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Comparison of biogas development from households and medium and large-scale biogas plants in rural China

Zilin Song [a,b], Chao Zhang [a], Gaihe Yang [a,b,*], Yongzhong Feng [a,b], Guangxin Ren [a,b], Xinhui Han [a,b]

[a] Northwest A&F University, Yangling, Shaanxi Province 712100, PR China
[b] Research Center for Recycling Agricultural Engineering Technology of Shaanxi Province, Yangling, Shaanxi Province 712100, PR China

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ABSTRACT

As a renewable energy source, biogas not only alleviates energy shortage in rural areas but also effectively reduces the environmental risk associated with agricultural waste management. This study presents a comprehensive overview of development of household bio-digesters and medium and large-scale biogas plants (MLBPs) in China, and discusses the advantages and disadvantages of both biogas systems in terms of environmental performance, role in agriculture, economic benefit, government support, energy efficiency, societal influence, and resident living mode. Both systems have their relative strengths and weaknesses. The operation and maintenance of household bio-digesters are easier, and their environmental and economic performances are superior compared to those of MLBPs. However, MLBPs have higher energy efficiency and better social effect. Thus, the choice of a biogas generation system depends on the local circumstances. Household bio-digesters are suitable for undeveloped regions where the rural residents live far apart from each other, whereas MLBPs are suitable for developed regions where people live close together. The government can play a positive role in preventing the negative impacts of rural social structural change, such as those of urban migration of adults, on household biogas development. Additionally, establishment of scientific and technological support and service systems is recommended for further development of biogas in rural China.

Contents

* Corresponding author at: Northwest A&F University, Yangling, Shaanxi Province 712100, PR China. Tel.: +86 13201647310; fax: +86 29 87092265.
E-mail address: gaiheyang@gmail.com (G. Yang).

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1. Introduction

Using non-fossil fuel energy resources, especially renewable energy, has become an important component of sustainable global energy strategy [1]. As of 2012, targets and policies for renewable energy had been established in more than 100 countries, a significant increase from 55 countries in 2005 [2]. Among fossil fuel alternatives, biogas shows great promise as a renewable energy source because it is produced by anaerobic fermentation of household wastes, such as straw, crop stalks, human waste, livestock manure and other organic waste mixtures, and thus provides multiple environmental benefits [3].

As one of the largest agricultural countries in the world, China has abundant biomass resources, including crop straw, firewood, agricultural residues, and organic wastes [4–6]. According to a 2011 estimate by the National Bureau of Statistics of China, about 827 million ton of crop straw and 3.6 billion ton of livestock and poultry manure were produced in China in 2010, and rice straw, corn stalk, and wheat straw accounted for 71.1% of the crop straws produced [7,8] (Figs. 1 and 2). These agricultural residues, if transformed into biogas, can generate 340.8 billion m^3 of biogas, which can address the shortage of energy in rural areas [9]. In addition, effective use of waste biomass can provide significant environmental benefits. Therefore, the Chinese government should put more attention on biogas use in rural areas and provide strong financial support to rural biogas development in order to achieve sustainable development.

Currently, biogas production in rural areas of China comes from two primary sources: household biogas digester, and medium and large-scale biogas plants (MLBPs). Recent years have witnessed promotion of both household biogas digesters and MLBPs [10]. As of 2010, more than 40 million household biogas digesters and 27 thousand MLBPs were being used in rural China, and the number of people benefiting from biogas use had reached 150 million [11]. Rural biogas development in China promotes the construction of a new socialist countryside and improves the environment as well as the quality of rural life. In recent years, the Chinese government has shown increasing preference for MLBPs over household biogas because MLBPs separate livestock farm or energy production from residential areas [12]. Is this preference of government for MLBPs in line with the better performance of MLBPs? Although previous studies have discussed biogas development in China, most have focused on one of these two systems [13–32] (Table 1) or one aspect (e.g., economic assessment, environmental performance, and social preference) of these two systems [33,34]. An overall assessment and comparison of the strengths and weaknesses of both systems is necessary for a comprehensive understanding of biogas development in rural areas of China.

