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Research Article

Study on Utilizing Potentiality of Agricultural Biomass Resource-A Case from Hubei Province

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Abstract: The aim of this study is to analyze the potential of agricultural biomass resource and take full advantage of it. The problem of energy shortage and environmental pollution has become a hot topic all over the world, there is growing concern on how to tapping the potentials and taking full advantages of agricultural biomass resource in the context of resource constraints. In this study, the authors evaluate the quantity of agricultural biomass of Hubei province and obtain its development potential by using the analytical methods. In 2011, all residues of various crops can be converted to 18.3921 million tons of standard coal, among which could be used as energy about 9.38 million tons. The energy amount of animal waste can reach 117621 tons, which could be used for powering about 3.34×108Kw.h. The results show that: Taking full advantage of agricultural biomass resource will reduce the quantity of standard coal greatly; it should research and develop the technology of biomass resource and bring the huge potential of agricultural biomass into full play of Hubei province.

Keywords: Agricultural, biomass energy resource, hubei province

INTRODUCTION

With the growing speed of industrialization and urbanization in China, the demand for energy presents rigid growth. By the influences of global energy security and climate changes, the problems that resource and environmental constrain the economic and social development are becoming serious. On July 5, 2007, the Ministry of Agriculture issued "The Industry development plan of agricultural biomass" and putted forward that the industry of agricultural biomass in China should stick to the development strategy which can develop rural biogas vigorously, develop crop curing and gasification and develop energy crop. Establish the development priorities and industrial layout and strive to out of the path Chinese characteristics.

Hubei, as a major agricultural province in the central of China, has rich reserves of agricultural biomass energy; so it is important to researching the utilization potential of agricultural biomass of Hubei province. In this study, by studying, we evaluate the potential of agricultural biomass resource of Hubei province using relative methods, in order to provide some references for some departments and solve the problem of resource shortage.

MATERIALS AND METHODS

With the increasing application of biomass, the researches on evaluating the potential of biomass become more and more.

The study Hoogwijk *et al*. (2003) and Marc and Faaij (2009) evaluate the potential of biomass resource of the world and European separately. (Liu and Shen, 2007) evaluated the biomass energy's potential in China quantitatively. (Ding *et al*., 2007) predicted the amounts of straw resources of Hubei province. (Zhao and Long, 2009) study the energy potential of woody biomass in Yunnan. Chen and Wang (2012) take ARIMA model to assess the rural biomass resource potential. There are also scholars using the theory of gray prediction predicting the biomass potential.

Firstly, this study uses the model of supply potential to evaluate the potential of agricultural waste and livestock waste. Secondly, this study using the calculation model of agricultural biomass resources potential to predict the potential for heating and power generation.

The ideas as follows:

The supply potential model of agricultural biomass resources (Wang *et al*., 2012)

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- **The supply potential of the agricultural waste:** The evaluation of agricultural waste takes the coefficient of Grass and Valley; it is the ration of crop stalks and crop yields, which is related to crop types

The production of agricultural waste is calculated using the following equation:

$$M_{bi} = M_{pi} S_{gi}$$

where,

M_{bi} = Production of agricultural waste (kg / a)

M_{pi} = Production of crop yield (kg / a)

S_{gi} = The ratio of grass and valley

Take the method of coefficient of standard coal to calculate the utilization potential of agricultural waste, the formula of standard coal's coefficient as follows:

$$X_{bi} = \frac{LHV_{biomass}}{LHV^{s}_{coal}}$$

where,

X_{bi} = The standard coal coefficient of agricultural waste

$LHV_{biomass}$ = Net calorific power of agricultural waste (kj / kg)

LHV^{s}_{coal} = Presents the net calorific power of standard coal

The connotation of standard coal is that the heat productivity of standard coal, that is the heat value which produced by per ton standard coal, is 29270 kj, 29271 kj / kg. The net calorific value of agricultural waste is about between 15000-18000 kj / kg, the coefficient of standard coal usually between 0.5-0.6. This equation that convert agricultural waste into standard coal as follows:

$$B_{bi} = M_{bi} x_{bi}$$

Among this, B_{bi} represents the quantity of standard coal of agricultural waste (kg / a).

