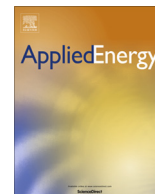




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The relationships between household consumption activities and energy consumption in china— An input-output analysis from the lifestyle perspective

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HIGHLIGHTS

- 24.7% of China's final energy consumption in 2012 is caused by household consumption.
- Energy linkages between supply side and demand side are shown in a Sankey diagram.
- Adopting low-carbon consumption and decreasing energy intensity can conserve energy.
- Energy conservation potential of several household consumption behaviors is revealed.

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ABSTRACT

The household sector has become the second largest consumer of final energy, ranking only next to the industrial sector in China. Except for the direct energy consumption of the household sector, people's consumption activities also indirectly affect the energy consumption of multiple production sectors. Previous studies have shed light upon consumer-oriented energy consumption and carbon emission, however, the critical problem of sector-to-sector energy linkages between supply side and demand side has not been fully addressed. Besides, there also lacks sufficient research on the energy conservation potential of residents' lifestyle change. This paper investigates the direct and indirect impact of household consumption activities on energy consumption in China from the consumers' lifestyle perspective based on the input-output analysis. The relationship between household energy consumption and industrial energy consumption and the effect of lifestyle change on energy conservation are also considered. It is estimated that China's energy consumption caused by household consumption activities in 2012 is 29141.97 PJ in total, which accounts for 24.7% of the total final energy consumption. The indirect energy consumption of household consumption activities is 1.35 times more than the direct energy consumption. Housing activities cause the most indirect energy consumption, and the smelting and pressing industry of ferrous metal is the most energy-consuming industrial sector influenced by household consumption. We also find that adopting low-carbon consumption pattern and accelerating the decrease of energy intensity are both effective means to reduce the total energy consumption by scenario analysis. Finally the energy conservation potential by comparing different types of household consumption behaviors is revealed to make policy makers form vivid impressions on the importance of demand side regulation.

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1. Introduction

Since 2010, China has been the world's largest energy consumer. According to the *BP Statistical Review of World Energy*

2015 [1], China's primary energy consumption accounted for 23% of the world's total in 2014, which was 5.2% higher than the second-ranked United States' energy consumption. As the massive energy consumption has posed serious threats to energy security, environmental quality, climate change and human health, reducing energy consumption has become one of the most important national strategies in China.

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Industrial sector has always been the focal point of energy conservation as it consumed around 70% of national direct energy consumption in China [2]. However, the second largest direct energy consumer – household sector should never be neglected. On the one hand, according to the experiences in the developed countries such as the United States, when entering the post-industrialization stage, the proportion of industrial energy consumption will decline, and the household energy consumption will occupy the main share of the national energy consumption. In China, this trend is also emerging. In recent years, the direct household energy consumption is gradually increasing, while the industrial energy consumption has entered the platform period with a slow decline trend. The final energy consumption structure of China and the United States is shown in Appendix A. On the other hand, the household sector is actually the backstage driving force for the high industrial energy consumption. For instance, the direct energy consumption caused by driving a private car is the amount of consumed gasoline, while the indirect energy consumption involves the energy consumption in the production, transportation, marketing process of the car. To meet people's increasing consumption demand is one of the main reasons that industrial sectors' energy consumption grows. Therefore, when taking the indirect energy consumption into account, the household sector's proportion in the total energy consumption will rise sharply [3]. There has been a growing awareness of indirect energy consumption of the household sector. It is found that in the United States, even more than 80% of the total national energy consumption was a consequence of consumer demands and the economic activities to support these demands [4]. However, more evidence is needed to supplement existing research for there is no unanimous conclusion about the ratio and amount of energy consumption caused by household consumption. And the current study doesn't further correlate household consumption activities with the energy consumption of the industrial sector, which hampers the identification of the highest energy-consuming consumption activity and the formulation of energy conservation policies (especially demand side control policies). In addition, there is little research on the energy conservation potential of residents' lifestyle change, making it difficult for policy makers to form vivid impressions on the importance of demand side regulation. Based on the research background and literature gap, this paper combines input-output analysis and consumer lifestyle analysis to accomplish the following three research targets in China: (1) measure the impact of household consumption including food, clothing, housing, transport and other types of consumption on energy consumption, and find the consumption products or behaviors which have the most significant influence on national energy consumption; (2) clarify the relationship between household consumption and industrial energy consumption, and find the production sectors whose energy consumption is influenced most significantly by household consumption; (3) explore the future energy consumption caused by household consumption under different consumption scenarios, and investigate the impact of lifestyle change on energy consumption to identify opportunities for energy conservation from the demand side.

