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Rapid growth of petroleum coke consumption and its related emissions in China

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HIGHLIGHTS

- This study first examines China's petroleum coke consumption growth since 2010.
- Petroleum coke-related CO_2, CH_4, and N_2O emissions doubled from 2010 to 2016.
- Shandong produced the most petroleum coke, Tianjin and Guangdong consumed the most.
- Non-metallic mineral and power production are the major petroleum coke consumers.
- China should pay more attention on the increasing petroleum coke use.

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ABSTRACT

Petroleum coke, a non-environmentally friendly energy source, is gradually replacing other power fuels in China's industrial enterprises because of its price advantage. Petroleum coke has high emission factors and thus emits more greenhouse gases (GHGs) and air pollutants than even raw coal. This study first examines the rapid growth of petroleum coke consumption in China since 2010 by industry sector and region and then estimates the petroleum coke-related emissions. We conclude that the total consumption of petroleum coke increased by 18.9% from 2010 to 2016 and that the industry final consumption for burning in boilers increased dramatically (by 158.2%). Petroleum coke-related CO_2 emissions reached 28 million tonnes in 2016, whereas CH_4 and N_2O emissions totaled 870 and 143 tonnes, respectively. The increased use of petroleum coke will increase the urgency for the development of climate change mitigation and emissions reduction measures in China. We propose several possible policy suggestions for petroleum coke management and emissions control, such as strongly restricting the production and import of high-sulphur petroleum coke, as well as burning petroleum coke to provide power; more power plants and industrial kiln stoves/boilers should be equipped with efficient decontamination systems; the development of advanced industrial processes and the clean utilization of petroleum coke should be encouraged.

1. Introduction

China is the largest energy consumer in the world, and its energy consumption pattern is "rich coal, deficient oil, and lean gas". Coal and its related products constitute approximately 70% of the total energy consumption in China. Under pressure from environmental protection groups and international negotiations on climate change mitigation, China's government has proposed several policies to control coal consumption in recent years [1]. For example, according to the "Strategic action plan for energy development (2014–2020)", the total national coal consumption must fall below 4.2 billion tonnes by 2020 [2]. After implementing a series of energy/emissions control policies, the coal share in China decreased from 72.5% in 2007 to 62.0% in 2016. Simultaneously, China strived to develop renewable and clean energies, such as natural gas, hydropower, and nuclear power. Renewable and clean energies now contribute 19.5% of overall energy consumption

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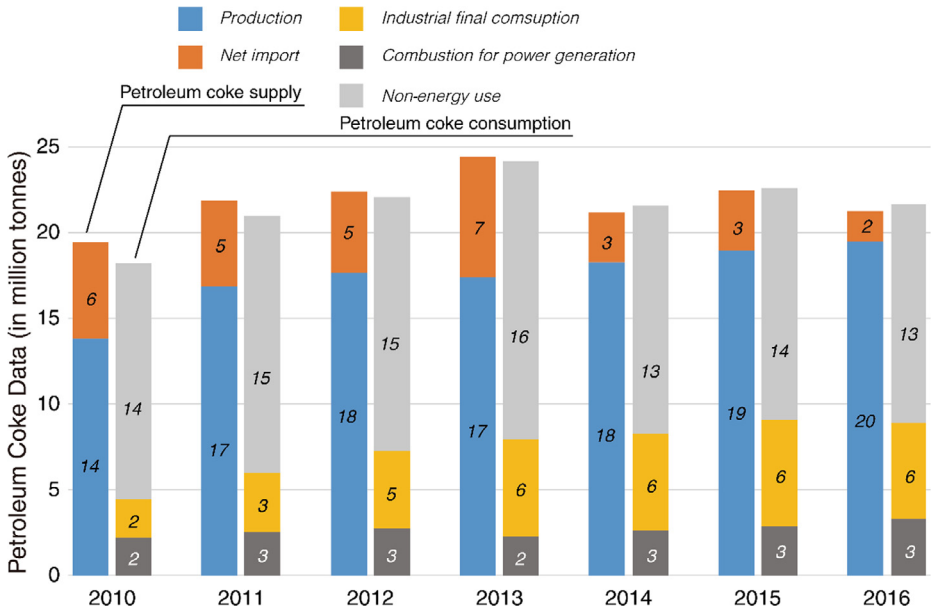

Fig. 1. Supply and consumption of petroleum coke in China.

and have almost doubled since 2000 (9.5%).

