Editorial

Understanding the energy consumption and Greenhouse Gas emissions and the implication for achieving climate change mitigation targets

Background

Anthropogenic greenhouses gases (GHGs), mainly released during the combustion of fossil fuels (coal, oil and natural gas) and industrial production processes, are the major contributors to global climate change and considered as one of the most serious challenges facing sustainable development. Despite global efforts on curbing human-induced climate change, greenhouse gas emissions (GHGs) have been rapidly increasing since the signing of the Kyoto protocol in 1997 [1]. Understanding the dynamics of energy consumption and associated greenhouse gas emissions at the global and regional level will be critical for achieving mitigation targets and a low carbon economy.

Facing such challenges, countries are taking actions to curb fossil fuel energy consumption to mitigate GHGs and to seek a low-carbon developmental path. Measures include the investment into renewables and emission reduction technologies, as well as changes to current wasteful consumption patters, all of which are important steps towards a low-carbon economy. However, there are considerable knowledge gaps r to guide this process: First, the amount of energy consumption and associated emissions are estimated based on energy statistics rather than direct measurements, which contributes to the uncertainty and inconsistency of GHG accounts and mitigation targets [2], especially at the sub-national (regions, cities) level. Quantification and accurate baselines of GHG emissions are considered a precondition towards mitigation. Moreover, GHGs are related with other air-pollutions, which makes emission accounts critical for achieving co-benefits of climate mitigation and air pollution control. Second, big emitters such as China show significant heterogeneity among regions which introduces challenges for achieving national mitigation targets balancing regional development and economic goals. For example, the mitigation targets among Chinese provinces can differ by 30% for the period of 2010-2015 (12^{th} Five year plan) [3]. There is an urgent need to develop reliable subnational GHG accounts to support national mitigation. Thirdly, international trade and flows of goods and services, energy and technology are intensifying the interactions among regions and nations. The dramatic increase of national carbon footprint has caused increasing attention from academia, politics and the public [4, 5]. Studies show that emissions embodied in traded goods and services globally have increased to 28% of global emissions with a growth rate in trade related emissions that is much higher than the growth of total carbon emissions and [4]. Thus reliable mitigation targets require a further understanding of the cross-national/boundary activities and associated GHG emissions. Finally, there are a range of potential measures for pursuing GHG mitigation such as economic measures including cap and trade and carbon taxes, which can help to incentivize development of renewable energy technologies or discourage use of carbon intensive products.

In order to address some of these knowledge gaps, we co-organized this special issue, to learn from experiences of multi-disciplinary analyses across scales, and to discuss best practices of low carbon development and GHG mitigation. This special issue also provides a platform for cross-cutting analyses that inform global, national and regional GHG mitigation targets and comprehensive attempts of redesigning energy systems towards a low-carbon economy.

There are in total 48 papers accepted in this issue, which can be grouped into 5 topics.

1. Accounting and uncertainty of energy consumption and GHG emissions

Emission inventories provide the baseline for mitigation research and targets. However, uncertainties are within national emission estimation, mainly due to the rapid growth of emissions in emerging economics and frequently still underdeveloped statistics [6]. Reducing the uncertainty requires the investigation and analysis of energy consumption and GHG emissions in specific regions and sectors.

In their paper, Shan et al. [7] calculated the provincial emission inventories in China during 2000-2012, adopted the measurement based emission factors and new estimated energy consumption with more reliable data sources. Their results suggest that China's total carbon emission are 12.7% smaller than the ones calculated by the traditional approach and IPCC default emission factors. Such results will have significant impacts on the achievement of China's 2030 emission peak and associated mitigation policies.

Ji et al. [8] suggest that the difference of GHG emission factors caused by the cross-boundary electricity supply needs to be considered when conducting regional GHG emission inventories.

Su and Pauleit [9] performed the GHG emission accounting for EU member states from 1991 to 2012, and observe the remarkable decrease of total GHG emissions in EU member states. The decrease of total emissions in the EU constitutes a sharp contrast to emerging economics.

Precise and reliable emission baseline also provide an understanding and guidance for mitigation for regions and sectors. In their paper, He et al. [10] find that cities have significant GHG mitigation opportunities: 10.2% and 6.8% of CO_2 emissions between 2015 and 2030 (from business-as-usual levels) can be reduced from megacities like Beijing and Shanghai, respectively, by adopting economically attractive low carbon measures.

