Applied Energy 102 (2013) 785–793

Contents lists available at SciVerse ScienceDirect

Applied Energy

journal homepage: www.elsevier.com/locate/apenergy

Cost Analysis of straw-based power generation in Jiangsu Province, China

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HIGHLIGHTS

- ▶ We estimate the straw-fired power generation costs in Jiangsu Province, China.
- ▶ The causes for the deficit of straw-fired power generation plants are identified.
- ▶ Poor management is the primary factor for explaining the deficit of the plants.

ARTICLE INFO

Article history:
Received 29 May 2012
Received in revised form 19 August 2012
Accepted 22 August 2012
Available online 6 October 2012

Keywords:
Straw
Biomass
Power generation
Power plant

ABSTRACT

As one of the most developed provinces in China, Jiangsu Province has been actively developing bio-energy in order to deal with its electricity supply shortage. By the end of 2010, there are 12 grid-connected straw-based power plants, but only two of them are profitable in this province. This paper presents a simple and detailed method for estimating the cost of straw-based power generation with life cycle analysis, and identifies the main causes for the financial deficit of these plants through a sensitivity analysis and survey. It concludes that: (i) compared with coal-fired power generation, the cost of straw-based power generation is indeed high. (ii) The fuel cost takes the largest share in the operation cost. (iii) The basic causes of the high cost are from straw characteristics, mismatch between demand and supply, immature technology, inappropriate project planning and low motivation of farmer selling straw. Based on the basic causes, we propose the countermeasures.

1. Introduction

Crop residues are very rich in China and the annual output is roughly equal to 728 million tons [1]. The Chinese Government realized the importance of straw-based power generation and proposed four programmes about it in 2006–2010. Under these programmes, the NDRC and other governmental agencies developed a series of auxiliary policies, such as mandatory grid connection, cost-sharing, feed-in tariff and tax credits.

JSP is a large province in both economic size and energy consumption, which locates in the Yangtze River Delta region of China. However, JSP is lack of energy resources. It has been estimated that the electricity supply shortage accounts for 10% of total electricity consumption [2]. Meanwhile, it has abundant crop residues and the annual output is about 40 million tons [3]. In view of these facts, JSP has been actively exploring and utilizing straw-based power generation. In early November 2003, JSP started to implement the CRESP project that aimed to promote the development and utilization of its renewable energy resources. In September 2004, the NDRC for the first time approved three straw-based power generation projects in China, which included the project in Rudong County, JSP. By September 2010, JSP had 12 grid-connected SPPs with the total 273 MW; Meanwhile China had 85 SPPs with the total 1669 MW.[1] Despite these policy supports, only two SPPs in JSP are profitable [4,5]. Straw-based power generation has been implemented successfully in some of the European countries, such as Denmark as a pioneer user of wheat straw, UK and Spain [6]. This has led us to examine why the SPPs in JSP are under deficit. Additionally, because the number and scale of the SPPs in JSP rank first in China, we take JSP as an example to investigate the reasons for their financial deficit. The findings could also be useful to help us identify the root of economic losses of the SPPs elsewhere in China.

Several authors examined the profitability or cost of SPPs in China. Gu [7] pointed out that the price of the feedstock in different regions and the vapor parameters of boiler in addition to policy

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[1] Data source: calculate according to our survey and NDRC, State Electricity Regulatory Commission. On notifications of renewable electricity price subsidies and quota trading scheme from January to September, 2010.

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http://dx.doi.org/10.1016/j.apenergy.2012.08.032

