Housing and Energy: Review of Cases in China

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Abstract:

The rapid urbanization of China has generated a large demand of energy services. According to the statistical data, the building energy consumption has kept rising during the past few decades, and the proportion of building energy consumption rose to 27.8 per cent of the China's total energy consumption in 2008 from 10 per cent in 1980 (CNBS, 2008; Kong et al., 2012). It is expected that the building energy will account for 30-40 per cent of the total energy usage in 2030-2040, which will meet the current level of Europe and the United States. This situation is leading substantial attention in the Hot-Summer Cold-Winter zone (HSCW) where together with the long period of summer and winter, the building energy consumption in HSCW Zone takes about 45% of the whole country (Yu, 2009). In the context of the changing urban patterns associated with energy consumption, this paper aims to analyse the way buildings are designed and its substantial impact on building energy consumption for HSCW region to enable crafting realistic region specific urban energy conservation strategies. Based on the previous literature review and case study, this paper will also evaluate the energy efficiency conditions in residential buildings and on building operation of selected cases and their correlations with local building energy efficiency polices.

This research study is part of an on-going EPSRC-DfID funded research programme, under the 'Energy and International Development' scheme. The project is titled 'Energy and Low-Income Housing in Tropical Housing' and has a huge scope of housing and community analysis in both rural and urban areas of China, Thailand, Tanzania and Uganda. The focus of this research paper is on China's urban housing.

Key words: Energy, Housing, Energy Efficiency, Energy Consumption, China.

A. Rationale

The rapid urbanization of China has generated a large demand of energy services. According to the statistical data, the building energy consumption has kept rising during the past few decades, and the proportion of building energy consumption rose to 27.8 per cent of the China's total energy consumption in 2008 from 10 per cent in 1980 (CNBS, 2008; Kong et al., 2012). It's expected that the building energy will account for 30-40 per cent of the total energy usage in 2030-2040, which will meet the current level of Europe and the United States. This situation is leading substantial attention in the HSCW where together with the long period of summer and winter, the building energy consumption in HSCW Zone takes about 45% of the whole country (Yu, 2009). The situation is rather more complicated because the inefficient of its energy system, the lack of consistent

data-surveys of household residential energy and some BEE standards have been not fully implemented. Alongside this, China has become the world's second-largest consumer of energy all these has led to a number of challenges which have the potential to work against its future economic growth. In the context of the changing urban patterns associated with energy consumption, this paper aimed to analyse the way buildings are designed and its substantial impact on building energy consumption for HSCW region to enable crafting realistic region specific urban energy conservation strategies. Based on the previous literature review and case study, this paper also evaluates the energy efficiency conditions in residential buildings and on building operation in Ningbo and its correlations with local building energy efficiency polices.

B. Objectives

a) To describe the overview of the China residential building structure (layout, orientation, height and age) and its relation with its energy consumption.
b) To evaluate the building energy consumption conditions in the HTCW climate zone.
c) To evaluate the current Ningbo's BEE code implementations conditions.

