

Characteristics, Drivers and Transitions of Household Energy Consumption in China: An Overview

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Abstract: Energy plays a crucial role in our daily lives, not only as a basis for survival and development, but also as a national strategy. This paper focuses on household energy consumption, which is a key factor in promoting economic development and social progress. Globally, household energy consumption accounts for 25-30% of the total energy consumption, and in China it accounts for 12.4% of the total national energy consumption, making it the second largest force after the first major energy consumer. Since household energy consumption is closely related to climate change, ecological quality, and population health, this paper analyzes the current situation of household energy in China, and conducts a literature review from three key aspects: first, it discusses in depth the characteristics and trends of household energy consumption, and reveals its important position in the global and domestic consumption patterns; second, it examines the drivers that influence household energy consumption, including household size, economic level, geographic location, and many other factors; finally, it focuses on household energy transition and explores the key issues of sustainable energy and green low-carbon transition. Through the review of the literature, this paper aims to provide an in-depth understanding for future research and policy development to effectively address the environmental, ecological and social issues that may arise from household energy consumption.

Keywords: Household energy consumption, Consumption characteristics, Energy consumption drivers, Energy transition.

1. Introduction

Energy is the basis for our survival and development and an important guarantee for national strategy. Energy consumption is closely related to our production and life, promoting economic development and social progress.

It is estimated that globally, household energy consumption accounts for 25-30% of the global energy consumption; in China, household energy consumption accounts for 12.4% of the national total energy consumption, which has become the second largest energy consumption main body. Since household energy consumption is closely related to climate change, ecological quality and population health, the spatial and temporal changes in household energy consumption may bring new environmental, ecological and social problems [1-3]. Therefore, an in-depth study of the current situation and development trend of household energy consumption is the key to systematically promoting the green and low-carbon transition of household energy and realizing the United Nations 2030 Sustainable Development Goals.

2. Current Situation of Household Energy Consumption in China

In 2021, China's total energy consumption will reach 5.24 billion tons of standard coal, a year-on-year increase of 5.2%, with a growth rate of 3% higher than that of 2020; total energy production will be 4.33 billion tons of standard coal, a year-on-year increase of 6.2%. In terms of sectoral structure, the household sector is the second largest energy consumption sector after the industrial sector. According to the National Bureau of Statistics of China (NBSC), as shown in Figure 1, China's final energy consumption is mainly composed of seven sectors, which are agriculture, forestry, animal husbandry and fishery, industry, construction, transportation, storage and postal services, wholesale and retail trade, accommodation and catering, Others, Resident.

storage and postal services, wholesale and retail trade, accommodation and catering, and residential and other consumption. Among them, the industrial sector has long dominated China's final energy consumption, and the residential sector is the second largest sector after industry, and the one that accounts for more than 10 percent of the overall energy consumption among the remaining six sectors, so the importance of residential energy consumption cannot be ignored.

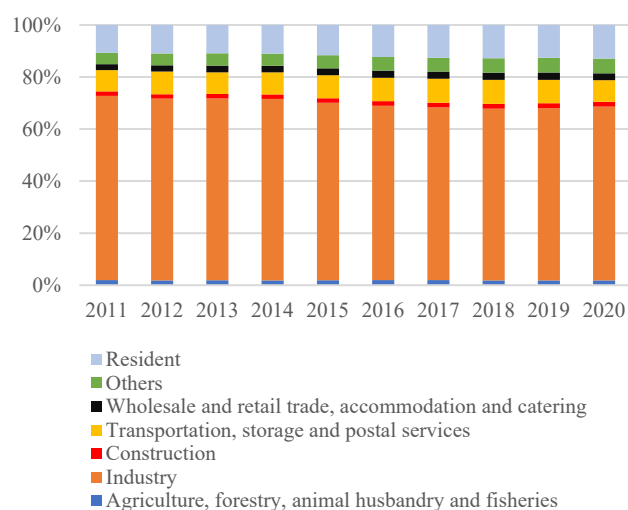


Figure 1. China's final energy consumption and its components (2011-2020)

Chinese household domestic energy consumption continues to grow. According to the National Bureau of Statistics of China, China's residential energy consumption will grow from 166.95 million tons of standard coal in 2000

to 643.8 million tons of standard coal in 2020. With the acceleration of urbanization and the significant improvement of people's living standards, the penetration rate of air conditioners, refrigerators and other electrical appliances has increased rapidly, and China's household electricity consumption has grown rapidly from 145.2 billion kilowatt-hours (kWh) in 2000 to 1,139.6 billion kWh in 2020, surpassing the construction sector and becoming the second largest electricity consumption sector after the industrial sector. China's natural gas consumption grew from 3.2 billion cubic meters in 2000 to 56 billion cubic meters in 2020.

