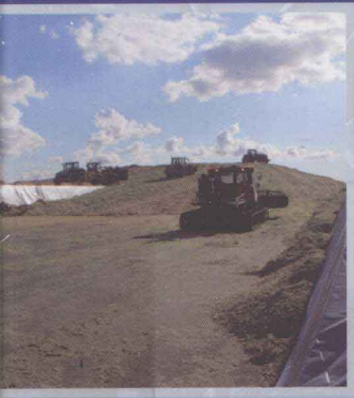
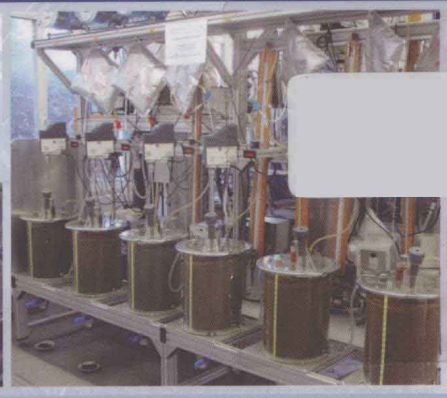
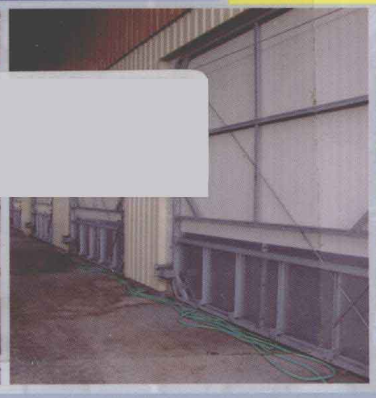
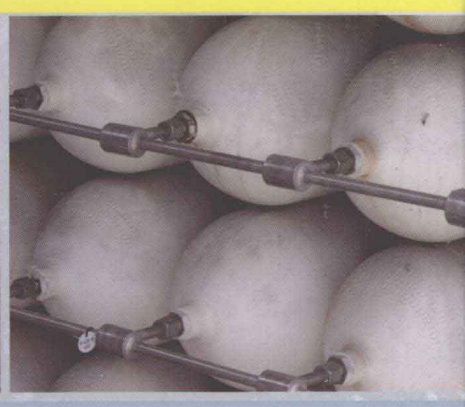
沼气工程与技术

Biogas Engineering and Application

第2卷
Volume 2

董仁杰　(奥)伯恩哈特·蓝宁阁　主编

Edited by: Prof. Dr. DONG Renjie
Prof. Dr. Bernhard Raninger

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- **Papers of the Sino-German GIZ Biomass Utilization Project of MOA in China**
  德国国际合作机构与中国农业部合作的中德生物质能优化利用项目论文集
- **Proceedings of 2011 Forum of Renewable Energy Promotion in Developing Countries**
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PREFACE

After the so-called 19th century of 'coal' and the 20th century of 'oil', the 21st century would be probably a century of 'gas'. Carbon neutral gases from renewable sources will have priority to play an important role in energy supply, in order to tackle fossil carbon emissions, which is another challenge and threat to our planet's ecological condition to survive.

The power sector is one of the main carbon emitters and therefore Germany intends to provide in the year 2050 about 60 percent of its energy from renewable sources, from which again 60% will derive from biomass. The natural gas demand in Germany should be covered in 2030 by at least 10 billion m^3 or by 11.5% through biogas and the electric power supply will derive in 2050 by 100 percent from renewable sources with a potential of at least 12% up to 20% deriving from biogas. The transport shall be fuelled in the future by electricity for small cars for mainly local traffic and trains and with biogas for heavy duty vehicles and far distance ground transportation. Bio-methane from biogas can easily be stored in the national gas grids and storage systems and it will turn out, as one of the most likely options, to solve the issue of electric power storage, derived from surplus wind and solar power, at times when the production exceeds the demand, through producing hydrogen through electrolysis and to convert this hydrogen into bio-methane. By this way bio-methane can be produced at biogas plants even without additional purification steps.

Biogas is basically a base-load energy supply regime and available when wind or solar is not available or not sufficient. In the future biogas can be produced more predictable on demand for peak load coverage, to be available when the power market prices are high, without compromising on specific performances. Biogas for peak load coverage can be achieved on one hand by using the before mentioned natural gas storage options, but as well by producing biogas or bio-methane on demand through advanced biogas technologies.

