Biogas from Municipal and Agricultural Bioorganic Waste: Renewable Energy for China

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Biogas kommunaler und landwirtschaftlicher biogener Abfälle: erneuerbare Energie für China

Abstract

China became in 2005 the world’s largest coal consumer and second largest user of mineral oil and electricity. The Energy demand in China makes the country already to the second largest CO_2 producer worldwide (3,540m t CO_2 in 2003) and it’s going to surpass the US in 2009, even though China's per capita CO_2 emissions will still be only three-fifths of the average in industrialised countries in 2030. The politically recognised drivers to develop renewable energies in China are the constantly growing energy demand in parallel with the need to replace fossil energy and the aspect of climate change and global warming prevention. The potential renewable energy sources are wide spread, but the availability is restricted. For biogas generation from biomass NDRC considers energy crops, agricultural waste, landfills and sewage sludge. Within this mix of resources bioorganic municipal waste (BMW) is underestimated, as its biogas potential is at least one fourth of the target for feed-in-grid biogas energy in 2020.

Keywords

Biogas, renewable energy China, bioorganic municipal and agricultural waste, landfill-gas, anaerobic digestion, waste management, mechanical biological treatment

1 Introduction

Currently at least 100m t/a wet bioorganic matter contained in municipal solid waste (about 300m t/a MSW in 2050), 580m t/a agricultural (manure)- and agro industrial biodegradable wastes, landfills and waste water are potential sources to produce biogas as renewable energy in China. The strongly supported, but as well heavily discussed production of liquid and gaseous bio fuels from energy crops (about 50 to 100m t/a seen possible in 2020), which are somehow conflicting with food production, are in comparison to MSW from even limited importance. Besides energy production the Chinese development aims are, lessening of green house (GHG) gas emissions from waste storage and disposal and the reduction of CO_2 emissions from replacement of coal (29% of CO_2 will be avoided if a coal substitution of 14 to 16% by using MSW-biogas can be achieved - based on heat equivalent). Avoidance of GHG emissions contributes to lessen global warming. The current political framework in China is supportive to implement the required infrastructure jointly by authorities, entrepreneurs and farmers, but the capacities to do so have to be developed.

2 Key Policy Framework

The following are the main relevant policy drivers in China to foster organic waste utilisation jointly with energy production:

(1) '*Circular Economy Policy*' inspired by Japanese and German Recycling Economy Laws and its targets till 2020, based on the '*Cleaner Production Promotion Law*' (2002) by NDRC and SEPA, including a 'Life Cycle Assessment' approach.

(2) '*The Renewable Energy Law*' by NDRC, effective from 2006, is a framework policy, which lays out the general conditions for renewable energy to become a more important energy source, and supports various types of grid-connected renewable power generation. It includes wind, solar, water, biomass, geothermal and ocean energy. Obligations and prices are defined which enable the feed-in-grid of renewable energy into the existing power, gas or heat grids.

(3) '*National* 11^{th} *5-Year Plan*' from 2006 till 2010, aims to
- increase the treatment ratio of MSW after collection from 53.5% in 2005 to 60%, which implies a capacity increase from 80m t/a to 120m t/a, till 2010,
- support the electricity generation from landfill gas and on the other hand
- set energy efficiency targets, such as to limit energy consumption per industrial output value and to promote energy saving measures.

(4) *'China's National Rural Biogas Construction Plan'*, BCP by MOA (2003), is targeting operating 15m households biogas plants (using native organic waste) by 2006 and to make with 23m units 20% of the farmers biogas users in 2010.

(5) *'Minimization of Environmental Pollution from Livestock Breeding Waste'*, a SEPA policy (1999) triggered off by the severe impact to water bodies from diffuse pollution from intensive animal farming (Xiaoyan WANG).

(6) *'Construction of New Socialist Countryside'* national policy, 2006 to boost modern agriculture, infrastructure, pubic services and the farmers' income till 2010.

All the above-mentioned policies are supportive to develop an integrated bioorganic waste management scheme in China considering the renewable energy production within the 11th 5-Year Plan till 2010 and the long-term targets till 2020 and 2050.

3 Status of Biogas Production in China

China may be famous for the ability to use organic wastes for biogas production. By the end of the 19th century, simple biogas digesters appeared in southern China. In 1932 the first biogas company was opened in Shanghai with branches along the Yangtze River and in the southern provinces. China supported mass adoption of biogas in 1975 under the slogan "biogas for every household". The Chengdu Biogas Research Institute (BIOMA) was founded in 1979 to disseminate this know-how even on international level. But the application of the biogas technology is still until today primarily limited to decentralised small-scale biogas digesters in rural areas in the south and south–west of China. There is restricted experience with large-scale applications, and especially those technologies appropriate to the climatically colder provinces in northern China. Some middle and large-scale plants were built in the meantime, mainly under rural environmental protection aspects and biogas was a by-product. Under the renewable energy legislation the targets are changing and energy production is getting the focal point.