- **Supply potential of livestock waste:** The best way that energy utilization of livestock waste is to anaerobic fermentation to produce biogas, either heating or power generation. The different kinds of livestock waste produce different amount of biogas and contain different amount of methane, there is different net calorific power, also different coefficient of standard coal. The convert method of livestock waste is similar to the convert method of agricultural waste. The method that can calculate and discuss the biogas production and the heat are as follows:

The quantity of fecal dry that produced by per animal per day:

$$W = w \times d \times a$$

W = The quantity of fecal dry that produced by per animal per day $[kg / (each) \times d]$

w = The average quality of each animal $(kg / unit)$

d = The quantity of livestock waste that produce by per unit daily $[kg / (kg \times d)]$

a = The dry matter content of the manure (kg / kg)

According to the dry mass of livestock, it can obtain the biogas production as follows:

$$V = W \times v$$

where,

V = The biogas production that produced by per animal per day $[m^3 / (unit \times d)]$

v = The amount of biogas production by unit mass (m^3 / kg)

It can estimate the low calorific value of biogas by the methane content, the equation is as follows:

$$LHV_{bgas} = LHV_{CH4} \times b$$

LHV_{bgas} = The low calorific value of biogas (kj / m^3)

LHV_{CH4} = Thelowcalorificvalue of methane (kj / m^3)

b = The methane content of the biogas (%)

In this study, we take the low calorific value of methane is $3.59*10^4 kg / m^3$.

The biogas energy that produced by livestock manure is as follows:

$$Q_i = LHV_{bgas} \times V \times m \times n$$

where,

Q_i = The biogas energy that produced by single animal manure (kj / a)

V = The biogas production by per animal per day $[m^3 / (unit \times d)]$

m = The availability of livestock per annual $(unit)$

n = The days per annual (d)

The calculation model of utilization potential of agricultural biomass resources:

- **The heating potential model of agricultural waste:**

$$Q_1 = g_1 \times B_1 \times LHV'_{coal} \times h_{1g}$$

Q_1 = The heating potential of agricultural waste (kj / a)

g_1 = The ratio that the heating part accounting for the quantity of standard coal which produced by agricultural waste

B_1 = The total quantity of agricultural waste which could be used as energy (kg / a)

h_{1g} = Heating efficiency of agricultural waste $(\%)$

- **The heating potential model of livestock waste:**

$$Q_2 = g_2 \times B_2 \times LHV'_{coal} \times h_{2g}$$

Q_2 = The heating potential of livestock waste per annual (kj / a)

g_2 = The ratio that heating part accounting for standard coal which converted by livestock waste

B_2 = The quantity of standard coal that converted from biogas energy of livestock waste (kj / a)

h_{2g} = The efficiency of biogas heating $(\%)$

The total heating potential agricultural biomass is:

$$Q = Q_1 + Q_2$$

(Q indicates heating potential of biomass (kj / a)

The power potential model of agricultural waste:

$$P_{e1} = \sum \frac{B_{1i} \times LHV'_{coal} \times h_{1i}}{3600}$$

P_{e1} = Total quantity of power of agricultural waste $(kW \times h/a)$

B_{1i} = The quantity of standard coal of biomass fuels that produced by different power technologies (kg / a)

h_{1i} = The efficiency of biomass power generation $(\%)$

The Power potential model of biogas energy:

$$P_{e2} = \sum \frac{B_{2i} \times LHV'coal \times h_{2i}}{3600}$$

P_{e2} = The total power quantity of biogas $(kW \times h / a)$

B_{2i} = The quantity of biogas fuel which converted by different technologies (kg / a)

h_{2i} = The power efficiency of biogas $(\%)$

The total quantity powering potential of agricultural biomass is as follows:

$$P_e = P_{e1} + P_{e2}$$

P_c indicates the total quantity powering potential of biomass (kW×h/a).