In another case, Wang and co-authors [11] provide detailed GHG estimates from energy consumption, pre-treatment sector, combustion of condensed black liquor, and methane emitted from incomplete aerobic digestion during sewage treatment of the Pulp and Paper Industry (CPPI). Such sectoral inventories based on life-cycle analysis show the mitigation potential for sectors. Their approach can be extended to analyze the emission status from other sectors and technologies.

Recently, rapid development of input-output analysis and related data sources provide measures that allow researchers to investigate GHG emission baseline not only from production side, but also from the consumption side by adopting a supply chain perspective.

In their study, Fan et al. [12] explore the characteristics of production-based and consumption-based CO_2 emissions for 14 major economies through a multiple dimension comparison to gain insights into emissions equity among major emitters. They found that consumption-based emissions are more highly correlated with per capita GDP.

2. Co-benefits of GHG mitigation with other environmental issues

The combustion of fossil fuels is not only the main contributor for GHG emissions but also other air pollution such as SO_2, NOx and particular matters. Mitigation of GHG through the control of fossil fuel combustion could achieve co-benefits alleviating other environmental pressures.

Chen and colleagues [13] suggest that cooking fuel transition from solid fuels to cleaner gas fuels can simultaneously reduce emissions of both air pollutants and GHG emissions.

Wang and colleagues [14] show that efficiency improvements in the coal-fired power sector could contribute more than 3% of regional total GHG emission reductions and save million dollars in preventing associated health and environmental costs.

Chen et al. [15] conducted seasonal inventories for global electricity and fuel consumption for the residential sector, by using regression models and validated global electricity and fuel consumption in the residential sector based on a series of physical and socioeconomic factors. Their results can be used to predict temporal variations of residential energy consumption, pollutant emissions, and net effects of climate warming on energy consumption and emissions.

Theoretically, GHG mitigation is a multi-disciplinary challenge and thus requires analysis and measures from multiple perspectives. For example, Choi et al. [16] developed a novel generic sequential input-output framework to model economy-wide changes in resource consumption and environmental emissions. By addressing the case of the US, they emphasize the importance of focusing on a wide range of environmental outcomes and unintended side effects when introducing a specific environmental policy.

Horschig et al. [17] introduced a new approach to estimate the market potential of biomethane by analyzing biogas markets and their relative environmental and economic advantages. They find that several environmental pollutants are highly co-related with GHG emissions in terms of spatial-temporal distribution.

Meng et al. [18] provide an analysis of the impacts of domestic and international trade on urban air pollution using a three-scales ranging input-output model, they found that trade plays a dominant role in national $PM_{2.5}$ air pollution. Gilmore and colleagues [19] evaluate the range of passenger vehicles available in the Indian market to identify options that minimize the costs, human health effects and contribution to climate change.

Uncovering the linkages among GHG emissions and other environmental elements are critical for achieving co-benefits. For example, energy intensive manufacturing is not only the main contributor for GHG emissions but the associated production processes are also very water intensive. Wang et al. [20] compared the electricity intensity and associated carbon emissions of wastewater treatment plants in four countries: the USA, Germany, China, and South Africa. They find that 100% energy self-sufficient wastewater treatment plants are feasible by a combination of increased energy efficiency and energy harvesting from the wastewater.

Carbon emissions of wastewater treatment plants depend strongly on the electricity fuel mix, wastewater treatment technologies, treatment capacity, and influent and effluent water quality. In order to uncover the linkage of the air pollutions and GHG emissions, Yang et al. [21] adopted network analysis to investigate the emissions of PM2.5 embodied in economic activities.

Kucukvar and colleagues [22] assess the linkage of energy, climate and manufacturing at the global scale. They show that onsite and upstream supply chains are found to be responsible for over 90% of total energy use and carbon footprint for all industrial sectors.

Electricity, Gas and Water Supply is usually found to be as the main contributor to global climate change. Chen and Chen [23] propose a system based framework to re-assemble the interwoven connections between energy consumption and water use in a city. Such system approach helps researchers to target the co-benefits of mitigation opportunities.

Climate change mitigation requires actions not only at the national scale, but also at fine spatial scales.