The remainder of the paper is arranged as follows. Section 2 reviews the related literature. Section 3 describes the methodology and data. Section 4 discusses the results. Section 5 concludes with this paper's policy implications.

2. Literature review

Existing literature mainly analyze the direct and indirect impact of household consumption on energy consumption and carbon emission by four methods: consumer lifestyle approach (CLA),

input-output method, life cycle assessment and emission coefficient method. The former two methods are more in common use. The CLA provides us with an explicit framework which connects influence factors that affect lifestyle, with related consequences [5]. Wei et al. (2007) [6] found approximately 26% of total energy consumption and 30% of CO₂ emission every year from 1999 to 2002 were a consequence of residents' lifestyles based on CLA in China. Feng et al. (2011) [7] applied the CLA to analyze the impact of consumption by urban and rural households on energy use and CO₂ emissions for different regions and income levels in China. The results showed that the indirect energy consumption and CO₂ emissions for urban households were much greater than the direct consumption values. Wang and Yang (2014) [8] also used the CLA to analyze resident CO₂ emissions in the perspective of energy ecological footprint. Their results indicated that the most energy-intensive household consumption choices were residence, food and education, cultural and recreation services. The input-output method explores the goods and services' energy footprint and carbon footprint based on the input-output table. Park and Heo (2007) [9] found the Korean household sector was responsible for about 52% of the national primary energy requirement in the period from 1980 to 2000 and more than 60% of household energy requirement was indirect by applying input-output analysis. Papatana-sopoulou (2010) [10] showed that the 44% increase in Greece's household expenditure between 1990 and 2006 was accompanied by a 67% increase in fossil fuel demand based on the input-output analysis. Of this total, indirect demand accounted for approximately 60% throughout the 16-year period. Liu et al. (2011) [11] used input-output table and found the direct and indirect CO₂ emission from household consumption accounted for more than 40% of total carbon emissions from primary energy utilization in China in 1992 to 2007. Zhang et al. (2015) [3] used the input-output model to get the conclusion that the indirect energy consumption and CO₂ emission appeared the main parts of total energy consumption and CO₂ emission caused by household consumption, accounting for 69% to 77% and 77% to 84% respectively. Fan et al. (2016) [12] used the multi-regional input-output method to explore the characteristics of production based and consumption-based CO₂ emissions for 14 major economies. They found there were uniquely increasingly larger gaps between production-based and consumption-based emissions in China and Chinese Taiwan. Other researchers also have focused on the consumption-based energy and carbon footprints by input-output analysis [13–21], life cycle assessment [22–25] and emission coefficient method [26,27].

It can be found that the energy consumption and carbon emission caused by household consumption derived from different study vary widely. On the one hand, the differences in consumption-based energy and carbon among countries may be caused by differences in country context such as economic driving force and consumption structure. On the other hand, the differences in consumption-based energy and carbon within the same country may be due to different methodologies, research scope (e.g. the scope of household activities) and time period adopted by different studies. Overall, there is no unanimous conclusion about the ratio and amount of energy consumption and carbon emission caused by household consumption, and more evidence is needed to supplement existing research.

Apart from calculating consumption-based energy consumption and carbon emission, some studies have shed light upon effects of household consumption patterns on energy and carbon requirements and tried to put forward proposal about sustainable lifestyle. Wier et al. (2001) [28] showed that different family types had different CO₂ requirements. These differences were primarily due to differences in household expenditure, the type of accommodation, urbanity and age. Weber and Perrels (2000) [29] concluded

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