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# Toward a Sustainable Low-Carbon China: A Review of the Special Issue of "Energy Economics and Management"

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**Abstract:** Severe environmental quality deterioration, along with predatory exploitation of energy resources, are generally associated with economic growth, especially in China. Against this background, the 6th Annual Conference of Energy Economics and Management provides a platform for examining outperforming governance factors and mechanisms of energy economics and policy. Thanks to *Sustainability* for providing this special issue. This editorial highlights the contents and methodologies of the special issue for this conference, presenting diverse issues in energy economics and management. We also suggest guidelines for future study in energy economics and management.

**Keywords:** energy policy; carbon reduction; sustainable development; 6th-annual-conf-EEM

## 1. Background of the Special Issue

For the past two decades, with the continuous progress of reform and opening-up, China has been one of the world's fastest growing economies. However, serious environmental quality deterioration and predatory exploitation of resources have occurred as the economy has expanded. For instance, China has seen a dramatic increase in energy consumption and $CO_2$ emissions. It is now the world's largest $CO_2$ emitter, accounting for 25.9% of the world's total, creating severe environmental problems, such as toxic haze. These environmental effects have stimulated a growing public consciousness of the need for environmental protection. Furthermore, ignoring the effective control of environmental quality is likely to cause further contradictions between economic growth and environmental quality, which is not conducive to social stability and sustainable development [1]. Therefore, lowering the environmental costs of economic growth to strike a balance between environmental protection and economic growth is an urgent issue at present.

Against this background, the 6th Annual Conference of Energy Economics and Management was held in Guangzhou, China, 11–13 November 2015. The conference was co-hosted by the National Natural Science Foundation of China (NSFC), the Project Management Research Committee of China, and Jinan University (Guangzhou). Nearly 400 experts and scholars from more than 100 colleges and scientific research institutes in the field of energy economics and management took part in the conference.

The theme of the conference was "Toward a sustainable low carbon China: New global carbon Reduction Agreements and Energy Policy". In addition to carbon emission reduction, resources and sustainability management, renewable and sustainable energy, energy and environmental modeling, and many other topics in sustainable energy research were tied to the conference theme. This conference provides opportunities for delegates to exchange new working papers and application experiences, in order to establish research or collaboration relations. My deepest thanks go to *Sustainability*, which provided a special issue for this conference. The scope of this Special Issue encompasses topics related to energy economics and management in Asia, at both the macro- and micro-levels, as presented at the 6th Annual Conference of Energy Economics and Management.

A total of 17 journal papers were selected and published in this special issue, through the standard peer review process (http://www.mdpi.com/journal/sustainability/special_issues/6th-annual-conf-EEM). These selected papers concentrate on issues of "Energy Economic and Management" in order to control China's excessive energy consumption and resulting $CO_2$ emissions problem, thus finally improving environmental quality and accelerating the development of an environmentally-friendly society. The 6th Annual Conference of Energy Economics and Management was the cornerstone of a new platform for academic networking to present ongoing research activities and exchange research ideas in the area of energy economics and management. This conference has made a positive contribution to the overall level of scholarship in the field and inspired young researchers in energy economics and management.

## 2. Important Issues for China's Energy Economics and Management

Energy economics and management is an important topic that attracts attention from both academia and government policy-makers. As a sustainability science, it is composed of the three pillars of the environment, economics, and social studies. Therefore, most papers on this issue are based on the harmonization of these perspectives and encompass topics related to energy economics and management, at both the macro-levels and micro-levels, such as low carbon and sustainable development, resources and sustainability management, and energy and environmental modeling. Most of the papers address issues of energy economics and management in China. China's economy has made remarkable achievements since the continuous progress of reform and opening-up, but the development of the economy has inevitably generated severe environmental quality deterioration and energy shortages. For example, electricity is a driving force of economic development and the electricity industry is a basic industry of national economy, closely related to economic development. However, China has been experiencing large-scale power shortages, including blackouts and brownouts, which seriously affect the development of the economy and cause large economic losses [2]. To address this problem, quantitative assessment of the economic impacts of power shortages is required. One study presented in this issue uses a static computable general equilibrium (CGE) model to simulate the economic impacts of blackouts and brownouts and compiles a social accounting matrix (SAM) of eight sectors of China in 2007. The simulation results show that power shortages have a significant adverse impact on economic development and that the industrial sector suffers most from blackouts. The main reason for power shortages is the specific administrative pricing system in China. Low electricity prices lead to insufficient construction and blackouts in the long term, with brownouts in the short run. Therefore, the paper proposes power system reforms to address the problem of power shortages [2].