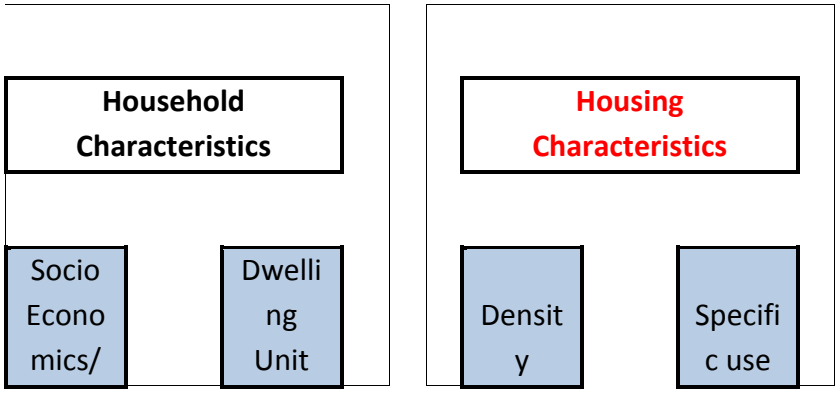
C. Methodology

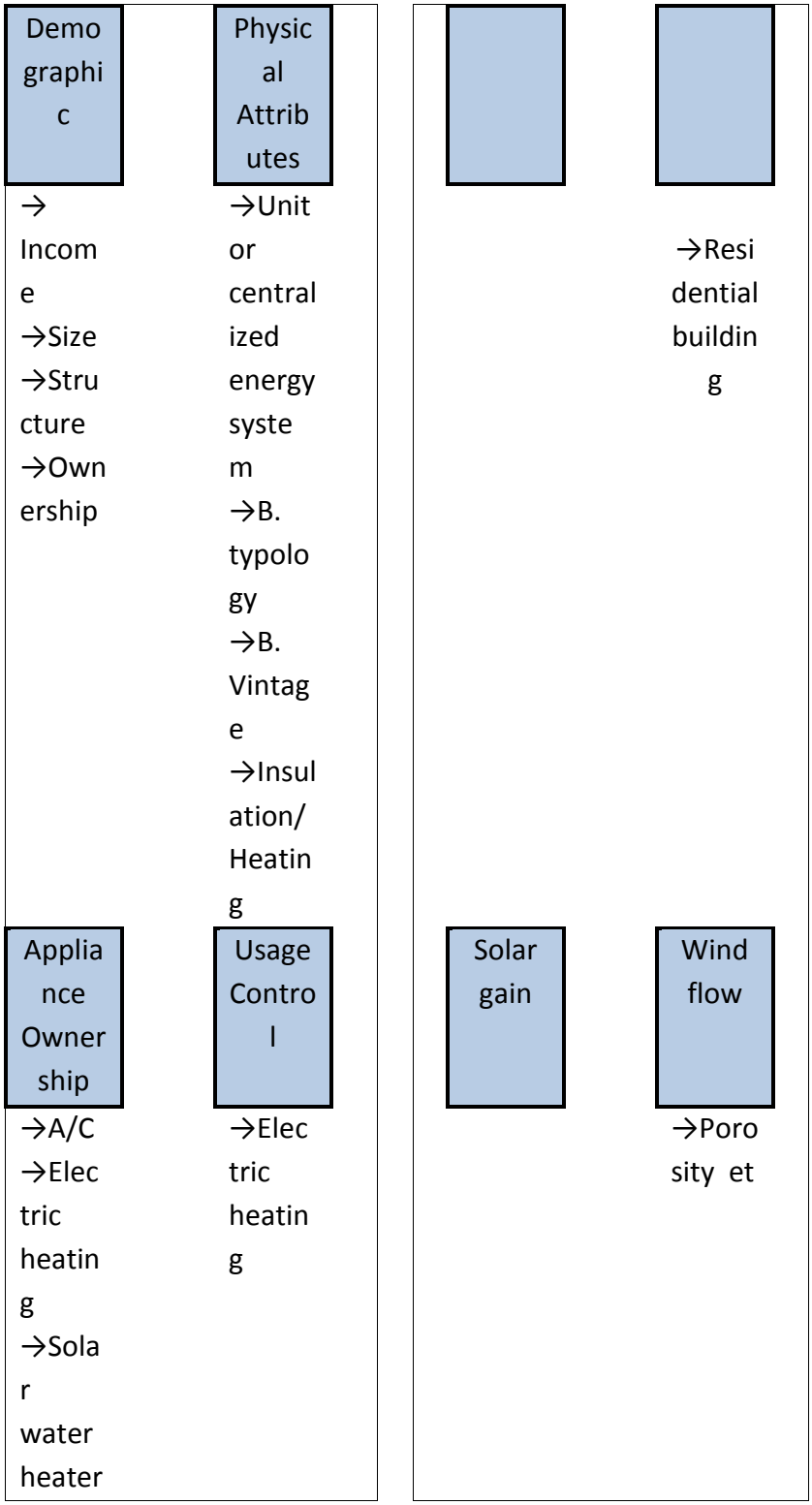
d) Content analysis on existing literatures and research reports are adopted to examine and describe the current China's REC.
e) This paper will accordingly take Ningbo City Residential Building as a case for analysis of energy consumption and building operation on the China's current urban pattern.