In Germany the potential to extend biogas is somewhere between 2-3 times of the current capacities and only in combination with a strict energy saving target, which anticipates to reduce energy consumption by 50% till 2050 will help to keep biogas playing a prominent role in the renewable energy mix. In China, as the development of grid connected biogas is still at the beginning, the potential to develop biogas is still much higher. Chinas biogas potential is at least 20 times that of Germany and as the energy produced from Chinese biogas plants is currently only about 10% of that in Germany, the extension factor in China will about at least

200 times. But reliable and matured technologies and suitable business and market conditions are required to make biogas a competitive business.

In the future the agricultural sector will take more and more over an important role in energy provision, with an expected overall agricultural market share of 11%. China can use this opportunity as well to strengthen agribusinesses and to further support the socio-economy in rural areas.

Highly required new waste management solutions in China growing urban areas to catch up the demand of waste disposal and low carbon society, where biogas from the bioorganic waste fraction will and must play a key function, and the growing understanding that bio-ethanol as liquid transport bio-fuel is also not the best possible economic and sustainable solution and the ecological threats from nuclear power, experienced once more in Fukushima this year, will propel further the biogas sector. The Chinese Government is taking action to support the biogas sector framework conditions, inter alia by settling further close cooperation with the German government to jointly develop biogas from domestic to international performance.

The 2nd volume of Biogas Engineering and Application is reflecting this development and we wish all readers the insights they expected.

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Beijing, December 2011

前　言

如果说十九世纪是“煤炭”时代，20 世纪是“燃油”时代，那么 21 世纪或将是“燃气”时代。21 世纪以来，化石燃料燃烧导致的碳排放严重威胁着地球的生态环境，由可再生资源生产的碳中性燃气将得到优先重视。

能源领域是主要的碳排放源之一。以德国为例，计划到 2050 年，可再生能源将占国内能源产量的 60%，且其中 60%源于生物质。到 2030 年，天然气需求的 11.5%（即 1×10^{10} m^3）将由沼气代替。到 2050 年，可再生资源将提供德国全部的电能，其中沼气发电将达到电力生产总量的 12%～20%。未来小型运输工具如小轿车，当地主要交通工具和火车的燃料将由电能所代替；大型交通工具和远距离地面运输将使用沼气为燃料。沼气所产生的生物甲烷并入国家天然气管网或储存于燃气贮存系统中，这也为电力的存储提供了另一种解决方法。当电力产量大于需求量时，风能与太阳能所产电能可以用于电解产氢，再将氢气转化为生物甲烷；使用这种方法，沼气厂甚至可以不需要额外的提纯工艺便可生产生物甲烷。

沼气主要是一种基本负荷型能源，在风能或太阳能不足时可以供给能源。未来沼气能够根据用能需求定量生产，而且能够在能源市场价格较高时生产。沼气能够通过上述天然气储存方法实现用能高峰期补充能源，也能够通过先进的沼气技术生产沼气或生物甲烷来定时补充能源。

德国沼气潜力可以是目前沼气产量的 2～3 倍；只有在严格遵循节能目标，即在 2050 年减少 50%能耗的前提下，才能使沼气在可再生能源中扮演重要的角色。在中国，沼气并网尚处于初级阶段，因此有着巨大的发展潜力。中国沼气潜力约为德国的 20 倍，但是目前沼气产量只有德国的 10%，这就意味着中国沼气的增长空间可以达到目前的 200 倍。为了使沼气工程成为一种具有竞争力的产业，中国需要发展成熟可靠的沼气技术并完善合理的商业与市场环境。

农业在未来能源供给中所扮演的地位将越来越重要，预计占整个农业市场份额的 11%。中国可以借此契机加强农村商业发展并进一步巩固农村经济。

中国急需能够满足废弃物处理需求的新型废弃物管理方案以实现向低碳社会转型，而利用生活垃圾生产沼气则是实现该目标的最佳选择。人们已经逐渐了解到燃料乙醇作为液体生物燃料或许不是最经济可行的可持续方案，而今年日本所经历的福岛核泄漏事故，也使人们认识到核能对生态环境有着极大的威胁，进一步发展沼气技术成为时代的需要。中国政府制定了各种政策来支持沼气工程的发展，并通过与德国政府的合作，共同推进沼气技术，并使之逐步走向国际市场。

沼气工程与技术系列丛书第二卷将展示上述成果，希望能满足各位读者的需求。

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2011 年 12 月于北京

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BIOGAS TO GRID IN CHINA-CHALLENGES AND OPPORTUNITIES OF A NEW MARKET FOR INDUSTRIAL LARGE SCALE BIOGAS PLANTS

