Energy and Buildings 102 (2015) 307–316

Contents lists available at ScienceDirect

Energy and Buildings

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

Building energy use in China: Ceiling and scenario

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ARTICLE INFO

Article history:
Received 10 March 2015
Received in revised form 28 May 2015
Accepted 29 May 2015
Available online 1 June 2015

Keywords:
Building energy use
Energy supply
CO_2 emissions
Ceiling

ABSTRACT

With increasing levels of urbanization and a growing economy, total building energy use in China is rapidly increasing. However, energy use must be controlled due to limited energy supply and the goal of lowering carbon emissions. This study tried to define a reasonable limit for total energy use in China, and, more specifically, a target for building energy use. Domestic energy production, energy imports, and the need to reduce CO_2 emissions and fossil fuel combustion were considered when analyzing the available energy for China. The current status and future trends of energy use by industry, building, and transportation sectors were analyzed to determine how much energy the building sector can use considering economic growth and improving living conditions. Within the framework of "Ecological civilization," this study suggests that annual building energy use in China has to be limited to no more than 1 billion tce.

1. Introduction

Building energy use in China has been increasing rapidly in recent years. In 2011, the total building energy use was 687 Mtce (million tons of coal equivalent) [1], 1.5 times that of 2000. The total residential electricity use almost tripled from 145 TWh (terawatt-hours) to 562 TWh [2].

These large increases of building energy use were caused by the rapid increase of building floor space and energy use intensity for all building types. Constructed building floor space was about 3.16 billion m^2 in 2011, up from only 1.6 billion m^2 in 2000. In addition, more people are moving from rural regions of the country to urban areas. The urbanization rate is expected to increase from 51.3% to 70% by 2030, which means that China's urban population will increase to more than 300 million [3]. As additional buildings will be built to accommodate these people, energy use will also increase as the demand grows. The ownership rate of domestic appliances and air conditioning units is also rapidly increasing which is reflected in the rapid growth of the energy use [4].

However, building energy use in China continues to remain far below that of developed countries, whether per capita or per square meter. In per capita terms, China's building energy use was only 1/8 that of the USA and 1/4 that of Japan and the EUG4 countries (United Kingdom, France, Germany and Italy) in 2012 (Fig. 1) [1,5,6]. With regard to factors that affect building energy use, different usage modes and lifestyles are the main reasons for the differences in energy use intensities [7–9].

Building energy use will increase as the economy develops and people's living standards improve, which means that usage modes and lifestyles will change. These changes may include an increase of appliance ownership and usage, as well as improvements to the indoor environment. For example, with an ownership rate for air conditioners of 126.8% for urban households, people will be able to install about three air conditioners per household (one air conditioner per room) [2]. The indoor temperature is considered too low during the winter in the Yangtze River basin and too high during the summer in the southern areas of the country. If the per capita energy use would reach the level of the EUG4, China's building energy use alone would be 2.9 billion tce (tons of coal equivalent), close to China's total energy use in 2010. If the energy use per capita reached the level of the USA, the building energy use will be more than twice China's total energy use in 2010.

Several institutes are investigating China's building energy use, including the International Energy Agency (IEA), U.S. Energy Information Administration (EIA), Lawrence Berkeley National Laboratory (LBNL), Energy Research Institute National Development and Reform Commission of China (NDRC), and the Building Energy Research Center of Tsinghua University (BERC), all of which have published reports about building energy use in China. These reports predict that China's building energy use will increase in the future as shown in Fig. 2, even though opinions about the current situation differ [10,11]. All reports used a bottom-up approach for their

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http://dx.doi.org/10.1016/j.enbuild.2015.05.049
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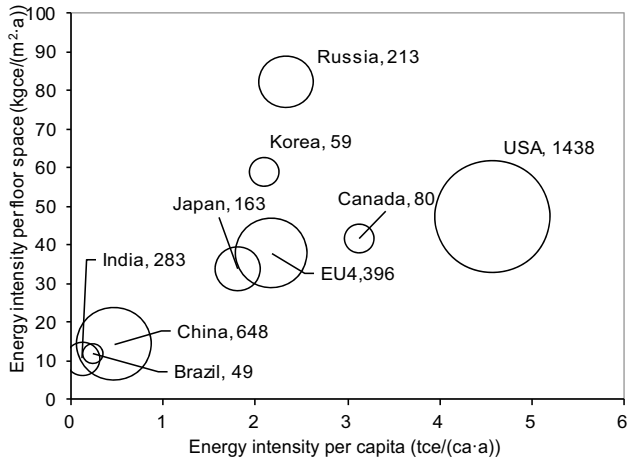

Fig. 1. Building energy use intensities in 2010.

scenario analyses by analyzing the energy demand for each type of end use. However, the obtainability of energy resources in China was not considered.