3.1 China's Biogas, a Part of the Renewables Mix

The overall Chinese energy policy target is to achieve a renewable energy supply of 16% in 2020, starting from 7% in 2004 (Figure 1). Biogas shall contribute with 24bn nm^3 biogas (grid-connected), deriving from all applicable biomass sources. This is at least three times more biogas production compared to the 7.3bn nm^3 generated in 2006 (current status see Table 1). Within China 'renewables' 18.5%, or 3% of the entire energy demand in 2020 should come from biomass (agriculture, industry, MSW, sewage sludge, small- and large-scale units, landfills), as shown in Table 2.

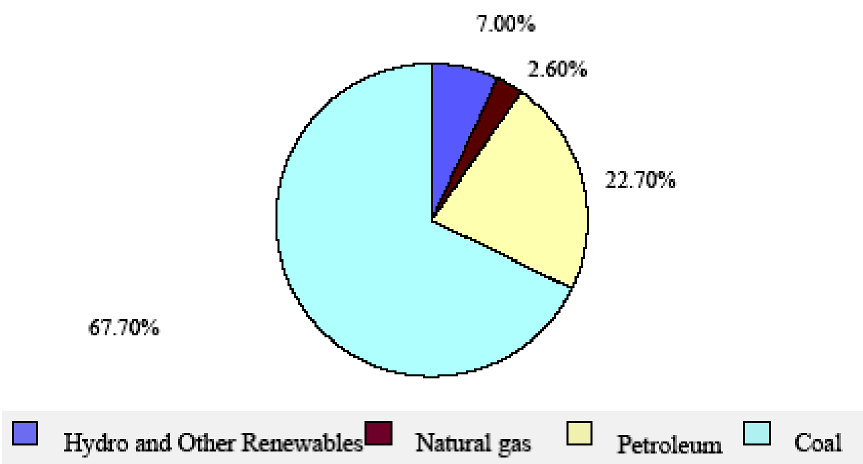

Figure 1 China's energy consumption with 7% renewables, 2004

Table 1 Production of biogas from waste biomass in China (2006) (bn nm^3/a)

Source / type of application	**Units** (n)	**BG**	**Source/Commend**
Agriculture or industry	> 4,000	> 1.0	MOA
Municipal wastewater and septic sludge	137,000	0.05	MOA
Household biogas digesters (small-scale)	17m	6.5	NDRC, MOA
Landfillgas installations	24	app. 0.12	EU Asia Pro Eco Proj.
Biogas from BMW or MSW, test scale	No	No	ICEEE, RRU-BMW
Total Biogas in 2006		> 7.3	= 4.6 GW_{tot} / 1.5 GW_{el}

Table 2 Status and targets in biomass based biogas generation within the renewable energy framework legislation, ( ) = estimates

	2005	**2010**	**2020**	**2030**	**Source**
Share of RE among total energy mix (%)	7	10	16	(30)	NDRC, CS
Share of biomass within total RE mix (%)		18.4	18.5		NDRC, CS
Biogas: total production (bn nm^3/a)	> 7.3		> 24		State Grid Comp.

Table 3 National annual biogas plants and electrification targets (bn nm^3/a) in China, till 2020

	2010	**2020**	**Source**
Landfillgas (in 2020: 100 out of 580 potential sites)	0.32 0.2 GW el	1.6 1.0 GW el	NDRC
Medium & large scale biogas production from agriculture and industry	1.3 0.8 GW el	4.8 3.0 GW el	NDRC
	4.700 units		MOA (BCP)
Biogas generated from municipal wastewater & septic sludge treatment	0.1		MOA
Rural small-scale household biogas (no electrification)	23m units (= 20% of pop.)	56m units (= 50% of pop.)	NDRC, MOA (BCP)
Overall biomass electrification target	-	30 GW el	NDRC

Regarding biogas generation from MSW the vision of the authorities is on landfill gas recovery CDM projects, following the tendency in many industrialised countries and the suggestions of international donors. But with this aspect it should be more carefully dealt with. The different waste quality (low content on slowly digesting bioorganic matter) is changing the landfill behaviour of the waste disposed off considerably (see also chapter 3.6). This contributes to an already low gas collection efficiency of LFG collection systems. In Table 3 the expected electricity generation from biogas and the anticipated number of LGF collection and utilisation plants is listed. This is part of the 2020 overall biomass electrification target of 30 GW.

3.2 Biogas from Small-scale Household Digesters

The small-scale household biogas digesters are well established and politically strongly supported in the southwestern rural areas of China and the number of household biogas digesters is growing for some million units every year. In 2003 8m units (typical size 8 to 10 m^3) were built. In 2005 already about 10% of the rural population is producing 5.5bn nm^3/a biogas from 15m units. 56m digesters will be operated till 2020 and 20bn nm^3/a of biogas (Table 6) will be produced for decentralised energy supply (cooking, lightning), and will make these areas widely independent from central energy supply systems. Furthermore water and soil pollution problems from liquid and solid organic waste disposal are widely solved. This is an additional motivation to develop further this sector based on the ‘National Biogas Construction Plan of the MOA 2003.

3.3 Middle- and Large-scale Agricultural and Agro-Industrial Plants

From 2001 on, the Chinese government is emphasizing on the importance of biogas technology development and its implementation for agricultural production, rural energy supply, and environmental protection, and finally on the improvement of the living conditions of the rural population. Since that time 0.35bn EUR were invested into biogas technology dissemination. 4,000 middle- and large-scale biogas plants were built mainly at pig, chicken and cattle farms, and the total biogas output is about 0.34bn nm^3/a, from which a part is used for electricity production (400m kWh per year in “island” mode, no grid-feed-in) and the rest is supplied for cooking to 1.4m households.