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EXECUTIVE SUMMARY

By setting the target to reduce the intensity of CO_2 emissions per GDP by 40% to 45%, compared to 2005, till 2020 China has committed itself to a stringent climate policy. At the same time fossil fuels are getting more expensive. This drives the development to generate 15% renewable energy in 2020 by inter alia using the energetically potential of China's abundant biomass resources. They derive mainly from large-scale livestock breeding, agro-industries, forests, residential areas as bioorganic municipal waste, from straw and even potentially from energy crops grown on marginal land (considering 'no food for energy'!). Biomass has the potential to replace one third of China's coal consumption in 2050, which is equivalent to one billion tons of standard coal. Biogas from large-scale biogas plants shall contribute at least three Giga Watts grid-connected energy in 2020 (NDRC, 2006). The actual contribution of middle and large scale biogas plants to energy generation is very limited. Therefore 'international best practice' technology shall support the change from environmental protection driven to rather power producing industrial scale biogas plants, wherever condition permits. The SINO-German Project of Optimization of Biomass Utilization, supported by the German Ministry for International Cooperation (BMZ) and implemented by the 'Deutsche Gesellschaft fuer Internationale Zusammenarbeit (GIZ)' together with the Foreign Economic Cooperation Center (FECC) of the Chinese Ministry of Agriculture (MOA) aims to provide technical support to design and operate large scale biogas plants financed through an ADB loan, according to best practice and to create demonstration cases which landmark the future development in this sector. International equipment suppliers will have, in the course of an improved technical standard, increasingly more opportunities to get involved.

Key words: China biogas sector; biogas technology; biogas plant performance; biogas utilization; Sino-German biogas cooperation

1 Biogas development in China

China is well known for its rural biogas utilization program. Since the 50ies more than 35 million household scale biogas digesters with an estimated annual biogas output of 12 billion m^3 were installed. The development target is 80 million units by 2020, including the climatically colder regions in the northern

parts of China.

The small, middle and large scale biogas plants construction has developed since the early 1990s, mainly using Up-flow Sludge (USR), Up-flow Anaerobic Sludge Blanket (UASB) and simple High Concentration Flow (HCF) reactors. This environmentally friendly treatment is suitable to treat the liquid effluent from animal husbandries and agro industries, such as breweries, alcohol production factories, and slaughterhouses. Biogas was at that time more a by-product, which was used for self supply or local biogas supply to neighboring households. In 2009 about 34 000 small-scale biogas plants and 22 900 medium and large scale biogas plants (MLBGPs, Fermenter $>$ 50 m^3), with 3 717 large scale installations (Fermenter $>$300 m^3) included (*Figure 1*). A biogas-driven power generation capacity of 42 MW_{el} was installed on biogas plants sites by 2009.

