Boosting the Market for the Commercialization of Industrial Scale Biogas Projects in China

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Abstract: *With the world's largest population and one of the world's fastest growing economies, China's choice of development paths will have a dramatic impact on the rest of the world. In the industrial sector China produces more than 2.5 billion tons of wastewater effluents, and 70 million tons of residues per year (2002), which has a potential for conversion to more than 10.6 billion m3 of biogas. The potential for electricity generation from all sources of biogas is about 23 TWh from a generating capacity of 3.8 GW at current resource levels. The United Nations Development Programme and the Global Environment Facility have cooperated with the National Development and Reform Commission and the State Environment Protection Administration to assist in stimulating the development of a commercial market for biogas technologies and applications in China to develop the potential of using biogas as an energy resource and as a means of mitigating environmental pollution. With the passage of the Renewable Energy Law in 2005, biogas development is likely to benefit from new feed-in tariffs and access to utility grids to further drive commercialization and investment. This paper will discuss the current barriers and drives for commercializing biogas development in China.*

Keywords: *"Anaerobic digestion"; "biogas"; "commercialization"; "Renewable Energy Law"*

1. Introduction

With the world's largest population and one of the world's fastest growing economies, China's choice of development paths will have a dramatic impact on the rest of the world. With a population of 1.3 billion to feed, China produces more than 5 billion tons of biomass related solid residues annually, associated with agricultural and forestry residues; municipal liquid and solid wastes and landfills; and wastewater effluents from industrial processes and livestock farms. These biomass waste products are a significant resource in China that can be utilitzed for thermal and electric energy production. However, at present, actual energy produced is small compared to the potential utilization of biomass for energy production, and underutilized biomass resources otherwise contribute to China's already severe environmental pollution problems [1].

1.1. Current Scale and Potential for Biogas Production

For biogas production specifically in China, sources consist mainly of anaerobic treatment of animal waste in small, mid and large scale livestock farms, treatment of wastewater effluents from industrial processes, extraction of gas from municipal landfills, and municipal wastewater treatment plants. At the end of 2005 there were approximately 2,500 biogas plants using anaerobic fermentation technologies located at mid- to large-scale livestock farms and industrial facilities, about 17 million household biogas digesters in rural China, and 140,000 municipal wastewater treatment facilities. Production of biogas from all sources is currently estimated to be about 8 billion m^3 annually, mainly from the large installed base of small household biogas digesters [2].

Data from 2002 estimates that the industrial sector in China produces about 2.5 billion tons of wastewater and 70 million tons of solid residues per year. Sources of industrial effluents include the prodution of alcohol products (alchohol, beer, wine, spirits), food processing (slaughterhouses, starch, sugar, flour, beverages, vegetable oils, etc.), production of pharamaceuticals, and paper making. The potential for biogas generation from all industrial sources is estimated to be about 10.6 billion m^3 per year. In addition the Ministry of Agriculture estimates that mid- to large-scale animal feedlots and livestock farms produce aobut 49 million tons of solid excrement per year. The potential for biogas production from large livestock farms is estimated to be 2.7 billion m^3 per year and 1.2 billion m^3 per year from smaller farms. The total potential biogas production from industy and livestock farms (14.5 billion m^3 per year) could in principle support 3.8 GW of electric power capacity, generating 23 TWh of electricity annually [3].

In the future up to 2020, the National Development and Reform Commission (NDRC) has estimated that the potential for biogas generation from all sources could grow to 80 billion m^3 per year. Of this potential, about 21.5 billion m^3 from industrial sources and 20 billion m^3 from livestock farms is considered to be technically and economically feasible to develop (not including landfill gas resources). The 41.5 billion m^3 of biogas from industry and livestock farms alone could in principle support 13.8 GW of installed electric power capacity generating 83 TWh of electricity per year, assuming a 25-30% improvement in the efficiency of biogas

generating equipment in China [3].