With regard to industrial energy consumption, China has introduced a series of policies and measures to adjust and optimize the industrial structure and energy structure, and the effect of implementation has been relatively obvious, with the proportion of its overall energy consumption showing a year-on-year downward trend, from 72.47% in 2010 to 66.16% in 2019. Meanwhile, residential energy consumption showed an upward trend from 2010 to 2019, and its share of overall energy consumption rose from 10.11% in 2010 to 12.66% in 2019. However, living energy consumption is mainly individual consumption behavior with families as the main body, compared with the industrial energy policy, the accuracy of the energy policy to regulate living energy consumption is far less than the regulation of industrial energy consumption, and the strength and effect of the policy impact is not as obvious as industrial energy. Therefore, as an important part of China's final energy consumption, the study of household energy consumption has strong practical significance.

3. Literature References

3.1. Characteristics of household energy consumption and its trends

China's total household energy consumption has risen sharply. According to the National Bureau of Statistics of China, household energy consumption in China increased from 167 million tons in 2000 to 5 billion tons in 2015, with an average annual growth rate of 7.6 per cent over the 15-year period. Household coal consumption declined by an average of 5.88% per year, from 790,000 tons to 280,000 tons. Globally, there has been a downward trend in coal consumption as governments have increased electricity supply and developed policies to encourage the use of cleaner energy sources to replace coal as a cooking fuel due to the negative impacts of coal combustion on air quality and health. The average annual growth rates of natural gas and electricity consumption in Chinese households were 17.51 per cent and 11.6 per cent, respectively, followed by heat (9.75 per cent) and LPG (7.53 per cent), and the amount of natural gas used in households increased from 12.6 billion cubic metres in 2000 to 18.4 billion cubic metres in 2008.

Biomass energy as the main energy source is widely used in rural households in a traditional way. The China Household Energy Consumption Survey (CRECS) study showed that biomass energy accounted for 27.2% of China's household energy structure in 2014, with an average consumption of 295.11 kg per household [4]. In rural areas, it was found that bioenergy consumption in Zhejiang, Shanxi and Guizhou provinces accounted for 18% of total energy consumption in rural areas in 2012 [5]. China's biomass energy stock is about 5 billion tons, which is four times more than all energy sources, however, only 5% of the biomass energy stock is

currently used [6]. Biomass energy is used for traditional stoves, so strategies for sustainable bioenergy use need to be considered, especially in northwestern provinces of China such as Gansu province [7].

Urban household energy is dominated by liquefied petroleum gas (LPG) and electricity. Natural gas consumption is growing rapidly, as is the consumption of LPG and electricity. According to a research study conducted in 2015 in 31 regions of China (excluding Hong Kong, Macau or Taiwan), in addition to electricity, 56% of urban households use natural gas, 19% use gas and 17% use LPG. In addition, electricity has become the main source of energy in about 20% of urban households [8], and in order to realize sustainable development, the gap between urban and rural areas should be narrowed and an integrated urban-rural energy system should be established [4]. It has been shown that with every 1% increase in urbanization in China, energy consumption will be driven by 80 million tons [9].

There are significant differences in household energy consumption between urban and rural areas in China. In fact, urban-rural and regional disparities are long-standing problems in China [10], and a great deal of research has been conducted by scholars on the sustainability of a range of energy poverty and income inequality from different perspectives [11]. Rural household energy comes mainly from biomass energy sources, and in some ethnic minority areas in Gansu and Yunnan, rural residents still use traditional biomass energy sources, such as fuelwood, as their primary energy source. Commercial energy sources such as coal and electricity are not used as alternative energy sources in these areas [12]. Household energy in rural areas of northeastern Yunnan is dominated by fuelwood, which accounts for 90% of energy demand. Renewable energy sources such as solar energy, biogas and hydropower account for only 5% of consumption [13]. Traditional biomass energy sources such as animal dung and fuel wood dominate the production energy of Tibetan farmers and herders [14]. Although household energy consumption in rural China is transitioning from traditional biomass energy to modern commodity energy [15] and renewable energy sources [16], the main energy consumption in rural areas is still traditional biomass energy [17].

Overall, electricity in Chinese households is mainly used to primarily meet basic living needs such as lighting and cooking.

