Comprehensive Evaluation of the Introduction of Integrated Biomass Utilization System and Optimal Environmental Policies with Simulation Modeling Approach: Case study of Jilin Province, China

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Study on the Construction of Integrated Biomass Energy Utilization System:

Chapter 1 Introduction

With the increasingly depletion of conventional and non-renewable energy sources, research on biomass energy, which is a kind of renewable, abundant and environmentally friendly substitutive energy has been a hot issue around the world. Biomass energy is a kind of energy form that converts from solar energy to chemical energy through photosynthesis of green plants directly or indirectly and stored inside biomass (Wang & Ai, 2006).

Jilin Province, located in the northeast of China, is important industrial base and commodity grain base of China. Along with the acceleration of industrialization and urbanization, energy consumption of Jilin Province is increasing rapidly. Shortage of primary energy, low energy self-sufficiency rate and unreasonable energy structure are urgent problems for Jilin Province to solve. Besides, consumption of conventional fossil fuels has resulted in the exacerbation of global warming and air pollution. Reserve of primary energy of Jilin Province only accounts for 0.3% of China and its energy self-sufficiency rate is less than 50% (Zhao, 2011). Energy consumption is increasing continuously and there is large disparity between energy production and consumption. Figure 1 shows energy production and energy consumption of Jilin Province from 2000 to 2010. In 2010, conventional fossil energy accounted for 94.1% of the total energy consumption and new and renewable energy only accounted for 5.9%. Figure 2 shows the consumption ratio of different kinds of energy.

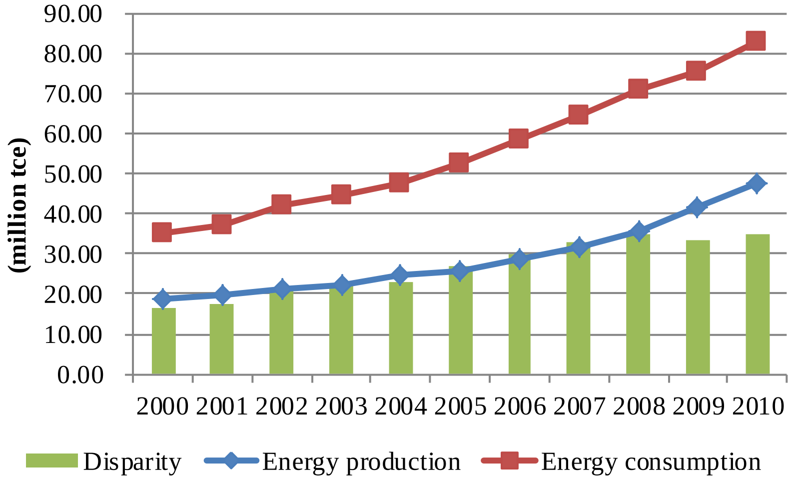

Figure 1. Energy production and consumption of Jilin Province from 2000 to 2010

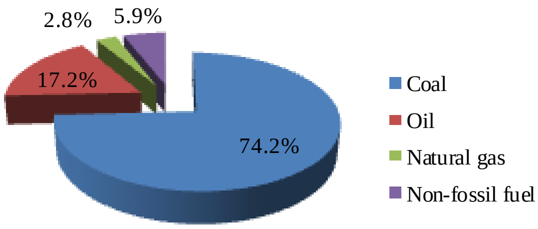

Figure 2. Energy consumption structure of Jilin Province in 2010

As a traditional agricultural province, there are a lot of advantages to support the biomass energy development in Jilin Province. Jilin Province has abundant reserve of biomass resources. Wide arable land, high yield of grain, scaled breeding and forestry industries are providing material basis for the utilization of agro-forestry residues and livestock manure. According to the 12th 5-year plan, Jilin Province has proposed a target to raise the biomass energy production to 8.4 million tons of standard coal. The utilization of biomass energy can not only substitute conventional fossil energy to mitigate the energy crisis but also adjust the energy consumption structure to reduce the emission of green house gases and air pollutants.

This article is aimed to estimate the biomass energy potential of Jilin Province quantitatively to show its mitigation capacity for energy shortage and determine the major utilization direction of biomass energy in Jilin Province. Based on the supply potential of biomass energy, corresponding biomass energy technologies can be determined and adopted. Finally an integrated biomass energy utilization system can be constructed, which will be introduced into the socioeconomic activities to make comprehensive evaluation of its effect on energy crisis mitigation, environmental preservation and economic development in study area.

Chapter 2 Quantitative estimation of biomass energy potential

2.1 Organic biomass waste resources

There are different indexes for the availability evaluation of biomass energy and the amount calculation of organic biomass resources in corresponding to different criterion. (Li, Ren, & Zhuang, 2001) Here three definitions including physical reserve, acquirable and utilizable amount, and equivalent of standard energy are introduced. (Liu & Shen, 2007) The amount of major biomass resources is evaluated step by step according to these three definitions.

With the calculation analysis and data summary (collected from Statistical Yearbook of Jilin Province 2011), results of physical reserves, acquirable and utilizable amount and equivalent of standard energy of four major organic biomass waste resources are obtained and shown in Table 1.

