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A discussion on China's vehicle fuel policy: Based on the development route optimization of refining industry

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ABSTRACT

In recent years, Chinese government has been accelerating the implementation of high-quality standard of petroleum products. National Standard V of gasoline and diesel will be put into effect by 2018. However, as most of the gasoline and diesel are supplied by domestic refineries, whether the domestic refineries are capable to produce National Standard V products remains a question. This paper develops a mix integer programming model for long-term development route of refining industry in China from 2015 to 2050. The model provides optimal route of refinery construction, upgrading and retirement under different scenarios. Three scenarios are designed to discuss the mutual influence between long-term development of refining industry and fuel quality standard implementation. In the three scenarios, the schedule of 100%-National-Standard-V refining capacity target should be realized by 2018, 2030 and 2040 respectively. Based on the modeling results, we conclude that the 100%-National-Standard-V target by 2018 is difficult to realize. Putting off the schedule to 2030 is more practical in consideration of the current situation in China. To realize the 2030 target, extra investment for building new refineries and upgrading existing ones is needed in short term. However, impulse investment will result in over-capacity problem in the future.

1. Introduction

In recent years, people are more and more aware of the severe haze problem in China. The particulate matter (PM), sulfur dioxide (SO_2) and nitrogen oxide (NO_x) emissions from the combustion of low-quality gasoline and diesel is one of the major causes of haze problem. According to environmental statistics, in 2016, 71.9% of the 338 cities in China suffered from > 35 $\mu g/m^3$ PM2.5[1] concentration, 58.3% suffered from > 70 $\mu g/m^3$ PM10 concentration, 43.5% suffered from > 20 $\mu g/m^3$ SO_2 concentration, and 79.3% suffered from > 20 $\mu g/m^3$ NO_2 concentration. Motor vehicle exhaust emission is highly responsible for the urban air pollution. For example, the contribution of motor vehicle exhaust emission to the PM2.5 concentration in urban atmosphere was about 20% in Harbin and 40% in Shenzhen in 2016 (MEPC, 2017). By 2015, the private motor vehicle population of China was 162.8 million (NBSC, 2016). With the rapid progress of urbanization in China, private motor vehicle population is going to grow, especially in urban areas.

Haze problem severely influences human health. In recent years, the central government has been accelerating the implementation of high-quality standard of petroleum products, however the actual implementation of these standards lags far behind. In 2011, National Standard IV of Automotive Gasoline (sulfur content ≤50 ppm[2]) was released, and the required transition period for petroleum enterprises was up to the end of 2013. According to the requirement of the State Council, from July 2013, the diesel for domestic trade should meet the National Standard III of Automotive Diesel (sulfur content ≤350 ppm). In 2013, National Standard IV of Automotive Diesel (sulfur content ≤50 ppm) was released, and the required transition period for petroleum enterprises was up to the end of 2014. National Standard V of Automotive Gasoline (sulfur content ≤10 ppm) and National Standard V of Automotive Diesel (sulfur content ≤10 ppm) were released by the end of 2013, and the required transition period for petroleum enterprises was up to the end of 2017. Actually, from 2013, Beijing has implemented Beijing Standard V of Automotive Diesel and Gasoline (sulfur content < 10 ppm). In the same year, Shanghai, Guangzhou and Nanjing have implemented National Standard IV of Automotive Gasoline. More than ten cities in Jiangsu, Zhejiang and Guangdong have implemented National Standard IV of Automotive Gasoline and National Standard IV of Automotive Diesel. Meanwhile, except the cities mentioned above, in many regions of China, low-quality gasoline and

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[1] PM2.5 is defined as particulate matter with a mean aerodynamic diameter of 2.5 μm or less than 2.5 μm.
[2] 1 ppm = 1 mg/kg.

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diesel are still in use.

Most of the studies on vehicle exhaust emission in China focus on three aspects as followed:

1.1. The investigation of exhaust emissions from the combustion process of diesel and gasoline engines

For example, Deng et al. studied tailpipe exhaust of three typical in-use diesel vehicles under warm idling conditions to characterize primary emissions and secondary organic aerosols formation during photo-oxidation (Deng et al., 2017). Wang et al. summarized the studies of volatile organic compounds source profiles from on-road motor vehicles from 2001 to 2016, with a focus on the comparisons among different studies and the potential impact of different factors (Hong-li et al., 2017). Liu et al. investigated the vehicle emission trends in China's Guangdong Province from 1994 to 2014. They concluded that light passenger cars and motorcycles were the main contributors to CO and VOC emissions (65–80%), and heavy duty trucks and passenger cars were the main contributors to NO_x, PM2.5 and PM10 emissions (around 42–50%) (Liu et al., 2017). Huang et al. studied the causation mechanism of haze pollution related to the vehicle emission for Guangzhou city by employing the Fault Tree Analysis method (Huang et al., 2016). Zhang et al. conducted a field campaign in 2014 in the Zhujiang Tunnel to obtain emission factors (EFs) of PM2.5, carbonaceous aerosols and trace gases for road vehicles (Zhang et al., 2015).

