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Modelling tools to evaluate China's future energy system - a review of the Chinese perspective

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Motivation and relevance

- Research efforts of Chinese institutions to analyse China's future energy system increased tremendously over the past decade. One prominent research area is China's first binding CO₂ emission intensity target per unit of GDP (Gross Domestic Product) and its impact on the country's economy and energy system.
- Robust, transparent and credible modelling tools to analyse China's future economy and energy system will play a key role in informing decision makers about a range of energy and climate policy impacts.



• This literature review of Chinese energy modelling tools aims to discuss and compare modelling tools, research questions, scenario results and policy recommendations of high priority from a Chinese perspective.

Methodology

Establish a database of Chinese energy modelling tools

- academic journals and project based research reports
- English language
- publication period 2005 to 2013



- underlying model structure
- research focus
- key result indicators of scenario studies



Summarize key policy recommendations

• to complement the quantitative results with qualitative policy recommendations

Chinese energy-economy model	Representing Chinese Institution	Modelling approach	Access to model information in English	Recent international model comparison studies and international research projects	Number of publications since 2005				
BOTTOM UP									
2050 Calculator	Energy Research Institute (ERI), Reijing	Bottom up,	Dedicated website	UK 2012	0				
(2050 Low Carbon Model)	Energy Research Institute (FRI)	Bottom un	Research reports	DK 2013 forthcoming	2				
(2000 LOW Carbon Wrodely	CNREC, Beijing	Bottom up	Research reports	DR 2015 Iorencoming					
CRESP Economic Evaluation	Energy Research Institute (FRI) China	Bottom un	Research reports	ESMAP Low Carbon Growth	2				
Model	CRESP, Beijing ERI and	Tsinghua w	<mark>/ith</mark>	Country studies 2012					
LEAP China	Tsinghua Unive many bo	ttom up	ic paners		more than 5				
MESSAGE China	University of Cr Sciences, nowr		many	cooperations,	1				
Power Mix Planning Model	Tsinghua University, Beijing	Bottom Up	Academic pa	ewerregular	1				
PECE Technological Optimization	Remnin University, Beijing	Bottom up	Research rep Englis	sh iournal	3				
Model			Academic pa						
MARKAL China model family	Tsinghua University, Beijing	Bottom up,	Academic pa PUDII	cations	more than 5				
		Optimization	research reports	BASIC 2007					
TIMES China model family	Tsinghua University, Beijing	Bottom up, Optimization	Academic papers		1				
TOP DOWN			*	<u>,</u>					
IPAT	University of Mining Technology, Yuzhou, Jiangtu Brovince	Top down, set of	Academic papers		1				
CGE model	State Council Development Research	Top down, CGE,	research reports	World Bank 2012, EU BASIC	4				
- many institut	ions	CES function		2007					
		Top down, CGE, CES function	research reports	OECD 2013, EU BASIC 2007	3				
models	ity, Beijing	Top down, CGE, CES function	Academic papers	EU BASIC 2007	2				
MR	my of Sciences, Beijing	Top Down, IO	Academic papers	EU BASIC 2007	2				
IO model	Tsinghua University, Beijing	Top down, IO	Academic papers		1				
Portfolio optimization model for power	University of Science and Technology, Hefei	Top Down	Academic papers		1				
CGE model	North China Electric Power University	Top down, CGE, CES function	Academic papers, research reports		1				
HYBRID	• 								
IPAC model framework	Energy Research Institute (ERI), Beijing	Bottom up IPAC	Academic papers,	Asia Modelling exercise 2013, EC2 2012, US LBNL China	more than 5				
	one hy	brid mode		model comparison 2010, EU BASIC 2007, UNEP RISO 2007,					
	particip	pating in m	nost	ongoing projects POEM & ROSE					
	interna	itional proj	ects	1.00527					



Limitations: Access to information

- The publication of modelling results in peer reviewed journals is mainly driven by the different Chinese universities. Only 13 of the 18 reviewed modelling tools are however discussed in peer-reviewed journal papers.
- For some of the modelling tools reviewed, the number of international available publications since 2005 was moreover limited. All of the modelling tools developed by a Chinese university published at least once in a peer reviewed scientific journal in English since 2005.
- Non-university institutions of the Chinese state publish results from energy modelling studies almost exclusively in project reports, related policy briefs and magazines.
- Multiple Chinese modelling tools are rarely compared in one study, such as done in the Asia Modelling Exercise in 2013.



The study included 18 Chinese modelling tools from 10 Chinese institutions

Overview of modelling tools and institutions.

