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What drives the carbon mitigation in Chinese commercial building sector? Evidence from decomposing an extended Kaya identity

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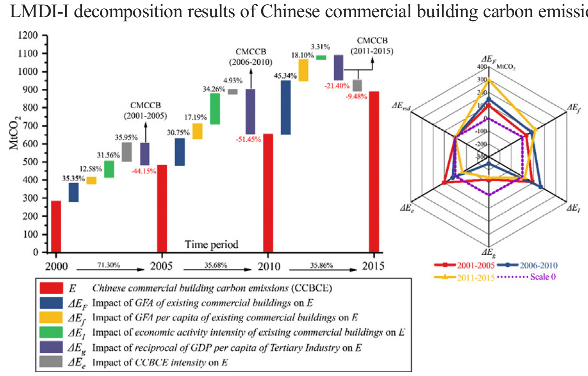
HIGHLIGHTS

- Carbon mitigation in Chinese commercial buildings (CMCCB) in 2001–2015: 625.9 $MtCO_2$
- We utilised the Kaya identity and the LMDI method to assess the CMCCB values.
- Data source is *China Database of Building Energy Consumption and Carbon Emissions*.
- Root cause of the growing CMCCB is the effective building energy efficiency project.

GRAPHICAL ABSTRACT

LMDI-I decomposition results of Chinese commercial building carbon emissions during 2000–2015.



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ABSTRACT

Energy efficiency in the building sector is expected to contribute >50% to the nationwide carbon mitigation efforts for achieving China's carbon emission peak in 2030, and carbon mitigation in Chinese commercial buildings (CMCCB) is an indicator of this effort. However, the CMCCB assessment has faced the challenge of ineffective and inadequate approaches; therefore, we have followed a different approach. Using the *China Database of Building Energy Consumption and Carbon Emissions* as our data source, our study is the first to employ the Logarithmic Mean Divisia Index (LMDI) to decompose five driving forces from the Kaya identity of Chinese commercial building carbon emissions (CCBCE) to assess the CMCCB values in 2001–2015. The results of our study indicated that: (1) Only two driving forces (i.e., the reciprocal of GDP per capita of Tertiary Industry in China and the CCBCE intensity) contributed negatively re_{m_i} to CCBCE during 2001–2015, and the quantified negative contributions denoted the CMCCB values. Specifically, the CMCCB values in 2001–2005, 2006–2010, and 2011–2015 were 123.96, 252.83, and 249.07 $MtCO_2$, respectively. (2) The data quality control involving the CMCCB values proved the reliability of our CMCCB assessment model, and the universal applicability of this model was also confirmed. (3) The substantial achievements of the energy efficiency project in the Chinese commercial building sector were the root cause of the rapidly growing CMCCB. Overall, we believe that our model successfully bridges the research gap of the nationwide CMCCB assessment and that the proposed model is also suitable either at the provincial level or in different building climate zones in China. Meanwhile, a global-level assessment of the carbon mitigation in the commercial building sector is feasible through applying our model. Furthermore, we consider our contribution as constituting significant guidance for developing the building energy efficiency strategy in China in the upcoming phase.

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Nomenclature

Acronyms
CABEE China Association of Building Energy Efficiency
CBEM *China Building Energy Model*
CCBCE (i.e., *E*) Chinese commercial building carbon emissions
CDBECCE *China Database of Building Energy Consumption and Carbon Emissions*
CMCCB Carbon mitigation in Chinese commercial buildings
CNY Chinese Yuan (i.e., *Renminbi*, the currency of PR China)
EEP energy efficiency project
GFA gross floor area
LBNL Lawrence Berkeley National Laboratory, USA
MOHURD of PRC Ministry of Housing and Urban-Rural Development of PR China
NBOS of PRC National Bureau of Statistics of PR China
RMI Rocky Mountain Institute, USA
THUBEEI Tsinghua University Building Energy Efficiency Institute, PR China

Symbols
e CCBCE intensity
F GFA of existing commercial buildings in China
f GFA per capita of existing commercial buildings in China
G GDP of Tertiary Industry in China
g reciprocal of GDP per capita of Tertiary Industry in China
I economic activity intensity of existing commercial buildings in China
P employed population of Tertiary Industry in China
ΔE_e impact of e on E
ΔE_F impact of F on E
ΔE_f impact of f on E
ΔE_g impact of g on E
ΔE_I impact of I on E
ΔE_{rsd} random error during the LMDI-I decomposition analysis
ΔE_{tot} value of E changes during a period

