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Chinese residential energy demand: Scenarios to 2030 and policies implication

Chiara Delmastro, Evasio Lavagno*, Guglielmina Mutani

DENERG—Energy Department, Politecnico di Torino, 24 Corso Duca degli Abruzzi, 10129 Torino, Italy

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ABSTRACT

In China, the population is expected to continue to grow together with construction of new buildings. Consequently, the energy demand required by the building sector will inevitably rise. This paper focuses on the Chinese residential sector and describes the structure by using the EfB—energy for buildings model. Using this tool it is possible to simulate the trend of the energy demand until 2030. A range of different scenarios – at national and regional level – is presented and discussed, including government plans and the application of some proposed recommendations. The analysis suggests that the energy consumption in this sector will not stop its growth and in 2030 it will comprise between 9500 and 14,000 PJ. Meaningful energy savings can be achieved with the introduction of more aggressive policies and behavioural change. Many difficulties have been faced in this work because of the complexity and rapid evolution of the Country; anyway, it can be considered as a starting point for future research. Among further improvements, the paper suggests the introduction of a more complete description of the building types, the association of the floor area evolution to the construction sector activity and the inclusion of economic and environmental evaluations.

1. Introduction

In recent years China, due to its rapid economic growth, has become the largest energy consuming nation in the world, overtaking the US; its per capita CO_2 emission exceeds the average world level [1] and the population is expected to continue to grow [2], together with construction of new buildings.

In 2010, the construction sector was one of the most dynamic and the building stock accounted for 45.3 billion square metres of floor area [3]; about 2 billion new square metres have been added each year during the last decade [4].

The building sector is one of the larger energy consumers accounting for about 25% of the final energy consumption, of which the residential sector was responsible for about 50%. The buildings (residential and commercial) operational commodity consumption grew from about 290 million tce (8470 PJ) in 2000 to about 735 million tce (21,512 PJ) in 2011 [4,5]. Driven by the increase of urbanisation and the improvements in living standards, the number of electric appliances is rising and heated and cooled floor areas will also increase: as a consequence, the residential energy demand will inevitably rise.

This trend is not sustainable for China and the Government action is focused on the research of appropriate energy policies in order to reduce the residential energy demand and the energy use.

The aim of this paper is to analyse the historical evolution of this sector and to develop reasonable projections to 2030 of the energy demand and consumption, taking into account the influence of energy policies and measures.

Due to the lack of well-documented insights and of reliable statistical data, the effectiveness of energy policies is difficult to prove and much research has been carried out: the IEA World Energy Outlook [6,7] points out that the total energy consumption in China will be 170,277 PJ (5.81 billion tce) by the year 2030 and building energy will account for 44,547 PJ (1.52 billion tce). Main gains are expected to be achieved by improvement at the technological level [8].

Other EIA research suggests that the total energy consumption in China will be 187,569 PJ (6.4 billion tce) by the year 2030, with building energy accounting for 37,807 PJ (1.29 billion tce) [9]. The LBNL points out that building energy consumption in China will be 29,307 PJ (1 billion tce) by the year 2020, the chief key factor being the level of urbanisation [10].

All the research describe the growth trend of possible building energy demand but, currently, there is few literature focused on

* Corresponding author. Tel.: +39 0110904429.
E-mail address: evasio.lavagno@polito.it (E. Lavagno).

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Nomenclature

BAU	business as usual scenario
BERC	Building Energy Research Centre, Tsinghua University
CK	cooking (PJ)
CSY	China Statistical Yearbook
CZ	cold zone
EA	electrical appliances (PJ)
EC2	Europe China Clean Energy Centre
ECZ	extremely cold zone
EDPM-CN	energy demand projection model for China
EfB	energy for buildings model
EIA U.S.	energy information administration
FA	floor area (billion sq.m.)
FYP	Five Year Plan
GCAM	global change assessment model
GDP	global domestic product
GHG	greenhouse gases
HSCW	hot summer cold winter
I(t)	yearly per capita income (k€/cap/y)
IEA	International Energy Agency
IPAC	Integrated Policy Assessment Model for China
LAME	Laboratorio Analisi Modelli Energetici, Politecnico di Torino
LI	lighting (PJ)
LP	low policy scenario
M_i	for $i = 1–5$: $Module_i$
NP	no policy scenario
PcE	yearly per capita electricity demand (koe/cap/y)
PV	photovoltaic
RES	reference energy system
SC	space cooling (PJ)
SH	space heating (PJ)
SP	strong policy scenario
SP + GL	strong policy plus green lifestyle scenario
UN	United Nations
WH	water heating (PJ)