Methodology: The supply potential of agricultural waste in Hubei province. The data resource of agricultural production of Hubei province from the National Bureau of Statistics, which is showed in Table1:

The key issue of estimating straw resource is to establish the coefficient of crops; it is a group of empirical constants which can be obtained through field experiments and observations, different regions and different crops are the same, may be slightly different. Different scholars take different values when they estimate the straw resource.

Table 1: The yield of agricultural products in Hubei province (unit: ten thousand tons)

Crop	Rice	Wheat	Corn	Beans	Tuber coops	Cotton	Peanut	Rapeseed	Sesame	Bast fiber crops
Yield	1616.9	344.8	276.2	39.5	99.8	52.6	68.7	220.4	1406	2.9

Table 2: The ratio of grain to straw of main crops in Hubei province

Crop	Rice	Wheat	Corn	Beans	Tuber coops	Cotton	Peanut	Rapeseed	Sesame	Bast fiber crops
Ration of grain to straw	1.1	1.1	2	0.5	4	5.3	1.2	2	7.5	3

Table 3: The standard coal equivalent coefficient of various biomasses (kg/standardcoal/kg)

Rice stalks	Wheat-straw	Corn stalk	Potato stalks	Beans talk	Cotton stalk	Peanut stalk	Oil stalks	Sesamestalks	Bastfiberplantstalks
0.429	0.5	0.529	0.486	0.543	0.543	0.529	0.529	0.529	0.500

Table 4: The convert quantity of standard coal of various crops (Unit: ten thousand tons)

Crop	Rice	Wheat	Corn	Beans	Tuber coops	Cotton	Peanut	Rapeseed	Sesame	Bast fiber crops	Total
Quantity	763.02	189.64	292.22	76.79	27.1	151.38	43.61	233.18	57.93	4.35	1839.21

Table 5: The relevant parameters of manure

Animal species	Average quality (kg/unit) (w)	The amount of produced manure [kg/(kg, d)] (d)	Dry matter content/% (a)	The amount of Biogas production (m^3/kg) (v)	Methane content % (b)
Cow	240	0.062	8	0.205	59
Pig	61	0.084	13	0.425	65
Poultry	2	0.036	2	0.310	67

The coefficient in this study is from the agricultural department of energy office of Hubei province, which is shown in Table 2.

Coal equivalent, which is also called convert ratio of coal equivalent, means an integrated indicator which is used in the process of calculating thermal equivalent. The rule in the "Relevant terms of coal and coal quality analysis" GB/T3715 provides that, any quantity fuel that can generate 29.27MJ can convert 1kg standard coal. The coefficients of various biomass of standard coal are shown in Table 3.

Data resource: China energy statistical yearbook 2010.

From Table 4, it can be seen that, the total quantity that converted by agricultural waste in Hubei province is 18.3921 million tons per annual.

According to the study of China Electric Power Institute, there are about 51% of agricultural waste could be used as energy. Therefore, the study takes the factor of energy utilization as 0.51 and concludes that the quantity of standard coal is 9.38 million tons of Hubei province in 2011.

The supply potential of livestock energy of Hubei province

The quantity of waste that produced by farmed animals is related to the kinds and quality of animals, the average quality, the manure amount daily, the dry matter content, the biogas quantity and the methane content in the biogas are different.

The methane content determines the quality of the biogas calories, the study reference the existing literature Xiao and Zhou, (2006); Yao and Wang, (2006), the manure parameters are shown in Table 5:

The quantity of livestock and poultry is get from China academic literature library, due to lack of the quantity of poultry in 2011, it is calculated by the average annual growth rate according to the data from 2008-2010.

