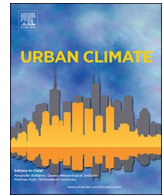




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The impact of urbanisation on energy consumption: A 30-year review in China

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ABSTRACT

Cities are a major battlefield in humanity's struggle to save energy and combat climate change. In China, the cities have surpassed the industrial sector and become the largest consumers of energy. This paper explores how the process of urbanisation affected energy use in China 1980–2010. The results of the analyses show that for every 1% increase in the urban population relative to the total population, national energy consumption rose 1.4%, while industrialisation was not significantly associated with the growth of energy use during this period. Urbanisation has increased energy consumption along three main pathways: urban spatial expansion, where urban sprawl has increased energy consumption in new buildings and the transport sector; urban motorisation, which induces energy-intensive transportation; and the rising quality of energy-intensive lifestyles. Urban households consume 50% more energy than rural households per capita, which indicates that continued urbanisation in China will promote the growth of national energy consumption. Urban policies designed to encourage compact urban growth, green buildings and new energy vehicles could thus play a vital role in saving energy. Undoubtedly, the changes in lifestyle and growth of a consumption society and e-Society will bring new challenges to energy-saving policies and climate change mitigation initiatives in China.

1. Introduction

Cities have become a major focus in the field of global climate change. This is not only because cities are one of the main contributors to fossil-fuel energy consumption and greenhouse gas (GHG) emissions in the world, but also because city policies are vital for the mitigation of and adaptations required in relation to climate change (Bulkeley, 2013). It has been reported that cities consume the great majority – between 60 and 80% – of energy production worldwide and account for roughly an equivalent share of global CO₂ emissions (OECD, 2010).

Cities contribute to climate change in three main ways: through direct emissions of GHGs that occur within city boundaries; through the GHG emissions that originate outside the city boundaries but are embodied in civil infrastructure and urban energy consumption; and through city-induced changes to the earth's atmospheric chemistry and surface albedo. In particular, energy use in cities is a key issue for GHG emissions. In OECD cities, GHG are increasingly driven less by industrial activities and more by the energy required for lighting, heating and cooling, as well as electronics and transport mobility (IEA, 2009).

Recently, the relationship between urbanisation and energy use has been attracting the increasing interest of researchers and politicians (Salim and Shafiei, 2014; Pachauri and Jiang, 2008; Liu, 2009). Growing urbanisation will lead to a significant increase in

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energy use and CO₂ emissions, particularly in non-OECD countries in Asia and Africa, where urban energy use is shifting from CO₂-neutral energy sources such as biomass and waste to CO₂-intensive energy sources (OECD, 2010). In practice, policymakers are often confused about how to manage urban growth to reduce the impact of urbanisation processes on energy use. Although many researchers have discussed the issue, a consensus has yet to be reached, especially since the issue is viewed within different contexts (Sadorsky, 2014; Pachauri and Jiang, 2008; Poumanyvong et al., 2012; Hossain, 2011).

In China, there has been rapid urbanisation since the 1980s, known as 'China's growth miracle' (Wu, 2004). During the period from 1978 to 2012, the country's urbanisation rate (the percentage of the total population that is considered urban) increased from 17.92% to 52.57%. The urban population increased by 10 million annually (China Statistical Bureau 2012) and 498 cities were newly recognised during the same period, many of which had begun as villages or small rural towns. China is thus shifting from a conventional agricultural society to an industrial and urban society (Deng et al., 2008; Lin, 2002). Such rapid urbanisation has caused problems for environmental protection and energy savings. Energy consumption grew from 410.1 million tonnes of oil equivalent (mtoe) in 1980 to 2735.2 mtoe in 2012 (China Energy Statistical Yearbook 2012). In the meantime, China has become the world's largest emitter of greenhouse gases, showing a vigorous growth from 1467 megatons in 1980 to 8287 megatons in 2010 (World Bank, 2015). A recent forecast by the International Energy Agency highlights this continuous growth, showing that energy consumption in China will reach 5500 mtoe – double the US level – and account for more than a quarter of the world's total energy consumption by 2040 (International Energy Agency, 2013). In China, 60% of this energy was consumed in cities, and energy consumed individually by the urban population is on average 1.3 times that consumed by the rural population (China Energy Statistical Yearbook 2012).

