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Economic analysis of waste-to-energy industry in China

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ABSTRACT

The generation of municipal solid waste is further increasing in China with urbanization and improvement of living standards. The "12th five-year plan" period (2011–2015) promotes waste-to-energy technologies for the harmless disposal and recycling of municipal solid waste. Waste-to-energy plant plays an important role for reaching China's energy conservation and emission reduction targets. Industrial policies and market prospect of waste-to-energy industry are described. Technology, cost and benefit of waste-to-energy plant are also discussed. Based on an economic analysis of a waste-to-energy project in China (Return on Investment, Net Present Value, Internal Rate of Return, and Sensitivity Analysis) the paper makes the conclusions.

1. Introduction

The rapid urbanization and industrialization of China have resulted in an increasing volume of municipal solid waste (MSW). The amount of MSW increased from 31.3 million tons in 1980 to 179.36 million tons in 2011 China (Zheng et al., 2014). At present, the delivering quantity of household waste averages 170 million tons in China, and the amount of untreated MSW has reached 7 billion tons with an annual increase of 8–10%. The huge amount and rapid increase of MSW has become another major social problem along with energy shortages in China. The MSW poses threats to environment quality and human health, which is an obstacle to the economic and social development. If not properly managed, the MSW would not only occupy huge land - resources, but also get in the way of city construction. What's more, the stench of MSW and harmful substances could be a cause of urban environment pollution. Due to the lack of MSW disposal capacity, backward infrastructure and operational skills of MSW treatment facilities, as well as the lack of supporting facilities, nearly two-thirds of China's cities are being afflicted with "waste siege".

Traditionally, the MSW is disposed in landfill, or by ways of direct incineration or composting. However, the growing public awareness of environmental protection and the restrictions on landfill sites have made the government to seek more effective ways of MSW disposal. The use of landfills can no longer be considered a satisfactory way, therefore new methods have to be chosen and waste-to-energy (WTE) plants would provide an answer (Messineo and Marchese, 2008). Compared with other MSW treatment technologies, MSW incineration performs best (Dong et al., 2014), and WTE plant is a better waste management option (Ofori-Boateng et al., 2013).

WTE refers to the recovery of the energy from waste materials into useable heat, electricity, or fuel. WTE plant (waste incineration) is the primary approach of WTE process that converts biomass to electricity (Tan et al., 2015). In most cases the WTE refers solely to WTE plant in China, incinerating MSW to generate electricity. The application of large-scale incineration technologies is inevitable as landfill areas would ultimately cease (Abd Kadir et al., 2013). Thus, the most common alternative to landfill site is WTE plant in the future. It is an important part of China's "12th five-year plan" on comprehensive energy conservation.

Generally speaking, the technologies are mature and WTE plants should have a good prospect in China (Fu et al., 2015). However, in the past few years, the development of WTE plants was not satisfactory with many problems. On the one hand, there are some difficulties from social aspects affecting the development of WTE industry, such as potentially toxic emissions and public opposition. On the other hand, some characteristics of WTE plants are also not

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Nomenclature

Pt	pay back period
NCF_T	net cash flow in the "T" year
$CNCF_{T-1}$	cumulative net cash flow in the "$T-1$" year
T	the particular year when the cumulative net cash flow is positive or zero for the first time
NPV	net present value
n	the operation period of a project
i	basic discount rate
t	a certain year
P_t	due principals of the year when all the debts are paid off
I_t	due interests of the year when all the debts are paid off
F_t	amount of funds can be used for debt repayment in the year when all the debt are paid off
T^*	the particular year when the debts are paid off
T_P	loan repayment period
tons/day	tons of waste per day
CI_t	the cash inflow in a certain year
CO_t	the cash outflow in a certain year
P/F	the factor of present value
IRR	internal rate of return
P	unit revenue
Q^*	break-even volume
C_f	annual fixed cost
C_v	variable cost
E^*	capacity utilization rate of BEP
Q_c	annual power generation capacity
P^*	electricity sale price of BEP
$C_v{}^*$	the variable cost of BEP
$/t	US dollar per ton of waste
$/kW h	US dollar per kilowatt-hour

conducive to the development of this industry, such as high costs and difficulties in financing (Zhang et al., 2010).