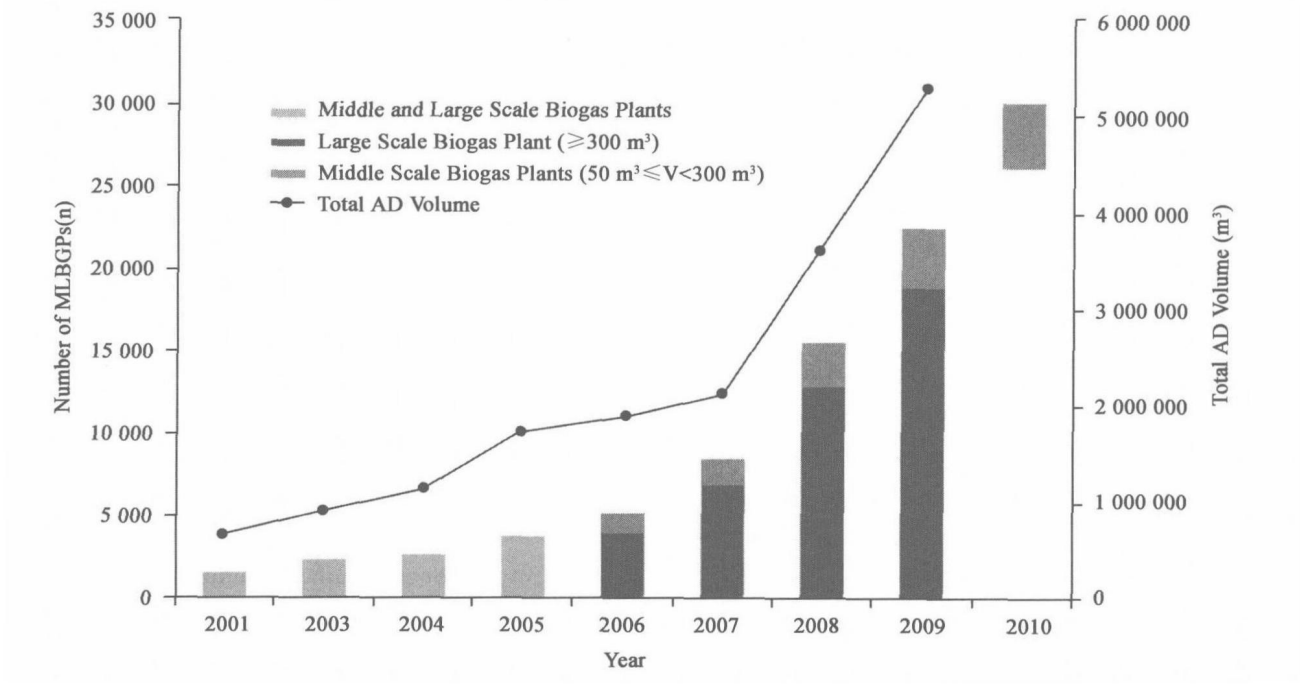

Figure 1 Middle and large scale biogas plants developed in China, number of plants and fermenter volume 2001—2010 (China Biogas Association, BIOMA and NDRC, 2006—2020). NDRC-Chinese National Development and Reform Committee, ministerial authority in the government.

Biogas plants built under the aspect of the overall energy generation are fairly new. At waste water treatment plant, biogas as a by-product was usually not collected and used. So far the self-use or the supply to local biogas grids was realized, but due to lack of temperature control very commonly the biogas plants are just effectively run in the warm seasons. The Chinese Ministry of Agriculture Asian Development Bank 'Integrated Renewable Biomass Energy Development Sector Project', should be supportive to the improvement of biogas plants management and to a much proper and reasonable development of new power generation oriented MLBGPs in China.

2 Political and financial supports

The policy drivers to support biogas generation in China are quite similar to Germany (see *I*). The awareness, that biogas plants are not only contributing to environmental protection, but seriously can supply energy, was promoted after the China Renewable Energy Law (NDRC, 2006) was enacted.

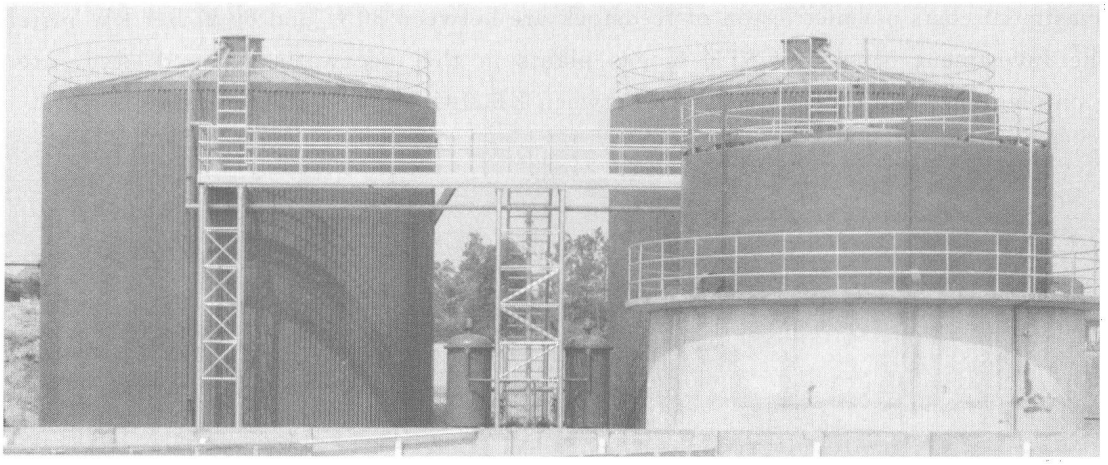

Figure 2 Qionglai Jinli pig farm near Chengdu, Sichuan Province, a traditional USR Biogas plant for the liquid farm effluent operates a small 30 kW_{el} gas engine, the effluent is treated as waste water, built in 2009.

Renewable energies derived from wind turbines, hydropower, solar, geothermic, and biomass (solid and liquid bio-fuels and biogas) shall reach 15% in the overall primary energy mix in 2020.