Overall, China's energy structure appears to be developing along a low-carbon path. However, a few industrial enterprises and power plants have recently begun to use cheap but environmentally unfriendly energy sources, especially petroleum coke. According to the Intergovernmental Panel on Climate Change (IPCC) guidelines, *"petroleum coke is defined as a black solid residue, obtained mainly by cracking and carbonizing of petroleum derived feedstocks, vacuum bottoms, tar and pitches in processes such as delayed coking or fluid coking. It consists mainly of carbon (90 to 95 percent) and has a low ash content. It is used as a feedstock in coke ovens for the steel industry, for heating purposes, for electrode manufacture and for production of chemicals"* [3]. According to a previous study that compared emissions factors [4], petroleum coke emits 2.21 times the CO_2, 6.15 times the CH_4, and 5.48 times the N_2O emitted by lignite coal during combustion. Lignite coal is primarily used as thermal coal in power plants and industrial boilers in China. Therefore, petroleum coke is a more carbon- and pollution-intensive energy source, even when compared with raw coal and crude oil. The usage of petroleum coke, especially for combustion, degrades the local air quality and threatens residents' health [5].

Recently, the increasing consumption of petroleum coke in China has attracted more and more attentions [6,7]. Petroleum coke production and consumption have increased rapidly in China. From 2010 to 2016, the production of petroleum coke increased by 40.9%, and its use in industrial final combustion increased by 158.2%, as it was used in kiln stoves/boilers to provide power. However, accurate accounts of China's petroleum coke consumption and its related environmental impacts are still lacking.

Previous studies on China's energy consumption and related emissions generally concentrated on either overall regional issues [8–10] or major energy sources, such as coal [11,12] or oil [13]. There are barely any studies available that target petroleum coke consumption in China. Those that exist can be divided into two categories. First, there are those that discuss the environmental impacts of petroleum coke consumption. For example, Caruso, Zhang [14] use Detroit and Chicago as cases to explore the petroleum coke's effects on urban environment and residential health. McKee and White [15] report on the effects of petroleum coke on aquatic mammals. Second, there are studies that discuss the clean utilization of petroleum coke from a technical perspective. For example, Wang, Anthony [16] discuss the possible CO_2 recovery and sulphur removal approaches for petroleum coke combustion in power plants. Zou, Zhou [17] introduce a gasification technology to convert the abundant petroleum coke into syngas with near zero emissions. There are still not many studies that discuss petroleum coke management and control from a socio-economic perspective.

Considering petroleum coke's adverse effects on the environment and air quality, the Chinese government should take actions to restrain the combustion of petroleum coke. However, the Chinese government has not yet recognized the hazard posed by the widespread use of petroleum coke. Indeed, in the "10 key energy conservation projects during the 11th five-year plan (2006–2010)", the use of petroleum coke as a replacement for fuel oil (burnt in oilfield exploitation) and heavy oil (used in the production of construction materials) is actually encouraged [18]. Only in the "Air pollution prevention and control action plan", which was published in 2013 [19], did the government intensify its controls on the import of high-sulphur petroleum coke. However, this policy was issued without any detailed measures. To some extent, this is restricted by the lack of accurate accounts of petroleum coke combustion. Understanding the consumption characteristics and related emissions is the first step of petroleum coke management. This is the first study that analyses the increasing consumption of petroleum coke in China and its regions. We also estimate the related greenhouse gas and air pollutant emissions. Such socio-economic-emission analysis can not only provide robust and transparent data support for petroleum coke management, air pollution and greenhouse gas emissions control policy-making in China, but also support the clean utilization of the energy source.

2. Methods and data source

To elucidate the adverse effects of China's growing petroleum coke consumption on the climate and air quality, we estimate the CO_2, CH_4, and N_2O emissions from petroleum coke combustion in this country. All three gases are considered greenhouse gases (GHGs). CH_4 and N_2O are also classified as air pollutants.

According to the IPCC guideline [3], this study calculates the emissions with the consumption data of petroleum coke. Generally, petroleum coke is used in two ways in China. (1) Over 60% of the petroleum coke is consumed as a raw material, i.e., for a non-energy use, such as in the smelting of steel or aluminium and the manufacturing of graphite (shown as the grey bar in Fig. 1); (2) Less than 40% of the petroleum coke is combusted in industrial kiln stoves/