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Biofuel for vehicle use in China: Current status, future potential and policy implications

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ABSTRACT

Biofuel is considered to be a promising solution to the energy and environmental challenges in the transport sector. However, there are few studies focusing on the current status, future potential, policy framework, barriers and opportunities of biofuel development in China, these are analyzed in this study. This study finds that China has been promoting biofuel commercialization with multiple measures, including framing national strategy, initiating demonstration programs, providing financial incentives, and establishing national standards. However, due to technology and market barriers, the actual commercialization scale is far lower than previously projected. Accordingly, it is recommended that the development of non-plantation resource-based biofuel should be given high priority, while plantation resource-based biofuel should be developed with caution. Meanwhile, technology innovation for increasing production efficiency and reduce cost is essential for strengthening biofuel market competitiveness. Subsequently, mandatory legal and policy system for regulating the biofuel industry in China should be established, which can effectively engage different stakeholders in promoting biofuel development. Regarding fuel ethanol, the trade price between the fuel ethanol producers and the oil companies should be further adjusted. As for biodiesel, the illegal utilization of waste oil should be strictly prohibited, which can help to increase the feedstock supply, as well as bring down the price. Last but not the least, the financial incentives for biofuel production should also be optimized.

1. Introduction

Transport is a major sector concerning energy consumption and CO_2 emissions. As estimated by International Energy Agency (IEA), the oil consumption by transport sector accounted for over half of total oil consumption globally [1]. Transport sector was responsible for 23% of global energy-related CO_2 emissions in 2013 [2]. China, as the representative of emerging economies, has experienced rapid growth in its vehicle market over recent years [3]. China's domestic vehicle sales increased from 2.1 million in 2000 to 23.5 million in 2014, with an annual growth rate of 19% [4]. By the end of 2014, China's vehicle stock reached 154 million [5]. This has caused great concerns over China's urban air quality, energy security, and CO_2 emissions. For example, China's major mega cities have experienced frequent smog weathers over recent years, which can be partially attributed to vehicle tailpipe emissions. GHG emissions from China's passenger vehicles accounted for around 5% of total GHG emissions in 2014 [6], and the freight transport sector for around 8% [7]. To cope with these challenges, intensive mitigation measures have been implemented both in China and globally.

Abbreviations: 1 G biofuel, First-generation biofuel; 1.5 G biofuel, 1.5-generation biofuel; 2 G biofuel, Second-generation biofuel; 3 G biofuel, Third-generation biofuel; BP, British Petroleum; CAAM, China Association of Automotive Manufacturers; CARB, California Air Resource Board; CNOOC, China National Offshore Oil Corporation; CNPC, China National Petroleum Corporation; COFCO, China Oil & Foodstuffs Corporation; DEA, Data Envelopment Analysis; EIA, Energy Information Administration; EJ, exajoule; EPA, Environmental Protection Agency; EU, European Union; FAHP, Fuzzy Analytic Hierarchy Process; GHG, Greenhouse Gas; GIS, Geographic Information System; GJ, gigajoule; Gt, gigaton; IEA, International Energy Agency; LCA, Life Cycle Assessment; MOF, Ministry of Finance; Mt, megaton; Mtoe, megaton of oil equivalent; NBS, National Bureau of Statistics; NDRC, National Development and Reform Commission; NEA, National Energy Administration; PJ, petajoule; SAC, Standardization Administration of China; Sinopec, China Petroleum & Chemical Corporation; SWOT, Strength, Weakness, Opportunity and Threats; VAT, Value Added Tax

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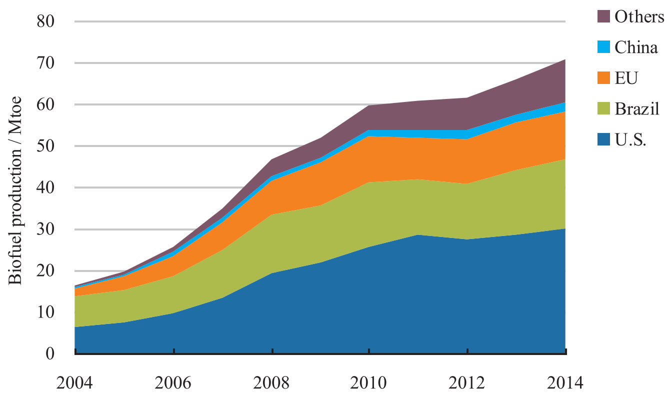

Fig. 1. Global biofuel production over the past decade.

Biofuel is considered to be part of the solution to the transport issues. Biofuel is derived from biomass, which helps to decouple transport fuels from petroleum resources. The life cycle CO_2 emissions of biofuels are generally lower than petroleum-derived fuels, contributing to reducing CO_2 emissions from the transport sector [8]. Moreover, biofuels improve fuel quality when blended with conventional fuels, which helps to reduce vehicle tailpipe emissions and improve air quality [9,10].

Globally, biofuel production and consumption increased steadily over recent years, as Fig. 1 shows [11,12]. Total biofuel production increased from 16.4 Mtoe (megaton of oil equivalent) in 2004 to 70.8 Mtoe in 2014, implying an annual growth rate of 15.7%. As projected by IEA, global biofuel consumption will continue to increase in the coming decades, reaching over 30 EJ (exajoule) (equivalent to about 720 Mtoe) by 2050, implying a ten fold growth compared to the current level [13]. At the same time, the biomass as feedstock for biofuel production will show a major shift from food crops to non-food crops and non-plantation resources. In China, biofuel production and consumption also experienced rapid growth, from 0.5 Mtoe in 2000 to 2.1 Mtoe in 2014 [11]. According to the Mid-long Term Planning on the Development of Renewable Energy released in 2007 [14], China's fuel ethanol and biodiesel consumptions were projected to reach 10 Mt (megaton) and 2 Mt by 2020, respectively.