Industries, such as the sugar industry may generate electricity from waste (-water). For example more than 800 MW are generated in the sugar-growing provinces of Guangdong and Guangxi alone. Another example is the alcohol production industry, such as the distillery in Nangang (Henan), which supplies 20,000 households with biogas. The Chinese agricultural biogas plant potential includes at least 14,000 intensive livestock farms with more than 100 livestock units (1 LSU = 500 kg of animal live weight) each. In the 11th 5-Year Plan period, the investment from the Ministry of Agriculture in biogas plants is expected to be 250m EUR per year.

3.4 Biogas from Municipal Wastes

In China most of the municipal solid waste (155m t in 2005), which contains an extremely high biodegradable organic matter content (between 60 to 80% FM), is produced in the 660 cities, where about 360m or 28% of the population live. Urbanisation is further progressing and in 2050 about 900m people will reside in cities.

The discussion about ecological inefficiency of large installations versus decentralized small-scale installations on household level is not applicable to all those metropolis areas, from which the waste must be taken out to treatment sites of environmental reasons anyway, and where no possibility exists to built decentralized small-scale AD plants within the dense structure of high rise and multi storage buildings.

Landfills, still the destinations for 86% of the collected MSW in Chinese cities, are usually located in remote areas outside the cities. However industrialized large-scale biogas plants can be built within the city, and for cost- and eco-efficiency optimisation MSW biogas plants or agricultural co-generation plants should be located nearby the generation of waste and close to the place of energy consumption.

For example: from 1m people 70,000 t/a BMW can be collected by source separation at households. Out of this amount of feedstock about 8m nm^3 of biogas can be produced (65% CH_4, heat value 6.2 kWh/m^3) (see Sino-German RRU-BMW project, BMW net-collection rates and biogas generation potential, Raninger et. al. 2006). With this biogas a gas engine (CHP) with 4.5 MW (1.5 MW_{el}) can be continuously operated, or the gas can be directly supplied into the public city gas grid and be mixed with natural gas (up to 5% without any treatment, done in about 12 countries worldwide already). For biogas delivered through a gas grid the prices in China are between EUR 0.05 and $0.12/m^3$. Further the biogas can be used for cooling and heating, cooking, lightning and as well as liquefied transport fuel. But processing and compressing costs for liquefaction are with EUR $0.12/m^3$ not competitive (Anshan/Liaoning landfillgas liquefaction test plant).

3.5 MSW/BMW Biogas Potential Forecast

Basically both, mixed MSW and BMW from source separation can be used for biogas production. In order to comply better with the principles of ‘Circular Economy’ and to close the recycling loops by providing organic fertilizer instead of landfill material, the RRU-BMW project in Shenyang is focusing on source separation of BMW.

Following the results and by means of a conservative estimation the following energy production forecast can be made (Table 4): 70 kg/c.a (per capita and year) source separated BMW (participation rate 70%, without commercial BW sources) can be realistically collected in a residential area. This relates to a 69% bioorganic matter recovery rate. Chinese cities collect 155m t in 2005 of MSW. If we consider that under the abovementioned conditions only 40% of the BMW potential is used (28% bioorganic matter recovery rate) 28m t/a of BMW would be available as feedstock for biogas plants. The gas yields of source separated BMW was investigated with 120 m^3/t. From 28m t/a about 2.8bn m^3/a biogas will derive, which is equivalent to 1.8 GW_{tot}.

The biogas generation prognosis from MSW/MSW till 2050 considers an
- increase of urban population (urbanisation rate of 70% in 2050)
- increase of specific MSW production of 0.8% per year (packaging and secondary raw material recycling is not seen as MSW for disposal and therefore not included)
- increase of MSW collection rate in the cities from 53.5% (2005), 60 % (2010, 11th 5-Year Plan) and up to 75% estimate (2050)
- increase of relative organic content by further reduction of coal ash from decentralised cooking and heating in the non-gas or centrally heated areas (widely completed)
- increase of participation rate in BMW separation from 70% (as found in the RRU-BMW project 2006) to 80% estimate in 2050
- increase of BMW residential catchment areas (or MSW utilisation) from 40% to 75%
- a decrease of organic matter content in MSW from average 66% (actual China wide average content in 2005), to 45% by assumption that the consumer behaviour of Chinese people will change (instant food, increased number of single households,).

