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A comprehensive analysis of building energy efficiency policies in China: status quo and development perspective

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ABSTRACT

This article is concerned with a comprehensive analysis of building energy efficiency policies in light of improvements in energy performance, living standards and climate change mitigation in China's built environment. In recent years, China has added about 1.7 billion square meters of new floor space in both urban and rural areas on an annual basis. In 2010, the total area of existing buildings in China was approximately 48.6 billion square meters, nearly twice the total of existing buildings areas in the European Union. How to improve energy efficiency in the soaring number of new buildings and accelerate the retrofit of the huge number of existing buildings are two daunting challenges currently facing China in terms of energy security and climate change mitigation at a global level. China has gradually altered the building energy efficiency policy portfolio, from a purely regulatory approach with a mandatory building code at the initial stage to voluntary green buildings initiatives. This paper is structured as a critical assessment of building energy efficiency policies for new and existing buildings. Both strengths and weaknesses of the implemented energy efficiency policies are detailed in each of the studied areas. It also discusses the dilemma of public games in green and sustainable buildings production in the context of Chinese economic development and societal transition. The analysis emphasises the importance of guaranteeing the consistency between policies in the current regulatory framework to maximise the effectiveness of energy efficiency policies in the built environment in China. For this, it is necessary to articulate building energy efficiency policies implementation and broader energy and climate policies. This integrative study provides both a retrospective assessment and prospective direction of building energy efficiency policy development in China.

1. Introduction

According to the latest IPCC AR5 WGIII report, buildings accounted for 32% of total global final energy use, nearly one-fifth of energy-related GHG emissions (including electricity-related) and approximately one-third of black carbon emissions in 2010 (IPCC, 2014). Improving the energy efficiency of buildings envelope is expected to save almost 144 million toe in 2050 under the 2 °C scenario, equivalent to the current energy consumption of the United Kingdom (IEA, 2013). The primary energy consumption of buildings throughout China (excluding biomass energy) is nearly 380 million tons of oil equivalent (Mtoe), accounting for about one fifth of China's total primary energy consumption in 2008 (BEERC, 2011; NBS, 2012). Overall, buildings are responsible for around 18% of energy-related carbon dioxide emissions in China (Hong, 2009).

In recent years China has been adding about 1.7 billion square meters of new floor space on an annual basis (including both urban and rural areas). In 2010, the total area of existing buildings in China was approximately 48.6 billion square meters, nearly twice the total of existing buildings areas in the European Union (NBS, 2011; BPIE, 2013). The construction industry has been a significant mainstay in China's rapid economic development for a number of years, accounting for some 6.6% of gross domestic product in 2009. China will build 40 billion square meters of floor space by 2025 while urban population in 2030 will be nearly double that of 2000 (Woetzel et al., 2009). Given the long lifetime characteristics of the construction industry, choices made today on the construction of

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List of acronyms and abbreviations

ASHRAE	American society of heating, refrigerating and air conditioning engineers
BEE	building energy efficiency
BPIE	building performance institute Europe
BREEAM	BRE environmental assessment method
CASBEE	comprehensive assessment system for built environment efficiency
CDD	cooling degree day (reference degree: 26 °C)
CHP	combined heat and power
CSTC	centre of science and technology of construction
CUSS	China urban studies society
DGNB	Deutsche Gesellschaft fuer Nachhaltiges Bauena
ECP	energy performance certificate
EPBD	energy performance building directive
FYP	five-year plan
GHG	greenhouse gases
HDD	heating degree day (reference degree: 18 °C)
HQE	Haute Qualité Environnementale
HSCW	hot summer cold winter climate zone
HSWS	hot summer warm winter climate zone
HVAC	heating, ventilation systems and air conditioning
IEA	international energy agency
IECC	international energy conservation code
IPCC	intergovernmental panel on climate change
kgce	kilogram of coal equivalent
LEED	leadership in energy & environmental design
MOHURD	ministry of housing, urban and rural development
Mtoe	million tonne of oil equivalent
NDRC	national development and reform commission
nZEB	net-zero energy building

buildings in fast growing economies will have long-term effects influencing countries' overall energy efficiency for decades to come. How to improve the energy efficiency of the soaring number of new buildings and accelerate the retrofit of the huge stock of existing buildings are two daunting challenges currently facing China.