Zhao et al. [24] analyzed the environment-economy tradeoff for Beijing-Tianjin-Hebei’s exports. They contrasted economic gains (value added) against atmospheric pollutant emissions (sulfur dioxide (SO_2), nitric oxide (NOx), primary fine particulate matter ($PM_{2.5}$) and non-methane volatile organic compounds (NMVOC)) and the widely concerned CO_2 emissions associated with international and interprovincial exports from Beijing-Tianjin-Hebei (BTH). The results call for refocusing and restructuring of BTH's industry and trade to balance economic gains and environmental losses, so that integrated mitigation measures can be achieved.

For the sector level, Fujii et al. [25] conducted firm level analysis for more than 500 firms and suggest that policy makers need to consider industrial and regional characteristics to develop effective policies that conserve energy and reduce CO_2 emissions.

Wu et al. [26] for the first time established a complete inventory of energy inputs in the life cycle of domestic coal-fired plant. Such analyses also contribute to regional adaption of climate change.

Liang et al. [27] provide a tool for the management of electricity shortage caused by heat wave shocks, which can have policy implications for the climate change mitigation and adaption at the city level.

3. Technology and renewable energy

Development of low carbon technology and renewable energy is one of the major approaches for achieving national mitigation targets. However, there are various technology options.

Hao et al. [28] reviewed the literatures on the topic of low-carbon energy technology investment based on bibliometric methods and the databases of Science Citation Index Expanded (1981-present) and Social Sciences Citation Index (2002-present). The literature review suggests that strength (as indicated by bibliometric) of low-carbon technology investment in developed countries is far greater than that in developing countries.

For specific technology options that could contribute to GHG mitigations, Zafirakis and colleagues [29] determined the value of arbitrage for energy storage across European markets and analyzed the roles for energy storage in GHG mitigating.

Zhang et al. [30] evaluated the scenario and performance of two wind power technological options, pumped hydro storage (PHS) and electric boilers (EBs). The case study shows the potential and implication for China's wind power development.

More cases can be found from papers such as, Hofmann et al. [31] analyzing the impacts of the gasoline vehicle replacement program with EVs at different penetration rates on petroleum and electricity sectors and their CO_2 emissions; as well as Xie and Shao [32] on enhancing the R&D investment of energy-saving technology and the cleaner transition of energy structure, as well as formulating industrial emission-reduction policies from a perspective of the whole industrial chain rather than certain single sub-sectors.

Liu et al. [33] developed a life cycle rebound effect model to evaluate the environmental effects of a new Energy Efficiency Standard for room air-conditioners. They show that the rebound effect of Chinese urban air-conditioners is around 67%, which shall be taken into account when assessing the potential benefits of energy efficiency technologies in the household sector.

Zeng and colleagues [34] predicted baseline GHG emissions of different motor vehicles of Chinese cities from 2013 to 2035, and suggest that GHG emissions from tank to wheel and well to wheel in all cities will continuously increase yet at different rates.

Particular, technology improvement or renewable development in power generation sector can have direct mitigation impacts, given that the power sector is the major consumer of fossil fuel energy and producer of GHGs. Research interests are increasing in analyzing the performance and GHG mitigation potentials for the power sector. For example, Zhang et al. [35] show that technology advances of wind energy would increase global energy security and stability through the impact on the whole energy system, such as a decrease by 30% of gas based electricity in the long term.

Rauner et al. [36] identified the spatial dissonance between power demand and renewable power supply, they developed an approach for mapping the progress towards Smart Renewable Power Provision, and evaluated the GHG mitigation effects from smart power provision.

Li et al. [37] present an improved graphical pinch analysis-based approach that considers carbon-constrained regional electricity planning and supply chain synthesis of biomass energy. By using such measures, they provide an evaluation of the renewable electricity at the regional level.

Supply chains, international trade and embodied GHG emissions

Differences in economic comparative advantage is the main driver of international trade. A side effect is the flows of "virtual" emissions embodied in international trade and transferred between countries.

Arce and colleagues [38] show that through changes in international trade, there is a possibility of reducing emissions, which have to be included in international, multilateral and bilateral agreements to mitigate climate change.

Such "embodied emissions" are also remarkable at regional levels. Mi et al. [39] found substantial differences between production- and consumption-based accounting in terms of both overall and per capita carbon emissions.