Acronym	Modelling tool	Institution
2050-Calc-ERI CGE-NCEPU	China 2050 calculator Computable general equilibrium model	Energy Research Institute North China Electric Power University
CREAM-ERI	China renewable energy analyses model	Energy Research Institute
EEM-ERI	Economic evaluation model	Energy Research Institute
IPAC-ERI	Integrated policy assessment model for China	Energy Research Institute
IPAT-CUMT	IPAT model	China University of Mining and Technology
LEAP-TU	Long-range energy alternatives planning model	Tsinghua University
MARKAL-TU	Market allocation model	Tsinghua University
MESSAGE-UCAS	Model for energy supply strategy alternatives and their general environmental impact	University of the Chinese Academy of Sciences
MRIO-CAS	Multi-regional input output model	Chinese Academy of Sciences
MSCGE-DRC	Multi-sector computable general equilibrium model	Development Research Centre, State Council
PMP-TU	Power mix planning model	Tsinghua University
POM-USTC	Portfolio optimization model	University of Science and Technology of China
TEDCGE-RU	Technology oriented dynamic computable general equilibrium model	Renmin University of China
TIMES-TU	The integrated MARKAL-EFOM system	Tsinghua University
TOM-RU	Technological optimization model	Renmin University of China

 Beijing based institutions are currently the drivers of energy model development in China.



Results: Classification of modelling tools



- From the 18 reviewed modelling tools: 8 bottom-up models and 8 top-down models, among these 2 simulation models; 3 optimization models; 4 CGE models and 2 IO models were described.
- A hybrid modelling framework was less frequently described.



Results: Comparing GDP growth projections across models



Fig. 1. Comparison of China's future GDP growth across models - reference scenarios.



Results: Comparing energy demand and CO₂ emission growth accross reference scenarios



Fig. 2. Comparison of China's future energy demand across modelling tools - reference scenarios.

Fig. 3. Comparison of China's future CO2 emissions across modelling tools - reference scenarios.



Results: Main application areas

Modelling tool – acronym	Economic and system costs	Economic Re-structuring	Labour adjustments	Impact on energy demand	Comparison of multiple end use sectors	Power system transition	Emissions, natural resources and environment
2050-Calc-ERI				1	1		\checkmark
CGE-NCEPU	\checkmark	\checkmark		1		\checkmark	
CREAM-ERI	1	1		1	\checkmark	1	\checkmark
DCGE-SIC	1	1	1				\checkmark
EEM-ERI	1					\checkmark	
IO-TU	\checkmark		\checkmark				
IPAC-ERI	\checkmark	\checkmark		\checkmark	\checkmark	\checkmark	\checkmark
IPAT-CUMT	\checkmark			\checkmark			\checkmark
LEAP-TU	\checkmark			\checkmark	\checkmark	\checkmark	\checkmark
MARKAL-TU	\checkmark			\checkmark	\checkmark	\checkmark	\checkmark
MESSAGE-UCAS	1				V	1	\checkmark
MRIO-CAS				\checkmark			\checkmark
MSCGE-DRC	\checkmark	\checkmark					
PMP-TU				\checkmark		\checkmark	
POM-USTC	\checkmark					\checkmark	
TEDCGE-RU	\checkmark						\checkmark
TIMES-TU	\checkmark			\checkmark	\checkmark	\checkmark	\checkmark
TOM-RU	\checkmark					\checkmark	\checkmark

Comparison of main application areas - policy scenarios.

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Results: energy – economy links





Results: technology choices

Fossil power will dominate in China Nuclear and hydropower as well as until 2050, even after the demand management will play an introduction of carbon pricing. increasing role when introducing emission reduction policies in the electricity sector. Coal will remain the major future energy carrier in China. CCS technologies will be more promising to reduce China's CO_2 emissions until 2050 than wind and Mandatory renewable energy targets nuclear energy. will challenge resource limits and regional energy disparities inside China, but will decrease air Power technology diversifications pollution. away from coal decreases China's portfolio risk, but increases generation costs. Under ambitious renewable energy targets, the renewable energy share in primary energy demand could Any future mitigation of the increase from 9% in 2010 to 56% in country's CO₂ emissions will mainly 2050. come from cleaner coal combustion and CCS.



Results: future emissions

The period before 2020 is very crucial to determine the future direction and level of energy demand, supply and emissions in China. There is a need to transform economic development patterns timely to control rapid growth of final energy demand.

A potential emission stabilization period between 2035 and 2050 is suggested for China, after a period of growing energy demand from industry, transport, buildings and consumers.

An absolute emission reduction pledge of China under the Kyoto protocol should be avoided. Emissions from the iron and steel industry are a key future challenge for China.

Recent and continued technological progress will make it possible for China to limit its CO₂ emissions and for these emissions to peak before 2025.

Resource availability and environmental pressures will present mid- and long-term constraints to China's economic growth.

Key conclusions

- Chinese researchers showed a strong research focus on cost-related impacts of energy and climate policies - independent from the underlying modelling approach and the institution
- Economic growth in line with the official government targets is a main factor driving future energy demand and CO₂ emission increase across models.
- Many models suggested a cleaner and more efficient use of coal, partly combined with an increase in nuclear power generation. Only a few modelling studies pointed out to benefits of increased use of renewable energies in China.



An improved standardisation with regards to model descriptions and results presentations is suggested for future research in this area.



Further information

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China energy blog: www.peggymischke.com

These results are published in ENERGY. DOI: 10.1016/j.energy.2014.03.019 The publication includes an extensive appendix with a description of each reviewed model.



Sino – Danish Center for Education and Research