1.2. The policy suggestions and strategy design for vehicle emission reduction

For example, Wu et al. reviewed vehicle emission controls in China including measures related to vehicle, fuel, traffic and economic aspects. Policy suggestions are provided for China's vehicle emission controls during the mid-term future (Wu et al., 2017). Wang, Ou and Zhang developed a transportation mode-technology-energy-CO_2 model based on discrete choice method. Based on the model, transportation energy use and CO_2 emissions in future in China were simulated. Scenarios were used to investigate the relative influences of improving vehicle energy efficiency, promoting EV use, and increasing taxes for fossil fuels and CO_2 (Wang et al., 2017). Walls talked about various vehicular emission policies in Hong Kong, providing good examples for the implementation of vehicular emission policies in China (Rusco and Walls, 1995). Zhang et al. assessed the vehicle emission in Yangtze River Delta Region in China, and concluded that mitigating vehicle emissions of NO_x would be more difficult than reducing the emissions of other major vehicular pollutants (e.g., CO, HC and PM2.5) in the YRD region. City-specific emission control strategies for three vehicle-populated cities in the YRD region were designed (Zhang et al., 2017). Yue et al. summarized the status of China's fuel quality standards, fuel supply and vehicle emission standards focusing on the major problems of fuel quality management. The gaming of stakeholders in the development of fuel quality standard formulation and fuel supply was illustrated, and key policy suggestions to improve future fuel quality in China were provided (Yue et al., 2015).

1.3. The contribution of alternative fuels and electric vehicles to reducing vehicular emission

For example, Han et al. examined life-cycle cost and GHG emissions of conventional vehicles, hybrid electric vehicles and battery electric vehicles, and comparing their cost-effectiveness for reducing greenhouse gas emissions (Hao et al., 2017). Hofmann et al. analyzed the impacts of the gasoline vehicle replacement program with electrical vehicles at different penetration rates on petroleum and electricity sectors and their CO_2 emissions. Their study concluded that electrical vehicles can contribute to a reduction of petroleum dependence, air quality improvement and CO_2 emission reduction only when their introduction is accompanied by aggressive electricity sector decarbonisation (Hofmann et al., 2016). Zhu et al. tested tailpipe and evaporative emissions of vehicles with different fuels. They concluded that E10 and M15 reduced CO, PN compared with gasoline, while increased NO_x seriously (Zhu et al., 2017). Ke et al. conduct a fine-grained well-to-wheel analysis to the city level based on real-world data and end-of-pipe control progress and estimated the WTW energy consumption and CO_2 and air pollutant emissions for various light-duty passenger vehicle technologies currently (2015) and in the mid-term future (2030) of Beijing (Ke et al., 2017).

In summary, improving vehicle energy efficiency, promoting alternative fuel and EV use, increasing taxes for fossil fuels and CO_2, implementing strict fuel standard, etc., can effectively reduce vehicular emission. Currently in China, the government has been implementing a series of policies and supportive projects in reducing vehicular emissions. Except the schedule of National Standard V for diesel and gasoline, Chinese government has released subsidy policies for hybrid electric vehicles and battery electric vehicles. Pilot projects of car sharing is deployed in Beijing, Shanghai and Shenzhen, in order to reduce the private cars on road.

However, rare study has mentioned the mismatched fuel-quality standards and the actual capability of fuel quality control in refineries in China. According to Yue's survey from 2010 to 2011, the average sulfur content of domestic gasoline was about 100 ppm, and the average sulfur content of domestic diesel was about 1000 ppm (Yue et al., 2015). The sulfur content values are almost ten times and 100 times higher than National Standard V of gasoline and diesel (sulfur content < 10 ppm). The crude oil resource in China is heavy and high-sulfur content. It leads to difficulties in improving the quality of petroleum products. The high cost of new refinery construction, facility upgrading and replacement is the major difficulty.

Current studies on refining industry mainly focus on optimizing the refining process and improving the economic, energy and CO_2 emission performances. For refining process optimization, plenty of papers can be found. For example, Feng et al. developed a special double powder injection lances system to improve the refining efficiency during Rheinstahl-Heraeus process (Feng et al., 2017). Chen et al. investigated the catalytic ozonation of heavy oil refining wastewater over activated carbon supported iron oxides catalysts using activated carbon as the reference (Chen et al., 2014). Song et al. designed and optimized a comprehensive Organic Rankine Cycle system to recover multi-strand waste heat sources in Shijiazhuang Refining & Chemical Company in China, involving defining suitable working fluids and operating parameters (Song et al., 2014). Liu et al. identified four key technologies for China National Petroleum Co.'s oil refining industry. They concluded that the four key technologies are: integrated fluid catalytic cracking (FCC), hydroprocessing, residue hydrocracking, and high-grade lubricant production. The most significant technology will be the integrated FCC technology that can economically increase the yield of light fractions as well as upgrade transportation fuels (Liu et al., 2007).

For performance improvement, Xie, Shao and Lin conducted decomposition and scenario analyses on the CO_2 emissions of China's petroleum refining and coking industry. They concluded that industrial activity is the dominant driving force of the growth of CO_2 emissions, followed by industrial scale and energy intensity (Xie et al., 2016). Lin and Xie estimated the energy conservation potential of refining industry by applying a co-integration model to investigate the long-run equilibrium relationship between energy consumption and some factors such as energy price, enterprise scale, R&D investment and ownership structure (Lin and Xie, 2015). Liu et al. modeled and analyzed the energy-savings potential for refining and conversion processes in the context of technological change. They concluded that upgrading process heaters have been a priority during recent years, but heat recovery and advanced process control systems will gradually begin to dominate the technological marketplace in the long term (Liu et al., 2013). Barros and Szklo developed and applied a methodology to evaluate the