China's economic growth is usually described as "unstable, unbalanced, uncoordinated and ultimately unsustainable" [3]. Based on the concept of sustainable development, achieving green growth has been an important target for the Chinese government. Green growth can foster economic growth and development while ensuring that natural assets continue to provide the resources and environmental services the nation requires. However, accurate measurement of green development performance remains an issue. In proposing a green development growth index (GDGI) for measuring the changes in sustainable development over time, Li et al. [4] adopted a new approach which allows for the incorporation of heterogeneity across provinces and non-radial slack in the conventional green development index. Li et al. measure green development performance based on the four main types of environmental pollution in 30 provinces of China over the period 2000–2012. Their main results include: (1) the average score of GDPI in China during the sample period is 0.398, indicating a low level of green development, but it is improving 2.58% per year driven by innovation effects in recent years; and (2) green development is primarily led by the eastern region. Nevertheless, the average score of GDPI for the eastern region is 0.525, still a low level of green development. This implies that the eastern region's performance is better than the central and the western regions [4]. For the individual provinces, the GDPI scores show huge differences, and the eastern provinces performed better than the central and western provinces.

Interprovincial competition is believed to be one of the most essential driving forces for China's economic growth, as proposed by Li and Zhou [5], based on the promotion tournament model. However, competition among provinces may lead to serious pollution problems and high environmental costs because provincial officials are evaluated based on economic performance. This causes local governments to compete with each other to ease environmental regulation in order to attract investment for economic growth [6]. Thus, whether competition among local governments leads to a race to the bottom, or green development, remains uncertain. A paper in this issue thus explores the strategic interactions in provincial development using an environment-economic indicator, pollution intensity in China. It tests the strategic interactions among two groups of regions according to whether the pollutant is regulated based on the spatial lag term by employing the spatial Durbin model. The results show that the "race to the bottom" is not the case at the national level, and provincial governments do implement strategies for environmental protection. It also shows that the "race to green development" hypothesis is supported in the east for pollutants with obligatory emission reduction targets, such as $SO_2$ and Chemical Oxygen Demand (COD). Moreover, increasing environmental legislation has been effective in reducing PI, especially for pollutants with obligatory reduction targets [6].

The rapid development of the national economy generates enormous energy consumption and $CO_2$ emissions. With the increasing prevalence of climate disasters, scholars have begun to focus on $CO_2$ emissions and their relationship to economic growth, especially for industrial economies. One of the papers in the special issue analyzes China's five major IPPU department $CO_2$ emissions levels from 1991–2012 and examines the relationship between IPPU $CO_2$ emissions and the economic level. It shows that the overall emissions level is indeed rising yearly, and that steel and iron alloy manufacturing and nonmetal manufacturing account for roughly 80% of the total emissions. The IPPU $CO_2$ emissions and the corresponding gross industrial output value do not present a classic Kuznets curve in most industrial sectors because of the increasing size of the population employed in industry [1].

Most previous studies empirically test the environmental Kuznets (EKC) hypothesis at the regional or industry level. Nevertheless, with the development of spatial econometrics, researchers have the opportunity to incorporate spatial dynamics into their analyses of the trends and drivers of China's carbon emissions [7]. Liu et al. proposes the stochastic impact regression on population, affluence, and technology (STIRPAT) model to investigate the factors driving industrial carbon emissions based on panel data from 2006–2010. The determinants of regional industrial carbon emissions are investigated by a spatial Durbin model and a geographically- and temporally-weighted regression is applied to investigate temporal and spatial variations in the impacts of these driving factors on the scale and intensity of regional industrial carbon emissions. The results indicate that spatial correlation, heterogeneity, and spillover effects should be taken into account when formulating policies aiming at reducing industrial carbon emissions [7]. One study in this special issue estimates the contribution of industry structure adjustment to the carbon intensity target of Guangdong Province, which had ranked first in terms of economic performance for over 20 successive years. By using the Markov chain model, least squares support vector machine, and scenario prediction, the obtained results show, in the ideal scenario, that carbon intensity in 2015 will be 25.53% less than in 2010, making a 130.94% contribution to the carbon intensity target. Meanwhile, in the conservative scenario, carbon intensity in 2015 will be 23.89% less than in 2010, making a 122.50% contribution to the carbon intensity target [8].