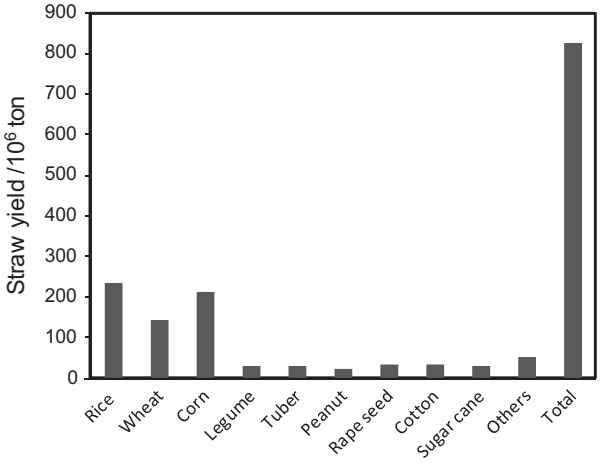

Fig. 1. Crop straw yield in China in 2010 [7].

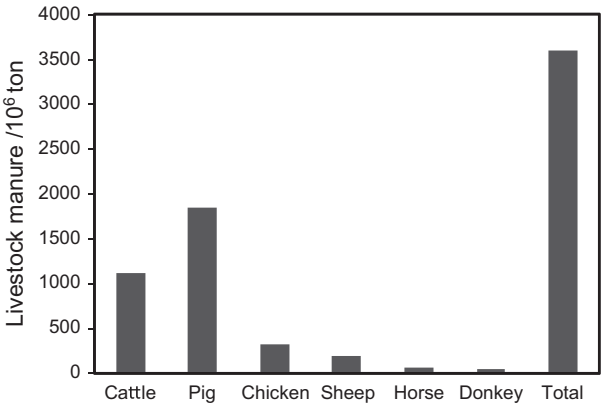

Fig. 2. Livestock manure yield in China in 2010 [8].

Table 1
Studies on biogas development in China.

Biogas model	Corresponding contents	Reference
Household	Ecological and social benefit	[13]
	Environmental performance (CO_2 emission reduction)	[14–16]
	Economic effectiveness	[17,18]
	Policy support and related law	[19–21]
	Energy and emergy analysis	[22–24]
	Available resources for biogas	[4]
	Sustainability effects	[10]
	Bio-digester models	[25]
MLBPs	Biophysical emergy analysis	[26]
	Ecological benefit	[27,28]
	Economic assessment	[29,30]
	Effect of solar energy on biogas production	[31]
	Digestate biological properties	[32]

MLBPs, medium and large biogas plants.

The present study aims to evaluate household biogas and MLBPs in rural China in terms of their strengths and weaknesses by conducting a review of the existing literature. Literature and information on household biogas and MLBPs of China were collected by searching the Web of Knowledge database (http://apps.webofknowledge.com) and China Academic Journal Network Publishing database (http://epub.cnki.net) using the keywords 'biogas', 'household', 'biogas plants', 'biogas project', and 'China'. All relevant government policies, rules, and funding investment were collected from official websites and relevant documents. Data on agriculture straw yields and population distribution were obtained from China Statistical Yearbook. The information collected from these sources was grouped in terms of seven dimensions: environmental performance, role in agriculture, economic benefit, government support, societal influence, energy efficiency, and the resident living mode. The advantages and disadvantages of household and MLBPs are compared side by side within each dimension. The remainder of the study is organized as follows: Section 2 presents a comprehensive overview of development of household biogas and MLBPs in rural China, which is followed by a comparison of the advantages and disadvantages of the two biogas systems in terms of aforementioned dimensions in Section 3. Conclusions and recommendations are formulated in Section 4.