

# Study on the exploitation of biomass energy in environmental engineering

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**Abstract:** New energy and renewable energy with little pollution on environment are urgently-needed supplement and they are the foundation of energy structure in future. With the fast development of national economy in China, there is the sharp increase of municipal organic waste, therefore anaerobic treatment of the municipal organic waste and biosolids can both help control the pollution and obtain clean energy. Based on the review and analysis of anaerobic treatment of the urban sewage and organic waste to obtain bio-energy in our country, this paper enumerates the major reasons limiting spread of anaerobic digestion technology, such as immature process flow, high-cost in production, lack of competitive competence, imperfect project design and standard and poor awareness of environmental protection etc, and it also puts forward measures and suggestions of promoting the use of biomass energy in cities, seeking a practical way to protect environment and exploit new energy in our country.

**Keywords:** environmental engineering, biomass energy, anaerobic digestion technology

The world's energy markets rely heavily on the fossil fuels coal, petroleum crude oil, and natural gas as sources of energy, fuels, and chemicals. Since millions of years are required to form fossil fuels in the earth, their reserves are finite and subject to depletion as they are consumed. Some analysts now believe that the end of the Fossil Fuel Era is in sight because depletion of reserves is expected to start before the middle of the 21st century, probably first with natural gas[1]. This eventuality and the adverse impact of fossil fuel usage on the environment are expected to be the driving forces that stimulate the transformation of biomass into one of the dominant energy resources. Any living household is a continuing balancing act between conflicting demands and resources. With the environmental pollution getting more serious in recent years, mankind has already fully realized the significance that utilizes the biomass as a new energy. The biomasses in environmental projects are fully renewable sources in the sense that they are salvaging and do not add to global warming. Further, they are always inexhaustibly there with city life, no conflicts with food production. So we should discuss the relationship between China's renewable energy and its sustainable development.

## 1. The basic concept of biomass

Biomass has been a major energy source all the time. Biomass has been the fourth largest energy after

petroleum, coal and natural gas among the total amount of energy-consuming in the world. The statistics shows that the total amount of biomass consumption accounts for 9.4% of global energy consumed in 1995, which is equivalent to the summation of nuclear power and hydroelectricity. The biomass (mainly firewood and charcoal) accounts for about 70% of total amount of energy consumed in some developing countries<sup>[2]</sup>.

Biomass is a nonfossil organic materials that have an intrinsic chemical energy content. The Food and Agriculture Organization of the United Nations defines "biomass" as "all forms of plant-derived matter (terrestrial and aquatic) other than that which has been fossilized." It includes all water- and land-based vegetation and trees, or virgin biomass, and all waste biomass such as municipal solid waste (MSW), municipal biosolids (sewage) and animal wastes (manures), forestry and agricultural residues, and certain types of industrial wastes.

Increased levels of carbon dioxide in atmosphere lead to green-house effect, so new industrial technology that is environmental friendly and reduces petroleum consumption must be our priority. Photosynthesis is the best method of recycling carbon dioxide in the biosphere.[3]



Unlike fossil fuels, biomass is renewable energy and can be replaced in a short period. The upper limit of the

capture efficiency of the incident solar radiation in biomass has been estimated to range from about 8% to as high as 15%, but under most conditions, it is generally around 1% or less. However, the global virgin biomass has a very large energy potential. It is estimated that the world's standing biomass carbon; i.e., the renewable, above-ground biomass that could be harvested and used as an energy resource, is about 100 times the world's total annual energy consumption. We can predict that biomass, as a clean, pollution-free renewable energy, will play a major role in the structure of future energy resource.[4]

## 2. The anaerobic digestion in environmental project

Anaerobic bacteria are some of the oldest forms of life on earth. They existed even before the photosynthesis of green plants released large quantities of oxygen into the atmosphere in evolution. . Anaerobic bacteria break down or "digest" organic material in the absence of oxygen and produce "biogas" as a waste product. (Aerobic decomposition, or

composting, requires large amounts of oxygen and produces heat.)