1. Introduction

For the past four decades, China has undergone unparalleled economic development to become the second largest economy worldwide (Mi et al., 2017; Shan et al., 2018; Shen et al., 2016; Shuai et al., 2017b). The country has also become the world's largest carbon emitter, with building carbon emissions representing the second highest amount of nationwide carbon emissions (Berardi, 2017; Delmastro et al., 2015; Dong et al., 2018). The Chinese government has promised that China will achieve a carbon emission peak in 2030, and, in 2017, it issued its official plan for a total carbon emission control strategy (State_Council_of_PRC, 2017). Given that the potentials of achieving energy efficiency and carbon mitigation in the building sector are greater than in the industry and transportation sectors, respectively, achieving energy efficiency in the building sector is expected to provide >50% of the national carbon mitigation required to achieve China's carbon emission peak in 2030 (Lynn et al., 2017; RMI and LBNL, 2016). A strong building energy efficiency strategy can promote carbon mitigation in the building sector effectively (Liang et al., 2014; Lin and Liu, 2015; Zuo et al., 2014). Thus, an effective energy efficiency project (EEP) in the Chinese building sector can be regarded as a key roadmap for achieving the Chinese 2030 carbon emission peak (Kong et al., 2012; McNeil et al., 2016).

As a member of building carbon emissions, Chinese commercial building carbon emissions (CCBCE) constitute >35% of the building carbon emissions in China at present (CABEE, 2017; THUBEEI, 2017). Given that the potential for carbon mitigation in commercial buildings is greater than in residential buildings (Liu et al., 2018, 2017b; Zuo et al., 2012a), launching the EEP in the Chinese commercial building sector should be of high priority (MOHURD_of_PRC, 2017). Moreover, assessing carbon mitigation in Chinese commercial buildings (CMCCB) is urgent for direct examination of the achievements of the EEP in the Chinese commercial building sector.

In view of this, using the *China Database of Building Energy Consumption and Carbon Emissions* (CDBECCE) as our data source, we put forward an assessment model combining the Logarithmic Mean Divisia Index I (LMDI-I) with an extended Kaya identity to decompose five driving forces of CCBCE [i.e., the gross floor area (GFA) of existing commercial buildings in China, the CCBCE intensity, the reciprocal of GDP per capita of Tertiary Industry in China, the GFA per capita of existing commercial buildings in China, and the economic activity intensity of existing commercial buildings in China] for assessing the CMCCB values during 2001–2015. After determining the CMCCB values, a comparative analysis between the official expected and actual values of CMCCB, a data quality control exercise involving the CMCCB values, and a comprehensive evaluation of the CMCCB assessment model were undertaken separately to identify the reliability of our CMCCB assessment model. Moreover, the EEP in the Chinese commercial building sector was discussed in retrospect to reveal the root cause of the rapidly growing CMCCB.

The framework of this study is organised as follows. Section 2 presents the literature review. In Section 3, we introduce the CMCCB assessment model established by the Kaya identity and the LMDI-I decomposition analysis. The leading data source (i.e., our CDBECCE) is shown in Section 4 and Appendix D. The outputs of the LMDI-I and, in particular, the CMCCB values (2001–2015) are shown and analysed in depth in Section 5. In Section 6, we discuss the advantages, shortcomings, and universal applicability of our CMCCB assessment model and launch a retrospective assessment of the EEP in the Chinese commercial building sector from the mid-1990s to 2017. Section 7 illustrates the main findings, policy implications, and further research.

2. Literature review

Reliable time-series data of building carbon emissions are the foundations for exploring carbon mitigation in the building sector (Tanikawa, 2018). Currently, the official process of collecting statistical

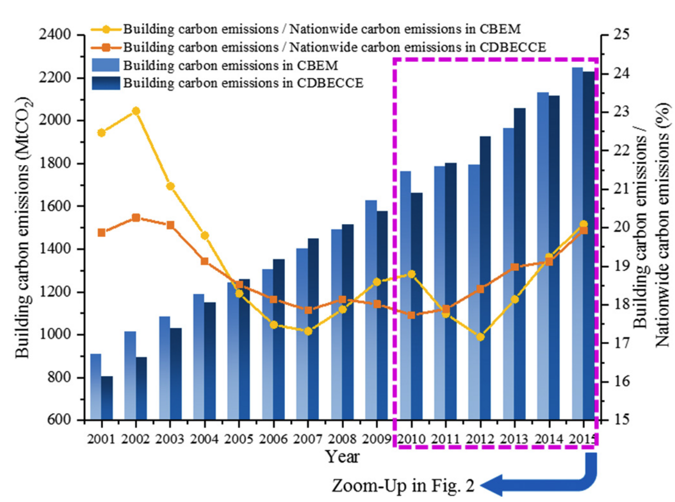

Fig. 1. Data comparison of Chinese building carbon emissions between CBEM and CDBECCE during 2001–2015. *Sources of CBEM: THUBEEI (2017) *Sources of CDBECCE: CABEE (2017).