Table 1. Results summary of organic biomass energy in Jilin Province

Types	Physical reserves (10^6t)	Acquirable and utilizable amount (10^6t)	Standard energy equivalent (10^6tce)	Percentage
Straw and agricultural residues	39.78	25.06	12.69	40.3%
Firewood and forestry residues	13.74	2.30	1.31	4.2%
Livestock manure	90.03	36.54	16.69	53.1%
Municipal waste	6.24	3.61	0.77	2.4%
In total	149.80	67.51	31.46	100.0%

The results show that total amount of biomass energy in Jilin Province is 31.46 million tce, among which 40.3% comes from farming, 53.1% comes from animal husbandry, 4.2% comes from forestry and 2.4% comes from city. The total amount of biomass energy can be accounted for 34.9% of total energy consumption of Jilin Province in 2011. Compared with the disparity of energy production and consumption in 2010 in Jilin Province (35.07 million tce), once the biomass energy is fully developed and utilized, it can facilitate to the mitigation of severe energy crisis in Jilin Province. Agriculture is the biggest source of biomass energy in Jilin Province providing a advantageous condition for the utilization of straw and livestock manure.

2.2 Marginal lands and raw material plant resources

When estimating the amount of organic biomass waste resources, this paper introduces the concept of marginal land resources. It will be considered to plant feasible raw material plants on marginal lands to acquire biomass resources. In China there are three kinds of marginal land: (1) the lands that are suitable for agriculture and forestry among the lands that can be tapped but not yet; (2) the current energy forests including firewood, oil forest and shrubberies; (3) the current marginal farmland that can be used to plant energy crops through adjusting the planting structure among the low yield non-food farmlands. (SHI, 2008) The marginal lands are not suitable for traditional planting of crops and forests. However once they are effectively utilized associated with raw material plant, considerable amount of biomass energy can be produced and acquired. The raw material plant suitable for the climate and agricultural conditions in Jilin Province should be in accordance with the following combination:

(1) Salinized low yield land—Sweet sorghum

(2) Highly dry and thin land—Sweet potato

(3) Untapped marginal lands suitable for forestry—Woody energy plant and woody oil plant

Table 2. Energy yield of raw material plant resources on the marginal lands in Jilin Province

Types of marginal lands		Area (10^6ha)	Suitable plants	Energy yield of unit area* (tce /ha)	Total energy yield	
					Standard coal(10^6tce)	%
Untapped marginal lands suitable for agriculture		0.306	Sweet potato (30%)	Sweet potato: 2~3	3.18	71.2%
Current marginal farmland		0.443	Sweet sorghum (70%)	Others: 4~6		
Untapped marginal lands suitable for forestry		0.312	Woody energy plants (60%)	3.3	0.98	21.9%
			Woody oil plants (20%)	1.8		
			Energy crops (20%)	3~5		
Current energy forests	Firewood forests	0.018	Firewood forests	4.2	—	—
	Oil forests	0.029	Oil forests	1.8	0.31	6.9%
	Shrubberies	0.100	Shrubberies	2.6		
In total		1.208	—	—	4.47	100%

*some figures are indefinite and the intermediate value is adopted

Table 2 shows that total energy output of marginal lands in Jilin Province is 4.47 million tons of standard coal, among which the marginal agricultural lands can generate 3.18 million tons of standard coal (71.2%) and marginal forestry lands can generate 1.29 million tons of standard coal (28.8%). The energy yield of marginal agricultural lands is nearly twice as that of marginal forestry lands due to the larger area and higher energy yield of unit area.

Chapter 3 Biomass energy technologies and utilizing modes

According to the raw materials, industrial conditions, ultimate products and so on, there are many classification of biomass energy technologies. This paper focuses on the conversion methods to classify the biomass energy technologies as physical conversion, thermo-chemical conversion and bio-chemical conversion as is shown in Figure 3 (NEDO, 2010).