Urban consumption not only leads to carbon emissions within a city's own boundaries but also induces emissions in other regions via interregional trade. Chen et al. [40] constructed a multi-scale, global MRIO model to describe a transnational city carbon footprint network among the five Chinese megacities and the five largest Australian capital cities. The results show how local emission reductions influence other regions through carbon networks. Such hierarchy shows that cites should be differentiated in shouldering responsibility for climate change mitigation.

Embodied emissions in trade can be observed within a country. Zhang et al.[41] present a multi-regional input-output analysis of embodied energy transfers via China's domestic trade in 2002 and 2007. They show that significant growth of net embodied energy transfers can be identified from China's central and western inland regions to eastern coastal regions, and the Central region partly served as a "transmission channel". Knowledge for understanding both producers and consumers on the GHG emissions provides benefits for policy makers aiming for effective mitigation measures.

However, precise estimates of embodied emissions remains a challenge, limited by data availability. Liu and co-authors [42] found that emissions embodied in Chinese exports might be lower than commonly thought, and thus would increase China's responsibility for carbon emissions even from a consumption based approach. They show that ignoring firm heterogeneity causes a 20% overestimation of embodied CO_2 emissions in Chinese exports at the national level with huge differences at the sector level for 2007. This is due to the fact that different types of firms who are allocated in the same sector of the conventional Chinese input-output table have large variation in terms of market share, production technology and carbon intensity.

Social and economic factors of GHG emissions

To achieve national mitigation target in a cost effective way, many nations have implemented a market-based emission trading scheme (ETS). For example, China initiated pilot markets in seven regions. Wu et al. [43] evaluated the performance and effectiveness of China's pilot ETS in Shanghai, and suggest that in order to implement the national ETS effectively capacity building efforts and improved legislation are required to better deal with new features of the carbon markets such as scientific allowance allocation, monitoring, reporting and verification of emissions.

Another market based solution is the carbon tax. Wang et al. [44] provided a literature review on the distributional impacts of carbon taxes and discuss policy implications.

GHG emissions are highly correlated with economic activities. Jiang and Guan [45] analyzed the driving factors of global CO_2 emissions growth in 1995-2008, showing that the upgrades in infrastructure and changes in electricity demand were the dominant driving forces behind the coal-driven CO_2 emissions growth in developing countries. By contrast, consumption by the public and social services as well as a few carbon-intensive goods, such as chemical products, were the dominant driving forces of gas-related CO_2 emissions growth in developed countries.

Regional heterogeneity plays important role in the mitigation performance from market measures. Yao et al. [46] established a meta-frontier non-radial Malmquist CO_2 emission performance index (MNMCPI) to measure dynamic changes in CO_2 emission performance by combining the non-radial directional distance function and the meta-frontier CO_2 emission performance index (MCPI).

Chen et al. [47] investigated the effect of carbon emissions and study the impact of optimizing interregional carbon emissions.

Similar suggestions can be found in Li and Zhang [48] who found a high level and heterogeneity in rebound effects in China's energy consumption and GHG emissions, and suggested that new strategies are necessary for energy conservation in China's industrial sectors.

For impact on energy saving and emission reduction from governance, Lu and Shao [49] suggested that government subsidies generally play a crucial role in pricing and the choice of performance levels in Energy Performance Contracting (EPC).

Zhang et al. [50] found that energy activities as the largest contributor hold about half of China's total CH_4 emissions, mainly from coal mining, and inherent economic driving factors covering consumption, investment and international exports played an important role in determining regional CH_4 emission inventories.

Du et al. [51] seek to understand changes in energy efficiency in China, and find that R&D Investment when energy prices are rising, are a driver of energy efficiency improvements.

GHG reduction can be achieved by optimizing employment, household consumption, and human behavior. Duarte et al. [52] evaluated the adoption of energy efficient appliances, modal shift to public transport, healthier diets, and the associated carbon emissions and job effects by using a Computable General Equilibrium (CGE) model, and suggested that reductions in carbon dioxide, methane, and sulphur dioxide emissions may be compatible with increases in income and reductions in unemployment. Thus household consumption and consumer's individual behavior could be important drivers of GHG emissions.