In order to control the country's excessive energy consumption and resultant $CO_2$ emission problem, China has committed to reducing its $CO_2$ emissions by 40%–45% from 2005 levels per unit of GDP by 2020 [9]. Therefore, Sun et al. [9] developed the traditional data envelopment analysis (DEA) model based on improved Kuosmanen environmental DEA technology, which avoids the effect of positive shadow prices on undesirable outputs and designs a dual model to analyze shadow prices on $CO_2$ emissions for each province and its industrial sectors in China [9]. Likewise, by adopting an energy-input based directional function, Lai et al. [10] have calculated the shadow price of energy (i.e., coal, oil, gas, and electricity) across 30 areas in China. The study estimates the macro-energy efficiency index, which is divided into intra-provincial technical efficiency, the allocation efficiency of energy input structure, and the inter-provincial energy allocation efficiency [10]. This is because industrial production is the primary contributor to carbon emissions in China, and industrial land is an important input to industrial production. Therefore, modeling the dynamic changes in carbon emission performance and industrial land use in recent years and forwarding constructive policy implications is urgently needed [11]. Wang et al. [11] use a global directional function (DDF) approach to compute the total-factor carbon emission performance of industrial land use (TCPIL) and find that the TCPILs for China and its three regions rise over the study period, and the eastern region performed much better in TCPIL than the central and western regions. This study uses a non-radial Luenberger carbon emission performance of industrial land use (NLCPILs) index to model the dynamic changes in the TCPIL, with results showing that the NLCPILs for China were greater than zero in most years of the study period, and their growth was primarily driven by ECs before 2009 and by TC subsequently. Last, the study analyzes factors which significantly affect carbon emission reduction, including more investment in industrial research and development (R and D), the implementation of carbon emission reduction policies, reduction in the use of fossil energy, especially coal, in the process of industrial production, actively learning about foreign advanced technology, solving the problem of surplus labor in industry, and the expansion of industrial development [11].

If we focus on a micro approach to $CO_2$ emission regulatory issues, the heating industry is a key industry, since China's heating industry is necessary for its tough winters. Further, more residents of Southern China are demanding central heating. China's heating industry, thus, accounts for 89.4% of the total energy consumption during 1985–2010 [12]. $CO_2$ emissions from the heating industry accounted for an average 6.1% of China's carbon emissions during 1985–2010 and there is a long-run equilibrium relationship between $CO_2$ emissions and factors such as energy intensity, industrial scale, labor productivity, and energy productivity by the co-integration method. The Monte Carlo technique is adopted for the risk analysis. The results indicate that there is considerable potential for $CO_2$ emissions mitigation in China's heating industry [12]. In addition to the above research, the threshold effect of the relationship between financial development and carbon emission intensity from the perspectives of financial scale and financial efficiency were tested. The results indicate that both raising the level of openness and improving the industrial structure will have significant positive effects on carbon intensity [13].

In addition to the issues surrounding $CO_2$ emissions, other resource and management issues have captured the attention of researchers. Water resources are a precondition of improving the environment. From the ecological perspective of water resources management and sustainable development, one study examines water consumption and the determinants of water utilization of Tianjin, which is located in the northeast of North China Plain and in the center of the Bohai economic circle. Using the grey correlation analysis method, the survey shows that the main factors affecting the water utilization structure are industrial structure, per capita green area, cultivated area, effective irrigation area, rural electricity consumption, animal husbandry output, resident population, and per capita domestic water use [14]. Natural gas resources [15] and the crude oil market [16] were also studied. One paper develops an optimization model for the long-term exploitation of limited natural gas reserves in China and analyzes its exploitation scale and related factors, including recovery rate, discount rate, and the gas well exhaustion cycle, that affect the optimal exploration path of this gas field [15].