When burned, 1 cubic meters of biogas yields about  $2.5 \times 10^4$  KJ of heat energy. Anaerobic decomposition occurs naturally in swamps, water-logged soils and rice fields, deep bodies of water, and in the digestive systems of termites and large animals. Anaerobic processes can be managed in a "digester" (an airtight tank) or a covered lagoon (a pond used to store manure) for waste water treatment. The primary benefits of anaerobic digestion are nutrient recycling, waste water treatment, and odor control[5](see Fig. 1). Anaerobic treatment of industrial wastewater has become a viable technology in recent years due to the rapid development of high-rate reactors, low excess sludge production, and enclosure of odours and aerosols[6]. The treatment capacity of an anaerobic digestion system is primarily determined by the amount of active population retained within the system, which in turn is influenced by wastewater composition, system configuration and operation of anaerobic digestion.

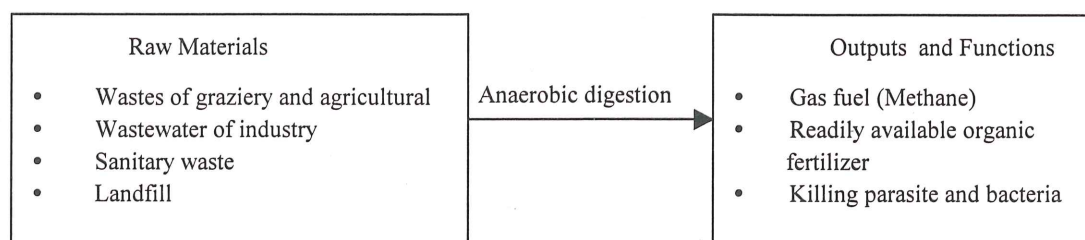


Fig. 1 The raw materials, outputs and functions of biomass by anaerobic digestion

Biogas comes from the organic waste, landfill plant, brewery, food-processing factory, livestock breeding plant etc. Biogas produced in anaerobic digesters consists of methane (50%-80%), carbon dioxide (20%-50%), and trace levels of other gases such as hydrogen, carbon monoxide, nitrogen, oxygen, and hydrogen sulfide. The relative percentage of these gases in biogas depends on the feed material and management of the process.

Anaerobic digestion is taken as a three-step process, even though it is really a coupled sequence of microbiological interactions[7]. At the initial stage, complex organic materials are depolymerized and converted to  $\text{CO}_2$ ,  $\text{H}_2$  and fatty acids, mainly acetic, propionic and butyric. In the next stage, all the higher acids are converted to acetic acid. In the final stage, a biogas containing methane and  $\text{CO}_2$  is produced along two different pathways: from acetic acid (acetoclastic

methanogens) and from  $\text{CO}_2$  and  $\text{H}_2$  ( $\text{H}_2$ -utilizer methanogens). In anaerobic reactors, acidogenic bacteria convert soluble organic material mainly to acetate, propionate, butyrate,  $\text{H}_2$ , and  $\text{CO}_2$ , presumably via the known pathway of metabolism. The optimum pH of acidogenic bacteria is 5.2 to 6.5, and the specific growth rate is over 2 days. Some of the products of acidogenic bacteria, namely acetate, and  $\text{H}_2$ , can be metabolized by methanogenic bacteria, but others, such as propionate and butyrate, cannot. Propionate and butyrate must be further degraded to acetate and  $\text{H}_2$  by acetogenic bacteria. These bacteria grow very slowly, with a minimum doubling time of 3.6 days. The optimum pH of these microorganisms is 6 to 7. Methanogens are among the most fastidious of anaerobes; they require or are stimulated by growth factors such as vitamins, unusual trace minerals (Co, Ni), fatty acids (acetate) or specific cofactors

(coenzyme M) unique to methanogenic microorganisms. In a typical anaerobic digester, the two major methanogenic precursors are acetate and  $H_2$ - $CO_2$ . Approximately 70 % of the digester methane comes from acetate and the remainder from  $CO_2$  reduction to  $CH_4$ . The optimum pH environment for methanogens is within the range 7.5 to 8.5.

Under ordinary circumstances, virgin biomass is harvested for feed, food, fiber, and materials of construction or is left in the growth areas where natural decomposition occurs. Biomass can be transformed into available electric power, fuels or chemicals through several ways, which include a variety of thermal and thermochemical processes by combustion, gasification, and liquefaction and the microbial conversion of biomass to obtain gaseous and liquid fuels by fermentative methods. Many factories in the world have been using biogas to run their machines.