The IEA analysis, which included an effort to reduce CO_2 emission (450 Scenario), found that China's building energy use should not exceed 835 Mtce by 2030.

A "total energy use control" plan was announced in former President Hu Jintao's report at the 18th Party Congress as an important part of the "ecological civilization", which is one of the five overarching plans for the development of China. It states that there should be a ceiling for energy use and that total energy use should be strongly controlled. With this guiding ideology, the Chinese government published the Energy Development "Twelfth Five Year Plan" at the beginning of 2013, which announced that China would limit total energy use to no more than 4 billion tce by 2015 [12]. This target was set by considering energy security, resources, environment, technologies, and economic factors. The plan also announced that imported oil should contribute no more than 61% to the total oil demand. The total primary energy use will be limited to no more than 4.8 billion tce by 2020 in the "National Climate Change Plan for 2014–2020" which was released in November 2014 by the NDRC [13]. However, if energy supply cannot meet the energy demand, the country's entire economy will be in danger. China cannot depend on imported energy to support its development, as China is a very large country whose total energy use represents a large part of the global energy use. Thus, China is determined to

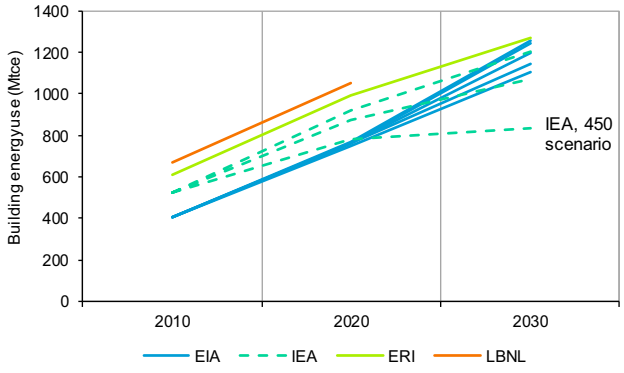

Fig. 2. Predicted future building energy use in China. *Note*: 1. Biomass energy was not included; 2. Different energy policies were considered in the IEA scenarios and different energy prices were considered in the EIA scenario.

achieve its energy conservation targets by controlling total energy use.

In general, China's building energy use is significantly lower than of developed countries. However, driven by social and economic development, the country's building energy use is growing fast, which has received much attention from academia and government. If the increase in building energy use continues too rapidly, the environment and the economy will be adversely affected.

Most existing research has focused on energy use forecasts and carbon emissions reductions, but there have been few studies of China's energy supply. Different features of China's building energy use also have to be carefully considered since developments of China's building sector are quite different from those in other countries. This study presents a method to predict the ceiling of Chinese building energy use. The model describes each type of building energy use based on BERC's CBEM (China Building Energy Model) and current building energy use characteristics.

2. Method

As mentioned in the introduction, there have been various scenario analyses of China's building energy use. However, there has been little consideration of energy use constraints such as limited energy reserves, which may present significant limitations. At the same time, China's building energy use will differ from that of developed countries due to its dual urban–rural structure and large amount of building floor space with district heating systems in northern urban areas [1].

This study uses a constraint model for building energy use and the national building energy use model (CBEM) developed by THUBERC to predict how building energy use can be limited to a predetermined ceiling.

2.1. Energy use constraint analysis model

Energy use is limited by the total energy supply and requirements of CO_2 emission reductions. Combined energy resources include fossil fuels, renewable energy resources, and nuclear energy, with all three categories being limited by reserves, technical limitations, and environmental and economic factors. Total energy supply from both domestic and foreign sources cannot increase indefinitely. In addition, fossil fuel usage must be restricted to limit climate change [14]. For these reasons, China's energy use has to be limited to a predetermined ceiling both for total energy use and energy use of each sector, including industry, buildings, and transportation. Each of these sectors will see growing energy demand in the future.

The energy use constraint analysis model is described in Fig. 3. Total energy use is limited by energy supply and CO_2 emissions. Domestic and imported energy supplies and energy types must be considered when analyzing energy supply limitations. The current fossil fuel energy supply structure and CO_2 emissions are references for CO_2 emission limitations. On the other hand, economic and social development will require increasing industrial, building, and transportation energy supply as China develops. As the manufacturing industry is China's economic pillar, it is difficult to reduce industrial energy use. Increasing travel and car ownership rates are the main drivers for transportation energy use. The drivers for building energy use include population (total population and urbanization rate), economic growth, building floor space, and the culture of energy consumption. Building energy use must be carefully assigned if there is a ceiling on total energy use. Otherwise, any economic and social development will be severely affected.

Finding the ceiling for building energy use requires a large amount of data on energy supply and CO_2 emissions. China's