1.2. Future Development Plans

The National Development and Reform Commission has established targets for energy production from biomass resources up to 2010 and 2020, for agricultural and forestry residues, municipal solid waste, landfill sites, and industrial scale biogas (including industrial processes and livestock farms). For 2010 the NDRC has established a national target for electric power generation of 5,500 MW from all forms of biomass, of which 800 MW is targeted for large scale biogas generation facilities. For 2020, the national target of 30,000 MW has been established for total biomass power generation, of which 3,000 MW is expected to be contributed by large scale biogas facilities, which is slightly more than 20% of the estimated potential for biogas power generation by 2020 [4].

As of 2004 the estimated installed biomass power generating capacity in China was approximately 2,000 MW of which 85% was bagasse cogeneration using steam turbine generators in sugar mills. In 2004 only about 20 MW of non grid-connected biogas electric power generation was installed in industrial facilites, which generated electricity for internal use [4]. By comparision, at the end of 2005 there were 2,700 biogas plants in Germany with an electric power generating capacity of 660 MW. In addition the German Renewable Energy Federation estimates that by 2020 there could be 42,000 biogas plants constructed in Germany with 8,500 MW of installed electric power capacity [5]. By comparison, China's 2020 target of 3,000 MW seems modest. Given the current biogas development base in China, the long term targets are aggressive, requiring similarly aggressive policy, technology, and financial development, but nevertheless are feasible given the examples of other countries.

2. Barriers to Biogas Development

At present there are a number of barriers in China that have the potential to stall the rapid deployment of biogas technologies and limit the utilization of biogas for energy production, especially electricity generation. Currently the existing structure of incentives for biogas plant development encourage the use of biogas technologies for pollution control. In 2002 the State Environmental Protection Administration (SEPA) promulgated new standards for the allowable organic content in wastewater effluents from industrial plants and livestock farms discharged into the environment. SEPA also developed a strong regulatory structure to enforce the new standards and started to actively shut down offending industrial plants and livestock farms. In response to prior and recent pollution control measures, to date most biogas plants have been constructed in China to optimize the control of industrial water pollution.

As a consequence of using biogas technologies for pollution control, the design of biogas plants is usually optimized to treat water to meet national standards for discharge of wastewater effluents into the surrounding watersheds of rivers and lakes. Common anaerobic fermentation technologies used in China include the UASB (Upflow Anaerobic Sludge Bed) and CSTR (Continuously Stirred Tank Reactor) digesters, accounting for 49% and 32% respectively of the anaerobic reactors used in industrial scale biogas plants. In addition, in order to meet rigorous discharge standards, many industrial biogas plants use a two stage design with a second stage aerobic process using SBR (Sequential Batch Reactor) tanks following the anaerobic fermentation tanks. This can increase the cost of the pollution control plant by more than 40%.

Typically, solids are also separated from the incoming wastestream and composted to produce a solid fertilizer, for which there is a ready market in China, but which places a limit on the maximum biogas that can be generated from waste streams. While in Europe the digestate from anerobic reactors can be used as a liquid organic fertilizer on crop land, in China there is as yet no significant commercial market for this product. In addition, up to 2006, it was extremely difficult to connect to the grid and sell biogas-generated electricity, and electricity used internally for industrial processes was regulated by utility companies. Biogas generated in large scale industrial plants has mainly been used as a combustion fuel in inefficient industrial boilers for process heat, but significant quantities of biogas generated in China have not been utilized.

The combination of expensive plant designs and limits on commercially viable products to generate income has made biogas plants expensive with limited investment potential. For example, the capital cost of a biogas treatment plant for an alcohol distillery with an annual production of 10,000 tons of alcohol products can be equal to or more than 50% of the total capital cost of the entire distillery project. The investment characteristics of most biogas plants constructed in China to date have been poor, with internal rates of returns substantially lower than typical hurdle rates for investors and payback times exceeding 8 years [6].