Table 2 Biogas generation potential from municipal solid waste in China till 2050

Description	**2005**	**2010**	**2020**	**2050**
Urbanisation rate (%)	28	36	51	70
Citizens (million)	360	470	650	940
MSW (t/c.a)	0.83	0.85	0.9	1.0
MSW collection rate (%)	52	60	65	75
MSW from cities (m t/a)	**155**	**240**	**380**	**700**
MSW organic matter (%)	66	62	55	45
Organic matter in MSW (t/a)	102	150	210	315
Citizens participation * (%)	70 *			80
BMW overall potential (m t/a)	**71**	**105**	**147**	**252**
BMW collection area (%)	40	45	55	75
BMW net-potential (m t/a) *	**> 28**	**> 47**	**> 80**	**> 189**
Biogas potential (bn $m^{3/}$a)	**> 2.8**	**> 4.7**	**> 8.0**	**> 19**
BG energy potential (GW_{tot})	> 1.8	> 2.9	> 5.0	> 11.8

* acc. to RRU-BMW field test results, participation rate 70% and net-BMW collection amount 70kg/c.a (2005/2006)

Till 2050 the amount of MSW and BMW will raise by app. 2.5 times and 19bn nm^3 gas could be generated (Table 4). The total potential is still higher, as so far in 2050 still only 75% of waste is anticipated to be collected in the cities and only 80% of the collected waste is considered for this kind of treatment. This, up to now by the Chinese authorities not fully considered potential, would be supportive to achieve the targets of the 'renewable energy law' to grid-feed-in 24bn nm^3 biogas in 2020 more easily. A significant portion of one third could come from MSW sources.

3.5.1 Status of Development of MSW/BMW Biogas Plants in China

So far full-scale MSW/BMW biogas plants do not exist in China, but at present some 20 MSW-, food waste- and manure co-fermentation-AD projects are under preparation /implementation (Table 5). This development has started to solve the problem of an environmentally and hygienically sound utilisation of the large amount of restaurant waste in Chinese cities (Beijing 1,050 t/d, Shanghai 1,200t/d, all China 60m t/a; Nie Yongfeng, 2006). The currently planned biotechnological MSW projects using anaerobic digestion (anaerobic MBTs), may cover a capacity of 4m MSW t/a and make use of less than 3% of the biogas potential from MSW /BMW sources in 2010. Only 1.5% of anticipated MSW treatment ration increase (11^{th} 5-Year Plan target 53.5 – 60 %) will be achieved. In Europe, besides of a booming number of BMW biogas plants, 80 MBT plants are operating in 2005. 50 of them in Germany, and app. 30% are using AD to produce biogas.

Table 3 MSW/BMW and food waste biogas plants currently under consideration in China

Location	Start	Feedstock	Technology Developer	Capacity m t/a	€	Commends
Beijing Dong Cun Taihu Coun.	2007	Restaurant- & MSW,manure	Linde Valorga Biomax	0.2	Inv.18m Fee 13.5/t	Feasibility 2005, CDM
Beijing	till 2010	Restaurant- &. MSW, ..				9 plants anticipated
Shanghai Jinshan	2008	MSW, BMW		0.22	Inv. 32m	Ppublic tender
Shanghai Putuo, Shanghai	2007	Municipal wet waste	Valorga Biomax	0.18 to 0.29	Inv.30m Fee 17/t	Feasibility 2005, CDM PDD1/06
Guangzhou Likeng (Guandong)	2007	Municipal wet waste	Valorga Biomax	0.36	Inv.32m	Preparation
Changsha Huiming (Hunan)	2005	MSW		0.73	Inv.11m	Biogas power plant
Mianyang (Sichuan)	2002	MSW	Tunnel type	0.25 AD: 3600t/a		AD as pilot project
Yingkou (Liaoning)	2007	MSW, SS	Tsinghua Tongfang	0.27	Inv.20m	
Shenyang (Liaoning)	2010	BMW (source separation)	Wet AD recommended	0.12 to 0.20	Inv.12m Fee >6/t	Prefeasibility-study

3.6 Biogas from Waste Water and Sewage Sludge

In 2005, the total discharge amount of wastewater across China amounted to 52.5bn t, among which the industrial effluent came up to 24.3bn t and domestic sewage amounted to 28.1bn tons. The COD emission was in total 14.1m tons. Some cities such as Shenyang have achieved within 5 years a WWT treatment ratio of 73% (2006).

About the same amount of biogas generated from MSW can derive from sewage sludge fermentation at communal and industrial wastewater treatment plants or decentralised wastewater treatment systems (DEWATS). Organic wastewater treatment in anaerobic steps has the potential of recovery of methane in industrial plants with high organic load. Until the end of 2004 anaerobic treatment plants, which are installed for decentralised treatment of municipal wastewater accounted for 137,000 units, treating 0.5bn t/a of wastewater. The size ranges from 5 to 100 m^3 wastewater per day. The accumulated digester size was more than 5m m^3, which correspond to around 50m nm^3 biogas generated annually. Although the amount of biogas per unit produced may be not significant from the energy point of view, but the biogas settler supports pollution reduction, increasing public health and protecting water resources. Until 2010 the goal of the MOA is to implement more than 200,000 DEWATS in peri-urban areas, townships and villages.

In 2020 the number of middle- and large-scale biogas plants will reach 10,000. The pool for anaerobic grey water treatment should increase by 120,000 accumulating to 260,000 in total. Besides sewage sludge, there is a total amount of estimated 300m t/a of septic tank sludge and “night soil” collected in rural, semi-urban, and urban areas without sewage connection. This source offers a biogas potential of at least 15bn nm^3/a.

