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Editorial

Recent trend of industrial emissions in developing countries

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ABSTRACT

Greenhouse gas (GHG) emissions from industrial sectors are increasing, particularly in the developing world where pursuing industrialization has been highly addressed. This calls for further studies to learn and share experiences for developing countries. In order to fill in such a research gap, this special issue focuses on examining the recent trend of industrial emissions in developing countries. Among the manuscripts submitted to the Special Issue, twelve papers have been accepted after review, covering assessment indicators, tools and methods, and policies. Key industrial sectors, including cement, lime, aluminum, coal, mining, glass, soda ash, etc, have been investigated. Valuable policy insights have been raised, including wide scale upgrading, replacement and deployment of best available technologies, integrated information platforms, cross-cutting technologies and measures, a shift to low carbon electricity, radical product innovations, carbon dioxide capture and storage (CCS), demand on new and replacement products, systematic approaches and collaboration among different industries. These useful suggestions could be shared or learned by industrial policy makers or managers in the developing world so that the overall GHG emissions from their industrial sectors can be mitigated by considering the local realities.
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1. Introduction

Greenhouse gas (GHG) emissions from industry are rapidly increasing and higher than those from other end-use sectors. According to IPCC AR5 [1], total emissions from the industrial sector reached 14.86 $GtCO_2e$ in 2010, representing 30% of total global GHG emissions. Particularly, from a global perspective, with both urbanization and industrialization, GHG emissions from industrial sectors in developing countries experienced a rapid growth, while such emissions in developed countries are declining. Under such a circumstance, it is necessary to pursue an absolute reduction in emissions from the industrial sector. In order to achieve such a target, a broad set of mitigation options should be considered, including energy efficiency, material use efficiency, recycling and reuse of materials and products, industrial symbiosis, product service efficiency, demand reductions. These measures have been widely applied in developed countries. However, there are few studies from developing world. As a response to such an issue, we organize this special issue in Applied Energy, a leading journal in the field.

The objective of the special issue (SI) is to address both global and local issues (such as energy security, carbon emissions, air pollution and public health) from industrial sectors while contributing to development needs. It focuses on integrating climate change concerns with industrial development objectives by encouraging industrial decision-makers to encompass low-emission and/or climate-resilient economic growth in their industrial development strategies. The editorial presents an overview of the twelve selected articles of this SI, which not only detail the innovative indicators, methods, cases and tools for promoting low carbon industrial development in the developing world, but also provide valuable policy insights to policy-makers and industrial managers from developing countries. We expect that new ideas and perspectives on how positive changes can be attained as well as an understanding on how different regions can generate solutions that have large, short and long-term positive benefits and how innovative industrial emission mitigation measures can be effectively embedded into local policy settings to contribute to low carbon industrial development at the local and regional levels. Most of the papers in the SI are focused on China. This is rational since China is the largest industrial emission country in the world and its industrial production scale is more profound. Nevertheless, we presume that valuable lessons can be learned or shared from these studies in China so as to promote win-win situations in resource efficiency, climate change prevention and adaptation from industrial sector in the developing world.

2. Evaluations

Appropriate evaluation methods are valuable for managing sectorial emissions and for providing guidelines on low carbon development of industrial sectors. Various performance assessment methods and indicators for different industrial sectors have been developed, based on well-known assessment methods, such as: energy consumption, IPCC methods, on-site emissions, carbon footprints, and input-output analysis. Each method has its advantages and disadvantages and can address some specific parameters of low carbon industrial development. The selection of different methods is based upon the needs and available data. For instance,

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Cai et al. [2] targeted to evaluate the overall CO_2 emissions from China's cement industry based on the detailed information of China's total 1574 cement enterprises in 2013. It reflects the aspect that cement industry triggered by intensive construction activities in the country has become one of the key industrial emission sectors in China. Due to different factors process and energy emission intensities vary significantly between different enterprises. The average CO_2 emissions performance of China's cement enterprises (806 kg CO_2/ton clinker) is approx. 4% lower than the global average level in 2013. This commendable result is very much based on the performance of the best production facilities as the CO_2 emissions intensity of the best 20th clinker production, is even lower than the IEA's 2020 target. That's why the authors propose that those enterprises could be the entry threshold for future new enterprises and top runner benchmark for the existing enterprises. Also, CO_2 emissions related to cement production differ from regions to regions. In China the Yangtze River Delta region is the most important hotspot of the cement CO_2 emissions. Wuhu & Tongling are the hottest emission centres, with an average of 8,288 ton of CO_2 emissions per square kilometers. As emissions factors differ widely, amongst others ownership of cement enterprises should be carefully considered in designing appropriate policy instruments. Favorable policies could focus on medium sized facilities, and initially focus on specific areas (e.g. along the Silk Road Economic Belt) and technologies.

