Energy and Buildings 107 (2015) 155–162

Contents lists available at ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Situations and challenges of household energy consumption in Chinese small towns

Min Chen, Xudong Yang*

Department of Building Science, School of Architecture, Tsinghua University, Beijing 100084, PR China

ARTICLE INFO

Article history:
Received 22 March 2015
Received in revised form 5 August 2015
Accepted 6 August 2015
Available online 7 August 2015

Keywords:
Household energy consumption
Biomass
Space heating
Small town

ABSTRACT

A large scale survey of household energy consumption in Chinese small towns was conducted to obtain the fundamental data and analyze the key problems. Based on the survey results, the total annual household energy consumption in Chinese small towns is around 156 million tons of coal equivalence (tce) (4.6×10^9 GJ). The breakdowns include 74 million tons of raw coal (1.5×10^9 GJ), 11 million tons of firewood (0.2×10^9 GJ), 38 million tons of straw (0.6×10^9 GJ), 5.7 million tons of liquefied petroleum gas (LPG) (0.3×10^9 GJ), 8478 million m^3 natural gas (NG) (0.3×10^9 GJ), 1.5 million tons of charcoal (0.5×10^8 GJ) and 160 billion kW h electricity. Space heating accounts for the most proportion of household energy consumption in northern small towns in whole country. Coal is widely used for space heating. There will be a big challenge on energy and environment with a large number of migration from rural areas to small towns during the urbanization. To avoid significant increase of energy and pollutant emissions, making full use of biomass energy for household space heating in small towns is proposed based on the analysis of supply and demand of biomass resources. The results obtained from this study could also provide references to guide the development in small towns in other countries, particularly the developing world during the process of rapid urbanization.

1. Introduction

Currently there are over 20,000 small towns in China [1]. Total population of small towns in 2013 was 247 million and it will continue to increase with the process of rapid urbanization. The Chinese State Council recently issued a "New National Urbanization Plan", with the ambition of encouraging another 100 million people to settle in urban over the next 10 years [2]. Hence, small towns will play an important role in the future societal structure of China [3]. Correspondingly, great changes will take place in building sector in small towns. On one hand, more and more buildings will be constructed due to higher demand. On the other hand, there is an upward trend to build multiple-story apartments in small towns to improve land utilization [4]. According to the past experiences, significant increase of building energy consumption occurs along with the improvement of economy and living standard during the process of rapid urbanization [5–7]. In the near future, China will face more challenges of increased energy consumption in small towns and the whole building sector. Thus, promoting and accelerating the sustainable development of small towns has the strategic meaning to China's future development in the building sector.

At present, research has been largely focused on the building energy consumption in large cities and rural areas, the information of household energy consumption in small town is lacking [8–14]. Only a few small-scale surveys conducted many years ago were available to provide historical data of energy consumption in some small towns [15–21]. These studies however do not reflect the current situations in China. Fundamental data are the base for understanding current situation, capturing the key problems and solving these problems in small towns.

The main purpose of this paper is focused on the following two aspects:

(1) Analyzing the situation and characteristics of household energy consumption as well as addressing the key problems and challenges in Chinese small towns based on a large scale field survey.
(2) Proposing feasible suggestions on energy policies to put forward the sustainable development of Chinese small towns.

In particular, our survey will form an important database for studies on household energy consumption in Chinese small towns and provide references to policy makers. China's energy problems

* Corresponding author. Tel.: +86 10 6278 8845; fax: +86 10 6277 3461.
E-mail address: xyang@tsinghua.edu.cn (X. Yang).

http://dx.doi.org/10.1016/j.enbuild.2015.08.017
0378-7788/

Nomenclature

SCZ	severe cold zone
CZ	cold zone
HSCWZ	hot summer and cold winter zone
HSWWZ	hot summer and warm winter zone
TZ	temperate zone

are becoming a global issue. Results of this study could also provide references to guide the development of other developing countries.

2. Methodology

To obtain a set of national data with information on household energy consumption in Chinese small towns, an independent survey was conducted in 2014. Key information and methodologies of the survey are given below.

2.1. Survey areas

China occupies a huge geographical area with a wide variety of climatic conditions, one of the most important factors influencing building energy consumption. For the purpose of thermal design, the whole country is divided into five climatic zones, namely severe cold zone (SCZ), cold zone (CZ), hot summer and cold winter zone (HSCWZ), hot summer and warm winter zone (HSWWZ), and temperate zone (TZ) (Fig. 1). Table 1 shows weather conditions of five climate zones. SCZ and CZ are known as the heating zones where space heating is essential in winter. HSCWZ also requires space heating, whereas HSWWZ and TZ do not.