Chinese cities are facing the situation that the amount of sewage sludge from central wastewater treatment is constantly increasing, in line with the ongoing construction of new wastewater treatment plants. But due to severe pollution of the sludge land application is not acceptable and incineration is too costly. Therefore anaerobic digestion could be at least a step to produce energy prior to storage of this pre-stabilised and dewatered sludge at landfills. Sewage sludge digestion, even with a low efficiency is currently only done at some WWTPs in China (f.e. Hangzhou Sibao 600,000 t/d, partly at the Shenyang North WWTP 400,000t/d,). The MOA calculates with 0.1bn nm^3/a biogas from wastewater and sewage sludge treatment in 2010.

3.7 Biogas from Municipal Waste Landfills

The 11th National 5-Year Plan encourages the energy production from wastes, including biogas, incineration and landfillgas recovery. The latter is currently installed at 24 landfills, from which app. 0.12bn nm^3/a biogas is deriving (Table 1). 15 of them are approved or “in the pipeline” for CDM. The average installed capacity per landfill is 2MW and the electricity generated by gas engines (GHP) is fed in the public electricity power grid. The potential in China is about 100 out of 580 'official' landfill sites. For incomes from electricity sales from landfillgas to grid companies, the revenues are between EUR 0.046 and 0.06/kWh, no VAT and no VAAT and only 15% income tax to be paid. These are the highest tax benefits among all types of renewable energies, where the VAT amounts usually from 6% to 13%, the VAAT to 8% and the reduced income tax (except for hydropower) to 15% (Table 8).

But on a long-term land filling has to be seen as an 'end of the pipe' solution. In China only 20 to 40% of the generated landfill gas (LFG) can be recovered at sites, which are equipped with a state of the art LFG-collection system. The reasons are:

- *The composition of waste:* high content on fast degradating bioorganic waste (with a very low content on cellulose, lignin and other slowly degradating biopolymers,)
- *The conditions in the landfill body:* water saturated, high density, high temperatures
- *The operating practise of landfills:* uncontrolled water levels, widespread open filling areas without temporary top-covers, if top-cover layers they are without HDPE linings, no functioning (horizontal) active gas well systems

By 2010, the LFG recovery and utilization rate of 10% amounts to 0,84bn nm³, equivalent to 0.42bn m³ of CH_4. By 2020, 50% recovery and utilization may amount to 5bn m³ of LFG, equivalent of 2.5bn m³ of (Table 3). Thus, the amounts of carbon emission reduction will be 2.5m t by 2010, and 15m t by 2020. But landfill gas collection projects in China, and especially if they are implemented under CDM, will have to proof CH_4 capturing quantitatively for many years (CERS, Certified Emission Reduction). The conditions and practice of landfills in China may keep the CER results far behind the expectation of the CDM project developers. Therefore, following the EU policy, landfilling of biodegradable waste has to be banned and landfill gas collection should only be seen as temporary pollution control measure for existing sites.

4 Overall Biogas Production and Potential

Decentralised AD systems (household small-scale bio digesters and decentralised waste water systems DEWATS), as well as centralised biogas plants (middle- and large-scale AD plants in the agricultural, industrial and municipal sector) will contribute to the energy from biogas production in China. The biogas production in 2006, the estimated or targeted BG quantities 2010 and 2020 and the overall production potential are drawn up in Table 6. Besides of about two times 25bn nm^3 of biogas from MSW and from municipal wastewater (sewage sludge), agricultural residues and livestock waste can produce 70bn m³ of biogas (MOA). In total there are about 1.5 to 2bn t/a from biomass and the landfills which may produce 150 to 200bn nm³ biogas, or at least 96 GW).

Table 4 Biogas production in 2006, forecast for 2010 and 2020 and overall production potential, (bn nm^3/a), (italic = estimates).

	Source	**2006**	**2010**	**2020**	**Potential**
De-central	Household small-scale bio digesters	6.5	11.0	19 - 22	25 **
	Waste water DEWATS (<100 m^3/d)	0.05	0.12	*1.0*	15
				20	
Central	Urban MSW/BMW	0.0	0.16	*6.0?*	**25** – 30 *
	Agriculture and agro industry, med/large (wet waste, manure,)	0.34	3.8	5.6	70 - 80
	Landfills (old and new MSW)	0.36	1.4	4.4	< 2 - 5 ***
	Sewage sludge (WWTP)	0.05	*0.5 ?*	*6.0?*	25 *
Biomass based biogas production target (State Grid Company)				**24**	
Production / production target, potential		7.3	**19**	**44**	> 155
Non waste sources: Energy crops (but mainly to produce liquid bio fuels)					*10*

* potential for 2050, consideration of urbanisation and infrastructure development

** 50% realisation

*** in 2010 China 290m t/a MSW. If 70% is disposed of in landfills with methane collection, the landfill gas recovered could be equivalent to 40 to 280bn m3 (UNEP, Intergovernmental Panel of Climate Change), the World Bank estimates are much more realistic with 10bn m3/a.

