RESIDENTIAL ELECTRICITY CONSUMPTION AND TIME-USE MEASURED LIFESTYLE: QUANTIFYING THE IMPACTS OF URBANIZATION IN CHINA

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Overview

Urban residents are projected to account for 66% of the worlds' population in 2050 with the majority of the growth occurring in Asia and Africa (United Nations, 2015). In China, an even more rapid urbanization might be resulted under the New Urbanization Plan announced in 2014, aiming to raise the proportion of permanent urban residents by 6% within seven year (www.gov.cn, 2014). With the brief understanding of the rural-urban differential in energy consumption pattern, there is a general agreement on the relationship between urbanization and energy use. Yet, there is still a huge uncertainty on how the mechanisms of urbanization influence energy consumption. Numerous studies have been conducted to investigate the mechanism of urbanization and its effect on energy use. Yet, whether top-down or button-up approaches adopted, there were still shortcoming needed to be overcome. First, for analyses at the macro-level, critics argued that most of them have not fully considered the heterogeneity among studied regions and their results did not provide detailed explanation for the underlying mechanisms of urbanization. While for those micro-level studies, even they succeeded in explaining the relationship between urbanization and energy by introducing the concept of lifestyle as the bridge, their quantification method, using monetary consumption as the major indicator, failed to capture temporal dimension of individual behaviors, which is crucial in dictating ones' activity pattern. To alleviate these shortcomings, the concept of "time-use" might be the solution

Time-use, detailing activity pattern in sequential order, serves as an alternative in measuring people's behavioural pattern (Michelson, 2005). In the fields like sociology and public health, successful empirical applications have further proved its strength in revealing individual lifestyle over monetary expenditure. However, in relation to energy consumption, time-use data still dimly perceived, and only few studies briefly discussed the impacts of time-use pattern on energy use. The linkage of social changes, time-use pattern and energy use was still in puzzle. Therefore, using urbanization in China and residential electricity consumption as the starting points, this study aims 1) to explore how energy is embedded in urban and rural lifestyle and 2) to unpack the urban-rural differential into time use and energy intensity of activity, i.e. time spent on various activity and energy consumption per hour of activity respectively.

Methods

In this study, energy consumption is viewed as the consequence of lifestyle and technological efficiency; therefore, person-day residential electricity E is decomposed into time spent on activity T_i and energy intensity of activity EI_i by employing time use data and residential energy consumption data collected from the 2008 Chinese Time Use Survey and the 2012 Residential Energy Consumption Survey (National Bureau of Statistics, 2009; Zheng et al., 2014), *Eq. 1*. All activities the resident engaged throughout the day are included, and time spent on each activity category i is the sum of time spent on related sub-activity categories *j*, *Eq. 2*. In term of energy intensity, or energy consumption per person per hour of activity of an average resident, it consists of consists of three parts: background EI_0, indoor comfort EI_I and activity-related EI_j. To overcome the problem of mismatch in categorization between two datasets, data was processed and matched based on the nature of activity and characteristics of appliance usage. Estimated result was reported to have less than 15% difference from the actual figure. And non-SNA activities was reported to be the most energy-consuming activity throughout the day.

$$E = \sum_{i=1}^{N} E_i = \sum_{i=1}^{N} (T_i \times EI_i) \quad \textit{Eq. 1}$$

$$\sum_{i=1}^{N} T_i = \sum_{i=1}^{N} \sum_{j=1}^{N} T_{i,j} = 24hours \quad \textit{Eq. 2}$$

$$EI_{\mathrm{i}} = EI_{i,0} + EI_{i,1} + EI_{i,j} \quad \textit{Eq. 3}$$

To address the second objective of the study, the urban-rural differential in residential energy consumption was decomposed into time effect and intensity effect by employing Sun (1998)'s complete decomposition analysis, *Eq. 4 & Eq. 5,* which is proved to be effectively to analyse energy problem, especially when dealing with the issues with two to three factors.