Petrol use and coal burning have caused a serious problems with public health. In China, more than one million people have died from air pollution created by road transport. Emissions from cars are the main source of PM_{2.5} and haze weather every year, which the central government and local authorities both consider the most important environmental problem; for example, road transport contributed > 30% of the total PM_{2.5} in Beijing, 21% in Tianjin and 26% in Guangzhou.

Reducing energy use and promoting green energy in cities has become a key mission at different levels of government in China. In 2009, the central government developed a national-level policy which aimed 'to build an environmentally friendly society and a resource-saving society'. According to the policy, protecting the environment, saving energy and reducing emissions are essential elements of urban development in China. Detailed institutional reforms to the existing governance organisation, laws and regulations were undertaken to implement this national policy. According to the latest National Energy Development Strategy, cities are the main battlefield for governments struggling to constrain the rapid growth in energy consumption. Many new sustainable strategies have been discussed and applied by local governments to decrease energy use in cities, including low-carbon cities, green cities and eco-cities.

China's cities provide researchers with a good case study of the relationship between urbanisation and energy use. While a large amount of literature has discussed the relationship between urbanisation and energy use at the national level (Jones, 1989; Parikh and Shukla, 1995; Lariviere and Lafrance, 1999; Ewing and Rong, 2008; Poumanyvong et al., 2012; Al-mulali et al., 2012; Hossain, 2011), consensus is still lacking. Moreover, most previous studies conducted at the national level have focused on identifying the relationship between energy consumption and urbanisation: few studies discuss how urbanisation affects energy consumption. Apart from total energy use, urbanisation and related changes in lifestyle could also affect the structure of energy use, but this issue is less discussed in the existing literature.

This paper aims to fill these research gaps by exploring the impact of urbanisation on energy use in China during the period 1980 to 2010. While some similar studies have been conducted on urbanisation and energy use in China (Dhakal, 2009; Liu, 2009; O'Neill et al., 2012; Poumanyvong and Kaneko, 2010a, 2010b; Zhang and Lin, 2012), several important questions still require further investigation. Firstly, how does urbanisation affect energy consumption in China? This remains to be addressed (Adams and Shachmurove, 2008). Secondly, which urban policies should be applied to change the course of urbanisation so that increasing energy demand is constrained and green energy use promoted in China? This paper intends to answer these two major questions.

The paper is organised as follows: Section 2 provides a comprehensive literature review on the dynamic relationship between urbanisation and energy consumption. Section 3 describes the trends in China's energy consumption during the rapid urbanisation period from 1980 to 2010, with a quantitative analysis of energy consumption and urbanisation also being presented. Section 4 discusses how urbanisation in China affects energy consumption, including the differences in energy consumption patterns between urban and rural areas. Section 5 will present a discussion and policy implications, while Section 6 will offer our conclusions.

2. Literature review and theoretical framework

The management of urbanisation and city growth may have important implications for energy-saving strategies (Ewing and Rong, 2008; Zhang and Zhao, 2016). The effectiveness and efficiency of urban management in terms of energy savings depends on the relationship between them. Many studies have examined this relationship, with most verifying that urbanisation is significantly correlated with energy consumption. For example, Jones (1989) found that, on a national level, a higher level of urbanisation was related to a higher level of energy use in 59 developing countries. This positive relationship was also confirmed by Parikh and Shukla (1995), who conducted a double logarithmic regression model of 78 developed and developing countries. One major reason for the link is that urbanisation causes a growth in the share of the urban population. Other studies found that urbanisation may increase energy efficiency; for example, Lariviere and Lafrance (1999) found that urbanisation led to lower per capita energy consumption in Canada, indicating that more urbanised areas have increased energy efficiency. Similar results have been reported by Ewing and Rong (2008) in the US.

It is possible that the relationship between urbanisation and energy use is nonlinear. Malenbaum (1978) argued that energy use

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