long-term residential energy demand analysis; the rapid and atypical evolution of the Country that makes many factors uncertain: population and economic growth, migration from rural to urban, increase in floor space, new technologies. In this research a building energy demand simulation model for China – the EfB: energy for buildings – has been developed. By using this model is possible to downscale the analysis into three climatic region; two building types (urban and rural) were modelled in each region. This study focuses on the operation phase of buildings and analyses new and existing residential constructions. End-uses are split into space heating, air conditioning, cooking, water heating, lighting and electrical appliances. The understanding of Chinese residential buildings end-use paths in different climatic conditions will help policy makers to develop suitable policies and prioritize measures. Following the description of the adopted methodology and model, this work analyses the residential energy consumption trends to 2030 considering five scenarios depending on technological advancement, energy policies and lifestyles paths.

2. Methodology

The analysis described in this paper refers to a simulation approach that has been developed by the LAME Team of the Energy Department of Politecnico di Torino [11] in cooperation with the Energy Research Institute of China (ERI), during the Five Year Action Plan of the Europe—China Clean Energy Centre (EC2) at Tsinghua University [12]. This model, the EfB—energy for buildings model, is a sub-model derived from the more general EDPM-CN model [13].

The aims of the model is to analyse the effects of population and economic growth, economic structure, technology advancement, availability of resources, production and consumption styles, environment capacity, institutional structure and management on short/mid-term energy demand under different scenarios (with different time-frame, technology, energy and environment policy) in an objective, quantitative, scientific and comprehensive way, to support the design and implementation of energy strategies and plans. For the short-term projections, the prescriptions of the last Five Year Plan are assumed, while for the next periods until 2030 suitable scenario assumption are adopted.

The model formulation and the background concepts are described in the following paragraphs.

Otherwise of methodologies and tools that describe the full energy system (supply, transformation and demand sides) as a part of the global Chinese economy, that sometimes, is acting into an international context like GCAM (global change assessment model) [14], IPAC (Integrated Policy Assessment Model for China) [15] and Markal [16]), EfB—energy for buildings is focused only on short- and mid-term projections of the energy demand inside the Chinese residential sector. Residential energy demand projections are produced by the end-use services requirements growth rate induced by the evolution of the main global drivers like population and income. The service demands' projection criteria are explained in Section 2.7.

There are no links with other sectors, neither with the energy supply sub-sector. This very strong modelling limitation (even if for a partial equilibrium, bottom up approach), however, allows:

a) to put in evidence the dynamic mechanisms of the chain constituted by (i) the main global drivers (population and income) (ii) the service demand and (iii) the energy demand, without particular elasticities;
b) the role of measures and policies and of the expected technological improvement.

However, the regional structure of the EfB model allows to analyse, in addition to the whole Country, also particular geographical areas for putting into evidence conditions associated to climate, urban and rural areas and local building types.

2.1. Analysed areas

China occupies a huge geographical area with a wide variety of climatic conditions, one of the most important factors influencing building energy performances.

For the purpose of thermal design, the climate of China is classified into five main types [17], and consequently, the Country is divided into five climatic zones.

In this analysis the five climatic zones have been grouped into three spatial regions, accordingly to Building Standard coverage areas and to the different climatic conditions (Fig. 1): North (cold zone and extremely cold zone), HSCW (Yangtze Valley and Fujian) and South (warm zone and hot summer warm winter).

The first two zones (CZ and ECZ) are collectively known as the "heating zone" in which heating is required by law; in these northern areas, central heating is the dominant solution in urban areas. The heating zone is separated from the other parts of China by the Yangtze River.

The northern heating zone covers the 70% of the national total area and district-heating system constitutes a large proportion of the total residential energy consumption [18]. The remaining apartments are heated by individual heating systems (gas or electricity).