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Mischke, Peggy

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

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Peggy Mischke
Technical University of Denmark
Energy System Analysis
peym@dtu.dk

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 CO_2 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

Review and classify the identified modelling tools by:

- 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), Beijing	Bottom up, Simulation	Dedicated website	UK 2012	0
(2050 Low Carbon Model)	Energy Research Institute (ERI), CNREC, Beijing	Bottom up	Research reports	DK 2013 forthcoming	
CRESP Economic Evaluation Model	Energy Research Institute (ERI), China Renewable Ene CRESP, Beijing	Bottom up	Research reports	ESMAP Low Carbon Growth Country studies 2012	2
LEAP China	Tsinghua Unive		ic papers		more than 5
MESSAGE China	University of Ch Sciences, now r		ic pa		1
Power Mix Planning Model	Tsinghua University, Beijing	Bottom Up	Academic pa		1
PECE Technological Optimization Model	Remnin University, Beijing	Bottom up	Research rep Academic pa		3
MARKAL China model family	Tsinghua University, Beijing	Bottom up, Optimization	Academic pa research reports	BASIC 2007	more than 5
TIMES China model family	Tsinghua University, Beijing	Bottom up, Optimization	Academic papers		1
TOP DOWN					
IPAT	University of Mining Technology, Xuzhou, Jiangsu Province	Top down, set of equations	Academic papers		1
CGE model	State Council Development Research	Top down, CGE, CES function	research reports	World Bank 2012, EU BASIC 2007	4
SIC	on Center	Top down, CGE, CES function	research reports	OECD 2013, EU BASIC 2007	3
PEC	sity, 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 model comparison 2010, EU BASIC 2007, UNEP RISO 2007, ongoing projects POEM & ROSE	more than 5

ERI and Tsinghua with many bottom up models

many cooperations, but fewer regular English journal publications

many institutions developping CGE models

one hybrid model participating in most international projects

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.

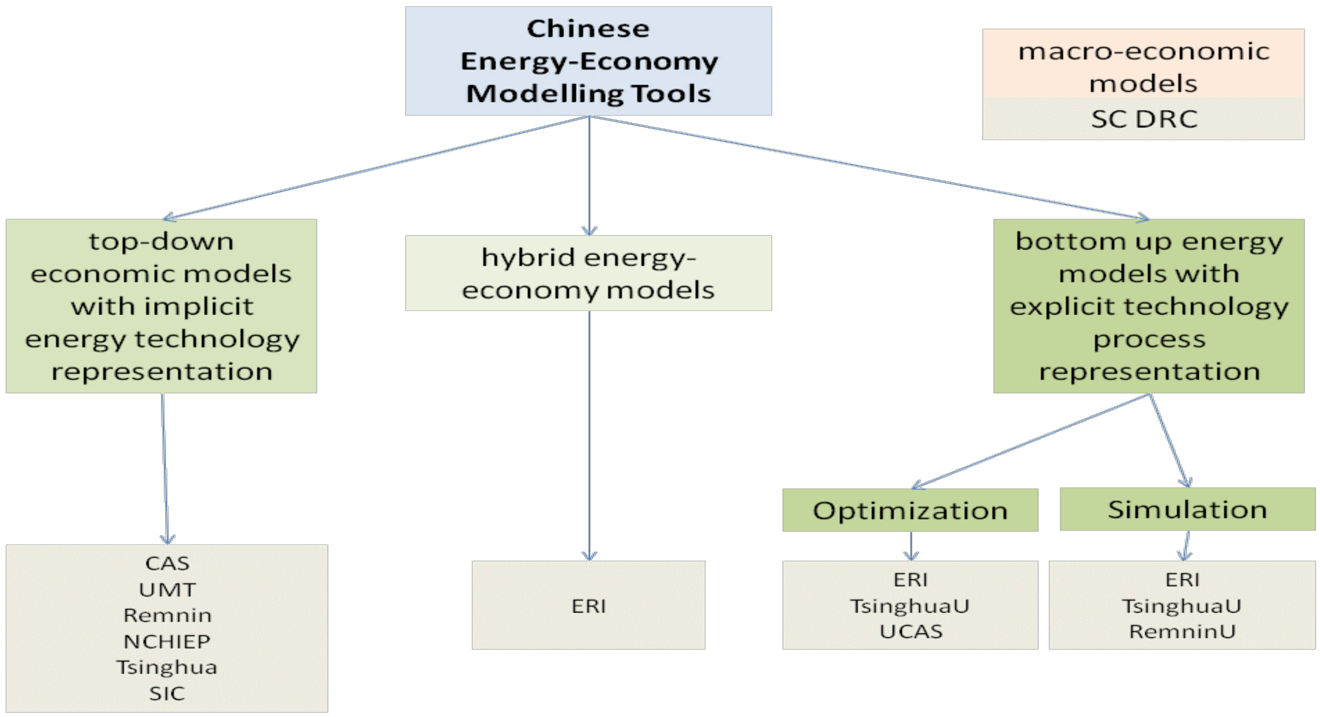
The study included 18 Chinese modelling tools from 10 Chinese institutions