Zhou et al. [3] proposed a Malmquist energy conservation and emission reduction performance index (MECERPI) for assessing the performance changes in energy use and pollutant emissions over time. Their index is built upon the non-radial directional distance function and can be derived by solving data envelopment analysis. 15 MECERPIs were applied in order to empirically investigate the industrial performance of energy conservation and emission reduction in over two hundred cities in China as well as its influential factors. Their empirical results show that due to the combined effects of technological progress and efficiency improvement, the energy conservation and emission reduction performance of Chinese industry has improved at an average annual rate of 16%. The catch-up effect and convergence exist throughout the country, including the eastern, central, western and northeastern regions. The best performers, which act as the benchmark for industrial energy conservation and emission reduction, are the coastal cities in eastern China. Such findings implicate that the future cooperation between different regions should be enhanced so that advanced technologies and management measures can be transferred from the east to the central and west China.

Long et al. [4] measured the industrial carbon productivity of 30 provinces in China from 2005 to 2012 and examined the space-time characteristics and the main factors of China's industrial carbon productivity by using Moran's *I* index and spatial panel data models. Their empirical results indicate that there is significant positive spatial dependence and clustering characteristics in China's province-level industrial carbon productivity. The spatial dependence may create biased estimated parameters in an ordinary least squares framework. According to the analysis of their spatial panel models, industrial energy efficiency, the opening degree, technological progress, and the industrial scale structure have significantly positive effects on industrial carbon productivity, while per-capita GDP, the industrial energy consumption structure, and the industrial ownership structure exert a negative effect on industrial carbon productivity. Such findings implicate that governmental organizations should encourage the exchange and sharing of information, technology, talents, and other resources across different provinces so that interprovincial cooperation on energy conservation and emissions reduction can be initiated, while industrial CO_2 abatement should depend on technology updates, including the alternative energy, energy saving, and carbon-sequestration technologies. In addition, due to the remarkable regional disparity, some sustainable industries in the southeast coastal provinces may better move to the mid-west inland provinces so that advanced technologies and management experiences can be shared by these backward regions.

3. Tools and methods

Innovative tools and methods are essential to the success of low carbon industrial development since they can help researchers and policy maker to identify new industrial mitigation opportunities and measures. For instance, Shao et al. [5] selected mining sector to investigate the key driving factors on inducing corresponding carbon emissions since mining sector is the foundation of the whole industrial production as well as a carbon intensive sector. By employing a novel index decomposition method, namely, Generalized Divisia Index Method, they decomposed the energy-related carbon emission changes of China's mining industry and its sub-sectors over the period of 1999–2013 into some absolute value indices and relative value indices, including output scale, energy use, carbon intensity, emission coefficient, and energy intensity. In addition, a scenario analysis approach was applied to seek the feasible mitigation pathways on China's mining sector and its five sub-sectors. Their results indicate that output scale effect is the primary contributor of the increase in the carbon emissions of both mining sector and its five sub-sectors and energy use effect also plays a promotion role, while carbon intensity effect contributes most to the decrease in carbon emissions. Another finding is that all sub-sectors have achieved the target of 45% carbon intensity reduction except the extraction industry of petroleum and natural gas. Even though, more efforts should be made for the whole mining sector in order to achieve the 2030 peak target of carbon scale.

In another regard, industrial process emissions are increasing in the developing countries due to their fast industrialization. However, few studies have been reported on carbon emissions from the production of industrial materials, such as mineral products (e.g., lime, soda ash, asphalt roofing), chemical products (e.g., ammonia, nitric acid) and metal products (e.g., iron, steel and aluminum). It is also difficult to find effective data on carbon emissions from the production processes of these industrial products (in addition to cement production) from current international carbon emission datasets. Under such a circumstance, Liu [6] estimated the carbon emissions resulting from the manufacturing of 5 major industrial products in China. Based on an investigation of China's specific production processes, he applied the Tier 1 approach depicted in IPCC, which is an output-based approach that estimates emissions based on the production volume and the default emission factors. The results indicate that China's total carbon emission from the production of alumina, plate glass, soda ash, ammonia and calcium carbide was 233 million tons in 2013, equivalent to the total CO_2 emissions of Spain in 2013. The cumulative emission from the manufacturing of these 5 products during the period of 1990–2013 was approximately 2.5 Gt CO_2, more than the annual total CO_2 emissions of India. Such a result indicates that quantifying the emissions from industrial processes is critical for understanding the global carbon budget and to develop suitable mitigation technologies and policies for these processes are crucial.

In addition, Shan et al. [7] further examined the emissions from lime production, the second largest source of carbon emissions from industrial processes after cement production. Their study analyzes CO_2 emissions from China's lime production for the period of 2001–2012 and estimated the process emissions (scope 1 direct emissions caused by the process), fossil fuel combustion emissions (scope 1 direct emissions caused by fossil fuel combustion), and scope 2 indirect emissions (CO_2 emissions caused by

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