The data framework of the analysis is based on a literature review (Wang, 2010): which includes the **Household characteristics** and the **Housing characteristics** (density, mixed use, solar gain and wind flow).

Household characteristics data come from a survey data on selected household characteristics that impact operation energy consumption. The elements included are: socio-economics and demographics aspects, dwelling physical attributes, appliance ownership and usage control.

Physical characteristics of buildings come from XXX. The variables include density, mixed use, solar gain and wind flow.





Proposed site(s) of data collection

Two –three gated communities have been addressed:

1) 南裕二期安置社区- No. 2 Nanyu Gated Community – 215 Taikang East Road, Ningbo, China.

2) 钟盈社区- Zhongying Gated Community- 1366 Ningnan North Road, Ningbo, China.
3) 学府 1 号 B 区社区-宁波市鄞州区学府一号. Sunday Plaza.

D. Project Activities

a) Selection of Urban Neighbourhoods (November 10th)
b) Building Condition Assessment (on-site evaluation) Operation
   Elements: Building envelope (wall/ roof/ window/structure)
   Heating/ Cooling/ HVAC/Shading/ Lighting- (November 24th- November 30th)
c) Report Analysis (December)

E. Case Study

The data framework of the analysis is based on a literature review (Wang, 2010): which includes the Household characteristics and the housing physical characteristics (density, mixed use, solar gain and wind flow). Household characteristics data come from a survey data on selected household characteristics that impact operation energy consumption. Survey research is used face-to-face interviews with 50 household residential of Nanyu Gated Community, 100 from the Zhongying Gated Community and 50 from Sunday Plaza Building. The questionnaire consists of four criteria including questions on dwelling physical attributes, socio-economic demographic status, appliance ownership and usage control. The items within the questionnaire are: building type and design (dwelling physical attributes), gender, family structure (socio-economic demographic status), Lighting, cooking, entertainment, transportation, heating system (appliance ownership). And a finally behavioural question is added in order to know the attitudes toward energy consumption and usage control.

F. Expected Output

G. Literature review

There is an extensive literature on China's residential energy consumption and total energy consumption. Studies have explored housing energy efficiency form different perspective.

The first strand of research focuses on the China energy consumption, characteristics and situations.

Li et al. (2012) studied the characteristics of energy consumption, including energy consumption per household breakdown based on energy sources and usage, seasonal variation of energy consumption and energy consumption distribution in Nanjing Tulou. Others (Ouyang and Ge (2009); Chen et al., 2008; Yoshino et al. 2006) investigated the evaluation or saving of energy consumption in residential building sector. Zhao et al. (2012) used the LMDI method to a decomposition of China's urban REC during the period of 1998–2007 to study the forces driving the fast-growing residential energy consumption in urban China. Liu et al. (2012) conducted a survey on energy consumption status in public buildings in Chongqing and analysed the current energy management and challenges, and discusses the differences between governmental office buildings and commercial buildings. Cai et al. (2009) have analyzed China BEC situation and the challenges of rapid increasing BEC due to the increasing demand of more new buildings and household appliances. Zhang et al. (2014) used structural decomposition approach to uncover the regional

disparities in energy consumption from 1987 to 2007 such as the historical view of contributors to changes in energy consumption in China during this time. Zheng et al. (2014) made a survey of 1450 households in 26 Chinese provinces in 2012 to identify the characteristics and potential driving forces of residential energy consumption in China. Sun et al. (2014) explored the factors that influence household energy consumption and analysed the structure of residential energy consumption in China by exploring the electricity, heating and transport energy consumption of rural and urban households. Niu et al. (2012) analyzed the trends in household energy demand; the quantity and structure of the energy used by rural and urban households, and described people's living status in terms of the level of energy used by their household. Chang et al. (2013) used the I-O LCA model to quantify the life cycle energy consumption of urban and rural residential buildings built in China in 2007. Chen et al., 2013 propose a heat pump heating (HPH) system as a replacement for UDH to help realize energy-saving and emission-reduction goals to a greater extent in northern China. Wang (2010) conducted a large-scale survey of approximately 4,000 households in 23 urban neighborhoods and verified the influence of household and neighborhood characteristics on household operational energy consumption.