From energy consumption point of view, household energy consumption in small towns in TZ is small because neither spacing heating nor cooling is required due to the temperate climate. Furthermore, households in small towns in TZ only account for 3% of the whole country. To balance the reliable results and logistical costs, the survey covered four provinces in SCZ (Heilongjiang, Jilin, Liaoning and Inner Mongolia), five provinces in CZ (Gansu, Hebei, Tianjin, Shanxi and Henan), four provinces in HSCWZ (Anhui, Jiangsu, Chongqing and Jiangxi) and one province (Fujian) in HSWWZ. For provinces that were not directly covered in our survey, the average household energy consumption index was extrapolated based on the nearby surveyed towns which have similar weather condition and living habits. In estimation, the levels of energy consumption in different households are assumed to be the same when weather conditions and living habits are similar. Random sampling method was adopted to choose approximately one small town in each province and about 150 households in each town.

Table 1
Weather conditions of five climate zones in China.

Climate zone	Weather condition
SCZ	The average temperature of the coldest month is below 0 °C More than 145 days with a mean daily temperature below 5 °C in a year
CZ	The average temperature of the coldest month is between 0 °C and −10 °C About 90–145 days with a mean daily temperature below 5 °C in a year
HSCWZ	The average temperature of the coldest month is between 0 °C and 10 °C The average temperature of the hottest month is between 25 °C and 30°C About 0–90 days with a mean daily temperature below 5 °C in a year About 40–110 days with a mean daily temperature above 25 °C in a year
HSWWZ	The average temperature of the coldest month is above 10 °C The average temperature of the hottest month is between 25 °C and 29 °C About 100–200 days with a mean daily temperature above 25 °C in a year
TZ	The average temperature of the coldest month is between 0 °C and 13 °C The average temperature of the hottest month is between 18 °C and 25 °C About 0–90 days with a mean daily temperature below 5 °C in a year

2.2. Data collection methods

In the summer of 2014, approximately 40 undergraduate students from Tsinghua University were recruited to conduct the survey in 14 small towns. All interviewers were required to attend a training lecture before going to the field. During the field survey, they conducted face-to-face questionnaire interview and carefully recorded the data house by house. The questionnaire included five parts: (1) basic information of dwelling, such as dwelling vintage, structure, size and performance of building envelop which includes the materials and sizes of doors, windows, walls, roofs, thickness and type of heat insulation materials, etc.; (2) basic information of household, such as occupation, age, gender, education, household size and annual income; (3) consumption amount and costs of each type of energy, such as electricity, coal, natural gas (NG), liquefied petroleum gas (LPG) and straw; (4) energy using behavior, such as space heating and cooling period, space heating and cooling time, temperature setting, frequency of cooking and bathing, appliance types, frequency and duration of appliances use; (5) subjective assessment on indoor thermal environment. Interviewers collected the information by own observation or asking house owners. To ensure data quality, the entire questionnaire must be filled out by the interviewers.

In order to ensure the representativeness and universality of the selected samples, two measures were taken in the study design. First, all the residential districts were selected in the township, and each residential district was required to represent the common situation of energy use. Then, households were chosen from these residential districts by random sampling. Only households who met all the following three criteria were invited to participate in the survey. First, the household was able to provide the complete information of energy consumption in 2013. Second, the household used energy only for consumption purposes, rather than for industry or business purposes. Third, the households had lived in the town for more than one year. Among the candidate households in the 14 small towns covered, 2072 households passed the validity and consistency checks for final analysis.

2.3. Data analysis methods

Three methods are commonly used to analyze building energy consumption, namely top-down approach, bottom-up approach and hybrid approach [22]. Top-down approach requires information on the total energy use and total building floor area, which may be disaggregated by different building types and other parameters. Hybrid approach requires information on total floor area and most importantly, specific energy consumption index, which allows for calculating total energy use for different end-uses, building types, climate zones, etc. at the level of a region. Bottom-up approach offers the opportunity to obtain data for sample buildings, which can be then aggregated and used in the hybrid approach to extrapolate the results to national. Top-down approach is mostly useful, when the assessment has to be done on a large scale (e.g. country) and there is a lack of detailed data on that level. Hybrid approach, on