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Economic performance evaluation of bio-waste treatment technology at the facility level

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ABSTRACT

The objective of this paper is to investigate the economic performance of a major Chinese biowaste treatment pilot project in Hainan province. Our methodology involved comprehensive on-site survey to collect economic performance data. Performance modelling tools used included net present value (NPV) analysis, internal rate of return, sensitivity analysis and uncertainty analysis based on Monte Carlo methods The results show that (1) weak economic performance in one of China's most eminent biowaste projects: NPV was found to be negative at RMB – 115,311,390; and (2) sensitivity analysis showed that natural gas prices would need to be subsidized by 2.19 RMB/Nm^3 for the project to break-even; (3) Monte Carlo analysis showed that the project had a probability of 86% to lose money. The policy implications for China are important: (1) capital and operating costs should be minimized in subsequent pilot project iterations; (2) subsidies towards the sale price of biomethane should be increased; and (3) the outputs produced by biowaste treatment plants should be further diversified. These policy implications are especially pertinent given that the surveyed case study is one of the newest and most advanced projects of its kind in China, and may serve as a model for the further development of biogas plants across China. For that reason, it is imperative that the identified economic issues are resolved quickly.

1. Introduction

This paper seeks to investigate the economic performance of a major Chinese biowaste treatment project that produces biomethane vehicle fuel in Hainan province, in the south of China. This research is timely due to China's recent favorable policy shifts towards the treatment of bio-waste, which represents a large potential source of energy in China. According to Raninger and Dong (2013), the potential of bioenergy in China until 2050 is 1000 Bn standard coal equivalent (SCE) per year. Biowastes such as livestock waste, agro-industry waste, straw, forest residues, organic municipal waste and industrial organic wastewater together account for 68% of this total amount, with the remainder coming from energy crops.

Recent policy attitudes towards enhanced management of such biowaste are exemplified by China's 12th five-year plan investment budget of 236.6 billion RMB for municipal solid waste (MSW) treatment. 4.1% of this total budget was reserved for treatment of kitchen waste (Li and Li, 2014), which is an important component of biowaste produced in Chinese cities (kitchen waste is also treated in the project surveyed in this paper). Between 2011 and 2015, China ratified 100 pilot cities across the country to treat such restaurant waste; in these cities, 242 treatment facilities will be constructed, with a total treatment capacity of 30,000 tons/day (State Council, 2012). Therefore, as biowaste treatment facilities continue to be built across China it is necessary to conduct preliminary performance assessments of such facilities in order to evaluate whether government policies are successfully leading to the sustainable development of the biowaste treatment sector.

In addition to biowaste treatment, China needs to find less polluting fuels for its rapidly expanding vehicle population. Economic growth has led to a dramatic increase in the possession of civil motor vehicles in China from 1,358,400 in 1978 to 126,701,400 in 2013, and Chinese megacities with concentrated vehicle populations such as Beijing, Shanghai and Guangzhou are facing increasing pressure to improve air quality and reduce vehicle greenhouse gas (GHG) emissions. In Beijing for instance, the total vehicle population reached 4.96 million in 2012; vehicle ownership was 240 per

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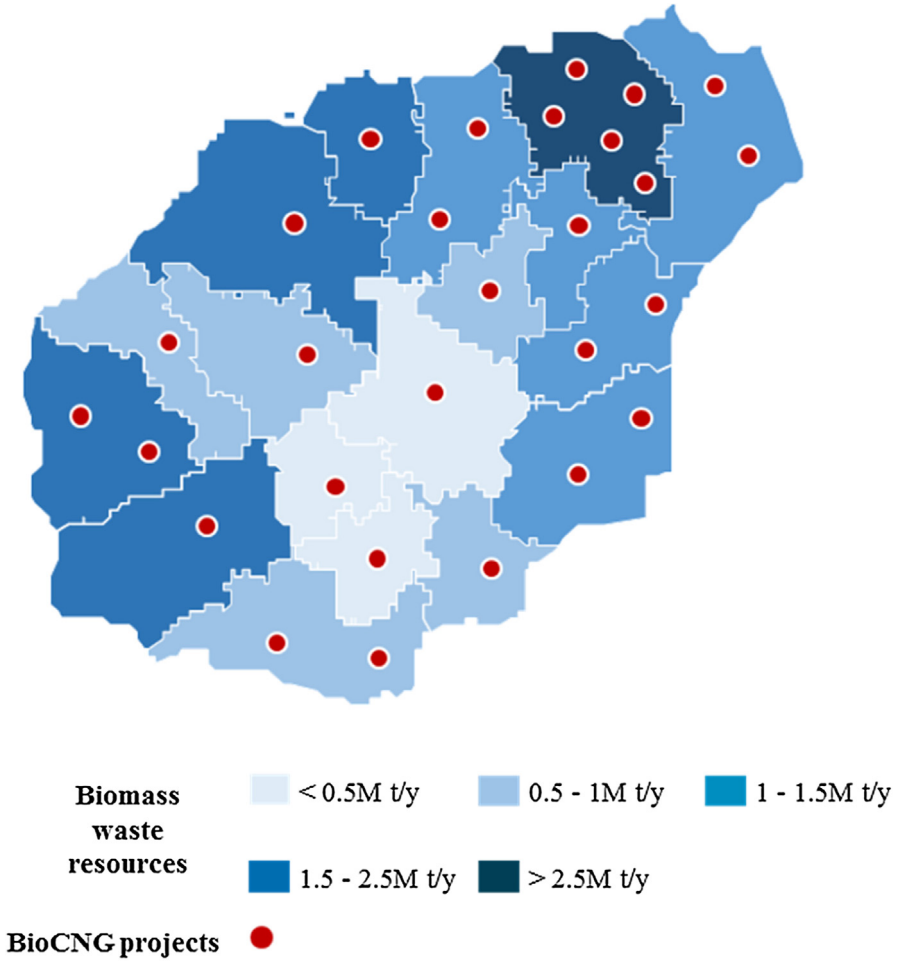