Many of the processes are suitable for either direct conversion of biomass or conversion of intermediates. The using in the environmental project is the waste biomass. The pyrolysis or thermal decomposition of MSW to yield liquid fuel oils and chemicals; and the hydrofining of tall oils from wood pulping to obtain high-cetane diesel fuels. In general environment engineering, the conversion is the anaerobic digestion of biosolids to yield fuel gas (biogas) of medium-calorific-value, and the alcoholic fermentation of corn to obtain fuel ethanol for use as an octane-enhancing additive in motor gasolines. Many questions are involved in a large scale of conversion. In the idealized case, the synfuel plants are located in or near the biomass growth areas to minimize the cost of transporting biomass to the plants, all the non-fuel effluents of which are recycled to the growth areas[8].

Several environmental impacts are directly related to biomass energy production and consumption. With view to environmental protection, the methane is a greenhouse gas with strong function. The greenhouse effect of methane is 27 times of carbon dioxide. Another beneficial environmental impact results from the combined application of waste biomass disposal and energy recovery technologies. It is an important respect to control the emission of biogas into atmosphere. Examples are biogas recovery from the treatment of biosolids in municipal wastewater treatment plants by anaerobic digestion, landfill gas

(LFG) from MSW landfills, which is the equivalent to combining anaerobic digestion of waste biomass and LFG "mining," and the conversion of MSW, refuse-derived fuel (RDF), and farm, forestry, and certain industrial wastes, such as black liquor generated by the paper industry, by combustion to produce heat, steam, and/or electric power. At the same time, the displacing fossil fuel usage and a reduction in any adverse environmental impacts, which are caused by fossil fuel consumption, are obvious environmental benefit [9].

As an energy, biogas has been a good fuel whose calorific value is more than 21.98 MJ/m<sup>3</sup> (methane 60% content, carbon dioxide 32% content) for pure gases, and it is the renewable energy of biomass. In addition, the use of a fossil fuel and biomass together in certain applications, such as electric power generation with coal and wood or coal and RDF in dual-fuel combustion or co-combustion plants, can result in less undesirable emissions. The substitution of fossil fuels and their derivatives by biomass and biofuels also help to conserve depletable fossil fuels. Resource conservation and environmental benefits certainly accrue from such applications [10]. So, the utilizing biogas high-efficiently has double sense in which biogas pollutes and develops the new energy.

### 3. The condition of biomass utilization in china

The idea of using renewable biomass as a substitute for fossil fuels is not new. Biomass, primarily woody biomass, has provided over 14% of the energy and fuel needed in China. The data of the United Nations show that global biomass energy consumption was about 6.7% of the world's total energy consumption in 1990. It is estimated that the biomass will likely become a part of sustainable future energies, which will account for more than 40% of global total energy consumption by new technology by the middle of centuries[11]. China, which has quite fragile ecological condition with only 13 percentage of forest coverage and shortage of water resource, should strengthen the exploitation and utilization of biomass [12].

With the fast development of national economy in recent years, the quantity of urban waste runs up. The emission amount of rubbish reached 122 390 000 tons in 1995, if all of them were used for generating electricity, 49 billion degrees of electricity could be generated. Every year, the emission of animal wastes reaches 580 million tons, and the breeding plants have

66 million tons. The wastewater that can be used for producing biogas in the light industry reaches 130,000 tons.

The technology, with which anaerobic digestion disposes organic offal to get biogas, has steadily developed after a few decades' efforts made. A thousand large and medium-sized biogas plants have already been built up, which can produce biogas of several hundred million cubic meters per year. Generally speaking, a large-scale sewage treatment plant or a rubbish landfill plant can daily produce biogas 10, 000 cubic meters, and a medium-sized plant also produce thousands of cubic meters. By the end of 1994, 5,430,000 biogas pool has already been developed with annual output 1,347 million cubic meters. There are also 583 large-and-medium-scale biogas projects, with 220,000 cubic meters total pool hold and 35,800,000 cubic meters of annual marsh gases production. In more than 3 million peasant households of the whole country, they have developed the marsh gas to utilize synthetically. Many large-and-medium-scale biogas projects have increased post-treatment technology, and remarkable progress of utilizing the natural pond and dreg synthetically has been made[13]. Biomass supplied the rural resident high quality organic fertilizer and 2.1 billions m<sup>3</sup> biogas in 1998. Its benefits measured by money form and good social acceptability have already made it enter pre-commercialization stage. Biomass has been recognized by the World Energy Committee and other international authoritative organizations as an success technology industry. Besides, through the construction for many years, already there are researcher, research institution, corresponding industry team and industry scale of a batch of high levels in this field in our country, Form each engaged in basic research, application study, engineering design and construct, develop theory and team who reality combine together that utilize synthetically already. After year's efforts in this field in China, there has already been a group of high level researchers, research institutions and corresponding industries and teams engaged in basic research, application study, engineering design and construction, theory study and practical use have been formed.