Other barriers are related to the biogas industry itself. There is a substantial technology base for biogas equipment in China today, but the technology levels can be improved, for example, for plant designs, control and automation of plant operations, advanced construction techniques, and materials. China also has a base of competent bioengineering companies as a business base for the desin and construction of biogas projects, but this base is small with low profit margins and in need of investment to expand capacity. There also is a relative lack of standards in the industry for the design and construction, monitoring, and servicing of biogas plants.

There is a need for policy support from the Government of China, particularly if the mid to long-term targets for biogas development are to be achieved. Some policy actions have already occurred with the passage of the

Renewable Energy Law in 2005 making it easier for small power producers to connect to the grid, negotiate power purchase agreements, and provide a support price for electricity sales. Enforcement of environmental regulations by SEPA, while increasing in effectiveness recently, still needs to be stronger and more consistent with stronger penalties for non compliance.

Addressing the issue of the lack of investment viability for biogas projects requires restructuring in several sectors, including encouraging the construction of centralized grid-connected biogas power projects having viable economies of scale, changing land use policies and creating markets for new bioagas plant products, such as liquid fertilizers, and delivering appropriate information to bioengineering companies and industrial plant managers/owners.

3. Support for Biogas Development

Since the year 2000, the United Nations Development Programme (UNDP) and the Global Environment Facility (GEF) have cooperated with the National Development and Reform Commission and the State Environmental Protection Administration to assist in stimulating the development of a commercial market for biogas technologies and applications in China. The cooperation has been provided through the project "Capacity Building for the Rapid Commercialization of Renewable Energy in China" (NDRC/UNDP/GEF Project) and includes support for: i) introducing advanced technologies in several pilot biogas commercialization projects, ii) creating business opportunities through a series of regional biogas development workshops that provide a forum for information exchange between the Government, bioengineering companies, and potential customers in the industry and livestock farming sectors, iii) introducing new concepts for the commercial deployment of industrial scale biogas technologies in China, and iv) supporting policy development through environmental regulations and renewable energy legislation.

3.1. Industrial Scale Biogas Pilot Projects

Support has been provided through the NDRC/UNDP/GEF Project for three pilot commercial biogas projects in partnership with: i) the Hangzhou Dengta Ta Yang Zhi Zong Chang Livetock Farm in Hangzhou, Zhejiang Province, ii) the Kunpeng Food Processing Group in Beijing (Shunyi Livestock Breeding Farm), and iii) the Jiuchang Alcohol Distillery in Jiazhou City in Qingdao, Shandong Province. The projects were constructed at various times during the period of 2000 through 2002 and were designed to provide a demonstration of practical and commercial biogas technologies available in China, but also introducing advanced design and engineering practices from European companies. The characteristics of these plants are shown in Table 1. The investment of the UNDP Project ranged from 18 to 30% of the project cost.

Table 1: Characteristics of Industrial Scale Biogas Pilot Projects

Characteristics	Dengta Pig Farm*	Shunyi Pig Farm	Jiuchang Distillery
Scale	200,000 pigs	60,000 pigs	10,000tons/year alcohol
Location	Hangzhou, Zhejiang	Shunyi, Beijing	Qingdao, Shandong
Wastewater	3,000 tons/day	600 tons/day	1,500 tons/day
Biogas Produced	8,500 m^3/day	2,200 m^3/day	10,000 m^3/day
Biogas Applications	Heat for farm use	Heat for farm use	Boiler fuel and electricity
Other Output	142 tons fertilizer/day	8 tons fertilizer/day	Liquid fertilizer
Cost in RMB	14,970,000	6,160,000	6,910,000
Cost in USD	1,820,000	748,000	840,000

*Relocated to new site in late 2002

A key design criterion for the pilot projects was meeting the strict environmental standards for the discharge of industrial and livestock farm effluents. The Dengta and Jiuchang [7] projects had to meet the second level emission requirements of the National Comprehensive Sewage Discharge Standard GB8978-96 and the Shunyi [8] project had to meet the Beijing Municipal Wastewater Discharge Standard. In general the plants were successful in meeting these wastewater discharge standards as shown in Table 2.