Fig. 1. Hainan's bio-waste resources and distribution of BioCNG project locations.

1000 people, 167% greater than the national average (Zhang et al., 2014). As a result, motor vehicle tail emissions have become the primary contributor to $PM_{2.5}$ emissions, accounting for 31.1% of the total. On-road vehicles in Beijing also accounted for approximately 64.1%, 57%, 11% and 35% of atmospheric NOx, NMVOC, POC and BC concentrations (Lang et al., 2014). One policy measure has been to increase the use of natural gas buses in the public bus fleet since 1999, and according to Beijing's Clean Air Action Plan 2013–2017, natural gas vehicles will account for 50% of public buses, 20% of heavy-duty passenger vehicles and 7% of taxis in 2020.

The surveyed project in Hainan is at the crossroads of recent trends in better biowaste management and greater utilization of cleaner vehicle fuel in China. Hainan's ambitious "rising of green" development strategy was outlined in April 2012 to promote international tourism and sustainable development on the island. The plan's objective is to increase the percentage of clean energy in primary energy consumption to about 40% by 2016. Under this strategy, a major project called the Hainan new energy biogas vehicle use demonstration project (henceforth referred to as "BioCNG") has been designed on the island, which uses the Swedish biogas-to-vehicle fuel models of two cities, Stockholm and Linkoping. The project uses locally available organic waste to produce biomethane vehicle fuel for public buses and taxis. The total project funds are 3 billion RMB, which will fund the construction of 20 biogas plants in 18 towns and counties, for an annual production of 200,000,000 m^3/y of biogas (Luo, 2014). The locations of the planned biogas projects are indicated on a map of Hainan in Fig. 1.

The economic performance assessment in this study investigates whether a surveyed anaerobic digestion (AD) biogas project built under the BioCNG scheme will achieve a minimum acceptable performance threshold based on net present value (NPV) and internal rate of return (IRR). Moreover, Monte Carlo simulation is applied to estimate the probability that the surveyed project will lose money, i.e. operate at a negative NPV over its lifetime. The results provide a better understanding of the challenges to the expansion of China's biowaste-to-energy industry. Given that this project is the first demonstration project of this kind in Hainan, which may serve as a model for other provinces around China, it is worthwhile to evaluate the economic performance of co-digesting various biomass feedstock and utilization of biomethane as a vehicle fuel.

This study offers a valuable contribution to the sparse literature available on biowaste-to-biogas plants in China. There have been some LCA studies of biogas projects in China, for instance Xu et al. (2015), which found AD preferable to landfill. De Clercq et al. (2016) surveyed a food waste treatment facility in Beijing and identified operation issues such as (1) mono-digestion of food waste (FW), resulting in sub-optimal biogas production and lower revenues; (2) a very high parasitic load, meaning that little energy output is actually marketed; and (3) a low level of mass balance monitoring, resulting in frequent operational disturbances. Wen et al. (2016) conducted a techno-economic analysis of a food waste project in Suzhou, China. There have been some studies applying NPV and Monte Carlo economic performance evaluation methods to biogas plants (Sgroi et al., 2015; Di Trapani et al., 2014), but our research