Intensive studies have been conducted regarding biofuel development in China. Ren et al. compared the life cycle energy efficiency of six biofuels in China by using the Data Envelopment Analysis (DEA) approach, finding that fuel ethanol with sweet potatoes as feedstock has the highest life cycle energy efficiency [15]. Liu et al. established a life cycle assessment (LCA) based biofuel supply chain multi-objective optimization model, with the aim of identifying the optimal conversion pathway, biomass type, biomass locations, facility locations, etc. [16]. Ou et al. evaluated the life cycle energy consumption and GHG emissions of six biofuel pathways in China's context [17]. Lu and Zhou conducted a comprehensive review of the environmental assessments on liquid biofuels in China [8]. Wang discussed the time for commercializing non-food biofuel in China, arguing that more efforts are needed [18]. Koizumi argued that biofuel competes with food and agricultural production in China, and should be promoted with caution [19]. A similar conclusion was reached by Yang et al., who argued that China's biofuel development could pose significant impacts on China's food supply and trade, as well as the environment [20]. Huang et al. examined the impact of biofuel development on China's poverty situation, concluding that China's farmers, especially the poor, might benefit from biofuel development [21]. Besides, biofuel technology evolution in China's context has been examined by several studies, mostly based on patent statistics [22,23].

Macro-level polices are essential in promoting biofuel development. Ren et al. analyzed biofuel development in China by combining Strength, Weakness, Opportunity and Threats (SWOT) and Fuzzy Analytic Hierarchy Process (FAHP) approaches, concluding that policy instruments regarding improving technical performance and consumer awareness are both important in promoting its further development [24]. Qiu et al. comprehensively reviewed China's policies on biofuel development, arguing that the targets of China's biofuel development are cautious and feasible [25]. Chen et al. reviewed China's industrial policies for different kinds of biofuels [26]. Chang et al. assessed the potential policies needed to achieve China's biofuel development target in 2020 [27]. Besides macro-level policies, the micro-level behavior and management factors also affect the market competitiveness of biofuels. Zhang et al. compared the recycling modes of waste cooking oil in China and Japan, finding that the recovery rate of Chinese mode is not necessarily lower than that of Japanese mode [28]. Wang and Shi developed a Geographic Information System (GIS)-based optimization model for the selection of biofuel factory sites, and presented the optimal locations for biofuel factories by using the case of Guangdong province [29]. Zhang et al. compared the incentive effects of four common subsidy modes on waste cooking oil supply by establishing a dynamic game model, finding that raw material price subsidies and finished products sales subsidies have better overall effects [30].

Numerous studies focused on evaluating the potential of biofuel commercialization in China. Chen et al. estimated the potential of non-food biofuel production in China, concluding that there will be 76 Mt to 152 Mt potential capacity from 2015 to 2030 [31]. Jansson et al. discussed the potential of cassava for fuel ethanol production in China [32]. Ji assessed the agricultural residue resources for liquid biofuel production in China, concluding that around 930 Mt crop residuals will be available in 2015, which can be used to produce 44 Mt fuel ethanol or 131 Mt biodiesel [33]. Wang et al. explored the quantity of China's field crop residue and its availability for biofuel production, finding that the total residue quantity for biofuel production could potentially reach 314 Mt [34]. Elmore et al. calculated the spatial distribution of rice straw in China for the period 2000–2004 [35]. Tian et al. estimated the unused land potential for biofuels development in China, suggesting a 22 Mt potential of fuel ethanol production in 2020 [36]. Zhao et al. projected the long-term liquid biofuel potential, finding that the scale of biofuel consumption in China can range from 45 Mtoe to 120 Mtoe by 2050 [37]. Lu and Zhang introduced a species of invasive plant, Spartina alterniflora, and evaluated its potential as biofuel feedstock in China. Their study indicated that its total annual biomass reaches 2.53 Mt, capable of producing 39 PJ (petajoule) bioenergy [38]. Liang et al. evaluated the potential of waste oil as feedstock for biodiesel production, finding that it was equivalent to approximately 7.4% of China's diesel consumption in 2010 [39]. Zhang and Chen evaluated the role of biofuel in China's transport sector by developing the China-TIMES model. The study revealed that the use of biofuel will realize a 0.43 Gt (gigaton) of CO_2 emissions reduction in 2050, contributing to 35% of the overall reduction [40].

Besides regular biofuels, the development of emerging biofuel technologies in China has also received attentions from the research community. Li et al. estimated the biological potential of microalgae for biofuel production in China in an integrated bio-refinery approach [41]. Li et al. evaluated the characteristics of Enteromorpha prolifera as feedstock for biofuel production [42]. Zhou et al. conducted a comprehensive review on the development of densified solid biofuel in China [43]. A similar research was conducted by Chen et al. with a focus on the technological aspects [44]. Gu et al. discussed the possibility and potential of utilizing waste nitrogen for biofuel production in China [45]. Zhou et al. analyzed the utilization of the so-called low-input high-diversity grassland biomass to produce biofuel, finding that the potential reaches 15% of China's energy consumption in 2002 [46]. Some alternative biofuels, such as biobutanol, furanic biofuel, etc., are also being considered as potential biofuel options. The production technologies of these alternative biofuels have been intensively developed [47–49]. The impacts of using such biofuels on the performance of the combustion devices have also been investigated [50–52].