It is necessary and useful to make economic analysis of WTE plants. A systematic literature review is made which applies economic analysis and theories to the issue of waste incineration (Massarutto, 2015). A social cost-benefit analysis of WTE in the UK and a techno-economic analysis based on the WTE plants in Brazil have been made to discuss the economic effects of WTE plants (Jamas and Nepal, 2010; Leme et al., 2014). WTE plants are highly dependent on MSW treatment fees owning to its high installation, operation and maintenance costs. Besides, WTE plants have better environmental benefits and remarkable external benefits (Lim et al., 2014; Tsai and Kuo, 2010; Tan et al., 2014a, 2014b), and they have better impacts on society and environment (Michael, 2013; Pavlas et al., 2010).

Although some economic analyses have made with respect to WTE plants in some countries, there are lacking for economic analyses of China's WTE plants. This paper would introduce the latest industrial policies and market prospect of WTE industry in China. Based on the current policies and industry status, this paper makes a comprehensive and detailed economic analysis of WTE plants. The loan debts, feed-in tariff, revenues and tipping fees (waste disposal subsidy) are taken into account, and the profitability and debt-payment capability is discussed. Also, the break-even analysis and sensitivity analysis are made to understand how the economic effects could be influenced when some factors change.

2. Status quo

2.1. National policy

A series of national policies have been released to provide better conditions for the development of WTE industry (Table 1). One the one hand, there are a number of incentive policies to encourage WTE industry. WTE plants enjoy preferential corporate income taxes (Financial Ministry, 2009), the unified feed-in tariff of 0.106 $/kW h and tipping fees from local government ranging from 13.04 to 19.56 $/t (National Development and Reform Commission, 2012). The tipping fees are exempt from tax, and the value added tax (VAT) from electricity sales is instantly returned after paying. Only the income tax is levied on BOT projects according to "three exemptions and three halves". That is, the plants enjoy 100% tax exemption for income tax in the first three years when it gains profits, and 50% tax exemption for income tax from the fourth to the sixth year. In 2012, "the 12th Five-Year Plan on National Facility Construction of Urban Waste Harmless Disposal" put forward the goals, major tasks and standards for the harmless disposal of MSW and WTE industry (State Council, 2012). Besides, waste incineration technology is expected to increase by 10%, achieving a proportion of 30% in 5 years, with a total of $ 4.24 billion investments (National Development and Reform Commission, 2014).

One the other hand, standards and supervisions for WTE industry become more strengthened. The minimum registered capital for WTE plants and access to WTE industry has been strictly restricted (Ministry of Construction, 2007). The operation and emission standards of WTE plants are further defined. The provision for environmental protection distance of new WTE projects is made for not less than 300 m (Ministry of Environmental Protection, 2008). In 2013, the pollution control standards for harmless disposal of MSW were updated or revised (Ministry of Environmental Protection, 2013). In 2014, the strictest new national standards for pollution control on the MSW incineration began to be implemented in phases in China's history (Ministry of Environmental Protection, 2014). Thus, these regulations would contribute to the healthy development of WTE industry.

In general, the incentive policies are expected to encourage the governments to strengthen policy support and financial support for WTE projects, which are beneficial to accelerating the development of WTE industry. At present, those regulations make it difficult for enterprises to enter WTE industry. But they could help select enterprises. Those enterprises with powerful financial strength, advanced technologies and rich experiences may get more guarantees and favors from government and will have a broader development space. Thus, a great upsurge in WTE industry has been raised over the country.

2.2. Market

The market potential is great for WTE industry because the rate of harmless disposal of MSW is very low and the amount of MSW is huge and increases fast. Besides, being the guidance for WTE industry, the "12th five-year plan" puts forward the goals and requirements for the disposal of MSW. In 2012, the MSW disposal capacity is 446.3 thousand tons/day and MSW incineration capacity only took 27.5% of total harmless treatment capacity. It requires an annual compound increase of 25% to achieve the MSW disposal capacity up to 871.5 thousand tons/day by 2015. Also, the annual

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