Energy xxx (2014) 1–12

Contents lists available at ScienceDirect

Energy

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

Review

Modelling tools to evaluate China's future energy system – A review of the Chinese perspective

Peggy Mischke*, Kenneth B. Karlsson

Department of Management Engineering, Energy Systems Analysis Division, Technical University of Denmark, Denmark

ARTICLE INFO

Article history:
Received 17 July 2013
Received in revised form
4 March 2014
Accepted 6 March 2014
Available online xxx

Keywords:
Energy-economy models
China
Chinese modelling tools
Future energy system
Energy systems analysis
energy planning

ABSTRACT

Research efforts to analyse China's future energy system increased tremendously over the past decade. One prominent research area is China's first binding CO_2 emission intensity target per unit of GDP (Gross Domestic Product) and its impact on the country's economy and energy system. This paper compares 18 energy modelling tools from ten Chinese institutions. These models have been described in English language publications between 2005 and 2013, although not all are published in peer-reviewed journals. When comparing the results for three main energy system indicators across models, this paper finds that there are considerable ranges in the reference scenarios: (i) GDP is projected to grow by 630–840% from 2010 to 2050, (ii) energy demand could increase by 200–300% from 2010 to 2050, and (iii) CO_2 emissions could rise by 160–250% from 2010 to 2050. Although the access to the modelling tools and the underlying data remains challenging, this study concludes that the Chinese perspective, independently from the modelling approach and institution, suggests a rather gradual and long-term transition towards a low carbon economy in China. Few reference scenarios include an emission peak or stabilisation period before 2040. While policy scenarios frequently suggest efficiency improvements, a short-term and large-scale introduction of non-fossil power technologies is rarely recommended.

1. Introduction

A clean-air, low-carbon, and green-growth debate has been emerging in China over the past decade. China announced its first binding CO_2-emission-intensity-reduction-target per unit of GDP (Gross Domestic Product) in 2009, which has been integrated in the current 12th Five-Year-Plan (2011–2015). On the international level, China submitted an initial communication on climate change to the UNFCCC (United Nations Framework Convention on Climate Change) in 2004. After a four-year preparation, discussion and approval process within China a second official communication on climate change was released to UNFCCC in 2012 [1]. This domestic debate has been benefitting from a stronger focus on scientific development and energy-economy interactions in the main planning documents, including Five-Year-Plans, as well as an increase in research funding [2]. Environmental problems related to increased coal use, such as air pollution, are furthermore taking a stronger position on the agenda of Chinese policy makers [3].

A large number of modelling tools to evaluate China's future energy system has been developed subsequently by China's domestic research and non-university state institutions during the 11th and 12th Five Year Plan. In the past decade, Chinese energy modelling tools were mainly discussed in Chinese language in the country's domestic journals [4]. Chinese researchers and energy planners are increasingly publishing their results in English language, thus contributing with a Chinese perspective to the international debate on prospects and challenges for China's future energy system.

A growing body of knowledge for modelling tools to evaluate future pathways for China's energy system is evolving. We aim to contribute with this literature review to an improved understanding of the most recent Chinese energy modelling tools. We hope that the results of this paper will assist researchers and decision-makers in identifying suitable Chinese modelling tools and corresponding institutions for future, energy-related research and business collaborations.

This paper is structured as follows: Section 2 describes the methodological aspects used for comparing the various energy system models. Section 3 summarizes the results of the model review, relating to different structural model aspects and the comparison of modelling results. Section 4 comprises the

* Corresponding author. Frederiksborgvej 399, P.O. Box 49, Build. 130, DK-4000 Roskilde, Denmark. Tel.: +45 4677 5173; fax.: +45 4677 5100.
E-mail addresses: peym@dtu.dk (P. Mischke), keka@dtu.dk (K.B. Karlsson).

http://dx.doi.org/10.1016/j.energy.2014.03.019
0360-5442/

discussion of results across models, followed by the author's conclusions in Section 5. A model by model description, arranged in alphabetical order of the model's acronym, is available in the Appendix A.

2. Methodology

A three-phase literature review was carried out to focus on the growing number of modelling tools that have been developed by various Chinese institutions to evaluate China's future energy system.