Table 2: Results for Wastewater Discharge Emissions from the Pilot Projects

Pollutant	Dengta		Shunyi		Jiuchang		GB8978-96	Beijing Standard
	Before	After	Before	After	Before	After		
COD_{cr} (mg/l)	17,000	97	13,500	61	55,000	250	≤300	≤80
BOD_5 (mg/l)	8,500	25	7,000	16	24,000	60	≤100	≤40
SS (mg/l)	12,000	60	7,000	35	22,700	120	≤150	≤50
pH	7.1	8-9	7	8.6	4.2	7-8	6-9	6-9

All projects used a two-stage anaerobic/aerobic treatment process, with the Shunyi and Dengta projects using UASB anaerobic digesters, and Jiuchang using a two-stage system employing CSTR and UASB anaerobic reactors designed to match the characteristics of the distillery wastewater effluent. The projects also used advanced technology from international companies, such as licensed technology from Lipp GmbH in Germany employed by the Hangzhou Energy and Environmental Engineering Company for USAB and SBR tank construction and advanced desulphurization equipment designed by ECB ENVIRO Berlin AG. All projects adopted a PLC automatic control system to monitor and control processes. The Jiuchang alcohol distillery biogas plant is shown in Figure 1 and the Shunyi pig farm biogas plant is shown in Figure 2.

The pilot project plants were designed to: 1) demonstrate advanced technology commercially available in China for construction of biogas projects that meet national environmental regulations, ii) introduce international technology advances in plant design and equipment that result in improvements of plants constructed in China, iii) introduce applications for biogas utilization that increase the investment potential for plants by creating additional sources of income not previously widespread in China, and iv) provide experience and assistance for Chinese bioengineering companies to increase the technical and business development capacity of their operations.

Figure 1: Jiuchang alcohol distillery plant

Figure 2: Shunyi pig farm biogas plant

All of the pilot projects use biogas as a boiler fuel to produce heat for farm use or industrial processes and the Dengta and Shunyi projects have sold solid fertilizer in commercial markets for 30-80 RMB/ton. In addition, the Jiuchang plant also uses two 150 kW biogas generators equipped with heat exchange systems to produce electricity and extract heat for building heating applications. The Jiuchang project is also creating a market for liquid organic fertilizer working with local tree nurseries in Qingdao.

3.2. Regional Workshop Series for Business Development

Four workshops have been supported by the NDRC/UNDP/GEF Project for industrial scale biogas project development in Hangzhou, Zhejiang Province during February 2001, in Zhaoqing, Guangdong Province during December 2001, in Beijing during March 2002, and in Qingdao, Shandong Province during February 2004. The workshops were organized in partnership with the National Development and Reform Commission and the State Environmental Protection Administration, as well as other agencies, and were attended by a total of more than 700 local government representatives, owners and managers of livestock farms and industrial plants, bioengineering companies, and other key decision makers from all stakeholder groups important for the commercial development of biogas technologies in China.

Workshops were accompanied by tours of advanced operating biogas plants, including the pilot projects discussed in section 3.1. The workshops were structured in the form of business development forums, which included: 1) introductions from SEPA regarding new wastewater discharge standards and environmental enforcement regulations applicable to industrial plants and livestock farms, and introductions of government policies for biogas development by the NDRC and the Chinese Ministry of Agriculture, 2) discussions of the technical and economic characteristics of biogas technologies and project development by international and national experts, 3) information for the design, construction, and operational experience from advanced biogas projects by leading bioengineering companies, and 4) breakout sessions of the customer base of industry and

livestock farm representatives with bioengineering companies for detailed information exchanges followed by business discussions. A survey taken after the first three workshops identified 45 biogas projects developed directly as a result of workshop business exchanges in the form of contracts for technical assistance, design, or construction of plants.