Pothitou et al. [53] found that household behavior and habits have significant impacts on energy consumption. Residents with positive environmental values and greater environmental knowledge are more likely to demonstrate behaviors, attitudes and habits which lead to energy saving activities in households and GHG mitigation.

By adopting an atmosphere-ocean general circulation model (GCM) and constructed the hourly weather years from 2015-2100, Huang and Hwang [54] shed light on how a building's energy consumption behavior may change in the future and suggested adequate countermeasures to adapt existing buildings to climate change.

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Guest Editors

Zhu Liu[a]

[a] Resnick Sustainability Institute, California Institute of Technology, Pasadena, CA 91125, USA

Kuishuang Feng[b]

[b] Department of Geographical Sciences, University of Maryland, College Park, MD 20742, USA

Steven J. Davis[c]

[c] Department of Earth System Science, University of California, Irvine, USA

Dabo Guan[d]

[d] Tyndall Centre for Climate Change Research, School of International Development, University of East Anglia, Norwich NR4 7TJ, UK

Bin Chen[e]

[e] School of Environment, Beijing Normal University, Beijing 100875, China

Klaus Hubacek[b]

[b] Department of Geographical Sciences, University of Maryland, College Park, MD 20742, USA

Jinyue Yan[f,g]

[f] Royal Institute of Technology (KTH), 100 44 Stockholm, Sweden

[g] Malardalen University (MDU), Box 883, 721 23 Västerås, Sweden

References

[1] Peters GP, Marland G, Le Quéré C, Boden T, Canadell JG, Raupach MR. Rapid growth in CO2 emissions after the 2008-2009 global financial crisis. Nature Climate Change. 2012;2:2-4.

[2] Liu Z, Guan D, Wei W, Davis SJ, Ciais P, Bai J, et al. Reduced carbon emission estimates from fossil fuel combustion and cement production in China. Nature. 2015;524:335-8.

[3] Liu Z, Guan D, Crawford-Brown D, Zhang Q, He K, Liu J. Energy policy: A low-carbon road map for China. Nature. 2013;500:143-5.

[4] Peters GP, Minx JC, Weber CL, Edenhofer O. Growth in emission transfers via international trade from 1990 to 2008. Proceedings of the National Academy of Sciences. 2011;108:8903-8.

[5] Wiedmann T, Minx J. A definition of 'carbon footprint'. Ecological economics research trends. 2008;1:1-11.

[6] Guan D, Liu Z, Geng Y, Lindner S, Hubacek K. The gigatonne gap in China's carbon dioxide inventories. Nature Climate Change. 2012;2:672-5.

[7] Shan Y, Liu J, Liu Z, Xu X, Shao S, Wang P, et al. New provincial CO_2 emission inventories in China based on apparent energy consumption data and updated emission factors. Applied Energy. 2016, 10.1016/j.apenergy.2016.03.073

[8] Ji L, Liang S, Qu S, Zhang Y, Xu M, Jia X, et al. Greenhouse gas emission factors of purchased electricity from interconnected grids. Applied Energy. 2015, 10.1016/j.apenergy.2015.10.065

[9] Su M, Pauleit S, Yin X, Zheng Y, Chen S, Xu C. Greenhouse gas emission accounting for EU member states from 1991 to 2012. Applied Energy. 2016, 10.1016/j.apenergy.2016.02.074

[10] He Q, Jiang X, Gouldson A, Sudmant A, Guan D, Colenbrander S, et al. Climate change mitigation in Chinese megacities: A measures-based analysis of opportunities in the residential sector. Applied Energy. 2016, 10.1016/j.apenergy.2016.07.112

[11] Wang Y, Yang X, Sun M, Ma L, Li X, Shi L. Estimating carbon emissions from the pulp and paper industry: A case study. Applied Energy. 2016, 10.1016/j.apenergy.2016.05.026

[12] Fan J-L, Hou Y-B, Wang Q, Wang C, Wei Y-M. Exploring the characteristics of production-based and consumption-based carbon emissions of major economies: A multiple-dimension comparison. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.076

[13] Chen Y, Shen H, Zhong Q, Chen H, Huang T, Liu J, et al. Transition of household cookfuels in China from 2010 to 2012. Applied Energy. 2016, 10.1016/j.apenergy.2016.07.136

[14] Wang K, Wang S, Liu L, Yue H, Zhang R, Tang X. Environmental co-benefits of energy efficiency improvement in coal-fired power sector: A case study of Henan Province, China. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.059