Further, another paper proposes an improved method, the multivariate empirical model decomposition (EMD)-based model, to take advantage of the heterogeneous characteristics of the price movement and model them in the crude oil markets. The proposed model demonstrates performance superior to that of benchmark models [16]. In addition, agricultural labor productivity was evaluated by using the Difference-in-Differences (DID) method to examine the establishment of the Poyang Lake Eco-Economic Zone, an area surrounding Poyang Lake, the largest lake in China [17]. The results show that the establishment of the zone reduced agricultural GDP by 3.6% and this negative effect has increased each year since 2009. It was found that the lack of agricultural R and D activities and the abuse of chemical fertilizers may be the main reasons behind the negative influence of the policy [17].

With mounting pressure for a green, low carbon economy, materials selection plays a crucial role in product design. Some studies have focused on materials selection by market demand, while others have found that materials selection is also motivated by cost considerations. However, most studies have not treated environmental management as a key aspect of materials selection in product design [18]. Thus, a paper in this special issue presents an integrated multi-attribute decision-making (MADM) approach to aid selection of commercially-available materials for sustainable design. In the study, grey relation analysis (GRA) and analytic hierarchy process (AHP) are used to rank alternative materials in terms of their economic, environmental, and social performance. In addition, three alternative polymer materials, i.e., poly (vinyl chloride) (PVC), polypropylene (PP), and polyethylene (PE), are examined to determine their sustainability for plastic pipe design [18]. Naturally, as in much recent research, consumer willingness to pay (WTP) for sustainable products is analyzed. One paper presents household-level tuna steak consumption, based on an investigation of consumer preference for the attributes of tuna and the impact of eco-labels, particularly Certified Turtle Safe (CTS) labels, on consumer demand, and examines individuals' perceptions and attitudes toward farm-raised and wild-caught tuna species based on an Internet survey [19]. The empirical study shows that respondents on average preferred turtle-safe-labeled tuna steak and were likely to pay more for it and they were less likely to purchase wild-caught species. Moreover, significant heterogeneities were found across individuals regarding tuna steak purchases. The findings indicate evidence of public support for environmental friendliness, particularly with regard to eco-labeling [19].

## 3. Methodologies of Energy Economics and Management

The field of energy economics and management includes resource and sustainability management, the innovation of methodology, and pluralism; major concerns of the international community, and one of the main challenges of our time. Since economic theory measuring a "sustainable green" economic growth model was developed, it has been argued that sustainable economic growth only depends on technological progress in the long term. Many studies analyze the sustainability of China's economic growth based on total factor productivity (TFP) via growth accounting, or non-parametric methods. However, conventional TFP studies ignore the environmental costs of economic growth (such as $CO_2$ emissions). Therefore, these studies may overestimate the true contribution of TFP to output growth, thus yielding a false picture of China's green development [4]. Perhaps it is difficult for researchers to put forth a robust theory of energy economics and management, but it is certainly meaningful to propose diverse methodological approaches and raise awareness and emphasize of the importance of sustainable performance.

Most papers in this Special Issue show great interest in the $CO_2$ emissions [1,7,9,11,12] and the carbon intensity [8,13]. Some of these studies use the conventional regression to analyze $CO_2$ emissions [1,8,13], but the downside of this method is that conventional regressions cannot solve the problems of multiple inputs/outputs in these models. Therefore, a centralized DEA approach was used to determine the optimal path for controlling $CO_2$ emissions at the sector level for each province in China, which can avoid positive shadow prices on undesirable outputs [9]. The global directional function (DDF) and non-radial Luenberger productivity index were used to analyze the dynamic change in the total-factor carbon emission performance of industrial land use (TCPIL) [11].

This method can also be used to measure green development performance [4] and evaluate the total factor energy efficiency [10]. In addition, there is a classic environment Kuznets curve (EKC) between IPPU $CO_2$ emissions and the economy. The EKC hypothesis is usually verified at the regional or industry level [1]. The development of spatial econometrics and the use of the spatial panel data model incorporate spatial dynamics into the analysis of the trends and drivers of China's carbon emissions [7]. Finally, a paper evaluates the potential for reducing $CO_2$ emissions by co-integration analysis and scenario analysis [12].