At present, the treatment amount of poultry feces and organic wastewater anaerobic digestion in our country is less than 4%, which implies large potential

for future resource development. With the view of our country, biomass development has encountered many obstacles and difficulties before it can displace fossil fuels. Such as immature process flow, high-cost in production, lack of competitive competence, imperfect project design and standard and poor awareness of environmental protection etc., all of these limit the spread of biomass conversion technology in China.

#### **4. The countermeasure of biomass energy marketization in china**

We will have to derive fuel from biomass because of two driving forces: first, "the end of the Fossil Fuel Era" will be in sight by 2050; second, fossil fuel usage adversely impacts the environment[15]. Petroleum crude oil has been the single largest source of energy for many years in China. To achieve the target of China's becoming comparatively developed country and improving ecological environment by 2050, the biogas users in whole country would be up to 12,350,000 families in 2010 (include concentrated air supply and family), and the mount of renewable energy with present technology by 2020 and 2050 should be 195 million T and 270 million T of standard coal respectively per year[4].

The biomass project is a point of growth in future economy. The integrated biomass production-conversion system (IBPCS) is a systematic engineering. But without such systems, biomass energy is limited to niche markets. Because of the nature of IBPCSs, employment in agriculture and forestry and the supporting industries will exhibit significant increases over many different areas in a country. When full-scale, well-designed IBPCSs are in place in industrialized countries and are supplying energy, organic fuels, and commodity chemicals to consumers, conventional fossil fuel production, refining, and marketing will have undergone major changes. Numerous economic impacts will occur. Biomass energy production and distribution will be a growth industry, while the oil and gas industries will be in decline. Some predictions indicate that when crude oil prices stabilize at \$25/bbl or more, many of the markets available to biomass energy will not require national tax incentives or government mandates to facilitate market entry. Future social and economic pattern will be changed from oil-oriented to biomass-oriented and biomass will certainly play a major role in future society and economy. We

should pay more attention to exploit in this field which is significant for China's sustainable development

- 1) The most important thing presently is to fully understand the urgency of energy and environment, which are in crisis. Though fossil fuels are used continually in a large amount at present, but under long-term consideration, it is more reliable and sustainable to develop our own fuels rather than depend on imported fossil fuels with rising prices. Therefore, under overall situation and market economy, there should be some operable support policy for the utilization of biomass in our country.
- 2) Government should advocate using biomass technology actively, and put forward clearly as the social developing goal. The biomass energy uses have market entry problems. Tax incentives should be provided to stimulate and encourage the use of biomass-based energy, and there are many plants that are fueled throughout the country with waste biomass. The competitiveness of the renewable energy (include the biomass) can be enhanced through legislation, tax revenue and economic measures in a way that the external social cost of the energy and environmental cost can be counted in total energy cost. These plants often take credits for waste disposal, such as the tipping fees for accepting and disposing of MSW, and get an excess fee from available waste biomass. Through the preferential policy and providing loan and derating taxes to support the market of biomass technology, the balance of agriculture, ecological environmental protection and biomass utilization can be kept by careful planning and considering regional difference; more funds should be invested into technology, which has not totally ripen for commercialization but having a good prospect.
- 3) Actively following the rule of marketization, firstly, we should follow the rule of market economy, and make a scientific programming arrangement on the switch technology of biomass. Secondly, the rights of markets should not be infringed to guarantee free and equal competition. Either monopolization or excessive competition should be monitored. In addition, there should be some corresponding requirements on entering markets, such as the standards of technical, pollution controlling and sanitary, etc.
- 4) We should reinforce the applied study of intermediate process of biomass and improve the actual level of using it. At the same time, we will establish and perfect the design specification and standard of large-and-medium-scale biogas project; improve the capacity of accommodating whole set equipment; facilitate the development of fermentation technology and device and its commercializing and industrializing; exploit utilization and commercialized technology of biogas byproducts.
- 5) We should guide and manage model pilot project carefully, provide good technological service; harmonize the relationship among the sewage treatment system, regional economy, urban ecology and urban water treatment system; establish different scale model fields, improve urban ecological environment. Social factors, which are public's knowledge, as well as technological and economic factors should be put into consideration in order to market the switch technology of biomass.

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