Ⅰ. Main Biogas Policy Drivers in China

- Environmental Protection (waste water pollution; ground- and surface waters, and soil protection);
- Renewable Energy (substitution of fossil fuels, sustainable energy resources development);
- Circular Economy (Organic fertilizer);
- Greenhouse Gases Mitigation (Kyoto Protocol 2002, Copenhagen 2009, low carbon economy);
- Rural Development (agro-industrialization, farmers income, diminishing urbanization).

During the last 10 years, climate change mitigation emerged as an additional driver to biogas plant construction. In the course of China's Greenhouse Gases emission reduction policy, China signed the Kyoto Protocol in 2002. During the 11th Five Year Plan, the Chinese government had reduced CO_2 emission per unit GDP by 20%. A total investment of about CNY 2 trillion (240 billion€) had been made to achieve this goal (NDRC, 2010). In the course of the Copenhagen UN Climate Change Conference 2009, the 2020 voluntary target, to reduce the intensity of CO_2 emissions per GDP by 40% to 45%, compared to 2005, was announced by China. China has recognized already a negative impact from climate change on agriculture and infrastructure, and has recognized the importance of international efforts for preventing global climate change.

To support the biogas sector and the development of biogas plants in China, there are various systems and mechanisms. Till 2010 MOA invested more than CNY 24 billion (2.8 billion€) into biogas construction. During the last 3 years, the average annual investment support was CNY 5-6 billion. Per plant the central government subsidy varied between 25% and 45% of the total project investment, similar investment comes from the provincial and municipal governments, based on an application and evaluation process; the optimistic situation for a biogas plant owner is he just needed to cover about 15% of the total cost. Some important supports for large scale biogas plants constructions came in types of international loans, donations, and businesses. International loans used to be from ADB and World Bank. Donations were from the Global Environmental Facility, UNDP and bilateral cooperation partner countries such as the Netherlands, Sweden, Denmark, Finland, and Germany (BMZ, GIZ, CIM, BMBF, Robert Bosch Stiftung). Business cooperation was conducted with the United States, Canada, Japan and so on. The

specific Investment costs per metric ton of feedstock are between 30 € and 60 € Per kW installed power capacity the Investment costs of CSTR biogas plants in the megawatts range of size, are between, depending on plant size and type of feedstock between 1 600 €/kW and 3 300 €/kW.

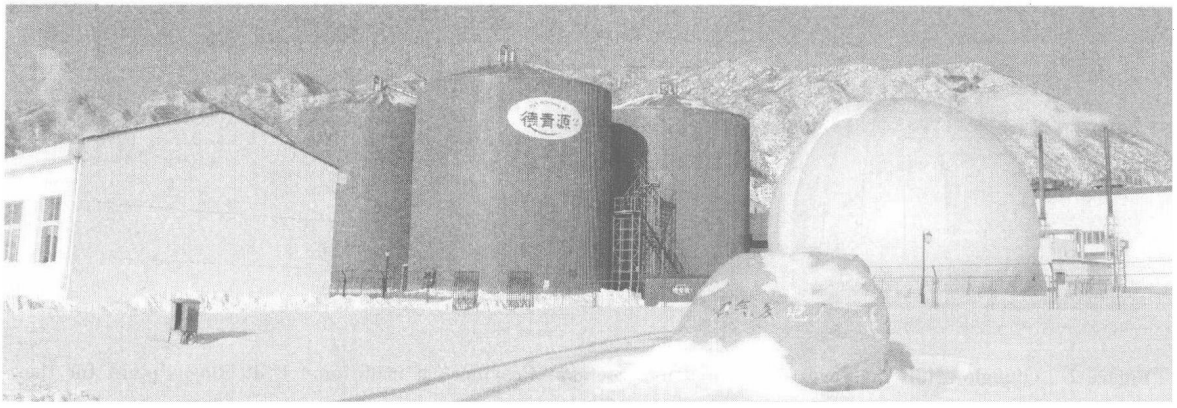

Figure 3 Biogas plant Deqingyuan in Yanqing Beijing, UNDP, GEF, USAID demonstration CSTR technology, the biogas from 2.2 million layers drives 2 GE Jenbacher gas engines with 2.4 MW_{el}, grid connected, operation since 2007, CDM since 2009.

Biogas electricity generation in China is not popular because of year-round biogas availability and power installation size requirement. Only when electricity generation capacity exceeds 500 kW (there are exceptions locally) will be an obligation to have access to the grid and then can benefit from the financial supporting policy. There however is one successful case in China. The biogas plant in Deqingyuan is to produce electricity for grid connection, receiving feed-in tariff support according to the Renewable Energy Law, with a top up of at least 0.25 CNY /kWh (0.03 €/kWh) to the local coal power generation price (*Table 1*).