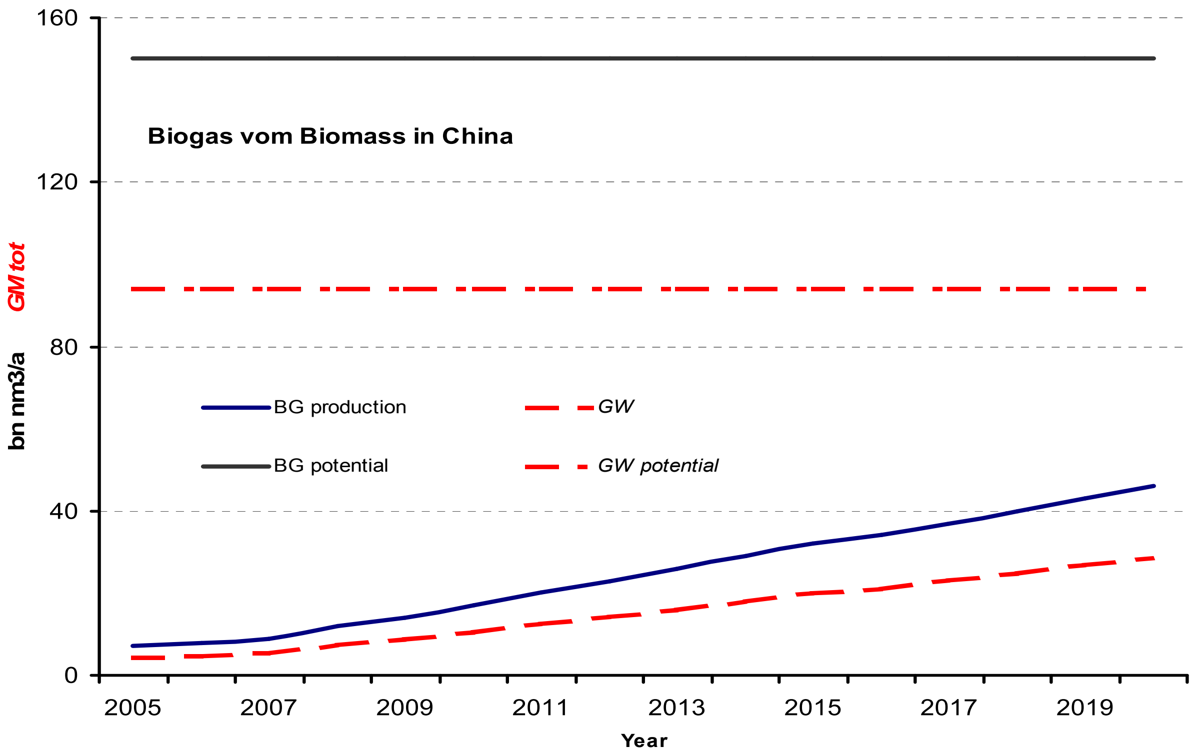

Figure 2 Course of expected biogas and energy production from biomass (bn nm^3/a) in China and biomass biogas and energy production (GW_{tot}) potential.

It is estimated that about one third (43bn nm^3) biogas might be generated till 2020. The forecasted figures are seen in Table 6 and Figure 2. The tendency will be, that due to the urbanisation more suitable biogas sources will be appear in the city, and in the rural areas, because of the industrialisation of agriculture, more middle- and large-scale plants will be required. According to Tab. 6 there will be the need for using urban waste sources to comply with the renewable energy targets. The benefit of using BMW from source separation and not just from mixed MSW is, that the separation could be introduced right away (PR measures required) in the catchment areas of biogas plants and no landfill fraction will be produced as the compost is 'clean'. However the product after AD of urban wastewater sludge has to be disposed, and it may take extensive (but necessary) efforts to achieve a pollution level appropriate for sludge land application.

5 Operating Models

5.1 General Business Models

The investment and/or operation of MSW/BMW AD plants can be carried out by governmental owned organisations, jointly between municipal and private service providers or by private entrepreneurs. So far it depends on the attitude of the individual municipal government, whether public services are going to be outsourced. In Shenyang the privatisation of street cleaning has created competition between the contractors and this was the key to success to effectively change the city appearance by stopping waste littering. Shanghai has already started for some times to leave waste services, such as landfill operation and biogas-plant operation, to private companies.

5.2 How to Involve the Rural Population in MSW Biogas Production

A new income and employment opportunity for the rural population could be developed as part of the 'Reconstruction of New Socialist Countryside' policy if farmers act in the suburbs of the large cities or in smaller townships as BMW collectors and AD plants operators. The basis would be BOT or BOO contracts, in which the type of requested services is clearly defined. What has to be done, by which technology, for how long time (8 to 15 years recommended), and for how much money, (terms of remuneration, fee based, revenues for product and energy sales) will be subject of this contract, further the way of financing (private investment, international soft loans, CDM,), preferential local conditions (tax benefits,), etc. in order to keep the gate fee socially acceptable.

This proposal would follow the management models in some middle European countries, where the farmers took over partly biowaste collection and treatment services. BMW from townships or suburbs from large cities is collected by the farmers themselves and treated or co-treated with their own agricultural waste at their own composting or biogas plants. Biowaste, yard-, and green waste from public parks, gardens, road and riverbanks, restaurant waste and even bioorganic waste from industrial or commercial activities are taken over against gate fees, treated and converted into biogas and /or Electricity (GHP) and the solid remainings (compost) are used to maintain their own arable land. In Austria 20% of the total bioorganic waste is treated in this way. The farmers earn between EUR 30 and 50 per ton BMW for collection and between EUR 40 and 60 per ton for treatment, plus the benefits from biogas/electricity and compost sales. In Lower Austria 60% of the plants are operated by farmers running plants up to 5,000t/a.