3.2. Drivers of household energy consumption

Household energy consumption is influenced by multiple factors, mainly including household attributes, socio-cultural, and geographic environment.

Family characteristics mainly include three indicators such as family income, family size and education level. Household income is the main economic factor influencing energy consumption decisions, and some scholars have found a highly significant positive correlation between the two through empirical studies [15-18]. The indicator of annual per capita income can explain the changes in the energy consumption structure of rural households in China, such as the increase in income drives the growth of household commodity energy consumption. In Beijing, for every 10,000 yuan increase in annual household income, the annual per capita consumption of electricity, coal, and gas increased by 19.57 kgce, 32.11 kgce, and 22.09 kgce, respectively, but the

annual per capita consumption of traditional biomass decreased by 36.98 kgce [19]. The increase in household income also leads to an increase in the type and number of household appliances, which indirectly leads to an increase in household electrical energy consumption [20]. Meanwhile, comfort is the primary factor in energy choice for households with high income levels, while economy is the primary choice factor for households with low income levels, e.g., low-income households are more likely to choose traditional fuel wood as their primary energy source, whereas higher-income households prefer electricity and natural gas, and higher-income households are more likely to make the transition to cleaner energy sources than lower-income households [21]. In terms of total energy consumption, there is a positive relationship between household size and total household energy consumption, and households with large household size tend to choose non-commodity energy with low or zero cost. However, in terms of per capita energy consumption, affected by economies of scale, household energy-consuming appliances and heating energy can be shared internally, household size is negatively correlated with per capita energy consumption, and per capita energy consumption decreases with an increase in household members [22]. For example, in Jiangsu, an increase in household size leads to a small increase in total household electrical energy consumption, while at the same time reducing per capita electrical energy consumption [23]. Households with higher levels of education are more likely to choose clean energy, and those with fewer years of education are more likely to use traditional biomass energy sources, for example, in rural areas of Shaanxi Province, for every level of education of the head of the household, household energy consumption decreases by 4%, and the proportion of household consumption of commodity energy increases by 1%, with the probability of choosing to use clean energy being 1.25 times higher than not choosing that energy source [22].

Households with different cultural backgrounds also have more obvious differences in energy consumption behaviors [24], for example, households advocating collectivist culture have more willingness to optimize energy consumption behaviors than households advocating individualism, and generate green consumption behaviors for the purpose of creating a clean environment to share with others [18], and households with good energy-saving habits have lower levels of energy consumption. Therefore, improving residents' awareness of resource conservation can effectively increase energy-saving behavior [25]. In addition, ethnic attributes and their traditional culture also have a significant impact on households' energy choices, for example, in the traditional culture of Yunnan's ethnic minorities, the concept of reverence for forests and trees will reduce their consumption demand for fuelwood to a certain extent [26]. However, with the advancement of urbanization, the degree of influence of traditional culture on energy consumption of different ethnic groups in multi-ethnic areas has gradually become smaller [27]. It mainly includes what kind of occupation, where to live, when (or if) to get married and have children, what kind of household energy-consuming equipment to buy, and environmental awareness have an impact on household energy consumption [28]. Lifestyles vary from household to household; for example, homeowners are more likely to improve the energy efficiency of their homes compared to renters. Lifestyle also determines household decisions and behaviors regarding the use of energy-consuming products

[29], with rural areas consuming more electricity compared to urban areas under the same climatic conditions, mainly due to the more frequent use of washing machines, dryers, and dishwashers by rural households. Environmental awareness can also have an impact on energy consumption, studies have shown that 37% of electricity consumption in households is influenced by environmental awareness, suggesting that occupant behavior will influence energy use, in light of this, house designers should be aware of the impact of occupant behavior on energy use and incorporate it appropriately into their designs [30].

Studies have shown that household energy consumption is more closely related to geographic location than the industrial and transportation sectors [31]. Due to the heat island effect, temperatures in cities are generally higher than in surrounding rural areas, and to achieve the same indoor problems, urban households require less energy for winter space heating than rural households [32]. Wind speed and precipitation are also major climatic factors affecting household energy consumption [33]. Meanwhile, geography is a determinant of rural energy supply [34]. Generally, biomass energy consumption of households in mountainous and highland areas is higher than that in the plains, while commodity energy is concentrated in the plains. Hilly and mountainous areas have a single energy use structure due to the lack of natural conditions, and firewood-based non-commodity energy is predominant [35]. As the altitude increases, the proportion of traditional non-commodity energy use increases sequentially, while the proportion of commodity energy use, including coal, shows a clear downward trend, such as in the Tibetan Plateau region, where per capita energy consumption is higher in high altitude areas than in low altitude areas in agricultural areas [36]. Although the trend of the influence of climatic environment on energy consumption is generally consistent, the relative degree of change in energy consumption demand varies with geographic location, time period, and research methodology, e.g., biogas, which is used by 22% of farm households in Yunnan, compared to 3% of farm households in Gansu [37].