Carbon trading revenues from the UNFCC Clean Development Mechanism (CDM) would ensure the financial viability of large scale biogas plants (PPTA, 2009). Large scale biogas plants can reach an amount of between 40 000 and 100 000 t CO_{2eqv}. Certified Emission Reduction (CERs) (UNFCCC, PDDs). Since 2008 NDRC requests for at least 7 €/t CO_{2eq}. and depending on the quality of the projects and the market situation 14 € and more can be achieved. But so far, due to the complexity and costs of registration and monitoring and due to the low performance of most current plants, Biogas CDM projects developers have not make sufficient use of this possibility in China.

Table 1 Grid feed-in tariff and tax privilege for biogas and-mass power (status 2010)

	Power benchmark tariff	Power subsidy (obligatory for grid companies >500 kW)	Grid connection subsidy (to grid comp.)	Tax concession
Livestock- & poultry waste	Provincial price of desulfurized coal power in 2005 (app. 0.45 CNY/kWh*)	0.25 CNY/kWh, Since 2010, new projects get 2% decrease than the last year projects. Duration 15years.	0.01 CNY/kWh (<50 km) 0.02 CNY/kWh (50-100 km) 0.03 CNY/kWh (>100 km)	No income tax (first three years), 50% income tax (second three years).
Agro- & forestry-biomass waste	a. 0.75 CNY/kWh (incl. tax) b. For the approved project or tendering project, the feed-in tariff required approval			If 70% of feedstock is crop straw, husk and /or corn crop, 10% income is tax free.

* This tariff was increased by the Chinese Government by 0.025 CNY/kWh in December 2011.

3 Potential of large-scale biogas plant development

According to MOA in 2010 there were 4.2 million commercial livestock and poultry farms holding livestock equivalent to 610 million pigs, which produced about 3 billion tons of manure that year. Amongst about 1.1 billion tons was available as feedstock for biogas plants with a potential biogas production of 67 billion m^3. In addition, 90 million of pigs, 16 million of cattle, 85 million of chickens and 26 million of sheep were raised by 140 million small farms in the suburbs of the metropolis cities. It is estimated to have an additional annual biogas production potential of 54 billion m^3. Those distributed small farms can either hold their own household digesters or put the manure treated in centralized co-digestion biogas plants (see GEF Component of the ADB Project).

NDRC anticipates in the 'Medium and Long Term Program of Renewable Energy Development Plan 2006-2020' that 10 000 MLBGPs, at mainly animal husbandries, and 6 000 MLBGPs processing industrial organic wastewater, with an overall annual biogas yield of 14 billion m^3 and an installed electricity capacity of 3 GW by 2020 will be in place. As in 2010 about only 15% of the biogas electricity generation capacity (3 GW) was installed (but not fully operated), the biogas power generation has a big step to go. For the total energy potential from biomass in 2050, see *Table 2*.

Table 2 Potential of Bio-energy till 2050 (1 billion standard coal equivalent-SCe, per Year)

Biomass source	standard coal equivalent/a
Waste from livestock production	90*
Agro-industry waste	40*
Straw (corn, rice, grain) 60% of potential	340**
Forest residues and firewood	100
Bioorganic municipal waste and restaurants waste (50% of potential)	90*
Industrial organic wastewater	20*
Energy crops, including bioethanol, biodiesel, biogas (200 million ha marginal, reclaimed and unused land)	320**
Total	1 000

Note: 1. * mainly biogas, ** including biogas
2. 120 billion Nm^3 biogas from about 1.1 billion tons(1 Nm^3 biogas = 0.75 kg SCe)

4 Current biogas plant performance

No systematic assessment of biogas plant operation conditions has been accomplished. China Agriculture University (CAU) has started to develop an assessment in four pilot provinces, which should be further developed to a national cadastre. But as a matter of fact the biogas plants performance is far behind international standard, showing a low availability and productivity, insufficient specific biogas production, operating at low dry matter contents, low organic loading rates, lacking of process control and monitoring. Only a few plants are connected to the electricity grid, only seven biogas plants are registered CDM projects, from which so far only one can generate some CDM carbon credits based on certified emission reduction (CER). On environmental aspect such as the flaring of unused biogas and the minimization of biogas leakage is not observed. The mainly subsidy oriented support policy had boosted the construction activities without putting attention on operation and use of outputs, gas and digestates.