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An assessment of agricultural residue resources for liquid biofuel production in China

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ABSTRACT

The increasing importance of lignocellulosic biomass as a renewable energy source has led to an acute need for reliable and detailed information on its assessment, consumption and supply. With the passage of China's legislative targets for renewable portfolio standards, agricultural residue resources have the potential for an increasing role in meeting liquid fuels demand in China. An assessment of current and near future agricultural residue resources (including agricultural crop residues and secondary agricultural processing residues) in China at national scale was conducted. This paper gave the theoretical quantity, collectable quantity, usable quantity and potential quantity for liquid biofuel production of agricultural residues in China. The spatial and seasonal distributions of crop residues were analyzed. The theoretical output of crop residues in China at national scale in the near future were forecasted by means of an artificial neural network (ANN) model. The availability of agricultural residues in China was presented, as a result, the potential of liquid biofuels from agricultural residues was discussed. The ANN predicted results have shown that the theoretical output of crop residues in China at national scale will be up to 930.8 million tons in 2015. About 44 million tons per year of bioethanol or 131 million tons per year of bio-oil would have been produced, if the total usable output of agricultural crop residues were used to produce bioethanol through biochemical conversion process or bio-oil through fast pyrolysis, which could replace 26.9 million tons of gasoline or 58.2 million tons of diesel at national scale in 2015, respectively. The above results will be helpful for commercialization of bioenergy industry and their market-oriented development strategy, so as to accelerate the development of industrialization of biofuel technologies.

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1. Introduction

China is one of the important petroleum producing countries in the world. In 2010, China's petroleum production exceeded 200 million tons per year (mt/y). China is now the world's fifth largest oil producer, however, China has been a net oil importer since 1993 [1]. With strong and sustained economic growth, its demand for petroleum has also increased, from 212.3 mt/y in 2000 to near 430 mt/y in 2010. According to the literature [2], China's total petroleum demand in 2020 will exceed 630 mt/y. In 2010, China imported over 220 mt/y of petroleum, accounting for about 53% of its total demand [3]. With the volume of China's petroleum and petroleum products imports rising exponentially and its dependence on imported oil mounting, the issue of supply shortage began to be perceived as a long-term strategic issue by the late 1990s [4].

Considering China's expected continuing industrialization and relatively high carbon intensity for electricity production, reduced energy and natural resources consumption, and increased efficiency in energy will be requisites for reversing these potentially destructive trends [5]. China is in need of expanding its renewable energy use and finding alternative liquid fuels to power the rapid growth of the economy in general and the transportation sector in particular [6]. Chinese government paid great attention to its renewable energy development. On January 1st 2006, China issued the Law of Renewable Energy, and then a series of related regulations, technology specifications and management measures have been enacted and implemented [7].

The target set by National Development and Reform Commission in China on the promotion of the use of energy from renewable sources for 2020 is a 15% share of energy from renewable sources in overall primary energy use, while only 7.5% share of energy from renewable resources in 2005. Biomass will continue to play a major role in achieving this target, although the contribution of other renewables, such as solar energy, wind power, and hydro energy, is expected to increase [7]. Priorities for biomass energy development will be biomass power generation, biogas, biomass pellets, and liquid biofuels. On August 31, 2007, the National Development and Reform Commission released the Medium and long-term development plan for renewable energy in China for the next 15 years [8]. The proportion of the use of energy from renewable sources for 2020 is a 15% share of energy from renewable sources in overall primary energy use, which is an increase of 7.5% from 7.5% in the 2005 reference year. The 2020 targets are to increase the use of biomass power to 30 GW per year, biomass pellets for fuel to 50 mt/y, biogas to 44 million m^3 per year, non-grain bioethanol to 10 mt/y, and biodiesel to 2 mt/y.

There are numerous challenges facing the development of bioenergy in China, including uncertainty of available land potential for bioenergy development, the potential impact of bioenergy production on the grain security, economic supply of feedstock and potential ecological environment problems caused by large-scale cultivation of energy crops [9]. To develop bioenergy industry in China, the systematical analysis of amount and availability of biomass resources is the first thing. As the biggest agricultural country in the world, China has abundant agricultural residue resources. Many studies have been conducted on the assessment of the amount and distribution of crop residues for biomass in China. Long et al. [10] gave some recent research progress of biomass and bioenergy potential estimation from the perspectives of methods, results and current situation. Jiang et al. [11] performed the assessment of availability of straws in China based on geographic information system (GIS) approach. However, they didn't give other competitive uses of these crop residues, which significantly influence the availability of crop residues for bioenergy production. Wang et al. [12] evaluated the collectable and usable amount of existing straw resources and gave the suitability of these resources. However, in their study, secondary processing agricultural residues were not included and the availability of straw resources as bioenergy use was not given. Cai et al. [13,14] conducted the assessment of the amount and availability of agricultural residues in Mainland China and describe the potential uses for energy of agricultural residues. However, in their research, the availability of agricultural residues for bioenergy production was based on the theoretical amount of those resources. Liu et al. [14] reported the distribution, utilization structure and potential of crop residues in rural China and the results have shown that from 1995 to 2005, China produced about 630 million tons of crop residues per year, 50% of which came from east and central south of China. Xie et al. [15] reviewed the research on the availability of crop residues in China and discussed the methodology for evaluating crop residues. They pointed out that the reasons for the significant variations of crop residues quantities from different researches are due to the disagreement on the crop residue definition and different residue-to-grain ratio data. Liu et al. [16] systematically analyzed the temporal and spatial patterns of crop straw resources and the results showed that 8.82 million tons crop straws could be used for bioenergy production. Zhuang et al. [17] and Qin et al. [18] focused on the assessment of marginal land resources and biofuel potential in China. Yanli et al. [19] estimated the amount of main biomass resources for possible energy use and their energy utilization potential in China, and Shi [20] did similar research on organic wastes. The above efforts were mainly based on agricultural statistical data on the provincial level. The total amount of crop residues produced in China was estimated at 600–800 mt/y. However, a detailed assessment of the distribution of agricultural residues for different regions and periods and their competing uses is still missing. And the production prediction of agricultural residues in China in the future and the potential of