For China it is suggested to take over a similar model with the benefit to provide new jobs for the farmers and to support the recycling of organic matter. It is estimated that 10 - 20% of BMW from the cities could be left to 'new entrepreneurs' in the rural areas around the large cities (development of urban areas in China nearby the city suburbs). The size of the BMW or co-treatment plants could be small- and middle-scale plants from 20 to 80 t/d each. The required number of decentralized AD plants might be app. 800, whilst the demand for large-scale plants is estimated to be 200 till 2020 (Table 7).

Figure 3 Potential markets of MSW and BMW biogas plants in China (source ICEEE)

Biogas plant operator	2006 - 2010	2010 - 2020	Commends
Municipal & Private Large scale MSW and BMW from cities (200 - 600 t/d)	Projects for about 4m MSW t/a under implementation (Tab. 5)	> 4.6 – 7bn m³/a 200 – 400 units (150,000 t/a for average 2m people each)	Potential market for waste service companies
Agriculture & Private Middle size BMW plants at city suburbs (20 – 80 t/d) *Agricultural waste seen as co-substrate*	No (Restaurant waste for animal feeding)	> 1.2 – 2.6bn m³/a about 800 – 1600 units (40,000 t/a for average 12,000 people each)	Potential market for rural population, new concept to be promoted

5.3 Investment in the Municipal Biogas Sector

In the Chinese biogas sector the following basic forms of foreign direct investment are possible: a) wholly foreign-owned enterprises, b) China-foreign joint ventures, c) China-

Figure 4 Renewable energy tax incentives in China 2007, (%)

	Value-Added Tax (VAT)	Value-Added Annex Tax (VAAT)	Corporate Income Tax	Import duties
General	17	8 % of VAT	33 / 25 **	23
Small Hydropower	6	8 % of VAT	33 / 20-25**	
Biogas	13	8 % of VAT	15 *	Favourable import duties up to 0% for high-tech equipment
Wind	8.5	8 % of VAT	15 *	
Landfillgas	No	No	No	

* might be further reduced locally (Inner Mongolia Autonomous Region and Xinjiang Uygar Autonomous Region)

** New corporate income tax enforced at 01.01.2008, reduced rate for low profit companies foreign cooperative enterprises d) cooperative development. The time limit for foreign investment enterprises is usually 10 to 30 years and can be negotiated. Tax and other preferential financial incentives (Table 8). Some bio-energy equipment, such as gas engines, are classified as high-tech and may be exempt from customs duties.

6 Summary

Within the context of the recent Chinese Renewable Energy Policy the biogas potential from municipal solid waste is still an underestimated resource. The utilisation of clean bioorganic municipal wastes (BMW) from source separation for biogas and clean compost production offers, besides of the ecological benefits, new employment opportunities in the waste sector as well as for the rural population in the neighbourhood of cities. Farmers may operate bio-treatment and biogas plants (20 to 80 t/d), they may co-treat wet-organic bioorganic waste from urban and rural sources and they will benefit from biogas energy sales and from upgrading the soil fertility. In addition the support of rural household scale biogas plants (56m in 2020) will continue.

Chinese authorities may recognize the BMW biogas energy potential. About one third, or 8bn nm3, of the targeted feed-in-grid biogas production in 2020 could derive from municipal waste biogas plants and is to be seen in line with the other non-fossil energy targets in China. In 2050 18 GWel from biogas electrification, deriving from 300m t/a BMW feedstock, may generate the same amount of Energy as the worldwide recognised ‘Three Georges Hydropower Project’.

Due to the low efficiency of landfillgas collection systems (20 – 40%) in Chinese landfills, filled with easy-biodegradable organic matter, degassing systems should only be applied for existing landfills in the sense of pollution prevention and more emphasis should be put on MSW/BMW biogas plants prior to landfilling.

To establish a successful municipal-agriculture biogas demonstration projects, jointly supported by MOC, MOA and SEPA, for example in Jiangsu province, management, engineering, know-how for operating and financing (including CDM) and key equipment should be provided from international partners. Germany might have a strong position to provide technical know how and to be partner in pilot projects, due to the own country experience with organic waste management and renewable energy enforcement. But till 2010 the predictable municipal waste biogas projects (anaerobic MBT projects) in China will only make use of 3% of the MSW/BMW potential and will only contribute an additional 1.5% MSW treatment (see 11^{th} 5-Year Plan target). Finally it will depend on the success of the first demonstration projects in China whether the mind will be open to solve the long awaited waste management and energy problems jointly.

7 Zusammenfassung

Kommunale biogene Abfälle sind in China immer noch eine unterbewertete Biogas Ressource, dessen Potential bei der Umsetzung des Erneuerbaren Energie Gesetzes und der Produktion von Energie aus Biomasse nicht in vollem Umfang berücksichtigt ist.