[15] Chen H, Huang Y, Shen H, Chen Y, Ru M, Chen Y, et al. Modeling temporal variations in global residential energy consumption and pollutant emissions. Applied Energy. 2015, 10.1016/j.apenergy.2015.10.185

[16] Choi J-K, Bakshi BR, Hubacek K, Nader J. A sequential input–output framework to analyze the economic and environmental implications of energy policies: Gas taxes and fuel subsidies. Applied Energy. 2016, 10.1016/j.apenergy.2016.05.033

[17] Horschig T, Adams PW, Röder M, Thornley P, Thrän D. Reasonable potential for GHG savings by anaerobic biomethane in Germany and UK derived from economic and ecological analyses. Applied Energy. 2016, 10.1016/j.apenergy.2016.07.098

[18] Meng J, Liu J, Guo S, Huang Y, Tao S. The impact of domestic and foreign trade on energy-related PM emissions in Beijing. Applied Energy. 2015, 10.1016/j.apenergy.2015.09.082

[19] Gilmore EA, Patwardhan A. Passenger vehicles that minimize the costs of ownership and environmental damages in the Indian market. Applied Energy, 2016, 10.1016/j.apenergy.2016.09.096

[20] Wang H, Yang Y, Keller AA, Li X, Feng S, Dong Y-n, et al. Comparative analysis of energy intensity and carbon emissions in wastewater treatment in USA, Germany, China and South Africa. Applied Energy. 2016, 10.1016/j.apenergy.2016.07.061
[21] Yang S, Fath B, Chen B. Ecological network analysis of embodied particulate matter 2.5–A case study of Beijing. Applied Energy. 2016, 10.1016/j.apenergy.2016.04.08
[22] Kucukvar M, Cansev B, Egilmez G, Onat NC, Samadi H. Energy-climate-manufacturing nexus: New insights from the regional and global supply chains of manufacturing industries. Applied Energy. 2016, 10.1016/j.apenergy.2016.03.068
[23] Chen S, Chen B. Urban energy–water nexus: A network perspective. Applied Energy. 2016, 10.1016/j.apenergy.2016.03.042
[24] Zhao H, Zhang Q, Huo H, Lin J, Liu Z, Wang H, et al. Environment-economy tradeoff for Beijing–Tianjin–Hebei's exports. Applied Energy. 2016, 10.1016/j.apenergy.2016.04.038
[25] Fujii H, Cao J, Managi S. Firm-level environmentally sensitive productivity and innovation in China. 2016, 10.1016/j.apenergy.2016.06.010
[26] Wu X, Xia X, Chen G, Wu X, Chen B. Embodied energy analysis for coal-based power generation system-highlighting the role of indirect energy cost. Applied Energy. 2016, 10.1016/j.apenergy.2016.03.027
[27] Liang Z, Tian Z, Sun L, Feng K, Zhong H, Gu T, et al. Heat wave, electricity rationing, and trade-offs between environmental gains and economic losses: The example of Shanghai. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.045
[28] Yu H, Wei YM, Tang BJ, Mi ZF, Pan SY. Assessment on the research trend of low-carbon energy technology investment: A bibliometric analysis. Applied Energy. 2016, 10.1016/j.apenergy.2016.07.129
[29] Zafirakis D, Chalvatzis KJ, Baiocchi G, Daskalakis G. The value of arbitrage for energy storage: Evidence from European electricity markets. Applied Energy. 2016, 10.1016/j.apenergy.2016.05.047
[30] Zhang N, Lu X, McElroy MB, Nielsen CP, Chen X, Deng Y, et al. Reducing curtailment of wind electricity in China by employing electric boilers for heat and pumped hydro for energy storage. Applied Energy. 2015, 10.1016/j.apenergy.2015.10.147
[31] Hofmann J, Guan DB, Chalvatzis K, Huo H. Assessment of electrical vehicles as a successful driver for reducing CO_2 emissions in China. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.042
[32] Xie X, Shao S, Lin B. Exploring the driving forces and mitigation pathways of CO_2 emissions in China's petroleum refining and coking industry: 1995–2031. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.008
[33] Liu J, Sun X, Lu B, Zhang Y, Sun R. The life cycle rebound effect of air-conditioner consumption in China. Applied Energy. 2016, 10.1016/j.apenergy.2015.11.100
[34] Zeng Y, Tan X, Gu B, Wang Y, Xu B. Greenhouse gas emissions of motor vehicles in Chinese cities and the implication for China's mitigation targets. Applied Energy. 2016,
[35] Zhang X, Ma C, Song X, Zhou Y, Chen W. The impacts of wind technology advancement on future global energy. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.130
[36] Rauner S, Eichhorn M, Thrän D. The spatial dimension of the power system: Investigating hot spots of Smart Renewable Power Provision. Applied Energy. 2016, 10.1016/j.apenergy.2016.04.029
[37] Li Z, Jia X, Foo DC, Tan RR. Minimizing carbon footprint using pinch analysis: The case of regional renewable electricity planning in China. Applied Energy. 2016, 10.1016/j.apenergy.2016.05.031

