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A study on the economic efficiency of hydrogen production from biomass residues in China

Pengmei Lv, Chuangzhi Wu, Longlong Ma, Zhenhong Yuan*

Key Laboratory of Renewable Energy and Gas Hydrate, Guangzhou Institute of Energy Conversion, Chinese Academy of Sciences, Nengyuan Road, Wushan, Tianhe, Guangzhou 510640, China

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Abstract

As part of Pilot Project of KIP of CAS, a feasibility study of hydrogen production system using biomass residues is conducted. This study is based on a process of oxygen-rich air gasification of biomass in a downdraft gasifier plus CO-shift. The capacity of this system is 6.4 t biomass/d. Applying this system, it is expected that an annual production of 480 billion N m^3 H_2 will be generated for domestic supply in China. The capital cost of the plant used in this study is 1328\$/(N m^3/h) H_2 out, and product supply cost is 0.15\$/N m^3 H_2. The cost sensitivity analysis on this system tells that electricity and catalyst cost are the two most important factors to influence hydrogen production cost.

Keywords: Economic efficiency; Biomass; Hydrogen; China

1. Introduction

1.1. Background

Concerns about the depletion of fossil fuel reserves and the pollution caused by continuously increasing energy demands make hydrogen an attractive alternative energy source. Biomass is a CO_2 neutral resource, which makes hydrogen from biomass a prospective technology. Till now, a lot of work has been done on hydrogen production from biomass and different researchers apply different routes. Rapagnà et al. [1,2] explored hydrogen production from biomass catalytic gasification, while others [3–5] investigated hydrogen production from steam gasification of biomass-derived oil. Iwasaki [6] investigated the economic efficiency of hydrogen production from biomass pyrolysis and further reforming. The main assumption he made is that the system can supply its own power and heat by utilizing waste heat from the system itself. Lau et al. [7] have a thorough analysis on the feasibility of biomass-derived hydrogen.

China is an agricultural country and has huge quantity of biomass residues. Meanwhile, China is a densely populated country, 70% of the population living in rural areas and depending largely on biomass energy. For a long history, China has been using biomass as energy, especially in its rural areas. In most areas, biomass is utilized by a way of direct burning in a traditional stove and the heat efficiency only reaches 10%. In recent years, Chinese government has been attaching high importance on advanced biomass conversion technologies and has initiated a series of National Programs for Key Science and Technology projects. Hydrogen production from biomass residues also gets much financial support from Chinese government.

The study reported here is one of the working contents of Pilot Project ‘‘Biomass liquefaction and hydrogen production’’ of Knowledge Innovation Program (KIP) of Chinese Academy of Sciences (CAS). As a Pilot Project of KIP of CAS, the objective of this study is to present a feasibility study on economic efficiency of hydrogen production from biomass residues in China.

Thus, based on a process of biomass oxygen-rich air gasification in a downdraft gasifier, plus CO-shift with commercial catalysts, the economic efficiency of this system

*Corresponding author. Fax: +86 20 87057737.
E-mail address: yuanzh@ms.giec.ac.cn (Z. Yuan).

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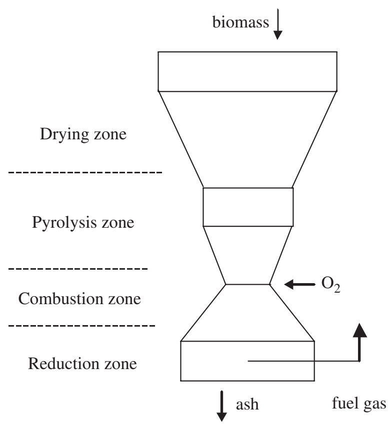

Fig. 1. Schematic diagram of biomass gasification in a downdraft gasifier.

is investigated. Meanwhile, the potential of hydrogen production from biomass residues in China is also evaluated.

1.2. Chemical processes in a downdraft gasifier

As shown in Fig. 1, because gases and solids move forward with the same direction in the downdraft gasifier, different reactions occur in the different zones.

In the drying zone, the temperature is about 150–300 °C; therefore, water vaporization mainly occurs in this zone. In the pyrolysis zone, temperature being about 600 °C, the pyrolysis of biomass starts and produces char, tar and gas as reaction (1) shows. In the combustion zone, because of the presence of oxygen, oxidization reactions of biomass pyrolysis products proceed here to provide

Table 1
Hydrogen supply potential from agricultural residues in China in 2003

	Product (10^4 t)	Residue source	Coefficient	Availability (10^4 t)	H_2 supply potential (10^8 N m^3)
Rice	16065.5	Straw	0.623	5875.2	529.2
Soya bean	1539.4	Stems and leaves	1.5	1355.4	122.1
Grain sorghum	286.5	Straw	1	168.2	15.2
Wheat	8648.8	Straw	1.366	6935.0	624.7
Sugar cane	9023.5	Leaves	0.1	529.7	47.7
Sunflower seed	174.3	Stalks	2	204.6	18.4
Rape seed	1142.0	Stems and leaves	2	1340.7	120.8
Corn	11583.0	Stalks	2	13598.4	1224.9
Cotton	486	Stalks and leaves	3	855.8	77.1
Hemp	85.3	Stems	2.5	125.2	11.3
Total	–	–	–	30988.2	2791.4

Table 2
Hydrogen supply potential from forest residues in China in 2002

Forest groups	Product yield (kg/ha) [12]	Residue/product ratio [12]	Forest area (10^3 ha) [13–19]	Product yield (10^4 t)	Residue (10^4 t)	H_2 supply potential (10^8 N m^3)
Timber stands	3750	0.5	86536.4	32451.2	16225.6	1461.6
Economic forest	1875	0.1	20332.6	3812.4	2033.3	183.2
Forest for special uses	1875	0.1	3208.7	601.6	320.9	28.9
Protection forest	3750	0.2	24988.3	9370.6	1874.1	168.8
Firewood forest	3750	1.0	4989.5	1871.1	1871.1	168.5
Total	–	–	–	–	22,325	2011

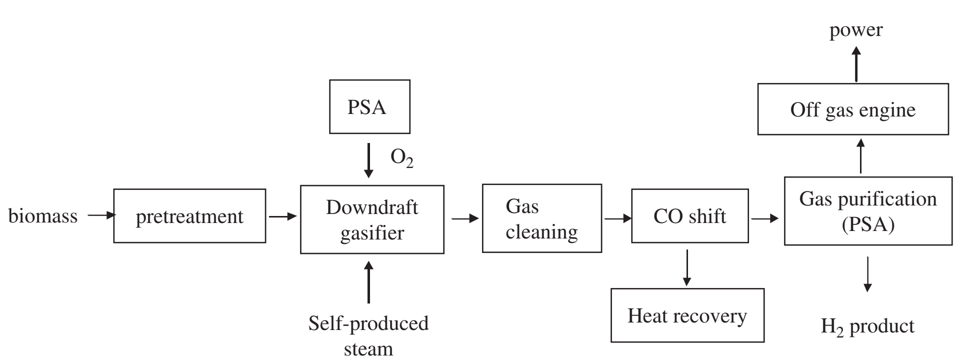

Fig. 2. Process flow diagram of hydrogen production system.