A database of Chinese energy modelling tools was established in a first phase, drawing on academic journals and project based research reports in English language from 2005 to 2013. The review period was chosen from 2005 to 2013 in order to select the most recent modelling studies carried out under the 11th five year plan (2006–2010) and the 12th five year plan (2011–2015). In a second phase, the established model database served to systematically review and classify the identified modelling tools by their underlying model structure and to compile key results from recent modelling studies. Frequently used quantitative results indicators were identified and compared across the reference scenarios of the 18 models, based on the published information in English language. In a third phase, main quantitative policy recommendations from recent policy scenario studies were summarized and discussed, model by model, to complement the quantitative results with qualitative policy recommendations. The presentation of the 18 Chinese models follows an alphabetic order of the models' acronyms. The acronyms were created by combining the model name and the corresponding Chinese institution.

The limitations of this literature review relate to (i) the accessibility of the Chinese modelling tools and their underlying data; (ii) the presentation of the modelling results; and (iii) the geographic representation of China. The access to the modelling tools and their underlying data remains challenging. Therefore this paper intentionally avoids making any judgements about the performance, accuracy and reliability of the reviewed models. While keeping a narrow focus on Chinese energy modelling tools discussed in English language publications, this review is targeted to those models and related studies that are easily accessible within the international research community. Modelling tools and studies that are currently published in Chinese language are thus explicitly not considered. Limited details in the description of the model structure and the presentation of results in this paper relate to the limited availability of comparable, often quantitative data in the reviewed publications. We chose to focus on tools that represent China at a country scale, including possible sub-regional definitions, to allow for result comparison across models. Models focussing only on a single Chinese province or city are thus not included here.

3. Results

In total 18 Chinese modelling tools were included in the review. For the subsequent model review and comparison of results we introduced acronyms for each modelling tool in Table 1.

3.1. Overview of modelling tools and institutions

The 18 identified modelling tools were developed by ten different Chinese institutions during the period of 2005–2013. Both Chinese universities and high level non-university state institutions are driving the development of energy modelling tools in China. Most of these Chinese institutions are located in Beijing, the administrative and research centre of China.

Twelve of the 18 modelling tools are developed by a Chinese university. As shown in Table 1, Tsinghua University is strongly represented with five of the 18 energy models. Three institutions associated with the CAS (Chinese Academy of Sciences) are furthermore active in energy system modelling, including the University of the Chinese Academy of Sciences and the University of Science and Technology of China. Two of the 18 modelling tools are developed by the Renmin University and one by the North China Electric Power University.

Six of the 18 modelling tools are developed by non-university related institution of the Chinese state. One of the reviewed energy models is used by the Development Research Centre of the State Council, China's highest administrative authority. Four of the reviewed modelling tools are developed by different groups within the ERI (Energy Research Institute). Another modelling tool is developed by the SIC (State Information Centre). ERI and SIC are part of the NDRC (National Development and Reform Commission), a central planning agency under the State Council.

Table 1
Overview of modelling tools and institutions.

Acronym	Modelling tool	Institution	References
2050-Calc-ERI	China 2050 calculator	Energy Research Institute	[25]
CGE-NCEPU	Computable general equilibrium model	North China Electric Power University	[4,23]
CREAM-ERI	China renewable energy analyses model	Energy Research Institute	[37]
DCGE-SIC	Dynamic computable general equilibrium model	State Information Centre	[2,4,34]
EEM-ERI	Economic evaluation model	Energy Research Institute	[32,33]
IO-TU	Input output model	Tsinghua University	[15]
IPAC-ERI	Integrated policy assessment model for China	Energy Research Institute	[4,13,22,26–31]
IPAT-CUMT	IPAT model	China University of Mining and Technology	[24]
LEAP-TU	Long-range energy alternatives planning model	Tsinghua University	[4–7]
MARKAL-TU	Market allocation model	Tsinghua University	[4,8–13]
MESSAGE-UCAS	Model for energy supply strategy alternatives and their general environmental impact	University of the Chinese Academy of Sciences	[19]
MRIO-CAS	Multi-regional input output model	Chinese Academy of Sciences	[4,17]
MSCGE-DRC	Multi-sector computable general equilibrium model	Development Research Centre, State Council	[4,35,36]
PMP-TU	Power mix planning model	Tsinghua University	[14]
POM-USTC	Portfolio optimization model	University of Science and Technology of China	[18]
TEDCGE-RU	Technology oriented dynamic computable general equilibrium model	Renmin University of China	[4,20]
TIMES-TU	The integrated MARKAL-EFOM system	Tsinghua University	[16,39,40]
TOM-RU	Technological optimization model	Renmin University of China	[21,22]

Please cite this article in press as: Mischke P, Karlsson KB, Modelling tools to evaluate China's future energy system – A review of the Chinese perspective, Energy (2014), http://dx.doi.org/10.1016/j.energy.2014.03.019