[38] Arce G, López LA, Guan D. Carbon emissions embodied in international trade: The post-China era. Applied Energy. 2016, 10.1016/j.apenergy.2016.05.084
[39] Mi Z, Zhang Y, Guan D, Shan Y, Liu Z, Cong R, et al. Consumption-based emission accounting for Chinese cities. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.094
[40] Chen G, Wiedmann T, Wang Y, Hadjikakou M. Transnational city carbon footprint networks–Exploring carbon links between Australian and Chinese cities. Applied Energy. 2016, 10.1016/j.apenergy.2016.08.053
[41] Zhang B, Qiao H, Chen Z, Chen B. Growth in embodied energy transfers via China's domestic trade: Evidence from multi-regional input–output analysis. Applied Energy. 2015, 10.1016/j.apenergy.2015.09.076
[42] Liu Y, Meng B, Hubacek K, Xue J, Feng K, Gao Y. 'Made in China': A reevaluation of embodied CO_2 emissions in Chinese exports using firm heterogeneity information. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.088
[43] Wu R, Dai H, Geng Y, Xie Y, Masui T, Tian X. Achieving China's INDC through carbon cap-and-trade: Insights from Shanghai. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.011
[44] Wang Q, Hubacek K, Feng K, Wei Y-M, Liang Q-M. Distributional effects of carbon taxation. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.083
[45] Jiang XM, Guan DB. Determinants of global CO2 emissions growth. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.142
[46] Yao X, Guo C, Shao S, Jiang Z. Total-factor CO_2 emission performance of China's provincial industrial sector: A meta-frontier non-radial Malmquist index approach. Applied Energy. 2016, 10.1016/j.apenergy.2016.08.064
[47] Chen J, Cheng S, Song M, Wu Y. A carbon emissions reduction index: Integrating the volume and allocation of regional emissions. Applied Energy. 2016, 10.1016/j.apenergy.2016.03.032
[48] Li K, Zhang N, Liu Y. The energy rebound effects across China's industrial sectors: An output distance function approach. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.117
[49] Lu Z, Shao S. Impacts of government subsidies on pricing and performance level choice in Energy Performance Contracting: A two-step optimal decision model. Applied Energy. 2016, 10.1016/j.apenergy.2016.05.106
[50] Zhang B, Yang TR, Chen B, Sun XD. China's regional CH_4 emissions: Characteristics, interregional transfer and mitigation policies. Applied Energy. 2016, 10.1016/j.apenergy.2016.04.088

[51] Du H, Matisoff DC, Wang Y, Liu X. Understanding drivers of energy efficiency changes in China. Applied Energy. 2016, 10.1016/j.apenergy.2016.05.002

[52] Duarte R, Feng K, Hubacek K, Sánchez-Chóliz J, Sarasa C, Sun L. Modeling the carbon consequences of pro-environmental consumer behavior. Applied Energy. 2015, 10.1016/j.apenergy.2015.09.101

[53] Pothitou M, Hanna RF, Chalvatzis KJ. Environmental knowledge, pro-environmental behaviour and energy savings in households: An empirical study. Applied Energy. 2016, 10.1016/j.apenergy.2016.06.017
[54] Huang K-T, Hwang R-L. Future trends of residential building cooling energy and passive adaptation measures to counteract climate change: The case of Taiwan. Applied Energy. 2015, 10.1016/j.apenergy.2015.11.008