Overview of modelling tools and institutions.

Acronym	Modelling tool	Institution
2050-Calc-ERI	China 2050 calculator	Energy Research Institute
CGE-NCEPU	Computable general equilibrium model	North China Electric Power University
CREAM-ERI	China renewable energy analyses model	Energy Research Institute
DCGE-SIC	Dynamic computable general equilibrium model	State Information Centre
EEM-ERI	Economic evaluation model	Energy Research Institute
IO-TU	Input output model	Tsinghua University
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

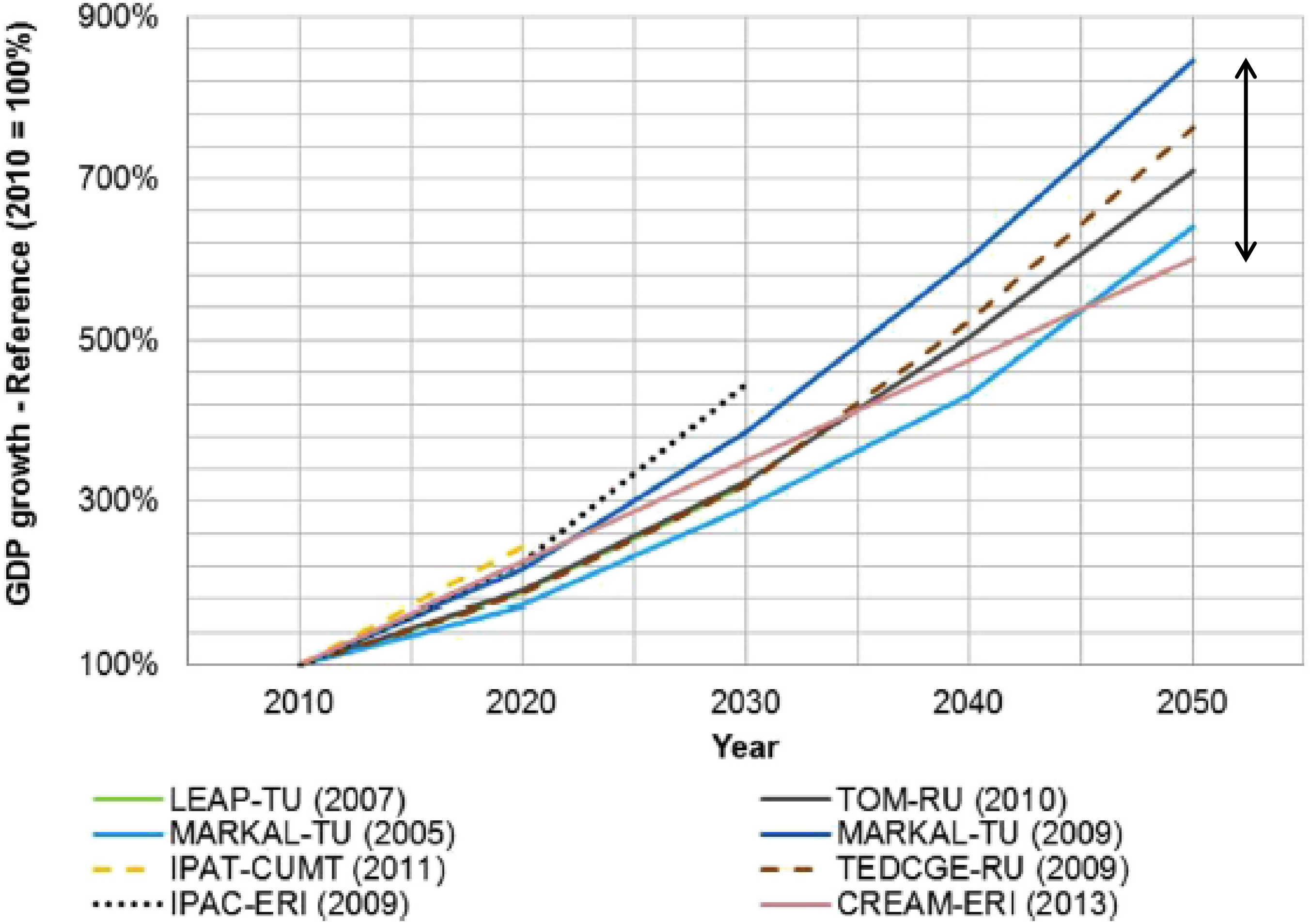


Fig. 1. Comparison of China's future GDP growth across models – reference scenarios.

Results: Comparing energy demand and CO_2 emission growth accross reference scenarios

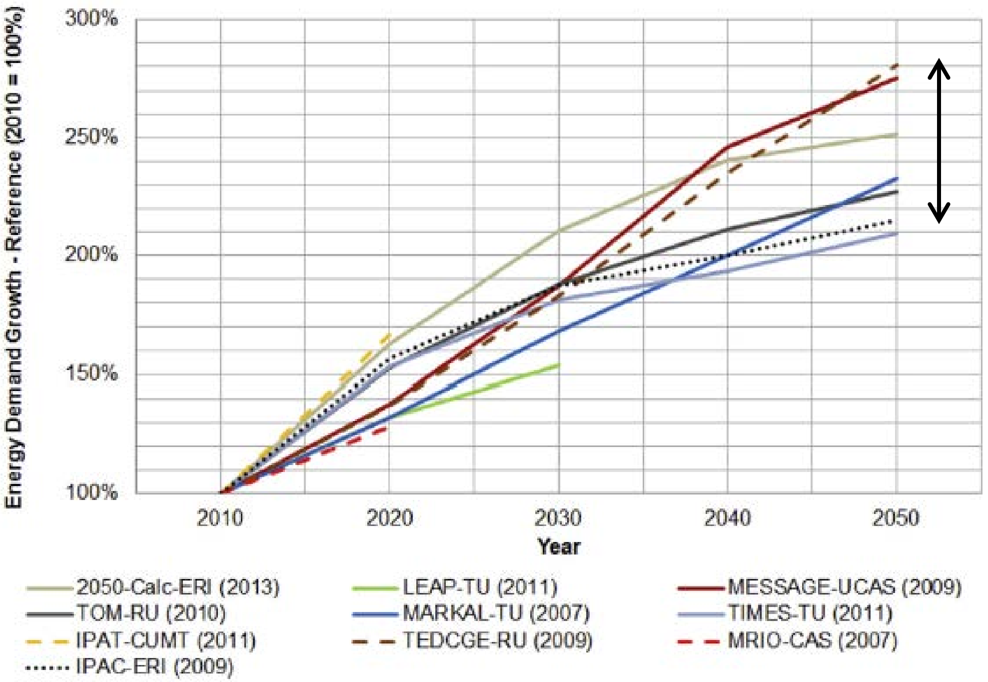


Fig. 2. Comparison of China's future energy demand across modelling tools – reference scenarios.