The linear regression or linear transformation of multivariate variables is introduced as well. Using the spatial lag term by employing the regional Durbin model, the strategic interactions among regions is tested. How pollution intensity is influenced by the direct and spatial spillover effects of environmental regulation was also explored [6]. One paper uses a logit model to examine purchasing propensities [19], another takes the establishment of Poyang Lake Eco-Economic Zone in 2009 as a quasi-natural experiment because of its exogeneity and utilizes the DID method to evaluate its influence on agricultural labor productivity [17].

Linear programming is also used in this special issue. A static CGE model is constructed and the social accounting matrix (SAM) of eight sectors of China is compiled to simulate the economic impacts of power blackouts and brownouts. The CGE model is a good method to simulate the effects of policies or the shocks of exogenous events and can be understood as an input-output model [3]. One paper proposes a new multivariate EMD-based methodology for combining distant data features during the modeling and the forecasting of crude oil price. The researchers propose a time delay embedding method to analyze a higher dimension domain and introduce the multivariate EMD model to analyze and model the geometric multi-scale data features in the higher dimensional domain [16]. Unlike crude oil in China, the natural gas economy is a coal-dominated energy structure economy and suffers from serious pollution problems. A paper develops an optimizing approach to model gas production in China and conducts a sensitivity analysis of the factors affecting the path of natural gas exploitation [15]. In the real process of materials selection, a number of variables should be taken into account. Consequently, MADM methods, such as analytic hierarchy process (AHP) and grey relational analysis (GRA) are able to rank material alternatives and help designers determine the best material. A paper introduces a computational approach for materials selection in the context of green design by using GRA, integrated with AHP [18]. Another paper used information entropy analysis and GRA to analyze the changes in water utilization structure and its impact factors using water consumption data for agricultural, industrial, domestic, and ecological areas in the city of Tianjin [14].

Due to the interdisciplinary character of energy economics and management, diverse approaches could, and should, be imported and used for better understanding of multivariate complexity, as well as for the generation of more systematic implications and suggestions [20].

## 4. Conclusions

Environmental problems related to carbon emissions have become increasingly serious in China, pacing increased levels of consumption, because China's energy consumption structure has given priority to coal in recent years. Thus, saving energy and reducing consumption is necessary for sustainable development, because of the non-renewability and scarcity of fossil fuels, such as coal and gas. The optimization of energy production systems is a relevant issue that must be considered if China is to adhere to reduction policies for fossil fuel consumption and regulations on $CO_2$ emissions ([13], p. 271). Therefore, the Chinese Government has proposed targets for reducing the energy consumption, optimizing the energy structure by lowering the reliance on fossil fuels, and promoting marketization of energy prices by reforming energy pricing mechanisms [21,22]. These issues of energy economics and management have captured the attention of the participants at the 6th Annual Conference of Energy Economics and Management.

Coordinating economic growth alongside improvement in environmental quality may be daunting, but it is certainly not impossible [23]. We must pay close attention to the shifting patterns among energy economics and management norms and practices, and to governance institutions in China to keep pace with the world and its challenges [24]. Further, most papers in this special issue emphasize the importance of creating a new paradigm of energy economics and management, as well as sustainable management geared toward value creation. The papers in this Special Issue, thus, make important contributions in helping to understand key attributes of the changes now underway.