$$T_{effect} = \sum_{i=1}^{7} EI_{i_{rural}} \Delta T_i + \frac{1}{2} \sum_{i=1}^{7} \Delta T_i \Delta EI_i \quad \textit{Eq. 4}$$

$$EI_{effect} = \sum_{i=1}^{7} T_{i_{rural}} \Delta EI_i + \frac{1}{2} \sum_{i=1}^{7} \Delta T_i \Delta EI_i \quad \textit{Eq. 5}$$

Results

The majority of the urban-rural difference in residential energy consumption were contributed by intensity effect, while time effect only accounted for 0.02% of the difference, i.e. 0.0477kWh and 0.001kWh out of the total difference of 0.478kWh. In term of energy consumption by activity, intensity effect made positive contribution to all activities, with the highest in sleeping, following with watching TV and Non-SNA productive activities. While, for the contribution of time effect, it varies among activity categories, with significant positive effect in leisure activities and watching TV and negative effect in SNA productive activities and non-SNA productive activities. Besides, intensity effect is further divided into background, indoor comfort and activity-related intensity. It is found that major difference in electricity consumption are mainly contributed by activity-related intensity, except sleeping. Known that energy efficiency of appliance did not have obvious difference between those owned by urban and rural resident, it was believed that other major component, appliance ownership, was the major factor leading the urban-rural differential in residential electricity consumption.

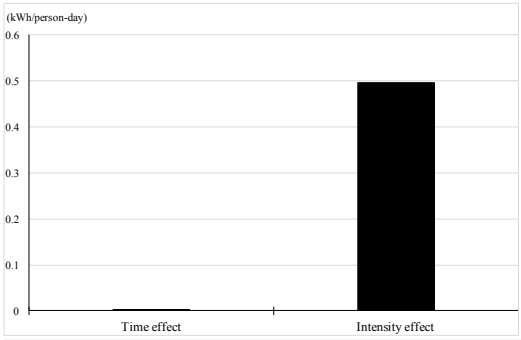

Figure 1a. Contribution of time effect (T_{effect}) and intensity effect (EI_{effect}) on urban-rural differential in residential electricity consumption

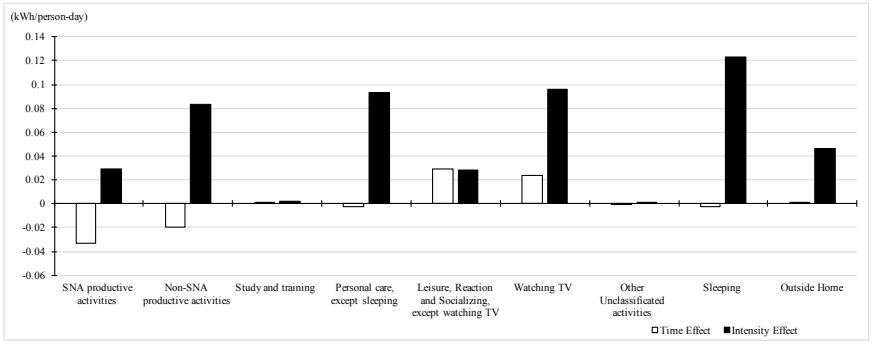

Figure 2a. Contribution of time effect (T_{effect}) and intensity effect (EI_{effect}) on urban-rural differential in residential electricity consumption by activity

Conclusions

This study introduced a novel approach in study residential electricity consumption in bottom-up perspective. With the use of existing time use and residential energy consumption survey data, it decomposes residential energy consumption in time spent and energy intensity of activity. Besides, results of decomposition analysis showed that urban-rural differential in per person-day residential energy consumption was mainly contributed intensity effect, in particularly, activity-related energy intensity. It also suggested that difference in appliance ownership was the major factor lead to the difference. This finding also provides a preliminarily explanation for the narrowing gap in pre per-day residential electricity consumption between urban and rural Chinese in recent decade.

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