According to the annual rate of change from 2008 to 2010, it concludes the average annual growth is 8.64%, base on this, calculate the quantity of poultry is 506.969 million. The concrete production is shown in Table 6:

Table 6: The livestock production of Hubei province in 2011 (Unit: ten thousand)

Animal species	Cattle	Pig	Poultry
Quantity	320.5	6404.5	50696.9

According to the table of yield and parameter and the described method previously, it can be calculated the total quantity of livestock waste resources, it is shown in Table 7:

As can be seen from the table, the total amount of standard coal which converted from livestock waste is 117621 tons in 2011. Because it will cause groundwater pollution if the livestock waste were discharged into field or rivers directly, the Chinese government advocated comprehensive utilization of livestock waste. First, to produce biogas energy to utilization, second, make the biogas sludge as fertilizer to field.

Therefore, it makes the efficient of livestock waste energy utilization as 1, that is to say, it makes full use of all livestock waste as energy and concludes that the amount of standard coal which converted from livestock waste energy about 117621 tons per year in Hubei province.

The utilization potential analysis of agricultural biomass energy

- **Heating potential:** The total amount of standard coal that converted by agricultural waste is 18.3921 millions tons of Hubei province in 2011, of which 20% is used for heating and equivalent to 3.678 millions tons standard coal

The total amount of standard coal that converted by livestock waste are 117600 tons, 50% of which is used for heating and equivalent to 58800 tons of standard coal.

Based on this, it calculates the amount of standard coal that used for heating about 3.74 millions tons per

Table 7: The livestock waste of Hubei province in 2011

Animal species	The number of animals (× 10)	The amount of biogas per annual (:×10j)	The coversion coefficient of standard coal	The equivalent amount of Standard coal (t)
Cattle	320.5	6050	0.7236	4378
Pig	6404.5	140000	0.7972	111608
Poultry	50696.9	1990	0.8217	1635
Total	57421.9	148040		117621

Table 8: The powering potential of agricultural waste in Hubei province

Project	Direct-fired	Co-firing	Internal combustion engine	Gasification gas-steam combined cycle
Enersy distribution/%	50	25	10	15
Power generation efficiency/%	20	38	30	35
Power capacity/(*10kw.h)	119.62	113.65	35.89	62.81
Total power capacity/(*10kw.h)	331.97			

Table 9: The powering potential of livestock waste in Hubei province

Project	Combustion motor	Gas turbine	Turbine
Enersy distribution/%	40	30	30
Power generation efficiency/%	43	40	35
Power capacity/(*10kw.h)	0.82	0.57	0.5
Total power capacity/(*10kw.h)	1.89		

annual. In the case of hypothetical that the heating efficiency was 80%, it can provide total heating energy 8.76×109J.

- **Powering potential:** The agricultural waste also could be used for powering and it always takes the powering technology such as direct-fired power generation, co-firing, gasification power and so on.

There are 80% of agricultural waste are used for powering, according to different efficiency of different power technology, it can be estimate the powering potential.

Refer to the power potential of agricultural waste and livestock waste of Henan province, the powering potential of Hubei province is shown in Table 8 and 9.

RESULTS AND DISCUSSION

It can be concluded from the above methods and models make full use of agricultural biomass can optimize the energy structure and ensuring energy security.

Hubei province, as a major agricultural province in the central of China, has abundant crop straw resources and different kind of livestock and poultry industry. It should take some measures to collect agricultural biomass, in this way; we can save a lot of coal-fired.

CONCLUSION

Due to the constraints of geographical location and climatic conditions, the distribution of agricultural straw resources is uneven and also it has strong regional characteristics, so it should adopt various mode of utilization such as district heating, biomass direct combustion power generation of biogas generation. Meanwhile, it should try our best to research and develop biomass utilization technologies which are newer and higher in order to reduce the use of coal combustion and to protect the ecological environment.

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