The series of workshops have increasingly emphasized regional development strategies for government environmental programs and policy support, resulting in planning that expands the government emphasis from individual biogas projects to large numbers of projects in a given sensitive environmental region. For example, SEPA is now conducting regional watershed pollution control planning for the most sensitive lakes and river systems in China, which includes addressing wastewater effluents from all industrial and livestock farming activities within a given watershed.

3.3. Trends for Increased Commercial Viability of Biogas in China

With the passage of the Renewable Energy Law by the National Peoples' Congress in February 2005 and the announcement of implementing regulations for the law by the National Development and Reform Commission in 2006, biomass power projects, including biogas, now have access to the grid and can sell electricity based on a feed-in tariff that is the price electricity is sold from the electricity generating company to the grid company plus 0.25 RMB. As a result, biogas-generated electricity is a viable income stream for investors and the law has increased the importance of biogas utilization for electricity generation, increasing interest in biogas power projects. There will also be an impact on biogas plant design and construction, with more emphasis on biogas generation, use of CSTR and similar reactors, and development of centralized biogas power projects with multiple feedstock sources, resulting in more cost effective plant designs.

The NDRC/UNDP/GEF has supported the preparation of the first feasibility study in China for a centralized 2 MW biogas power project located in the Nanhu District south of Tai Lake in Zhejiang Province, a region that raises 23% of all the pigs produced in Zhejiang Province. The project is supported by the local government in Jiaxing, near Hangzhou in Zhejiang, and will utilize the waste from 300,000 pigs from multiple farms in the Xinfeng Township. A system of central collection stations for small farm waste aggregation has been established by the Zhejiang Rural Energy Office, which simplifies the collection of waste for the project. Potential investors have been identified for the project.

Other trends include: i) increasing number of domestic and international manufacturers, availability, and improved quality of biogas generator equipment in China, including combined heat and power (CHP) equipment, ii) increasing interest in co-generation applications, especially for industrial process heat and power, iii) developing interest in the use of the Clean Development Mechanism (CDM) for biogas projects (particularly active for landfill gas projects), which can improve the income of power projects by 15%, and iv) increased investor interest for biogas power projects, beyond the investment from the industrial and livestock farm sectors for pollution control projects.

Policy support for biogas development, especially for electric power generation, is also increasing from the National Development and Reform Commission, which in 2006 has drafted a National Biomass Development Roadmap. The NDRC/UNPD/GEF Project has also contributed to this effort by preparing a National Action Plan for Industrial-Scale Biogas Development that supports the near term and longer terms targets for biogas power generation of 800 MW by 2010 and 3,000 MW by 2020, as previously mentioned in Section 1.2. The Chinese Ministry of Agriculture actively supports biogas development for small household and mid- to large-scale farm applications, and the State Environmental Protection is currently executing its regulatory enforcement plan for control of industrial wastewater pollution.

4. Conclusions

The potential for biogas development in China is enormous based on estimates of resources from industrial and livestock farm wastewater effluents, landfill gas, and municipal waste treatment facilities. China's biogas power generation goals of up to 3,000 MW by 2020 are technically and economically achievable and could well be exceeded if more aggressively pursued. At present, however, the deployment of biogas technologies in China places a priority on pollution mitigation, which creates some limitations on the economic development of the biogas power sector. With the passage of the Renewable Energy Law in 2005, grid-connection and feed-in tariff incentives have been created that will expand the commercial range for biogas applications, including investment in biogas power plants. A restructuring of biogas technology development is needed to take full advantage of the commercial potential for biogas and create investor interest. Restructuring will include some adjustments in pollution and environmental regulations from SEPA, some changes in land use policies to help create new markets for biogas plant products, adjustments in farming and industrial practices, taking greater advantage of CDM project development, opening of new markets for industrial co-generation, and faster introduction of more efficient CHP and advanced biogas power equipment. With the incentives already in place, the transition to a more commercial deployment of biogas technologies in China is beginning to take place.

5. References

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