Die Einführung einer Verwertung getrennt gesammelter kommunaler biogener Abfälle in Chinas Großstädten und die Herstellung von Biogas und hochwertigem Kompost bietet neben ökologischen Vorteilen neue Arbeitsplätze im Bereich Abfallwirtschaft aber auch allenfalls in der ländlichen Bevölkerung, wenn diese in den Stadtrandgebieten als Biofallverwerter nach Europäischem Muster eingebunden werden. Dies wäre weiteres im Sinne der aktuellen Chinesischen Schwerpunktpolitik ‚Entwicklung des ländlichen Raumes' 2006 bis 2010 zusätzlich förderungswürdig. Die Bauern könnten dann selbst städtische und ländliche biogene Abfälle in Anlagen mittlerer Größe (5,000 – 20,000 t/a) gemeinsam behandeln und die Vorteile aus der Biogasverwertung und der dringend erforderlichen Bodenverbesserung ziehen. Ungeachtet dessen sind die dezentralen Kleinbiogasanlagen im Süden Chinas (56m Einheiten bis 2020) weiterhin zu fördern.

Die Chinesischen Behörden sollten sich des hohen Biogaspotentials aus Siedlungsabfällen besser bewusst werden. In etwa ein Drittel (oder 8 Billionen nm^3) derjenigen Biogasmenge die im Jahr 2020 zur Herstellung von Energie für die Netzeinspeisung geplant ist, könnte realistischer Weise von Biogasanlagen kommen die mit kommunalem Bioabfall betrieben werden. Somit ist Biogas aus kommunalen Abfällen als relevante Energiequelle gemeinsam mit den anderen nicht fossilen Energieträgern in China (Wind, Sonne, Geothermal,) zu sehen. Im Jahr 2050 könnte aus 300 Millionen t kommunalen biogenen Abfällen 18 GW Elektrizität hergestellt werden, was der Stromproduktion des ‚Drei-Schluchten Staudamm Projektes' entspricht.

Aufgrund der, speziell unter Chinesischen Verhältnissen, äußerst geringen Effizienz von Deponienentgasungssystemen (20 - 40%), sollte von dieser Strategie für neu abzulagernde Abfälle abstand genommen werden (einschließlich der zahlreich geplanten Deponiegas CDM Projekte), und besser die Behandlung der, hoch mit biogenen, extrem leicht abbaubaren Substanzen versehenen Abfälle, vor der Deponie in Biogas- und MBA anlagen gefördert werden. Im Sinne der Emissionsminimierung sollten Deponiegasprojekte somit nur für Altdeponien unter realistischen Annahmen betrieben werden.

Neben anderen Standorten zeigt sich die Provinz Jiangsu insbesondere an dem Ansatz landwirtschaftliche und urbane Abfälle gemeinsam zu behandeln interessiert. Um ein auf nationaler Ebene wegweisendes Demonstrationsprojekt zu etablieren bedarf es der Unterstützung der nationalen Ministerien für Bauten, Landwirtschaft und der Umwelt Agentur SEPA. Das technische Know–how wie auch das Investment könnte von Deutschen Partnern eingebracht werden, die aufgrund der langjährigen Erfahrungen mit Bioabfallverwertung im eigenen Lande die nötige Erfahrung aufweisen.

Die bis 2010 in Vorbereitung/Planung befindlichen Biogasanlagen (MBAs) für kommunale Abfälle in China sehen jedoch lediglich eine Nutzung von weniger als 3% des MSW/BMW potentiales in China vor, und diese werden nur zu 1,5 % zur Verbesserung der im 11-ten Fünf-jahresplan angestrebten Verbesserung der Abfallbehandlung beitragen. Letztendlich wird es vom Erfolg der ersten Demonstrationsanlagen in Beijing, Shanghai, Guangzhou, abhängen ob die energetische Nutzung von nass-biogenen Abfällen einen Durchbruch erzielen kann, um in weiterer Folge Energie- und Abfallprobleme Chinaweit in synergetisch zu lösen.

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Abbreviations

AD	Anaerobic digestion (fermentation)
BCP	China's National Rural Biogas Construction Plan
BG	Biogas
BOT	Build-Own-Transfer
BOO	Build-Own-Operate
BMW	Bioorganic municipal waste
CDM	Clean Development Mechanism (emission trading system under the Kyoto protocol)
CDM PDD	CDM project design document
CER	Certified Emission Reduction
CIM	Center for International Migration and Development of the German Government, Frankfurt
CHP	Combined heat and power generation
COD	Chemical oxygen demand
CS	Credit Swiss
DBFO	Design-Build-Finance-Operate
DEWATS	Decentralized Waste Water Treatment System
EU	European Union
GHG	Green house gas
HDPE	High density Polyethylene
ICEEE	Institute of Clean Energy and Environmental Engineering of SYIAE
LFG	Landfill gas
LSU	Livestock unit
MOA	Ministry of Construction
MBT	Mechanical biological treatment
MSW	Municipal solid waste
MOA	Ministry of Agriculture, Beijing
MOC	Ministry of Construction, Beijing
MW	Municipal waste
NDRC	China National Development and Reform Commission, Beijing
PSP	Private sector partnership
SEPA	State Environmental Protection Agency, Beijing
SKL	State Key Laboratory
RE	Renewable energy
RRU-BMW	Sino-German Project on Resource Recovery and Utilization of Bioorganic Municipal Waste
VAT	Value added tax
WWTP	Waste water treatment plant

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