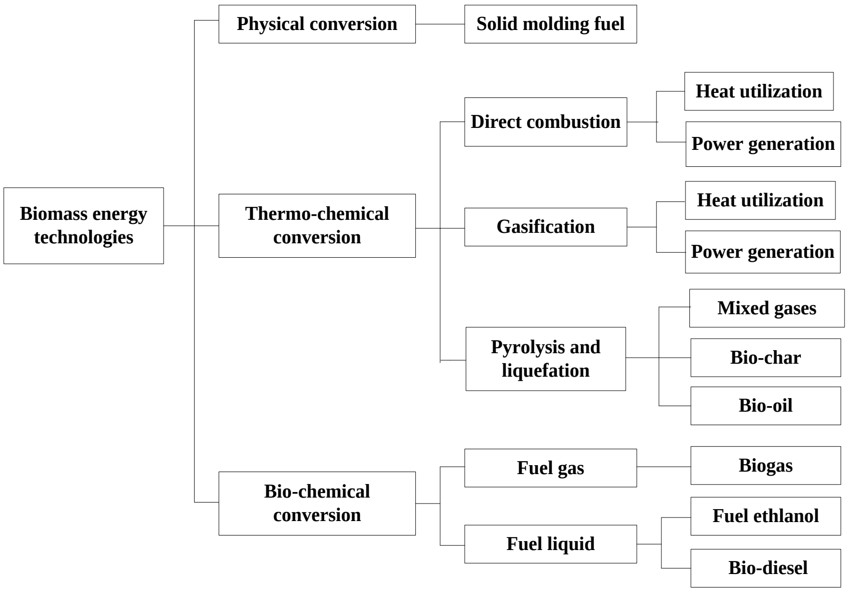

Figure 3. Biomass energy technological system

Based on the supply potential of biomass energy and the biomass energy conversion technologies, five industrial modes that are suitable for Jilin Province including Biomass power generation, Household biogas, Large and medium-scaled breeding farm, Biomass fuel ethanol and Bio-diesel can be proposed. (GAO, 2010)

Chapter 4 Integrated biomass energy utilization system

Integrating sources of biomass, biomass resources, biomass technologies, products of biomass utilization, a comprehensive biomass energy utilization system can be formulated as is shown in Figure.4. This system comprises of four sub-system as 1)Biomass raw material production system, 2)Biomass logistics system, 3)Biomass energy conversion system and 4)Production and living consumption system. The raw material production system is the basis of the whole biomass utilization system that determines how much biomass energy can be produced and utilized. The logistics system makes the supply of biomass raw material more stable and assures different raw material demand. The energy conversion system calls for various technologies according to the raw materials. With major biomass conversion technologies, the biomass energy is converted into electricity, heat, fuel and various bio-chemical products for human production and living. The organic wastes generated from production and living consumption can be reused to the system for energy.

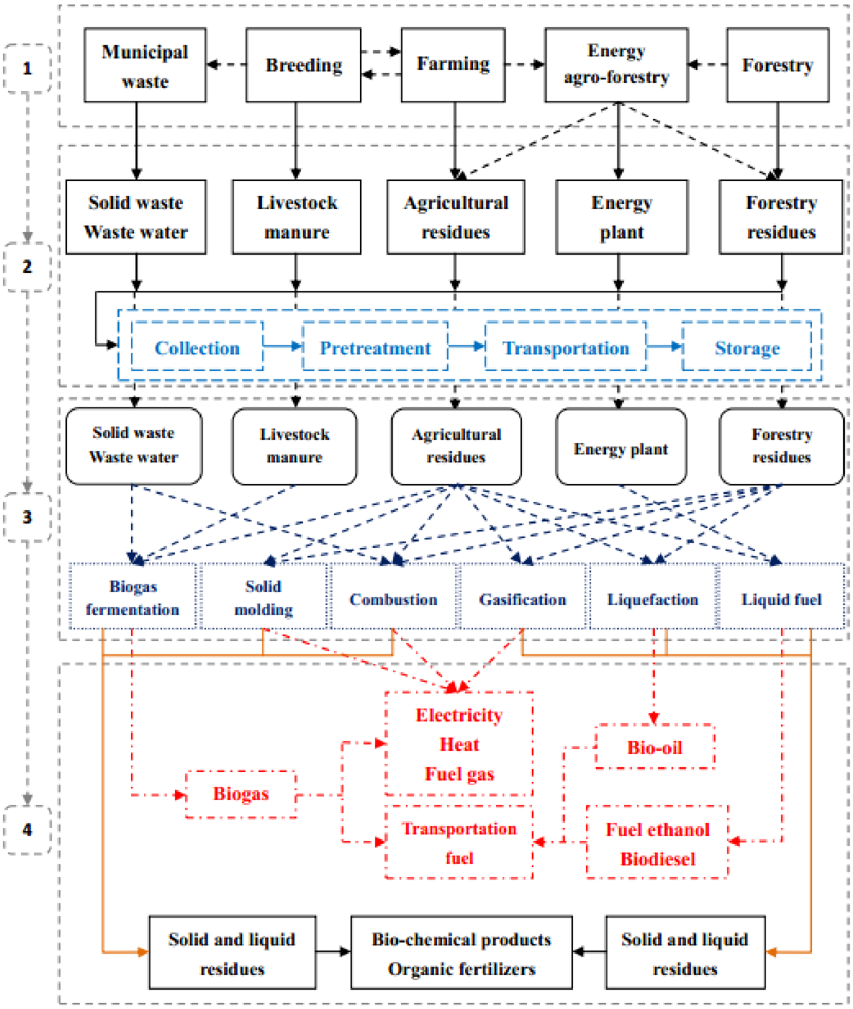

Figure 4. Integrated biomass energy utilization system

Chapter 5 Future research

An integrated biomass utilization system consisting of four sub-systems including biomass raw material production system, biomass supply system, biomass energy technological system and biomass energy consumption system has been constructed. Considering the material balance, energy balance and value balance, simulation modeling approach will be adopted as the evaluation method to make comprehensive evaluation of the environmental and economic effects of introducing the integrated biomass utilization system with the maximum GPR as the objective function. Finally it's expected to reach a decision regarding the optimal solution to the simultaneous pursuit of energy utilization, environmental preservation and economic development in study area and ultimately achieve the governmental planning goals.

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