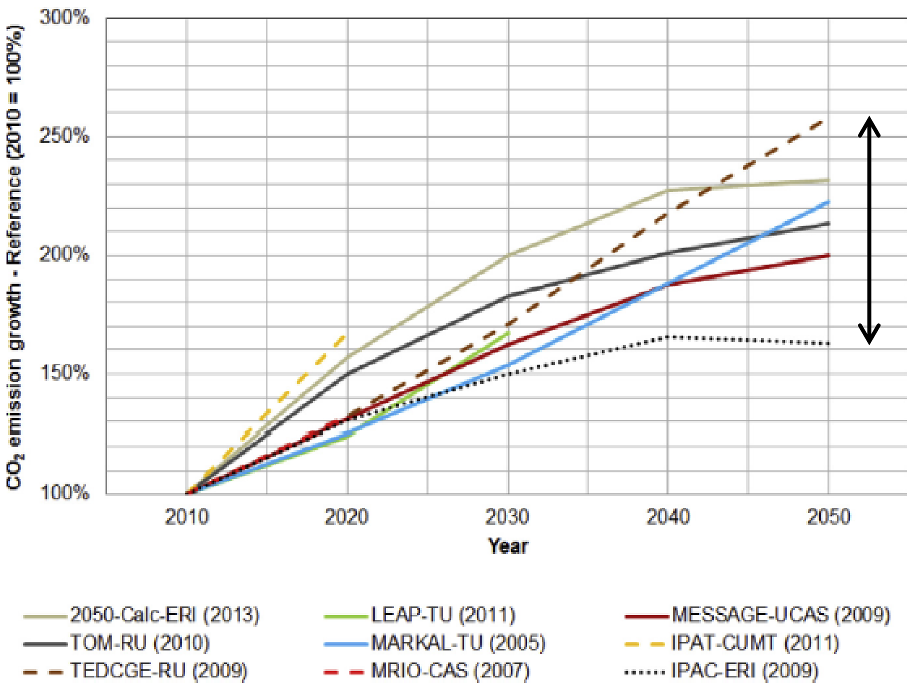


Fig. 3. Comparison of China's future CO_2 emissions across modelling tools – reference scenarios.

Results: Main application areas

Comparison of main application areas – policy scenarios.

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				√	√		√
CGE-NCEPU	√	√		√		√	
CREAM-ERI	√	√		√	√	√	√
DCGE-SIC	√	√	√				√
EEM-ERI	√					√	
IO-TU	√		√				
IPAC-ERI	√	√		√	√	√	√
IPAT-CUMT	√			√			√
LEAP-TU	√			√	√	√	√
MARKAL-TU	√			√	√	√	√
MESSAGE-UCAS	√				√	√	√
MRIO-CAS				√			√
MSCGE-DRC	√	√					
PMP-TU				√		√	
POM-USTC	√					√	
TEDCGE-RU	√						√
TIMES-TU	√			√	√	√	√
TOM-RU	√					√	√

Results: energy – economy links

A continuous rapid growth is possible for China with the right policy mix, including economic adjustment towards less industry and more services in a mid- and long-term perspective.

Carbon pricing has a strong negative impact on China's energy intensive sectors → large decline of coal mining, petroleum industry and power generation sectors

There are important net losses for China's coal industry under a renewable electricity generation target of 15% by 2020.

There are high costs when introducing low carbon technologies at a larger scale in China.

Investments in low-carbon technologies in the short-term should be avoided until further research is carried out.

The earlier an emission constraint is implemented in China, the higher the GDP loss.

Emission reduction policies will reduce future economic growth in China.

There will be high social welfare loss and GDP loss under various carbon constraints in China.

Results: technology choices

Fossil power will dominate in China until 2050, even after the introduction of carbon pricing.

Coal will remain the major future energy carrier in China.

Nuclear and hydropower as well as demand management will play an increasing role when introducing emission reduction policies in the electricity sector.

CCS technologies will be more promising to reduce China's CO_2 emissions until 2050 than wind and nuclear energy.

Mandatory renewable energy targets will challenge resource limits and regional energy disparities inside China, but will decrease air pollution.

Power technology diversifications 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 increase from 9% in 2010 to 56% in 2050.

Any future mitigation of the country's CO_2 emissions will mainly 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 CO_2 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 CO_2 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.

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.

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

Further information

Email: peym@dtu.dk

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.

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Review

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Peggy Mischke*, Kenneth B. Karlsson

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

Sino – Danish Center for Education and Research

中国科学院研究生院
GRADUATE UNIVERSITY OF CHINESE ACADEMY OF SCIENCES

国家可再生能源中心
CHINA NATIONAL RENEWABLE ENEGY CENTRE