Since the reform and opening up, policies have always played a key role in China's social and economic development [38]. Policies affecting household energy consumption can be classified into psychological and structural policies: psychological policies aim to influence residents' perceptions and motivations to change household energy consumption behaviors, mainly including energy conservation education and promotion, provision of energy information, and energy conservation demonstration sites, etc. Structural policies constrain household energy consumption behaviors by altering the external environment, such as adopting pricing strategies, changing livelihood strategies, and increasing energy supply. to constrain household energy consumption behavior, such as adopting pricing strategies, changing livelihood strategies, and increasing energy supply, specifically including "new urbanization"[9], "returning farmland to forest"[39], "natural forest conservation"[40], "returning farmland to forest"[41], and "rural power grid project"[42]. The electricity consumption of residents who have undergone urbanization have all shown significant growth, mainly due to the increase in the number of household appliances and their frequency of use [20].

3.3. Household energy consumption transition

Nowadays, more and more scholars are focusing on the

study of energy transition, which needs to be more scientific and rapid in the 21st century, and transition to a cleaner, more environmentally friendly and more equitable energy system.

In China, scholars have been exploring the stages of energy transition and the methods to promote it. This part of the research mainly uses the energy ladder model and the energy stacking model as the theoretical basis to explore the relationship between changes in energy structure and energy transition. First, the study shows that energy used for cooking and heating in rural households is an important source of air pollutants in China, affecting people's health and climate change. In recent years, the increase in the share of these non-solid fuels, especially the use of energy sources such as natural gas and electricity, has reduced emissions of carbon dioxide and major air pollutants [43], mitigate climate change and improve indoor air quality [44]. Second, advances in energy technology have also greatly improved energy efficiency [45], for example, new photovoltaic (PV) technologies are dedicated to the development of more cost-effective, flexible, and efficient solar cells; and subsidies for PV panels from governmental agencies have brought new energy projects to rural households. In addition, the development of energy infrastructure plays a crucial role in households' access to quality energy [46]. For example, the full coverage of the electricity grid, the construction of household biogas digesters, and new heating systems (e.g., gravity-circulating hot water systems, i.e., underfloor heating) are gradually replacing the traditional heating equipment (kang) in rural China. Fourth, the growth of commodity energy consumption has improved the living standards of the population [47], while at the same time increasing the financial burden of households. Income is a key factor in the growth of energy consumption by rural residents in China, so only a significant increase in household income can reduce the direct use of biomass. Fifth, the utilization of renewable energy sources is becoming an increasingly prominent issue. For example, wind, solar and hydroelectric power enhance the sustainability of the energy system, but the decrease in biomass consumption reduces sustainability [48]. Finally, the uses of energy have changed and extended dramatically over the years. Household lifestyles, especially daily activity patterns, can greatly influence household energy use [49]. It extends from basic living needs (lighting, cooking and space heating and cooling, etc.) to developmental needs, including cleanliness and sanitation, learning, recreation, communication, transportation, and many others.

All in all, the energy transition is profoundly changing the lifestyle of the population as a window of improvement in their standard of living and social progress.

4. Conclusion

Currently, research on household energy consumption mainly focuses on the characteristics and drivers of energy consumption. Some scholars have analyzed the characteristics and trends of changes in household energy consumption from a time-series perspective [50], and studies have shown that most households use more than one type of energy [51]. Studies on the drivers of household cooking energy consumption have shown that the main drivers are: household income [52-53], household structural characteristics [54], geographic characteristics [55], price of available fuels [56], and lifestyle [57], which may all influence household energy choices.

However, there are some shortcomings in the above literature. First, the existing studies lack long-term tracking reports on household energy consumption, and most of them basically compare the changes in household energy consumption in different years to get the results of the changing characteristics of household energy consumption, which makes it difficult to scientifically understand the changes in the structure of household energy consumption over a longer time series. Second, most of the literature only analyzes how multiple independent variables affect household energy consumption, and rarely considers whether there are interactions among the independent variables and how these independent variables directly and indirectly affect household energy consumption after interaction.

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