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## References

1. Duan, Y.; Mu, H.; Li, N. Analysis of the Relationship between China's IPPU $CO_2$ Emissions and the Industrial Economic Growth. *Sustainability* **2016**, *8*, 426. [CrossRef]
2. Peng, O.; Huang, R.; Yao, X. Economic Impact of Power Shortage. *Sustainability* **2016**, *8*, 687. [CrossRef]
3. Chen, S.; Golley, J. Green's productivity growth in China's industrial economy. *Energy Econ.* **2014**, *44*, 89–98. [CrossRef]
4. Li, K.; Song, M. Green Development Performance in China: A Metafrontier Non-Radial Approach. *Sustainability* **2016**, *8*, 219. [CrossRef]
5. Li, H.; Zhou, L. Political turnover and economic performance: The incentive role of personnel control in China. *Public Econ.* **2005**, *89*, 1743–1762. [CrossRef]
6. Huang, J.; Xia, J. Regional Competition, Heterogeneous Factors and Pollution Intensity in China: A Spatial Econometric Analysis. *Sustainability* **2016**, *8*, 171. [CrossRef]
7. Liu, Y.; Xiao, H.; Zhang, N. Industrial Carbon Emissions of China's Regions: A Spatial Econometric Analysis. *Sustainability* **2016**, *8*, 210. [CrossRef]
8. Wang, P.; Zhu, B. Estimating the Contribution of Industry Structure Adjustment to the Carbon Intensity Target: A Case of Guangdong. *Sustainability* **2016**, *8*, 355. [CrossRef]
9. Sun, Z.; Luo, R.; Zhou, D. Optimal Path for Controlling Sectoral $CO_2$ Emissions among China's Regions: A Centralized DEA Approach. *Sustainability* **2016**, *8*, 28. [CrossRef]
10. Lai, P.; Du, M.; Wang, B.; Chen, Z. Assessment and decomposition of Total Factor Energy Efficiency: An Evidence Based on Energy Shadow Price in China. *Sustainability* **2016**, *8*, 408. [CrossRef]
11. Wang, W.; Xie, H.; Jiang, T.; Zhang, D.; Xie, X. Measuring the Total-Factor Carbon Emission Performance of Industrial Land Use in China Based on the Global Directional Distance Function and Non-Radial Luenberger Productivity Index. *Sustainability* **2016**, *8*, 336. [CrossRef]
12. Lin, J.; Lin, B. How Much CO2 Emissions Can Be Reduced in China's Heating Industry. *Sustainability* **2016**, *8*, 642. [CrossRef]
13. Pan, X.; Yan, Y.; Peng, X.; Liu, Q. Analysis of the threshold Effect of Financial Development on China's Carbon Intensity. *Sustainability* **2016**, *8*, 271. [CrossRef]
14. Zhang, C.; Dong, L.; Liu, Y.; Qiao, H. Analysis on the Impact Factors of Water Utilization Structure in Tianjin, China. *Sustainability* **2016**, *8*, 241. [CrossRef]
15. Xiao, J.; Wang, X.; Wang, R. Research on Factors Affecting the Optimal Exploitation of Natural Gas Resources in China. *Sustainability* **2016**, *8*, 435. [CrossRef]
16. He, K.; Zha, R.; Wu, J.; Lai, K.K. Multivariate EMD-Based Modeling and Forecasting of Crude Oil Price. *Sustainability* **2016**, *8*, 387. [CrossRef]
17. Wu, T.; Wang, Y. Did the Establishment of Poyang Lake Eco-Economic Zone Increase Agricultural Labor Productivity in Jiangxi Province, China? *Sustainability* **2016**, *8*, 8. [CrossRef]
18. Zhao, R.; Su, H.; Chen, X.; Yu, Y. Commercially Available Materials Selection in Sustainable Design: An Integrated Multi-Attribute Decision Making Approach. *Sustainability* **2016**, *8*, 79. [CrossRef]
19. Zhou, G.; Hu, W.; Huang, W. Are Consumers Willing to Pay More for Sustainable Products? A Study of Eco-Labeled Tuna Steak. *Sustainability* **2016**, *8*, 494. [CrossRef]

20. Choi, Y.; Zhang, N. Introduction to the Special Issue on "The Sustainable Asia Conference 2014". *Sustainability* **2015**, *7*, 1595–1602. [CrossRef]
21. Zhang, N.; Wang, B.; Liu, Z. Carbon emissions dynamics, efficiency gains, and technological innovation in China's industrial sectors. *Energy* **2016**, *99*, 10–19. [CrossRef]
22. Zhang, N.; Wang, B.; Chen, Z. Carbon emission reductions and technology gaps in the world's factory, 1990–2012. *Energy Policy* **2016**, *91*, 28–37. [CrossRef]
23. Zhang, N.; Wei, X. Dynamic total factor carbon emissions performance changes in the Chinese transportation industry. *Appl. Energy* **2015**, *146*, 409–420. [CrossRef]
24. Zhang, N.; Xie, H. Toward Green IT: Modeling Sustainable Production Characteristics for Chinese Electronic Information Industry, 1980–2012. *Technol. Forecast. Soc. Chang.* **2015**, *96*, 62–70. [CrossRef]