Improvement in buildings' energy efficiency (BEE) may be regarded as enhancing building envelope's energy performance by means of surface insulation, the application of innovative materials, design optimisation and enhanced natural ventilation, as well as the behaviour control of inhabitants and end users. More generally, the high-performing buildings may also include on-site renewable energy production to meet (or even exceed) the buildings' energy demand; these are often dubbed near-zero energy buildings (nZEB). A frequently-quoted example of nZEB is the German Passivhaus certification standard which stipulates that the building must have a specific annual heat demand (q_H) ≤ 15 kWh/m^2 yr or a specific peak load (p_H) ≤ 10 W/m^2, together with a specific primary energy demand (q_p) ≤ 120 kWh/m^2 yr relative to the treated floor area (McLeod et al., 2012).

A number of studies have documented the BEE development status and future development and its contribution to energy savings and GHG mitigation in both developed and developing countries (see for example Marszal et al., 2011; Gustavsson and Joelsson, 2010; Peuportier et al., 2013; Huang et al., 2012; Broin et al., 2013; Griego et al., 2012). Due to its sizeable buildings' stock and rapidly growing property market with stunning construction speeds in the newly urbanised areas, buildings' energy performance plays a critical role in shaping energy and environmental prospects in China and has received increasing attention in recent buildings' research literature with numerous publications on this subject. For instance, Lang (2004) was the first study which outlined the general landscape of building energy efficiency in China's residential sector. Liang et al. (2007) analysed the situation and trends in building energy efficiency management in China by focussing on survey data of the energy efficiency products demand and efficient buildings supply across 22 provinces. Hong (2009) investigated specifically the energy efficiency standard for public buildings in China. Zhang et al.'s (2010) review analysis compared different energy use in China's building sector with its international counterparts. Li and Colombier (2011) assessed the cost-effectiveness of policy instruments in mitigating greenhouse gases emissions in China's building sector and examined the relevance of carbon finance. Kong et al. (2012) reviewed the BEE policies in the 11th FYP period. Shui (2012) analysed the role of the third parties in the implementation of Building Energy Codes in China. Nevertheless, despite a large body of papers published in energy and building research journals, a comprehensive review and commentary on the strengths and weaknesses of the policies implemented and envisaged in China's building sector is still scant.

This study aims to fill this gap by providing a systematic review based on the most up-to-date data and a comprehensive analysis. It addresses an integral spectrum of national and sectoral policies with regard to BEE improvement and climate change mitigation in China since the 1980s. Based on analysis of secondary data concerning building energy use and BEE policies implementation, a comprehensive review is carried out to assess the effectiveness of BEE policies in light of identifying strengths and weaknesses of implemented instruments and specific sectoral schemes. The content will not only provide useful information for researchers and policymakers interested in the progress in China's building energy efficiency, it will also provide a benchmark for commendable cross-country comparison in light of enhanced international cooperation in best practices scale up in the global buildings sector. To the best of our knowledge, this is the first integrative study which provides both a retrospective assessment and prospective direction of building energy efficiency policy development in China.

The analysis starts with the identification and description of the key Chinese institutions that are in charge of enforcing and implementing policies for BEE, in particular the recently established nation-wide building energy performance monitoring system. This is then followed by an investigation of policies in new build and existing buildings in urban areas, respectively. In this article, BEE policies are referred primarily to urban buildings focused policies unless otherwise stated. The reason why urban and rural BEE policies are being treated separately is twofold. First, there still exists stark difference between urban and rural areas in China in terms of economic development as well as technological and institutional capacities; rural areas lag far behind their urban counterparts in many aspects. Second, BEE policies have been implemented exclusively in urban areas and for the time being have just been initiated in parts of rural buildings which are not subject to mandatory buildings codes. Based on the comprehensive review of regulatory issues and institutional framework of policy implementation, strengths and weaknesses of the implemented BEE policies in China are analysed in detail. The analytical review presented in this paper also shows that in the current regulatory framework, it is necessary to articulate BEE policies' implementation and broader energy and climate policies in China. Last, the