Nomenclature

C	installed Capacity of a SPP (MW)
c_c	cost of collecting straw (RMB yuan/t)
c_d	cost of diesel consumed for shipping straw (RMB yuan/t)
c_e	cost of energy consumption (RMB yuan/t)
c_i	cost of total investment of a collection station (RMB yuan)
c_l	cost of lubricant consumed for shipping straw (RMB yuan/t)
c_m	cost of vehicle maintenance for shipping straw (RMB yuan/t)
c_p	cost of processing and storage (RMB yuan/t)
c_s	cost of shipping straw (RMB yuan/t)
c_{sm}	cost of collection station maintenance (RMB yuan/year)
c_{sw}	cost of labor in collection station (RMB yuan/t)
c_{vd}	cost of vehicle depreciation for shipping straw (RMB yuan/t)
c_w	cost of labor for shipping straw (RMB yuan/t)
D	demand for straw of a SPP (t/year)
d	distance for shipping straw (km)
G	on-grid quantity of electricity (MW h)
h	cost of inventory holding (RMB yuan/t)
I	total investment of a SPP (million RMB yuan)
L_p	loan principal (million RMB yuan)
m_f	managerial fee of collection station (RMB yuan/year)
n	number of worker and manager in collection station
N_y	number of years of repayment
n_s	number of worker for shipping straw
p_d	price of diesel (RMB yuan/L)
p_p	price of the straw at plant (RMB yuan/t)
p_s	price of purchasing straw (RMB yuan/t)
p_v	price of vehicle (RMB yuan)
p_w	price of water (RMB yuan/t)
Q	stock size of straw in collection station (t/year)
q_e	quantity of diesel consumed by empty vehicle (L/km)
q_f	quantity of diesel consumed by full-loaded vehicle (L/km)
q_t	quantity of vehicle shipping straw (t/d)
r	rate of return on investment capital (ROIC)
W	quantity of water used for production (t/h)
w_s	weigh of straw loaded by vehicle (t)
w_w	wage of one worker/driver (RMB yuan/d)
y	depreciable life of vehicle (year)
α	net residual value rate of vehicle (%)
β	rate of power consumption in production (%)
λ	annual interest of loan (%)
θ	Broker's profits rate of the total relative expenses (%)
NDRC	National Development and Reform Commission, a government agency of China.
JSP	Jiangsu Province, a province of China.
CRESP	China Renewable Energy Scale-up Program, a collaborative project for renewable energy policy development and investigation sponsored by China, the World Bank and the Global Environment Facility.
SPP	straw-based power plant.
CHP	combined heat and power
CDM	clean development mechanism

would have effects on whether a straw-based power generation project is profitable or not. Jiang and Zhu [8] showed that the straw-based power generation in Yancheng City of JSP is economically feasible. Jiang et al. [9] developed an integrated model for assessing the benefits of SPPs from economic, ecological and social points of view. The empirical analysis on the Sheyang SPP in JSP showed that a 25 MW SPP requires more than six years to become profitable. Li and Hu [10] analyzed the cost compositions about construction and electricity generation in SPPs in JSP, and concluded that the actual grid-connected electricity tariff is lower than that estimated from a breakeven analysis. Liu et al. [11] evaluated the environmental externality, i.e. the greenhouse gases emissions, of Shiliquan SPP in Shandong Province, China by Life Cycle Analysis. Sun et al. [12] aimed to shed light on the interaction mechanism of cost risks for biomass material supply in power generation, especially for biomass-coal dual-fuel systems by simulation. Wu et al. [13] analyzed the economic characteristics of biomass gasification and power generation in China from investment, electricity cost, and cost for waste treatment. Liu et al. [14] systematically analyzed the temporal and spatial patterns of crop stalk resources, evaluated the bioenergy potential of crop stalk resources, and explored possible pathways of developing stalk-based energy strategies in Inner Mongolia, China. Perlack and Turhollow [15] evaluated the costs for collecting, handling, and hauling corn stover to an ethanol conversion facility. Kumar et al. [16,17] investigated the relationships between the costs and the issues such as payment, profitability, and optimum size of SPP. Cameron et al. [18] studied the relationship between distance variable cost and distance fixed cost. Delivand et al. [19] investigated the logistics cost consisting of machinery cost, operating cost, fuel cost and labor cost in three regions of Thailand. Delivand et al. [20] assessed economic feasibility of rice straw utilization for electricity generating through combustion in Thailand. Dassanayake and Kumar [21] focused on the techno-economic assessment of triticale straw based power generation and the GHG abatement cost in Canada, by field cost, construction cost of power generation project, operating costs. Mobini et al. [22] investigated the logistics of supplying forest biomass to a potential power plant, put forward a simulation model based on the framework of Integrated Biomass Supply Analysis and Logistics to evaluate the cost of delivered forest biomass, the equilibrium moisture content, and carbon emissions from the logistics operations.

Although several earlier studies described above also mentioned the costs of some SPPs in JSP or elsewhere, this paper is different from them in estimation method and data acquisition. Specifically, we present a simple but more detailed method for calculating the cost of straw-based power generation by life cycle analysis. A method for finding out the causes of the costs is also given. Using these methods, we can easily derive the unit cost of power generation and find the main causes. In the next section, we briefly introduce the status of straw-based power generation in JSP. Section 3 gives the cost breakdown and calculation method. Section 4 discusses the causes of the high cost and proposes the countermeasures. Section 5 obtains the conclusions.

2. Status of straw-based power generation in JSP

2.1. Straw production and distribution[2]

JSP has different kinds of straw resource. However, the rice, wheat, rape and corn straw accounts for more than 80% of the total straw resource. Other crops mainly include barley, highland barley, cotton, soybean, peanut, potato, vegetables and melons. The wheat,

[2] Data source: calculate according to JSP Statistical Yearbook 2009.