The second strand of research focuses on household energy saving behavior characteristics. Yue et al. (2013) investigated the differences in households' willingness to adopt three types of energy-saving behavior types in Jiangsu Province. Wang et al. (2011) conducted a survey on electricity-saving behaviour in household appliance usage in Beijing. Their focus to identify the relationship between of the residents' willingness and behavioural characteristics in electricity saving. Xu et al. (2013) conducted a survey on occupant's behaviors in a representative nine-story apartment building in northern China. Their focus is to identify the energy and behavioral impacts of integrative retrofits in residential buildings in northern China. Yu et al. (2011) used the Multiple Discrete–Continuous Extreme Value (MDCEV) model to investigate the ownership and usage of various in-home end- uses (appliances) and vehicles, the actual energy consumption, as well as the socio-demographic attributes of households and their representative members. The results of the survey questionnaire in Beijing indicate the strong influence of household attributes, housing attributes, and residential location on households' energy consumption behavior. Ma et al. (2013) conducted a survey on attitudes towards energy (knowledge, awareness and stated preferences) and energy saving in the context of household electrical appliances out in Chongqing during the period 2009–2010. They found that citizens in Chongqing receive relatively little information and guidance on how to save energy in the home and that their stated level of knowledge on this subject is also rather limited.

The third strand of research focuses on building energy saving policies. Zhang et al. (2013) discussed China's policies on building energy efficiency from a macroscopic view and identified the main barriers in promoting building energy efficiency. Li et al. (2009) discussed the different building energy efficiency (BEE) standards/codes on build energy consumption in China in the context of centralized urban district heating system in northern China (Tianjin). Kong et al. (2012) explored also the BEE policies in China, but they focused on the fiscal policies and four important programs of BEE taking by the Chinese government. Yu et al. (2014) have assessed impacts of building codes on building energy use in the presence of economy- wide carbon policy. Li and Wang (2012) investigated the major energy and climate targets and actions specified in the 12th FYP to gain insights into the nature and magnitude of challenges and difficulties with regard to the medium and long run economic and environmental policies. Liu et al. (2013) explored the Renewable Energy Applications Buildings (REAB) measures taking by the Chinese government,

including economic incentive mechanisms, organising agencies, application and evaluation systems, online monitoring platforms, acceptance inspections, assessment systems, standard criteria and so forth. Yan-ping et al. (2009) bravely discussed the policies and barriers of energy efficiency of large public buildings in China. Xu et al. (2031) used the energy simulation tool eQuest to analyze the building energy saving potential in HSCW Zone of China. They found that heating energy consumption took one third of the building energy consumption for residential building in the HSCW Zone, which means that the priority of building energy conservation in China may be the solid implementation of existing standard, instead of establishing higher energy standard. Yao et al. (2014) used a quantile regression and counterfactual analysis to evaluate the impact of the effects of the policy incentive (energy subsidy program) and key household characteristics, respectively, on residential electricity consumption in both urban and rural areas of Rizhao city. Yuan et al. (2010) have studied the relations between Chinese energy consumption and energy prices are researched by co-integration equations, impulse response functions, granger causality and variance decomposition.

In sum, the above studies mainly have analysed the residential energy consumption from different perspective. However, analyses for urban residential energy consumption in HTWC are still insufficient. Household/Residential energy consumption patterns are distinct in different regions in China due to the differences in economic development level, urban pattern, the implementation of BEE standards at local level, neighbourhood typologies, population density (more than 40% of Chinese population lives in this area, which is less than 20% of Chinese total area, leading to much higher population density than other regions) and climate pattern. Especial attention is the heating/cooling system, not having central heating system aggravates the increase of the building energy consumption since Chinese household are able now to have individual household heating which is primary electric. Therefore the evaluation onsite of the residential building's energy consumption in Ningbo is needed.

Datasets for both cases are provided separately.